

BITSAT Biology Sample Paper-15

Duration: 60 Minutes

Maximum Marks: 120

Instructions

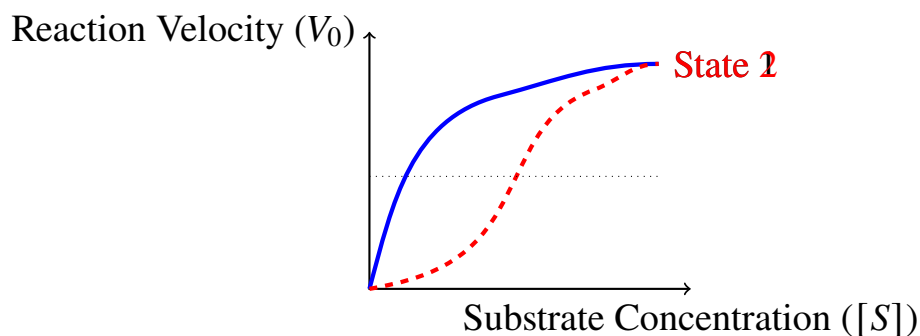
- This paper contains **40** Multiple Choice Questions (Single Correct).
- Each correct answer carries **+3** marks. Each incorrect answer carries 1 mark. Unattempted questions carry **0** marks.
- Only **one** option is correct for each question.
- Use of mobile phones, smartwatches, calculators, or any electronic gadgets is strictly prohibited.

Q1. During an in vitro metabolic isolation experiment, functional mitochondria are suspended in a buffer containing an excess of pyruvate and oxygen. The addition of an investigative compound, oligomycin, completely shuts down oxygen consumption by blocking the proton channel of the F_oF_1 -ATP synthase complex. Which of the following secondary interventions will successfully restore oxygen consumption without synthesizing any ATP?

- (A) Introduction of an explicit competitive inhibitor of succinate dehydrogenase.
- (B) Addition of a chemical uncoupler, such as 2,4-dinitrophenol (DNP), which dissipates the proton gradient across the inner mitochondrial membrane.
- (C) Increasing the partial pressure of molecular oxygen (pO_2) within the incubation chamber by 200%.
- (D) Supplementing the buffer with high concentrations of adenosine diphosphate (ADP) and inorganic phosphate (P_i).

Q2. The biochemical profile below maps the initial reaction velocity (V_0) against substrate concentration ($[S]$) for a multi-subunit cooperative enzyme system under two distinct functional states. If the addition of a physiological effector coordinates a structural shift from State 1 to State 2, analyze the underlying mechanical transition.





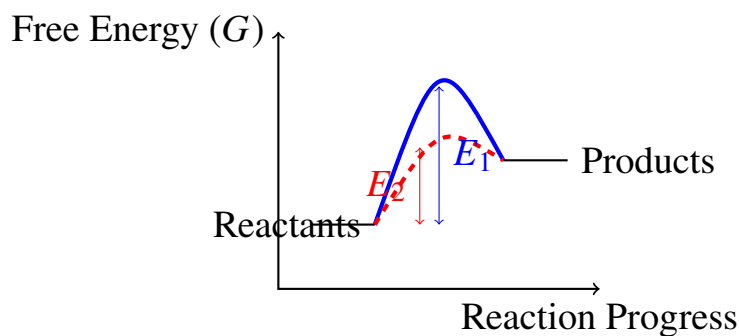
- (A) State 1 represents the tense (*T*) low-affinity state, stabilized by an allosteric inhibitor.
- (B) The transition from State 1 to State 2 represents the binding of an allosteric activator that decreases the apparent K_m value.
- (C) State 2 represents the relaxed (*R*) high-affinity state, showcasing a complete loss of subunit-subunit cooperativity.
- (D) The transition from State 1 to State 2 indicates the presence of an allosteric inhibitor that shifts the enzyme equilibrium toward the tense (*T*) conformation, increasing the $K_{0.5}$ value.

Q3. A pediatric patient presents with severe skeletal abnormalities, psychomotor restriction, and elevated plasma levels of multiple lysosomal hydrolases. Fibroblast analysis reveals that these hydrolytic enzymes are synthesized normally in the rough endoplasmic reticulum but are completely mis-targeted to the extracellular space rather than the lysosomal matrix. This functional lesion is rooted in the genetic absence of an enzyme responsible for adding which specific targeting tag in the cis-Golgi network?

- (A) Ubiquitin peptide chains
- (B) Mannose-6-phosphate (M6P) residues
- (C) Polyadenylated nucleotide tails
- (D) Glycosylphosphatidylinositol (GPI) anchors

Q4. The biochemical configuration below tracks the change in free energy (ΔG) of an endergonic metabolic process under two distinct environmental states. Identify the true statement regarding the energy values marked as E_1 and E_2 .





- (A) E_1 represents the activation energy in the presence of an allosteric activator.
- (B) E_2 represents the activation energy lowered by the stabilization of the transition state by an enzyme.
- (C) The absolute value of ΔG for the overall reaction is calculated as $E_1 - E_2$.
- (D) E_2 indicates the un-catalyzed activation energy threshold typical of mammalian physiological systems.

Q5. A molecular biologist isolates a 300 base pair double-stranded DNA fragment from a novel halophilic archaeon. Quantitative chemical analysis reveals that Adenine and Thymine bases together account for exactly 40% of the absolute nucleotide composition. Determine the total number of hydrogen bonds stabilizing the secondary helical structure of this specific genomic fragment.

- (A) 600
- (B) 780
- (C) 840
- (D) 900

Q6. An enzyme kineticist isolates a novel metabolic enzyme with an absolute total concentration ($[E_t]$) of 2.0×10^{-6} M in a reaction mixture. Under saturating substrate conditions, the maximum catalytic velocity (V_{max}) of the reaction is measured to be 1.2×10^{-2} M \cdot s $^{-1}$. If the Michaelis constant (K_m) for this specific substrate is evaluated to be 3.0×10^{-4} M, calculate the absolute catalytic efficiency (k_{cat}/K_m) of this enzyme under standard conditions:

- (A) 2.0×10^3 M $^{-1} \cdot$ s $^{-1}$



(B) $6.0 \times 10^3 \text{ M}^{-1} \cdot \text{s}^{-1}$

(C) $2.0 \times 10^7 \text{ M}^{-1} \cdot \text{s}^{-1}$

(D) $4.0 \times 10^7 \text{ M}^{-1} \cdot \text{s}^{-1}$

Q7. The enzymatic conversion of substrate S to product P follows classic Michaelis-Menten kinetics. In the presence of a structural analogue, the apparent K_m increases by a factor of 4 while the V_{max} remains entirely unperturbed. This system indicates the presence of a:

- (A) Non-competitive inhibitor interacting exclusively at an allosteric domain.
- (B) Competitive inhibitor competing directly for the active substrate-binding pocket.
- (C) Uncompetitive inhibitor that selectively binds the pre-formed enzyme-substrate $[ES]$ complex.
- (D) Irreversible covalent inactivator of the active site catalytic triad.

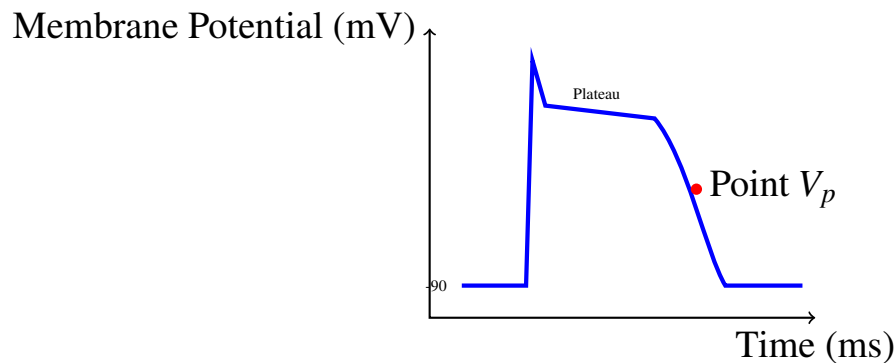
Q8. A molecular cell biologist constructs a temperature-sensitive mutant yeast strain that fails to synthesize functional Cyclin-Dependent Kinase 1 (CDK1/CDC2) at restrictive temperatures (37°C). If a synchronized culture of these cells is shifted to the restrictive temperature precisely at the boundary entry point of the G_2 phase, what is the phenotypic arrest state of the population?

- (A) Sudden arrest at the G_1/S transition point, showing completely un-replicated nuclear DNA.
- (B) Unchecked progression through mitosis resulting in cell division with broken, fragmented chromosomes.
- (C) Absolute cell cycle arrest at the G_2/M transition boundary, failing to initiate chromatin condensation or nuclear envelope breakdown.
- (D) Permanent exit from the active cell cycle into the quiescent G_0 metabolic storage state.

Q9. An electrophysiological patch-clamp recording of a mammalian ventricular cardiomyocyte measures the distinct phases of a normal action potential. If



an experimental pharmacological agent selectively blocks the delayed rectifier potassium channels (I_{K_r}) during the phase marked at point V_p , predict the immediate structural transformation in the electrical readout profile.



- (A) Accelerated repolarization, causing a drastic shortening of the total action potential duration (APD).
- (B) Prolongation of the plateau phase and delayed repolarization, significantly lengthening the QT interval.
- (C) Immediate abolition of the phase 0 rapid depolarization upstroke.
- (D) Exaggerated hyperpolarization bringing the resting membrane potential down to -130 mV.

Q10. An isolated nerve axon is treated with an experimental neurotoxin that completely immobilizes the inactivation gates (h-gates) of voltage-gated sodium channels in their open configuration. What distinct transformation will be observed in the resulting action potential recording?

- (A) Complete failure to achieve the threshold depolarization potential.
- (B) Prolonged, sustained depolarization with an absolute failure of rapid repolarization.
- (C) Accelerated repolarization causing an exaggerated hyperpolarization phase down to -110 mV.
- (D) A complete shift of the peak overshoot potential up to the equilibrium potential of calcium.

Q11. A clinical patient undergoes an intensive medical evaluation showing a profound hereditary loss of the sodium-glucose cotransporter 2 (SGLT2) in the apical



membranes of the renal epithelium. This specific molecular lesion will manifest as:

- (A) Total block of water reabsorption in the collecting ducts, causing diabetes insipidus.
- (B) Massive glucosuria in the complete absence of systemic hyperglycemia.
- (C) Elevated plasma glucose levels accompanied by systemic metabolic alkalosis.
- (D) Complete failure to establish the hyperosmotic medullary concentration gradient.

Q12. During skeletal muscle contraction, the cross-bridge cycle must be continuously energized. Which mechanical transition step is directly coupled to the dissociation of inorganic phosphate (P_i) from the catalytic core of the myosin head?

- (A) Binding of the myosin head to the exposed actin active site.
- (B) The conformational power stroke that pulls the thin filament toward the center of the sarcomere.
- (C) Detachment of the myosin head away from the structural actin filament track.
- (D) Re-cocking of the myosin head into its high-energy state via ATP hydrolysis.

Q13. A human volunteer is placed inside a metabolic chamber where the partial pressure of carbon dioxide (pCO_2) in the inspired air is systematically doubled. The primary physiological sensor system that triggers the immediate hyperventilation reflex is:

- (A) Central chemoreceptors in the medulla oblongata sensing decreased pH in the cerebrospinal fluid.
- (B) Peripheral baroreceptors in the carotid sinus responding to structural mechanical stretch.
- (C) Pulmonic stretch receptors signaling a limit to vital capacity parameters.
- (D) Juxtaglomerular apparatus systems releasing a wave of systemic renin molecules.



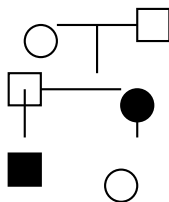
Q14. A mutation in the gene encoding the structural components of the gastric proton pump (H^+/K^+ ATPase) completely disrupts its catalytic activity. This clinical deficiency will directly result in:

- (A) Hyperchlorhydria leading to aggressive duodenal ulcerations.
- (B) Complete loss of pepsinogen activation and a severe impairment in dietary protein digestion.
- (C) Massive overproduction of intrinsic factor by the underlying chief cells.
- (D) Systemic metabolic acidosis due to unbuffered bicarbonate absorption.

Q15. During the structural adaptation of xerophytic plants to highly arid zones, which anatomical configuration is routinely deployed across the leaf epidermis to minimize water loss via transpirational pathways?

- (A) Protruding, elevated guard cells displaying thin, non-lignified primary outer walls.
- (B) Sunken stomata localized within specialized trichome-lined crypts.
- (C) Complete elimination of the waxy cuticular matrix layer to maximize gas exchanges.
- (D) Increased stomatal density across the adaxial surface relative to the abaxial surface.

Q16. The pedigree chart below tracks a rare metabolic syndrome across three consecutive generations of a family line. Analyze the distribution layout to determine the mode of inheritance.



- (A) Y-linked holandric inheritance profile showing absolute father-to-son transmission.
- (B) Autosomal dominant mode with complete penetrance across all branches.



- (C) X-linked dominant inheritance pattern where affected males pass the trait to all daughters but no sons.
- (D) Mitochondrial (maternal) inheritance pattern where all offspring of an affected female manifest the clinical trait.

Q17. A molecular biology workflow builds an in vitro translation assay containing a selectively mutated tRNA molecule. If the anticodon loop of this specific tRNA has been mutated from 5'-GAA-3' to 5'-UAA-3' but remains fully charged with its native amino acid, Phenylalanine, how will it read an incoming mRNA strand?

- (A) It will incorporate Phenylalanine opposite the stop codon 5'-UAA-3', causing nonsense suppression.
- (B) It will incorporate Phenylalanine opposite the leucine codon 5'-UUA-3', causing a targeted translational misreading error.
- (C) It will completely terminate translation initiation at the ribosomal entry site.
- (D) It will cause an immediate ribosome stalling event that triggers mRNA decay.

Q18. In an experimental multi-factorial genetic cross, an organism with the genotype *AaBbCcDd* is testcrossed with an individual of genotype *aabbccdd*. Assuming all four loci assort completely independently, calculate the probability of obtaining an offspring showing the dominant phenotype for exactly two of the four traits evaluated:

- (A) $\frac{1}{16}$
- (B) $\frac{3}{8}$
- (C) $\frac{1}{4}$
- (D) $\frac{5}{16}$

Q19. During a deep-sequencing genomic analysis of an isolated population of island finches, a researcher identifies a multi-gene locus undergoing selection. If the selection favors both extreme peripheral phenotypic morphs while actively eliminating intermediate phenotypes, this evolutionary scenario is classified as:

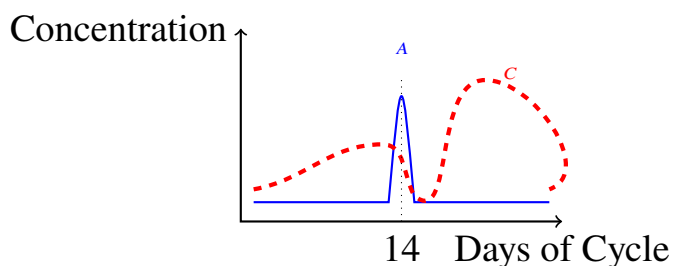


- (A) Stabilizing selection, reducing phenotypic variance over time.
- (B) Disruptive (diversifying) selection, which can drive sympatric speciation events.
- (C) Directional selection, shifting the mean population value toward a single extreme.
- (D) Balancing selection via frequency-dependent mechanisms.

Q20. A bacterial transcription assay evaluates a mutant RNA Polymerase that lacks a functional sigma (σ) subunit. What is the operational consequence of this structural deletion during transcription?

- (A) Absolute failure to catalyze phosphodiester bond formation during elongation steps.
- (B) Loss of specific promoter recognition and binding, resulting in random, non-specific transcription initiation.
- (C) Permanent binding to the termination hairpin loop structure.
- (D) Failure to execute the 5' capping modification process.

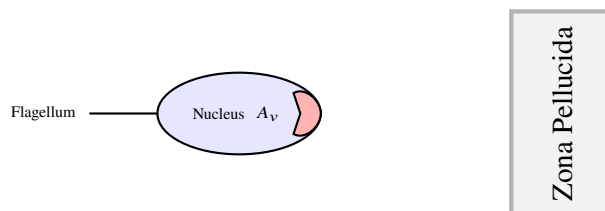
Q21. The developmental tracking profile below tracks the steady-state plasma concentrations of three key hormones (A, B, C) across the human menstrual cycle. Identify the physiological role of hormone C during the luteal phase.



- (A) Triggering the mechanical rupture of the Graafian follicle.
- (B) Stimulating the anterior pituitary to secrete high levels of FSH.
- (C) Maintaining the structural integrity and secretory capacity of the endometrial lining for potential implantation.
- (D) Mediating the fast block to polyspermy at the zona pellucida boundary.



Q22. The structural layout below diagrams the functional mechanics of a human sperm cell making initial contact with the extracellular matrix of a secondary oocyte. If a specific genetic mutation renders the specialized enzymatic vesicle A_v completely devoid of the proteolytic enzyme acrosin, evaluate the precise block in the downstream fertilization pathway.



- (A) Complete failure of the sperm cell to perform targeted flagellar chemotaxis toward the follicular fluid gradient.
- (B) Absolute inability of the sperm head to physically digest and penetrate the transparent glycoprotein shell of the zona pellucida.
- (C) Destruction of the maternal cortical granules, causing immediate and uncontrolled polyspermy.
- (D) Premature activation of the secondary oocyte's metabolic systems prior to pronuclear fusion.

Q23. During human spermatogenesis, which distinct cellular stage undergoes the first reductive meiotic division (Meiosis I) to yield two equal-sized haploid cells?

- (A) Spermatogonia type B
- (B) Primary spermatocytes
- (C) Secondary spermatocytes
- (D) Multipotent primordial germ cells

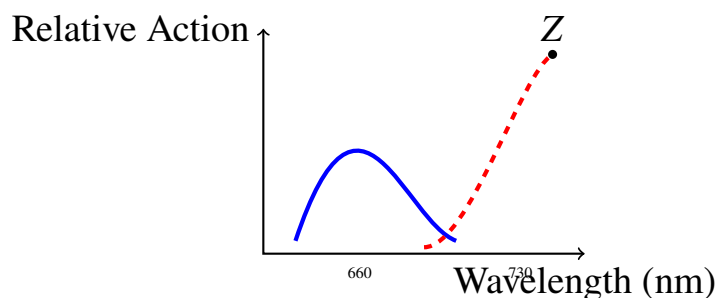
Q24. A patient presents with non-functional mutations within the gene encoding the structural glycoprotein zona pellucida protein 3 (ZP3). This molecular defect will directly disrupt which fertilization step?

- (A) Blastocyst attachment to the uterine endometrial surface layer.
- (B) Species-specific sperm recognition and binding, which triggers the acrosome reaction.



- (C) The slow block to polyspermy mediated by cortical granule exocytosis.
 (D) Fusion of male and female pronuclei configurations during amphimixis.

Q25. The graphical plot below tracks the functional action spectrum of a key plant photomorphogenic tracking system. Identify the physiological family matching the response display that shows maximum alternative state activation under far-red illumination at point Z.



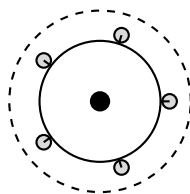
- (A) Cryptochrome blue-light sensing modules.
 (B) Phototropin systems regulating asymmetric auxinic phototropism.
 (C) Phytochrome systems shifting from the active P_{fr} state to the inactive P_r form.
 (D) Gibberellic acid feedback receptors in the aleurone layer.
- Q26.** A plant physiology researcher applies a synthetic chemical inhibitor that blocks the active proton pump (H^+ -Simple-ATPase) within the plasma membrane of guard cells. What is the immediate impact on stomatal dynamics?
- (A) Immediate hyperpolarization leading to massive K^+ ion influx and rapid stomatal opening.
 (B) Failure to establish the required electrochemical gradient for voltage-gated K^+ accumulation, completely preventing stomatal opening.
 (C) Accelerated malate synthesis, leading to persistent high turgor pressure states.
 (D) Rapid, uninhibited passive water influx into the guard cell vacuoles via aquaporins.



Q27. A mutant line of *Zea mays* shows high susceptibility to vivipary (premature seed germination while still attached to the parent plant cob). This phenotype is caused by a biosynthetically non-functional path in the production of:

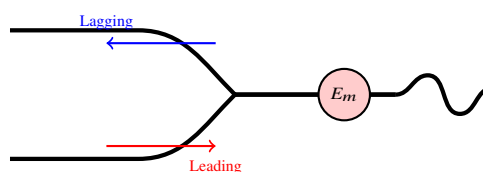
- (A) Indole-3-acetic acid (IAA)
- (B) Abscisic acid (ABA)
- (C) Gibberellic acid (GA_3)
- (D) Zeatin riboside configurations

Q28. The anatomical layout below captures the floral symmetry plan of an advanced plant family. Identify the core family name that displays this specific epipetalous, pentamerous, and syncarpous structural plan.



- (A) Fabaceae
- (B) Solanaceae
- (C) Liliaceae
- (D) Brassicaceae

Q29. The structural mapping below details the replication fork topology during eukaryotic nuclear DNA synthesis. If an experimental cell line undergoes a loss-of-function mutation in the gene encoding the enzyme that acts specifically at site E_m to alleviate over-winding strain, analyze the immediate downstream biophysical consequence on replication fork progression.



- (A) Accelerated template melting due to uncoupled hydrogen bond destabilization ahead of the replication assembly.

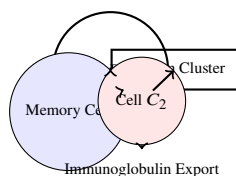


- (B) Immediate accumulation of positive supercoils ahead of the fork, creating a critical torsional strain that halts replication fork migration.
- (C) Spontaneous conversion of the downstream B-DNA structure into a left-handed Z-DNA configuration.
- (D) Complete breakdown of the sliding clamp (β -subunit) tracking mechanism along both strands.

Q30. A botanical inventory survey isolates a non-vascular terrestrial plant that features a dominant, photosynthetic gametophytic generation and a dependent sporophyte composed of a foot, seta, and capsule. This structural profiling places the specimen into which taxonomic class?

- (A) Pteropsida
- (B) Bryopsida (Musci)
- (C) Lycopsidea
- (D) Chlorophyceae

Q31. The cellular tracking schematic below displays the operational differentiation sequence of an adaptive immune component during a primary infection phase. Identify the cell type generated at step C_2 that is specialized for high-output macromolecular secretion.



- (A) Cytotoxic T-Lymphocyte
- (B) Mature Plasma Cell specialized for continuous antibody synthesis
- (C) Natural Killer (NK) cell
- (D) Dendritic antigen-presenting cell

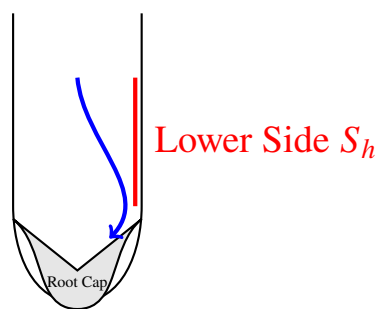
Q32. An analytical sample of monoclonal antibodies was developed to block the human immunodeficiency virus (HIV) from entering host target cells. This



therapeutic design should target which receptor or co-receptor configuration on human T-helper cells?

- (A) CD8 platform
- (B) CD4 molecule along with chemokine receptors CCR5 or CXCR4
- (C) B7-1/B7-2 surface proteins
- (D) CD28 costimulatory molecule

Q33. The longitudinal schematic below diagrams the micro-anatomical architecture of a developing root tip. When a higher plant is oriented horizontally, an asymmetric accumulation of a specific phytohormone occurs localized strictly at side S_h due to gravity-sensing statolith sedimentation within the root cap. Identify the regulatory hormone and its mechanical effect on root curvature.



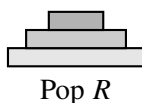
- (A) Gibberellic acid accumulates at S_h , driving rapid cell division to force the root tip upward away from the gravitational pull.
- (B) Auxin (IAA) accumulates at S_h , where high concentrations locally inhibit cellular elongation, causing the upper uninhibited side to grow faster and curve the root downward (positive gravitropism).
- (C) Cytokinin accumulates at S_h , triggering localized mechanical senescence and rapid cell wall dehydration.
- (D) Abscisic acid accumulates at S_h to universally shut down all cell elongations across the entire elongation zone.

Q34. A patient returns from a tropical research field station presenting with high cyclical fevers that recur every 48 hours, severe chills, and sudden hemolytic anemia. A peripheral blood smear reveals ring-stage trophozoites within microcytic erythrocytes. This pathological state is caused by:



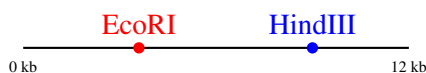
- (A) *Leishmania donovani*
- (B) *Plasmodium vivax*
- (C) *Wuchereria bancrofti*
- (D) *Trypanosoma brucei*

Q35. The age structure distribution profiles below track three isolated mammalian populations (P , Q , R). Choose the option that correctly states the demographic growth trajectory of population R .



- (A) Exponentially expanding profile with very high birth rates.
 - (B) Stable demographic equilibrium where the pre-reproductive group matches the reproductive cohort.
 - (C) Declining population trend characterized by a narrow base of pre-reproductive individuals.
 - (D) High intrinsic rate of natural increase (r).
- Q36.** An evolutionary ecologist tracks two sympatric species of granivorous desert rodents that exploit identical seed resources. Over generations, Species A evolves a narrower foraging jaw structure to process micro-seeds exclusively, while Species B maximizes deep-seed extraction. This adaptive shift illustrates:
- (A) Exploitative competitive exclusion leading to local extinction.
 - (B) Character displacement resulting from selection to minimize overlapping niche competition.
 - (C) Apparent competition driven by shared generalist predators.
 - (D) Directional group selection under a density-independent framework.
- Q37.** The restriction endonuclease map layout below sketches the cutting profile of a standard linear plasmid vector. If the vector is fully digested with EcoRI and HindIII simultaneously, determine the total number of distinct DNA fragments generated.



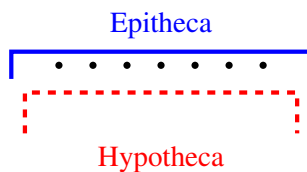


- (A) 1 fragment
- (B) 2 fragments
- (C) 3 fragments
- (D) 4 fragments

Q38. During a CRISPR-Cas9 gene editing workflow designed to knock out an oncogenic locus, a researcher designs a single guide RNA (sgRNA). For the Cas9 endonuclease to introduce a double-stranded break at the target site, what structural motif must be present immediately 3' of the genomic target sequence?

- (A) A TATA box promoter segment
- (B) A Protospacer Adjacent Motif (PAM) sequence matching 5'-NGG-3'
- (C) A polyadenylation signal tract
- (D) A palindromic restriction site line

Q39. The fundamental schematic below captures the structural organization framework of a highly specialized extracellular matrix system characteristic of certain eukaryotic microorganisms. Identify the taxonomic division or group that features this rigid, overlapping two-part siliceous structure which fits precisely together like a pillbox.



- (A) Dinoflagellates (Pyrrophyta) forming rigid cellulose plates.
- (B) Diatoms (Chrysophyta/Bacillariophyceae) producing non-decaying frustules that build diatomaceous earth.
- (C) Euglenoids (Euglenophyta) displaying flexible proteinaceous pellicle configurations.



(D) Slime molds (Myxomycota) developing multinucleate plasmodial networks.

Q40. A molecular biologist designs a selectable marker system for a novel cloning vector using the enzyme beta-galactosidase (β -gal) encoded by the lacZ gene. If a foreign cDNA fragment is successfully ligated into the unique restriction site situated precisely within the alpha-peptide coding region of this gene and transformed into competent *E. coli* cells, evaluate the phenotype of the recombinant colonies on a medium supplemented with X-gal and IPTG.

- (A) Bright blue colonies, due to the hyper-activation of the alpha-complementation assembly.
- (B) White colonies, because insertional inactivation of the alpha-peptide prevents functional enzyme assembly and subsequent substrate cleavage.
- (C) No colony growth whatsoever, because the disrupted lacZ gene product acts as a dominant lethal metabolic poison.
- (D) Fluorescent green colonies, because IPTG forces a spontaneous conformational frame-shift transition.



Detailed Solutions

Q1.

Solution

Concept: Cellular respiration couples the electron transport chain to ATP synthesis via an electrochemical proton gradient. Blocking ATP synthase stalls the proton pump due to high back-pressure; introducing an uncoupler provides an alternative pathway for protons to cross the inner membrane, restoring electron transport and oxygen consumption.

Solution: In functional mitochondria, the oxidation of pyruvate fuels the electron transport chain, which pumps protons out of the matrix to build a proton motive force. Oligomycin binds to the F_o subunit of ATP synthase, blocking the proton channel and preventing protons from flowing back into the matrix. This stalls ATP synthesis and causes the proton gradient to build up to a critical maximum, creating a high back-pressure that halts further proton pumping and stops electron transport and oxygen consumption. Adding a chemical uncoupler, such as 2,4-dinitrophenol (DNP), introduces a proton ionophore into the lipid bilayer. DNP binds protons in the intermembrane space, diffuses across the inner mitochondrial membrane, and releases them directly into the matrix. This dissipates the electrochemical gradient, bypassing the oligomycin block and allowing electron transport and oxygen consumption to resume at a high rate without synthesizing any ATP.

Final Answer: Uncoupler (e.g., DNP) dissipates the proton gradient.

Answer: (B)

[Go Back to Question 1](#)

Q2.

Solution

Concept: Allosteric enzymes transition between alternative quaternary structures. Allosteric inhibitors stabilize the low-affinity, tense (T) conformation, which shifts the substrate saturation curve to the right, increases the sigmoidal cooperativity profile, and increases the half-maximal saturation constant ($K_{0.5}$).

Solution: The velocity curve for State 1 shows a hyperbolic-like profile with a high affinity for the substrate. State 2 displays a sigmoidal or S-shaped curve, which is the hallmark of a cooperative, multi-subunit enzyme system. The shift from State 1 to State 2 indicates that higher substrate concentrations are required to achieve the same initial reaction velocity, meaning the apparent affinity of the enzyme for its substrate has decreased. This rightward shift and increased sigmoidal character are caused by an allosteric inhibitor binding to regulatory sites. This effector shifts the conformational equilibrium away from the active, high-affinity relaxed (R) state toward the tense (T) state. This transition increases the $K_{0.5}$ value (the substrate concentration required to reach half V_{max}) without changing the maximum velocity (V_{max}) at saturating substrate levels.

Final Answer: Allosteric inhibitor shifts enzyme to T state, increasing $K_{0.5}$.

Answer: (D)

[Go Back to Question 2](#)



Q3.

Solution

Concept: Lysosomal enzyme targeting requires a specific carbohydrate modification. Soluble acid hydrolases undergo a post-translational modification where a phosphotransferase adds a phosphate group to mannose residues, creating a recognition marker that is bound by sorting receptors in the trans-Golgi network.

Solution: The patient exhibits the classic clinical symptoms of I-cell disease (mucopolidosis II). In this autosomal recessive disorder, lysosomal enzymes are synthesized normally in the rough endoplasmic reticulum and undergo normal initial core glycosylation. However, they lack the specific targeting signal needed to route them to lysosomes. This defect is caused by a deficiency in the enzyme UDP-N-acetylglucosamine:lysosomal enzyme N-acetylglucosaminyl-1-phosphotransferase. This phosphotransferase normally adds a phosphate group to carbon-6 of mannose residues on oligosaccharide chains within the cis-Golgi network. Without this mannose-6-phosphate (M6P) tag, the trans-Golgi sorting receptors cannot recognize or package the acid hydrolases into clathrin-coated transport vesicles. Consequently, these enzymes travel along the default constitutive secretory pathway and are secreted into the extracellular space, leaving the lysosomes clear of degradative enzymes.

Final Answer: Mannose-6-phosphate (M6P) residues

Answer: (B)

[Go Back to Question 3](#)

Q4.

Solution

Concept: Biocatalysts speed up chemical reactions by decreasing the energy barrier of the activation step. Enzymes form weak non-covalent interactions that stabilize the high-energy transition state, lowering the activation energy (E_a) without altering the net thermodynamic free energy change (ΔG).

Solution: The graph tracks free energy changes across an endergonic reaction coordinate. The blue curve shows a high activation energy barrier (E_1), which represents the un-catalyzed pathway. The red dashed curve shows a lower activation energy barrier (E_2). This reduction in activation energy is achieved through enzymatic catalysis. Enzymes bind the substrate and stabilize the high-energy transition state configuration using weak non-covalent interactions, such as hydrogen bonds and ionic forces. This lowers the kinetic barrier from E_1 to E_2 , allowing the reaction to proceed faster at physiological temperatures. It is important to note that while the enzyme lowers the activation energy, it does not change the initial energy of the reactants or the final energy of the products, leaving the net free energy change (ΔG) unaltered.

Final Answer: E2 is the enzyme-lowered activation energy.

Answer: (B)

[Go Back to Question 4](#)



Q5.

Solution

Concept: The stability of the DNA double helix is determined by complementary base-pairing rules. Adenine pairs with thymine via two hydrogen bonds, while guanine pairs with cytosine via three hydrogen bonds. The total number of hydrogen bonds depends on the nucleotide composition of the fragment.

Solution: The double-stranded DNA fragment is 300 base pairs (bp) long, which means it contains a total of $300 \times 2 = 600$ nucleotides. The problem states that Adenine (A) and Thymine (T) together make up exactly 40% of the total nucleotide composition.

$$\text{Total A+T nucleotides} = 600 \times 0.40 = 240 \text{ nucleotides}$$

Since A always pairs with T, this equals 120 A-T base pairs. Each A-T base pair is held together by 2 hydrogen bonds.

$$\text{Hydrogen bonds from A-T pairs} = 120 \times 2 = 240 \text{ bonds}$$

The remaining 60% of the nucleotides must be Guanine (G) and Cytosine (C).

$$\text{Total G+C nucleotides} = 600 \times 0.60 = 360 \text{ nucleotides}$$

This equals 180 G-C base pairs. Each G-C base pair is held together by 3 hydrogen bonds.

$$\text{Hydrogen bonds from G-C pairs} = 180 \times 3 = 540 \text{ bonds}$$

Summing these values gives the total number of hydrogen bonds stabilizing the fragment:

$$\text{Total hydrogen bonds} = 240 + 540 = 780 \text{ bonds}$$

Final Answer:

Answer: (B)

[Go Back to Question 5](#)



Q6.

Solution

Concept: Catalytic efficiency measures how efficiently an enzyme converts substrate into product at low substrate concentrations. It is calculated by dividing the catalytic turnover number (k_{cat}) by the Michaelis constant (K_m), where k_{cat} represents the maximum number of chemical conversions per active site per second.

Solution: To find the catalytic efficiency (k_{cat}/K_m), we first need to determine the turnover number (k_{cat}). The turnover number is calculated by dividing the maximum velocity (V_{max}) by the total enzyme concentration ($[E_t]$):

$$k_{cat} = \frac{V_{max}}{[E_t]} = \frac{1.2 \times 10^{-2} \text{ M} \cdot \text{s}^{-1}}{2.0 \times 10^{-6} \text{ M}} = 6.0 \times 10^3 \text{ s}^{-1}$$

Now, we can calculate the catalytic efficiency by dividing k_{cat} by the Michaelis constant (K_m), which is given as $3.0 \times 10^{-4} \text{ M}$:

$$\text{Catalytic Efficiency} = \frac{k_{cat}}{K_m} = \frac{6.0 \times 10^3 \text{ s}^{-1}}{3.0 \times 10^{-4} \text{ M}} = 2.0 \times 10^7 \text{ M}^{-1} \cdot \text{s}^{-1}$$

Final Answer: $2.0 \times 10^7 \text{ M}^{-1} \cdot \text{s}^{-1}$

Answer: (C)

[Go Back to Question 6](#)

Q7.

Solution

Concept: Competitive inhibition occurs when an inhibitor binds reversibly to the active site of an enzyme. This increases the apparent K_m because higher substrate concentrations are needed to outcompete the inhibitor, while the maximum velocity (V_{max}) remains unchanged because high substrate levels can fully displace the inhibitor.

Solution: The problem states that the addition of a structural analogue increases the apparent K_m by a factor of 4 while leaving V_{max} unperturbed. This kinetic profile is the classic signature of competitive inhibition. A competitive inhibitor resembles the normal substrate structurally and binds reversibly to the same active substrate-binding pocket. Because it directly competes with the substrate for the active site, a higher concentration of substrate is required to achieve half-maximal velocity, which increases the apparent K_m . However, because the binding is reversible, saturating concentrations of substrate can completely displace the inhibitor from the active sites, allowing the enzyme to reach its normal maximum catalytic velocity (V_{max}).

Final Answer: Competitive inhibitor competing directly for the active substrate-binding pocket.

Answer: (B)

[Go Back to Question 7](#)



Q8.

Solution

Concept: The eukaryotic cell cycle is driven by specific cyclin-CDK complexes. Mitosis is initiated by the activation of CDK1 (CDC2) bound to mitotic cyclins, which phosphorylates targets required for nuclear envelope breakdown and spindle assembly; loss of this complex halts cells at the checkpoint before mitosis.

Solution: In budding and fission yeast, Cyclin-Dependent Kinase 1 (encoded by the *CDC2* or *CDK1* gene) is a master regulator required for passing major cell cycle checkpoints. Specifically, the complex formed by CDK1 and B-type mitotic cyclins (MPF, Maturation Promoting Factor) controls the entry into mitosis at the G_2/M transition boundary. When a temperature-sensitive mutant strain is shifted to a restrictive temperature (37°C) at the start of the G_2 phase, functional CDK1 cannot be produced or assembled. Consequently, the cells can replicate their DNA normally during S phase but fail to activate the downstream targets necessary for mitosis, such as lamin phosphorylation for nuclear envelope breakdown and condensin activation. This causes the cell population to arrest at the G_2/M boundary.

Final Answer: G₂/M arrest prevents mitosis initiation.

Answer: (C)

[Go Back to Question 8](#)

Q9.

Solution

Concept: The cardiac ventricular action potential features a prolonged plateau phase maintained by balanced ion currents. Repolarization requires the activation of delayed rectifier potassium channels (I_{K_r}), which export potassium ions; blocking these channels slows repolarization and prolongs the action potential duration.

Solution: The diagram illustrates a characteristic mammalian ventricular action potential. Phase 0 represents rapid depolarization driven by sodium influx, phase 1 is a brief initial repolarization notch, phase 2 is the prolonged plateau maintained by a balance between inward calcium currents ($I_{Ca,L}$) and outward potassium currents, and phase 3 is the rapid repolarization phase marked at point V_p . Rapid repolarization in phase 3 depends on the activation of delayed rectifier potassium channels (I_{K_r} and I_{K_s}), which allow potassium ions to exit the cell down their electrochemical gradient. If an experimental pharmacological agent blocks these I_{K_r} channels, the outward potassium current is reduced. This slows the rate of repolarization, prolongs the action potential duration, and lengthens the ventricular recovery period, which manifests on an electrocardiogram as a prolonged QT interval.

Final Answer: Prolonged plateau phase with delayed repolarization (long QT).

Answer: (B)

[Go Back to Question 9](#)



Q10.

Solution

Concept: Voltage-gated sodium channels rely on a dual-gate mechanism to regulate action potentials. The activation gate opens rapidly in response to depolarization, while the slower inactivation gate (h-gate) closes at the peak of the action potential to halt sodium influx and allow potassium-driven repolarization to occur.

Solution: Voltage-gated sodium channels possess two distinct gates that control ion flow: a voltage-dependent activation gate and a time-dependent inactivation gate (the h-gate). During a normal action potential upstroke, the activation gate opens rapidly, allowing sodium ions to rush into the cell. At the peak of depolarization, the slower h-gate closes, stopping further sodium influx even though the membrane remains depolarized. This inactivation is essential because it allows the slower voltage-gated potassium channels to repolarize the membrane back to its resting potential. If an experimental neurotoxin locks these inactivation h-gates in their open configuration, sodium influx will continue unabated. This persistent inward sodium current counteracts the outward potassium current, resulting in a prolonged, sustained depolarization phase and a complete failure to execute rapid repolarization.

Final Answer: Sustained depolarization with failed repolarization.

Answer: (B)

[Go Back to Question 10](#)

Q11.

Solution

Concept: Renal glucose reabsorption utilizes secondary active transport mechanisms. In the proximal convoluted tubule, specific cotransporters couple glucose reabsorption to the sodium gradient; a loss of these apical transporters prevents reabsorption, causing glucose to spill into the urine despite normal blood sugar levels.

Solution: In a healthy kidney, filtered glucose is reabsorbed from the luminal fluid in the proximal convoluted tubule back into the bloodstream, ensuring that urine is virtually free of glucose. This reabsorption is mediated primarily by the sodium-glucose cotransporter 2 (SGLT2), a secondary active transporter located on the apical membrane of the early segments of the proximal tubule. SGLT2 couples the movement of glucose against its concentration gradient to the downward movement of sodium ions. A profound hereditary loss of functional SGLT2 proteins prevents the proximal tubule from reabsorbing filtered glucose. As a result, the renal threshold for glucose drops significantly, leading to massive glucosuria. Because this condition is caused by a structural defect in the kidney rather than elevated systemic blood sugar, it occurs in the complete absence of hyperglycemia.

Final Answer: Massive glucosuria in the complete absence of systemic hyperglycemia.

Answer: (B)

[Go Back to Question 11](#)



Q12.

Solution

Concept: The cross-bridge cycle is driven by cyclic conformational changes in the myosin head. The hydrolysis of ATP primes the head, and subsequent binding to actin triggers the release of bound inorganic phosphate, which induces a strong structural tilt that slides the thin filament.

Solution: During the skeletal muscle cross-bridge cycle, myosin heads interact dynamically with actin thin filaments. In the resting state, the myosin head is "cocked" in its high-energy conformation, holding cleaved adenosine diphosphate (ADP) and inorganic phosphate (P_i) in its catalytic core. When calcium binds to troponin C, tropomyosin shifts to expose the active binding sites on actin, allowing the high-energy myosin head to attach loosely. This initial binding event triggers a conformational change that causes the immediate release of inorganic phosphate (P_i) from the catalytic pocket. The dissociation of P_i drives the mechanical power stroke—a structural rotation of the myosin neck region that pulls the thin actin filament toward the center of the sarcomere, generating contractile force.

Final Answer: Myosin power stroke pulls thin filament toward sarcomere center.

Answer: (B)

[Go Back to Question 12](#)

Q13.

Solution

Concept: Ventilatory drive is regulated by chemical tracking networks. Increased arterial carbon dioxide levels lower the pH of cerebrospinal fluid as CO_2 crosses the blood-brain barrier and is converted to carbonic acid, activating respiratory centers to increase ventilation.

Solution: When a volunteer inspires air with doubled partial pressures of carbon dioxide (pCO_2), the arterial blood gas levels of CO_2 rise quickly. Carbon dioxide is highly lipophilic and readily diffuses across the blood-brain barrier into the cerebrospinal fluid (CSF) and interstitial fluid of the brain. The CSF lacks significant protein buffers, so the enzyme carbonic anhydrase rapidly converts the dissolved CO_2 into carbonic acid, which dissociates into bicarbonate and hydrogen ions (H^+). This causes a sharp drop in CSF pH. Central chemoreceptors located on the ventrolateral surface of the medulla oblongata detect this increase in local hydrogen ion concentration. They send excitatory signals to the medullary respiratory centers, triggering an immediate hyperventilation reflex to expel excess CO_2 and restore homeostatic acid-base balance.

Final Answer: Medullary chemoreceptors detect decreased CSF pH.

Answer: (A)

[Go Back to Question 13](#)



Q14.

Solution

Concept: Gastric protein digestion requires an acidic luminal environment. Parietal cells express primary active transport pumps that secrete protons to maintain a low pH, which is essential for cleaving inactive zymogens into their active proteolytic forms.

Solution: Gastric parietal cells utilize apical H^+/K^+ ATPase proton pumps to actively secrete hydrogen ions into the stomach lumen against a steep concentration gradient, creating the highly acidic environment of gastric juice. This low pH (around 1.5 to 2.0) is essential for activating gastric digestive enzymes. Gastric chief cells secrete the inactive zymogen pepsinogen. Under acidic conditions, pepsinogen undergoes automatic conformational cleavage to remove an inhibitory peptide, converting it into the active proteolytic enzyme pepsin. If a mutation renders the H^+/K^+ ATPase pump completely non-functional, gastric acid secretion fails (achlorhydria). Without this acidic environment, pepsinogen cannot be activated, leading to a severe impairment in gastric protein digestion.

Final Answer: Loss of pepsinogen activation impairs protein digestion.

Answer: (B)

[Go Back to Question 14](#)

Q15.

Solution

Concept: Xerophytic plant adaptations reduce transpirational water loss. Arid-zone plants often restrict stomatal distribution and position guard cells within recessed epidermal cavities lined with microscopic hairs, which traps a layer of humid air and minimizes water vapor diffusion.

Solution: Xerophytes have evolved specialized anatomical adaptations to survive in arid environments where water loss from transpiration can be lethal. To limit transpiration, these plants reduce the exposure of their stomata to dry ambient air. A common adaptation is the development of sunken stomata, which are located deep within recessed epidermal cavities called stomatal crypts. These crypts are frequently lined with specialized epidermal hairs called trichomes. The trichomes trap a microenvironment of stagnant, humid air directly outside the stomatal pore, reducing the water vapor concentration gradient between the interior of the leaf and the atmosphere. This modification significantly lowers the rate of transpirational water loss while still allowing the gas exchange necessary for photosynthesis.

Final Answer: Sunken stomata localized within specialized trichome-lined crypts.

Answer: (B)

[Go Back to Question 15](#)



Q16.

Solution

Concept: Mitochondrial inheritance follows a maternal transmission pattern. Because the oocyte provides virtually all the cytoplasm and organelles to the zygote while sperm contribute only nuclear DNA, a trait encoded by the mitochondrial genome is passed from an affected female to all of her offspring.

Solution: The pedigree chart illustrates a distinct inheritance pattern across three generations. In Generation I, an unaffected female and an unaffected male have children. In Generation II, an affected female appears (indicated by the filled circle). When this affected female reproduces, all of her offspring—including the male in Generation III (indicated by the filled rectangle)—inherit the clinical syndrome. This pattern where a trait is transmitted exclusively through females to all of her children is the classic hallmark of mitochondrial (maternal) inheritance. During fertilization, the secondary oocyte contributes virtually all of the cytoplasm, nutrients, and cellular organelles to the resulting zygote, including thousands of maternal mitochondria. The sperm cell contributes only its nuclear genome, as its mitochondria are targeted for destruction upon entry. Thus, any mutation in mitochondrial DNA is passed from an affected mother to all of her offspring.

Final Answer: Maternal mitochondrial inheritance.

Answer: (D)

[Go Back to Question 16](#)

Q17.

Solution

Concept: Nonsense suppression occurs when a mutated tRNA reads a stop codon. If a tRNA anticodon is altered to match a termination sequence but remains charged with an amino acid, it inserts that amino acid at the stop site, allowing translation to continue.

Solution: In this in vitro translation assay, a tRNA molecule that is normally charged with the amino acid Phenylalanine has undergone an anticodon loop mutation, changing its sequence from 5'-GAA-3' to 5'-UAA-3'. According to mRNA-tRNA complementary base-pairing rules, this mutated tRNA will recognize and bind to the matching mRNA codon, which runs antiparallel: 5'-UAA-3'. The 5'-UAA-3' sequence is one of the three standard universal stop codons (ochre) that normally signals release factors to terminate translation. Because this mutated tRNA carries Phenylalanine but recognizes a stop codon, it will insert Phenylalanine at this site instead of allowing translation to stop. This mechanism is known as nonsense suppression, as it suppresses normal translation termination and allows the ribosome to continue elongating the polypeptide chain past a stop codon.

Final Answer: Phenylalanine incorporation at UAA causes nonsense suppression.

Answer: (A)

[Go Back to Question 17](#)



Q18.

Solution

Concept: Testcrosses involving multiple independent loci follow binomial probability distributions. For each heterozygous gene in the parent, the probability of the offspring inheriting the dominant phenotype is exactly one-half, allowing the overall distribution of dominant traits to be calculated using binomial expansions.

Solution: The multi-factorial genetic cross involves a fully heterozygous parent ($AaBbCcDd$) and a fully homozygous recessive tester parent ($aabbccdd$). Because all four gene loci assort completely independently, the probability of an offspring inheriting and displaying the dominant phenotype for any single trait is exactly $\frac{1}{2}$, and the probability of displaying the recessive phenotype is also $\frac{1}{2}$. This independent system can be modeled using a binomial distribution with $n = 4$ independent trials. We need to calculate the probability of obtaining an offspring that shows the dominant phenotype for exactly $k = 2$ of the four evaluated traits. Using the binomial probability formula $\binom{n}{k}p^kq^{n-k}$, where $p = \frac{1}{2}$ and $q = \frac{1}{2}$:

$$\text{Probability} = \binom{4}{2} \left(\frac{1}{2}\right)^2 \left(\frac{1}{2}\right)^{4-2}$$

$$\text{Probability} = \frac{4!}{2!2!} \left(\frac{1}{4}\right) \left(\frac{1}{4}\right) = 6 \times \frac{1}{16} = \frac{6}{16} = \frac{3}{8}$$

Thus, the statistical probability of an offspring displaying exactly two dominant phenotypes is $\frac{3}{8}$.

Final Answer: $\frac{3}{8}$

Answer: (B)

[Go Back to Question 18](#)

Q19.

Solution

Concept: Natural selection shapes phenotypic variance within populations. Selection that favors both extreme ends of a phenotypic spectrum while weeding out intermediate forms increases diversity and can drive the split of a single lineage into distinct groups.

Solution: Natural selection can alter the distribution of heritable phenotypes within a population in several ways. In this scenario, the selective pressures on the island finches favor individuals at both extreme ends of the phenotypic spectrum while actively eliminating the intermediate phenotypes. This pattern is classified as disruptive (or diversifying) selection. A classic example occurs when resource availability shifts, such as an ecosystem having only very hard, large seeds and very soft, tiny seeds, which favors finches with either very large or very small beaks while selecting against those with medium-sized beaks. Over evolutionary time, disruptive selection splits the population into two distinct phenotypic morphs, increasing genetic variance and serving as a powerful driver for sympatric speciation events.

Final Answer: Disruptive selection promoting sympatric speciation.

Answer: (B)

[Go Back to Question 19](#)



Q20.

Solution

Concept: Bacterial transcription initiation requires specialized holoenzyme components. While the core RNA polymerase handles elongation, the transiently bound sigma subunit is responsible for locating and binding specific promoter sequences to ensure accurate initiation.

Solution: In prokaryotic systems, the transcription of DNA into RNA is carried out by RNA polymerase. The complete, functional enzyme complex is called the holoenzyme, which consists of the core enzyme ($\alpha_2\beta\beta'\omega$) and a transiently attached regulatory subunit known as the sigma (σ) factor. The core enzyme possesses the catalytic activity required to synthesize phosphodiester bonds and elongate the RNA chain, but it cannot recognize or bind to specific DNA promoters on its own. The sigma subunit is responsible for specific promoter recognition, binding to the conserved -10 (Pribnow box) and -35 sequences ahead of the transcription start site. A mutant RNA polymerase lacking a functional sigma subunit can still catalyze RNA synthesis, but it loses specific promoter targeting, resulting in random, non-specific transcription initiation across the genome.

Final Answer: Loss of promoter recognition causes non-specific transcription.

Answer: (B)

[Go Back to Question 20](#)

Q21.

Solution

Concept: Ovarian steroid hormones regulate the uterine lining during gestation. Following ovulation, the corpus luteum secretes progesterone to transition the endometrium into a nutrient-rich, secretory state that can support a blastocyst.

Solution: The graph tracks plasma hormone concentrations across a standard 28-day human menstrual cycle. Hormone A displays a sharp pre-ovulatory peak around day 14, identifying it as luteinizing hormone (LH), which triggers ovulation. Following ovulation, the ruptured Graafian follicle transforms into the corpus luteum, which secretes large amounts of hormone C during the luteal phase (days 15 to 28). This hormone profile identifies C as progesterone. The primary physiological role of progesterone during the luteal phase is to act on the uterine endometrium, stimulating vascularization, glycogen secretion, and structural glandular modifications. This transitions the lining into a highly receptive, secretory state designed to sustain an embedding embryo if fertilization occurs.

Final Answer: Maintains endometrial integrity for implantation.

Answer: (C)

[Go Back to Question 21](#)



Q22.

Solution

Concept: Fertilization requires sperm to penetrate the egg's outer layers using enzymatic digestion. The acrosomal vesicle contains specialized proteases that break down the protective glycoprotein shell surrounding the oocyte, allowing the sperm head to reach the plasma membrane.

Solution: The diagram models a human sperm cell interacting with the zona pellucida, the thick extracellular glycoprotein shell protecting the secondary oocyte. The vesicle marked A_v represents the acrosome, a specialized lysosome-like organelle located at the tip of the sperm head. When sperm binds to the zona pellucida, it triggers the acrosome reaction, causing the outer sperm membrane to fuse with the acrosomal membrane and release its stored enzymes via exocytosis. Acrosin is a key serine protease packed within this vesicle. Its primary function is to proteolytically digest and dissolve the localized glycoprotein matrix of the zona pellucida. If a genetic mutation leaves the acrosome completely devoid of functional acrosin, the sperm will be physically blocked from penetrating the zona pellucida, halting fertilization before the sperm can fuse with the oocyte plasma membrane.

Final Answer: Sperm cannot penetrate the zona pellucida.

Answer: (B)

[Go Back to Question 22](#)

Q23.

Solution

Concept: Meiosis reduces chromosome number during gametogenesis. Diploid germ cells differentiate into primary gametocytes, which undergo the first reductive meiotic division to separate homologous chromosomes, yielding haploid secondary gametocytes.

Solution: Human spermatogenesis is a highly organized differentiation pathway that occurs within the seminiferous tubules of the testes. The process begins with diploid ($2n$) spermatogonia type A, which divide mitotically to maintain the stem cell pool and give rise to type B spermatogonia. These type B spermatogonia differentiate into diploid ($2n$) primary spermatocytes. The primary spermatocyte is the specific cellular stage that enters and completes Meiosis I—the reductive division of the cell cycle. During this division, homologous chromosome pairs separate, reducing the chromosome complement by half. The completion of Meiosis I yields two equal-sized haploid ($1n$) secondary spermatocytes, which then enter Meiosis II to separate sister chromatids and produce round spermatids.

Final Answer: Primary spermatocytes

Answer: (B)

[Go Back to Question 23](#)



Q24.

Solution

Concept: Mammalian fertilization depends on specific glycoprotein interactions. The outer matrix of the oocyte contains receptor proteins that recognize and bind complementary molecules on the sperm head, initiating the acrosome reaction required for entry.

Solution: The zona pellucida is a specialized extracellular matrix that surrounds mammalian oocytes, composed of structural glycoproteins including ZP1, ZP2, and ZP3. Zona pellucida protein 3 (ZP3) functions specifically as the primary receptor responsible for species-specific sperm recognition and binding. When a capacitated sperm binds to the ZP3 glycoprotein, it activates a heterotrimeric G-protein signaling cascade within the sperm head, triggering an influx of calcium ions that induces the acrosome reaction. A non-functional mutation in the ZP3 gene prevents sperm from recognizing and binding to the zona pellucida, blocking the acrosome reaction and halting fertilization at its earliest extracellular step.

Final Answer: Species-specific sperm binding triggers acrosome reaction.

Answer: (B)

[Go Back to Question 24](#)

Q25.

Solution

Concept: Phytochromes act as light-regulated molecular switches in plants. They exist in a reversible equilibrium between an inactive form that absorbs red light (660 nm) and an active form that absorbs far-red light (730 nm), which controls photomorphogenic development.

Solution: The graph tracks the action spectrum of the phytochrome system, a major family of photomorphogenic photoreceptors in plants. Phytochromes are dimeric proteins with covalently attached chromophores that act as light-regulated molecular switches, shifting between two interconvertible forms based on the wavelength of light absorbed:

- The P_r form is inactive and absorbs red light maximally at 660 nm. Absorbing red light converts it into the active P_{fr} form.
- The P_{fr} form is the physiologically active state and absorbs far-red light maximally at 730 nm (marked as point Z).

When exposed to far-red light at point Z, the active P_{fr} molecule absorbs the photon and shifts back into the inactive P_r conformation, reversing phytochrome-mediated responses.

Final Answer: Phytochrome systems shifting from the active P_{fr} state to the inactive P_r form.

Answer: (C)

[Go Back to Question 25](#)



Q26.

Solution

Concept: Stomatal movements are driven by active transport and osmotic gradients. Plasma membrane proton pumps generate an electrochemical gradient that opens inward voltage-gated potassium channels; water follows the accumulating ions into the guard cells, increasing turgor pressure to open the pore.

Solution: Stomatal opening is an active physiological process initiated by plasma membrane-bound H^+ -ATPase proton pumps within guard cells. When activated by environmental cues like light, these pumps hydrolyze ATP to extrude hydrogen ions out of the cytoplasm into the surrounding apoplast. This active transport establishes a strong negative electrical potential across the plasma membrane. This hyperpolarization activates inward voltage-gated potassium channels, driving a massive influx of K^+ ions into the guard cells, followed by counter-ions like chloride and malate. If a researcher applies a synthetic chemical inhibitor that blocks this proton pump, the guard cells cannot generate the required membrane potential. Consequently, potassium ions do not accumulate, osmotic water movement is blocked, and the stomata remain tightly closed.

Final Answer: Lack of electrochemical gradient prevents K^+ uptake and stomatal opening.

Answer: (B)

[Go Back to Question 26](#)

Q27.

Solution

Concept: Seed dormancy is maintained by hormonal cross-regulation. While gibberellins trigger pathways that lead to germination, abscisic acid acts as an inhibitor that enforces dormancy during development, preventing premature germination on the parent plant.

Solution: Vivipary is a developmental anomaly where seeds bypass normal dormancy and germinate prematurely while still attached to the fruit or cob of the parent plant. In healthy plants, seed dormancy is established and maintained by high concentrations of the hormone abscisic acid (ABA) during seed maturation. ABA counteracts the growth-promoting effects of gibberellins, preventing the embryo from growing until the seed is shed and encounters favorable environmental conditions. A mutant line of *Zea mays* that displays vivipary typically harbors a genetic defect that breaks the biosynthetic pathway for abscisic acid, or leaves its downstream receptors non-functional. Without active ABA signaling to enforce dormancy, the embryo germinates prematurely on the cob.

Final Answer: Abscisic acid (ABA)

Answer: (B)

[Go Back to Question 27](#)



Q28.

Solution

Concept: Floral anatomy defines the taxonomic groups of flowering plants. A flower featuring five fused petals, stamens fused directly to the inner surface of the corolla tube, and a superior ovary composed of fused carpels is a diagnostic hallmark of the nightshade family.

Solution: The floral diagram illustrates a flower with pentamerous symmetry (parts in multiples of five). The outer whorl shows fused sepals, and the next whorl shows five fused petals. The stamens are attached directly to the inner surface of the corolla tube, a condition known as epipetalous stamens. In the center, the gynoecium consists of a syncarpous superior ovary formed by fused carpels. This specific suite of anatomical characteristics—pentamerous organization, fused petals, epipetalous stamens, and a syncarpous superior ovary—is the diagnostic hallmark of the family Solanaceae (the nightshade family), which includes economically important crops such as tomatoes, potatoes, eggplants, and peppers.

Final Answer: Solanaceae

Answer: (B)

[Go Back to Question 28](#)

Q29.

Solution

Concept: DNA replication requires coordinated management of topological strain. As helicase unwinds the double helix at the replication fork, the DNA ahead becomes tightly overwound, generating positive supercoils that must be relieved by topoisomerases to prevent halting the replication machinery.

Solution: The diagram models a moving replication fork during nuclear DNA synthesis. As DNA helicase unwinds the parental strands to expose templates for the leading and lagging strands, the double-stranded DNA ahead of the fork becomes tightly overwound. This overwinding generates severe positive supercoiling and torsional strain. The enzyme acting at site E_m is Topoisomerase, which cleaves the phosphodiester backbone of one or both strands, allows the DNA to untwist to relieve the torsional stress, and then reseals the covalent bonds. If a cell line experiences a loss-of-function mutation in this topoisomerase gene, positive supercoils will rapidly accumulate ahead of the fork. The resulting structural strain creates a physical barrier that stalls the replication fork, halting further DNA synthesis.

Final Answer: Positive supercoils build up, stopping replication fork movement.

Answer: (B)

[Go Back to Question 29](#)



Q30.

Solution

Concept: Primitive land plants are classified by lifecycle dominance and tissue structure. Non-vascular plants exhibit an alternation of generations where the photosynthetic gametophyte is dominant, while the short-lived sporophyte is physically attached to and dependent on it.

Solution: The taxonomic description outlines a non-vascular terrestrial plant that lacks specialized conducting tissues like xylem and phloem. Its life cycle features an alternation of generations where the haploid gametophyte is the dominant, green, photosynthetic, and independent phase. The diploid sporophyte is short-lived, physically attached to, and nutritionally dependent on the gametophyte, consisting anatomically of a foot, a stalk-like seta, and a spore-producing capsule. These structural and reproductive traits define the class Bryopsida (true mosses) within the division Bryophyta, distinguishing them from vascular plants (like Pteropsida or Lycopsida) and aquatic green algae (Chlorophyceae).

Final Answer: Bryopsida (Musci)

Answer: (B)

[Go Back to Question 30](#)

Q31.

Solution

Concept: Humoral immunity relies on the clonal expansion and specialization of B-cells. Following antigen activation, B-lymphocytes differentiate into long-lived memory cells for future defense and short-lived effector cells specialized for high-rate immunoglobulin synthesis and secretion.

Solution: The schematic outlines the differentiation pathway of a naive B-lymphocyte during a primary immune response. When a naive B-cell encounters its specific antigen cluster and receives costimulatory signals from helper T-cells, it undergoes rapid clonal expansion and differentiates into two distinct cell lineages. The lineage marked C_1 represents memory B-cells, which persist long-term to provide rapid defense during secondary exposures. The lineage marked C_2 represents mature plasma cells. These effector cells contain an extensive rough endoplasmic reticulum and an enlarged Golgi apparatus, which are specialized for the high-output synthesis and continuous secretion of thousands of soluble immunoglobulin (antibody) molecules per second.

Final Answer: Mature Plasma Cell specialized for continuous antibody synthesis

Answer: (B)

[Go Back to Question 31](#)



Q32.

Solution

Concept: Viral entry depends on binding specific host surface proteins. The human immunodeficiency virus utilizes its envelope glycoproteins to dock onto the CD4 receptor of helper T-cells, requiring a secondary interaction with chemokine co-receptors to trigger membrane fusion.

Solution: The human immunodeficiency virus (HIV) targets helper T-lymphocytes by exploiting specific cell surface proteins to enter the host cytoplasm. The primary receptor for the viral envelope glycoprotein gp120 is the CD4 molecule on the T-cell surface. However, binding to CD4 alone is insufficient for entry; it induces a conformational change in gp120 that exposes a coreceptor-binding site. The viral glycoprotein must then interact with a specific G-protein-coupled chemokine co-receptor, either CCR5 (primarily on macrophages and memory T-cells) or CXCR4 (primarily on naive T-cells). This secondary docking step triggers the viral gp41 protein to undergo a structural change that mediates fusion between the viral envelope and the host cell membrane, making this receptor and co-receptor complex the primary target for entry-blocking therapeutics.

Final Answer: CD4 molecule along with chemokine receptors CCR5 or CXCR4

Answer: (B)

[Go Back to Question 32](#)

Q33.

Solution

Concept: Plant gravitropism is regulated by asymmetric hormone redistribution. Gravity-sensing cells trigger the accumulation of auxin along the lower side of a horizontally oriented root tip, where high concentrations inhibit cell elongation and cause downward bending.

Solution: The root tip diagram models positive gravitropism. When a plant is placed horizontally, dense starch-filled organelles called statoliths sediment to the lower side of columella cells in the root cap. This sedimentation triggers the asymmetric redistribution of the phytohormone auxin (indole-3-acetic acid, IAA) via PIN transport proteins, causing it to accumulate at high concentrations along the lower side of the root elongation zone (S_h). While high auxin concentrations promote cell elongation in shoots, they have the opposite effect in roots, where they stimulate ethylene production and locally inhibit cell elongation. Consequently, the cells on the upper side, where auxin concentration is lower, elongate normally and grow faster than the inhibited cells on the lower side. This unequal growth rate causes the root tip to curve downward toward the gravitational pull.

Final Answer: Auxin inhibits elongation on the lower side, causing positive gravitropism.

Answer: (B)

[Go Back to Question 33](#)



Q34.

Solution

Concept: Protozoan parasites drive cyclical erythrocyte lysis. The lifecycle of certain apicomplexan pathogens involves synchronous rounds of replication within host red blood cells, culminating in cell rupture that releases toxins and causes recurring fevers and hemolytic anemia.

Solution: The patient exhibits classic symptoms of malaria, which is caused by protozoan parasites of the genus *Plasmodium*. The key diagnostic indicators are cyclical fevers that recur every 48 hours (typical of a tertian fever pattern), severe chills, hemolytic anemia, and the presence of characteristic ring-stage trophozoites inside microcytic erythrocytes on a peripheral blood smear. This specific 48-hour cyclical symptom pattern is caused by the synchronous asexual reproduction cycle (erythrocytic schizogony) of *Plasmodium vivax* or *Plasmodium falciparum*. Every 48 hours, a new generation of merozoites ruptures out of the host red blood cells, releasing viral waste and metabolic toxins into the bloodstream, which triggers the host immune system to produce high fevers and chills.

Final Answer: Plasmodium vivax

Answer: (B)

[Go Back to Question 34](#)

Q35.

Solution

Concept: Demographic trajectories are reflected in age-structure diagrams. An inverted pyramid configuration features a narrow base of pre-reproductive individuals relative to older cohorts, indicating a birth rate that has dropped below replacement levels.

Solution: The age structure diagram for Population *R* displays an inverted pyramid configuration. In this profile, the lowest tier—which represents the pre-reproductive cohort—is significantly narrower than the middle tier representing the reproductive cohort. This narrow base indicates low birth rates over recent generations. Because fewer individuals are entering the reproductive pool to replace the older, aging cohorts, the population size is expected to shrink over time. This demographic distribution leads to a negative intrinsic rate of natural increase ($r < 0$), characterizing a declining population trend typical of nations or populations with below-replacement fertility rates.

Final Answer: Declining population with a narrow pre-reproductive base.

Answer: (C)

[Go Back to Question 35](#)



Q36.

Solution

Concept: Interspecific competition drives evolutionary niche divergence. Sympatric species that exploit identical resources experience strong selective pressure to diversify their phenotypic traits, which minimizes competitive overlap and allows stable co-existence.

Solution: When two species with overlapping ecological niches occupy the same geographic region (sympatry), they compete intensely for shared, limiting resources. This resource competition exerts strong selective pressure on both populations to minimize niche overlap. Over generations, individuals possessing phenotypic variations that allow them to exploit alternative resources will experience higher evolutionary fitness. This divergence in physical or behavioral traits between sympatric populations is known as character displacement. The evolutionary shift in jaw morphology between Species A and Species B reduces direct competition for the same seed sizes, allowing the two rodent species to partition their resources and achieve stable co-existence within the ecosystem.

Final Answer: Character displacement minimizes niche competition.

Answer: (B)

[Go Back to Question 36](#)



Q37.

Solution

Concept: Restriction endonucleases are enzymes that cleave double-stranded DNA at specific recognition sequences. The total number of fragments generated by restriction digestion depends on the topology of the DNA molecule (linear vs. circular) and the total number of unique cleavage sites present along its sequence.

Solution: The problem specifies that the template is a **linear** plasmid vector with a total length of 12 kilobases (kb). The restriction map indicates two distinct internal cutting positions: an EcoRI site at 1.8 kb and a HindIII site at 4.5 kb.

When a linear DNA strand is cut internally, each cleavage event increases the fragment count by one ($n_{\text{fragments}} = n_{\text{cuts}} + 1$). Performing a complete simultaneous double digestion with both enzymes executes exactly two cuts along the linear backbone:

- The first cut at the EcoRI site (1.8 kb) splits the 12 kb linear molecule into two fragments: a 0–1.8 kb piece and a 1.8–12 kb piece.
- The second cut at the HindIII site (4.5 kb) cleaves the remaining long piece, splitting it into a 1.8–4.5 kb segment and a 4.5–12 kb segment.

This yields a total of **3 distinct DNA fragments** with specific lengths of 1.8 kb, 2.7 kb (calculated as $4.5 - 1.8$), and 7.5 kb (calculated as $12 - 4.5$).

Final Answer: 3 fragments

Answer: (C)

[Go Back to Question 37](#)



Q38.

Solution

Concept: The CRISPR-Cas9 genome editing tool relies on dual-component recognition to achieve site-specific DNA cleavage. While the single guide RNA (sgRNA) specifies a complementary target sequence via Watson-Crick base pairing, the Cas9 endonuclease requires a conserved structural handle known as a Protospacer Adjacent Motif (PAM) to bind and introduce a double-stranded break.

Solution: In the type II CRISPR-Cas9 adaptive immune system from *Streptococcus pyogenes*, the Cas9 endonuclease scans foreign DNA by looking for a specific, conserved short nucleotide sequence called the Protospacer Adjacent Motif (PAM). For the standard *S. pyogenes* Cas9, the canonical PAM sequence is 5'-NGG-3', where "N" can be any nucleotide followed by two guanine bases.

Mechanistically, Cas9 first binds non-specifically to genomic DNA and interrogates the duplex for this PAM motif. Once a PAM site is located, Cas9 melts the adjacent DNA double helix to allow the 20-nucleotide targeting sequence of the single guide RNA (sgRNA) to attempt complementary base pairing with the upstream protospacer target strand. Crucially, this PAM motif must be located immediately **3'** of the genomic target sequence on the non-target strand. If the matching 5'-NGG-3' motif is missing or mutated, Cas9 cannot undergo the conformational transition required to activate its RuvC and HNH nuclease domains, failing to introduce a double-stranded break (DSB) even if the sgRNA matches the target site perfectly.

Final Answer: A Protospacer Adjacent Motif (PAM) sequence matching 5'-NGG-3'

Answer: (B)

[Go Back to Question 38](#)



Q39.

Solution

Concept: Single-celled eukaryotic microorganisms possess diverse, highly taxon-specific cell walls. Diatoms are distinguished by their complex, glassy cell walls called frustules, which are composed of silica and structured as two overlapping halves that fit together precisely.

Solution: The diagram models the unique architectural layout of a frustule, which is the siliceous, rigid cell wall characteristic of **diatoms** (belonging to the division Chrysophyta or class Bacillariophyceae). The frustule is composed of polymerized amorphous silica (SiO_2) ornamented with intricate, species-specific patterns of pores and striae.

This glass-like shell is engineered as a bipartite (two-part) structure that mimics a petri dish or pillbox. It consists of a slightly larger upper valve called the **epitheca** that overlaps and caps a slightly smaller lower valve called the **hypotheca**. When diatoms die, their chemically stable, non-decaying silica frustules sink to the aquatic floor, accumulating over millions of years to form massive sedimentary deposits known as diatomaceous earth, which is harvested commercially for filtration, abrasives, and pest control.

Final Answer: Diatoms form non-decaying frustules creating diatomaceous earth.

Answer: (B)

[Go Back to Question 39](#)



Q40.

Solution

Concept: Blue-white screening is a molecular biology technique used to visually identify recombinant colonies. It relies on alpha-complementation, where an inactive N-terminal fragment of β -galactosidase (alpha-peptide) unites with a defective host enzyme core to form a functional catalyst capable of cleaving chromogenic substrates.

Solution: The beta-galactosidase (β -gal) reporting system utilizes a mechanism called α -complementation. The multi-cloning site (MCS) of the vector is engineered into the coding region of the α -peptide (the N-terminus of the *lacZ* gene). The host *E. coli* strain contains a mutated chromosome encoding a defective β -galactosidase that lacks this specific α -peptide segment, rendering it completely inactive on its own.

When a vector with an *intact* alpha-peptide sequence is transformed into these host cells, the plasmid-born peptide complements the host deletion, assembling into a fully functional, active tetrameric β -galactosidase enzyme. In the presence of the inducer IPTG and the chromogenic substrate X-gal, this functional enzyme cleaves X-gal to form an insoluble blue pigment, yielding bright blue colonies.

However, when a foreign cDNA fragment is successfully ligated into the restriction site within the MCS, it disrupts the reading frame or physical sequence of the alpha-peptide—a phenomenon known as **insertional inactivation**. Cells transformed with these recombinant plasmids cannot synthesize the functional α -peptide, preventing the assembly of an active β -galactosidase enzyme. Consequently, the substrate X-gal remains uncleaved, causing the recombinant colonies to appear **white**, which allows for straightforward visual selection.

Final Answer: White colonies due to insertional inactivation of the alpha-peptide.

Answer: (B)

[Go Back to Question 40](#)



Answer Key

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

