

BITSAT Biology Sample Paper-10

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 a cell fractionation assay, a student isolates an organelle capable of executing post-translational core glycosylation, possessing its own luminal pH of approximately 6.0–6.5, and demonstrating structural continuity with the nuclear envelope. Which marker enzyme should be tested to confirm the identity of this fraction?

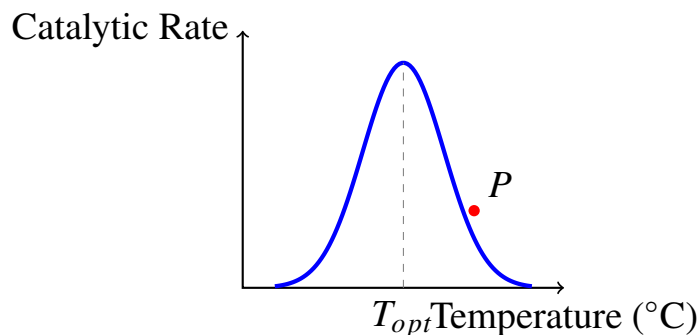
- (A) Succinate dehydrogenase
- (B) Glucose-6-phosphatase
- (C) Acid phosphatase
- (D) Catalase

Q2. A patient presents with a rare metabolic disorder characterized by the inability to oxidize long-chain fatty acids greater than 22 carbons in length. This pathobiological condition is most likely rooted in the structural or functional lesion of which specific cellular compartment?

- (A) Inner Mitochondrial Membrane
- (B) Peroxisomes
- (C) Rough Endoplasmic Reticulum
- (D) Lysosomal Matrix



- Q3.** An analytical sample of a purified enzyme was subjected to temperature denaturation dynamics. The graph below displays its relative catalytic rate as a function of temperature ($^{\circ}\text{C}$). Choose the option that perfectly describes the structural or thermodynamic behavior occurring at point P .



- (A) Complete hydrolytic cleavage of peptide bonds throughout the primary backbone structure.
- (B) Reversible competitive inhibition induced by rapid thermodynamic expansion of the active site cavity.
- (C) Irreversible thermal denaturation caused by the disruption of weak non-covalent interactions stabilizes tertiary folding.
- (D) Sudden alteration in the absolute isoelectric point (pI) of the prosthetic operational cluster.
- Q4.** Calculate the total yield of ATP synthesized purely via substrate-level phosphorylation when exactly two molecules of sucrose enter the eukaryotic glycolytic pathway and are fully converted to down-stream pyruvate under standard cellular conditions:
- (A) 8 ATP
- (B) 16 ATP
- (C) 12 ATP
- (D) 24 ATP
- Q5.** If the DNA of a hyperthermophilic archaeon contains 38% Guanine bases in its absolute genome composition, deduce the total number of hydrogen bonds



holding together a double-stranded genomic fragment that is exactly 200 base pairs long.

- (A) 480
- (B) 552
- (C) 576
- (D) 612

Q6. 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.

Q7. During the diakinesis phase of meiotic prophase I, a cell displays 12 distinct chiasmata structures across its chromosomal layout. Determine the absolute number of bivalents and total chromatids present in this specific micro-environment respectively:

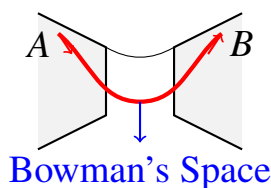
- (A) 6 bivalents, 24 chromatids
- (B) 12 bivalents, 48 chromatids
- (C) 12 bivalents, 24 chromatids
- (D) 24 bivalents, 48 chromatids

Q8. Which of the following amino acid residues acts as a structural disruptor within a standard alpha-helical conformation due to its rigid, cyclic secondary amino group, forcing a localized structural kink?



- (A) Glycine
- (B) Proline
- (C) Tryptophan
- (D) Histidine

Q9. The simplified schematic below depicts the operational filtration unit within the mammalian renal cortex. If the hydraulic pressure at point *A* drops substantially while the oncotic pressure at point *B* remains static, assess the structural impact on the Net Filtration Pressure (*NFP*) within the system.



- (A) *NFP* will rise exponentially due to compensatory vasodilation of the efferent branch.
 - (B) *NFP* will decline or hit zero, causing a total drop in the Glomerular Filtration Rate (*GFR*).
 - (C) Podocyte structural gaps will contract, accelerating total ultrafiltration capacity.
 - (D) The excretion rate of large plasma proteins into the tubular system will double.
- Q10.** An isolated cardiac muscle specimen is bathed in a solution containing an ultra-high physiological concentration of digitalis compounds. This molecular intervention directly blocks the Na^+/K^+ ATPase pump, leading immediately to:
- (A) Intracellular sodium depletion resulting in immediate hyperpolarization.
 - (B) Intracellular calcium accumulation via the reversal or inhibition of the Na^+/Ca^{2+} exchanger, boosting contractility.
 - (C) Enhanced potassium influx triggering prolonged diastolic arrest.



(D) Complete down-regulation of sarcoplasmic ryanodine receptor activation pathways.

Q11. During a deep-sea saturation dive, a researcher shifts suddenly to breathing an artificial gas mixture. If the partial pressure of carbon dioxide (pCO_2) in the arterial blood increases from 40 mmHg to 55 mmHg, what is the primary neurochemical mechanism driving the respiratory compensation center?

(A) Direct binding of molecular CO_2 to peripheral baroreceptors in the aortic arch.

(B) Diffusion of H^+ ions across the blood-brain barrier into the cerebrospinal fluid.

(C) Hydration of CO_2 in cerebrospinal fluid followed by dissociation, creating H^+ ions that stimulate central chemoreceptors.

(D) Direct activation of the pneumotaxic center by carbaminohemoglobin levels.

Q12. A physiological biopsy of the human small intestine shows a profound structural loss of the brush-border enzyme enterokinase. Which of the following digestive events will remain completely functional despite this specific clinical deficiency?

(A) Cleavage of chymotrypsinogen into active chymotrypsin.

(B) Hydrolysis of dietary starches into maltose fragments by pancreatic amylase.

(C) Activation of procarboxypeptidase into carboxypeptidase.

(D) Conversion of trypsinogen into active proteolytic trypsin.

Q13. Identify the correct sequence of vascular shunts and pathways that an erythrocyte follows when traveling from the maternal uterine artery directly to the fetal inferior vena cava:

(A) Uterine Artery \rightarrow Umbilical Artery \rightarrow Ductus Arteriosus \rightarrow Fetal Liver \rightarrow IVC

(B) Trophoblastic Lacunae \rightarrow Umbilical Vein \rightarrow Ductus Venosus \rightarrow Fetal IVC

(C) Intervillous Space \rightarrow Umbilical Artery \rightarrow Foramen Ovale \rightarrow Fetal IVC



(D) Placental Sinus → Vitelline Vein → Hepatic Portal Shunt → Fetal IVC

Q14. A patient displays severe muscle tetany following an accidental radical thyroidectomy. Laboratory metrics confirm profound hypocalcemia. This neuromuscular hypersensitivity state is fundamentally caused by:

- (A) A decrease in the extracellular threshold potential, making voltage-gated Na^+ channels hyper-excitabile.
- (B) Absolute failure of myosin heads to dissociate from actin binding configurations.
- (C) Persistent open states of voltage-dependent potassium channels across the sarcolemma.
- (D) Complete depletion of neurotransmitter packages inside the synaptic terminal.

Q15. Which of the following statements regarding the oxygen-hemoglobin dissociation curve is completely accurate when a physiological shift occurs due to intensive skeletal exercise?

- (A) Leftward shift driven by a high affinity for oxygen under systemic lactic acidosis.
- (B) Rightward shift induced by elevated temperature and H^+ concentrations, facilitating oxygen offloading to tissues.
- (C) Leftward shift triggered by 2,3-BPG accumulation inside the contracting muscular microenvironment.
- (D) Rightward shift reflecting an enhanced affinity of the heme iron configurations for free oxygen binding.

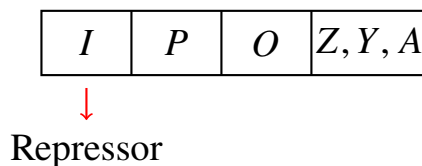
Q16. During C4 plant photosynthetic carbon fixation, the initial carboxylation step and the subsequent primary decarboxylation event happen sequentially inside which localized anatomical structures?

- (A) Mesophyll cell chloroplast matrix → Bundle sheath cell cytoplasm
- (B) Mesophyll cell cytoplasm → Bundle sheath cell chloroplast matrix



- (C) Bundle sheath cytoplasm → Mesophyll cell stroma
 (D) Epidermal guard cells → Vascular cambium lines

Q17. The operational model of a bacterial transcriptional regulation unit (Lac Operon) is diagrammed below. If a loss-of-function point mutation completely inactivates the product of domain *I*, predict the true expression status of the structural coding segments *Z*, *Y*, and *A* in the complete absence of environmental lactose.



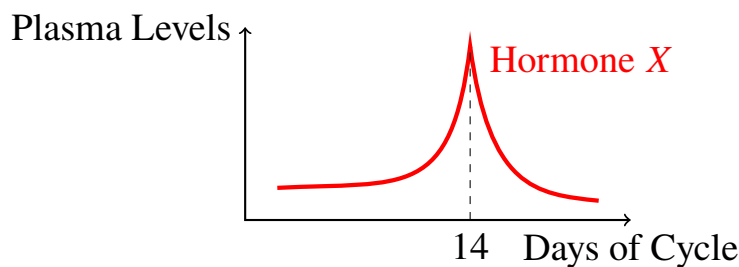
- (A) Absolute permanent repression; transcription is entirely blocked.
 (B) Constitutive continuous transcription occurs because the functional repressor cannot bind the operator.
 (C) Transcription occurs exclusively when high levels of cyclic AMP are added to the culture medium.
 (D) The promoter locus deletes itself dynamically via homologous recombination.
 (E) None of the above
- Q18.** A double-heterozygous testcross ($AaBb \times aabb$) yields the following offspring distribution phenotype metrics: 440 wild-type ($AaBb$), 460 double mutant ($aabb$), 52 recombinant type 1 ($Aabb$), and 48 recombinant type 2 ($aaBb$). Calculate the map distance separating these two genetic loci on the chromosome:
- (A) 5.0 centimorgans
 (B) 10.0 centimorgans
 (C) 20.0 centimorgans
 (D) 50.0 centimorgans



- Q19.** During eukaryotic mRNA replication and maturation, a pre-mRNA script is processed. If a specific genetic error mutates the invariant *GU* dinucleotide sequence at the 5' boundary layer of intron 2, what is the processing outcome?
- (A) Failure of polyadenylation at the 3' terminal tail region.
 - (B) Total block of spliceosome assembly at that boundary, resulting in complete intron retention or exon skipping.
 - (C) Accelerated transport of the unprocessed script into the cytoplasmic translation machinery.
 - (D) Immediate structural conversion of the script into a circular silencing RNA.
- Q20.** According to the Hardy-Weinberg equilibrium framework, a specific locus has two operating alleles, *M* and *N*. If the phenotypic frequency of the homozygous recessive trait (*NN*) within an isolated, non-migratory population of 10,000 individuals is 0.09, determine the number of heterozygous individuals (*MN*) present in this group.
- (A) 2,100
 - (B) 4,200
 - (C) 4,900
 - (D) 900
- Q21.** The Meselson-Stahl experiment proved the semi-conservative replication model of DNA. *E. coli* cells grown entirely in ^{15}N media were shifted to ^{14}N media for exactly three sequential rounds of cellular division. What is the precise ratio of hybrid ($^{15}\text{N}/^{14}\text{N}$) DNA molecules to light ($^{14}\text{N}/^{14}\text{N}$) DNA molecules at the end of this phase?
- (A) 1 : 1
 - (B) 1 : 3
 - (C) 1 : 7
 - (D) 1 : 15



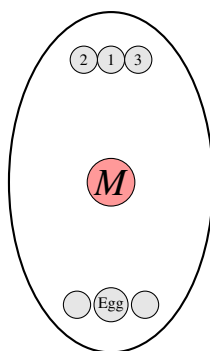
- Q22.** A point mutation within a functional coding sequence transforms a $5' - UAC - 3'$ codon assigning a Tyrosine residue into a $5' - UAA - 3'$ triplet sequence. This direct mutation is classified as a:
- (A) Missense transition mutation
 - (B) Silent transversion mutation
 - (C) Nonsense mutation causing premature translation termination
 - (D) Frameshift insertion mutation
- Q23.** The structural and hormone-driven changes of the human ovarian cycle are shown below. Identify the exact physiological mechanism that triggers the surge of hormone X at day 14 of the cycle.



- (A) High sustained levels of progesterone exerting a negative feedback loop on the posterior pituitary.
 - (B) Sustained high concentrations of estradiol from the dominant follicle exerting positive feedback on the anterior pituitary.
 - (C) Sudden mechanical rupture of the corpus luteum structural core.
 - (D) Decreasing inhibin-B outputs from the functional ovarian stromal matrices.
- Q24.** At what specific phase of nuclear maturation is the human secondary oocyte arrested within the fallopian tubes right before sperm penetration?
- (A) Prophase I of meiosis I
 - (B) Anaphase II of meiosis II
 - (C) Metaphase II of meiosis II
 - (D) Telophase I of meiosis I



- Q25.** During human blastocyst implantation, which embryonic cell population directly secretes human chorionic gonadotropin (*hCG*) and invades the maternal endometrial decidua?
- (A) Inner Cell Mass (Epiblast)
 (B) Syncytiotrophoblast
 (C) Cytotrophoblast
 (D) Extra-embryonic somatic mesoderm
- Q26.** A clinical condition arises where the maternal tracking antibodies target and destroy fetal red blood cells (Erythroblastosis Fetalis). This immunological incompatibility involves a:
- (A) Rh-positive mother carrying her first Rh-negative fetus.
 (B) Rh-negative mother carrying her second or subsequent Rh-positive fetus.
 (C) Rh-negative mother carrying her first Rh-positive fetus.
 (D) Rh-positive mother carrying her second Rh-positive fetus.
- Q27.** The structural diagram below isolates the double fertilization process within a classic angiosperm embryo sac. Identify the ploidy level and ultimate developmental fate of the tissue produced at site *M*.



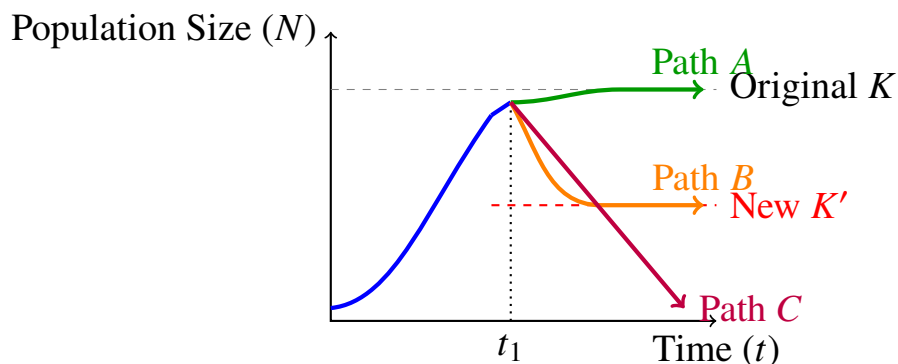
- (A) Diploid ($2n$), transforming into the protective seed coat (testa).
 (B) Triploid ($3n$), forming the nutritive endosperm tissue.
 (C) Haploid ($1n$), degenerating immediately into antipodal remnants.
 (D) Tetraploid ($4n$), developing into the primary cotyledon storage mass.



- Q28.** A mutant strain of *Arabidopsis thaliana* fails to synthesize functional small ubiquitin-like modifier proteins involved in auxin signaling. This structural defect prevents the degradation of Aux/IAA repressor proteins, directly blocking the activation of:
- (A) Gibberellin Insensitive Dwarf [GID1] factors
 - (B) Auxin Response Factors (ARFs) controlling transcriptional pathways
 - (C) Cytokinin Response Histidine Kinases
 - (D) Phytochrome Interacting Factors (PIFs)
- Q29.** A botanist exposes a short-day plant to a long night period. The continuous dark phase is briefly interrupted by a flash of red light (660 nm), followed immediately by a flash of far-red light (730 nm). What is the physiological behavior of the plant?
- (A) Flowering is completely suppressed.
 - (B) The plant flowers normally because the final flash of far-red light resets the phytochrome system.
 - (C) The plant undergoes rapid vegetative senescence.
 - (D) The plant converts its apical meristem into a root architecture.
- Q30.** Which cell layer within the root architecture is structurally responsible for the formation of lateral roots in higher plants via localized mechanical and mitotic reactivation?
- (A) Endodermis
 - (B) Pericycle
 - (C) Cortex
 - (D) Exodermis
- Q31.** The ecological monitoring graph below tracks the growth trajectory of a closed insect population introduced into a resource-limited habitat. If a sudden environmental perturbation dynamically drops the ecosystem carrying capacity



parameter by 50% at operational time t_1 , select the curve path that correctly represents the population's subsequent survival profile.



- (A) Path A, because intrinsic reproductive rate (r) inherently expands to compensate for sudden environmental stress.
- (B) Path B, reflecting a density-dependent adjustments as the population crashes back down to stabilize at the new carrying capacity (K').
- (C) Path C, because a resource drop of this magnitude permanently shuts down reproductive cellular vitality causing immediate extinction.
- (D) Path B initially, followed by an immediate exponential vertical spike as competition shifts toward zero.

Q32. A microbiologist unearths a unicellular organism from a deep hyper-saline thermal vent. Structural analysis shows a cell wall entirely lacking peptidoglycan, and cell membrane lipids featuring branched hydrocarbons linked to glycerol by ether linkages. This isolate belongs to:

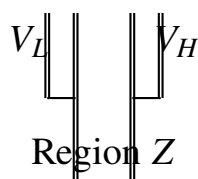
- (A) Cyanobacteria
- (B) Archaeobacteria
- (C) Mycoplasma strains
- (D) Proteobacteria

Q33. Consider the following four taxonomic designations: (1) Pteridophytes possess independent, free-living gametophytic and sporophytic phases. (2) Bryophytes lack specialized vascular cambium elements. (3) Gymnosperms exhibit double fertilization events. (4) Algae demonstrate absolute archegoniate configurations. Choose the combination of correct evaluations:



- (A) 1 and 2
- (B) 2 and 3
- (C) 1 and 4
- (D) 3 and 4

Q34. The classic structural scheme of a fundamental monomeric immune defense molecule is provided below. Identify the exact domain segment responsible for fixing complement proteins and binding to specific macrophage surface receptors.

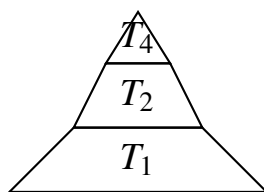


- (A) Variable domain of the light chain (V_L)
 - (B) Antigen-binding fragment (Fab) region
 - (C) Constant crystallizable fragment (Fc) domain denoted by Region Z
 - (D) Hypervariable complementarity-determining regions
- Q35.** A pharmaceutical design group produces a monoclonal antibody that selectively blocks the CD4 co-receptor platform on human T-helper cells. This molecular block directly disrupts the docking of which of the following immunogenetic structures?
- (A) MHC Class I molecules
 - (B) MHC Class II molecules
 - (C) B-cell core receptors (CD19)
 - (D) Perforin secretion pore loops
- Q36.** A patient returns from an equatorial research trip exhibiting cyclic high fevers every 48 hours, coupled with profound hemolytic anemia. A peripheral blood smear shows ring-stage trophozoites within microcytic erythrocytes. This pathological state is driven by:



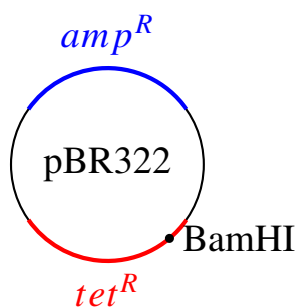
- (A) *Plasmodium malariae*
- (B) *Plasmodium vivax*
- (C) *Leishmania donovani*
- (D) *Wuchereria bancrofti*

Q37. The energetic pyramid configuration below traces structural tracking through successive trophic designations in a stable ecosystem. If the primary producers (T_1) synthesize 20,000 kcal/m²/year of energy, calculate the net energetic availability expected at the apex predator (T_4) tier under the Lindeman framework.



- (A) 200 kcal/m²/year
 - (B) 20 kcal/m²/year
 - (C) 2 kcal/m²/year
 - (D) 0.2 kcal/m²/year
- Q38.** In a long-term ecological study tracking a closed demographic group, the population growth kinetics follow the classic differential equation layout: $\frac{dN}{dt} = rN \left(\frac{K-N}{K} \right)$. If the measured population size (N) matches exactly half the carrying capacity value (K), the instantaneous growth rate will be:
- (A) Zero
 - (B) At its absolute mathematical maximum
 - (C) Altering towards a negative value
 - (D) Precisely equal to rK
- Q39.** The molecular structure below models a standard cloning vector, pBR322. If a researcher inserts a foreign genomic sequence into the unique BamHI restriction site within the Tetracycline resistance locus (tet^R), select the growth profile expected for transformed host bacteria.





- (A) Survival on medium containing both ampicillin and tetracycline.
- (B) Death on ampicillin medium but normal survival on tetracycline medium.
- (C) Survival on ampicillin medium but failure to grow on tetracycline medium due to insertional inactivation.
- (D) Total failure to pick up the plasmid during chemical transformation.

Q40. During a forensic analysis assay utilizing Polymerase Chain Reaction (PCR) workflows, a laboratory technician forgets to add the critical magnesium chloride ($MgCl_2$) cofactor solution to the assay mixture. This protocol error will result in:

- (A) Complete failure of Taq DNA Polymerase to coordinate substrate binding and catalyze phosphodiester bond formation.
- (B) Accelerated thermal denaturation of the primer templates at low temperatures.
- (C) Nonspecific primer annealing creating aberrant, uninterpretable band arrays.
- (D) Destruction of the genomic template molecules during the melting stage.



Detailed Solutions

Q1.

Solution

Concept: Organelle identity is established using biochemical markers specific to localized metabolic activities. The description of structural continuity with the nuclear envelope, post-translational core glycosylation, and a luminal pH of 6.0–6.5 uniquely distinguishes the rough endoplasmic reticulum, whose classical diagnostic marker enzyme is glucose-6-phosphatase.

Solution: The structural continuity with the nuclear membrane and the function of core glycosylation point directly to the endoplasmic reticulum (ER). Glucose-6-phosphatase is an enzyme bound to the ER membrane and serves as its classic marker during cell fractionation assays. For comparison, succinate dehydrogenase marks the inner mitochondrial membrane, acid phosphatase identifies lysosomes, and catalase identifies peroxisomes. Because the fraction isolates the ER, testing for glucose-6-phosphatase activity will verify its structural and biochemical integrity.

Final Answer: Glucose-6-phosphatase

Answer: (B)

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Q2.

Solution

Concept: Cellular lipid catabolism is compartmentalized by chain length. While most fatty acids undergo mitochondrial beta-oxidation, very-long-chain fatty acids (VLCFAs) with carbon backbones longer than 22 carbons cannot cross the inner mitochondrial membrane and require specialized preliminary catabolism within peroxisomes.

Solution: The patient presents with a defect in oxidizing very-long-chain fatty acids (VLCFAs) containing more than 22 carbons. The initial steps of VLCFA beta-oxidation are exclusively localized to peroxisomes rather than mitochondria. In these organelles, specialized acyl-CoA oxidases shorten the long carbon chains until they can be transferred to the mitochondria as carnitine derivatives for complete oxidation. A breakdown in this pathway leads to VLCFA accumulation, causing severe neurodegenerative conditions like Zellweger syndrome or X-linked adrenoleukodystrophy.

Final Answer: Peroxisomes

Answer: (B)

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Q3.

Solution

Concept: Protein thermal denaturation represents a cooperative structural transition. Beyond an enzyme's optimal temperature (T_{opt}), structural kinetic energy disrupts the weak, non-covalent interactions that stabilize the active tertiary conformation, leading to irreversible folding collapse and an exponential loss of biological catalytic activity.

Solution: At temperatures higher than the optimal temperature (T_{opt}), the catalytic rate drops rapidly. Point *P* lies on the descending arm of the temperature profile curve, which corresponds to thermal denaturation. The high thermal energy breaks weak non-covalent forces, such as hydrogen bonds, hydrophobic interactions, and ionic attractions, which hold the enzyme in its active tertiary shape. This unfolding destroys the active site configuration, preventing substrate binding and causing an irreversible loss of catalytic function.

Final Answer: Thermal denaturation disrupts weak bonds in tertiary structure.

Answer: (C)

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Q4.

Solution

Concept: Substrate-level phosphorylation yields energy through direct chemical coupling without an electron transport chain. The metabolism of sucrose requires calculating the total glucose and fructose units entering glycolysis, accounting for the ATP synthesized via phosphoglycerate kinase and pyruvate kinase reactions.

Solution: One molecule of sucrose is a disaccharide that breaks down into one glucose and one fructose molecule. Therefore, two molecules of sucrose yield two glucose and two fructose molecules, equivalent to four hexose monosaccharide units. In the standard eukaryotic glycolytic pathway, each hexose unit is cleaved into two 3-carbon triose fragments, producing a total of eight triose molecules. Each triose molecule generates exactly two ATP molecules via substrate-level phosphorylation: one at the phosphoglycerate kinase step and one at the pyruvate kinase step. Multiplying 8 triose units by 2 ATP gives a total yield of 16 ATP molecules.

Final Answer: 16 ATP

Answer: (B)

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Q5.

Solution

Concept: Total genomic hydrogen bonds depend on base composition and Chargaff's rules. Adenine-Thymine (A-T) base pairs form two hydrogen bonds, whereas Guanine-Cytosine (G-C) pairs form three hydrogen bonds. Total hydrogen bonding is determined by summing the bonds across both base pair pools.

Solution: The genomic fragment contains 200 base pairs. According to Chargaff's rules, the percentage of Guanine equals Cytosine, so the fragment is 38% Guanine and 38% Cytosine, giving a total G-C composition of 76%. The number of G-C base pairs is calculated as:

$$200 \times 0.76 = 152 \text{ base pairs}$$

The remaining base pairs are Adenine-Thymine (A-T):

$$200 - 152 = 48 \text{ base pairs}$$

Each G-C pair forms 3 hydrogen bonds, and each A-T pair forms 2 hydrogen bonds. Summing these values gives:

$$\text{Total Bonds} = (152 \times 3) + (48 \times 2) = 456 + 96 = 552$$

Final Answer:

Answer: (B)

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Q6.

Solution

Concept: Competitive enzyme inhibition features a shared binding site between the substrate and the inhibitor. Because the inhibitor can be outcompeted at high substrate concentrations, the maximum velocity (V_{max}) remains unperturbed, while the apparent Michaelis constant (K_m) increases due to reduced substrate binding affinity.

Solution: The problem states that the presence of the structural analogue increases the apparent K_m by a factor of 4 while leaving V_{max} completely unperturbed. This dynamic profile is the classic hallmark of a competitive inhibitor. Competitive inhibitors structurally resemble the substrate and compete directly for the active substrate-binding pocket. High concentrations of the natural substrate can displace the inhibitor, allowing the enzyme to reach its original maximum velocity (V_{max}), though a higher substrate concentration (K_m) is required to reach half-maximal velocity.

Final Answer:

Answer: (B)

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Q7.

Solution

Concept: Bivalents represent physical pairings of homologous chromosomes formed during meiotic prophase I. Every individual bivalent consists of two homologous chromosomes, which comprise a total of four distinct sister chromatid strands, regardless of the number of chiasmata crossing-over points.

Solution: In a cell undergoing meiotic prophase I, the number of bivalents corresponds directly to the haploid number of chromosome sets. The prompt indicates that the chiasmata are spread across the chromosomal layout, but the number of chiasmata does not dictate the number of bivalents. The options reveal that 12 bivalents are present. Because every single bivalent is a tetrad containing two homologous chromosomes, each consisting of two sister chromatids, the total number of chromatids is calculated as:

$$\text{Total Chromatids} = 12 \text{ bivalents} \times 4 \text{ chromatids/bivalent} = 48$$

Final Answer:

Answer: (B)

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Q8.

Solution

Concept: Alpha-helical secondary structures rely on regular backbone hydrogen bonding. Amino acids with restricted conformational flexibility or unusual side-chain geometry disrupt this regular pattern, introducing localized architectural kinks that alter the directional orientation of the peptide backbone.

Solution: Proline is unique among the amino acids because its side chain loops back to bind covalently to the alpha-amino group, forming a rigid, cyclic secondary amine (an imino acid). This five-membered ring structure prevents the nitrogen atom from participating in the regular hydrogen bonding network required to stabilize a standard alpha-helix. Additionally, the steric hindrance from the cyclic structure forces a localized architectural bend or kink in the peptide backbone, making Proline a classic alpha-helix disruptor.

Final Answer:

Answer: (B)

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Q9.

Solution

Concept: Net Filtration Pressure (*NFP*) inside the glomerular filtration apparatus is driven by physical forces. A drop in glomerular hydrostatic capillary pressure relative to static colloid oncotic and capsular pressures reduces the driving force for filtration, which lowers the glomerular filtration rate.

Solution: The Net Filtration Pressure (*NFP*) is governed by Starling forces: the glomerular hydrostatic pressure favoring filtration, minus the opposing forces of blood colloid oncotic pressure and Bowman's space hydrostatic pressure. Point *A* represents the afferent side supplying the glomerulus. A substantial drop in hydraulic pressure at point *A* lowers the glomerular capillary hydrostatic pressure. If the opposing oncotic pressure at point *B* remains static, the net pressure gradient drops toward or below zero, reducing or stopping filtration and lowering the overall Glomerular Filtration Rate (*GFR*).

Final Answer:

Answer: (B)

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Q10.

Solution

Concept: Cardiac inotropic mechanisms are regulated by intracellular ion gradients. Inhibiting the primary active sodium-potassium exchange pump alters secondary active transport mechanisms, increasing intracellular calcium concentrations and enhancing the contractility of cardiac muscle fibers.

Solution: Digitalis compounds function by directly binding to and inhibiting the membrane-bound Na^+/K^+ ATPase pump. This inhibition leads to an accumulation of intracellular sodium ions, reducing the sodium concentration gradient across the sarcolemma. Because the secondary active $\text{Na}^+/\text{Ca}^{2+}$ exchanger relies on this sodium gradient to pump calcium out of the cell, its function is slowed or reversed. As a result, intracellular calcium ions accumulate and are pumped into the sarcoplasmic reticulum, increasing calcium release during subsequent action potentials and boosting cardiac contractility.

Final Answer:

Answer: (B)

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Q11.

Solution

Concept: Central ventilatory regulation is driven by pH shifts within the central nervous system. Carbon dioxide crosses the blood-brain barrier and undergoes hydration to generate hydrogen ions, which stimulate chemoreceptors in the medulla oblongata to increase respiratory drive.

Solution: When arterial $p\text{CO}_2$ increases from 40 mmHg to 55 mmHg, the excess molecular CO_2 readily diffuses across the blood-brain barrier into the cerebrospinal fluid (CSF). Unlike CO_2 , charged hydrogen ions (H^+) cannot easily pass through this barrier. Once inside the CSF, the CO_2 reacts with water via carbonic anhydrase to form carbonic acid, which dissociates into bicarbonate and H^+ ions. Because the CSF has a low protein buffering capacity, these liberated H^+ ions lower the pH, directly stimulating central chemoreceptors in the medulla to increase respiration.

Final Answer: CO₂ hydration generates H⁺ ions stimulating central chemoreceptors.

Answer: (C)

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Q12.

Solution

Concept: Digestion involves a cascade of proteolytic activations initiated by duodenal mucosal enzymes. Enterokinase converts trypsinogen into active trypsin, which then activates other pancreatic zymogens; however, enzymes secreted in their fully active forms operate independently of this activation cascade.

Solution: Enterokinase (enteropeptidase) is a brush-border enzyme that converts pancreatic trypsinogen into active trypsin. Trypsin then cleaves and activates other zymogens, including chymotrypsinogen (to chymotrypsin) and procarboxypeptidase (to carboxypeptidase). A deficiency in enterokinase halts this proteolytic activation cascade, disrupting protein digestion. However, pancreatic amylase is secreted into the duodenum in its fully active form and does not require proteolytic cleavage. Thus, the hydrolysis of dietary starches into maltose remains functional.

Final Answer: Hydrolysis of dietary starches into maltose fragments by pancreatic amylase.

Answer: (B)

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Q13.

Solution

Concept: Fetal-maternal circulation involves specialized vascular shunts. Oxygenated blood from maternal uterine branches pools in the placenta before entering the fetal circulatory system through the umbilical vein, bypassing the liver via the ductus venosus to reach the inferior vena cava.

Solution: Oxygenated blood travels from the maternal uterine artery into the placental intervillous space (trophoblastic lacunae), where gas exchange occurs. The oxygenated blood is then collected by the fetal umbilical vein. From the umbilical vein, the blood travels toward the fetal heart, with the majority bypassing the fetal liver sinusoids through a specialized shunt called the ductus venosus. This shunt empties directly into the fetal inferior vena cava (IVC), delivering oxygenated blood to the right atrium.

Final Answer: Lacunae → UV → DV → IVC

Answer: (B)

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Q14.

Solution

Concept: Extracellular calcium levels regulate the gating sensitivity of voltage-dependent sodium channels. Hypocalcemia shifts the voltage threshold for channel activation closer to the resting potential, increasing membrane excitability and triggering spontaneous depolarization and muscle tetany.

Solution: Accidental removal of the parathyroid glands during a radical thyroidectomy causes a sharp drop in parathyroid hormone (PTH), resulting in profound hypocalcemia. Extracellular calcium ions normally bind to and stabilize voltage-gated sodium channels on excitable membranes, maintaining their activation threshold. When extracellular calcium levels drop, these sodium channels require a much smaller depolarization to open. This shift lowers the excitation threshold, causing voltage-gated sodium channels to fire spontaneously and inducing neuromuscular hypersensitivity and muscle tetany.

Final Answer: Lowered threshold potential causing Na⁺ channel hyperexcitability.

Answer: (A)

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Q15.

Solution

Concept: Allosteric regulation of hemoglobin alters its oxygen affinity based on tissue metabolic demand. Elevated carbon dioxide, hydrogen ions, temperature, and 2,3-BPG stabilize the low-affinity deoxygenated state, shifting the dissociation curve to the right to promote oxygen delivery to working tissues.

Solution: Intensive skeletal exercise accelerates local metabolism, causing a rise in temperature, partial pressure of CO₂, and hydrogen ion concentration (H⁺ from lactic acid). These conditions stabilize the T-state (deoxygenated form) of hemoglobin through the Bohr effect. This allosteric modification shifts the oxygen-hemoglobin dissociation curve to the right, reflecting a decreased affinity for oxygen. This rightward shift facilitates the offloading of oxygen from hemoglobin to the oxygen-depleted, metabolically active skeletal muscle tissues.

Final Answer: Rightward shift enhancing oxygen release to tissues.

Answer: (B)

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Q16.

Solution

Concept: C₄ photosynthesis minimizes photorespiration by physically separating initial carbon capture from the Calvin cycle. Initial carboxylation occurs in the cytoplasm of mesophyll cells, while decarboxylation and carbohydrate synthesis are localized to the chloroplasts of bundle sheath cells.

Solution: In C₄ plants, atmospheric carbon dioxide is first fixed in the cytoplasm of mesophyll cells by the enzyme PEP carboxylase, converting phosphoenolpyruvate into oxaloacetate. This four-carbon product is converted to malate and transported into the adjacent bundle sheath cells. Inside the chloroplast matrix of the bundle sheath cells, malate undergoes decarboxylation to release CO₂ directly around Rubisco, minimizing photorespiration and feeding the Calvin cycle efficiently.

Final Answer: Mesophyll cytoplasm → Bundle sheath chloroplast

Answer: (B)

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Q17.

Solution

Concept: Transcriptional operons utilize regulatory proteins to control gene expression based on environmental conditions. A loss-of-function mutation in a repressor gene prevents the synthesis of a functional repressor, resulting in continuous transcription of the structural genes regardless of inducer availability.

Solution: Domain *I* represents the regulatory gene that codes for the Lac repressor protein. In a wild-type system without lactose, the functional repressor binds tightly to the operator site (*O*), physically blocking RNA polymerase from transcribing the downstream structural genes *Z*, *Y*, and *A*. If a loss-of-function mutation inactivates the product of domain *I*, no functional repressor protein is produced to bind the operator. Consequently, RNA polymerase has unhindered access to the promoter, leading to constitutive transcription of the structural coding segments even in the absence of environmental lactose.

Final Answer: Continuous transcription due to failure of repressor binding.

Answer: (B)

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Q18.

Solution

Concept: Genetic linkage and map distance are determined by recombination frequency. The map distance separating two genetic loci on a chromosome equals the percentage of recombinant offspring relative to the total population, measured in centimorgans (cM).

Solution: To calculate the map distance, first sum the total number of offspring produced in the double-heterozygous testcross:

$$\text{Total Offspring} = 440 (\text{parental}) + 460 (\text{parental}) + 52 (\text{recombinant}) + 48 (\text{recombinant}) = 1000$$

Next, determine the total number of recombinant individuals:

$$\text{Total Recombinants} = 52 + 48 = 100$$

The recombination frequency is the ratio of recombinant offspring to total offspring, expressed as a percentage:

$$\text{Recombination Frequency} = \left(\frac{100}{1000} \right) \times 100\% = 10\%$$

Because 1% recombination frequency corresponds to 1 centimorgan (cM), a 10% recombination frequency indicates a map distance of 10.0 centimorgans.

Final Answer: 10.0 centimorgans

Answer: (B)

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Q19.

Solution

Concept: Splicing reactions require highly conserved consensus sequences at intron boundaries. The invariant dinucleotide GU defines the 5' splice donor site; mutating these bases prevents spliceosome recognition, leading to aberrant mRNA processing.

Solution: During pre-mRNA splicing, the 5' splice site donor boundary is marked by a highly conserved invariant *GU* dinucleotide sequence, which is recognized by the U1 small nuclear ribonucleoprotein (snRNP) component of the spliceosome. If a genetic mutation alters this *GU* sequence, the spliceosome cannot bind or assemble at this junction. This failure prevents splicing at the intron 2 boundary, typically resulting in the retention of intron 2 in the mature mRNA script or causing the splicing machinery to skip the adjacent exon entirely.

Final Answer: Failure of spliceosome assembly causing intron retention or exon skipping.

Answer: (B)

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Q20.

Solution

Concept: The Hardy-Weinberg equilibrium framework models allele and genotype frequencies in a stable population. Genotype frequencies are calculated using the equation $p^2 + 2pq + q^2 = 1$, where $2pq$ represents the frequency of heterozygous individuals.

Solution: Let p represent the frequency of the dominant allele M , and q represent the frequency of the recessive allele N . The phenotypic frequency of the homozygous recessive genotype (NN) corresponds to q^2 :

$$q^2 = 0.09 \implies q = \sqrt{0.09} = 0.3$$

Because $p + q = 1$, the frequency of the dominant allele p is:

$$p = 1 - 0.3 = 0.7$$

The frequency of heterozygous individuals (MN) is given by $2pq$:

$$\text{Frequency of } MN = 2 \times 0.7 \times 0.3 = 0.42$$

To find the absolute number of heterozygous individuals in a population of 10,000, multiply the total population size by the heterozygote frequency:

$$\text{Number of Heterozygous Individuals} = 10,000 \times 0.42 = 4,200$$

Final Answer: 4,200

Answer: (B)

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Q21.

Solution

Concept: Semi-conservative DNA replication preserves original parental strands across division cycles. In replication, the original heavy-isotope (^{15}N) parental strands serve as templates for newly synthesized light-isotope (^{14}N) strands, maintaining a constant number of hybrid molecules while light molecules increase exponentially.

Solution: Initially, the E. coli cells contain only heavy ^{15}N DNA. When shifted to ^{14}N media, each round of division doubles the total number of DNA molecules.

- Round 1: 2 molecules produced, both hybrid ($^{15}\text{N}/^{14}\text{N}$).
- Round 2: 4 molecules produced, 2 hybrid and 2 light ($^{14}\text{N}/^{14}\text{N}$).
- Round 3: 8 molecules produced. The 2 original ^{15}N strands still form exactly 2 hybrid molecules, while the remaining 6 molecules consist entirely of light ^{14}N DNA.

The ratio of hybrid to light DNA molecules at the end of three rounds is 2 : 6, which simplifies to 1 : 3.

Final Answer:

Answer: (B)

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Q22.

Solution

Concept: Point mutations alter codons within open reading frames. Substitutions that convert an amino acid-specifying codon into a stop triplet are classified as nonsense mutations, which terminate translation prematurely and typically yield truncated proteins.

Solution: The point mutation converts the codon $5' - UAC - 3'$ (which codes for the amino acid Tyrosine) into $5' - UAA - 3'$. Because UAA is one of the three standard universal stop codons (along with UAG and UGA), this substitution does not replace one amino acid with another, nor does it cause a shift in the reading frame. Instead, it creates a premature termination signal within the mRNA sequence. When the ribosome encounters this triplet during translation, it recruits a release factor that halts protein synthesis, resulting in a truncated polypeptide chain. This is classified as a nonsense mutation.

Final Answer:

Answer: (C)

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Q23.

Solution

Concept: The human menstrual cycle relies on feedback loops within the hypothalamic-pituitary-ovarian axis. While low levels of estradiol exert negative feedback, high and sustained levels of estradiol from the dominant follicle trigger a positive feedback loop that induces the preovulatory luteinizing hormone surge.

Solution: Hormone X exhibits a dramatic preovulatory spike peaking right around day 14 of the standard ovarian cycle, identifying it as Luteinizing Hormone (LH). Throughout the follicular phase, developing ovarian follicles secrete estradiol. As the dominant follicle matures, estradiol levels rise substantially. When estradiol concentrations remain high for a sustained period (typically over 48 hours), the feedback loop on the anterior pituitary and hypothalamus switches from negative to positive. This triggers a surge of LH, which induces ovulation of the secondary oocyte.

Final Answer: High estradiol levels causing positive feedback on the pituitary.

Answer: (B)

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Q24.

Solution

Concept: Oogenesis involves specific developmental arrests during meiotic maturation. The primary oocyte arrests in prophase I during fetal development, whereas the secondary oocyte ovulated into the fallopian tube remains arrested at metaphase II until fertilization triggers completion.

Solution: Human oogenesis is characterized by two distinct meiotic arrests. The first occurs during embryonic development, where primary oocytes halt at the diplotene stage of prophase I. At ovulation, the primary oocyte completes meiosis I and progresses into meiosis II as a secondary oocyte. This secondary oocyte then arrests at metaphase II within the fallopian tubes. It remains locked in metaphase II until fertilization occurs, at which point sperm penetration triggers the degradation of cyclin B and activates the anaphase-promoting complex to complete meiosis II.

Final Answer: Metaphase II of meiosis II

Answer: (C)

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Q25.

Solution

Concept: Implantation requires specialized extraembryonic trophoblast lineages. The outer syncytial layer lacks internal cell boundaries, invades the maternal endometrial lining to establish the early maternal-fetal interface, and secretes human chorionic gonadotropin to maintain the corpus luteum.

Solution: During blastocyst implantation, the outer trophoblast layer differentiates into two distinct cellular populations: the inner cytotrophoblast and the outer syncytiotrophoblast. The syncytiotrophoblast forms a multinucleated, continuous cytoplasmic mass that invades the maternal endometrial decidua by secreting proteolytic enzymes. Additionally, this tissue layer produces and secretes human chorionic gonadotropin (*hCG*). This hormone enters the maternal bloodstream to sustain the corpus luteum and maintain progesterone production during early pregnancy.

Final Answer: Syncytiotrophoblast

Answer: (B)

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Q26.

Solution

Concept: Maternal-fetal blood incompatibility results from immune sensitization. An Rh-negative mother carrying an Rh-positive fetus can be exposed to fetal red blood cells during delivery, generating IgG antibodies that cross the placenta and target erythrocytes in a subsequent Rh-positive pregnancy.

Solution: Erythroblastosis fetalis (hemolytic disease of the newborn) occurs when a mother lacks the Rhesus factor antigen (Rh^-) but carries a fetus that inherits the Rhesus antigen (Rh^+) from the father. During the birth of the first Rh^+ child, placental separation causes fetal red blood cells to enter the maternal circulation, sensitizing her immune system to produce anti-Rh antibodies. In a subsequent pregnancy with another Rh^+ fetus, these maternal IgG antibodies cross the placenta and target the fetal red blood cells for destruction, causing severe hemolytic anemia.

Final Answer: Rh-negative mother carrying her second or subsequent Rh-positive fetus.

Answer: (B)

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Q27.

Solution

Concept: Double fertilization is a defining feature of angiosperm reproduction. One haploid sperm cell fertilizes the egg to produce a diploid zygote, while a second sperm cell fuses with the binucleate central cell, creating a triploid endosperm tissue that provides nourishment.

Solution: The diagram shows an angiosperm embryo sac undergoing double fertilization. Site *M* marks the central cell, which contains two polar nuclei ($n + n$). During double fertilization, one of the two haploid ($1n$) sperm cells delivered by the pollen tube fertilizes the egg cell at the micropylar end to form a diploid ($2n$) zygote. The second haploid ($1n$) sperm cell moves to the center and fuses with the two polar nuclei at site *M*. This triple fusion event results in a triploid ($3n$) primary endosperm nucleus, which develops into the nutritive endosperm tissue that supports the growing embryo.

Final Answer: Triploid ($3n$), forming the nutritive endosperm tissue.

Answer: (B)

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Q28.

Solution

Concept: Auxin transcriptional activation relies on targeted protein degradation. The hormone coordinates the ubiquitination and degradation of Aux/IAA transcriptional repressor proteins, freeing Auxin Response Factors (ARFs) to bind promoters and activate gene expression.

Solution: Auxin regulates plant development by driving the degradation of Aux/IAA repressor proteins. In the presence of auxin, the TIR1/AFB F-box protein binds Aux/IAA proteins, targeting them for ubiquitination and subsequent degradation via the 26S proteasome. In this mutant strain, the failure to clear these Aux/IAA repressors means they remain bound to Auxin Response Factors (ARFs). Because the repressors stay bound, the ARFs cannot activate the transcription of auxin-regulated genes, halting downstream auxin signaling pathways.

Final Answer: Auxin Response Factors (ARFs) controlling transcriptional pathways

Answer: (B)

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Q29.

Solution

Concept: Photoperiodism is regulated by the photoreversible phytochrome system, which shifts between the inactive red-absorbing (P_r) and active far-red-absorbing (P_{fr}) forms. A final exposure to far-red light reverses any preceding red-light activation, preserving the long-night response in short-day plants.

Solution: Short-day (long-night) plants require an uninterrupted dark period longer than a critical threshold to induce flowering. A brief flash of red light (660 nm) during the night converts inactive phytochrome P_r into the active P_{fr} form, which inhibits flowering in short-day plants. However, the phytochrome system is photoreversible. Exposing the plant to a subsequent flash of far-red light (730 nm) converts the P_{fr} form back into the inactive P_r form. Because the final flash is far-red light, it cancels the inhibitory effect of the red flash, allowing the plant to perceive a continuous dark phase and flower normally.

Final Answer: Normal flowering due to far-red light reversal effect.

Answer: (B)

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Q30.

Solution

Concept: Lateral root development originates internally from differentiated vascular tissues. Cells within the pericycle layer retain mitotic capability, undergoing localized reactivation to form an organized primordium that pushes outward through the cortex and epidermis.

Solution: In higher plants, lateral roots do not originate from outer epidermal or cortical layers. Instead, they arise internally from the pericycle, which is the outermost cell layer of the central vascular cylinder (stele), located just inside the endodermis. Cells within the pericycle retain meristematic potential. Stimulated by local auxin accumulation, these cells undergo targeted periclinal and anticlinal mitotic divisions to form a lateral root primordium. This new primordium grows outward, pushing through the endodermis, cortex, and epidermis to establish a branch root.

Final Answer: Pericycle

Answer: (B)

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Q31.

Solution

Concept: Population dynamics under logistic growth are constrained by the habitat carrying capacity (K). When an environmental shift abruptly lowers this upper threshold, the existing population size (N) exceeds the available resource limit ($N > K$), creating a negative growth rate that forces a density-dependent decline back to equilibrium.

Solution: The graph models a classic logistic growth pattern that is interrupted at time t_1 . Prior to t_1 , the insect population size (N) is rising toward the original carrying capacity (K). At time t_1 , a sudden environmental perturbation dynamically cuts the carrying capacity by 50%, establishing a lower resource ceiling marked as New K' . At this exact moment, the population size is significantly greater than what the degraded ecosystem can support ($N > K'$). This resource deficit leads to severe intraspecific competition, increased mortality, and decreased birth rates. Mathematically, the logistic growth equation yields a negative value for dN/dt under these conditions. As a result, the population size must crash or decline via density-dependent adjustments, gradually stabilizing at the new lower equilibrium line, which is accurately tracked by Path B .

Final Answer: Path B shows density-dependent decline to new carrying capacity.

Answer: (B)

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Q32.

Solution

Concept: Archaeobacterial structural adaptations allow survival in extreme environments. Their cell walls lack standard peptidoglycan, and their plasma membranes feature branched hydrocarbon chains linked to glycerol via stable ether linkages, which resist thermal and chemical denaturation.

Solution: The isolated organism exhibits characteristics unique to domain Archaea (Archaeobacteria). Unlike Eubacteria, archaeobacterial cell walls lack true peptidoglycan and often consist of pseudomurein or surface-layer proteins. Furthermore, their membrane lipids feature branched-chain hydrocarbons linked to glycerol by ether bonds, rather than the straight-chain fatty acids linked by ester bonds found in bacteria and eukaryotes. These stable ether linkages and branched chains reduce membrane fluidity and permeability, allowing these organisms to survive in extreme environments like hyper-saline thermal vents.

Final Answer: Archaeobacteria

Answer: (B)

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Q33.

Solution

Concept: Plant taxa are distinguished by vascular organization, reproductive mechanisms, and life cycle patterns. Pteridophytes exhibit independent alternation of generations, and Bryophytes lack vascular tissue; however, double fertilization is unique to Angiosperms, and Algae do not form archegonia.

Solution: Evaluating each taxonomic statement:

- (a) Pteridophytes (ferns) exhibit an alternation of generations where both the diploid sporophyte and the haploid gametophyte (prothallus) are free-living and independent at maturity. This statement is correct.
- (b) Bryophytes (mosses and liverworts) are non-vascular plants that lack specialized vascular tissues like xylem, phloem, or a vascular cambium. This statement is correct.
- (c) Gymnosperms produce naked seeds and do not undergo double fertilization; this process is unique to Angiosperms. This statement is incorrect.
- (d) Most Algae do not possess multi-cellular reproductive archegonia, which evolve later in land plants. This statement is incorrect.

Statements 1 and 2 are correct.

Final Answer: 1 and 2

Answer: (A)

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Q34.

Solution

Concept: Antibody structural anatomy separates antigen recognition from effector functions. The antigen-binding fragments (*Fab*) recognize specific epitopes, while the constant crystallizable fragment (*Fc*) interacts with immune components like complement proteins and phagocytic surface receptors.

Solution: A monomeric antibody molecule features a flexible, Y-shaped structure composed of two heavy and two light polypeptide chains. The upper tips, containing the variable domains (V_L and V_H), form the antigen-binding fragments (*Fab*) responsible for recognizing epitopes. In contrast, the lower stem portion, labeled Region Z, consists entirely of the constant domains of the heavy chains. This stem is known as the constant crystallizable fragment (*Fc*) domain. The *Fc* domain is responsible for driving effector functions, including binding to C1q to activate the complement cascade and interacting with *Fc* receptors on macrophages to facilitate opsonization.

Final Answer: Constant crystallizable fragment (*Fc*) domain denoted by Region Z

Answer: (C)

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Q35.

Solution

Concept: T-cell immune recognition relies on specific coreceptor restrictions. Cytotoxic T-cells express CD8 to interact with MHC Class I molecules, whereas helper T-cells express CD4, which binds to invariant domains on MHC Class II molecules during antigen presentation.

Solution: T-helper (T_H) cells express the surface glycoprotein CD4, which acts as a critical co-receptor for the T-cell receptor (TCR) complex. During antigen presentation, the TCR recognizes foreign peptide fragments presented on the surface of antigen-presenting cells (APCs). For a helper T-cell to become activated, its CD4 co-receptor must simultaneously bind to a conserved, non-polymorphic region on the MHC Class II molecule. Designing a monoclonal antibody that blocks the CD4 co-receptor platform directly disrupts this docking interaction, preventing helper T-cell activation.

Final Answer: MHC Class II molecules

Answer: (B)

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Q36.

Solution

Concept: Malaria species exhibit distinct erythrocytic schizogony periods that dictate fever intervals. Synchronized rupture of host red blood cells releases merozoites and metabolic wastes, triggering cyclic paroxysms every 48 hours in tertian malaria variants.

Solution: The clinical symptoms described—cyclic high fevers occurring every 48 hours (known as tertian fever paroxysms), hemolytic anemia, and a peripheral blood smear showing ring-stage trophozoites within erythrocytes—are characteristic of malaria. The 48-hour cycle reflects the synchronized rupture of host red blood cells during erythrocytic schizogony. Among the options, *Plasmodium vivax* (along with *Plasmodium falciparum*) causes tertian malaria with a 48-hour cycle. In contrast, *Plasmodium malariae* causes quartan malaria with a 72-hour cycle.

Final Answer: Plasmodium vivax

Answer: (B)

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Q37.

Solution

Concept: Lindeman's efficiency rule models trophic energy transfers within ecosystems. On average, only about 10% of the net chemical energy stored at one trophic level is successfully transferred and integrated into the biomass of the next consecutive tier.

Solution: According to Lindeman's ten percent law of trophic efficiency, only 10% of the energy available at one trophic level is transferred to the next level. The rest is lost as heat, used for metabolic maintenance, or left unconsumed. We are given the energy at the primary producer tier (T_1) as 20,000 kcal/m²/year. We calculate the energy transferred through successive trophic levels up to the apex predator tier (T_4):

- T_2 (Primary consumers): $20,000 \times 0.10 = 2,000$ kcal/m²/year
- T_3 (Secondary consumers): $2,000 \times 0.10 = 200$ kcal/m²/year
- T_4 (Tertiary consumers / Apex predators): $200 \times 0.10 = 20$ kcal/m²/year

Final Answer:

Answer: (B)

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Q38.

Solution

Concept: Logistic population dynamics account for resource limitations through carrying capacity constraints. The instantaneous growth velocity varies continuously with density, reaching its mathematical maximum when the population size equals exactly half the environment's total carrying capacity ($K/2$).

Solution: The population growth kinetics follow the differential equation for logistic growth:

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

This equation forms a parabolic arc when plotting the instantaneous growth rate ($\frac{dN}{dt}$) against population size (N). To find the population size that maximizes the growth rate, take the derivative of $\frac{dN}{dt}$ with respect to N and set it to zero, or locate the vertex of the parabola. The mathematical maximum occurs exactly when the population size (N) reaches half of the carrying capacity ($N = \frac{K}{2}$). Substituting $N = \frac{K}{2}$ into the equation yields the maximum growth rate:

$$\frac{dN}{dt} = r \left(\frac{K}{2} \right) \left(\frac{K - \frac{K}{2}}{K} \right) = \frac{rK}{4}$$

Final Answer:

Answer: (B)

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Q39.

Solution

Concept: Plasmid cloning strategies utilize insertional inactivation to verify gene delivery. Cleaving a unique restriction site inside an antibiotic resistance gene and inserting a foreign DNA fragment disrupts the open reading frame, rendering the host bacteria sensitive to that specific antibiotic.

Solution: The pBR322 cloning vector carries two distinct antibiotic resistance genes: ampicillin resistance (amp^R) and tetracycline resistance (tet^R). The restriction enzyme BamHI has a unique cleavage site located within the coding sequence of the tet^R locus. When a researcher clones a foreign genomic fragment into this BamHI site, the insertion breaks the open reading frame of the tetracycline resistance gene, causing insertional inactivation. Transformed host bacteria will retain a functional, uncompromised amp^R gene, allowing them to survive on ampicillin media, but they will fail to grow on media containing tetracycline.

Final Answer: Ampicillin resistant but tetracycline sensitive due to insertional inactivation

Answer: (C)

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Q40.

Solution

Concept: DNA polymerases require divalent cation cofactors to catalyze nucleotide addition. Magnesium ions coordinate the phosphate groups of incoming dNTPs and lower the activation energy for nucleophilic attack, making them essential for phosphodiester bond formation during PCR.

Solution: Taq DNA Polymerase, like all DNA polymerases, relies on divalent magnesium cations (Mg^{2+}) as an essential cofactor to catalyze DNA synthesis. The Mg^{2+} ions form coordinate bonds with the negative phosphate groups on the incoming deoxynucleotide triphosphates (dNTPs) and the DNA template backbone. This stabilization polarizes the alpha-phosphate group, facilitating the nucleophilic attack by the 3'-hydroxyl group of the primer to form a new phosphodiester bond. Omitting magnesium chloride ($MgCl_2$) prevents the enzyme from coordinating substrate binding, resulting in a complete failure of the PCR amplification workflow.

Final Answer: Taq DNA polymerase fails to synthesize DNA.

Answer: (A)

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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	B	10	B
11	C	12	B	13	B	14	A	15	B
16	B	17	B	18	B	19	B	20	B
21	B	22	C	23	B	24	C	25	B
26	B	27	B	28	B	29	B	30	B
31	B	32	B	33	A	34	C	35	B
36	B	37	B	38	B	39	C	40	A

