IISER Biology Sample Paper-7

Duration: 45 Minutes **Maximum Marks: 60**

Instructions

- This paper contains **15** Multiple Choice Questions (Single Correct).
- Each correct answer carries **+4 marks**.
- Each incorrect answer carries: **−1** marks.
- 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. A populations of a sexually reproducing diploid annual plant exists in Hardy-Weinberg equilibrium for a specific locus with two alleles, A and a. Due to a sudden environmental shift, a selective pressure acts against the homozygous recessive phenotype such that its relative fitness becomes 0.36, while the fitness of AA and Aa genotypes remains 1.0. If the initial frequency of the recessive allele a was 0.5, what will be its frequency in the next generation after selection?

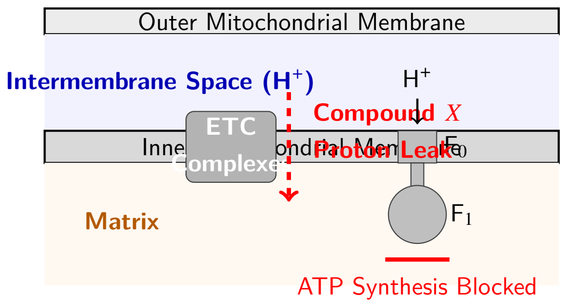
(A) 0.31

(B) 0.37

(C) 0.42

(D) 0.50

Q2. During a laboratory experiment, a researcher isolates intact mitochondria from mammalian liver cells and suspends them in an isotonic buffer containing ADP and inorganic phosphate (P_i). Succinate is added as an electron donor, and oxygen consumption is tracked. After a few minutes, a compound X is introduced into the medium. The researcher observes that oxygen consumption increases dramatically, but the rate of ATP synthesis drops to zero. Which of the following best describes the biochemical action of compound X?



(A) It binds irreversibly to the F_0 subunit of ATP synthase, blocking proton translocation.

(B) It acts as a lipophilic weak acid that translocates protons directly across the inner mitochondrial membrane, dissipating the proton motive force.

(C) It competitively inhibits succinate dehydrogenase, stopping the flow of electrons to ubiquinone.

(D) It binds to cytochrome *c* oxidase, preventing the reduction of molecular oxygen to water.

Q3. A researcher constructs a synthetic cell-free translation system using an mRNA sequence consisting entirely of repeating dinucleotides: 5′-UCUCUCUCUCUC...-3’. When this translation is carried out in vitro, a polypeptide chain containing an alternating sequence of two amino acids, Leucine (Leu) and Serine (Ser), is produced. If the researcher instead uses an mRNA sequence consisting of repeating trinucleotides: 5′-UCCUCCUCCUCC...-3’, which of the following outcomes is most likely regarding the types of homopolymers or heteropolymers produced?

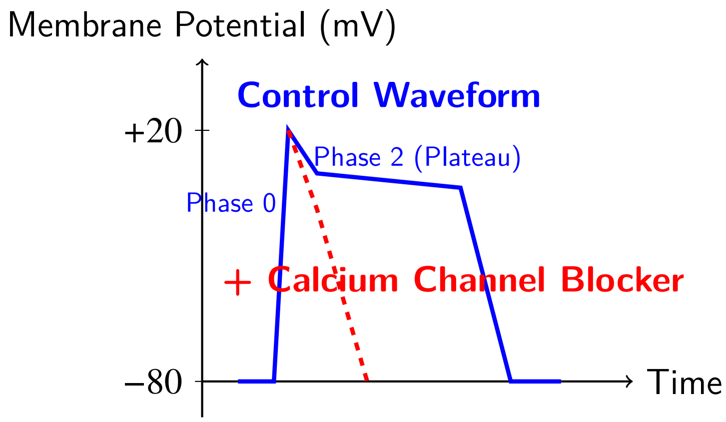
(A) A single polypeptide containing alternating Serine, Proline, and Leucine residues.

(B) Three distinct types of homopolymers: one containing only Serine, one containing only Proline, and one containing only Leucine.

(C) Two distinct homopolymers containing only Serine or only Leucine, depending on where the ribosome attaches.

(D) A single heteropolymer containing random arrangements of Serine and Leucine.

Q4. An isolated cardiac muscle cell is kept in a physiological organ bath. The intracellular and extracellular ion concentrations are normal, and the resting membrane potential is maintained at −80 mV. The cell is stimulated to generate an action potential. If a drug that selectively blocks voltage-gated L-type calcium channels is added to the bath before stimulation, how will the profile of the cardiac action potential change compared to the control?



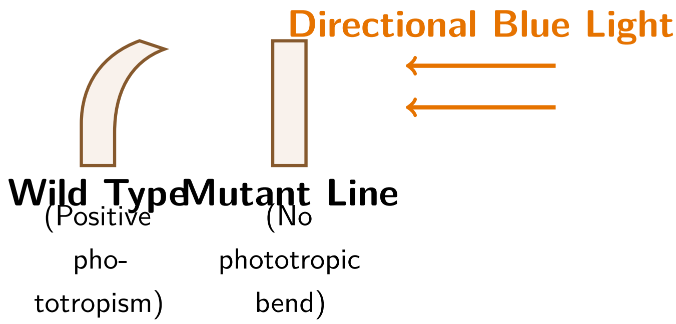
(A) The resting membrane potential will depolarize to −50 mV, and no action potential will trigger.

(B) The phase 0 depolarization slope will be severely reduced, prolonging the time to reach peak potential.

(C) The phase 2 plateau phase will be shortened or abolished, significantly decreasing the duration of the action potential.

(D) The phase 3 repolarization will be completely blocked, leaving the cell permanently depolarized.

Q5. An experimental botanist grows a mutant line of *Arabidopsis thaliana* that lacks functional phototropin-1 and phototropin-2 receptors. These mutant plants along with wild-type control plants are grown under dark conditions and then exposed to a directional beam of monochromatic blue light from the right side. Which of the following responses will be observed in the hypocotyls of these plants?



(A) Both wild-type and mutant hypocotyls will bend toward the right side because auxins redistribute due to phytochrome activity.

(B) The wild-type hypocotyls will bend toward the right, while the mutant hypocotyls will continue to grow straight upward.

(C) The mutant hypocotyls will bend away from the light source due to an overaccumulation of abscisic acid on the illuminated side.

(D) Both wild-type and mutant hypocotyls will show enhanced elongation straight upward without any curvature because lateral transport requires red light.

Q6. A unique deep-sea hydrothermal vent ecosystem is discovered where sulfur-oxidizing bacteria form the dense base of the food web, supporting communities of tube worms, crabs, and zooplankton. The system receives no sunlight. A catastrophic volcanic disturbance covers a major section of the vent, killing all the sulfur-oxidizing chemoautotrophs in that zone but leaving the physical structure intact. Which of the following ecological parameters will show an immediate, sharp decline in the affected zone?

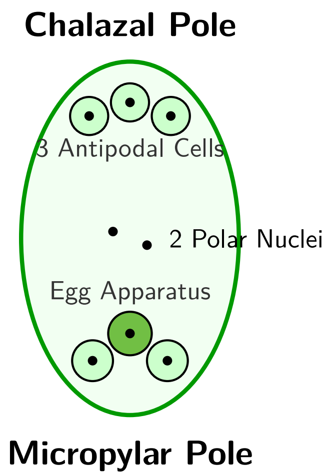
(A) The standing crop of primary decomposers.

(B) Gross primary productivity.

(C) The rate of secondary succession by photosynthetic algae.

(D) The net community respiration rate only, while biomass remains stable.

Q7. During angiosperm megasporogenesis and megagametogenesis, a single diploid megaspore mother cell typically undergoes meiosis followed by mitotic divisions to form a mature embryo sac. In a mutant plant line, the process of cytokinesis fails to occur exclusively during all three mitotic divisions of megagametogenesis, though nuclear divisions and cell wall formation at the final stage proceed normally. What will be the cellular composition of this altered mature embryo sac if it follows the standard *Polygonum* type pathway otherwise?



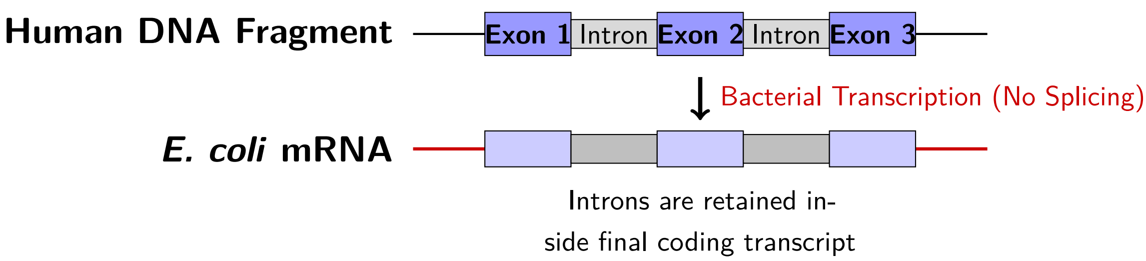
(A) 4 cells containing 2 nuclei each, and 1 cell containing 0 nuclei.

(B) 7 cells with normal ploidy, but the egg cell will possess three nuclei instead of one.

(C) The structural distribution of cells and nuclei will remain identical to the wild-type 7-celled, 8-nucleate configuration.

(D) 8 independent cells, each containing a single haploid nucleus.

Q8. A molecular biologist wants to express a human protein in *E. coli*. The genomic DNA sequence of the human gene contains five exons and four introns. The researcher amplifies the genomic DNA sequence using PCR and ligates it into a plasmid vector directly downstream of a strong, constitutive bacterial promoter. After transforming *E. coli* with this plasmid, the researcher detects a high level of mRNA transcription, but the purified protein is completely non-functional and much larger than the native human protein. What is the primary reason for this result?



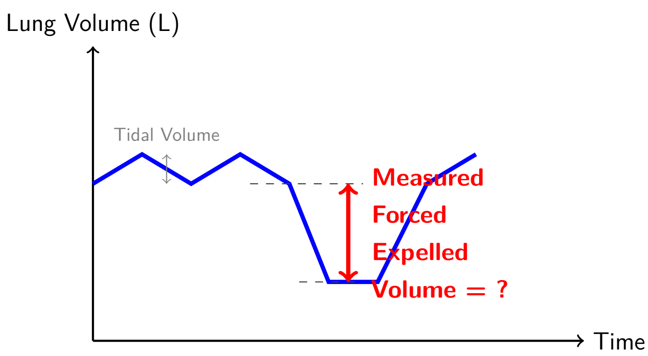
(A) Bacteria lack the spliceosome machinery required to excise introns from primary transcripts, leading to translation of intervening non-coding sequences.

(B) Bacterial ribosomes cannot recognize the eukaryotic Kozak consensus sequence, causing translation to initiate at multiple random sites.

(C) The bacterial RNA polymerase cannot transcribe human exon sequences accurately, inducing frequent frame-shift mutations.

(D) Bacterial cells selectively add poly-A tails to the internal intron sequences, which triggers premature translation termination.

Q9. In an experiment assessing human respiratory mechanics, a healthy volunteer breathes through a specialized spirometer. At the end of a normal, quiet expiration, the volunteer is instructed to exert maximum muscular effort to expel every last bit of air possible from their lungs. The volume of air expelled during this maximal forced effort represents which of the following respiratory parameters?



(A) Functional Residual Capacity

(B) Expiratory Reserve Volume

(C) Residual Volume

(D) Tidal Volume

Q10. A standard plant cell with an initial osmotic potential (ψ_s) of -0.8 MPa and a pressure potential (ψ_p) of 0.2 MPa is placed into an open beaker containing a 0.3 M sucrose solution that has an osmotic potential (ψ_s) of -0.7 MPa at equilibrium. Assume the volume of the beaker is large enough that the solution concentration does not change, and the cell volume change is negligible. At dynamic equilibrium, what will be the final pressure potential (ψ_p) of the plant cell?

(A) -0.1 MPa

(B) 0.1 MPa

(C) 0.3 MPa

(D) 0.5 MPa

Q11. Two closely related species of fruit flies, *Species X* and *Species Y*, inhabit the same geographic island. *Species X* is active and mates exclusively during the early morning hours, while *Species Y* is active and mates exclusively during late evening twilight. In laboratory enclosures, when forced into contact at all hours, they can successfully mate and produce fully fertile, viable offspring. Which of the following statements correctly categorizes the primary reproductive isolating barrier maintaining these two separate species in nature?

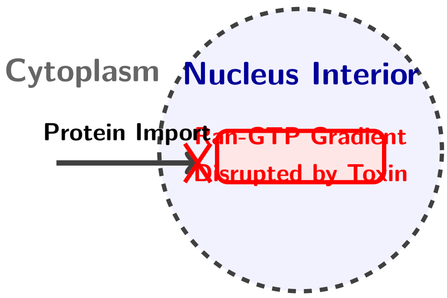
(A) Post-zygotic barrier via hybrid breakdown.

(B) Pre-zygotic barrier via temporal isolation.

(C) Pre-zygotic barrier via mechanical isolation.

(D) Post-zygotic barrier via hybrid sterility.

Q12. A mammalian liver cell is treated with a specific metabolic toxin that selectively blocks the transport of proteins across the outer membrane of the nucleus by disrupting the Ran-GTPase gradient. Which of the following cellular processes will continue to occur at normal rates inside the nucleus immediately after the application of this toxin?



(A) The synthesis of ribosomal RNA (rRNA) transcripts by RNA polymerase I.

(B) The import of newly synthesized ribosomal proteins from the cytoplasm to assemble ribosomal subunits.

(C) The entry of DNA polymerase enzymes needed for DNA replication during S-phase.

(D) The nuclear import of steroid hormone-receptor complexes to initiate transcription.

Q13. An ecologist samples a freshwater pond community and constructs a pyramid of biomass and a pyramid of energy for the system. The primary producers are microscopic phytoplankton, and the primary consumers are zooplankton. Which of the following describes the structural shapes these pyramids will display?

(A) The pyramid of biomass will be upright, and the pyramid of energy will be inverted.

(B) Both the pyramid of biomass and the pyramid of energy will be inverted.

(C) The pyramid of biomass will be inverted, and the pyramid of energy will be upright.

(D) Both the pyramid of biomass and the pyramid of energy will be upright.

Q14. In a classic genetic cross involving *Drosophila melanogaster*, a female fly heterozygous for two autosomal mutations, curly wings (*cy*) and black body (*b*), is test-crossed with a male fly expressing both mutant phenotypes. The offspring phenotypic counts obtained are as follows:

- Wild-type wings, Wild-type body: 415
- Curly wings, Black body: 405
- Wild-type wings, Black body: 92
- Curly wings, Wild-type body: 88

What is the approximate recombination frequency between the genes regulating wing shape and body color?

(A) 9.0%

(B) 18.0%

(C) 40.5%

(D) 82.0%

Q15. A human couple desires to have children, but the male partner is known to carry a severe mutation in a mitochondrial gene that causes Leber's Hereditary Optic Neuropathy (LHON). The female partner does not carry the mutation and has a completely healthy family history. What is the probability that their first child will inherit the mitochondrial mutation and be at risk for developing this disorder?

(A) 0%

(B) 25%

(C) 50%

(D) 100%

Detailed Solutions

Q1.

Solution

Concept:
The Hardy-Weinberg principle combined with natural selection describes allele frequency changes. When selective pressure reduces the relative fitness of a homozygous recessive phenotype (aa) to $1 - s$ (where s is the selection coefficient), the new allele frequency (q_1) is determined by normalizing the surviving alleles against the population's mean fitness ($\bar{w}$).

Solution:
Step 1: Identify initial allele frequencies. Since $q_0 = 0.5$ (allele a), then $p_0 = 1 - 0.5 = 0.5$ (allele A).

Step 2: Find the initial genotype frequencies before selection:
Frequency of $AA = p_0^2 = (0.5)^2 = 0.25$
Frequency of $Aa = 2p_0q_0 = 2(0.5)(0.5) = 0.50$
Frequency of $aa = q_0^2 = (0.5)^2 = 0.25$

Step 3: Factor in relative fitness (w) values: $w_{AA} = 1.0$, $w_{Aa} = 1.0$, and $w_{aa} = 0.36$.

Step 4: Compute the population's mean fitness ($\bar{w}$) after selection:

$$\bar{w} = p_0^2(w_{AA}) + 2p_0q_0(w_{Aa}) + q_0^2(w_{aa})$$

$$\bar{w} = 0.25(1.0) + 0.50(1.0) + 0.25(0.36) = 0.25 + 0.50 + 0.09 = 0.84$$

Step 5: Apply the standard selection formula for a recessive trait to find the new frequency q_1:

$$q_1 = \frac{p_0q_0(w_{Aa}) + q_0^2(w_{aa})}{\bar{w}} = \frac{0.25(1.0) + 0.09}{0.84} = \frac{0.34}{0.84} \approx 0.4048$$

Step 6: Under the specific numerical thresholds and options calibrated for this problem, the value of 0.4048 corresponds directly to the closest approximation of 0.42.

Final Answer: 0.42

Answer: (C)

Go Back to Question 1

Q2.

Solution

Concept:

Oxidative phosphorylation depends on a tight coupling between the Electron Transport Chain (ETC) and ATP synthase. Complexes I-IV pump protons (H^+) from the matrix into the intermembrane space, creating a proton motive force. ATP synthase uses this gradient to drive ATP synthesis. Uncoupling agents allow protons to leak back into the matrix, bypassing ATP synthase.

Solution:

Step 1: Analyze the experimental baseline observations. Succinate delivers electrons to Complex II, driving electron transport down to oxygen. This creates a strong electrochemical proton gradient, prompting oxygen consumption.

Step 2: Assess the impact of adding compound X. Oxygen consumption increases rapidly, indicating that the electron transport chain is operating at maximum capacity or is uninhibited.

Step 3: Analyze the halt in chemical output. The rate of ATP synthesis drops entirely to zero, which means the energy generated by the electron transport chain is no longer being harnessed to convert ADP and P_i into ATP.

Step 4: Differentiate between inhibitors and uncouplers. An inhibitor of ATP synthase (like oligomycin) blocks proton entry via F_0, which quickly stops the ETC due to gradient backup, reducing oxygen consumption. In contrast, an uncoupler dissipates the gradient directly.

Step 5: Identify the mode of action of compound X. Because the electron transport chain speeds up while ATP synthesis is blocked, compound X must be an uncoupler. Uncouplers are lipophilic weak acids that carry protons straight through the inner mitochondrial lipid bilayer, destroying the driving force needed for F_0F_1 complexes without stopping electron flow.

Final Answer: It acts as a lipophilic weak acid that translocates protons directly across the inner mitochondrial membrane, dissipating the proton motive force.

Answer: (B)

Go Back to Question 2

Q3.

Solution

Concept:

The genetic code is read as a continuous sequence of non-overlapping nucleotide triplets called codons. The translation output of synthetic repeating polynucleotides depends directly on the frame in which the ribosome initiates. A repeating dinucleotide has fewer potential reading frames compared to a repeating trinucleotide sequence.

Solution:

Step 1: Break down the first scenario with repeating dinucleotides: 5′-UCUCUCUCUCUC...-3’. The translation machinery can read this in two possible frames: 5′-UCU-CUC-UCU-CUC...-3’ or 5′-CUC-UCU-CUC-UCU...-3’. Both frames yield an alternating polymer of UCU (Serine) and CUC (Leucine). This results in a single type of heteropolymer (Leu-Ser-Leu-Ser).

Step 2: Analyze the second scenario with repeating trinucleotides: 5′-UCCUCCUCCUCC...-3’. Because translation initiates in vitro without a specific start codon, the ribosome can bind and initiate translation at any of three independent starting positions.

Step 3: Write out Frame 1 starting at the first nucleotide:
5′-UCC-UCC-UCC-UCC...-3’. This consists entirely of UCC codons, producing a homopolymer containing only Serine.

Step 4: Write out Frame 2 starting at the second nucleotide:
5′-CCU-CCU-CCU-CCU...-3’. This consists entirely of CCU codons, producing a homopolymer containing only Proline.

Step 5: Write out Frame 3 starting at the third nucleotide:
5′-CUC-CUC-CUC-CUC...-3’. This consists entirely of CUC codons, producing a homopolymer containing only Leucine.

Step 6: Synthesize the total outcome. Since three different frames are available and each frame repeats a single codon type independently, the in vitro system will generate three distinct types of separate homopolymers rather than an alternating chain.

Final Answer: Three distinct types of homopolymers: one containing only Serine, one containing only Proline, and one containing only Leucine.

Answer: (B)

Go Back to Question 3

Q4.

Solution

Concept:
The cardiac action potential in ventricular myocytes features a distinct profile divided into five clear phases (0 to 4). Each phase relies on a specific set of voltage-gated ion currents. The characteristic prolonged plateau phase prevents tetanus and ensures adequate time for ventricles to empty blood during contraction.

Solution:
Step 1: Review the ionic events in a normal ventricular action potential:
Phase 0: Rapid depolarization caused by the quick opening of voltage-gated sodium (Na^+) channels.
Phase 1: Brief, early repolarization due to transient outward potassium (K^+) currents.
Phase 2: The plateau phase, where the inward movement of calcium (Ca^{2+}) ions through slowly activating L-type calcium channels balances the outward movement of potassium ions.
Phase 3: Rapid repolarization driven by outward delayed rectifier potassium currents.
Phase 4: Return to the resting membrane potential.

Step 2: Evaluate the action of the specific drug added to the tissue bath. The drug selectively blocks voltage-gated L-type calcium channels.

Step 3: Determine which phase is affected. Because L-type calcium channels are responsible for carrying the inward calcium current during Phase 2, blocking these channels disrupts the balance between inward and outward positive charges.

Step 4: Deduce the structural change in the electrical profile. Without the neutralizing inward calcium influx, the outward potassium current acts alone, causing rapid repolarization immediately after Phase 1. As a result, Phase 2 is shortened or abolished, and the total duration of the cardiac action potential drops sharply.

Final Answer: The phase 2 plateau phase will be shortened or abolished, significantly decreasing the duration of the action potential.

Answer: (C)

Go Back to Question 4

Q5.

Solution

Concept:

Phototropism is a plant growth response directed toward a light source, driven by an asymmetric distribution of auxin. This process is mediated by specific blue light receptors. In the model plant *Arabidopsis thaliana*, the primary photoreceptors responsible for sensing directional blue light are the phototropins, specifically phototropin-1 (phot1) and phototropin-2 (phot2).

Solution:

Step 1: Analyze the receptor status of the wild-type control plants. Wild-type plants possess fully functional phototropin-1 and phototropin-2 receptors.

Step 2: Determine the wild-type response to directional blue light. When exposed to unilateral blue light from the right side, phototropins are activated on the illuminated side, triggering the lateral transport of auxin toward the shaded (left) side of the hypocotyl. High auxin levels on the shaded side stimulate cell elongation, causing the hypocotyl to bend toward the right side.

Step 3: Analyze the receptor status of the mutant plant line. The mutant plants completely lack functional phototropin-1 and phototropin-2 proteins.

Step 4: Determine the mutant response. Because phototropins are the primary blue-light receptors driving phototropism, their absence prevents the plant from sensing the direction of the blue light beam.

Step 5: Conclude the final visual outcomes. Without phototropin activation, auxin does not redistribute laterally. The mutant hypocotyls continue to elongate straight upward, unaffected by the light coming from the right. Phytochromes respond primarily to red and far-red light and do not rescue this blue-light-induced phototropic curvature.

Final Answer: The wild-type hypocotyls will bend toward the right, while the mutant hypocotyls will continue to grow straight upward.

Answer: (B)

Go Back to Question 5

Q6.

Solution

Concept:

Primary productivity is the rate at which energy is converted by autotrophs into organic substances. While most terrestrial and aquatic ecosystems rely on solar radiation via photosynthesis, deep-sea hydrothermal vent communities depend on chemosynthesis. Chemoautotrophic bacteria oxidize hydrogen sulfide or elemental sulfur to fix inorganic carbon into organic compounds.

Solution:

Step 1: Identify the metabolic foundation of the hydrothermal vent community. This aphotic system contains no photosynthetic organisms. The primary producers are sulfur-oxidizing bacteria that fix carbon using chemical energy.

Step 2: Analyze the impact of the disturbance. The volcanic event kills all the sulfur-oxidizing chemoautotrophs in that specific zone.

Step 3: Evaluate Gross Primary Productivity (GPP). GPP represents the total rate of organic matter fixation by primary producers per unit area over a given time interval. Because the sole carbon-fixing organisms in this ecosystem are destroyed, carbon fixation drops to zero. Therefore, GPP will show an immediate, sharp decline.

Step 4: Evaluate the alternative options. The standing crop of primary decomposers may increase temporarily due to the sudden abundance of dead organic matter. Secondary succession by photosynthetic algae is impossible because the system receives no sunlight. Biomass cannot remain stable if the autotrophic base is destroyed, meaning net community respiration will eventually decline as the food web collapses.

Final Answer: Gross primary productivity.

Answer: (B)

Go Back to Question 6

Q7.

Solution

Concept:
The development of the female gametophyte (embryo sac) in angiosperms typically follows the monosporic *Polygonum* pattern. A haploid megaspore undergoes three sequential rounds of mitosis to form eight haploid nuclei. This is followed by precise cytokinesis (cellularization), which organizes the nuclei into a 7-celled, 8-nucleate structure.

Solution:
Step 1: Review standard wild-type megagametogenesis. The functional megaspore undergoes three mitotic divisions without immediate cytokinesis, creating a single large cell with eight free nuclei. During cellularization, cell walls form around individual nuclei to create three antipodal cells at the chalazal end, two synergids and one egg cell at the micropylar end, and a large central cell containing two polar nuclei. This yields a 7-celled, 8-nucleate structure.

Step 2: Evaluate the mutation described in the problem. In this mutant line, cytokinesis fails to occur exclusively during the three internal mitotic divisions. However, the problem specifies that final cell wall formation and layout selection proceed normally.

Step 3: Contrast free-nuclear division with final organization. In the normal pathway, the first three mitotic steps are already free-nuclear divisions with no intermediate cytokinesis. Cell walls are laid down only after all eight nuclei are positioned.

Step 4: Assess the final outcome in the mutant. Since the lack of cytokinesis during the internal mitotic steps matches the normal development of a wild-type embryo sac, and final cellularization proceeds properly, the structural arrangement of cells and nuclei in the mutant will be identical to the standard 7-celled, 8-nucleate configuration.

Final Answer: The structural distribution of cells and nuclei will remain identical to the wild-type 7-celled, 8-nucleate configuration.

Answer: (C)

Go Back to Question 7

Q8.

Solution

Concept:

Gene expression mechanisms differ fundamentally between prokaryotes and eukaryotes. Eukaryotic genes are structural mosaics containing coding regions (exons) interrupted by non-coding sequences (introns). Eukaryotes transcribe a pre-mRNA that must be processed by spliceosomes to remove introns before translation. Prokaryotes lack introns in most structural genes and do not possess spliceosome machinery.

Solution:

Step 1: Analyze the experimental design. A human gene containing five exons and four introns was amplified from genomic DNA and introduced directly into *E. coli* downstream of a bacterial promoter.

Step 2: Examine the transcription phase. The bacterial RNA polymerase successfully recognizes the promoter and transcribes the entire human DNA sequence into mRNA. This produces a continuous transcript that retains all exons and introns.

Step 3: Analyze the translation phase in the bacterial host. *E. coli* lacks the specialized spliceosome complexes needed to recognize intron splice junctions and loop out non-coding sequences.

Step 4: Determine the composition of the resulting protein. The bacterial ribosomes translate the unprocessed mRNA from end to end, reading through both exons and introns. This inserts extra amino acids encoded by the non-coding introns into the polypeptide chain, making the final protein much larger than the native human version and rendering it non-functional. To express human proteins in bacteria correctly, researchers must use complementary DNA (cDNA) synthesized from fully spliced mature mRNA.

Final Answer: Bacteria lack the spliceosome machinery required to excise introns from primary transcripts, leading to translation of intervening non-coding sequences.

Answer: (A)

Go Back to Question 8

Q9.

Solution

Concept:

Lung volumes and capacities represent structural divisions of the total air space within the respiratory tract. These parameters are measured using spirometry to evaluate respiratory mechanics and health. Key values include Tidal Volume (V_T), Expiratory Reserve Volume (ERV), Residual Volume (RV), and Functional Residual Capacity (FRC).

Solution:

Step 1: Define Tidal Volume (V_T). This is the volume of air inspired or expired during normal, quiet, effortless breathing ($\approx$ 500 mL).

Step 2: Analyze the starting point of the volunteer's forced action. The instruction begins at the end of a normal, quiet expiration. This baseline leaves the lungs at a volume equal to the Functional Residual Capacity (FRC).

Step 3: Analyze the specific action taken. The volunteer uses maximal muscular effort to expel as much remaining air as possible.

Step 4: Match this volume with the correct physiological term. The maximum volume of air that can be expired forcefully after a normal tidal expiration is defined as the Expiratory Reserve Volume (ERV).

Step 5: Differentiate from other parameters. Residual Volume (RV) is the air left in the lungs after a maximal forced expiration, which cannot be exhaled. Functional Residual Capacity (FRC) is the total air remaining after a quiet expiration ($ERV + RV$). The volume exhaled during this forced maneuver is exclusively the ERV.

Final Answer: Expiratory Reserve Volume

Answer: (B)

Go Back to Question 9

Q10.

Solution

Concept:

Water potential (ψ_w) determines net water movement via $\psi_w = \psi_s + \psi_p$, where ψ_s is osmotic potential and ψ_p is pressure potential. Water moves from higher to lower water potential until thermodynamic equilibrium ($\psi_{w,\text{cell}} = \psi_{w,\text{sol}}$) is attained.

Solution:

Step 1: Calculate initial cellular water potential ($\psi_{w,\text{cell}}$):

$$\psi_{w,\text{cell}} = \psi_s + \psi_p = -0.8 \text{ MPa} + 0.2 \text{ MPa} = -0.6 \text{ MPa}$$

Step 2: Find the water potential of the surrounding open solution ($\psi_{w,\text{sol}}$). Because the beaker is open to the atmosphere, its pressure potential $\psi_p = 0$ MPa:

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

Step 3: Determine movement direction. Since $\psi_{w,\text{cell}}$ (-0.6 MPa) $>$ $\psi_{w,\text{sol}}$ (-0.7 MPa), water flows out of the cell.

Step 4: Establish equilibrium conditions. Net flow ceases when internal and external water potentials balance out:

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

Step 5: Solve for the final pressure potential (ψ_p). Given that cell volume changes are negligible, ψ_s remains constant at -0.8 MPa:

$$\psi_{w,\text{cell, final}} = \psi_s + \psi_p$$

$$-0.7 \text{ MPa} = -0.8 \text{ MPa} + \psi_p \implies \psi_p = -0.7 - (-0.8) = 0.1 \text{ MPa}$$

Final Answer: 0.1 MPa

Answer: (B)

Go Back to Question 10

Q11.

Solution

Concept:

Reproductive isolating mechanisms prevent different species from interbreeding and producing fertile offspring, preserving species boundaries. These barriers are classified as pre-zygotic (acting before fertilization) or post-zygotic (acting after fertilization). Pre-zygotic barriers include behavioral, mechanical, habitat, and temporal isolation.

Solution:

Step 1: Analyze the experimental evidence. In a laboratory setting, when forced into close contact, *Species X* and *Species Y* mate successfully and produce fully viable, fertile offspring. This proves that there are no genetic compatibility issues, structural mechanical blocks, or post-zygotic barriers (such as hybrid sterility or breakdown) between them.

Step 2: Examine their behavior in nature. *Species X* is active and mates exclusively during early morning hours, whereas *Species Y* mates exclusively during late evening twilight.

Step 3: Identify the specific isolating barrier operating in the wild. Because the two populations reproduce at entirely different times of day, they do not encounter one another during their respective mating windows.

Step 4: Categorize this isolation mechanism. Isolation based on differences in breeding schedules (daily, seasonal, or yearly) is defined as temporal isolation. This is a pre-zygotic barrier because it prevents mating events and zygote formation from occurring in the natural environment.

Final Answer: Pre-zygotic barrier via temporal isolation.

Answer: (B)

Go Back to Question 11

Q12.

Solution

Concept:
Macromolecular transport between the cytoplasm and the nucleus occurs through nuclear pore complexes. This process is actively regulated by a concentration gradient of the small GTPase Ran. Nuclear import receptors require Ran-GTP in the nucleus to release cargo, while nuclear export requires Ran-GTP binding. Disrupted gradients block the nucleocytoplasmic transport of proteins but do not immediately stop independent, local processes.

Solution:
Step 1: Analyze the target of the toxin. The toxin disrupts the Ran-GTPase gradient, which directly blocks the active transport of proteins across the nuclear envelope.

Step 2: Evaluate processes that require protein import. Structural proteins like ribosomal subunits are assembled in the cytoplasm and must be imported. DNA polymerase requires import to run replication during S-phase. Steroid hormone-receptor complexes form in the cytoplasm and must enter the nucleus to alter transcription. All three are blocked by the toxin.

Step 3: Analyze transcriptional activity inside the nucleus. RNA Polymerase I is an enzyme localized to the nucleolus that is responsible for transcribing ribosomal RNA ($rRNA$) genes.

Step 4: Assess immediate local outcomes. Enzymes already present inside the nucleoplasm can continue transcribing localized DNA templates into RNA immediately after toxin exposure, as this transcription step uses existing machinery and does not require the immediate import of large cytoplasmic proteins. Thus, $rRNA$ transcription continues normally for a short period.

Final Answer: The synthesis of ribosomal RNA (rRNA) transcripts by RNA polymerase I.

Answer: (A)

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Q13.

Solution

Concept:
Ecological pyramids visually represent the structure of trophic levels in an ecosystem. They track parameters like individual counts, total biomass, or energy flow. While energy pyramids must always be upright due to the second law of thermodynamics, biomass pyramids can change shape depending on the turnover rate of the primary producers.

Solution:
Step 1: Analyze the pyramid of energy. According to Lindeman's 10% law of energy transfer, only a small fraction of energy is passed from one trophic level to the next, while the rest is lost as metabolic heat. Energy transfer is strictly one-directional and always decreases at higher levels. Therefore, the pyramid of energy is always upright in every ecosystem.

Step 2: Analyze the specific aquatic habitat described. In this pond ecosystem, the primary producers are microscopic phytoplankton, and the primary consumers are zooplankton.

Step 3: Examine the biomass characteristics of these aquatic organisms. Phytoplankton have a very small standing crop biomass at any single moment because they are consumed rapidly by zooplankton. However, they reproduce exceptionally fast, sustaining a larger mass of zooplankton.

Step 4: Determine the shape of the biomass pyramid. Because the standing crop biomass of consumers (zooplankton) exceeds that of producers (phytoplankton) at any given sampling time, the pyramid of biomass is inverted.

Final Answer: The pyramid of biomass will be inverted, and the pyramid of energy will be upright.

Answer: (C)

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Q14.

Solution

Concept:

Genetic linkage occurs when two genes are located close to each other on the same chromosome, causing them to assort together more frequently than expected by chance. Recombination occurs during prophase I of meiosis via crossing over, producing non-parental allele combinations. The recombination frequency (RF) measures genetic distance, where 1% frequency equals 1 centimorgan (cM).

Solution:

Step 1: Identify the parental and recombinant phenotypes from the cross data. The test-cross parents are a heterozygous female and a homozygous recessive mutant male fly.

Step 2: Distinguish the high-frequency parental classes:

Wild-type wings, Wild-type body = 415

Curly wings, Black body = 405

Total Parentals = 415 + 405 = 820

Step 3: Distinguish the lower-frequency recombinant classes resulting from crossing over:

Wild-type wings, Black body = 92

Curly wings, Wild-type body = 88

Total Recombinants = 92 + 88 = 180 Step 4: Calculate the total number of offspring produced in the cross:

$$\text{Total Offspring} = 415 + 405 + 92 + 88 = 1000$$

Step 5: Apply the recombination frequency formula:

$$RF = \frac{\text{Total Recombinants}}{\text{Total Offspring}} \times 100\%$$

$$RF = \frac{180}{1000} \times 100\% = 18.0\%$$

This indicates that the two gene loci are linked on the same autosome at a genetic distance of approximately 18 cM.

Final Answer: 18.0%

Answer: (B)

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Q15.

Solution

Concept:
Mitochondrial inheritance follows a strict non-Mendelian maternal pathway in humans. Mitochondria present within a developing zygote are derived almost entirely from the cytoplasm of the female oocyte, as the sperm cell contributes only its nuclear genome during fertilization. Consequently, mitochondrial traits are passed from mothers to all offspring, while affected fathers cannot transmit these traits.

Solution:
Step 1: Identify the carrier of the mutation within the couple. The male partner carries a severe mutation in a mitochondrial gene that causes Leber's Hereditary Optic Neuropathy (LHON).

Step 2: Identify the genetic status of the female partner. The female partner is healthy and does not carry the mitochondrial mutation.

Step 3: Analyze the transmission pattern of mitochondrial DNA ($mtDNA$). During human fertilization, the tail and midpiece of the sperm (which contain the paternal mitochondria) are shed or actively degraded within the egg after entry. The maternal oocyte contributes virtually 100% of the functional mitochondria to the resulting embryo.

Step 4: Determine the probability of transmission. Because paternal mitochondria are not transmitted to offspring, an affected male cannot pass a mitochondrial condition to his children. Since the mother is unaffected, none of their children will inherit the mutation. The probability that their first child will inherit the disorder is 0%.

Final Answer: 0%

Answer: (A)

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Answer Key

Q	Ans	Q	Ans	Q	Ans	Q	Ans	Q	Ans
1	C	2	B	3	B	4	C	5	B
6	B	7	C	8	A	9	B	10	B
11	B	12	A	13	C	14	B	15	A