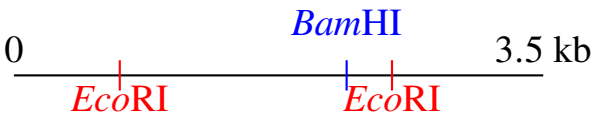
# IISER Biology Sample Paper-9

**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 linear DNA fragment of 3.5 kb has two restriction sites for the enzyme *Eco*RI and one site for *Bam*HI. Upon complete digestion with both enzymes simultaneously, a student observes fragments of sizes 1.5 kb, 1.0 kb, 0.7 kb, and 0.3 kb. If digestion with *Eco*RI alone yields fragments of 1.8 kb, 1.0 kb, and 0.7 kb, which of the following is the correct sequence of fragments liberated when the DNA is digested with *Bam*HI alone?




(A) 2.2 kb and 1.3 kb

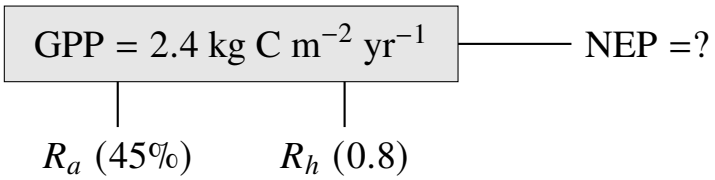
(B) 2.5 kb and 1.0 kb

(C) 2.0 kb and 1.5 kb

(D) 3.2 kb and 0.3 kb

**Q2.** During a field study in a tropical rainforest, an ecologist measured the net primary productivity (NPP) and respiration (R) of a specific forest patch. If the gross primary productivity (GPP) of this ecosystem is 2.4 kg C $m^{-2}$ $yr^{-1}$ and the autotrophic respiration ($R_a$) accounts for 45% of the GPP, while heterotrophic

respiration ($R_h$) accounts for 0.8 kg C $m^{-2}$ $yr^{-1}$, what is the Net Ecosystem Productivity (NEP) of this patch?



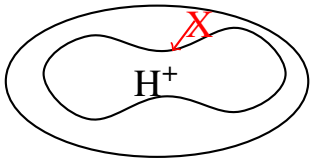

(A) 1.32 kg C $m^{-2}$ $yr^{-1}$

(B) 0.52 kg C $m^{-2}$ $yr^{-1}$

(C) 1.08 kg C $m^{-2}$ $yr^{-1}$

(D) 0.28 kg C $m^{-2}$ $yr^{-1}$

**Q3.** A researcher isolates an intact, fully functional organelle from a healthy mammalian hepatocyte. When placed in an isotonic buffer solution containing pyruvate, ADP, and inorganic phosphate, the oxygen consumption rate increases dramatically. However, when a specific chemical compound 'X' is added, oxygen consumption continues at an elevated rate, but ATP synthesis drops to zero. Which of the following best describes the structural or functional modification caused by compound 'X' in this organelle?




(A) It competitively inhibits the binding of succinate to Complex II of the electron transport chain.

(B) It increases the permeability of the inner membrane to protons, dissipating the electrochemical gradient.

(C) It binds irreversibly to the $F_0$ subunit of ATP synthase, blocking the physical rotation of the $\gamma$ subunit.

(D) It inhibits the adenine nucleotide translocase, preventing the export of newly synthesized ATP.

**Q4.** In a classic genetic cross involving *Drosophila*, a wild-type female (gray body, red eyes) is crossed with a mutant male (black body, purple eyes). All $F_1$ progeny

are wild-type. An $F_1$ female is then test-crossed with a black-bodied, purple-eyed male, yielding the following phenotypic distribution in the $F_2$ generation:

- Gray body, red eyes: 412
- Black body, purple eyes: 398
- Gray body, purple eyes: 94
- Black body, red eyes: 96

Based on this data, what is the map distance between the genes governing body color and eye color?

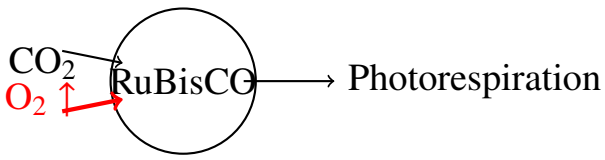
(A) 9.5 cM

(B) 19.0 cM

(C) 24.0 cM

(D) 38.0 cM

**Q5.** An experiment was conducted where healthy green leaves of a $C_3$ plant were exposed to a constant light intensity, but the ambient concentration of $O_2$ was suddenly increased from 21% to 50% while maintaining a stable $CO_2$ concentration. Which of the following metabolic adjustments will be observed immediately following this shift?



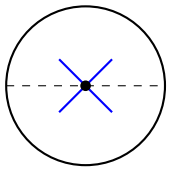

(A) An increase in the synthesis of 3-phosphoglycerate (3-PGA) and a decrease in phosphoglycolate production.

(B) A decrease in the rate of photosynthetic carbon reduction (PCR) cycle and an increase in the activation of the photorespiratory pathway.

(C) Increased carboxylation efficiency of RuBisCO due to the allosteric activation of the enzyme by oxygen molecules.

(D) Complete cessation of the light-dependent reactions due to the physical destruction of the PSII reaction centers.

**Q6.** A mutation in the gene encoding the mammalian regulatory protein "Securin" prevents its recognition and subsequent ubiquitination by the Anaphase-Promoting Complex/Cyclosome (APC/C). If a diploid cell carrying this mutation enters mitosis, at which specific stage will the cell cycle arrest, and what will be the molecular state of the sister chromatids?


Metaphase Plate

(A) Metaphase; sister chromatids remain physically linked by cohesin complexes.

(B) Anaphase; sister chromatids separate completely but fail to migrate toward opposite poles.

(C) Prophase; chromosomes fail to condense and cannot align on the equatorial plate.

(D) Telophase; daughter nuclei reform around unseparated, tetraploid chromosomal masses.

**Q7.** During the human menstrual cycle, the luteal phase is characterized by high levels of progesterone secreted by the corpus luteum. If fertilization does not occur, the corpus luteum degenerates into the corpus albicans. Which of the following sequential endocrine events directly triggers this structural degeneration?

(A) A sudden, massive surge of Luteinizing Hormone (LH) from the anterior pituitary.

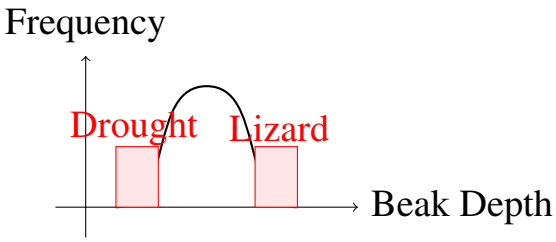
(B) A decline in human Chorionic Gonadotropin (hCG) feedback combined with the low basal levels of pituitary LH.

(C) A steep rise in Inhibin-B levels which positively stimulates the hypothalamic release of GnRH.

(D) A selective increase in Follicle Stimulating Hormone (FSH) that actively lyses the luteal cells.

**Q8.** In an isolated island ecosystem, a population of a seed-eating finch species displays a continuous variation in beak depth. A severe, decade-long drought

eliminates plants producing small, soft seeds, leaving only plants that produce large, woody, hard-to-crack seeds. Concurrently, an invasive predatory lizard arrives that selectively preys only on birds with exceptionally large bodies and deep beaks. Assuming beak depth correlates positively with body size, what type of natural selection will most likely operate on the finch population's beak depth over generations?



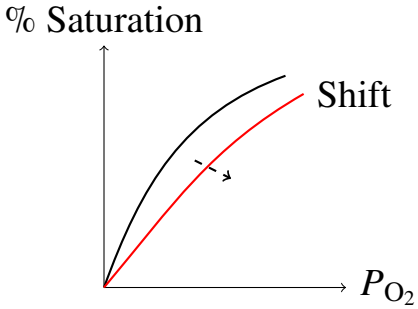

(A) Directional selection shifting the mean toward larger beak depths.

(B) Disruptive selection favoring both very small and very large beak depths.

(C) Stabilizing selection reducing the variance and maintaining an intermediate beak depth.

(D) Balancing selection leading to the immediate extinction of the entire population.

**Q9.** A medical student measures the physiological parameters of a healthy individual undergoing strenuous physical exercise on a stationary bicycle. Which of the following shifts in the oxygen-hemoglobin dissociation curve will occur in the systemic capillaries supplying the exercising skeletal muscles, and what is its primary physiological cause?




(A) Leftward shift; caused by decreased temperature and increased local pH.

(B) Rightward shift; caused by increased local $P_{CO_2}$, elevated temperature, and decreased local pH.

(C) Leftward shift; caused by increased affinity of hemoglobin for oxygen due to rapid 2, 3-BPG depletion.

(D) Rightward shift; caused by decreased $P_{CO_2}$ and decreased hydrogen ion concentration in the muscle tissue.

**Q10.** In angiosperms, double fertilization is a unique diagnostic feature. If a plant breeder prevents the functional expression of the gene encoding the secondary male gamete (or disrupts its migration), while the first male gamete successfully fuses with the egg cell, what will be the developmental fate of the resulting seed?

(A) A normal seed with a diploid embryo and a normal triploid endosperm.

(B) A seed containing a viable diploid embryo, but lacking a functional endosperm to support long-term germination.

(C) A seed with a triploid embryo and a completely degenerated diploid perisperm.

(D) The ovule will immediately abort, failing to form even the seed coat or embryonic structures.

**Q11.** The transport of water through the xylem of tall trees relies on the cohesion-tension mechanism. If a plant physiologist introduces a tiny air bubble into a functional xylem vessel element of a transpiring coniferous tree (a process known as induced cavitation), what is the immediate impact on the water column inside that specific vessel?

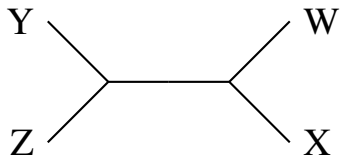

(A) The water column accelerates upward due to increased capillary action around the bubble.

(B) The continuous tension within the water column is broken, preventing further upward water movement through that specific vessel.

(C) Solute potential drops to zero, forcing water to move backward into the root cortex via symplastic pathways.

(D) The surrounding parenchyma cells immediately undergo lysis to fill the air gap with cytoplasm.

**Q12.** A molecular biologist constructs a phylogenetic tree for four newly discovered bacterial strains (W, X, Y, and Z) based on the sequence alignment of a highly conserved housekeeping gene. Strain W and X share 98% sequence identity, while strain Y shares only 82% identity with both W and X. Strain Z shares 97% identity with strain Y. Which of the following topologies best reflects the evolutionary relationships among these strains?




(A) (W, X) forms a sister clade, which is a sister group to the clade formed by (Y, Z).

(B) (W, Y) forms a sister clade, which is a sister group to the clade formed by (X, Z).

(C) Strain Z is the ancestral root from which W, X, and Y diverged simultaneously.

(D) Strain X is a hybrid lineage arising from a direct fusion event between W and Z.

**Q13.** A patient presents with chronic fatigue and muscle weakness. Laboratory tests reveal abnormally low systemic blood pressure, severe hyponatremia (low blood $Na^+$), and hyperkalemia (elevated blood $K^+$). A biopsy of the adrenal cortex confirms autoimmune destruction of a specific glandular zone. Which zone of the adrenal cortex is primary damaged, and which hormone deficiency explains these symptoms?

(A) Zona fasciculata; Cortisol deficiency

(B) Zona glomerulosa; Aldosterone deficiency

(C) Zona reticularis; Dehydroepiandrosterone (DHEA) deficiency

(D) Adrenal medulla; Epinephrine deficiency

**Q14.** In a marine intertidal community, a scientist removes all individuals of a predatory starfish species (*Pisaster ochraceus*) from a designated experimental plot, while leaving an adjacent control plot undisturbed. Over the next two years, the species richness of invertebrates in the experimental plot drops from 15 species to just 1 species (a dominant mussel), whereas the control plot maintains its high diversity. What ecological concept does this experiment directly demonstrate?

(A) Bottom-up control of community structure by primary producers.

(B) The Competitive Exclusion Principle operating in the absence of a keystone predator.

(C) Secondary ecological succession leading to a stable climax forest community.

(D) Character displacement reducing niche overlap among closely related sympatric species.

**Q15.** Consider a population of an annual plant species growing in a meadow. At the start of the breeding season, there are 500 individuals. During the season, each individual produces an average of 4 viable seeds that successfully germinate into mature plants the following year, while all the parent plants die after the seed release. What is the geometric rate of increase ($\lambda$) of this population, and what will be the population size after 3 years?

(A) $\lambda = 4$; $32,000$ individuals

(B) $\lambda = 5$; $62,500$ individuals

(C) $\lambda = 3$; $13,500$ individuals

(D) $\lambda = 2$; $4,000$ individuals

## Detailed Solutions

# Q1.

## Solution

**Concept:** This problem involves restriction mapping of a linear DNA fragment. By comparing the fragment sizes obtained from a double digestion with those from a single enzyme digestion, we can determine the relative positions of the restriction sites along the DNA molecule.

**Solution:** Step 1: Analyze the total length of the linear DNA fragment, which is 3.5 kb. When digested with *Eco*RI alone, it yields three fragments: 1.8 kb, 1.0 kb, and 0.7 kb. The sum of these fragments confirms the total length (1.8 + 1.0 + 0.7 = 3.5 kb). This tells us that there are two *Eco*RI sites inside the fragment.

Step 2: Examine the double digestion with both *Eco*RI and *Bam*HI, which yields four fragments: 1.5 kb, 1.0 kb, 0.7 kb, and 0.3 kb. Comparing this to the *Eco*RI single digestion shows that the 1.0 kb and 0.7 kb fragments remain completely intact.

Step 3: This implies that the single *Bam*HI site must lie within the 1.8 kb *Eco*RI fragment, cleaving it into two sub-fragments of 1.5 kb and 0.3 kb (1.5 + 0.3 = 1.8 kb).

Step 4: Determine the arrangement of the fragments. To find the arrangement, consider the placement of the 1.8 kb fragment relative to the others. The *Eco*RI fragments can be ordered as 0.7 kb – 1.8 kb – 1.0 kb or 0.7 kb – 1.0 kb – 1.8 kb. If the sequence is 0.7 – 1.8 – 1.0, the *Bam*HI site within the 1.8 kb segment must be adjacent to the 0.7 kb fragment to create a 1.0 kb distance from an end, or configured such that the cut occurs 1.5 kb away from one *Eco*RI site and 0.3 kb from the other.

Step 5: Let the linear map be oriented from left to right: an *Eco*RI site at 0.7 kb and another at 2.5 kb. This leaves a middle segment of 1.8 kb and a rightmost segment of 1.0 kb. Placing the *Bam*HI site at position 2.2 kb means it splits the middle 1.8 kb segment into a left part of 1.5 kb (from 0.7 to 2.2) and a right part of 0.3 kb (from 2.2 to 2.5).

Step 6: Calculate the single digestion products for *Bam*HI alone using this verified map. The *Bam*HI site is located exactly at the 2.2 kb mark from the left end. Therefore, digesting this linear DNA with *Bam*HI alone will cut the molecule into two pieces: one piece from 0 to 2.2 kb (totaling 2.2 kb) and the remaining piece from 2.2 kb to 3.5 kb (totaling 3.5 – 2.2 = 1.3 kb).

**Final Answer:** 2.2 kb and 1.3 kb

**Answer: (A)**

Go Back to Question 1

## Q2.

### Solution

**Concept:** Ecosystem productivity calculations rely on balancing gross carbon fixation against metabolic losses. Net Primary Productivity (NPP) is the energy remaining after autotrophic respiration ($R_a$), while Net Ecosystem Productivity (NEP) represents the net carbon accumulation after accounting for total ecosystem respiration ($R_e$), which includes both autotrophic ($R_a$) and heterotrophic ($R_h$) respiration.

**Solution:** Step 1: Identify the given values from the problem statement:
Gross Primary Productivity (GPP) = 2.4 kg C $m^{-2}$ $yr^{-1}$
Autotrophic respiration ($R_a$) = 45% of GPP
Heterotrophic respiration ($R_h$) = 0.8 kg C $m^{-2}$ $yr^{-1}$

Step 2: Calculate the absolute value of autotrophic respiration ($R_a$) by finding 45% of the total GPP:

$$R_a = 0.45 \times 2.4 = 1.08 \text{ kg C } m^{-2} \text{ } yr^{-1}$$

Step 3: Calculate the total ecosystem respiration ($R_e$), which is the sum of the respiration of the producers and the respiration of all consumers and decomposers:

$$R_e = R_a + R_h$$

$$R_e = 1.08 + 0.8 = 1.88 \text{ kg C } m^{-2} \text{ } yr^{-1}$$

Step 4: Determine the Net Ecosystem Productivity (NEP). NEP measures the net carbon gain or loss by the entire ecosystem over a period, computed as the difference between GPP and total ecosystem respiration ($R_e$):

$$\text{NEP} = \text{GPP} - R_e$$

$$\text{NEP} = 2.4 - 1.88 = 0.52 \text{ kg C } m^{-2} \text{ } yr^{-1}$$

Step 5: Alternatively, calculate NEP by first finding NPP. NPP = GPP − $R_a$ = 2.4 − 1.08 = 1.32 kg C $m^{-2}$ $yr^{-1}$. Then subtract heterotrophic respiration from NPP to yield NEP: NEP = NPP − $R_h$ = 1.32 − 0.8 = 0.52 kg C $m^{-2}$ $yr^{-1}$. Both methods align perfectly.

**Final Answer:** 0.52 kg C $m^{-2}$ $yr^{-1}$

**Answer: (B)**

Go Back to Question 2

## Q3.

### Solution

**Concept:** The mitochondrion generates ATP via oxidative phosphorylation, where substrate oxidation is coupled to ATP synthesis via a proton electrochemical gradient. Chemical agents that decouple these two processes are known as uncouplers. They allow electron transport and oxygen consumption to continue uninhibited while abolishing ATP production.

**Solution:** Step 1: Analyze the functional state of the isolated organelle (mitochondrion). Pyruvate drives the citric acid cycle, producing NADH and $FADH_2$, which donate electrons to the electron transport chain (ETC). This movement of electrons is coupled to proton pumping out of the matrix, creating a proton-motive force used by ATP synthase to phosphorylate ADP.

Step 2: Evaluate the action of compound 'X'. Upon addition of 'X', oxygen consumption remains high or increases, indicating that electron flow through complexes I-IV is completely functional or even accelerated. However, ATP synthesis stops entirely. This combination of active electron transport without ATP production is the hallmark of an uncoupling agent.

Step 3: Determine the mechanism of an uncoupler. Uncouplers like 2,4-dinitrophenol (DNP) act as lipophilic protonophores. They carry protons directly across the inner mitochondrial membrane into the matrix, bypassing the $F_0F_1$ ATP synthase complex.

Step 4: This action destroys the transmembrane electrochemical proton gradient ($\Delta$pH and electrical potential). Without this gradient, ATP synthase lacks the driving force to synthesize ATP from ADP and inorganic phosphate.

Step 5: Rule out alternative mechanisms. An inhibitor of Complex II or ATP synthase (like oligomycin) would cause an immediate, steep decline in oxygen consumption because electron transport becomes jammed when the proton gradient builds up or when electron entry is blocked. Only increased permeability to protons permits sustained or elevated oxygen use in the absence of phosphorylation.

**Final Answer:** It increases the permeability of the inner membrane to protons, dissipating the electrochemical gradient.

**Answer: (B)**

Go Back to Question 3

## Q4.

### Solution

**Concept:** Genetic mapping relies on the principle that the frequency of meiotic recombination between two linked genetic loci is directly proportional to the physical distance separating them on a chromosome. A testcross involving an $F_1$ dihybrid enables direct quantification of recombinant gametes produced during meiosis.

**Solution:** Step 1: Identify the parental alleles and configurations based on the initial cross. A wild-type female (homozygous dominant, assumed from true-breeding lines) crossed with a black, purple mutant male (homozygous recessive) produces all wild-type $F_1$ offspring. Let $B$ represent the wild-type gray body allele, $b$ represent the mutant black body allele, $P$ represent the wild-type red eye allele, and $p$ represent the mutant purple eye allele. The $F_1$ female is a dihybrid with alleles in the cis (coupling) configuration: $(BP/bp)$. Step 2: Examine the testcross progeny ($F_2$). The testcross partner is a homozygous recessive male ($bbpp$), contributing only recessive $b$ and $p$ alleles. Therefore, the phenotypes of the $F_2$ offspring reflect the gametic output of the $F_1$ female. Step 3: Classify the offspring into parental and recombinant classes. Parental phenotypes match the original grand-parental combinations:

- Gray body, red eyes ($BbPp$): 412
- Black body, purple eyes ($bbpp$): 398

Total Parentals = 412 + 398 = 810.

Step 4: Identify the recombinant phenotypes, which result from crossing over between the two genes:

- Gray body, purple eyes ($Bbpp$): 94
- Black body, red eyes ($bbPp$): 96

Total Recombinants = 94 + 96 = 190.

Step 5: Calculate the grand total of all individuals observed in the $F_2$ generation:

Total Progeny = 810 + 190 = 1000.

Step 6: Compute the recombination frequency (RF) as the percentage of recombinant individuals out of the total progeny:

$$\text{RF} = \left(\frac{\text{Total Recombinants}}{\text{Total Progeny}}\right) \times 100\%$$

$$\text{RF} = \left(\frac{190}{1000}\right) \times 100\% = 19\%$$

Since 1% recombination frequency equals 1 map unit (mu) or centimorgan (cM), the genetic map distance is 19.0 cM.

**Final Answer:** 19.0 cM

**Answer: (B)**

Go Back to Question 4

## Q5.

### Solution

**Concept:** The enzyme Ribulose-1,5-bisphosphate carboxylase-oxygenase (RuBisCO) is a dual-functional enzyme that catalyzes both carboxylation and oxygenation reactions using ribulose-1,5-bisphosphate (RuBP) as a common substrate. The partitioning between these two competitive reactions depends heavily on the relative concentrations of dissolved $CO_2$ and $O_2$ gases at the enzyme's active site.

**Solution:** Step 1: Consider the initial conditions of a normal $C_3$ leaf. Under regular atmospheric conditions (21% $O_2$), RuBisCO predominantly fixes $CO_2$ via the photosynthetic carbon reduction (PCR) or Calvin cycle, creating two molecules of 3-phosphoglycerate (3-PGA). However, photorespiration occurs at a basal rate.

Step 2: Analyze the effect of shifting the gas composition to 50% $O_2$ while holding $CO_2$ steady. Because $O_2$ and $CO_2$ compete directly for the same active site on RuBisCO, dramatically increasing the oxygen concentration shifts the kinetic equilibrium heavily in favor of the oxygenation reaction.

Step 3: Evaluate the chemical outcome of increased oxygenation. When RuBP reacts with $O_2$, it yields one molecule of 3-PGA and one molecule of the toxic 2-phosphoglycolate. This marks a sharp drop in the production efficiency of 3-PGA and an increase in phosphoglycolate.

Step 4: Track the downstream metabolic consequences. The accumulation of 2-phosphoglycolate forces the leaf to upregulate the photorespiratory carbon oxidation cycle to salvage carbon. This pathway spans the chloroplast, peroxisome, and mitochondrion, consuming energy and releasing fixed $CO_2$.

Step 5: Synthesize the net physiological response. Carboxylation and the regular Calvin cycle are severely hindered due to substrate competition. Simultaneously, the photorespiratory pathway is heavily activated. Thus, there is an immediate drop in photosynthetic carbon reduction alongside an increase in photorespiration.

**Final Answer:** A decrease in the rate of photosynthetic carbon reduction (PCR) cycle and an increase in the activation of the photorespiratory pathway.

**Answer: (B)**

Go Back to Question 5

## Q6.

### Solution

**Concept:** The transition from metaphase to anaphase during mitosis is tightly controlled by the proteolytic degradation of key regulatory proteins. Sister chromatids are physically held together by a multi-subunit protein ring called cohesin. For anaphase to commence, cohesin must be broken down by the active protease enzyme separase.

**Solution:** Step 1: Trace the normal pathway of metaphase-anaphase transition. Under normal cell cycle conditions, the protease separase is held in an inactive state by its binding partner, securin. When all chromosomes are aligned at the equatorial metaphase plate and proper bipolar spindle attachments are achieved, the Anaphase-Promoting Complex/Cyclosome (APC/C) becomes fully activated.

Step 2: The activated APC/C functions as an E3 ubiquitin ligase that specifically targets securin for polyubiquitination, leading to its destruction by the 26S proteasome. Free separase then cleaves the Scc1 subunit of cohesin, letting sister chromatids split and move toward opposite poles.

Step 3: Analyze the consequences of the given mutation. The mutated securin cannot be recognized or ubiquitinated by APC/C. Consequently, even when APC/C is active, securin remains intact and continuously bound to separase, keeping it permanently inhibited.

Step 4: Determine the state of the chromosomes. Because separase can never be activated in this cell, the cohesin complexes holding the sister chromatids together cannot be cleaved. The sister chromatids remain linked along their entire lengths or at the centromeres.

Step 5: Identify the exact point of arrest. The cell can progress through prophase and prometaphase, aligning its chromosomes successfully on the equatorial plate during metaphase. However, because the chromatids cannot separate, the cell cycle halts completely at metaphase. It cannot transition into anaphase.

**Final Answer:** Metaphase; sister chromatids remain physically linked by cohesin complexes.

**Answer: (A)**

Go Back to Question 6

## Q7.

### Solution

**Concept:** The mammalian ovarian cycle depends on a precise sequence of hormonal feedback loops between the hypothalamus, anterior pituitary, and ovaries. The maintenance and structural integrity of the corpus luteum during the luteal phase requires continuous trophic support from gonadotropins.

**Solution:** Step 1: Understand the formation and maintenance of the corpus luteum. Following ovulation, driven by a massive surge of Luteinizing Hormone (LH), the remnants of the ruptured Graafian follicle transform into the corpus luteum. This temporary endocrine gland secretes large quantities of progesterone and moderate amounts of estrogen.

Step 2: Examine the hormonal environment of the luteal phase. High levels of progesterone and estrogen exert strong negative feedback on the hypothalamus and anterior pituitary gland, suppressing the secretion of GnRH, FSH, and LH. As a result, circulating levels of pituitary LH drop to low, basal concentrations.

Step 3: Analyze what happens if fertilization does not take place. In the absence of a blastocyst implantation, there is no production of human Chorionic Gonadotropin (hCG) by a developing syncytiotrophoblast. hCG is an analog of LH that can sustain the corpus luteum by binding to its LH receptors.

Step 4: Connect the absence of hCG to luteal degeneration. Because hCG is completely absent and the pituitary's own LH production remains suppressed by steroid feedback, the corpus luteum is deprived of luteotrophic support.

Step 5: Conclude the outcome. Deprived of sufficient stimulatory signals from either pituitary LH or embryonic hCG, the luteal cells undergo programmed cell death (luteolysis). The gland breaks down and shrinks into a scar tissue mass called the corpus albicans. This drop in steroids triggers menstruation.

**Final Answer:** A decline in human Chorionic Gonadotropin (hCG) feedback combined with the low basal levels of pituitary LH.

**Answer: (B)**

Go Back to Question 7

## Q8.

### Solution

**Concept:** Natural selection alters phenotypic distributions in populations through distinct modes depending on selective pressures: directional selection shifts the mean value; stabilizing selection reduces variation around the intermediate mean; and disruptive selection favors extreme phenotypes while selecting against the intermediate values.

**Solution:** Step 1: Define the original phenotypic distribution of the population. The finch population displays continuous variation in beak depth, which typically follows a classic Gaussian bell-shaped curve where the majority of individuals possess intermediate beak depths.

Step 2: Analyze the first selective pressure (drought). The severe drought eliminates small, soft seeds, leaving only large, woody seeds. This pressure directly selects against individuals with small beak depths, as they cannot crack the hard seeds to feed. This single pressure favors deeper, larger beaks.

Step 3: Analyze the second selective pressure (predation). The newly arrived invasive predatory lizard targets and eats only large-bodied finches with deep beaks. This pressure acts against the upper extreme of the phenotypic spectrum.

Step 4: Evaluate the combined impact of both simultaneous pressures. Small beaks are eliminated because of the lack of food, while large, deep beaks are eliminated due to high predation. The intermediate phenotype is favored by both constraints: these birds have beaks large enough to crack the remaining seeds but bodies small enough to avoid detection or capture by the lizards.

Step 5: Classify the selection mode. Because both extremes (small and large beak depths) face strong negative selection while the intermediate phenotypes survive and reproduce, the overall phenotypic variance shrinks. The mean remains near the center, while the distribution curve narrows. This is the definition of stabilizing selection.

**Final Answer:** Stabilizing selection reducing the variance and maintaining an intermediate beak depth.

**Answer: (C)**

Go Back to Question 8

## Q9.

### Solution

**Concept:** The oxygen-hemoglobin dissociation curve illustrates how hemoglobin binds and releases oxygen in response to local biochemical factors. A rightward shift in this curve decreases hemoglobin's affinity for oxygen, promoting oxygen unloading to highly active metabolic tissues, a phenomenon known as the Bohr effect.

**Solution:** Step 1: Examine the metabolic state of skeletal muscle during strenuous physical exercise. The muscle tissue undergoes intense cellular respiration to generate ATP. This high metabolic rate consumes vast amounts of oxygen and produces large quantities of carbon dioxide ($CO_2$) and metabolic byproducts like lactic acid.

Step 2: Determine the changes in the microenvironment of the muscle capillaries. The concentration of dissolved $CO_2$ rises sharply, leading to an elevated partial pressure of carbon dioxide ($P_{CO_2}$). The accumulation of lactic acid and carbonic acid increases the concentration of hydrogen ions ($H^+$), causing a localized drop in pH. Additionally, the heat generated by muscle friction and metabolic inefficiency raises the local temperature.

Step 3: Relate these chemical changes to hemoglobin structure. High $P_{CO_2}$, elevated $H^+$ concentration (low pH), and increased temperature allosterically interact with the hemoglobin tetramer. Protons bind specific amino acid residues, and $CO_2$ forms carbamino compounds, stabilizing the low-affinity T-state (tense state) of hemoglobin.

Step 4: Identify the graphical shift. The stabilization of the T-state reduces hemoglobin's affinity for oxygen at any given partial pressure of oxygen. On a graph, this translates to an unambiguous rightward shift of the sigmoidal oxygen-hemoglobin dissociation curve.

Step 5: Deduce the physiological benefit. This rightward shift facilitates the unloading of oxygen from oxyhemoglobin into the interstitial fluid, ensuring that the working muscle cells receive the oxygen needed to sustain aerobic respiration and minimize anaerobic fatigue.

**Final Answer:** Rightward shift; caused by increased local $P_{CO_2}$, elevated temperature, and decreased local pH.

**Answer: (B)**

Go Back to Question 9

## Q10.

### Solution

**Concept:** Double fertilization is a characteristic reproductive process in angiosperms. It involves two distinct fusion events occurring simultaneously within the embryo sac: one male gamete fuses with the egg cell to form the zygote, while the second male gamete fuses with the central cell's polar nuclei to form the primary endosperm nucleus (PEN).

**Solution:** Step 1: Break down the normal components of double fertilization in flowering plants. The pollen tube delivers two haploid ($n$) male gametes into the embryo sac of the ovule.
Event 1: First male gamete ($n$) + Egg cell ($n$) $\rightarrow$ Zygote ($2n$) $\rightarrow$ Embryo.
Event 2: Second male gamete ($n$) + Central cell with two polar nuclei ($2n$) $\rightarrow$ Primary Endosperm Nucleus ($3n$) $\rightarrow$ Endosperm.

Step 2: Analyze the experimental modification given in the prompt. The breeder blocks the functional expression or migration of the secondary male gamete. This means the second fusion event cannot occur. The central cell remains unfertilized ($2n$).

Step 3: Analyze the first fusion event under these conditions. The first male gamete successfully reaches and fertilizes the egg cell. This produces a perfectly normal, viable diploid ($2n$) zygote that can develop into a functional embryo.

Step 4: Deduce the structural consequence for the developing seed. Because the central cell is never fertilized by a secondary male gamete, the primary endosperm nucleus (PEN) is not created. In most angiosperms, the development of the endosperm depends entirely on this triple fusion. Without it, a functional, nutrient-rich triploid endosperm fails to form.

Step 5: Conclude the final fate of the seed. The resulting seed will contain a living, viable diploid embryo but will lack the surrounding nutritive endosperm tissue required to sustain the embryo during development or long-term seed dormancy and germination.

**Final Answer:** A seed containing a viable diploid embryo, but lacking a functional endosperm to support long-term germination.

**Answer: (B)**

Go Back to Question 10

## Q11.

### Solution

**Concept:** The cohesion-tension theory explains long-distance water transport in vascular plants. Transpiration from leaves creates a strong, negative hydrostatic pressure (tension) that pulls a continuous column of water upward through the xylem. This relies entirely on the high cohesive forces between water molecules and adhesive forces between water and cell walls.

**Solution:** Step 1: Understand the physical state of water inside an actively transpiring xylem vessel. The water is not under positive pressure; instead, it exists in a highly metastable state under intense tension (negative pressure), akin to a stretched rubber band. This tension requires a continuous, uninterrupted liquid column.

Step 2: Define cavitation. Cavitation is the phenomenon where the tension within the xylem becomes so high that dissolved gases come out of solution, or an external pocket of air is drawn into the vessel through microscopic wall pits. This results in the formation of an air bubble, known as an embolism.

Step 3: Analyze the immediate physical impact of introducing an air bubble into the vessel element. Because gases can expand and compress easily under pressure changes, the presence of the air bubble disrupts the continuous liquid-to-liquid contact between water molecules.

Step 4: Assess the disruption of cohesive forces. The cohesive forces cannot span across the gas-liquid interface of the bubble. As a result, the continuous tension pulling the water column upward is snapped.

Step 5: Determine the functional consequence for that specific vessel. Once the tension is broken, the column collapses away from the bubble, and the affected vessel can no longer transport water. The plant must reroute water laterally through adjacent un-embolized xylem vessels to bypass the blocked conduit.

**Final Answer:** The continuous tension within the water column is broken, preventing further upward water movement through that specific vessel.

**Answer: (B)**

Go Back to Question 11

## Q12.

### Solution

**Concept:** Phylogenetic reconstruction uses genetic sequence identity to infer evolutionary relationships. Organisms that share a higher percentage of sequence identity in conserved housekeeping genes have diverged from a common ancestor more recently, meaning they are closely related and form sister groups on a phylogenetic tree.

**Solution:** Step 1: Analyze the sequence identity data provided for the four bacterial strains:
Strain W and Strain X share 98% sequence identity.
Strain Y and Strain Z share 97% sequence identity.
Strain Y shares only 82% identity with both W and X.

Step 2: Interpret the relationship between W and X. The high sequence identity (98%) indicates that strains W and X have undergone very few nucleotide substitutions since splitting from their shared ancestor. This shows they are closely related and form a distinct pair, known as a sister clade or sister group: $(W, X)$.

Step 3: Interpret the relationship between Y and Z. Similarly, the high identity value (97%) between strain Y and strain Z indicates they shared a common ancestor recently. They form their own separate sister clade: $(Y, Z)$.

Step 4: Connect the two pairs using the deep divergence data. The fact that strain Y (and by extension its close relative Z) shares only 82% sequence identity with W and X indicates a ancient divergence event. This low identity means the ancestor of the $(W, X)$ group and the ancestor of the $(Y, Z)$ group split from each other long ago in evolutionary history.

Step 5: Synthesize the final tree topology. The tree branches initially into two main lineages. One lineage leads to the common ancestor of W and X, which then splits into terminal branches W and X. The other lineage leads to the common ancestor of Y and Z, splitting into terminal branches Y and Z. Thus, $(W, X)$ forms a sister clade that is the sister group to the $(Y, Z)$ clade.

**Final Answer:** (W, X) forms a sister clade, which is a sister group to the clade formed by (Y, Z).

**Answer: (A)**

Go Back to Question 12

## Q13.

### Solution

**Concept:** The adrenal cortex is divided into three histologically and functionally distinct layers: the outer zona glomerulosa, the middle zona fasciculata, and the inner zona reticularis. Each layer synthesizes and secretes a specific class of steroid hormones regulated by distinct physiological feedback mechanisms.

**Solution:** Step 1: Analyze the patient's clinical and laboratory presentation. The symptoms include chronic fatigue, muscle weakness, low systemic blood pressure (hypotension), severe hyponatremia (low blood $Na^+$), and hyperkalemia (elevated blood $K^+$).

Step 2: Connect the electrolyte imbalances to a specific endocrine mechanism. Sodium reabsorption and potassium excretion in the distal convoluted tubules and collecting ducts of the kidney are primarily controlled by the mineralocorticoid hormone, aldosterone.

Step 3: Determine the hormone deficiency. A severe deficiency in aldosterone leads to a failure in reabsorbing sodium ions, causing them to be lost in urine (hyponatremia). This loss of sodium and water reduces blood volume, resulting in low blood pressure. Simultaneously, potassium ions cannot be effectively secreted into the urine, causing them to build up in the blood (hyperkalemia). This perfectly matches the patient's lab results.

Step 4: Identify the source of the deficient hormone. Aldosterone is a mineralocorticoid produced exclusively by the cells of the outermost layer of the adrenal cortex. This layer is the zona glomerulosa.

Step 5: Confirm the pathology. Autoimmune destruction of the zona glomerulosa leads to primary mineralocorticoid deficiency (a component of Addison's disease), explaining the severe electrolyte disturbances and hypotension. The zona fasciculata produces cortisol, and its loss would cause hypoglycemia and stress intolerance but not these specific electrolyte shifts.

**Final Answer:** Zona glomerulosa; Aldosterone deficiency

**Answer: (B)**

Go Back to Question 13

## Q14.

### Solution

**Concept:** A keystone species is an organism that exerts strong regulation on an ecological community out of proportion to its abundance or biomass. Often, keystone predators maintain high species diversity within an ecosystem by preying upon dominant competitors, preventing them from monopolizing critical, limiting resources.

**Solution:** Step 1: Evaluate the initial conditions of Robert Paine's classic intertidal community experiment. The community contains a variety of invertebrate species, including barnacles, chitons, limpets, and a dominant competitor for space, the mussel. The predatory starfish *Pisaster ochraceus* feeds preferentially on these mussels. Species richness is stable at 15 species.

Step 2: Analyze the changes in the experimental plot where the starfish was removed. In the absence of the predator, the population of the dominant competitor (the mussel) is no longer kept in check. Mussels reproduce and expand rapidly across the available substrate.

Step 3: Apply the Competitive Exclusion Principle (Gause's Principle). Space is a strictly limiting resource in the rocky intertidal zone. Because the mussels are superior competitors for space, they physically crowd out, smother, and exclude all other sessile invertebrates like barnacles and limpets.

Step 4: Track the effect on species richness. Due to unchecked competitive exclusion, 14 of the 15 species are driven to local extinction within the plot. The community collapses into a virtual monoculture consisting solely of the dominant mussel. The control plot, where the starfish remains, retains its high species diversity.

Step 5: Deduce the ecological lesson. This experiment demonstrates the Competitive Exclusion Principle operating in the absence of a keystone predator. The predator is essential for maintaining biodiversity by mitigating the competitive advantages of a dominant species.

**Final Answer:** The Competitive Exclusion Principle operating in the absence of a keystone predator.

**Answer: (B)**

Go Back to Question 14

## Q15.

### Solution

**Concept:** For populations with discrete, non-overlapping generations (such as annual plants or insects), population growth is modeled geometrically. The geometric rate of increase, denoted by the parameter $\lambda$ (lambda), represents the ratio of the population size at a future time step to the population size at the current time step.

**Solution:** Step 1: Identify the lifecycle characteristics and starting metrics. The plant is an annual species with non-overlapping generations, meaning all parents die after reproducing, and the next generation arises solely from the germinating seeds.
Initial population size ($N_0$) = 500 individuals.

Step 2: Determine the geometric rate of increase ($\lambda$). The problem states that each individual plant produces an average of 4 viable seeds that successfully survive and mature into adult plants the next year. Since the parents die, the population grows by a factor of 4 each generation:

$$\lambda = 4$$

Step 3: State the equation for geometric population growth over multiple time steps ($t$):

$$N_t = N_0 \times \lambda^t$$

where $t$ represents the number of years or generations. Here, we need to calculate the population size after $t = 3$ years.

Step 4: Execute the step-by-step multiplication for each year to verify:
Year 1 ($N_1$): $500 \times 4 = 2000$ individuals.
Year 2 ($N_2$): $2000 \times 4 = 8000$ individuals.
Year 3 ($N_3$): $8000 \times 4 = 32000$ individuals.

Step 5: Alternatively, use the exponential equation directly:

$$N_3 = 500 \times 4^3$$

$$4^3 = 4 \times 4 \times 4 = 64$$

$$N_3 = 500 \times 64 = 32000 \text{ individuals}$$

The geometric rate of increase is exactly $\lambda = 4$, and the final population size after 3 years is 32,000 individuals.

**Final Answer:** $\lambda = 4$; 32,000 individuals

**Answer: (A)**

Go Back to Question 15

# Answer Key

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