

01/02/2026



Solutions for

Indian National Biology Olympiad INBO - 2026

Homi Bhabha Centre for Science Education (HBCSE-TIFR)

Gold Medalist



Aarav Gupta
66th International Mathematical Olympiad (IMO) 2025



Yug Gandhi
Singapore Math Olympiad 2025



Arjun Tyagi
International Olympiad in Artificial Intelligence (IOAI) 2025



Dhruv Advani
34th International Biology Olympiad (IBO) 2023



Rohit Panda
34th International Biology Olympiad (IBO) 2023



Chirag Falor
International Olympiad on Astronomy & Astrophysics 2019

NEET (UG) 2025

5 Aakashians in Top 10 AIR



AIR 9
HARSH KEDAWAT
1 YEAR CLASSROOM



AIR 3
KRISHANG JOSHI
MAHARASHTRA TOPPER
3 YEAR CLASSROOM



AIR 2
UTKARSH AWADHYA
MADHYA PRADESH TOPPER
3 YEAR CLASSROOM



AIR 5
AVIKA AGGARWAL
3 YEAR CLASSROOM
ALL INDIA FEMALE TOPPER



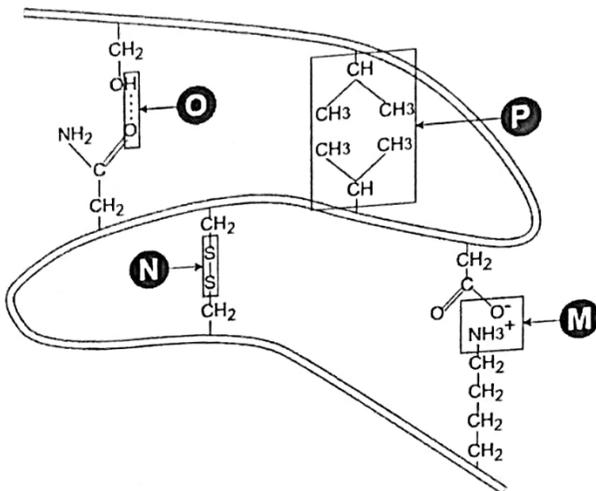
AIR 10
AARAV AGRAWAL
1 YEAR CLASSROOM

HOME OF PROBLEM SOLVERS

SECTION-A

CELL BIOLOGY (5 POINTS)

1. (1 point) A portion of the tertiary structure of a protein is represented below.



M, N, O and P respectively represent:

- (a) ionic bond; disulphide bridge; hydrogen bond and hydrophobic interactions
- (b) hydrophobic interactions; ionic bonds; disulphide bridge and hydrogen bond
- (c) hydrogen bond; disulphide bridge; ionic bond and hydrogen bond
- (d) ionic bond; disulphide bridge; hydrophobic interaction and hydrogen bond

Answer (a)

Sol. Option (a) is correct.

Diagram shows a part of the tertiary structure of a protein with different side-chains.

Different interactions are labelled as M, N, O and P.

- M.** One side chain has $-\text{NH}_3^+$ and other side chain has $-\text{COO}^-$. This is positive-negative charge attraction, so, this is an ionic bond.
 - N.** This is a covalent $-\text{S}-\text{S}$ bond between two cysteine residues. So, this is disulphide bridge.
 - O.** A dotted line interaction of hydrogen with another close electronegative atom e.g., oxygen, this is a hydrogen bond.
 - P.** Side chains contain $-\text{CH}_3$ (methyl) groups. Non-polar, no charges, no electronegative atoms, this is a hydrophobic interaction.
2. (1 point) The following agarose gel image shows the result of an experiment where a purified pUC57 plasmid (P) preparation was incubated with a DNA processing enzyme (E). Lane M is DNA ladder, Lane P is the plasmid-only control, and Lane P+E is Plasmid incubated with the enzyme.

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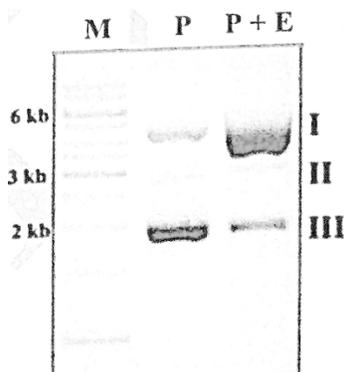
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The enzyme E most likely is:

- (a) blunt-end restriction endonuclease (b) type I topoisomerase
(c) sequence-specific exonuclease (d) nicking endonuclease

Answer (b or d)

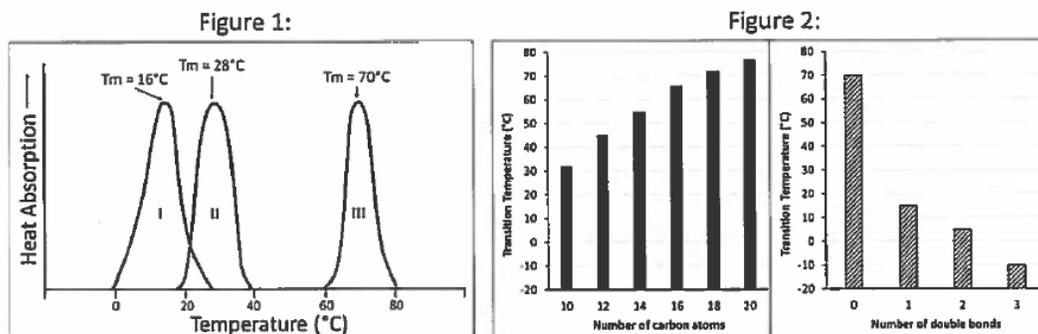
Sol. The correct option is (b or d).

Lane P (plasmid control): The two bodies visible are the supercoiled form (lower band) and the open circular or nicked form (upper band) of plasmid which is approx. 2.7 kb in size.

Lane P+E : Compared to lane P, the supercoiled band is less intense and the open circular band is more intense. Indicating enzyme E converted some of the supercoiled DNA into relaxed open circular form.

A nicking endonuclease introduces a single-strand break in the DNA, converting the supercoiled form to the relaxed open circular form, which runs slower on an agarose gel.

3. **(1 point)** The fluidity of a membrane depends primarily on the kinds of lipids it contains. When the temperature of a typical membrane preparation is increased slowly in a calorimetric chamber, a peak of heat absorption marks the gel-to-fluid transition temperature (T_m). Figure 1 depicts the T_m of three kinds of membranes while figure 2 depicts the effect of chain length and number of double bonds on the T_m of fatty acids.



Mark the correct statement,

- (a) Animals living in sub-zero habitats most likely have fewer double bonds with a chain length of 10 C atoms or more.
(b) Membranes with oleate enriched fatty acids are essential for homeotherms living in tropical climates.
(c) Curves I and II represent membranes of terrestrial animals while III represents aquatic animals.
(d) Membranes with higher stearate content are likely to be less fluidic than those with higher oleate content.

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Answer (d)

Sol. The fluidity of a membrane is inversely related to its transition temperature.

A lower T_m indicate, more fluid membrane at given temperature.

In figure 2, as the T_m increases, the number of carbon atom also increase. Longer fatty acid chain has less fluidity. Number of double bond increase resulting in decrease in temperature.

(a) Animals living in sub-zero habitats have more double bonds and lower T_m which will provide high fluidity and it will prevent freezing in low temperature.

(b) Membrane enriched with oleate is not essential for homeotherms living in tropical climate.

Oleate have one double bond with lower T_m and higher fluidity. Animal in tropical region require less fluid membrane at high temperature.

(c) Curve I can also represents the aquatic animals.

(d) Stearate is a saturated fatty acid characterised by zero double bonds between C atoms which will show high T_m .

Oleate have one double bond, which means the T_m will be less than stearate, and fluidity is more as compared to former.

4. **(1 point)** Suppose a biomolecule consisting of 100 atoms can exist in two structural states, O and P, at room temperature. The energies of the biomolecule are identical in both of these structural states. Suppose structural state O consists of 2000 conformations and structural state P consists of 5000 conformations (where a conformation refers to unique arrangement of atoms of the biomolecule in 3 dimensional spaces) at room temperature. Which of the following statement is correct regarding this biomolecule?

(a) State O will have lower free energy than State P.

(b) State O will have lower entropy than State P.

(c) State P will have lower entropy than State O.

(d) Both State P and State O will have the same entropy.

Answer (b)

Sol. One biomolecule contain 100 atoms

– Can exist in two structural states O and P at room temperature.

Number of conformations

State O – 2000

State P – 5000

As entropy depends on the number of possible conformations and the relationship between entropy and number of conformation (W) is

$$S = K_B \ln W$$

Here K_B is the Boltzmann constant.

Since $W_O = 2000$ (O has 2000 conformations) and $W_P = 5000$ (P has 5000 conformations)

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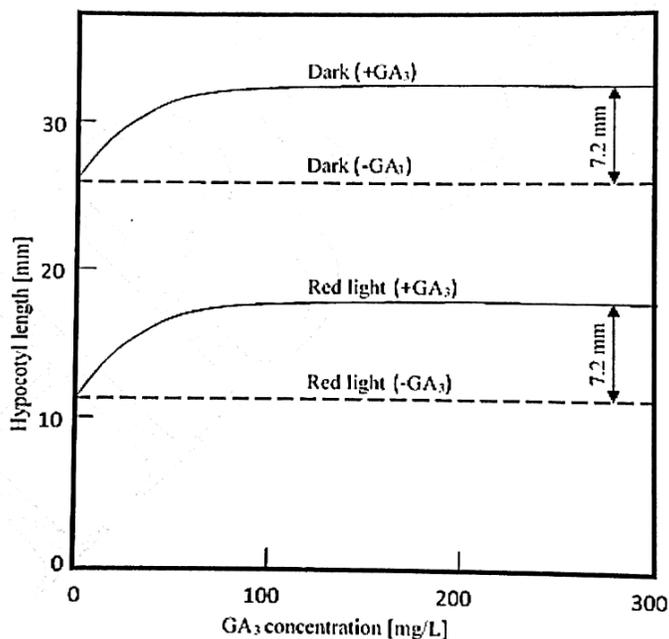
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Mark the correct statement.

- (a) GA₃ and light have a synergistic effect on hypocotyl length elongation.
- (b) GA₃ alone is an essential factor for elongation of hypocotyl to occur.
- (c) GA₃ cannot override the effects of light and lead to hypocotyl length stimulation.
- (d) Results are indicative of numerical additive inhibitory effect of P_{fr} and stimulating effect of GA₃.

Answer (d)

Sol. From the given graph,

- (a) GA₃ and light are not showing synergistic effect on hypocotyl length elongation. As red light alone is not inducing elongation. They are not together enhancing the effect on hypocotyl length elongation. GA₃ and light have antagonistic.
- (b) GA₃ along with light is essential for elongation of hypocotyl to occur.
- (c) GA₃ is able to exhibit the hypocotyl length elongation even in the absence of light, hence it is overriding the effect of light.
- (d) P_{fr} is physiologically active form of phytochrome protein, which regulate the plant growth *i.e.*, germination. Light can normally restrict hypocotyl growth and exogenous application of GA induce rapid elongation of hypocotyl even in light grown seeding.

Therefore, results obtained are numerical additive inhibitory effect of P_{fr} and stimulating effect of GA₃.

7. **(1 point)** In a heavily shaded forest, many auxiliary buds remain dormant. This helps to:
- (a) prevent loss of water by excessive transpiration over a wider area.
 - (b) prevent exchange of volatile signals from neighboring plants.
 - (c) redirect resources to enhance vertical growth.
 - (d) have better capillary pull of water to reach the ends of branches.

Answer (c)

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Sol. In a heavily shaded forest, many auxiliary buds remain dormant. Here, plant will prioritize vertical growth over branching by redirecting all the nutrients to the main stem.

In this type of condition, the phenomenon described is known as shade avoidance syndrome which allow plants to conserve energy and resources to quickly escape the shade, rather than wasting resources on branches that cannot effectively photosynthesize.

8. **(1 point)** Consider two types of plant cells X and Y.

The water potential data:

Cells X: Solute potential: 0 MPa

Net water potential: -0.2 MPa

Cells Y: Solute potential: -0.7 MPa

Net water potential: 0 MPa

When cells Y were subjected to a certain condition (M), the new net water potential becomes -0.7 MPa.

Which of the following are consistent with the above data?

- Cells X likely represents xylem cells while Y represents phloem cells.
- Condition M to which cells Y were subjected to is likely to be the addition of abscisic acid.
- Cells Y are likely to be expanding leaf cells and the condition M is immersing the cells in hypotonic solution.
- Cells X are likely to be turgid cells and cells Y are likely to be flaccid cells.

- i and iii
- iv only
- ii and iv
- iii only

Answer (b)

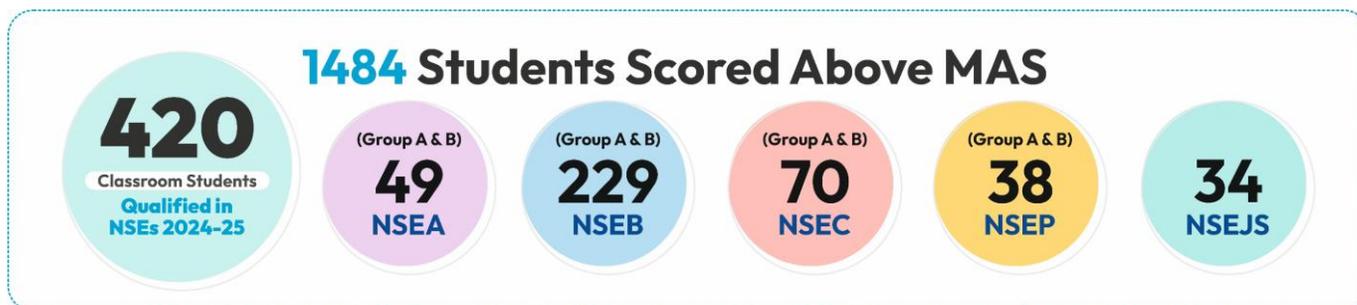
Sol. As solute potential of cell X is zero, it is implying that pressure potential is the only force that maintains water potential, which is likely to happen when pure water is entering inside cell making it fully turgid.

For cell Y, when it is subjected to condition M its pressure potential is zero. $\Psi_p = 0$ is true for flaccid cell which implies that cell Y is a flaccid cell.

9. **(1 point)** Sap exudation from an aphid stylet continues even if the stylet is severed from the aphid head. This phenomenon can be used to measure phloem transport rate. It has been observed that phloem sap exudation rate decreases if the plant is kept in dark. The correct order of underlying processes that lead to this effect is:

- reduced water entry into sieve tubes \rightarrow less sucrose loaded into phloem \rightarrow osmotic potential less negative \rightarrow slower sap exudation \rightarrow lower turgor pressure.
- less sucrose loaded into phloem \rightarrow osmotic potential more negative \rightarrow reduced water entry into sieve tubes \rightarrow slower sap exudation.
- osmotic potential less negative \rightarrow reduced water entry into sieve tubes \rightarrow lower turgor pressure \rightarrow slower sap exudation.
- less sucrose loaded into phloem \rightarrow water potential less negative \rightarrow increased turgor pressure \rightarrow slower sap exudation.

Answer (c)



Sol. Due to the high osmotic pressure in the phloem, sap flows out through the severed stylet at higher rate as compared to the normal sieve tube flow.

If the plant is kept in dark, photosynthesis rate decreases as a result concentration of sucrose reduced. When sugar are not loaded, the phloem's osmotic potential becomes less negative (Higher osmotic potential). The less negative osmotic potential, reduces water entry into sieve tubes. The decrease in osmotic pressure reduces the overall turgor pressure within the sieve tube, which is the driving force for phloem sap's exudation.

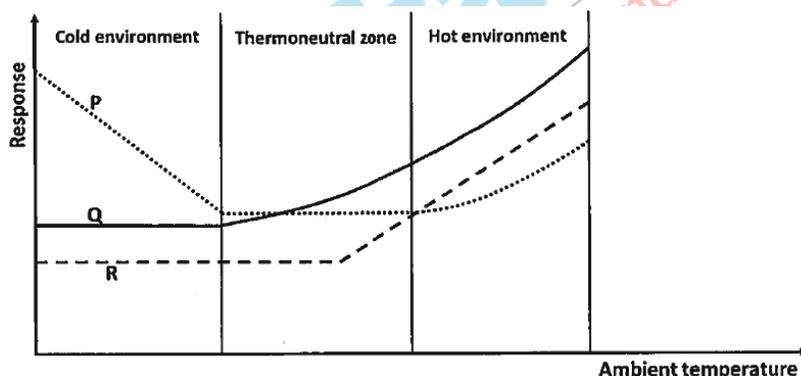
ANIMAL SCIENCES (3 points)

10. (1 point) Approximately four hours after death, the body stiffens (known as Rigor mortis). The reason behind this phenomenon is:
- Severe calcium deficiency in the skeletal muscles following death, leading to continuous contractile stimuli, as seen in the case of tetanus.
 - Progressive muscle fibrosis (a condition where extracellular matrix molecules, like collagen, deposits in muscles), which causes hardening of muscles.
 - Unavailability of ATP, which keeps the myosin head in 'lock' position with actin filaments.
 - Rapid degeneration of ligaments and tendons, which limits bone and muscle movement.

Answer (c)

Sol. The correct option is (c) as rigor mortis occurs because of the depletion of ATP after death that prevents myosin head from detaching from actin filaments, causing muscles to remain in a sustained contracted state causing rigidity. So, without ATP to break these actin-myosin complex, muscles cannot relax leading to stiffening of the body.

11. (1 point) Relationship between heat production and heat loss as a function of ambient temperature for a homeotherm is shown below:



P, Q, and R respectively indicate:

- Evaporative water loss, Peripheral blood flow, Oxygen consumption
- Oxygen consumption, Peripheral blood flow, Evaporative water loss
- Oxygen consumption, Evaporative water loss, Metabolic heat production
- Peripheral blood flow, Evaporative water loss, Oxygen consumption

Answer (b)

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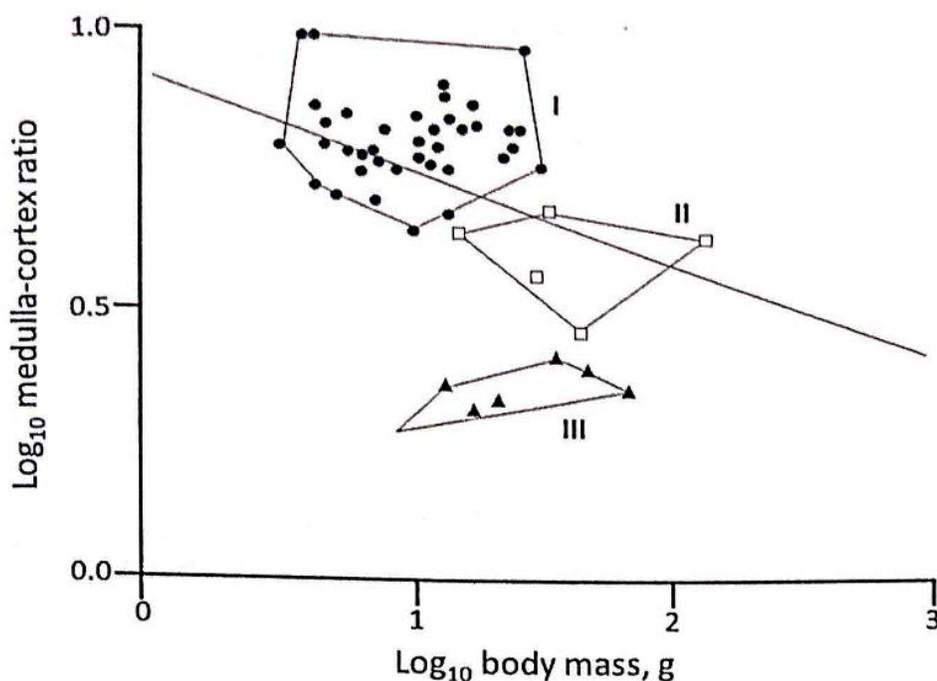
Sol. The correct option is (b) as

P (Oxygen consumption): In a cold environment, a homeotherm (warm-blooded animal) increases its metabolic rate to produce more heat and maintain a constant body temperature whereas O_2 consumption drops to its lowest constant level in thermoneutral zone as no active heat production or active cooling is needed.

Q (Peripheral blood flow): PBF is very low (vasoconstriction). In cold environment, which act as incubation to prevent heat loss. Blood flow increases gradually to regulate temperature in thermoneutral zone and blood flow becomes very high in hot environment to transport heat from core to surface for heat loss.

R (Evaporative water loss): It is low and constant in cold and thermoneutral zone. Once the temperature passes the point of evaporative regulation, it increases rapidly due to sweating and due to loss of water vapours through expired air.

12. (1 point) Food habits of mammals place differential demands on the renal system of these animals. This impact has been shown best in an examination of kidney morphology and function in bats having different diets. The renal indices of three such groups of bats are indicated in the scatter plots given below. The cortex region of the kidney is involved in the initial filtration while the medulla is responsible for the production of concentrated urine.



Group I, II and III most likely, respectively, represent:

- (a) Omnivores; Insectivores; Frugivores
 (b) Frugivores; Omnivores; Carnivores
 (c) Insectivores; Frugivores; Omnivores
 (d) Insectivores; Omnivores; Nectarivores

Answer (d)

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Sol. Correct answer is option (d)

Kidney structure is adapted to the process of filtration which occurs in the cortex region and concentration of filtrate occurs in medulla.

The important rule for animals is that who have higher medulla-cortex ratio will be better adapted to low water availability as they possess better ability to concentrate urine.

Here, Group I → Has highest medulla-cortex ratio.

Group II → Has intermediate medulla-cortex ratio.

Group III → Has least medulla-cortex ratio.

So, in terms of urine concentration ability

Group I > Group II > Group III

If we compare diet and water availability then we find that insectivores feed on dry insects and have less water availability, omnivores feed on moderate diet and have moderate water availability, frugivores and nectarivores feed on fruits and nectar so have high water availability.

GENETICS & EVOLUTION (2 points)

13. (1 point) An *E. coli* culture was grown under four nutrient conditions, and β -galactosidase activity was measured as an indicator of lac operon transcription:

| Condition | Glucose | Lactose | Observed β -galactosidase activity |
|-----------|---------|---------|--|
| A | + | – | Very low |
| B | + | + | Low |
| C | – | – | Very low |
| D | – | + | High |

Which of the following statements most accurately explains the molecular basis for the observed results?

- The presence of glucose prevents formation of CAP-cAMP complex limiting operon induction even when lactose is available.
- Absence of glucose permits efficient uptake of lactose, but allolactose cannot inactivate the repressor unless cAMP is degraded, hence transcription remains low.
- When both lactose and glucose are absent, the lac operon is repressed solely because CAP-cAMP complex binds strongly to the promoter, preventing RNA polymerase attachment.
- Glucose enhances adenylate cyclase activity, producing high cAMP that represses lac operon transcription until lactose concentration falls below threshold.

Answer (a)

Sol. In *lac* operon, *z* gene code for β -galactosidase, which is primarily responsible for the hydrolysis of disaccharide.

- CAP (catabolite activator protein) forms an active complex with intracellular cyclic adenosine monophosphate (cAMP), accumulates in the absence of glucose. RNA polymerase binds to the lac promoter efficiently only when the CAP-cAMP complex is also bound.

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- (b) If both lactose and glucose are present the regulatory mechanisms act to avoid expression of lac operon. Even though the repressor is inactivated by the presence of lactose, RNA polymerase cannot bind to the promoter since the CAP-cAMP complex is absent owing to the presence of glucose.
- (c) When glucose is absent and lactose is present cAMP level increases and allolactose binds to the repressor. If both sugars are absent, cAMP would be high, but the repressor would not be inactivated.
- (d) When glucose is absent, adenylate cyclase is active, leading to a high level of cAMP.

14. (1 point) Two individuals, P and Q, were analyzed cytogenetically:

| Parameter | Individual P | Individual Q |
|----------------------------------|------------------|---|
| Total chromosome count | 45 | 47 |
| Number of Barr bodies | 0 | 1 |
| Y-specific (SRY) probe | Absent | Present |
| Gonadal development | Rudimentary | Small testes |
| Secondary sexual characteristics | Poorly developed | Partial masculinization with gynecomastia |

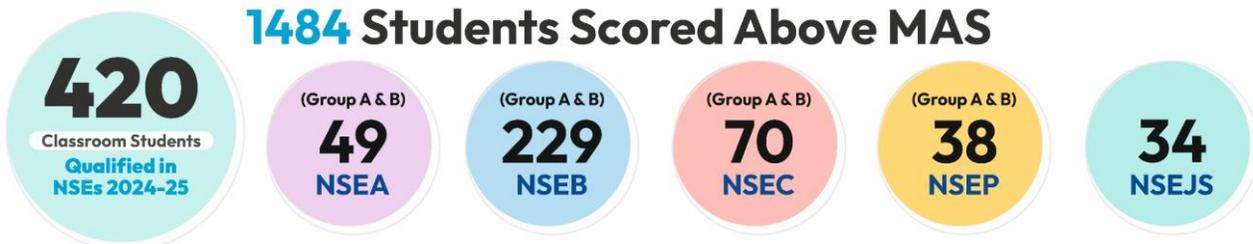
Which of the following interpretations best explains the chromosomal and molecular basis of these findings?

- (a) P: Loss of one X chromosome after fertilization (post-zygotic nondisjunction) → mosaic with defective ovarian development
 Q: Gain of one Y chromosome → abnormal testicular development due to Y-linked gene overexpression
- (b) P: 45, XY complement with mutation in SRY → defective testis differentiation
 Q: 47, XYY complement → enhanced spermatogenesis and masculinity
- (c) P: Loss of one sex chromosome during gametogenesis → monosomy leading to female phenotype due to absence of SRY
 Q: Gain of one sex chromosome during gametogenesis → presence of Y initiates male development but extra X causes partial feminization due to dosage imbalance
- (d) P: Duplication of X chromosome → overexpression of X-linked genes
 Q: Loss of one X chromosome → male phenotype by default

Answer (c)

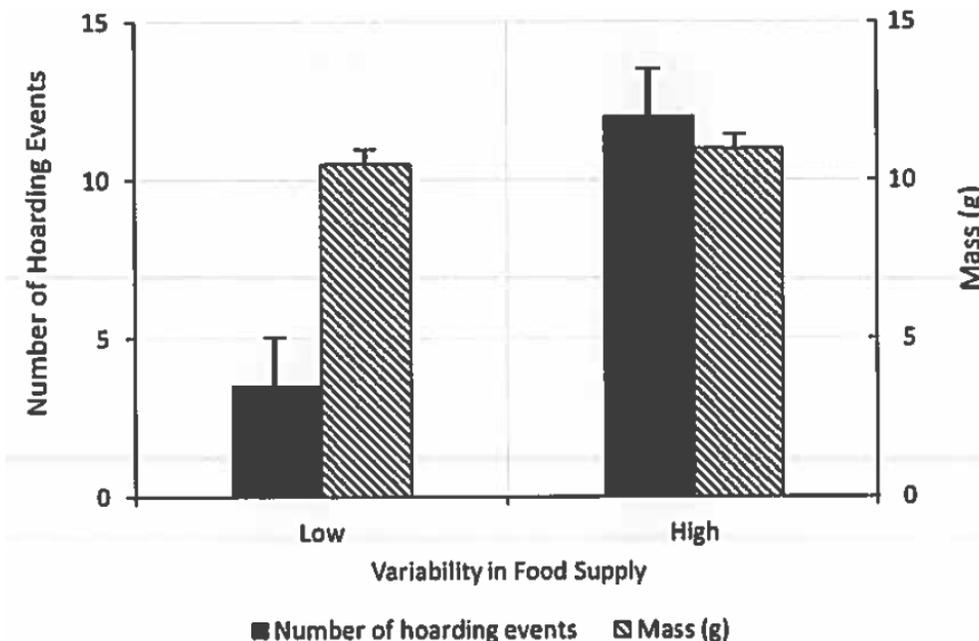
Sol. In individual P, the 45 total chromosomes indicate a 45, X karyotype (Turner's syndrome). Turner syndrome primarily occurs due to loss of X chromosome due to meiotic non-disjunction during gamete formation. In Turner's syndrome, females are sterile as ovaries are rudimentary and Y chromosome is absent (SRY probe is Y specific). Monosomy refers to the condition in which absence of one chromosome from a normal diploid pair, resulting in 45 chromosomes, instead of 46.

In individual Q, the 47 total chromosomes indicate Klinefelter's syndrome. This genetic disorder is caused by an additional copy of X chromosome resulting in a karyotype of 47, XXY. Such an individual has overall masculine development, however, the feminine development is also expressed. Such individuals are sterile. Klinefelter's syndrome is also caused by nondisjunction.



ECOLOGY (4 POINTS)

15. (1 point) In animals, food, once acquired can either be transported to another location for subsequent processing or storage, or consumed immediately. In an experiment done with active marsh tit birds, ecologist Hurley measured seed hoarding and body mass (indicative of adipose tissue content) changes in captive birds by using infrared detectors and computer-controlled balances. He used automatic feeders to feed the birds at uniform times versus highly unpredictable times. The results obtained are shown.



Based on the findings, mark the correct statement.

- (a) Hoarding is directly and fat storage is inversely proportional to variability in food supply.
- (b) Birds prefer to store the extra energetic buffer as fat when there is scarcity of food.
- (c) It is likely that the storage of food as fat is energetically more demanding than hoarding.
- (d) The birds may be adopting a strategy of reduction in energy requirements through prolonged fat-storing torpor during times of reduced food resource availability.

Answer (a)

Sol. Option (a) correct

As variability increases hoardings increases, fat storage decreases or becomes limited. So, it exactly coincides with the experimental pattern.

Hoarding allows energy buffering without physiological burden.

Option (b) is incorrect because scarcity does not favour fat storage. Predictable access favours fat accumulation.

Option (c) is incorrect because fat storage is metabolically costly, hoarding is behaviour wise costly but energetically cheaper.

Option (d) is incorrect because no evidence of torpor or fasting is seen and body mass is reliably stable.

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16. (1 point) Several animals migrate long distances at specific times of the year, with monarch butterflies and green sea turtles being classic examples. Which among the following is extensively used by migratory insects/birds/animals for navigation?
- Foliage density of forests along the route.
 - Ultraviolet polarized rays of the sun.
 - Earth's magnetic field.
 - Humidity and air density.
- Choose the correct option.
- i and ii only
 - ii, iii and iv
 - ii and iii only
 - iii and iv only

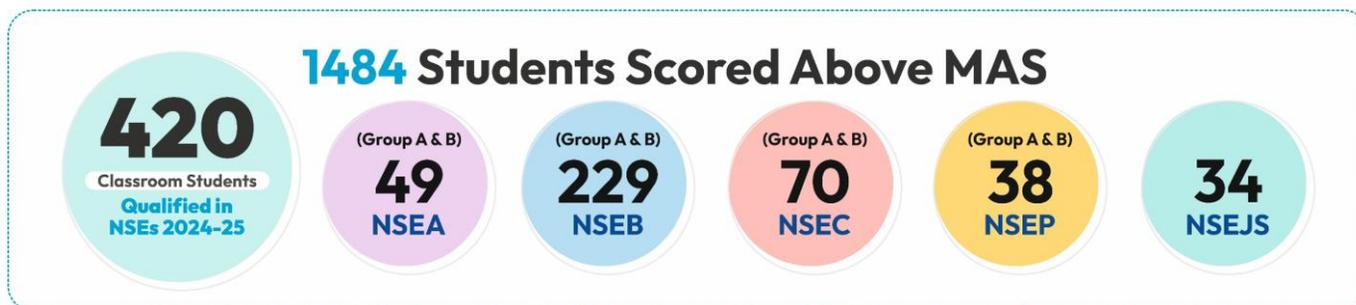
Answer (c)

Sol. Option (c) is correct as North American monarch butterflies have evolved sophisticated mechanisms to use polarized light from the sun to maintain a precise southward heading during their fall migration. Even when the sun is obscured, they detect the angle of polarized skylight, this is mediated by UV-light sensitive photoreceptors located in their compound eyes.

Many long distance migrants (e.g., sea turtles) use the Earth's magnetic field for navigation. Specifically, the polarity, intensity and inclination angle of the Earth's field can provide a reliable source of navigational information.

17. (1 point) The global hydrological cycle represents the dynamic movement of water among different reservoirs such as lakes, rivers, oceans, ice and the atmosphere. Turnover time is the time required for the entire volume of a particular reservoir to be renewed. Consider the statements below.
- The turnover time of water in the atmosphere is shorter than that of the largest lakes on earth like Lake Victoria.
 - The flux of evapotranspiration from terrestrial areas is greater than the flux of evaporated water moving from the ocean to land.
 - Water in the form of ice is a larger reservoir on earth than ground water.
 - The size of the atmospheric reservoir is larger than that of ground water.
- Which of the following combinations represents true statements?
- I, II and III only
 - I, III and IV only.
 - I and III only
 - II and IV only

Answer (c)



Sol. Statement-I is true, as the turnover time of water in the atmospheres is about 9 days. Whereas, a large lake takes decades for the complete renewal of its water.

Statement-II is false, because the rate at which the water vapours are transferred from oceans to the land is much greater than the flux of evapotranspiration from the terrestrial areas.

Statement-III is true, because water in the form of ice, such as glaciers, is a larger reservoir on earth than groundwater.

Statement-IV is false, because the groundwater reservoir is significantly higher than the atmospheric water.

18. (1 point) Which of the following represents the correct combination of the carbon to nitrogen (C:N) and carbon to phosphorus (C:P) ratio between plants and insects feeding on them?
- Higher C:N ratio and higher C:P ratio in plants as compared to insects.
 - Higher C:N ratio and lower C:P ratio in plants as compared to insects.
 - Lower C:N ratio and higher C:P ratio in plants as compared to insects.
 - Lower C:N ratio and lower C:P ratio in plants as compared to insects.

Answer (a)

Sol. Plants are primarily composed of carbon rich compounds, such as cellulose and have relatively low concentrations of minerals like nitrogen (N) and phosphorus (P). Whereas insects, being animals, are having tissues that are rich in proteins (nitrogen) and phospholipids, organic phosphates and nucleic acids (Phosphorus).

Hence, C : N and C:P ratio in plants is higher as compared to that in insects.

ETHOLOGY (2 points)

19. (1 point) An animal is generally known to adopt one of the two strategies - namely the Hawk or the Dove strategy, when in conflict. In speckled wood butterflies *Parage aegenia*, males compete for patches of sunlight on the ground layer of woods. Females are attracted to these spots and it is here that nearly all the courtship occurs. In a study by the ecologist Davies, only about 60% of the males held these temporary territories at any one time, the remainder patrolled for females up in the canopy top. Such patrolling males continually flew down from the canopy and rapidly took over vacant spots. If, however, the sunspot was already occupied, the intruder (P) and territory owner (Q) went into a short spiral flight (of few seconds), at the end of which, in every case, the intruder retreated, even if he was in prime condition and the territory owner had tatty wings.

In another experiment, a male (R) was released into a territory occupied by another male (S), without either butterfly initially noticing the other's presence.

The strategy adopted by each male P, Q, R and S respectively is likely to be:

- Dove, Hawk, Hawk, Hawk
- Hawk, Hawk, Hawk, Dove
- Dove, Hawk, Dove, Dove
- Hawk, Dove, Hawk, Dove



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Answer (c)

Sol. In the first scenario, an intruder (P) meets the territory owner [Q]. P immediately retreats after a short, non-injurious fight (a display) and Q retains the territory where, P acts as dove and Q acts as a Hawk.

- In second scenario

- R (Released Male): Male [R] was released into an occupied territory without initially noticing the owner [Q] and vice versa. When they inevitably meet, the actual owner [Q] will play the hawk role, [R], being the intruder, will ultimately retreat as a dove.

- S (Patrolling males): The description refers to the 60% of males held temporary territories and those that patrolled for vacant spots. The patrolling males [S] actively seek out and take over empty spots, suggesting a tendency towards opportunistic hawk behaviour when a resource is available to claim, but the problem refers to the general strategy they adopt when a conflict arises. Since they do not flight with [R], they adopt dove strategy in a contested situation.

20. **(1 point)** Which of the following strategies will NOT always minimize cost in migratory organisms?

- (a) Increasing body weight prior to migration (b) Formation of a V in migrating flocks
 (c) Butterflies flying on less windy days. (d) Taking the shortest route

Answer (d)

Sol. The correct answer is option (d)

Taking the shortest route may not always minimise the cost of migration because even the shortest route may have challenges like no food availability, topographic barriers, strong winds, etc., that would increase energy expenditure.

For migration, such strategies are adopted that will ultimately minimize the overall cost and maximise survival. Large relative fuel loads in the form of fat can increase flight range and reduce the number of stops needed for foraging, thus, reducing the cost in terms of energy, time and also reducing the chances of predation, thus, option (a) cannot be the answer.

Large avian migrants fly in V-formations that save energy by the use of up-wash or the “free lift” effect that saves energy; thus, option (b) cannot be the answer.

Butterflies select the most favourable tailwinds to migrate or fly so that the energy cost of migration is minimum. Thus, option (c) cannot be the correct answer.

BIOSYSTEMATICS (2 points)

21. **(1 point)** Desert environments brought evolutionary adaptations in two different categories of plant species such as Cacti and Euphorbias. Cacti spines are modified leaves whereas Euphorbias spines are modified shoots. This is an example of

- (a) Convergent evolution (b) Divergent evolution
 (c) Adaptive radiation (d) Disruptive selection

Answer (a)

Sol. Here, Cacti spines are → leaves modification

Euphorbias spines are → modified shoots

So, both of them perform same function but have different origin → convergent evolution.

Analogous structures are the structures in different organisms which are not similar anatomically though they perform similar functions. Morphologically they may or may not be similar which means that analogous structures

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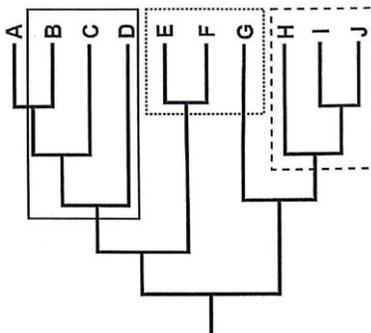
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may or may not look alike externally. The property of bearing analogous structures is called analogy. The analogous structures do not exhibit common origin. Unlike, homology which indicates common ancestry, the analogy do not indicate common ancestry.

The anatomically different structures evolved towards the same direction [e.g., same function] due to adaptations to similar needs or similar habitats, this is called the **convergent evolution**. Hence, analogous structures are the result of convergent evolution.

22. (1 point) A cladogram representing plant specimens A-J is shown below.



Boxes indicated by solid line, dotted line, and dashed line, respectively indicate:

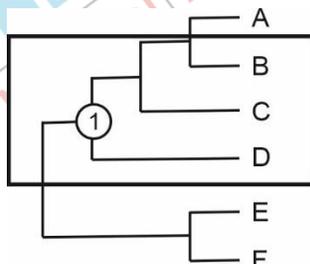
- (a) Monophyletic group; paraphyletic group; polyphyletic group
- (b) Paraphyletic group; polyphyletic group; monophyletic group
- (c) Polyphyletic group; paraphyletic group; monophyletic group
- (d) Monophyletic group; polyphyletic group; paraphyletic group

Answer (b)

Sol. The box indicated by **solid lines** represent → Paraphyletic group



- It consists of an ancestral species (labelled by 1) and some of its descendants (species B, C, D), but not all of them (does not include species A)



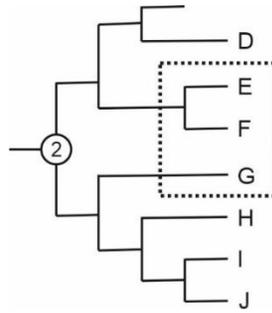
- The box indicated by **dotted lines** represents → Polyphyletic group



It consists of three species (E, F, G) but does not include the most recent common ancestor of the members (represented by 2)

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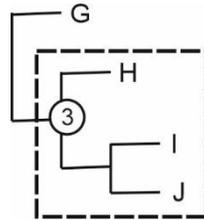




- The box indicated by **dashed lines** represents → Monophyletic group



It consists of three species (H, I, J) and their common ancestor (represented by 3) indicating that it contains the ancestral species and all of its descendants.



SECTION-B

CELL BIOLOGY (13.5 points)

23. (2 point) A few genes from human DNA were analysed and results obtained are given in the table below.

| | Gene | Gene size (kbp) | Number of introns | mRNA size (kbp) |
|----|---------------------------|-----------------|-------------------|-----------------|
| 1. | Collagen | 38.0 | 50 | 5.0 |
| 2. | Insulin | 1.7 | 2 | 0.4 |
| 3. | Dystrophin | 2000.0 | 50 | 17.0 |
| 4. | Albumin | 25.0 | 14 | 2.1 |
| 5. | Phenylalanine hydroxylase | 90.0 | 12 | 2.4 |

Based on the data given, mark each of the following statements as true or false by putting tick marks (✓) in the appropriate boxes.

- The average size of introns is directly proportional to the size of the gene.
- The dystrophin gene has the longest introns with an average size of about 40 kb.
- On translation, the albumin gene produces about 100 amino acids less than the phenylalanine hydroxylase gene.
- The average intron size of collagen is about 25 times smaller than that of insulin.

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Answer (a-F, b-T, c-T, d-F)

Sol. Calculation of average intron size : $\frac{\text{Gene size} - \text{mRNA size}}{\text{Number of Introns}}$

| | Gene | Average Intron Size |
|----|----------------------------|---------------------|
| 1. | Collagen | 0.66 kbp |
| 2. | Insulin | 0.65 kbp |
| 3. | Dystrophin | 39.6 kbp |
| 4. | Albumin | 1.6 kbp |
| 5 | Phenyl Alanine Hydroxylase | 7.3 kbp |

- (a) **False** : The gene size of Collagen (38 kbp) is larger than that of Albumin (25 kbp), but average intron size of albumin (1.6 kbp) is larger than that of collagen (0.66 kbp). Hence, the average size of gene cannot be considered directly proportional to size of gene.
- (b) **True** : The average size of introns in the Dystrophin gene can be calculated to be 39.6 kbp \approx 40 kbp.
- (c) **True** : The mRNA of Albumin (2.1 kbp) contains 300 nucleotides less than the mRNA of Phenyl alanine hydroxylase (2.4 kbp). Since 3 nucleotides code for one amino acid, the Albumin mRNA does produce about 100 amino acids less than Phenyl Alanine Hydroxylase mRNA.
- (d) **False** : The average intron size of collagen (0.66 kbp) is nearly equal to the average intron size of insulin (0.65 kbp)

Calculation of average intron sizes

$$\text{Size of intronic DNA} = \text{Gene size} - \text{mRNA size}$$

- For collagen: $38 - 5 = 33$ kbp
- For insulin: $1.7 - 0.4 = 1.3$ kbp
- For Dystrophin: $2000 - 17 = 1983$ kbp
- For Albumin: $25 - 2.1 = 22.9$ kbp
- For Phenyl: $90 - 2.4 = 87.6$ kbp

Alanine hydroxylase

$$\text{Average size of intron} = \frac{\text{Size of Intronic DNA}}{\text{Number of Introns}}$$

$$\text{Collagen} - \frac{33}{50} = 0.66 \text{ kbp}$$

$$\text{Insulin} - \frac{1.3}{2} = 0.65 \text{ kbp}$$

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$$\text{Dystrophin} - \frac{1983}{50} = 39 \text{ kbp}$$

$$\text{Albumin} - \frac{22.9}{14} = 1.6 \text{ kbp}$$

$$\text{Phenyl Alanine hydroxylase} - \frac{87.6}{12} = 7.3 \text{ kbp}$$

24. (2 point) A transcription factor has two subunits, X and Y. Subunit 'X' has the DNA binding domain, and the 'Y' has the transactivation domain. The X-Y heterodimers are sequestered in the cytosol when it binds to another subunit 'I'. The transcription factor is activated by an effector 'E', which causes the phosphorylation of I and Y. Phosphorylated I, further is ubiquitinated and degraded. Phosphorylated Y along with X is translocated to the nucleus for transactivation. Acetylation of 'Y' augments gene activation.

Based on the given information, mark whether each of the following statements is true or false by putting tick marks (✓) in the appropriate boxes.

- When the cells are treated with the effector (E) and inhibitor of phosphatase, the transcription factor will be translocated into the nucleus, and there will be activation of genes regulated by the transcription factor.
- When the cells are treated with the effector (E) and inhibitor of ubiquitinylation, the transcription factor will be translocated into the nucleus, but there will be no activation of genes regulated by the transcription factor.
- When the cells are treated with the effector (E) and inhibitor of deacetylase, the transcription factor will be translocated into the nucleus and there will be enhanced activation of genes regulated by the transcription factor..
- When the cells are treated with the effector (E) only, the transcription factor will not be translocated into the nucleus and there will be no activation of genes.

Answer (a-T, b-F, c-T, d-F)

- Sol.** (a) **True:** Inhibitor of phosphatase does not negatively impact the phosphorylation of Y and translocation of the transcription factor to the nucleus, hence the activation of genes regulated by the transcription factor will occur.
- (b) **False:** If ubiquitinylation of phosphorylated I subunit is inhibited, the heterodimer XY remains sequestered in the cytosol and so cannot be translocated into the nucleus.
- (c) **True:** The effector E is capable of inducing all steps necessary for translocation of phosphorylated y along with X subunit into the nucleus and activation of the gene. Since acetylation of Y subunit augments (enhances) gene activation, inhibition of deacetylation will increase acetylated Y subunits and promote gene activation.
- (d) **False:** The effector E is enough to trigger all the steps required for translocation of the transcription factor into the nucleus and activation of the gene.
25. (2 point) A molecular biologist was trying to make synthetic nucleic acid probes against the transcript of the given peptide. Although only one nucleotide sequence will actually code for the protein, the degeneracy of the genetic code could result in several different nucleotide sequences that will give the same amino acid sequence, and it is impossible to tell in advance which is the correct one. Because it is desirable to have as large a fraction of the correct nucleotide sequence as possible in the mixture of oligonucleotides to be used as a probe, those regions with the fewest possibilities are chosen, as shown by regions 1 and 2.

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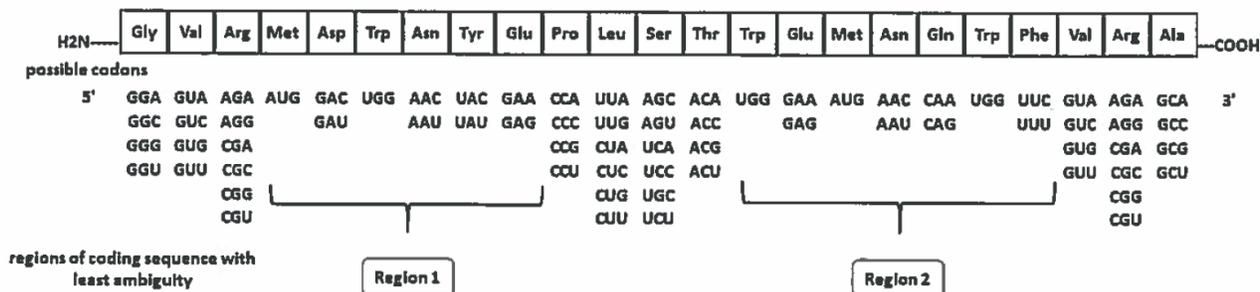
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known portion of amino acid sequence



If probes have to be designed separately for each region, how many total possible oligonucleotide probes would have to be synthesized?

Note that the final answer for this part of the question will be given marks only if calculations are shown in the box given and the final answer is filled in the blank.

Answer (32)

Sol. The genetic code is degenerate, thus the goal is to minimize degeneracy and maximize specificity.

[Region-1]: 1(Met) × 2(Asp) × 1(Trp) × 2(Asn) × 2(Tyr) × 2(Glu) → 16

[Region-2]: 1(Trp) × 2(Glu) × 1 (Met) × 2 (Asn) × 2 (Gln) × 1 (Trp) × 2(Phe) → 16

Hence, total possible oligonucleotide probes synthesised = Region 1 + Region 2 = 16 + 16 = 32

26. (2 point) Calculate the number of protein molecules in a typical eukaryotic hepatocyte in a situation where total proteins account for 20 percent of the weight of the cell. Assume the hepatocyte to be a cube with a side measuring 15 μm and having a cell density of 1.03 g/ml. Also, assume the average eukaryotic protein of molecular weight to be 52,700 g/mol and Avogadro's number to be 6.02 × 10²³.

Note that the final answer for this part of the question will be given marks only if calculations are shown in the box given and the final answer is filled in the blank.

Answer (N ≈ 7.942 × 10⁹ molecules)

Sol. The correct answer will be 7.94 × 10⁹ molecules.

The cell in the cube with a side length = 15 μm

First, convert the side length into centimeters

$$S = 15 \mu\text{m} = 15 \times 10^{-4} \text{ cm}$$

The volume V of the cube is

$$V = S^3$$

$$V = (15 \times 10^{-4} \text{ cm})^3 = 3.375 \times 10^{-9} \text{ cm}^3$$

Total cell mass of the cell:

The cell density P is 1.03 g/ml [1.03 g/cm³]

The total mass m cell is:

$$m_{\text{cell}} = P \times V$$

$$= 1.03 \text{ g/cm}^3 \times 3.375 \times 10^{-9} \text{ cm}^3$$

$$\approx 3.476 \times 10^{-9} \text{ g}$$

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The mass of total proteins:

Total proteins accounts for 20% of the cell's weight.

The mass of total proteins m_{proteins} is

$$\begin{aligned} \text{Mass of protein} &= 0.20 \times \text{mass of cell} \\ &= 0.20 \times 3.476 \times 10^{-9} \text{ g} \\ &\approx 6.952 \times 10^{-10} \text{ g} \end{aligned}$$

The average molecular weight of proteins is 52,700 g/mol

The number of moles n of proteins is

$$n = \frac{m_{\text{protein}}}{Mw} = \frac{6.952 \times 10^{-10} \text{ g}}{52,700 \text{ g/mol}} \approx 1.319 \times 10^{-14} \text{ mol}$$

Avogadro's number N_A is 6.02×10^{23} molecules/mol

The total number of protein molecules N is:

$$N = n \times N_A$$

$$N = 1.319 \times 10^{-14} \text{ mol} \times 6.02 \times 10^{23} \text{ molecules/mol}$$

$$N \approx 7.942 \times 10^9 \text{ molecules}$$

27. (2 point) In a restriction digestion experiment, a sample of a synthetic linear DNA molecule 21 kbp in length was treated with an enzyme 'P'. Another sample of the same DNA was treated with another restriction enzyme 'Q'. The fragments (in kbp) obtained after gel electrophoresis profiling are as follows:

Reaction 1: Treatment with enzyme P: 9, 7.2 and 4.8

Reaction 2: Treatment with enzyme Q: 10.4, 7.6 and 3

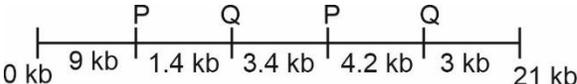
The fragment mixture obtained in reaction 1 was then treated with enzyme Q. Similarly, the fragment mixture obtained in reaction 2 was treated with enzyme P. The fragments (in kbp) obtained from these treatments are given below.

Reaction 3: Reaction mixture from reaction 1 treated with enzyme Q: 9, 4.2, 3.4, 3, 1.4

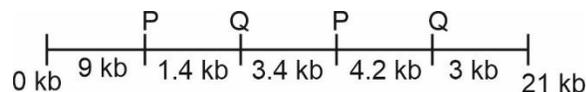
Reaction 4: Reaction mixture from reaction 2 treated with enzyme P: 9, 1.4, 4.2, 3.4, 3

Based on the fragments obtained, draw the restriction map indicating the positions of restriction sites of the enzymes P and Q. Also, indicate the fragment lengths between the sites

Note: Draw the restriction map in the given box. Only a completely correct answer will be given points.

Answer []

Sol. The correct restriction map is :



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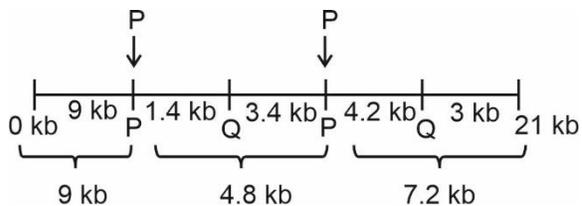
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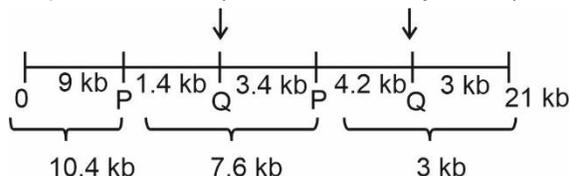
- As per reaction 1 (Treatment with enzyme P) :



- As per reaction 3 (Reaction mixture from reaction 1 treated with enzyme Q) :

9kb → Intact as no 'Q' site present
 7.2 kb → Fragmented into 4.2 kb and 3 kb
 4.8 kb → Fragmented into 3.4 kb and 1.4 kb

- As per reaction 2 (Treated with enzyme 'Q')

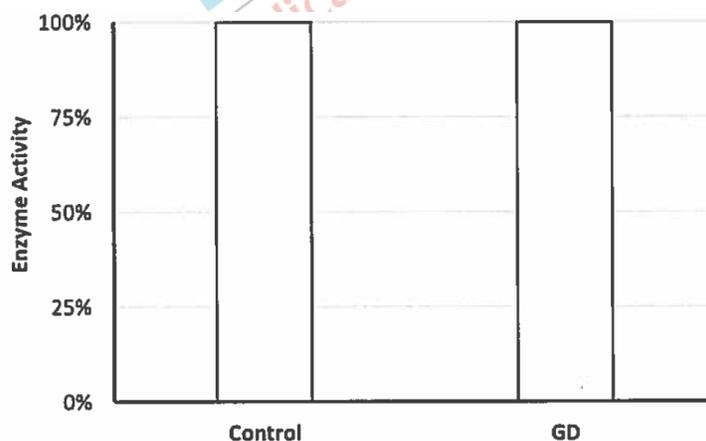


- As per reaction 4 (Reaction mixture from reaction 2 treated with enzyme P)

10.4 kb → Fragmented into 9 kb and 1.4 kb
 7.6 kb → Fragmented into 3.4 kb and 4.2 kb
 3 kb → Intact as no 'P' site present

28. (1.5 point) Gaucher disease (GD), the most common lysosomal storage disease in humans is caused by mutations in the gene encoding glucocerebrosidase (GCase). Symptoms include bone pain, enlarged liver, excessive fatigue, and cognitive disabilities. In order to understand the disease, researchers undertook a series of experiments to characterize the nature of defects in the enzyme.

A. Cells were obtained from a person without the disease (control) and patients with GD. G Case was isolated and enzyme activity of 10 μ g of protein was measured.



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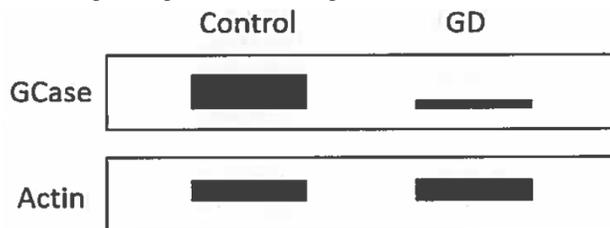
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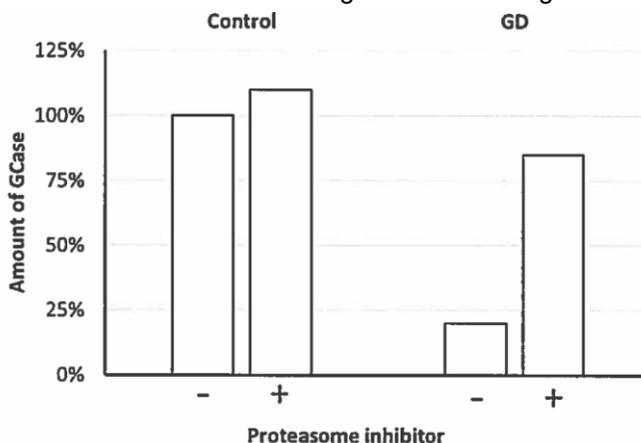
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B. In the next experiment, proteins were extracted from equal number of cells from control and GD individuals, and subjected to Western blotting using antibodies against GCCase and actin proteins.



C. Next, cells from control and GD individuals were grown in the presence and absence of a potent proteasome inhibitor. The amount of GCCase was determined using Western blotting



Based on the above experimental results, indicate whether the following statements are true, false or inconclusive by putting tick marks (✓) in the appropriate boxes.

- The mutation in GCCase was not in the active site of the enzyme.
- The mutation affected the transcription and hence the translation of GCCase gene.
- The mutation occurred at a site that enhanced proteasomal degradation of the GCCase protein.

Answer (a-T, b-F, c-T)

Sol. A. True-The first bar graph and research indicates that GCCase mutations often cause the protein to misfold and be prematurely degraded, rather than being an intrinsically inactive, stable protein.

Since the GCCase enzyme activity is same in both control and GD samples when the same amount of protein is used. This indicates the mutation in GCCase was not present in the active site of the enzyme.

B. False-The western blot in experiment B shows that the GCCase protein, is still produced. If transcription or translation were completely inhibited, the protein bands would be absent. The bands are present, but their intensity is different between normal and GD cells, and they are affected by subsequent treatment in experiment C, indicating that the primary issue lies in post- translational handling and degradation, not initial synthesis.

C. True- Addition of proteasome inhibitor increases the amount of GCCase protein in GD cells. This indicates that the mutant protein is specifically targeted for increased proteasomal degradation compared to the normal protein. The mutation causes misfolding which is recognised by the cellular quality control system and shunted to the proteasome for disposal.

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29. (2 point) Catalysis of the cleavage of peptide bonds in a small peptide by a proteolytic enzyme is described in the following table (the arrow indicates site of cleavage):

| Sr. no | Substrate | K _m (mM) | K _{cat} (s ⁻¹) |
|--------|-----------------------|---------------------|-------------------------------------|
| 1. | Glu-Met-Thr-Ala ↓ Gly | 4.0 | 24 |
| 2. | Glu-Met-Thr-Ala ↓ Ala | 1.5 | 30 |
| 3. | Glu-Met-Thr-Ala ↓ Phe | 0.5 | 18 |
| 4. | Glu-Met-Thr-Ile ↓ Phe | 9.0 | 18 |
| 5. | Glu-Met-Thr-Gly ↓ Tyr | 1.0 | 20 |

Mark whether each of the following statements is true or false or cannot be deduced by putting tick marks (✓) in the appropriate boxes.

- Substrate 3 is cleaved most efficiently.
- Alanine is the most preferred amino acid on either side of the cleavage site.
- The enzyme most efficiently cleaves the peptide bond between a small hydrophobic amino acid residue and a large, aromatic hydrophobic amino acid residue.
- A new substrate with a K_m value of 0.3 would be more efficiently cleaved compared to the given substrates.

Answer

| | True | False | Cannot be deduced |
|-----|------|-------|-------------------|
| (a) | ✓ | - | - |
| (b) | - | ✓ | - |
| (c) | ✓ | - | - |
| (d) | - | - | ✓ |

Sol. (a) **True:** The efficiency of an enzyme is defined by its specificity constant, which is expressed as the ratio of

$$\frac{K_{cat}}{k_m}$$

K_{cat} → Represents turnover number ; K_m → Represents Michaelis constant

A higher ratio indicates more efficient cleavages.

- Substrate 1 = $\frac{24 \text{ s}^{-1}}{4 \text{ mM}} = 6 \text{ s}^{-1} \text{ mM}^{-1}$
- Substrate 2 = $\frac{30 \text{ s}^{-1}}{1.5 \text{ mM}} = 20 \text{ s}^{-1} \text{ mM}^{-1}$
- Substrate 3 = $\frac{18 \text{ s}^{-1}}{0.5 \text{ mM}} = 36 \text{ s}^{-1} \text{ mM}^{-1}$
- Substrate 4 = $\frac{18 \text{ s}^{-1}}{9 \text{ mM}} = 2 \text{ s}^{-1} \text{ mM}^{-1}$
- Substrate 5 = $\frac{20 \text{ s}^{-1}}{1 \text{ mM}} = 20 \text{ s}^{-1} \text{ mM}^{-1}$

So we can see that substrate 3 has the highest ratio, thus, it was indeed cleaved most efficiently.

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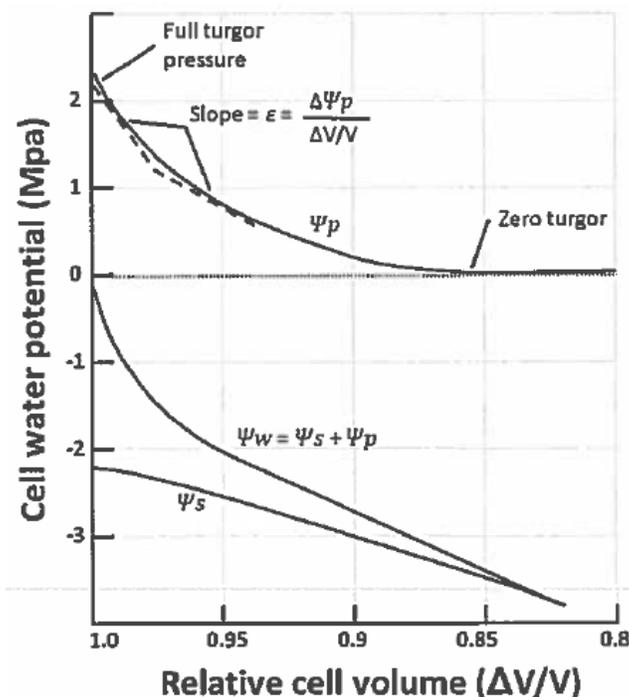
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Mark the following statements as true or false by putting tick marks (✓) in the appropriate boxes.

- Turgor pressure changes with an initial 5% change in cell volume is comparable with the changes observed in the osmotic potential.
- With a fall in cell volume from 90 to 80%, most of the change in the water potential is due to a drop in turgor pressure and not as much due to osmotic pressure.
- The elastic modulus (E) of the cell is not constant but decreases as the cell loses turgor.
- For leaf mesophyll cells of palm trees having relatively rigid cell walls, the volume change associated with turgor loss will be smaller than cells with extremely elastic walls.

Answer (a-✗, b-✗, c-✓, d-✓)

Sol. Relative Cell Volume (RCV): Cells volume relative to a reference state (v/v_0). change in RCV signifies osmotic water movement inside or outside the cell.

- Endosmosis → ↑ed RCV → Swelling of cell
- Exosmosis → ↓ed RCV → Cell shrinks

Elastic Modulus of the cell: $\left(\varepsilon = \frac{\Delta \psi_p}{\Delta V / V} \right)$

- Is a measure of change in turgor with relative to change in volume of the cell.
- Cells having rigid cell walls** have high elastic modulus and small volume change leads to large loss of turgor.
- Cells having elastic cell walls** have lower elastic modulus and small volume change does not lead to large loss of turgor.

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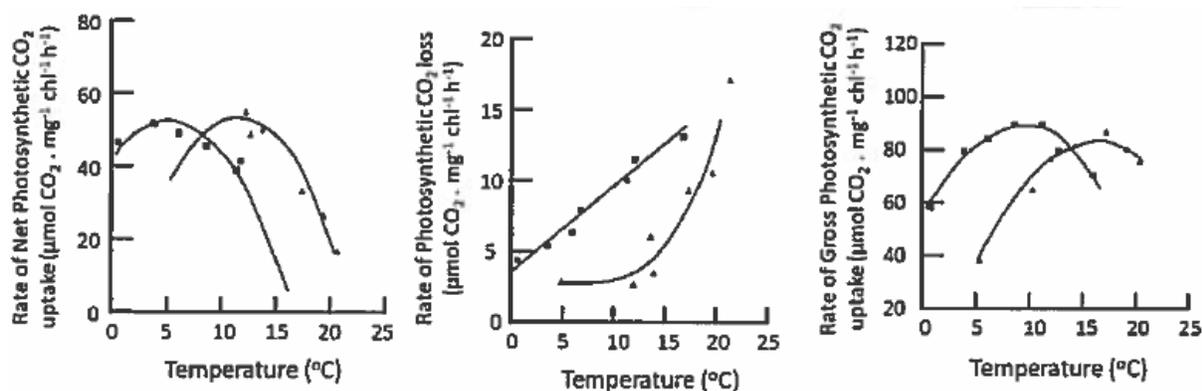
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- (a) False – With the initial 5% change in cell volume (1 to 0.95) turgor pressure falls from more than 2 to less than 1. A comparable change is not observed in osmotic potential.
- (b) False – With a fall in cell volume from 90% to 80% (0.9 to 0.8) the turgor pressure is already near zero, further change in water potential should be attributed more to osmotic pressure.
- (c) True – The elastic modulus (represented by steepness of the slope $\epsilon = \frac{\Delta \psi_p}{\Delta V/V}$) is very steep when turgor pressure is high and gradually becomes less steeper with loss of turgor pressure.
- (d) True – Palm trees mesophyll cells (Rigid cell walls), a lower volume change is required to lose turgor as compared to elastic walls.

32. (2 points) A group of researchers was studying effect of thermal acclimation on photosynthesis. They were working on a perennial herb, *Saxifraga cernua* which is widely distributed in Canadian Arctic region. A set of *S. cernua* plants was initially grown at 10°C for 5 to 7 weeks under controlled conditions. The rate of net photosynthesis, dark respiration and gross photosynthesis was measured with varying temperature. The same set was subjected to acclimation at 20°C for 10 days and the same parameters were measured. The results are shown in the graphs below.



KEY: ■ *S. cernua* at 10°C ▲ Same plant at 20°C

Mark whether each of the following statements is true or false by putting tick marks (✓) in the appropriate boxes.

- Acclimation to higher temperature resulted in higher rate of net photosynthesis.
- There is a linear increase in rate of dark respiration only above 10°C in *S. cernua* grown at lower temperature.
- Optimum temperature of gross photosynthesis increased to 12°C post acclimation.
- The difference between temperature optima of net and gross photosynthesis is due to dark respiration.

Answer (a-✗, b-✗, c-✗, d-✓)

Sol.

| Initial information: | Temperature | Duration |
|-------------------------|--------------------------------|--------------|
| Plant set (condition 1) | 10°C (control) | 5 to 7 weeks |
| Same set (condition 2) | 20°C (Acclimation temperature) | 10 days |

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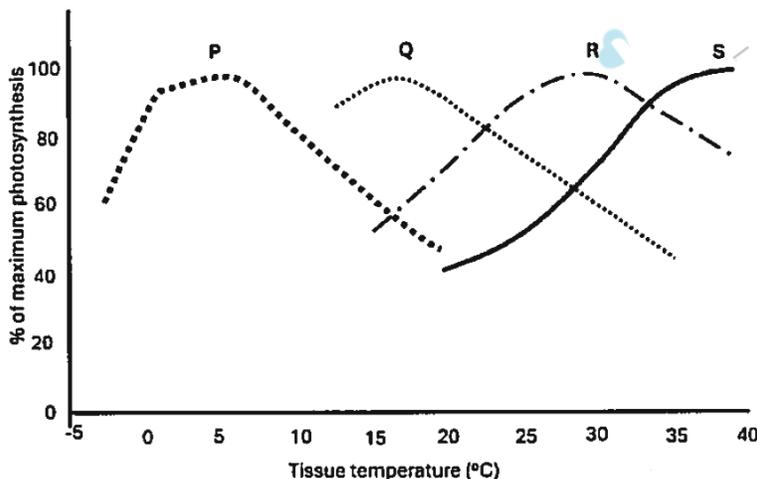
Impact of acclimation:

| | Temperature optima for gross photosynthesis | Net photosynthesis temperature optima |
|--------------------------------|---|---------------------------------------|
| Condition 1 (Pre acclimation) | 10 °C | 5°C |
| Condition 2 (post acclimation) | 15 °C | 12°C |

- (a) False : Acclimation to higher temperature shifts the temperature optima of net photosynthesis towards higher temperature, but the maximum rate of net photosynthesis remains unaltered after acclimation.
- (b) False : *S. cerrua* growing at lower temperature shows linear increase in rate of dark respiration even at temperatures lower than 10°C
- (c) False: Optimum temperature of gross photosynthesis increased to more than 15°C, post acclimation.
- (d) True: Since net photosynthesis is a measure of biomass gained by the plant, it is calculated as:
Net photosynthesis = Gross photosynthesis – Rate of dark respiration

We can conclude that temperature optima for net photosynthesis is lower than that of gross photosynthesis because the rate of dark respiration is lower at lower temperature and hence, the plant gains more biomass, by photosynthesising at lower temperatures.

33. (2 points) The photosynthetic temperature response curves for four terrestrial plant species (P,Q,R and S) are shown below. The difference in optimum temperature requirement for maximum photosynthesis indicates variations in their respective habitats. Match each plant name with the correct type of representative curve.



Choose from the following and indicate the answers by filling the corresponding option number in the blanks.

- i. *Atriplex hymenelytra*: C4 desert shrub growing on steep slopes or gravel deposited at the base of hill slope.
- ii. *Tidestromia oblongifolia*: C4 desert perennial growing in open spaces having scanty vegetation cover.
- iii. *Neuropogon acromelanus*: A lichen growing in arctic region.
- iv. *Abrosia chamissonis*: A herb found in cooler coastal environment.

Answer [(i) → R, (ii) → S, (iii) → P, (iv) → Q]

Sol. (i) *Artriplex hymenelytra*, an evergreen desert shrub (C4 photosynthesis) exhibit 'R' type of curve. Grow best in the range = 15°C to 35°C

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- (ii) Considered one of the most heat-tolerant plants known, thriving in death valley where surface temperature regularly exceed 50°C .

Tidestromia oblongifolia, a summer-active desert perennial plant, native to death valley, grows rapidly and even improves, its photosynthesis at temperatures exceeding 45°C . Its ability to maintain high photosynthesis efficiency at nearly 50°C suggests that its C_4 mechanism is more refined and adaptable than that of most known species \rightarrow exhibit 'S' type of curve

- (iii) *Neuropogon acromelanus*, Antarctic lichen \rightarrow exhibit 'P' type curve

- (iv) *Ambrosia chamissonis*, a cool coastal dune herb plant \rightarrow exhibit 'Q' type curve

34. (2 points) In a study on the effect of light on the bending of shoots, the following four treatments were given to growing shoots:

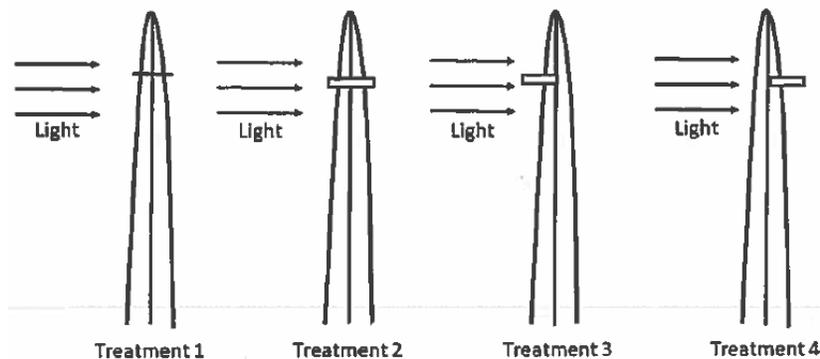
Treatment 1: Decapitated tip is replaced back.

Treatment 2: Decapitated tip is replaced on a gelatin block.

Treatment 3: Plastic strip inserted on illuminated side.

Treatment 4: Plastic strip inserted on the dark side.

Figures indicating the treatments are shown below.



Answer

| | Treatment 1 | Treatment 2 | Treatment 3 | Treatment 4 |
|--------------------------------------|-------------|-------------|-------------|-------------|
| • Bending of shoot tip towards light | ✓ | ✓ | ✓ | × |
| • Bending of tip away from light | × | × | × | × |
| • No bending | × | × | × | ✓ |

Sol. Treatment 1 : When decapitated tip is replaced back then shoot will resume its normal phototropic response.

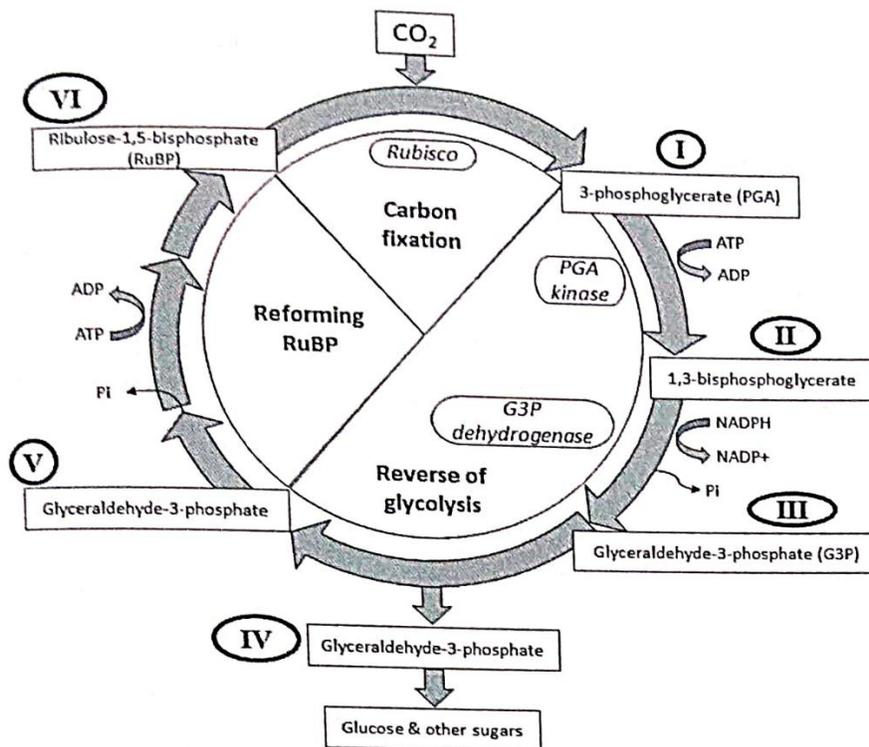
Treatment 2 : The auxin pass through gelatin and promote bending as cut off tips when placed on gelatin block, auxin will diffuse into the block.

Treatment 3 : When plastic is inserted on illuminated side of shoot, then there will be curvature obtained when light falls on one side of shoot, the auxin moves from illuminated side to shaded side. The high concentration of auxin on shaded side stimulate cells in elongation zone to grow longer.

Treatment 4 : When plastic is inserted on dark side of shoot, then there will be no curvature or bending of shoot towards light.



35. (3 points) The reactions of the Calvin cycle are represented below. The intermediates in the cycle are labeled as I – VI. Fill in the blanks against each intermediate with the number of molecules of each intermediate when 6 molecules of CO₂ are fixed.



Answer (I-12, II-12, III-12, IV-2, V-10, VI-6)

Sol.

| | | |
|-----|---|--|
| I | → | 12 molecules |
| II | → | 12 molecules |
| III | → | 12 molecules |
| IV | → | 2 molecules (Glyceraldehyde -3 phosphate for sugars) |
| V | → | 10 molecules (Glyceraldehyde-3 phosphate for regeneration) |
| VI | → | 6 molecules |

- 6 RuBP is utilized form 12 molecules of 3-phosphate glycerate.
- 12 molecules of 3-PGA is utilized to form 12 molecules of 1,3-bisphosphoglycerate.
- 12 molecules of 1, 3-Bisphosphoglycreate is utilized to form 12 glyceraldehyde-3 phosphate.
- 10 molecules (G3P) out of 12 will be utilized to regenerate the RuBP.

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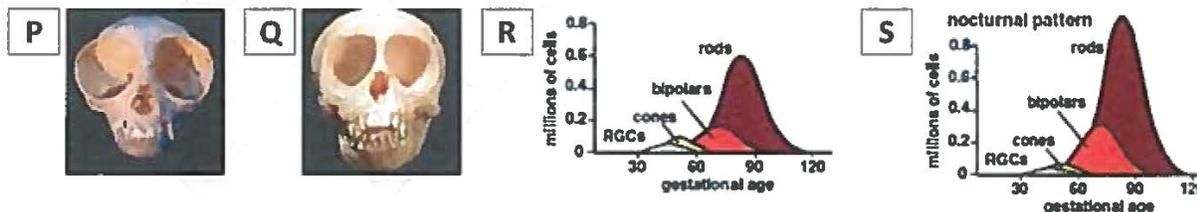
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ANIMAL SCIENCES (14 point)

36. (2 points) P and Q are the pictures of two mammalian skulls while R and S represent the composition of different types of retinal cells. RGCs in the plots indicate retinal ganglion cells.



Mark whether each of the following statements is correct or incorrect by putting tick marks (✓) in the appropriate boxes.

- P and R most likely represent a diurnal mammal.
- Retina of a mammal with composition as shown in S is less likely to have fovea in the retina.
- P and S most likely represent a mammal that is better adapted to nocturnal vision.
- Contrast sensitivity in both mammals is high giving them the ability to perceive finer details of objects.

Answer (a-x, b-✓, c-✓, d-x)

Sol. Skull 'P' has larger orbit to its skull size compared to skull 'Q'. Large orbit is an adaptation for nocturnal mammals to maximize light capture.

- Graph 'S' indicates nocturnal pattern as it shows massive peak in rods and very low cones.
 - Graph 'R' indicates diurnal pattern as it shows higher cones.
 - Statement a** is False because orbit of 'P' indicates that it is nocturnal while 'R' indicates diurnal animal as it has comparatively higher proportion of cones.
 - Statement b** is True, since 'S' has few cones but more rods which indicates about nocturnal pattern. Fovea is an area packed with cones for high acuity vision which is absent in nocturnals. Hence, it is unlikely to have well developed fovea.
 - Statement c** is True, because 'P' has large orbit and graph 'S' shows high rods to cone ratio. These are characteristic of nocturnals.
 - Statement d** is False, because nocturnal animals (P, S) prioritize sensitivity over acuity. Diurnals have high detail perception due to higher number of cones.
37. (2 points) The membrane potential (V_m) of a typical cell due to the diffusion of Na^+ or K^+ ions can be calculated using the simplified Nernst equation as follows:

$$V_m = 61.5 \log_{10} \frac{[\text{ion}]_{\text{outside}}}{[\text{ion}]_{\text{inside}}}$$

A combination of concentrations of these ions (represented as M and N) outside and inside of a cell are given below:

$$M_{(\text{outside})}: 5 \text{ mEq/L}$$

$$M_{(\text{inside})}: 140 \text{ mEq/L}$$

$$N_{(\text{outside})}: 142 \text{ mEq/L}$$

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$N_{(\text{inside})}$: 14 mEq/L

For a given cell, calculate the membrane potential due to potassium ions alone.

Note that the final answer for this part of the question will be given marks only if calculations are shown in the box given and the final answer is filled in the blank.

Answer (Membrane potential due to K^+ ion = - 88.99 or - 89 mV.)

Sol. In a typical animal cell usually K^+ is more inside the cell than outside and Na^+ is more outside than inside of the cell.

Ion M = 5m Eq/L outside, 140 mEq/L inside

Hence, it should be K^+

Ion N = 142 mEq/L outside, 14 mEq/L inside

Hence it is Na^+ .

Nernst equation is

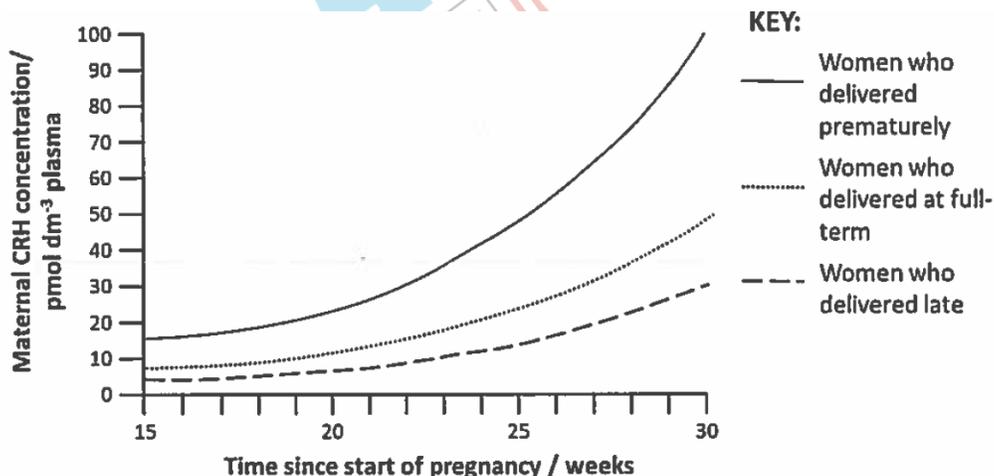
$$V_m = 61.5 \log_{10} \left(\frac{\text{Ion}_{\text{outside}}}{\text{Ion}_{\text{inside}}} \right)$$

To calculate about K^+ we must put the values of K^+

$$\begin{aligned} V_m &= 61.5 \log_{10} \left(\frac{\text{Ion}_{\text{outside}}}{\text{Ion}_{\text{inside}}} \right) \\ &= 61.5 \log_{10} (0.0357), \log_{10}(0.0357) \\ &= 61.5 \times (-1.447) = -1.447 \\ &= -88.99 \approx -89 \text{ mV.} \end{aligned}$$

\therefore Membrane potential due to K^+ ion = - 88.99 or - 89 mV.

38. (2 points) The results of a study on the placental secretion of a hormone Corticotropin Releasing Hormone (CRH) and its correlation with delivery of babies in a group of women during their pregnancy is represented in the graph below.



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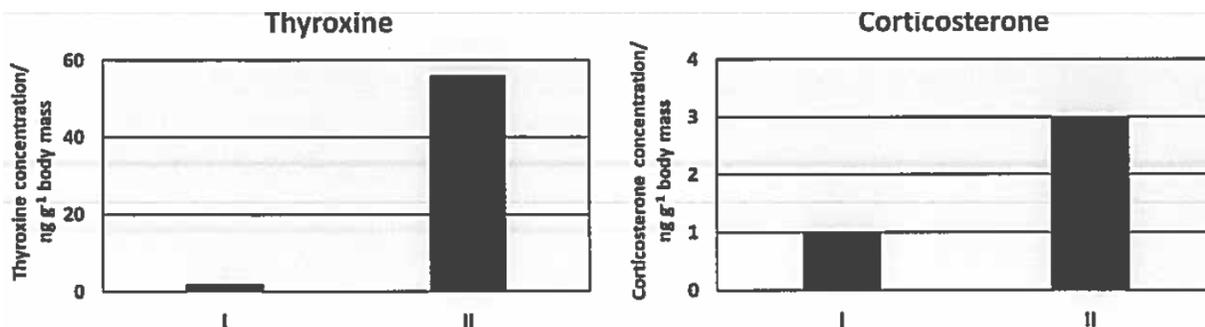
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Studies have shown that control of development by CRH might have evolved in amphibians long before mammals appeared. An increase in CRH concentration leads directly to an increase in the level of the hormone thyroxine and indirectly to an increase in corticosterone levels. The results of an experiment with tadpoles raised in two different environmental conditions (I and II) are shown.



Mark each of the following statements as true or false by putting tick marks (✓) in the appropriate boxes.

- In women who deliver prematurely, CRH levels show a steep rise towards the third trimester.
- High concentration of CRH at 30 weeks of pregnancy could indicate the need to induce labour.
- CRH concentration of about 20 pmol dm^{-3} at mid-pregnancy may require provision of special incubator for likely premature birth.
- Condition II most likely represents the physiology of tadpoles in a pond that is shrinking due to lack of rain.

Answer (a -T, b-F, c-T, d-T)

Sol. Statement a is True.

Solid line indicates premature delivery, shows sharp exponential increase in CRH, which is significantly higher than other two groups by 30 weeks.

Statement b is False.

High CRH shows natural premature delivery as shown in the graph. Inducing labor is an intervention typically used when pregnancy gets delayed (shown by dashed line).

Statement c is True.

At mid of pregnancy (20-25 week) CRH only reaches 20 pmol dm^{-3} . Since they deliver premature baby, an incubator would be required to survive as they lack sufficient fat to maintain body heat and have immature lungs, susceptible to infections.

Statement d is True.

Shrinking pond is highly stressed environment. Condition II shows higher level of thyroxine and corticosterone both of which are biological responses to escape from stress like the drying habitat is shrinking of pond in this case.

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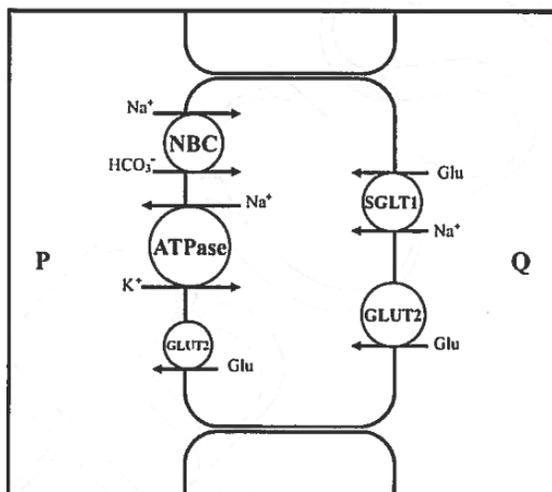
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39. (2 points) Schematic of an enterocyte showing transporters for various ions/solutes is depicted. These transporters play an important role in absorption of nutrients as well as cell homeostasis under different conditions.



Based on the given information, mark each of the following statements as true or false by putting tick marks (✓) in the appropriate boxes.

- The region marked as P represents interstitial fluid.
- In case of severe diarrhoea, drinking solution containing Na⁺, K⁺ and HCO₃⁻ ions will help restore cellular functions.
- In case of severe dehydration, drinking saline glucose solution will restore cellular osmolarity.
- In case of severe diarrhoea and vomiting, drinking hypertonic glucose solution will help restore cellular osmolarity.

Answer (a -✓, b-✗, c-✓, d-✗)

Sol. Region (Q) → Apical (luminal) side as SGLT-1 is here. It transports glucose from intestinal lumen into the cell alongside Na⁺.

Region (P) → Basolateral as Na⁺/K⁺ ATPase and GLUT-2 (moves glucose out into blood) are here.

- Statement (a) is true** as (P) is basolateral which faces interstitial fluid and blood stream.
- Statement (b) is false** as during severe diarrhoea, Na⁺, K⁺ and HCO₃⁻ ions are lost and they require glucose for optimum absorption in the gut *via* SGLT1 and without glucose the “solvent drag” effect that pulls water back into body is less effective.
- Statement (c) is true** as glucose facilitates Na⁺ uptake *via* SGLT1. This increase in intracellular solute concentration, creates osmotic gradient that pulls water back.
- Statement (d) is false** as hypertonic solution has higher concentration of solute than blood. This actually draws water out of the cell into the intestinal lumen

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40. (2 points) Consider 4 organs (P-S) of human body. Some values related to their weights and basal metabolic rate (BMR) considering an adult human of 80 Kg body weight are given in the table.

| Organ | Weight (kg) | Absolute BMR | % of total BMR |
|-------|-------------|--------------|----------------|
| P | 12 | 54 | 3 |
| Q | 0.37 | 163 | 9 |
| R | 1.5 | 300 | 17 |
| S | 32 | 416 | 23 |

Mark the following interpretations as true or false by putting tick marks (✓) boxes. in the appropriate boxes.

- Weight specific BMR is highest in Q and is likely to represent heart.
- R likely represents skeletal muscles as its contribution to total BMR is much higher than its contribution is to total body mass.
- Weight specific BMR is least in P and it likely represents adipose tissues.
- Since both absolute BMR and % of total BMR are largest in S, it is likely to represent brain.

Answer (a-T, b-F, c-T, d-F)

Sol. Weight specific BMR can be calculated by $\frac{\text{BMR}}{\text{Weight(kg)}}$.

$$\text{Weight specific BMR of 'P'} = \frac{54}{12} = 4.5 .$$

$$\text{'Q'} = \frac{163}{0.37} = 440.5$$

$$\text{'R'} = \frac{300}{1.5} = 200$$

$$\text{'S'} = \frac{416}{32} = 13$$

Statement a is true.

Small highly active organs like kidney, heart etc., have very high metabolic rate.

Statement b is False.

Weight of 'R' is 1.5 kg which is only 1.8% of a 80 kg human. Skeletal muscle usually make up 40% of total body weight.

Statement c is True.

Weight specific BMR of 'P' is 4.5, that indicates the tissue/organ is metabolically quiet. Adipose tissue exhibit the same.

Statement d is False.

Brain weighs 1.3 to 1.5 kg. Organ 'S' weighs 32 kg which is far heavier than brain. 'S' could be skeletal muscle while 'R' is brain.

41. (2 points) Bohr effect is the phenomenon where increase in CO₂ level or acidity reduces haemoglobin affinity for oxygen while Haldane effect is a physiological process where increasing O₂ level reduces haemoglobin affinity for CO₂. The haemoglobin saturation curves of maternal and fetal haemoglobin are shown. Gaseous exchange between the haemoglobin molecules of maternal and fetal blood can shift the position of the curves.

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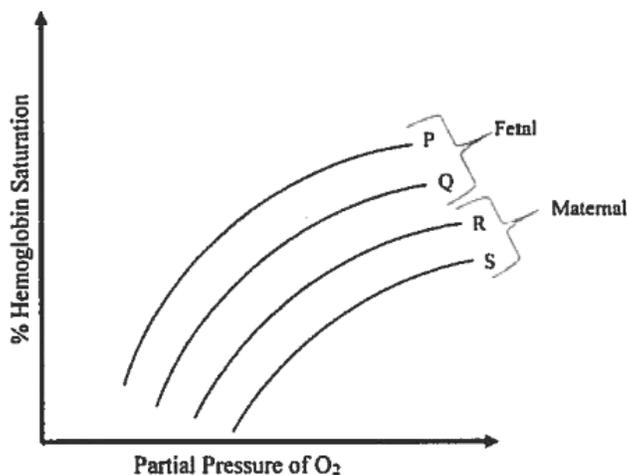
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Mark the following statements as true or false by putting tick marks (✓) in the appropriate boxes.

- As the blood of fetal and maternal circulation juxtapose (come in close vicinity) in placenta, the curve R shifts to S and is called Bohr effect.
- As the blood of fetal circulation comes in close vicinity of maternal blood, the curve P shifts to Q and it is Haldane effect.
- Curve P represents umbilical vein and Q represents umbilical artery.
- Curve R represents maternal arterial blood and S represents maternal venous blood.

Answer (a-T, b-F, c-T, d-T)

Sol. Statement a is True.

Maternal blood picks CO_2 from foetus which increases their concentration in mother's blood, causes right shift ($R \rightarrow S$) of curve, *i.e.*, decreasing affinity of Hb for O_2 .

Statement b is False.

Shifting of foetal curve (P & Q) is driven by Bohr's effect. Foetal blood gains O_2 , causes left shift of the curve, and shows higher affinity of Hb for O_2 due to presence of 2α , 2γ chains in their haemoglobin.

Statement c is True.

Umbilical vein carries oxygenated blood from placenta to foetus, showing higher affinity of Hb for O_2 and curve shifts towards left.

Umbilical artery carries deoxygenated blood from foetus, showing decrease in affinity of Hb for O_2 and curve shifts towards right.

Statement d is True.

Arterial blood (R) has less CO_2 and high pH than venous blood(S). As blood passes through placenta and picks CO_2 from foetus, it is represented as venous blood as curve shifts towards right.

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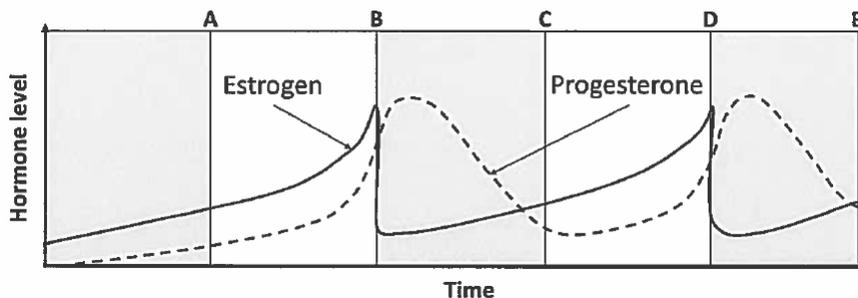
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42. (2 points) A certain species of whiptail lizards reproduce only asexually by parthenogenesis. This species has no males but females can act as males engaging in all aspects of mating behavior. The presence and variation in the levels of two hormones estrogen and progesterone in this species is depicted in the graph.



Indicate if each of the following statements is true or false by putting tick marks (✓) in the appropriate boxes.

- Ovulation is most likely to occur in mid A-B period of the ovarian cycle.
- A given individual behaves as a male during D-E and as a female during A-B period in the cycle.
- The act of copulation will trigger the release of eggs from the ovaries of the lizards.
- As compared to sexually reproducing species, the mode of reproduction adopted by this species of lizards is favoured when availability of resources is not a constraint.

Answer (a-F, b-T, c-T, d-F)

Sol. Whiptail lizards in an asexual lizard, that reproduces, parthenogenetically. Its individuals shows both male like and female like behaviour during phases of ovarian cycle due to hormone (estrogen/progesterone).

Statement a is False.

Ovulation usually occur at the peak of estrogen level (B) where is obtains at the end of B. Period A to B is follicular phase where estrogen is rising.

Statement b is True.

When estrogen level is higher, individual behave as female while when progesterone level is high individual behave like male.

Statement c is True.

The act of copulation performed in such individuals is called pseudocopulation, which triggers the hormonal surge necessary for ovulation.

Statement d is False.

Parthenogenesis generally favoured is stable environment. Sexual reproduction is favoured when environmental conditions are unpredictable.

GENETICS & EVOLUTION (16 points)

43. (2 points) Consider a plant species, wherein the height is determined by four independently assorting genes M, N, O and P. The contribution of the alleles of each of these genes to the basal height of the plant is additive and indicated as the superscript with '0' denoting no increment; '1' denoting an additional growth of 1 cm and so on. If 45 cm is the basic height of this plant and a gardener carries out selfing of plants with the genotype $M^0M^1N^0N^2O^0O^3P^0P^4$, then what proportion of plants would be 65 cm tall?

Note that the final answer for this part of the question will be given marks only if calculations are shown in the box given and the final answer is filled in the blank.

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Answer (1/256)

Sol. The plant with basic height, i.e., with recessive genotype $M^0M^0N^0N^0O^0O^0P^0P^0 = 45$ cm

The plants to be 65 cm tall = 45 cm + 20 cm

So for, extra 20 cm we need genotype to be

$M^1M^1N^2N^2O^3O^3P^4P^4 = 20$ cm

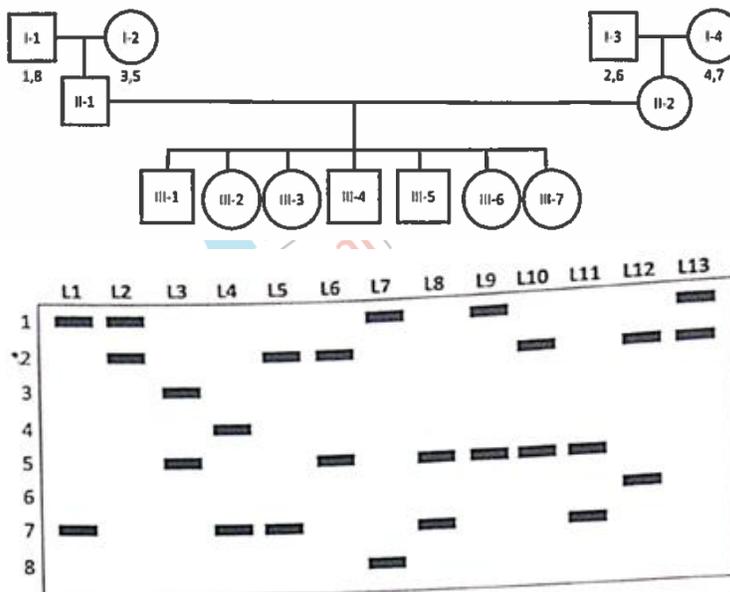
The probability to get M^1M^1 after selfing will be $\frac{1}{4}$

| | | |
|-------|----------|----------|
| | M^0 | M^1 |
| M^0 | M^0M^0 | M^0M^1 |
| M^1 | M^0M^1 | M^1M^1 |

Similarly, for N^2N^2 , O^3O^3 , P^4P^4 , the probability will be $\frac{1}{4}, \frac{1}{4}, \frac{1}{4}$ respectively.

So, the individual to have $M^1M^1N^2N^2O^3O^3P^4P^4$ genotype will have probability of $\frac{1}{4} \times \frac{1}{4} \times \frac{1}{4} \times \frac{1}{4} = \frac{1}{256}$.

44. (3 points) A pedigree representing three generations is shown. The inheritance of a RFLP marker through three generations in a single family is monitored and the gel profile obtained for the 13 members of this family is shown. A total of 8 alleles (numbered to the left of the blots) are present in the family.



The alleles present in the grandparents (Generation I) are shown in the pedigree. Based on the pedigree and the RFLP profile, answer the following.

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- (A) Indicate the lanes that represent the RFLP pattern of individuals II-1 and II-2 (Parents). *Fill in the blanks with the respective lane numbers. Only a completely correct answer will be given points.*
- (B) Indicate the number of individual/s with the respective alleles for the progeny in generation III. (E.g., 1 individual with 1, 8 alleles.)

Answer (A) II-1 = 1,5 (L9);

II-2 = 2,7 (L5)

(B) 2 individuals with alleles (1, 2); 1 individuals with alleles (1, 7); 2 individuals with alleles (2, 5);
2 individuals with alleles (5, 7)

Sol. As per the RFLP

⇒ I-1 (1, 8) will be indicated by L7

I-2 (3, 5) will be indicated by L3

So the next progeny can have (1, 3 ; 1, 5 ; 3, 8 ; 3, 5)

as per the RFLP II-1 (1,5) is indicated in L9

⇒ I-3 (2, 6) will be indicated by L12

I-4 (4, 7) will be indicated by L4

So the next progeny will have (2, 4 ; 2, 7; 4, 6; 4, 7)

So, (A) II - 1 = 1, 5 (L9)

II - 2 = 2, 7 (L5)

as per the RFLP II -2 (2, 7) is indicated in L5

⇒ I-1 (1, 5) × II-2 (2, 7) will have next progeny with (1,2 ; 1, 7 ; 2, 5 ; 5, 7)

The probability of having this alleles in male and female is equal

(B) 2 individuals with alleles 1 and 2

1 individuals with alleles 1 and 7

2 individuals with alleles 2 and 5

2 individuals with alleles 5 and 7

45. **(2 points)** An example of multiple alleles is seen at a locus that determines the feather pattern of mallard ducks. One allele, M , produces the wild-type *mallard* pattern. A second allele, M^R , produces a different pattern called *restricted*, and a third allele, m^d , produces a pattern termed dusky. In this allelic series, restricted is dominant over mallard and dusky, and mallard is dominant over dusky. In a given cross, if the F_1 progeny yield 50% restricted; 25% mallard and 25% dusky ducks, then the genotype of the parents would be:

(Note: Only a completely correct answer will be given points.)

Answer ($M^R m^d$ and $M m^d$)

Sol. The dominance order of the genes are : $M^R > M > m^d$

As the F_1 progenies, are having dusky ducks also that means both parents have m^d allele. Thus, the genotype of parents would be:

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Parents : $M^R m^d$ × $M m^d$
 Restricted Mallard
 Gametes: (M^R) (m^d) (M) (m^d)

F₁ generation:

| | | |
|-------|-------------------------|--------------------|
| | M^R | m^d |
| M | $M^R M$ Restricted | $M m^d$ Mallard |
| m^d | $M^R m^d$ Restricted | $m^d m^d$ dusky |

∴ Phenotypic ratio = 50% Restricted : 25% Mallard : 25% dusky.

46. (3.5 points) Coat color in a certain rodent species is governed by the 'S' allele. Pigment production occurs only in the presence of this allele. Thus, a rodent with the genotype 'ss' will produce no pigment (pale coat colour). When the pigment is produced, alleles B and b determine the color with B being the dominant allele resulting in brown phenotype. Homozygous recessive rodents have black coats.

(A) If a true breeding brown rodent is crossed with a rodent having completely recessive genotype, then the resulting phenotypic ratio in the F₂ generation would be:

(Only a completely correct answer mentioning the values in the ratio with coat colour will be given points.
 E.g., 1 brown: 2: black: 1 pale)

(B) Three separate crosses were carried out between brown females (genotypes unknown) and males with completely recessive genotype for the two genes. The phenotypic ratios obtained in progeny of each cross is given. Determine the maternal genotype for each of the cross and fill in the blanks.

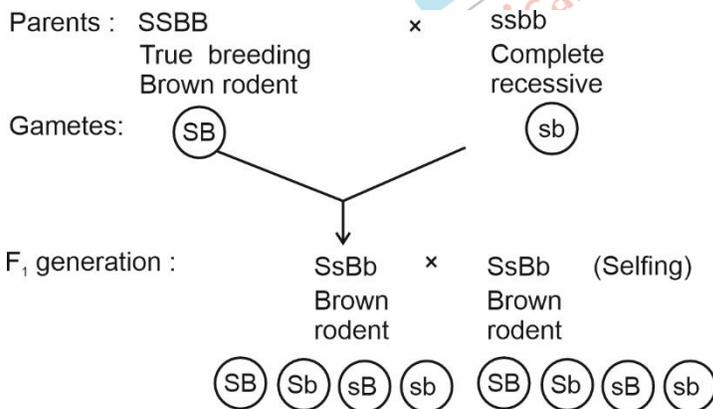
(i) 7 brown: 7 pale

(ii) 8 brown: 9 black

(iii) 5 brown: 6 black: 12 pale

Answer [(A)- 9(Brown):3(Black):4(Pale); (B) (i) $SsBB \times ssbb$, (ii) $SSBb \times ssbb$, (iii) $SsBb \times ssbb$]

Sol. (A)



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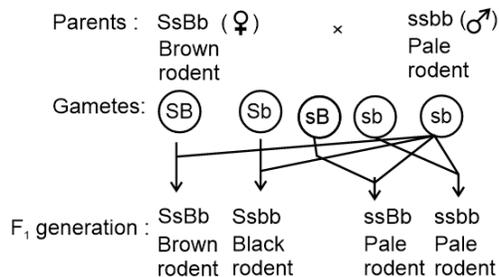
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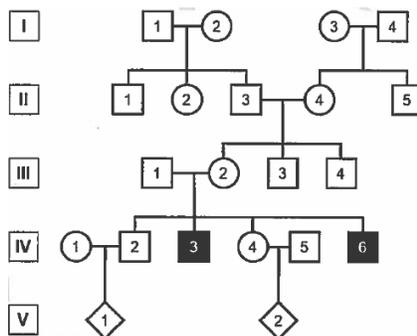
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(iii) In order to obtain all types of coat colour in the progenies, the genotype of the parents should be



47. (2 points) The Lesch-Nyhan syndrome, which is a very rare trait in the general population, is an X-linked trait. The abnormality of the enzyme hypoxanthine phosphoribosyltransferase (HPRT) results in the accumulation of purines in the joints and nervous tissues of affected individuals. A pedigree for the transmission of the trait is shown below.

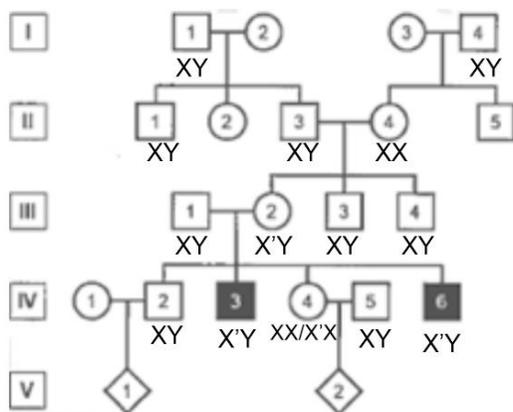


Answer the following questions related to the syndrome. (Fill in your answers in the blanks given)

- (A) The probability that V-1 is a son affected with the disease is:
- (B) The probability that V-2 is a daughter and who is not a carrier for the trait is:

Answer [(A) 1/8; (B) 3/8]

Sol. As we Know Lesch-Nyhan syndrome is an X-linked recessive disorder. Thus



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(A) If IV 1 is carrier only then the individual V-1 is going to have a chance to be affected with the disease.

So, the chance of IV-1 being a carrier is $1/2$.

\therefore The probability of V-1 to be a son = $1/2$

The probability of V-1 to be affected = $1/2$

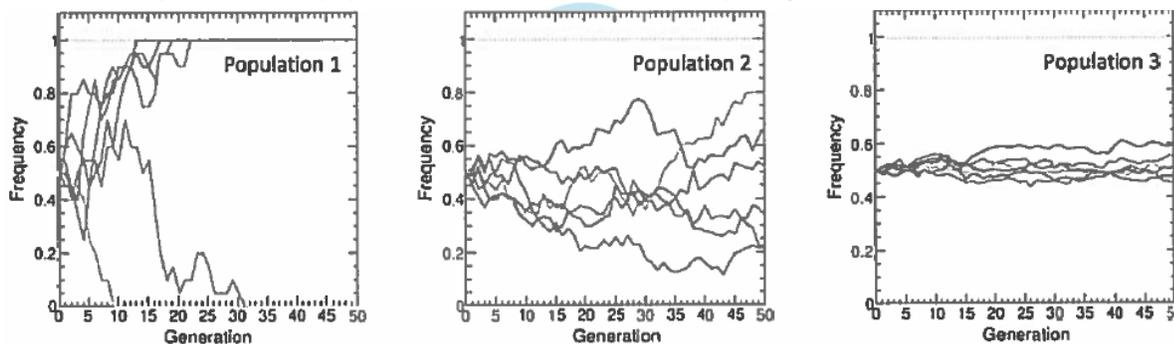
\therefore The probability of V-1 to be the son affected with the disease = $\frac{1}{2} \times \frac{1}{2} \times \frac{1}{2} = \frac{1}{8}$

(B) Probability of having a non-carrier daughter

= (Prob of V-2 to be daughter) \times (Prob of V-2 to not receive X' from the mother)

= $\frac{1}{2} \times \frac{3}{4}$ (\because Out of four possible combination in daughter three are normal) = $\frac{3}{8}$

48. (2 points) To study the role of genetic drift, a simulation was performed using a simple model on three different populations, namely, population 1, population 2, and population 3. A gene with two alleles was considered for modelling. The following assumptions were applied; (1) the population size does not change from generation to generation, (2) each allele has the same expectation of offsprings in the next generation (selection not acting), and (3) no new mutations would arise. In the starting (or the zeroth) generation, that is before any reproduction, both alleles are assumed to be in the same frequency. The following figures show the result of 6 independent simulation experiments on populations 1, 2, and 3. Y axis-frequency of the dominant allele is shown.



Mark whether the following statements are true or false by putting tick marks (\checkmark) in the appropriate boxes.

- (a) Population 1 has the largest number of individuals.
- (b) The effect of drift is seen only in population 1 and 2, but not in population 3.
- (c) Data from population 1 show that genetic drift does not distinguish between a recessive allele and a dominant allele.
- (d) The effect of random fluctuations in allele frequency tends to cancel each other in large population sizes.

Answer (a-F, b-F, c-T, d-T)

Sol. Genetic drift is inversely proportional to the population size.

Population-1, extremely volatile as many lines hit '0' or '1' within 50 generations, indicates small population,

Population-2, moderate fluctuation. Don't hit boundaries as quickly as population 1, medium size population.

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Population-3, very little fluctuation. Lines stay relatively close to starting frequency, indicates large size.

Statement (a) is false. It is small sized population, as many lines hit '0' or '1' within 50 generations.

Statement (b) is false.

The effect of drift can be seen in all population, but is more pronounced in population 1 and 2.

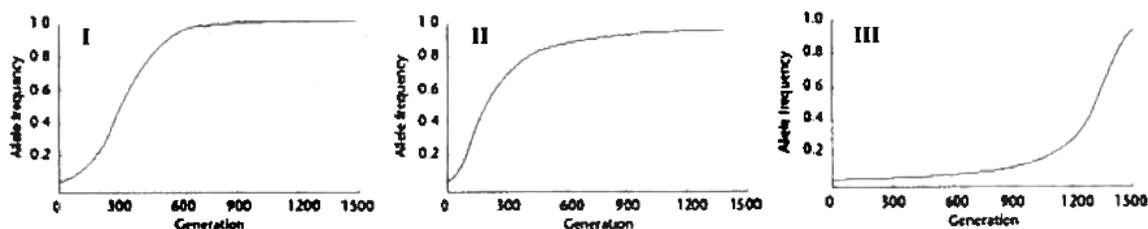
Statement (c) is true.

Genetic drift is a random process. It is independent of whether allele is dominant or recessive.

Statement (d) is true.

In large population the aggregate frequency usually remain stable because random increase in some are balanced by decrease in other.

49. (1.5 points) Change in allele frequency of an advantageous allele A2 is shown in the three panels, I, II, and III below under various types of selection given in the table. Match them with the appropriate type of selection and fill in the table with the respective correct graph number.



Type of selection:

- Dominant selection where A2 is dominant over A1
- Dominant selection where A1 is dominant over A2
- Codominant selection

Answer (a(ii), b(iii), c(i))

Sol. If advantageous allele is dominant, the heterozygotes will show advantage and selection will be strong at low frequency. In this case, allele rises fast initially but near fixation changes become slow and if advantageous allele is recessive, heterozygotes will not show the character and initially the selection will be ineffective. Once homozygote appear, frequency rise will occur at faster rate (like J-shaped graph)

If advantageous allele (A2) is codominant then heterozygous exhibit intermediate trait (advantage) and change is smooth and steady.

So, matching would be like. a(ii), b(iii), c(i).

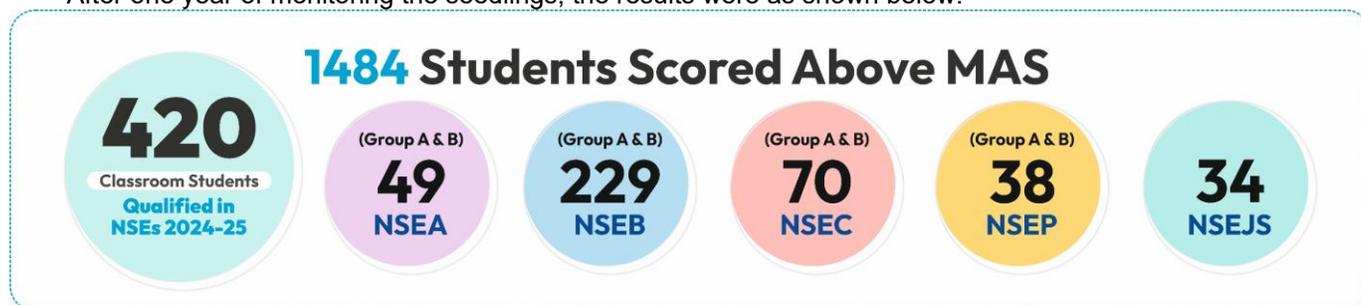
ECOLOGY (10 points)

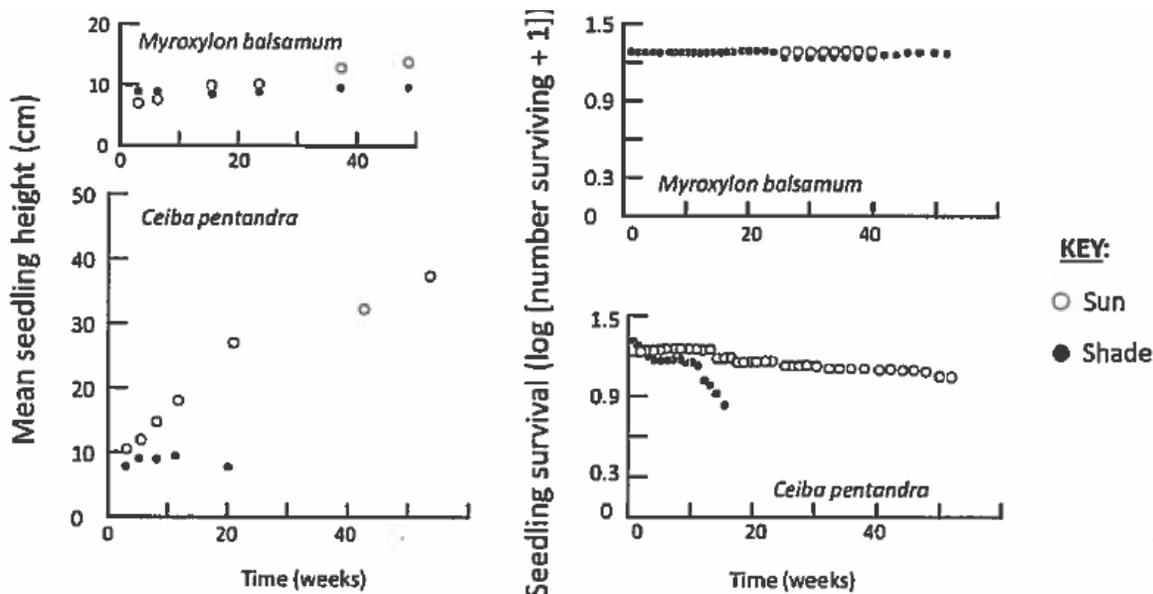
50. (2 points) Caroline Augspurger studied the effect of light conditions on seedling survival and growth. She worked on tree species growing in tropical rain forest. In a series of experiments, she grew tree seedlings of two species, *Myroxylon balsamum* and *Ceiba pentandra* under two different light conditions.

Condition 1: Shaded environment as found under continuous forest canopy.

Condition 2: High sunlight exposure found in openings or large gaps formed by falling of large trees.

After one year of monitoring the seedlings, the results were as shown below:





Indicate whether each of the following statements is true or false by putting tick marks (✓) in the appropriate boxes.

- Shaded condition drastically reduces the *M. balsamum* growth.
- Seedlings of *M. balsamum* are tolerant to high sunlight.
- M. balsamum* and *C. pentandra* are both shade intolerant species.
- M. balsamum* is shade tolerant while *C. pentandra* is better suited for higher sunlight.

Answer (a-✗, b-✓, c-✗, d-✓)

Sol. Statement (a) is false as in the successive weeks the growth of *M. balsamum* is comparable in shade and sun conditions.

Statement (b) is true because *M. balsamum* is growing well in sun conditions as well.

Statement (c) is false as *M. balsamum* is shade tolerant species as it is growing well in shade conditions.

Statement (d) is true as *M. balsamum* is growing well in shade and *C. pentandra* shows magnanimous growth in sun conditions.

51. **(2 points)** Foraging birds often face complex trade-offs between energy gain, predation risk, and the energy costs of travel. Decisions are made depending on food density, energy reserves and risks associated with behaviour.

Consider that a house sparrow has two food patches available as given below:

Food Patch 1 - high food density but unpredictable food availability

Food Patch 2 - low food density but stable food availability.

If the sparrow's current energy reserves are marginally above the survival threshold and if the risk of predation increases non-linearly with travel frequency, which of the following statements is correct? *Choose the correct option and put a tick mark (✓) in the appropriate box.*

- Choose Patch 1, because high expected gain minimizes risks of long-term energy deficits despite higher risks during travel.
- Choose Patch 2, because stable returns reduce the probability of short-term energy shortfall with lower risk of multiple travels

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- (c) Alternate rapidly between Patches A and B to overcome uncertainty, because increasing travel frequency reduces predation risk by unpredictable movement.
- (d) Avoid both patches until reserves increase further, decreasing predation risk and prevents the energy-risk trade-off.

Answer (b)

Sol. The correct option is (b) as

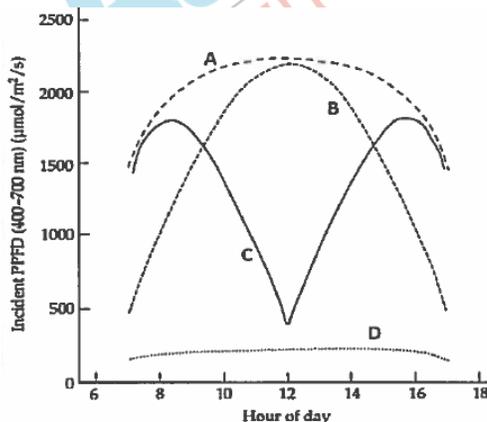
According to foraging theory, an animal's foraging decisions are influenced by its energy reserves relative to its survival needs.

- When an animal's energy reserves are low (marginally above the survival threshold), the primary goal is to avoid immediate starvation (short term energy shortfall).
- Patch 2 offers stable, albeit low, food density. This patch ensures a minimum energy intake, which is crucial for survival when reserves are low.
- Patch 1 offers high but unpredictable food density. While it has the potential for a large payoff, the unpredictability means there is significant risk of getting very little food, which could lead to immediate starvation.
- The risk of predation increases non-linearly with travel frequency. Thus, choosing patch 2 allows the bird to stay in one location for longer, minimizing travel frequency and thus reducing predation risk.

52. (2 points) The amount of light received by a leaf depends on its orientation with respect to the sun. Different species of desert plants orient their leaves in different ways to control the amount of solar radiation falling on them. Given below are four different orientation of leaves and the figure below depicts the amount of useful solar radiation (measured as photosynthetic photon flux density-PPFD) falling on it.

- i. Paraheliotropic solar tracking leaf (parallel to sun rays)
- ii. Diheliotropic solar tracking leaf (perpendicular to sun rays)
- iii. Horizontally placed leaf
- iv. East-West facing vertically oriented leaf

Match the above conditions with the curves shown in the diagram. Choose the correct option and put a tick mark (✓) in the appropriate box.



- (a) i-A, ii-B, iii-D, iv-C
- (b) i-D, ii-A, iii-B, iv-C
- (c) i-D, ii-C, iii-A, iv-B
- (d) i-C, ii-A, iii-B, iv-D

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Answer (b)

Sol. i. Paraheliotropic solar tracking leaf are parallel to sun rays *i.e.*, they have orient their leaves parallel to incoming rays of light usually as a means of minimizing excess light absorption.

Thus, they will be having least incident PPFD through out the day hours. So it is indicated by (D) curve.

ii. Diheliotropic solar tracking leaf orient themselves to track the sun throughout the day. Thus, helps maximizing sunlight absorption and enhances photosynthesis. So, it is indicated by (A) curve.

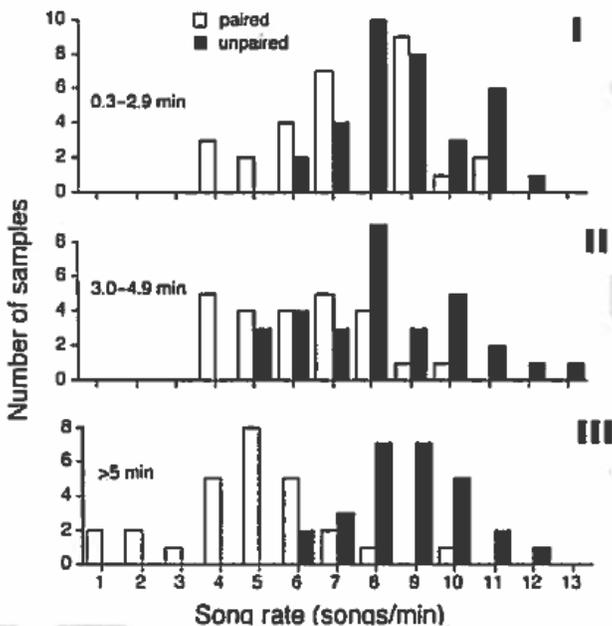
iii. Horizontally placed leaf will have maximum light absorption during the noon and will show rise in solar light absorption as day progresses towards noon and show decrease in absorption as day progresses towards night. So, it is indicated by (B) curve.

iv. East-West facing vertically oriented leaf will show two peaks one early morning and other at evening. So, it is indicated by (B) curve.

So, correct option is (b), i-D, ii-A, iii-B, iv-C.

53. **(2 points)** Male birds of American Redstarts (*Setophaga ruticilla*) have two categories of song, and they use these in different social contexts. In Repeat mode, males sing one song type in repetitive fashion; in Serial mode, they alternate among two or more other song types. In an experimental forest, ecologists studied the Repeat-song rates of paired versus unpaired males in more than fifty birds. The results are depicted in figure where "I" shows song recordings of short duration, "II" shows medium duration and "III" shows long duration. The sample duration indicates the length of the recording time in each graph.

Which of the following statement/s is/are correct? Choose the correct option/s and put tick mark/s (✓) in the appropriate box/es.



- (a) Unpaired males sang in repeat mode at significantly higher and less variable rates than did paired males.
- (b) The amount of overlap between the two samples of male birds decreased as the song duration decreased.
- (c) Unpaired males prefer to sing more types of songs than paired males.
- (d) Repeat songs are more useful in attracting females while serial songs are more useful in pair-bonding behaviours.

Answer (a-✓, b -✗, c -✗, d -✓)

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Sol. The correct statements are (a) & (d)

Statement (a) is correct.

The bar graph consistently show that unpaired males (black bars) have higher song rates (songs/min) compared to paired males (white bars) across all sample durations.

The distribution of song rates for unpaired males is centered around higher value, while paired males are centred around lower values.

The range of song rates for unpaired males is also slightly narrower (less variable) than for paired males.

Statement (b) is incorrect.

In graph-III (long duration, > 5 min), overlap between paired and unpaired males decreases as sample duration increases.

And, from the visual data, we can make out that the overlap between the two samples has not decreased with decrease in song duration. There is significant overlap seen in graph I.

Statement (c) is incorrect.

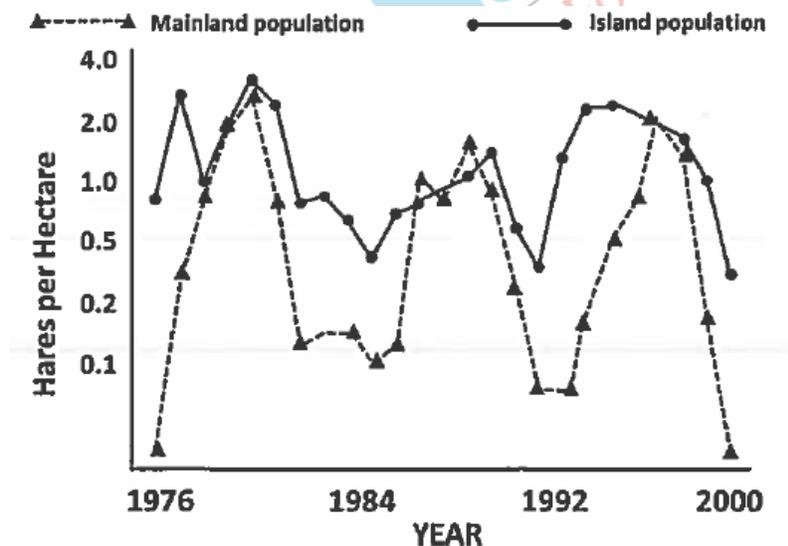
As per the given data, we can confer that the unpaired males show high singing rates of exclusively 'Repeat' songs. They do not sing more types of songs.

Statement (d) is correct.

Unpaired males sang in 'Repeat' mode almost exclusively, whereas paired males sang in both modes.

Use of 'serial' mode after dawn may reflect the presence of nests or young ones.

54. (2 points) The following figure shows hare population monitored on a lake island and the mainland adjoining the lake during 1976 to 2000. The trends obtained are shown below. What could be the possible reason for the observed variations in the densities of the two hare populations?



Choose the correct option and put a tick mark (✓) in the appropriate box.

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- (a) Lack of predator pressure on the island allows this population to reproduce freely and maintain certain population density for a prolonged period.
- (b) The mainland population has greater predator pressure that increases the intensity of population cycles (the difference between maximum and minimum densities).
- (c) Since both the habitats are close enough, the predator pressure from the birds of prey would be almost similar which explains the differences in the lower values of population densities.
- (d) Higher predation success could explain the magnitude of dip in the density of the population on the island.

Answer (a-✓, b-✓, c-x, d-x)

Sol. Option (a) is correct due to lack of predator pressure on the island it allows this population to reproduce freely and maintain certain population density for a prolonged period.

Option (b) is correct as per the data. There is higher dip in the main land than the island showing greater predator pressure. The adult and juvenile survival differences between the island and mainland are explained most consistently by predation.

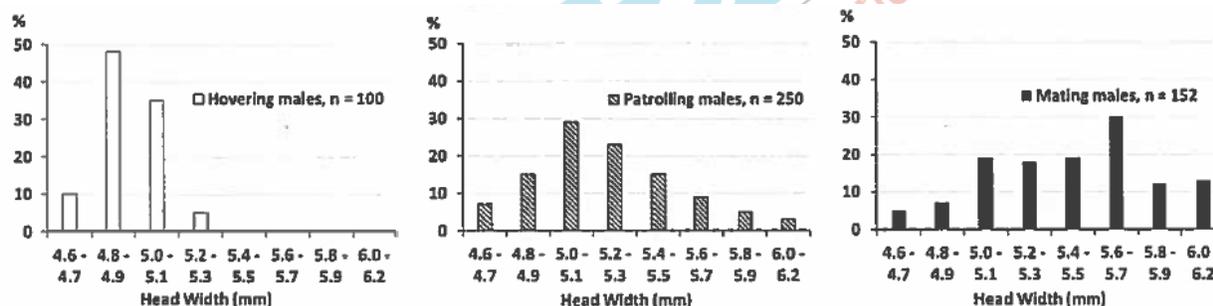
Option (c) is incorrect; though the habitats are close enough the predator pressure from birds of prey in mainland is higher thus higher dip in the graph.

Option (d) is incorrect; because the predation success is higher in mainland than island, thus showing lowest dip in hare population.

ETHOLOGY (6 points)

55. (2 points) Studies on the ground-nesting digger bee *Centris pallida*, showed that the males practice one of two very different mate-location behaviours - patrolling and hovering. Patrolling involves hunting over a home range, searching for sites where buried female virgins are about to emerge from pupation, finding the females, excavating them and mating with them. The hovering males, on the other hand, hover in and around emergence areas or near flowering trees.

The distribution of male bees with different head widths that were captured while hovering, patrolling and copulating is shown in the given graphs.



Based on the data, mark each statement as true or false by putting tick marks (✓) in the appropriate boxes.

- (a) Mate-location behavior exhibited by the bees can be predicted across the head widths studied.
- (b) Hovering males are unsuccessful in attaining mating success.
- (c) Male bees with smaller head width generally hover rather than patrol, even though large males do most of the mating.
- (d) It is likely that females who emerge from the nest when hovering males are fighting, escape and fly off to flowering trees where they become potential mates for the patrolling males.

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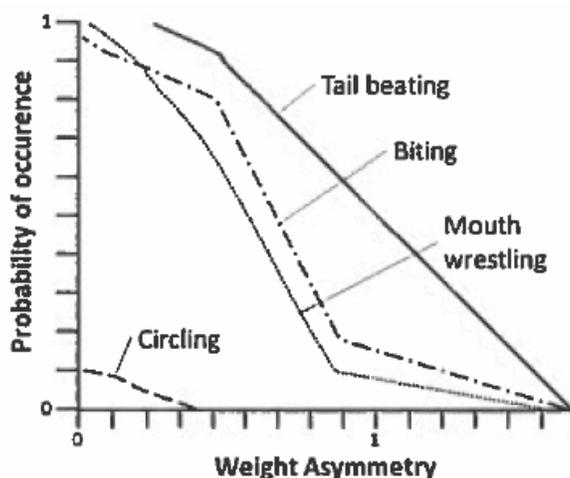
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Answer (a-T, b-F, c-T, d-F)

- Sol.** (a): **True**, patrolling males (search for sites where buried females and excavate) generally have larger head widths while hovering males hover in and around emergence areas near flowering trees and have smaller head widths. So, mate location behaviour exhibited by the bees can be predicted by the head width.
- (b) **False**, patrolling males attain highest mating success while males with head widths corresponding to the hovering range also achieve some mating success. Therefore, they are not entirely unsuccessful.
- (c) **True**, the hovering males graph shows highest percentage of males with smaller head widths. Conversely, the patrolling males graph, shows a peak for large head width, The “Mating males” graph clearly shows that the largest males with head width (5.5 to 5.7 mm) have the highest mating success.
- (d) **False**, hovering males are found near flowering trees, not the patrolling one.
56. **(2 points)** In a study on fighting in the cichlid fish *Nannacara anomala*, the number of times each of the four behaviors exhibited were recorded against weight asymmetry. Weight asymmetry is measured as logarithm of the weight of the heavier fish divided by the weight of the lighter fish. The observations are represented in the given graph.



Based on the graph, indicate whether each of the following statements is true or false by putting tick marks (✓) in the appropriate boxes.

- (a) Two fish of similar weight do not expend energy in the act of circling.
- (b) Fish of similar size are likely to show tail beating as the preferred behaviour.
- (c) The relative occurrence of biting is higher than mouth wrestling when the fish are of almost comparable weights.
- (d) It is likely that one of the fish adopts the Dove strategy and retreats when the weights of fish are almost similar leading to reduced aggression.

Answer (a-x, b-✓, c-✓, d-x)

Sol. A value near zero on the x-axis means the fish are of similar weight (symmetry), while a higher value indicates a significant weight difference.

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| | | | | | |
|--|---|--|---|---|--|
| <div style="border: 1px solid blue; border-radius: 50%; width: 60px; height: 60px; margin: 0 auto; display: flex; flex-direction: column; align-items: center; justify-content: center;"> <div style="font-size: 24px; font-weight: bold; margin-bottom: 5px;">420</div> <div style="font-size: 8px; font-weight: normal; margin-bottom: 5px;">Classroom Students</div> <div style="font-size: 8px; font-weight: normal;">Qualified in NSEs 2024-25</div> </div> | <div style="border: 1px solid blue; border-radius: 50%; width: 60px; height: 60px; margin: 0 auto; display: flex; flex-direction: column; align-items: center; justify-content: center;"> <div style="font-size: 8px; font-weight: normal; margin-bottom: 5px;">(Group A & B)</div> <div style="font-size: 24px; font-weight: bold; margin-bottom: 5px;">49</div> <div style="font-size: 8px; font-weight: normal;">NSEA</div> </div> | <div style="border: 1px solid blue; border-radius: 50%; width: 60px; height: 60px; margin: 0 auto; display: flex; flex-direction: column; align-items: center; justify-content: center;"> <div style="font-size: 8px; font-weight: normal; margin-bottom: 5px;">(Group A & B)</div> <div style="font-size: 24px; font-weight: bold; margin-bottom: 5px;">229</div> <div style="font-size: 8px; font-weight: normal;">NSEB</div> </div> | <div style="border: 1px solid blue; border-radius: 50%; width: 60px; height: 60px; margin: 0 auto; display: flex; flex-direction: column; align-items: center; justify-content: center;"> <div style="font-size: 8px; font-weight: normal; margin-bottom: 5px;">(Group A & B)</div> <div style="font-size: 24px; font-weight: bold; margin-bottom: 5px;">70</div> <div style="font-size: 8px; font-weight: normal;">NSEC</div> </div> | <div style="border: 1px solid blue; border-radius: 50%; width: 60px; height: 60px; margin: 0 auto; display: flex; flex-direction: column; align-items: center; justify-content: center;"> <div style="font-size: 8px; font-weight: normal; margin-bottom: 5px;">(Group A & B)</div> <div style="font-size: 24px; font-weight: bold; margin-bottom: 5px;">38</div> <div style="font-size: 8px; font-weight: normal;">NSEP</div> </div> | <div style="border: 1px solid blue; border-radius: 50%; width: 60px; height: 60px; margin: 0 auto; display: flex; flex-direction: column; align-items: center; justify-content: center;"> <div style="font-size: 24px; font-weight: bold; margin-bottom: 5px;">34</div> <div style="font-size: 8px; font-weight: normal;">NSEJS</div> </div> |
|--|---|--|---|---|--|

Statement (a), false: Circling occurs most frequently at low weight asymmetry (similar weight), indicating energy expenditure.

Statement (b), true: Tail beating has a high probability of occurrence across a wide range of weight asymmetries.

Statement (c), true: At any given weight asymmetry, the “Biting” line is consistently above the “mouth wrestling” line, meaning it occurs more often.

Statement (d), false: When weights are similar (low asymmetry), all aggressive behaviour are at their peak. This indicates intense fighting rather than retreat.

57. **(2 points)** By making appropriate observations and comparisons, behavioral scientists have been able to build a plausible case that each behavioral trait observed in specific bird species has adaptive significance. A list of behavioral interpretations is given below.

- (i) Reflects importance of territory ownership by a male if he has to acquire a mate.
- (ii) Needs to attract distant females in areas with other related species.
- (iii) Selection for a high degree of territorial aggressiveness in males leads to a low threshold for attacking any intruder into its own territory.
- (iv) Selection favors different actions leading to reduction in aggressiveness, synchronization of physiology and willingness to cooperate.

Correlate the reasons with the appropriate trait by choosing from the list of traits and filling in the correct alphabet against each interpretation.

- (a) Females are attracted to territory owners only.
- (b) Males give loud calls to announce territory ownership.
- (c) Courtship, mutual and contact displays.
- (d) Males are likely to attack females initially.

Answer [i-(a), ii-(b), iii-(d), iv-(c)]

Sol. Here are

- (i) Reflects importance of territory ownership by a male if he has to acquire a mate. **This matches with (a).** Females are attracted to territory owners only.
- (ii) Loud calls are the form of long-distance communication. Males give loud calls to announce territory ownership and attract distant females. **Thus (ii) matches with (b).**
- (iii) A low threshold for aggression means they attack almost any intruder indiscriminately. **Thus, (iii) matches with (d).**
- (iv) Courtship, mutual and contact displays often involve ritualised behaviours that reduce aggression between potential mates and synchronise their reproductive physiology. **Thus, (iv) matches with (c).**



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BIOSYSTEMATICS (5.5 points)

58. (2 points) The four major clades of extant molluscs are Chitons, Bivalves, Gastropods and Cephalopods. A table of few features for each clade is given. Note: + indicates of that feature.

| Feature | Clade 1 | Clade 2 | Clade 3 | Clade 4 |
|---------|---|------------------------|---------|----------------------------------|
| P | + | Modified for burrowing | + | Modified into arms and tentacles |
| Q | + | + | + | + |
| R | Feeding structure modified for scraping | + | + | + |

Based on the table, mark each statement as correct or incorrect by putting tick marks (✓) in the appropriate boxes.

- (a) Q could be gills.
- (b) 4 represents a gastropod.
- (c) R could be mantle.
- (d) 2 is a bivalve.

Answer (a → ✓, b → ✗, c → ✓, d → ✗)

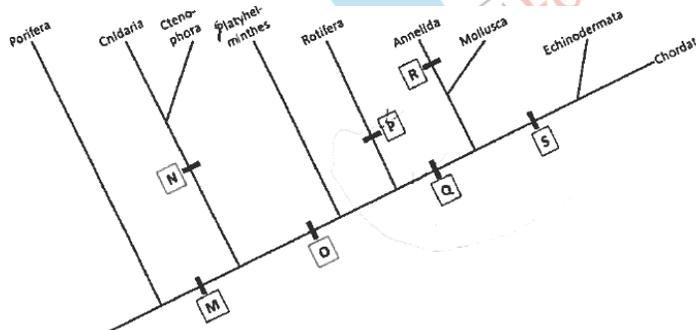
Sol. Here, **Clade 1** : Feature (R) is a feeding structure modified for scraping. This can be either mantle or radula. As radula is absent in bivalves. Thus, (R) is mantle.

Clade 2: Muscular foot for burrowing modified in gastropods to anchor in the sand, for swimming and for adhesion to the rocks.

Clade 3: Chitons: They have foot for creeping, gills for respiration and radula for scraping.

Clade 4: Cephalopods as they possess arms and tentacles. They have gills, radula and mantle.

59. (3.5 points) A relationship tree for some animals is depicted below.



Match the evolutionary traits M-S with the correct options. Choose from the options below and fill in the blanks with the correct option numbers.

Options:

- a. Pseudocoelom
- b. Radial symmetry
- c. True coelom
- d. Segmentation
- e. Diploblasty
- f. Deuterostomy
- g. Protostomy

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Answer (M-e, N-b, O-g, P-a, Q-c, R-d, S-f)

Sol. M- Diploblasty (e) : Appears after porifers in cnidarians and ctenophores.

N- Radial symmetry (b) : Cnidarians and ctenophores are radially symmetrical.

O- Protostomy (g) : Seen from the members of phylum Platyhelminthes to Mollusca.

P- Pseudocoelom (a) : Appears in roundworms / rotifers.

Q- True coelom (c) : Appears in annelids, arthropods, molluscs, echinoderms and chordates.

R- Segmentation (d) : Absent in molluscs.

S- Deuterostomy (f) : Seen in complex animals such as chordates but also in evolutionary advanced invertebrates such echinoderms.

END OF PART B



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