

Date: 04/02/2024



Max. Marks : 300

Time : 2 hours

Corporate Office: Aakash Tower, 8, Pusa Road, New Delhi-110005 | Ph.: 011-47623456

# Answers & Solutions

*for*

## Indian National Biology Olympiad (INBO) - 2024

### INSTRUCTIONS

(1) The question paper is divided into **Sections A** and **B**. All answers should be written in the **answer booklet only** which will be collected at the end of the examination. The question paper need not be submitted to the examiner.

(2) **Section A**

- Section-A consists of **34** questions carrying **1 point** each.
- All 34 questions are of multiple choice type, with only one correct answer for each question.
- Mark the correct answer with '■' in the answer booklet provided. The correct way of marking is shown below. Use a pen to mark your answer.

Q. No.	a	b	c	d
		■		

- Each wrong answer will have negative marking as indicated in the scoring key.

(3) **Section B**

- Section B consists of **29** questions with a total of **66 points**.
- The points for the questions in Section B vary depending on the number of answers and the complexity of the question. These points have been indicated along with the question.
- Contradictory answers will not be considered for marking.

## SECTION-A

**CELL BIOLOGY (8 points)**

1. **(1 point)** Hummingbird and chicken can be easily contrasted for the type of flight they exhibit. The former can have sustained flight for several seconds with very rapid movement of wings while the latter only shows intermittent short powerful flights probably to escape imminent danger. Which of the following characteristics can be attributed to the muscles of these birds respectively?
- i. Fast twitch oxidative and fast twitch glycolytic fibres.
  - ii. Low and high phosphofructokinase: lactate dehydrogenase ratio.
  - iii. Low and high % cell volume occupied by mitochondria.
  - iv. High and low superoxide dismutase activity in the muscles.
- (a) i only    (b) ii and iii only  
(c) i and iv only                                    (d) ii and iv

**Answer (c)**

**Sol.** Hummingbirds have the highest mass-specific metabolic rate of all vertebrates achieved through an outstanding capacity to deliver, uptake and utilize oxygen, allowing a constant supply of aerobically generated energy to the working muscles. This extremely advance oxidative system, must be accompanied by an equally-well developed system to neutralise the metabolic by-products of oxidative phosphorylation. Conversely, the chicken flight musculature has evolved as a largely, vestigial tissue, and is primarily composed of glycolytic muscle fibres rendering these muscles capable of short bursts of powerful contraction when required. Thus (i) is correct.

The phosphofructokinase : Lactate dehydrogenase enzyme activity ratio in hummingbirds is far higher than in other vertebrates, indicating that the glycolytic conversion of glucose to pyruvate is designed for complete oxidation through the Krebs cycle and electron transport chain. Thus (ii) is incorrect.

Hummingbirds had significantly higher cytochrome C oxidase, subunit iv content compared to chickens which aligns with their higher mitochondrial content (in 35% of cellular volume) compared to chickens. Thus (iii) is incorrect.

Hummingbirds impart higher activity of superoxide dismutase than chicken. Thus iv is correct.

By analysing the above facts it can be inferred that the correct answer is option (c).

2. **(1 point)** Due to dynamic phosphorylation-dephosphorylation process, almost all signaling pathways are reversible and in many cases phosphorylation activates the signaling. Which combination of following conditions will inhibit such a signaling pathway in operation?
- i. Application of kinase inhibitor.
  - ii. Treatment with a phosphatase inhibitor.
  - iii. Phosphorylated amino acid residue binder recruiting a phosphatase.
  - iv. Binding of a phosphorylation amino acid residue recognizing kinase.
  - v. An interaction stabilizing the half-life to phosphorylated amino acid residue.
- (a) Only i and iii
- (b) Only ii, iv, and v
- (c) Only i, iii, and iv
- (d) Only ii, iii, and v

**Answer (a)**

**Sol.** As the process is activated by the process of phosphorylation its inhibition will be stimulated by the activities that can inhibit the activity of kinase or stimulating the activity of phosphatase.

In the first treatment kinase inhibitor will inhibit the process of phosphorylation thereby inhibiting it. Thus (i) is correct.

In the second treatment phosphatase inhibitor will not allow the dephosphorylation process thus it will promote or stimulate the phosphorylation. Thus (ii) is incorrect.

If a phosphorylated amino acid residue recruit a phosphatase, dephosphorylation takes place which results in-inhibition of the signalling pathway activated by phosphorylation. Thus (iii) is correct.

In the third treatment the amino acid is already phosphorylated further if it recruits kinase either it will have no effect on the activity or can stimulate the phosphorylation process thus activates the signalling pathway. Thus (iv) is incorrect.

Interaction that stabilises the half-life of the phosphorylated amino acid residue thus enhances the activation of signalling pathway. Thus (v) is incorrect.

Thus after analysing all the treatments it can be inferred that the correct answer is 'a'.

3. **(1 point)** Acquired immune system produces different types of antibodies upon exposure to an antigen. The type of antibody produced varies based on the time from the initial exposure to antigen, the duration after the initial exposure, and secondary or every subsequent exposure to the same antigen. A murine model was infected with a bacterial pathogen. Serological analysis was carried out to monitor the presence of antigen-specific IgM and IgG antibodies at different Days Post Inoculation (DPI) as shown in the table below.

Sample No.	DPI	IgM	IgG
1	1	—	—
2	7	++	—
3	10	+	+
4	28	—	++

Which of the sample number/s in the above table indicate/s an ongoing active infection condition?

- (a) 1 & 2  
(b) Only 2  
(c) 2 & 3  
(d) 3 & 4

**Answer (c)**

**Sol.** The correct answer is option (c) as antibodies are formed upon interaction with antigens.

In sample 1, no antibodies are formed probably because the infection is at early stage, not actively infecting the person.

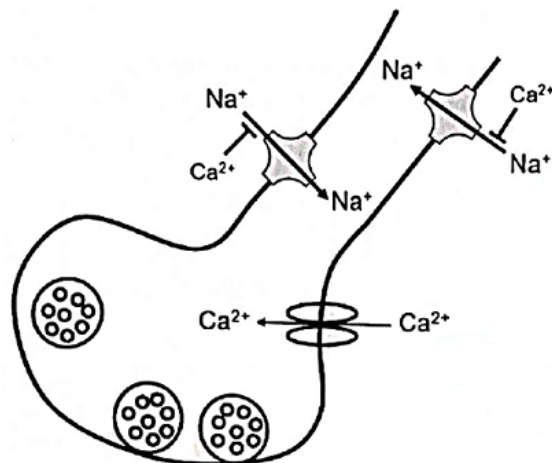
IgM is produced at early stages of the immune response whereas IgG is produced at the later stages of the immune response.

In sample 4, IgM is absent which is not possible in ongoing active infection.

Hence, in sample 2 and 3 ongoing active infection is taking place as in sample 2, IgM is formed in high concentration.

IgG takes time to form after antigenic stimulus. In sample 3, both antibodies are present.

4. (1 point) Movement of sodium and calcium ions at the nerve terminal end is shown.



Accordingly, which of the following options is the most accurate observation made from the nerve terminal of an individual suffering from hypercalcemia?

- (a) Increased depolarization as well as synaptic vesicle fusion causing hyper-excitability of neurons.
- (b) Reduced depolarization and reduced synaptic vesicle fusion affecting muscle function.
- (c) Normal depolarization but enhanced synaptic vesicle fusion causing muscle weakness.
- (d) Increased depolarization, normal synaptic vesicle fusion leading to unperturbed muscle functions.

**Answer (b)**

**Sol.** The correct answer is option (b) as high  $\text{Ca}^{2+}$  levels can inhibit sodium movement through voltage gated sodium channels, retarding sodium entry into excitable membranes. Thus, generation of action potentials is altered in neurons as well as in striated muscles. This causes reduced depolarisation and impaired action potential generation.

Hypocalcemia facilitates  $\text{Na}^+$  transport, as the normal inhibition by  $\text{Ca}^{2+}$  on  $\text{Na}^+$  movement through voltage gated  $\text{Na}^+$  channels is lost. Thus, results in hyper-excitability of neurons.

5. (1 point) 0.3 M sucrose and 0.3 M glycerol both show osmotic potential same as that found within a human erythrocyte. If RBCs are suspended in these solutions independently for about an hour, cells suspended in glycerol solution show hemolysis. Which of the following can be best deduced from this?
- (a) Glycerol is more hydrophilic than sucrose.
  - (b) Water from the glycerol solution enters the cells leaving a hypertonic solution of glycerol outside.
  - (c) Glycerol has greater cell membrane permeability than sucrose.
  - (d) Sucrose being a disaccharide requires a specific carrier protein to pass through the erythrocyte membrane.

**Answer (b)**

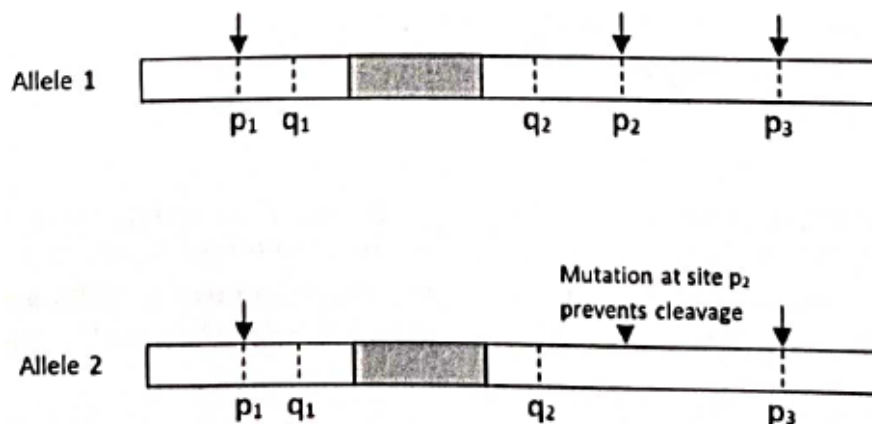
**Sol.** Even if the solution is isotonic to the RBCs then also the RBC placed in glycerol solution showed hemolysis. The most probable reason would be that due to certain non-specific pathway water enters into the cell leads to its lysis. Thus (b) is true.

Option (a) is incorrect as sucrose is more hydrophilic than glycerol.

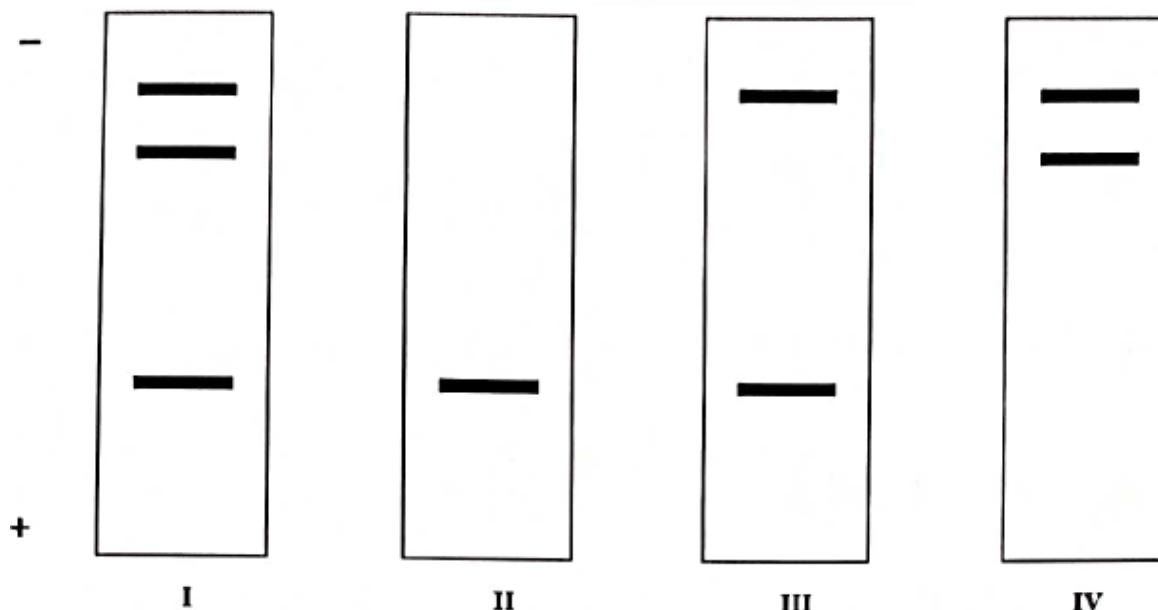
Option (c) and (d) are incorrect as RBCs are completely impermeable for sucrose.



8. (1 point) In the two homologous chromosomes shown below, DNA was treated with two different restriction enzymes P and Q which cut DNA at different sequences p and q respectively. The resulting fragments were subjected to Southern Blot analysis with a radioactive probe that binds to the DNA region (shaded) to detect the fragments.



A few possible gel patterns with relative band positions that could be obtained are shown:



The resulting patterns obtained when the DNA sample was completely digested with (i) only enzyme P and (ii) only enzyme Q respectively would be:

- (a) I and III respectively  
 (b) III and II respectively  
 (c) I and IV respectively  
 (d) IV and II respectively

**Answer (b)**

**Sol.** As per the given pattern of bands if the sample is treated with P only it could result in two different bands with the binding site of radioactive probe i.e., P<sub>1</sub>P<sub>2</sub> and P<sub>1</sub>P<sub>3</sub>. As P<sub>1</sub>P<sub>3</sub> is a larger fragment on the gel it will be closer to the reference line and P<sub>1</sub>P<sub>2</sub> will be far from reference line. It is attributed to the fact that in agarose gel electrophoresis used during southern blotting the DNA is separated on the basis of size. Thus, the pattern that will be obtained is going to be III.

If the samples will be treated by Q only then only one band having radioactive probe binding site will be observed i.e., q<sub>1</sub>q<sub>2</sub> as it is a smaller fragment its band will be obtained far from the reference line. Thus, the pattern that will be obtained is going to be II

Thus, the correct answer is option b

**PLANT SCIENCES (6 points)**

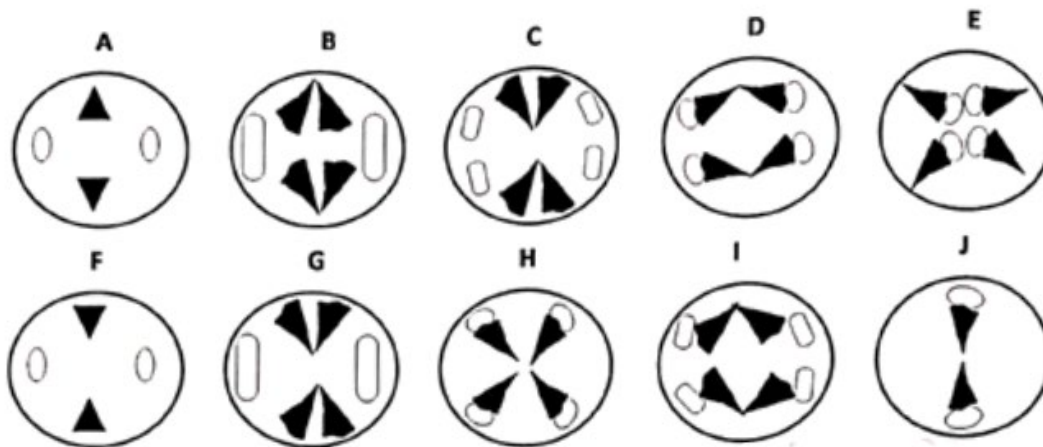
9. (1 point) An experiment was carried out where plants were grown in soils with varying water potentials and the various physiological changes were monitored. If the water potential is varied from  $-1$  to  $-3$  MPa then abscisic acid accumulation; cell expansion and stomatal conductance would respectively:
- (a) Increase; increase; increase                      (b) Increase; decrease; increase  
 (c) Increase; decrease; decrease                      (d) Decrease; increase; decrease

**Answer (c)**

- Sol. 1. Absciscic acid accumulation:** As water potential decreases (from  $-1$  to  $-3$  MPa) plants typically experience water stress. **As water availability decreases, ABA accumulation in the plant increases**, as it helps to regulate various physiological processes to cope with water deficit conditions.
2. **Cell expansion:** With decreasing water potential, cell expansion is inhibited. Water is essential for maintaining turgor pressure within plant cells, which is necessary for cell expansion. **As water availability decreases**, cells lose turgor pressure, leading to **reduced cell expansion** or even cell shrinkage.
3. **Stomatal conductance:** As water potential decreases, plants tend to **close their stomata** to minimise water loss and conserve water.

Therefore, **stomatal conductance decreases as water potential decreases**.

10. (1 point) Following are the depictions of the arrangement of the vascular tissues seen in the cross sections from various parts of a dicot seedling. Choose the option that correctly depicts the transition from root tip to stem tip



- (a)  $A \rightarrow B \rightarrow I \rightarrow D \rightarrow H$                       (b)  $F \rightarrow G \rightarrow C \rightarrow H \rightarrow J$   
 (c)  $F \rightarrow B \rightarrow C \rightarrow E \rightarrow J$                       (d)  $A \rightarrow G \rightarrow I \rightarrow E \rightarrow D$

**Answer (a)**

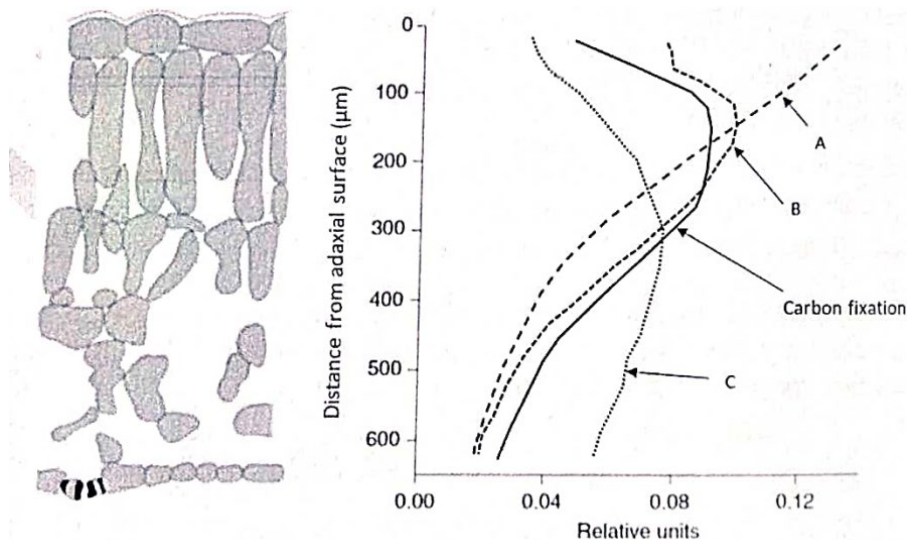
**Sol.**  $A \rightarrow B \rightarrow I \rightarrow D \rightarrow H$

**Type B** (Mostly found in *Cucurbita*, *Acer*, *Phaseolus* and *Tropaeolum* (Fabaceae))

- Initially xylem and phloem are at separate radii.
- Each xylem swing and join with a strand of phloem.
- Phloem does not change its orientation, but the xylem becomes inverted.
- Number of vascular bundle formed in the stem will be twice the number of phloem strands in the root.

11. (1 point) The figure below depicts a cross section of a spinach leaf (approximately 650  $\mu\text{m}$  thick). The profiles of photosynthetic carbon fixation and the following three parameters are shown in the graph.

- I. Intensity of incident light
- II. Light absorbed
- III. Amount of chlorophyll



Match the curves A to C with the correct parameters I, II and III.

- |                      |                      |
|----------------------|----------------------|
| (a) A-I, B-II, C-III | (b) A-III, B-I, C-II |
| (c) A-I, B-III, C-II | (d) A-II, B-I, C-III |

**Answer (a)**

**Sol.** Spinach is a  $C_3$  plant.

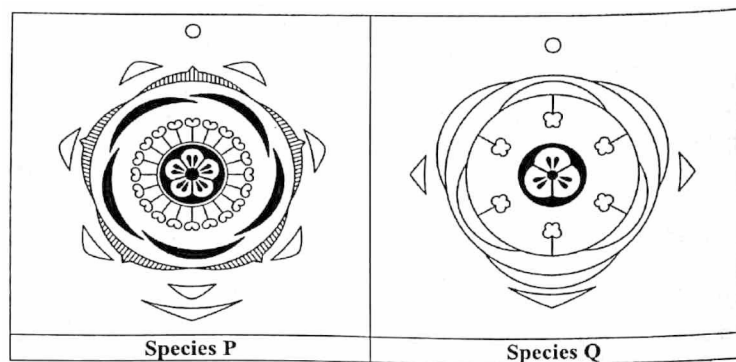
In  $C_3$  plant, on the adaxial surface, mesophyll cells are present and as we move towards abaxial surface, spongy parenchyma cells are present.

Intensity of incident light is more on adaxial surface than on abaxial surface.

Thus, graph A represents intensity of incident light. Graph B represents light absorbed. Graph C represents amount of chlorophyll.

Hence, option (a) is correct

12. (1 point) Given below are floral diagrams of two plant species P and Q.



Following are a few statements regarding the above.

- I. Both the species show syncarpous ovary.
- II. The stamens are monothealous in species P while they are ditheous in species Q.
- III. Both the species are bracteate.
- IV. Epipetalous condition of stamens is seen in both species.
- V. Each species show either a gamosepalous or gamotepalous condition.

Which of the following options shows all correct statements?

- |                     |                       |
|---------------------|-----------------------|
| (a) I, II, IV and V | (b) I, II, III and V  |
| (c) III, IV and V   | (d) I, II, III and IV |

**Answer (b)**

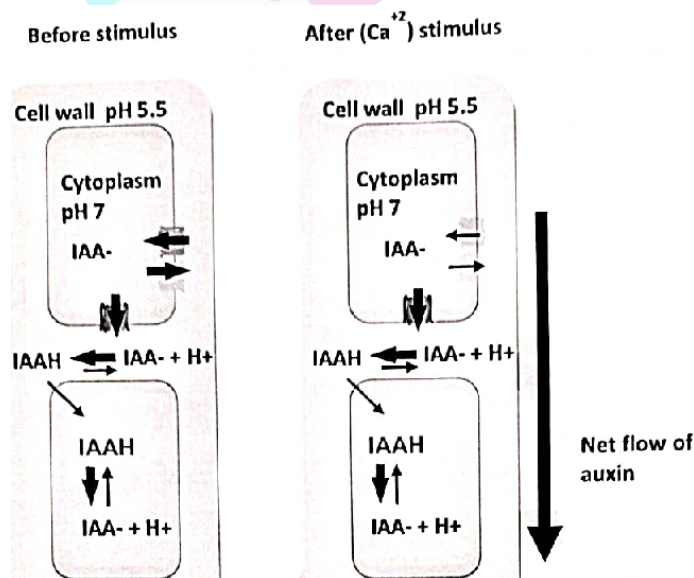
- Sol.** I. Both the species show syncarpous ovary in which the carpels of the gynoecium are united with each other.
- II. Stamens are monothealous in species P as it has only one lobe.  
In species Q floral diagram ditheous anthers are present with two theca in it.
- III. In both species symbol of bract is present.
- IV. In species Q floral diagram shows epitepalous condition of stamens.  
Species P shows gynandrous condition.
- V. Species P shows gamosepalous condition and species P shows gamopetalous condition.
- Therefore statements I, II, III and V are correct.

13. **(1 point)** The success of the early green revolution was largely due to
- i. Semi-dwarf varieties, that put more energy into seed production than vegetative growth, were introduced.
  - ii. Genetically modified high-yielding varieties were introduced.
  - iii. Use of chemical fertilizers was increased.
  - iv. Genetically modified disease resistant varieties were introduced.
- |                        |                     |
|------------------------|---------------------|
| (a) i, ii and iii only | (b) ii and iv only  |
| (c) i and iii only     | (d) iii and iv only |

**Answer (c)**

- Sol.** The success of early green revolution was due to usage of high yielding semi-dwarf crop varieties and chemical fertilizers.

14. **(1 point)** Auxin is a charged anion ( $\text{IAA}^-$ ) in the cytoplasm (pH 7). In the more acidic cell wall (pH 5.5) some auxin is uncharged ( $\text{IAAH}$ ). The uncharged form crosses the plasma membrane into the cell, where it is deprotonated and unable to exit other than through a specific transporter.



In response to a  $\text{Ca}^{+2}$  stimulus, the net flow of auxin (as shown in the figure) is controlled by

- the asymmetric conversion of protonated to deprotonated form of auxin.
- the asymmetric expression of auxin receptors.
- the asymmetric activity of the auxin transporters.
- the asymmetric conversion of deprotonated to protonated form of auxin.

**Answer (c)**

**Sol.** According to chemiosmotic hypothesis, the pH difference between acidic cell wall (pH-5.5) and the cytoplasm (pH-7) promotes the accumulation of IAA inside the cell. Deprotonated  $\text{IAA}^-$  can leave the cell only by the help of specific transporters. The asymmetric distribution of the auxin transporters within each cell promotes the polar transport of auxin from cell to cell. At the basic pH of cytoplasm, IAAH becomes deprotonated and remain trapped inside the cell. Deprotonated  $\text{IAA}^-$  can only leave the cell with the help of active efflux mediated by carriers/transporters.

### ANIMAL SCIENCES (7 points)

15. **(1 point)** Space flight of long duration can pose several challenges to human body and physiology. Sudden drop in gravity during launch, sustained absence of gravity (microgravity) during flight and sudden effect of gravity during landing all lead to some alterations in body parameters. Which of the following are appropriate changes that occur?

- Redistribution of fluid to the torso and head during launch.
- Reduction in plasma volume during flight.
- Transient hypertension at touch down after landing.
- Disuse of postural muscles during flight.

**Options:**

- |                    |                       |
|--------------------|-----------------------|
| (a) i and iii only | (b) ii and iv only    |
| (c) i, ii and iv   | (d) i, ii, iii and iv |

**Answer (c)**

**Sol.** The correct option is (c) as

- During a space flight launch, fluids in the human body experience shifts due to the absence of gravity. This can lead to changes in blood circulation, fluid distribution and pressure within the body.
- During space flight, there is reduction in plasma volume. The absence of gravity leads to fluids moving from the lower extremities to the upper body.
- During space flight, the absence of gravity leads to disuse of postural muscles.

16. **(1 point)** Students investigating the efficiency of oxygen transport measured the diameter and length of a trachea in four arthropods:

Arthropod P (Tracheal diameter - 0.1 mm, Tracheal length = 1 cm),

Arthropod Q (Tracheal diameter - 0.05 mm, Tracheal length = 2 cm),

Arthropod R (Tracheal diameter - 0.3 mm, Tracheal length = 1.5 cm) and

Arthropod S (Tracheal diameter - 0.4 mm, Tracheal length = 0.5 cm).

Based on the approximate tracheal volume (V), determine which one of the four arthropods (P – S) is likely to have the most efficient oxygen transport.

- |       |       |
|-------|-------|
| (a) P | (b) Q |
| (c) R | (d) S |

**Answer (c)**

**Sol.** The correct answer is option (c) as the volume of trachea directly affects the amount of oxygen that can be transported to cells. Larger tracheal volumes allow for more efficient gas exchange, ensuring an adequate supply of oxygen to support the insect's metabolic activities. Volume can be calculated by the formula;  $V = \pi r^2 h$  (where,  $\pi = 3.14$ ,  $r$  is half of diameter and  $h$  is length of tracheal tube)

By applying this formula, the highest tracheal volume is for arthropod R and the least is for arthropod Q.

17. **(1 point)** All aquatic animals whether marine, brackish or freshwater need to regulate their internal osmotic potential against the external one. Although the standard  $\text{Na}^+/\text{K}^+$ -ATPase pump operates at the basolateral cell membranes in these animals, the kinetic properties can vary based on the environment. Which of the following is true about the  $K_m$  (concentration for half maximal transport) for this enzyme?
- (a)  $K_m$  values in marine invertebrates are likely to be higher than fresh water invertebrates indicating high affinity for the pump.
  - (b) The enzyme in freshwater invertebrates is likely to show higher  $K_m$  values indicating low affinity for the pump.
  - (c) The enzyme in marine invertebrates is likely to show lower  $K_m$  values indicating higher affinity for the pump.
  - (d) The enzyme in freshwater invertebrates is likely to show lower  $K_m$  values indicating higher affinity for the pump.

**Answer (d)**

**Sol.** The correct answer is option (d) as, marine invertebrates are osmoconformers, their metabolic activity remains almost constant. As, they all are able to fix their internal homeostasis, the standard  $\text{Na}^+/\text{K}^+$ -ATPase pump need to be regulated more accurately in freshwater invertebrates.

To work with higher affinity w.r.t. the pump, the enzyme needs to have lower  $K_m$ , as lower  $K_m$  depicts higher affinity.

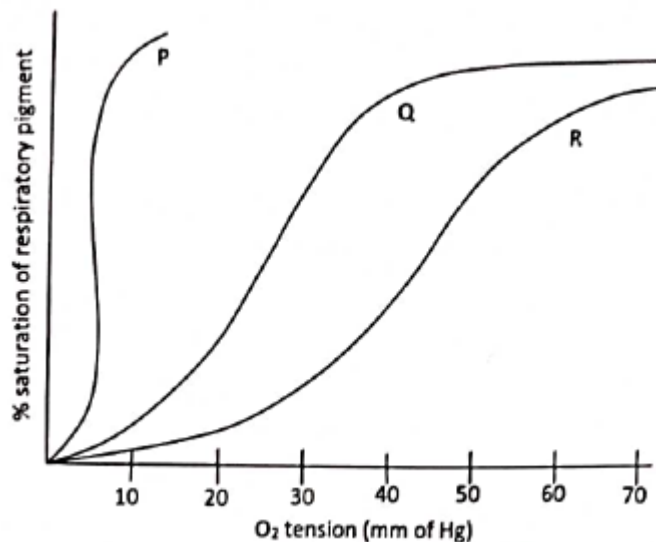
Therefore, the enzyme in freshwater invertebrates is likely to show lower  $K_m$  value indicating higher affinity for the pump.

18. **(1 point)** While rushing to the exam hall you fall and hurt your leg. You vigorously rub the affected area and feel less pain. This is because:
- (a) Rubbing the affected area releases analgesics (pain inhibitors) from the skin, which acts on the pain receptors.
  - (b) Vigorous rubbing opens mechanically-gated  $\text{Cl}^-$  channels on the sensory neurons causing  $\text{Cl}^-$  influx, which causes hyperpolarization of the sensory neurons.
  - (c) Vigorous rubbing desensitizes pain receptors at the affected area.
  - (d) Vigorous rubbing at the affected area generates multiple alternative impulses which act as competing sensory information.

**Answer (d)**

**Sol.** The correct answer is option (d) as vigorous rubbing in the affected area can generate multiple alternative sensory impulses, contributing to what is known as sensory competition. This concept aligns with the gate control theory of pain, which suggests that non-painful sensory input can compete with and inhibit the transmission of pain signals to the brain. The increased sensory input from rubbing may effectively close the gates in the spinal cord, reducing the perception of pain.

19. (1 point) Oxygen saturation curves of three animals (P-R) are shown.



Which of the following correctly explains the observed patterns?

- (a) Animal R is metabolically less active than animal Q.
- (b) Animal P requires to move its body in quick bursts and thus needs quick and large supply of oxygen in a short span of time.
- (c) Animal Q is likely to be found at higher altitude as compared to animal P.
- (d) Animal P is likely to be found in highly anoxic conditions as compared to animal R.

**Answer (d)**

**Sol.** The correct option is (d).

Metabolically active animals require more  $O_2$  and for that the affinity towards the respiratory pigment should be less. Hence, for animal R, the graph if shown in right means it is metabolically more active than P and Q.

If animal P need large supply of oxygen in a short span of time means the affinity of oxygen should be less. Therefore, it is incorrect w.r.t to curve shown as P.

Animal P is found in highly anoxic conditions as compared to R and the affinity of haemoglobin to oxygen is high in P that leads to less availability of oxygen to tissues.

Animal P is found at higher altitude as compared to animal Q, as P have adapted by lowering the  $P_{50}$  value. Thus, P would more easily obtain oxygen from a low pressure environment.

20. (1 point) The glomerular filtration rate (GFR) can be determined through the direct measurement of the clearance of exogenous substances, such as inulin, injected into the body. Alternatively, it can be indirectly calculated by evaluating the clearance of endogenous substances like creatinine. In primates, including humans, there is a certain amount of creatinine secretion and/or reabsorption in kidney tubules, which is absent in non-primate mammals. Which of the following statements are correct?
- (i) The measurement of clearance of creatinine can be employed for the precise assessment of GFR in humans.
  - (ii) The measurement of clearance of inulin can be employed for the precise assessment of GFR in humans.
  - (iii) The measurement of clearance of creatinine can be employed for the precise estimation of GFR in non-primate mammals.
  - (iv) The measurement of clearance of inulin can be employed for the precise assessment of GFR in non-primate mammals.

- (v) Measurement of clearance of inulin will be less accurate than creatinine as inulin is not produced by the body.

Options:

- |                              |                               |
|------------------------------|-------------------------------|
| (a) (i), (ii) and (v) only   | (b) (ii), (iii) and (iv) only |
| (c) (iii), (iv) and (v) only | (d) (i) and (v) only          |

**Answer (b)**

**Sol.** The correct option is (b).

For precise assessment of GFR in humans, inulin clearance would be more accurate if compared to creatinine clearance measurement because in primates (certain amount of creatinine secretion/absorption takes place), and therefore it probably would not give precise assessment of GFR.

In non-primates mammals, neither inulin nor creatinine get absorbed/secreted, therefore both can be used to determine GFR.

21. **(1 point)** The freshwater environment can be classified into two natural divisions namely lentic (standing water bodies) and lotic (running water bodies). In lotic habitat with rapid streams, several body adaptations can be observed in animals. A few are listed below. Which of these apply to lotic habitat?

- (i) Body with hooks and suckers
- (ii) Sticky dorsal surfaces
- (iii) Positive thigmotaxy (response of an animal to contact or touch)
- (iv) Negative rheotaxy (response to oncoming current)
- (v) Streamlined body

Options:

- |                         |                              |
|-------------------------|------------------------------|
| (a) (i) and (iv) only   | (b) (ii), (iii) and (v) only |
| (c) (iii) and (iv) only | (d) (i), (iii) and (v) only  |

**Answer (d)**

**Sol.** Option (d) is the correct answer as, lotic habitats include running water bodies, the organisms inhabiting these areas must exhibit adaptations like:-

- (i) Body with hooks and suckers → Hooks and suckers help organisms to attach themselves to a surface in flowing water.
- (ii) Sticky under surface → Many animals are able to adhere to the surface of the strata by their sticky under surfaces.
- (iii) Positive thigmotaxy → 'Thigmo' means 'touch' and 'taxis' means 'arrangement'. Many stream animals have an innate, inherent behaviour pattern to cling close to a surface or to keep the body in close contact with the surface.
- (iv) Positive rheotaxy → Stream animals almost invariably orient themselves upstream and if capable of swimming movements, they continually move against the water current.
- (v) Streamlined body → It helps minimise resistance against the flowing water.

### **GENETICS & EVOLUTION (6 points)**

22. **(1 point)** What are the three essential requirements for natural selection to occur?

- (a) Large population sizes, variation in traits, differential survival and/ or reproduction.
- (b) Large population sizes, heritability of traits, sexual reproduction.
- (c) Variation in traits, heritability of traits, differential survival and/ or reproduction.
- (d) Sexual reproduction, variation in traits, heritability of traits.

**Answer (c)**

**Sol.** Option (c) is the answer because, evolution by natural selection is the inevitable consequence of three simple conditions, *i.e.*, variation in traits, inheritance and differential reproductive success.

23. **(1 point)** In plants, Cytoplasmic Male Sterility (CMS) arises due to mutations in the mitochondrial genome. In many cases it has been found that male fertility can be restored by nuclear encoded fertility restorer ( $Rf$ ) gene. Lines that can restore CMS are called fertility restorer lines. A cross is made between a CMS and  $Rf$  line. All progeny produced are male fertile. If the progeny is selfed, what percentage of the progeny will be male fertile?

- (a) 0 (b) 25  
(c) 50 (d) 75

**Answer (d)**

**Sol.**  $Rf \rightarrow$  Fertility restorer line  $\rightarrow$  Male fertile

$rf \rightarrow$  Non-restorer line  $\rightarrow$  Male sterile

Parents: CMS/ $rf$   $\times$   $RfRf$   
Sterile male Fertile

Gametes  $(rf)$   $(Rf)$

$F_1$  progeny  $Rfrf$   $\times$   $Rfrf$  (Selfing)  
fertile male

Gametes  $(Rf)$   $(rf)$   $(Rf)$   $(rf)$

$F_2$  gen

	$(Rf)$	$(rf)$
$(Rf)$	$RfRf$ fertile male	$Rfrf$ fertile male
$(rf)$	$Rfrf$ fertile male	$rfrf$ sterile male

Thus, 75% of the progeny will be male fertile.

24. **(1 point)** Attenuation is a regulatory mechanism in tryptophan operon that results in premature termination of transcription. Such mechanism is not possible in an eukaryote because

- (a) Polycistronic mRNA is not transcribed.  
(b) Transcription and translation are not coupled  
(c) Sigma factor is not involved in transcription initiation  
(d) Shine-Dalgarno sequence needed for ribosome recognition is absent in eukaryotic mRNA

**Answer (b)**

**Sol.** Ribosome-mediated attenuation of the *trp* operon relies on the fact that in bacteria, transcription and translation proceed simultaneously.

Such attenuation mechanism is not possible in eukaryotes as in eukaryotes, transcription occurs in nucleus and translation occurs in cytoplasm *i.e.*, they are not coupled.

Thus, option (b) is correct.

Option (a) is incorrect as polycistronic mRNA can be transcribed in eukaryotes.

Option (c) and (d) are incorrect as the sigma factors and Shine-Dalgarno sequences are not regulating process of transcription in eukaryotes.

25. **(1 point)** While considering the genetic basis of behaviour, there are three levels where variation can contribute to behavioural differences, namely genome composition (X), gene variants (Y) and gene expression (Z).

Consider members of the following 3 species:

- (i) *Drosophila simulans*
- (ii) *Drosophila sechellia*
- (iii) *Culex pipiens*

Which of the following statements is true?

- (a) Members of (i) will differ from each other with respect to only Z.
- (b) Members of (i) and (ii) will differ from each other with respect to only Y and Z.
- (c) Members of (i), (ii) and (iii) will differ from each other with respect to X, Y and Z.
- (d) Members of (i) and (ii) will have the same X, Y and Z if they share the same environment and habitat.

**Answer (a)**

**Sol.** Members of same species closely resembles in the genetic constitution but can vary in terms of gene expression due to the environment and subsequent conditions. Thus (a) is correct.

Sister species like *Drosophila simulans* and *Drosophila sechellia* have same ancestor but vary in terms of gene, which means they can be majorly show behavioural variation because of being gene variant. In these gene expression is entirely different thus it cannot be considered as a basis of classification. Thus, option (b) cannot be considered appropriate.

(i) and (ii) will show entirely different genetic composition than (iii). Thus, we can negate option (c) as it is considering that (i) and (ii) both have different genome composition.

(i) and (ii) will not have the same variations in gene as they are sister species. Also, sechellia is restricted island species but simulans has a wide distribution. Thus option (d) can also be negated.

26. **(1 point)** Which of the following statements best describes evolution?
- (a) Genetic drift is a random process, but mutation and selection are non-random.
  - (b) Mutation and genetic drift are random processes, but selection is non-random.
  - (c) Mutation and selection are random processes, but genetic drift is non-random.
  - (d) Selection is a random process, but mutation and genetic drift are non-random.

**Answer (b)**

**Sol.** Option (b) is the answer because, mutations according to Hugo deVries are random and directionless.

Genetic drift is the change in frequency of an existing gene variant in the population due to random chance.

The genetic variation on which natural selection acts may occur randomly but selection itself is not random at all.

Hence, mutation and genetic drift are random processes but selection is non-random.

27. **(1 point)** In 2020, doctors used convalescent plasma therapy to treat coronavirus disease 2019 (COVID-19). This therapy used plasma from people who had recovered from COVID-19 which was transfused to the patient.
- i. Person who caught infection after being vaccinated and then recovered are likely to be better donors than those who were not vaccinated.
  - ii. The donor's plasma should have high levels of antigen for the treatment to be effective.
  - iii. In plasma therapy a person with AB Rh+ blood group will be universal donor.

Which one of the following options represents all correct statements?

- (a) ii only
- (b) ii and iii only
- (c) i and iii only
- (d) i, ii and iii

**Answer (c)**

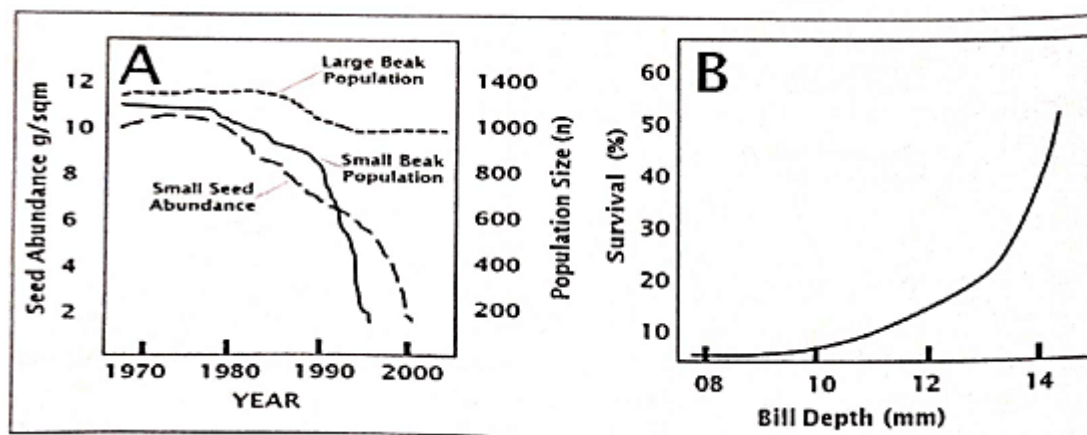
**Sol.** Option (c) is the correct answer as, individuals who have caught infection after being vaccinated and then recovered are considered as better donors because their plasma will contain high levels of antibodies as compared to individuals who are not vaccinated.

The donor's plasma should have high levels of antibodies (not antigen) for the treatment to be effective.

Individuals with AB blood group is the only universal donor for blood plasma as they do not contain any antibodies in their plasma against blood group antigens to interfere with the treatment.

#### **ECOLOGY (4 points)**

28. **(1 Point)** The bird species inhabiting the Gir forest had beak size (bill depth) variations from 8 mm to 14 mm and fed upon seeds of different sizes and hardness. Normal rainfall during 1950 to 1975 led to abundant growth of different plant species and therefore availability of seeds of different sizes. Severe recurring drought during 1975 to 1985 led to decline in the growth of small seed producing plants decreasing the small sized seed availability and a proportionate increase in the availability of bigger and harder seeds. In next ten years the bird population declined drastically due to mortality (Fig. A). The relationship of survival % and bill depth is shown in Fig B.



Which type of selection process is occurring under such an unfavourable condition?

- Stabilizing selection that modifies the mean of the beak size to stabilize it near the population mean.
- Directional selection that modifies the mean of the beak size towards one extreme.
- Disruptive selection that modifies the mean of the beak size into two populations, one with high survival and the other with a low survival rates.
- Conditional selection that modifies the mean of the beak size such that it can revert back to normal distribution easily once the evolutionary pressure subsides and the population mean does not change.

#### **Answer (b)**

**Sol.** Option (b) is the answer as the population of small beaked birds decreased drastically whereas large beaked population survived (As observed in Fig A).

And we can see that more the bill depth, higher the survival rate (in Fig B).

Here, selection acted to eliminate one extreme form and supported the other extreme. Hence, this is an example of directional selection.

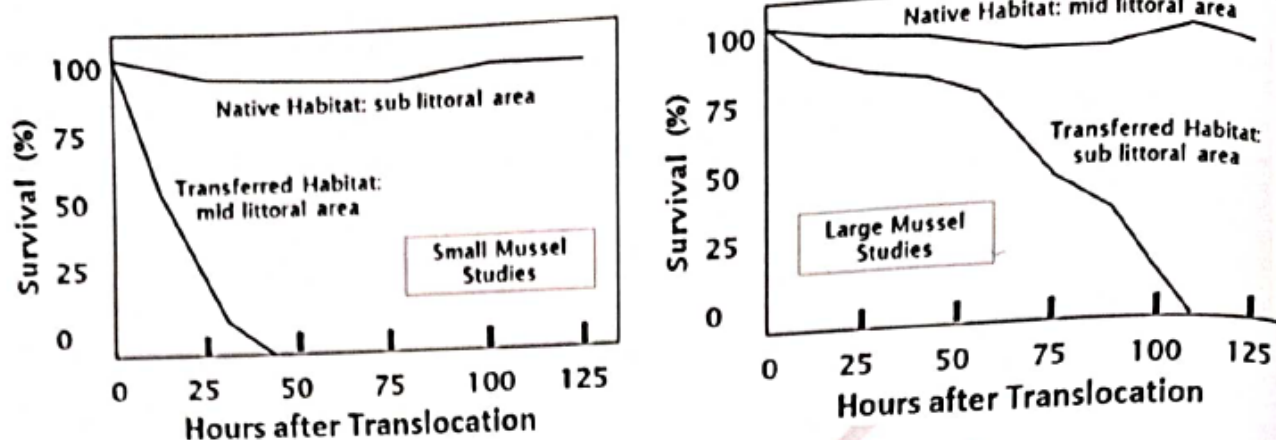
29. **(1 point)** Herbivores have evolved to feed effectively, while plants have countered with a wide variety of anti-herbivore defences. Extrafloral nectar is one such defence tool which attracts diverse predators and parasitoids, especially ants. Higher volumes of extrafloral nectar production attract more ants and can increase their aggressiveness. The relationship between the plant and the ants can be correctly described as:

- Mutualism
- Antagonism
- Commensalism
- Amensalism

#### **Answer (a)**

**Sol.** Extrafloral nectar produced by plants which attracts predators and parasitoids but especially ants. This interaction is an example of protection mutualism in which ants can reduce the foliar herbivory and increasing the fitness of the plant. Extrafloral nectars are generally active on the young leaves which are more vulnerable to damage. So, some species of plants produce extrafloral nectar on reproductive structures like fruits, floral buds etc. which directly influence the fitness of plant as ants feed on these structures and protect them against seed eating herbivores, lead to increase in fruit production.

30. **(1 Point)** The mussels are widespread species on the rocky shore of West Coast of India. Small sized mussel species occur abundantly on the sub littoral areas while large sized mussel species occur abundantly on the mid littoral area. Experiments were carried out where their locations were interchanged. The following graphs show survival % of both the mussel varieties in each habitat; their own native and translocated ones. Three species of crabs and one species of starfish were noted as predators of mussels. It was believed that predation of small mussel in mid littoral area rapidly decrease their population. To ascertain this, laboratory experiments with prey and predators were also carried out.



Which of the following interpretations are correct?

- In the sub littoral area, heavy wave action restricts the size of mussels and prevents predators from eliminating small mussels.
- In mid littoral area, predators eliminate most of the small mussels leading to survival of large mussels.
- Prey individuals can survive when translocated to a site where they do not normally occur if they are protected from predators.
- The distributions of prey organisms and suspected predator(s) are inversely correlated in the area where survival rate of mussels is high.

(a) ii, iii and iv

(b) i, iii & iv

(c) i & ii only

(d) i, ii & iii

**Answer (a)**

**Sol.** Three species of crabs and one species of starfish were noted as Predators of mussels.

Size of mussel is not controlled by the different zones of the lake.

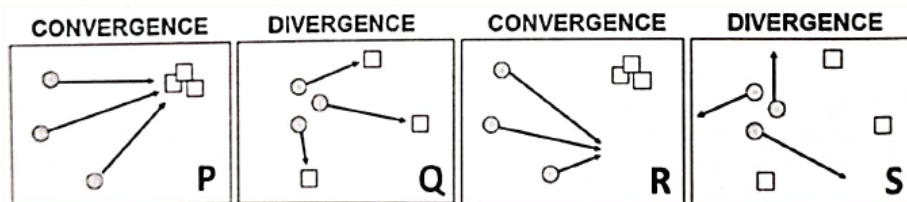
In mid littoral area, predators eliminate most of the small mussels leading to survival of large mussels.

Prey individual are protected from predators when they are translocated to another site.

The distribution of prey organism and suspected predators are inversely correlate in the area where survival rate of mussels is high.

Therefore statement, ii, iii and iv are correct.

31. (1 point) In the following diagram, four possible outcomes of Restoration programs are shown. They grey circles are present state of ecosystem and open squares are reference ecological end points. The arrows indicate the direction towards restoration and the ultimate achievement.



Mark appropriately the correct statement with reference to restoration goal accomplishment:

- 'P' is the best expected outcome since the restoration leads to single type of ecosystem from different existing states.
- 'Q' is a good outcome since the restoration leads to the reference ecosystems which are all of different types.
- 'R' is a good restoration program. Although, it largely deviates from the reference ecosystem, the three arrows are in single direction of restoration.
- 'S' is an unexpected but desirable restoration program where restoration leads to different and diverse type of ecosystems.

**Answer (b)**

**Sol.** Restoration can be done in two ways

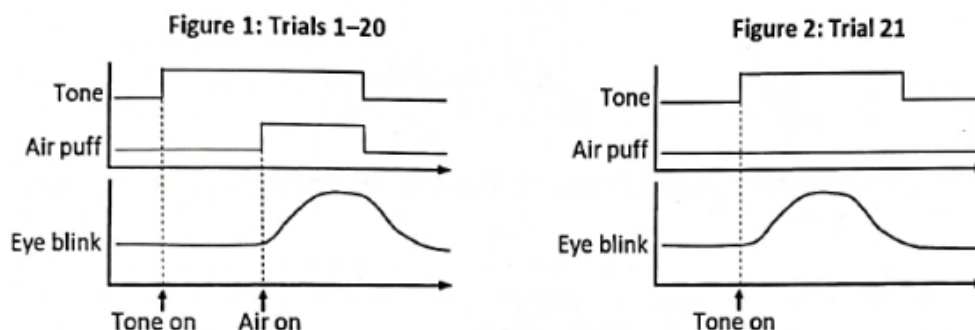
- Convergence in species composition
- Divergence in species composition

In condition R and S, the restoration is deviating from desired reference sites. In condition P, the restoration is leading to formation of single ecosystem which is good but not the best desirable outcome.

The condition Q is a good outcome as restoration leads to the formation of different ecosystems.

### **ETHOLOGY (2 points)**

32. (1 point) In a series of experiments led by Richard Thompson, a speaker was used to deliver a sound to a rabbit while a tube was used to deliver a puff of air to the eye. Blinking of the eye by the rabbit was recorded using a thread attached to the eyelid which triggered the eye movement measuring device. The results of trails 1 – 20 are shown in figure 1 and that of trail 21 is shown in figure 2.



Based on the graphs, which of the following statements is correct?

- (a) Figure 1 suggests that blinking of the rabbit eye is a conditioned reflex.
- (b) Figure 2 suggests that blinking of the eye in response to the tone is an example of innate behaviour.
- (c) Figure 2 suggests that this is an example of associative learning.
- (d) Paired stimuli i.e. both tone and air puff are required to elicit the eye blinking response by the rabbit.

**Answer (c)**

**Sol.** The correct answer is option (c) because,

we can see in the figure (1) that the study participants initially has no response to conditioned stimulus (Tone) but blink in response to the unconditioned stimulus (Air puff). After the CS and US are repeatedly paired, the individuals start to respond prior to the onset of US(as seen in Fig 2).

This is a dramatic evidence that the individual has learned the temporal relationship between the two stimuli. Hence, Fig 2 suggests that this is an example of associative learning.

33. **(1 point)** Culturally learned behaviours or information within a community are acquired through some from of social learning from conspecifics. These are transmitted socially rather than genetically and are shared by many members of the group. Which of the following animal behaviours would fall in this category?
- i. Baboons flaring their canines in threat display
  - ii. Japanese Macaques living on a seashore, washing peanuts in sea water before consuming.
  - iii. Nestlings of owls fluffing their body and spreading their wings to appear bigger in size.
  - iv. Female Olive Ridley turtles return to the same beach from where they hatched to lay their eggs.
- (a) i, ii and iii only
  - (b) ii and iv only
  - (c) iii and iv only
  - (d) i, ii, iii and iv

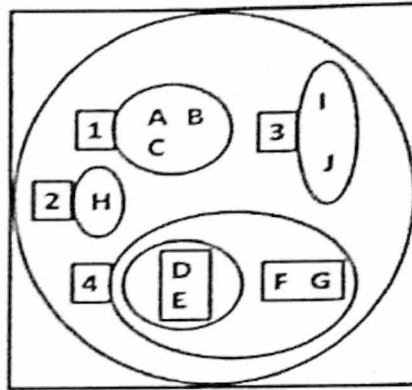
**Answer (a)**

**Sol.** The correct option is (a) as-

- (i) Higher primates such as chimpanzees, baboons, gorillas and orangutans share an elaborate communication system with one another using gestures, unique vocalizations, facial expressions and body language to convey information. This social and cultural learning extends to behaviours including play, gathering food, eating and communication.
- (ii) Japanese Macaques display a number of cultural behaviours including food washing, stone handling and certain grooming techniques.
- (iii) Nestlings of owls fluffing their body and spreading their wings to appear bigger in size occurs as an act of defense. This aggressive behaviour is considered as a social behaviour as even small owlets imitate it even in the absence of threat.

**BIOSYSTEMATICS (1 points)**

34. (1 point) In the following diagram, the relationship of species A to J is shown where 1, 2, 3 and 4 are the distinctive characters of the respective group of species. None of the character is symplesiomorphic for all the species.



Which of the following cladograms (P – S) correctly represents the relationships among species A – J?

- P.
- Q.
- R.
- S.
- (a) P (b) Q  
(c) R (d) S

**Answer (b)**

**Sol.** In the Q cladogram, character 1 is distinctive character of species A, B and C.

2<sup>nd</sup> character is distinctive of species H.

3<sup>rd</sup> character is distinctive of species I and J.

4<sup>th</sup> character is distinctive of species D and E and E and F.

So, option (b) is correct.

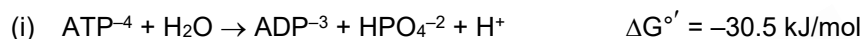
Option (a) is incorrect as cladogram P is showing that 4<sup>th</sup> character is symplesiomorphic for D, E, F, G, H, I and J.

Option (c) and (d) are incorrect as the cladograms R and S are showing that character 1 is symplesiomorphic for all the species.

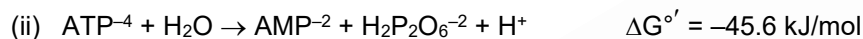
## SECTION-B

### CELL BIOLOGY (14.5 points)

35. (2 points) Adenosine triphosphate (ATP) is a commonly used energy coin in living system. Energy is released when the phosphates are hydrolysed in the following reactions:



In some reactions, the ATP is hydrolysed in another way as well:



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

- ATP is a thermodynamically unstable molecule.
- Hydrolysis of ATP in living systems does not require a catalyst.
- Since phosphate is a resonance stabilised molecule, the reaction is favoured towards hydrolysis.
- Since H<sup>+</sup> generated is quickly neutralised to maintain homeostasis, ATP hydrolysis is a favoured reaction.

### **Answer (T,F,T,T)**

- Sol. a. True.** ATP is thermodynamically unstable due to its high energy phosphate bonds, which release energy upon hydrolysis.
- b. False.** Hydrolysis of ATP in cells often requires a catalyst such as an energy. ATP hydrolase or ATPase, are a group of enzymes that catalyst ATP hydrolysis.
- c. True.** The resonance stabilisation of phosphate favour hydrolysis. The stable product drives the reaction forward and leads to hydrolysatation of ATP.
- d. True.** The quick neutralization of the released H<sup>+</sup> ions help maintain homeostasis, making ATP hydrolysis or favoured reaction for energy release.
36. (2 points) Atrazine and paraquat are the two herbicides used to control weed in farmlands. Atrazine acts by competitively binding with plastoquinone B binding site while paraquat under light takes up electrons from ferredoxin and transfers them to molecular oxygen.

A few statements about these herbicides are listed. Mark each of the statements as true or false by putting tick marks (✓) in the appropriate boxes.

- (a) Atrazine is an inhibitor of PSI & paraquat is an inhibitor of PS II.  
 (b) Atrazine is likely to act by affecting ATP production without reducing NADPH production.  
 (c) Paraquat is likely to induce necrosis due to formation of reactive oxygen species.  
 (d) Both herbicides act by interfering with the electron transport chain in mitochondria.

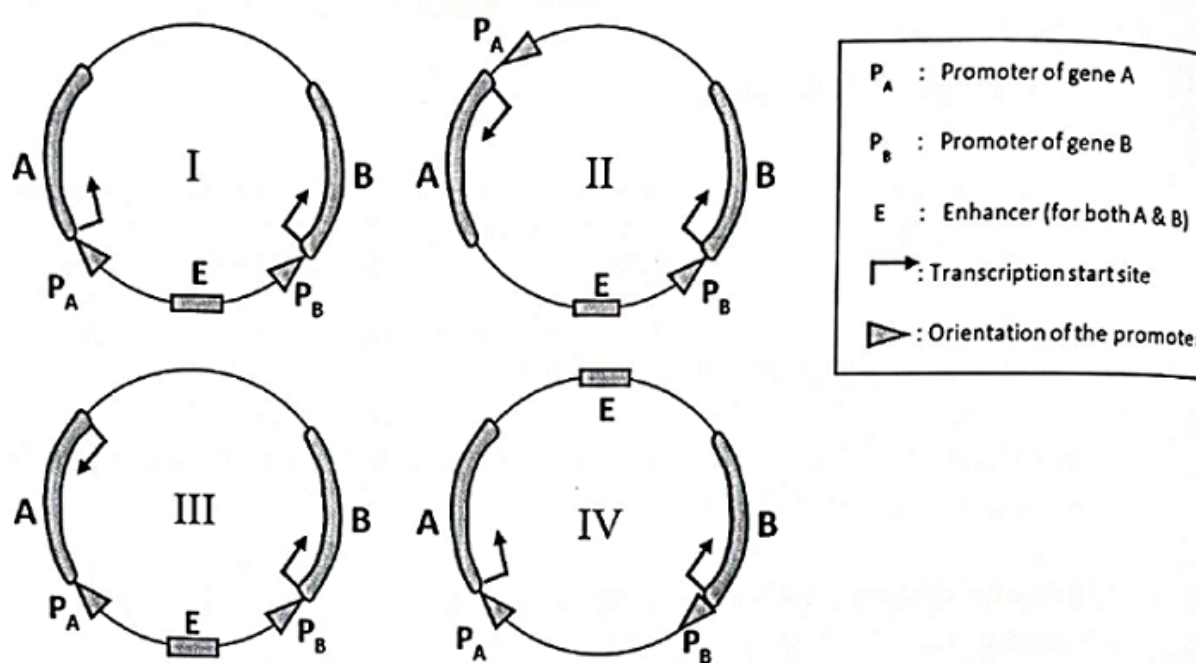
**Answer F, F, T, F**

**Sol.** Atrazine acts by competitive binding with plastoquinone and thus is an inhibitor of PS II.

Since atrazine inhibits PS II activity thus the further steps of the photophosphorylation will stop and NADPH production will not occur.

As the paraquat takes up electrons from ferredoxin and transfers to the molecular oxygen, the oxygen becomes reactive and cause damage to the cells. Plastoquinone and ferredoxin are present in chloroplast thus atrazine and paraquat do not interfere the ETS in mitochondria.

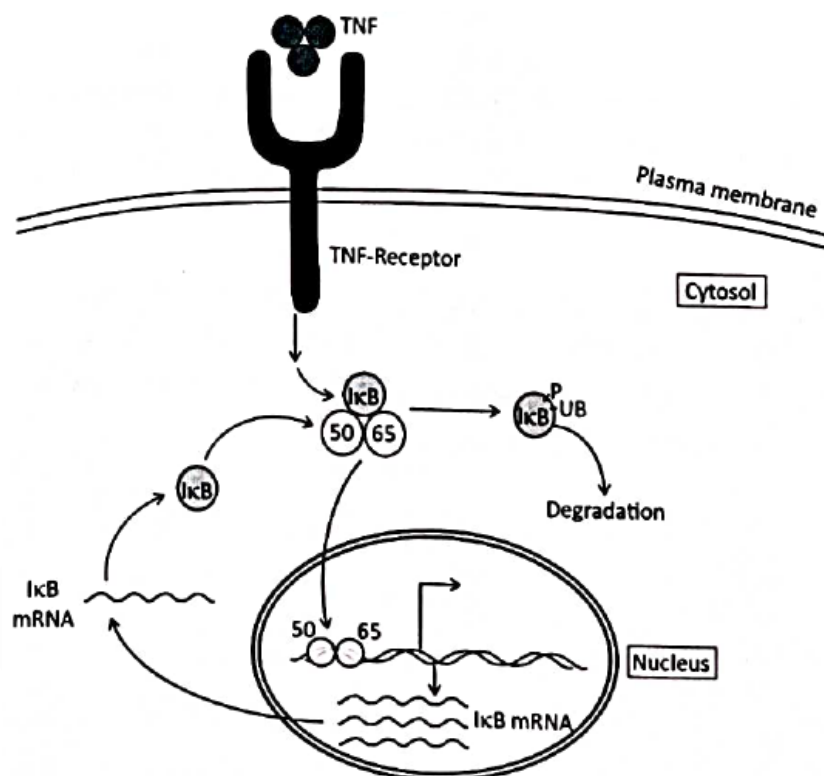
37. **(2 points)** Two eukaryotic genes A and B are cloned in an expression plasmid vector. Below are the four different constructs that were made. Indicate the expected outcomes for each construct by putting tick marks (✓) in the appropriate boxes. *Note that only a completely correct row will be given points*



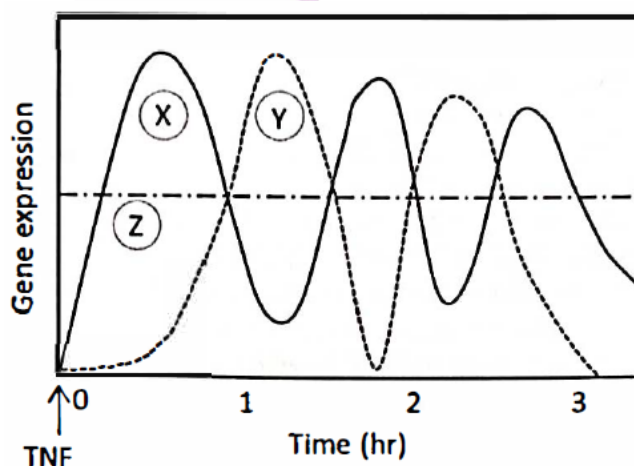
**Sol.**

	Gene A		Gene B	
	Will express	Will not express	Will express	Will not express
I	✓		✓	
II	✓		✓	
III		✓	✓	
IV	✓			✓

38. **(5 points)** Signal transduction events through transmembrane receptors in cells often culminate in the activation of a transcription factor. One such example is the activation of NF- $\kappa$ B (Nuclear Factor Kappa B) by TNF- $\alpha$  (Tumor Necrosis Factor- $\alpha$ ). NF- $\kappa$ B is a heterodimer of two subunits, p50 and p65, and it is retained in the cytoplasm by its inhibitor I $\kappa$ B- $\alpha$ . TNF signaling phosphorylates I $\kappa$ B- $\alpha$  leading to its degradation by ubiquitination. As a result, free NF- $\kappa$ B and its translocation into the nucleus, where it binds to a responsive promoter and activates gene expression. Activation of NF- $\kappa$ B by the TNF is transient in nature because one of the genes that NF- $\kappa$ B activates is the gene for I $\kappa$ B- $\alpha$  itself.

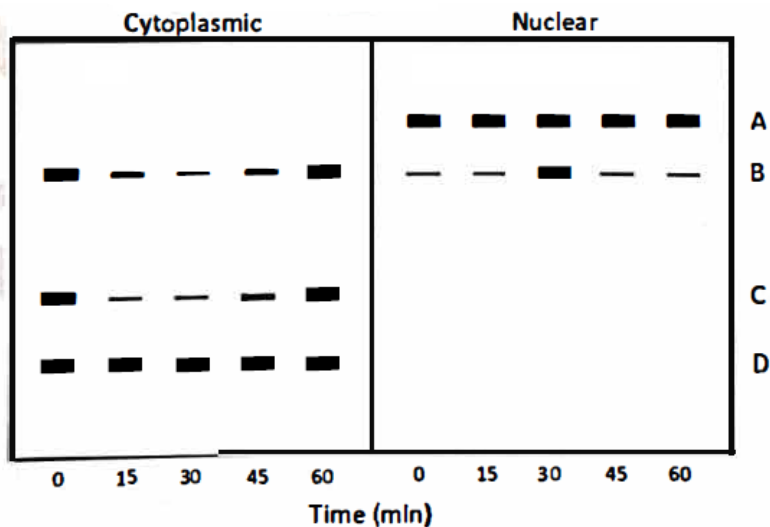


- (A) In one experiment, activation of NF- $\kappa$ B by TNF was studied in a macrophage cell line. The following were the results of gene expression of NF- $\kappa$ B responsive gene and the expression of I $\kappa$ B- $\alpha$  gene. Z in the graph represents expression of a housekeeping gene.



Indicate which one is NF- $\kappa$ B responsive gene and which one is the I $\kappa$ B- $\alpha$  gene expression. Fill in the appropriate alphabet (X or Y) in the table.

- (B) From the above experiment, cytoplasmic and nuclear extracts were prepared, proteins were separated on SDS-PAGE and Western blotting was performed using antibodies against p65 and I $\kappa$ B- $\alpha$  proteins. Also, antibodies against  $\alpha$ -actin and lamin were used to demonstrate the purity of the cytoplasmic and nuclear fractions as well as loading control.



Indicate which bands represent p65, I $\kappa$ B- $\alpha$ ,  $\alpha$ -actin and lamin respectively. Fill in the appropriate alphabet (A, B, C or D) in the table.

- (C) Experiments (1-4) were also conducted by adding either inducer or inhibitors of following activities and measuring the TNF-dependent NF- $\kappa$ B activated gene expression. Indicate the expected effect of each experiment by putting tick marks ( $\checkmark$ ) in the appropriate boxes.

**Sol.**

(A)	NF- $\kappa$ B responsive gene expression	I $\kappa$ B- $\alpha$ gene expression
	'X'	'Y'

TNF signalling phosphorylates I $\kappa$ B- $\alpha$  leading to its degradation and activates the gene expression of NF- $\kappa$ B

(B)	A	B	C	D
	Lamin	p65	I $\kappa$ B- $\alpha$	$\alpha$ -actin

Lamin is a nuclear protein.

(C)

No.	Effector in the presence of TNF	TNF dependent NF- $\kappa$ B induced gene expression	
		Induced	Inhibited
1	Inhibitor of kinase activity		$\checkmark$
2	Activator of phosphatase activity		$\checkmark$
3	Activator of ubiquitin dependent proteasome activity	$\checkmark$	
4	Inhibitor of nuclear transport activity		$\checkmark$

39. **(1.5 points)** Xanthine oxidase (XO) is a flavoenzyme with an atom of molybdenum and four iron-sulphur centers in its prosthetic group. It uses molecular oxygen as an electron acceptor to convert hypoxanthine to uric acid as a part of catabolism of purines. Excessive accumulation of uric acid causes a disease of joints called gout. Allopurinol is a compound that is used as a drug to inhibit the activity of XO. However, allopurinol is a substrate for XO and is converted to oxypurinol by XO. The oxypurinol tightly binds to the active site of XO. Further, since XO uses molecular oxygen for its activity, it produces reactive oxygen species (ROS).

In light of the above, mark each of the statements as true or false by putting tick marks (✓) in the appropriate boxes.

- Allopurinol can be classified as a suicide substrate for XO.
- Inhibition of XO by allopurinol will follow a competitive inhibition mechanism.
- In myocardial ischemia, XO catalysed hypoxanthine degradation is a major source of ROS and in such cases allopurinol can act as a potential drug.

**Sol.**

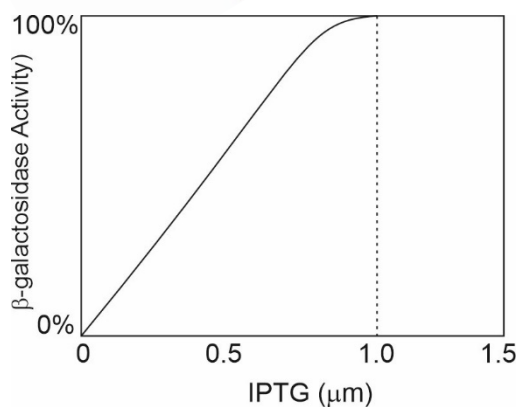
a	b	c
x	✓	✓

Statement (a) is false as oxypurinol is an active metabolite of allopurinol and is an inhibitor of xanthine oxidase.

Statement (b) is true as allopurinol is a competitive inhibitor of xanthine oxidase and blocks the conversion of purines to uric acid.

Statement (c) is true as inhibition of XO limits the formation of radical oxygen species hereby prevents the oxidative stress. Therefore, allopurinol can act as a potential drug.

40. **(2 points)** IPTG is a gratuitous inducer of *E.coli* lac operon. It induces the operon by binding to the lac-repressor. In an attempt to find out the number of lac-repressor molecules in each *E.coli* cell, the following experiments were done using mid-log phase *E.coli* cells:



Assume that IPTG freely permeates in the cell and its concentration in the medium and the cell equilibrates fast. Also assume that each lac-repressor (a tetramer) binds to 4 IPTG molecules. If the *E.coli* is taken as a sphere of 1  $\mu\text{m}$  diameter, calculate the number of lac-repressor (tetrameric) molecules in each *E.coli* cell.

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

**Sol.** Since, the activity of  $\beta$ -galactosidase reaches its maximum i.e., 100%, at the concentration of  $1.0 \mu\text{M}$  of the IPTG and 4 molecules of IPTG binds with one lac-repressor.

$1.0 \mu\text{M}$  solution of IPTG will have  $1.0 \times 10^{-6} \times 6.023 \times 10^{23}$  molecules of IPTG.

Therefore, number of repressor (tetrameric) molecules =  $\frac{6.023 \times 10^{17}}{4} = 1.505 \times 10^{17}$  molecules

### **PLANT SCIENCES (13 points)**

41. **(2 points)** For a plant in which the first stable product of  $\text{CO}_2$  fixation is a 3-carbon compound, about 500 molecules of water are lost for every molecule of  $\text{CO}_2$  fixed by Photosynthesis. This ratio is defined as the transpiration ratio (TR). Thus, the transpiration ratio of C3 plants is about 500. Sometimes this is expressed as water use efficiency which is the reciprocal of the TR. Indicate if each of the following conditions would lead to increased or decreased water use efficiency by putting tick marks ( $\checkmark$ ) in the appropriate boxes.

- (a) Decreased water efflux and increased  $\text{CO}_2$  influx.
- (b) Low concentration of  $\text{CO}_2$  in the air and relatively high concentration of water vapour within the leaf.
- (c)  $\text{CO}_2$  molecules having a smaller diffusion coefficient than water.
- (d) The plasma membrane, cytoplasm and chloroplast envelope adding to the resistance in the  $\text{CO}_2$  diffusion pathway.

**Sol.**

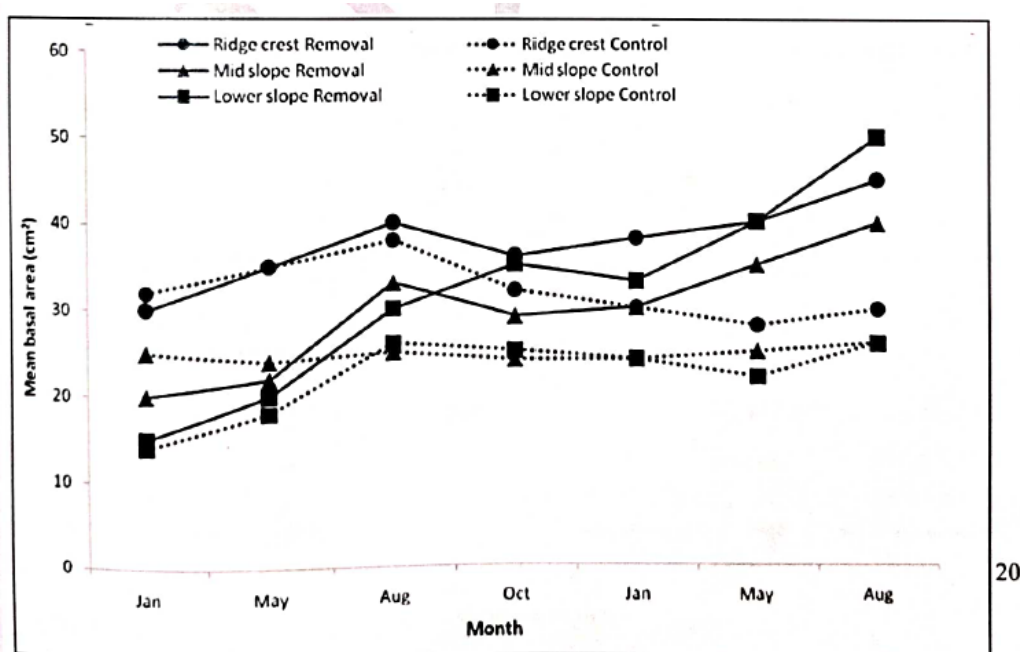
	Increased	Decreased
a.	$\checkmark$	
b.		$\checkmark$
c.		$\checkmark$
d.		$\checkmark$

- (a) Since water transpiration is less and  $\text{CO}_2$  intake is more, the water use efficiency will be increased.
- (b) As the water vapour concentration inside the leaf is more, but low concentration in the atmosphere shows that it evaporates more water for the intake of  $\text{CO}_2$  and thus shows decreased water use efficiency.
- (c) Smaller diffusion coefficient of  $\text{CO}_2$  as compared to water would lead to more water uptake and thus decreased water use efficiency.
- (d) Resistance of plasmamembrane, cytoplasm and chloroplast envelope w.r.t.  $\text{CO}_2$  will lead to high transpiration ratio and thus decreased water use efficiency.

42. **(2.5 point)** The given table lists different traits of leaves in two types of plant species namely sun-loving and shade-loving. Complete the table by filling the symbols 'H' for high/higher, 'L' for low/lower and 'S' for similar for a given trait when these two types of plants are compared.

**Sol.** Data Insufficient

43. **(2 points)** *Stipa neomexicana* is a  $C_3$  perennial grass found in semi arid grassland communities of south eastern Arizona. It is found only in dry ridge crests (highest part of the ridge) where the cover of other grass species is low. An experiment is performed wherein neighbouring plants from individuals of *Stipa* have been removed. Comparison of the mean basal area of *Stipa* plants in control (non-removal) and removal conditions are given in the graph. Select the correct statements.



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

- The removal of other species allows the growth of *Stipa neomexicana* throughout the crests.
- The seasonal variation is the only factor affecting the mean basal area of *Stipa neomexicana*.
- This is a typical example of resource partitioning of *Stipa neomexicana*.
- This is a typical example of role of interspecific competition on the distribution of *Stipa neomexicana*.

**Answer (a, d)**

**Sol.** Option (a) is correct as it is evident from the graph that without competitors *Stipa* would grow more rapidly and/or reproduce more successfully in the lower, moist sites than on the sites where it is usually found i.e., on the crest.

Option (b) is incorrect that apart from seasonal variation competitive capability, resource utilisation etc. are also the factors that affect the mean basal area of *Stipa neomexicana*.

Option (c) is incorrect as if *Stipa* was capable of resource partitioning than it should have equal growth in control samples as well.

Option (d) is correct as after the removal of other species interspecific competition gets negated and thus *Stipa* shows enhanced growth.

44. (3 points) Auxins play an important role in the growth of plants. The distribution of auxin and the resulting changes in the shoot growth were being observed in the plant kept near a window (plant 1) and the shoot of a fallen potted plant exhibiting negative gravitropism (plant 2). Complete the table by putting tick marks in the appropriate boxes for the two plants.

**Sol.** Data Insufficient

45. (2 points) The tallest trees in the world are the Sequoia and Eucalyptus trees found in North America and Australia respectively. The two main factors affecting the movement of water upto the top of the tree are the frictional drag of moving water from the soil to the top of tree and the frictional resistance due to gravity. Considering this, what would be the minimum pressure difference required to transport water from the base of the tree to the top of a 125 metres tall tree?

The pressure gradient generally found in trees is  $0.02 \text{ MPa m}^{-1}$  and the pressure due to weight of a standing column of water is  $0.01 \text{ MPa m}^{-1}$ .

*Note that the final answer will be given marks only if calculations are shown in the box given and the final answer is filled in the blank.*

**Sol.** Pressure gradient ( $\Delta P$ ):  $0.02 \text{ MPa/m}$

Pressure due to the weight of a standing column ( $\Delta P_{\text{gravity}}$ ):  $0.01 \text{ MPa/m}$

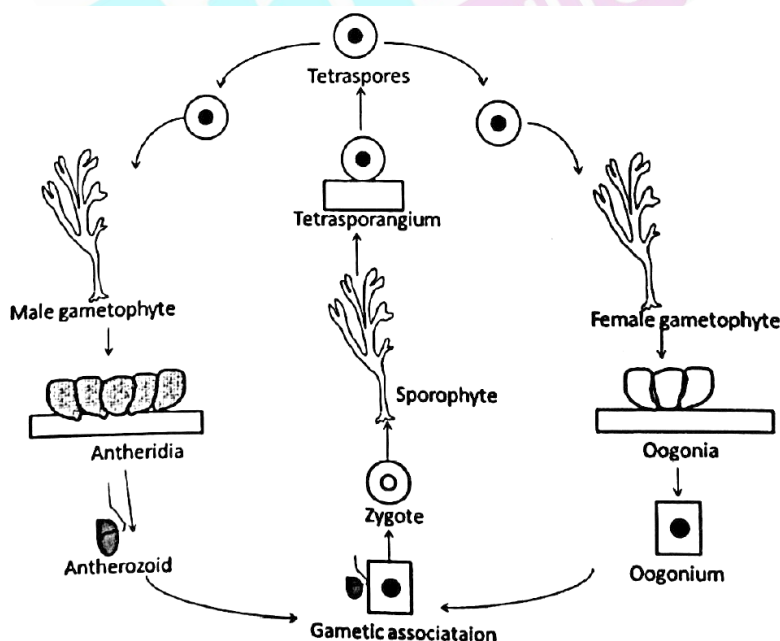
1<sup>st</sup>, we calculate the total pressure difference required to overcome both frictional drag and gravity:

$$\begin{aligned} \text{Total pressure difference } (\Delta P_{\text{total}}) &= \Delta P + \Delta P_{\text{gravity}} \\ &= 0.02 \text{ MPa/m} + 0.01 \text{ MPa/m} \\ &= 0.03 \text{ MPa/m} \end{aligned}$$

Now, we multiply the total pressure difference by the height of the tree to get the minimum pressure difference required for the entire height of the tree:

$$\begin{aligned} \text{Minimum pressure difference} &= \Delta P_{\text{total}} \times \text{Height} \\ &= 0.03 \text{ MPa/m} \times 125 \text{ m} = 3.75 \text{ MPa} \end{aligned}$$

46. (1.5 points) The life cycle of *Dictyota* (Brown algae) is given below



Based on the figure, mark the following statements as true or false by putting tick marks (✓) in the appropriate boxed.

- Fertilization is external
- Alternation of generations is isomorphic
- Gametophyte is homothallic

**Answer (T,T,F)**

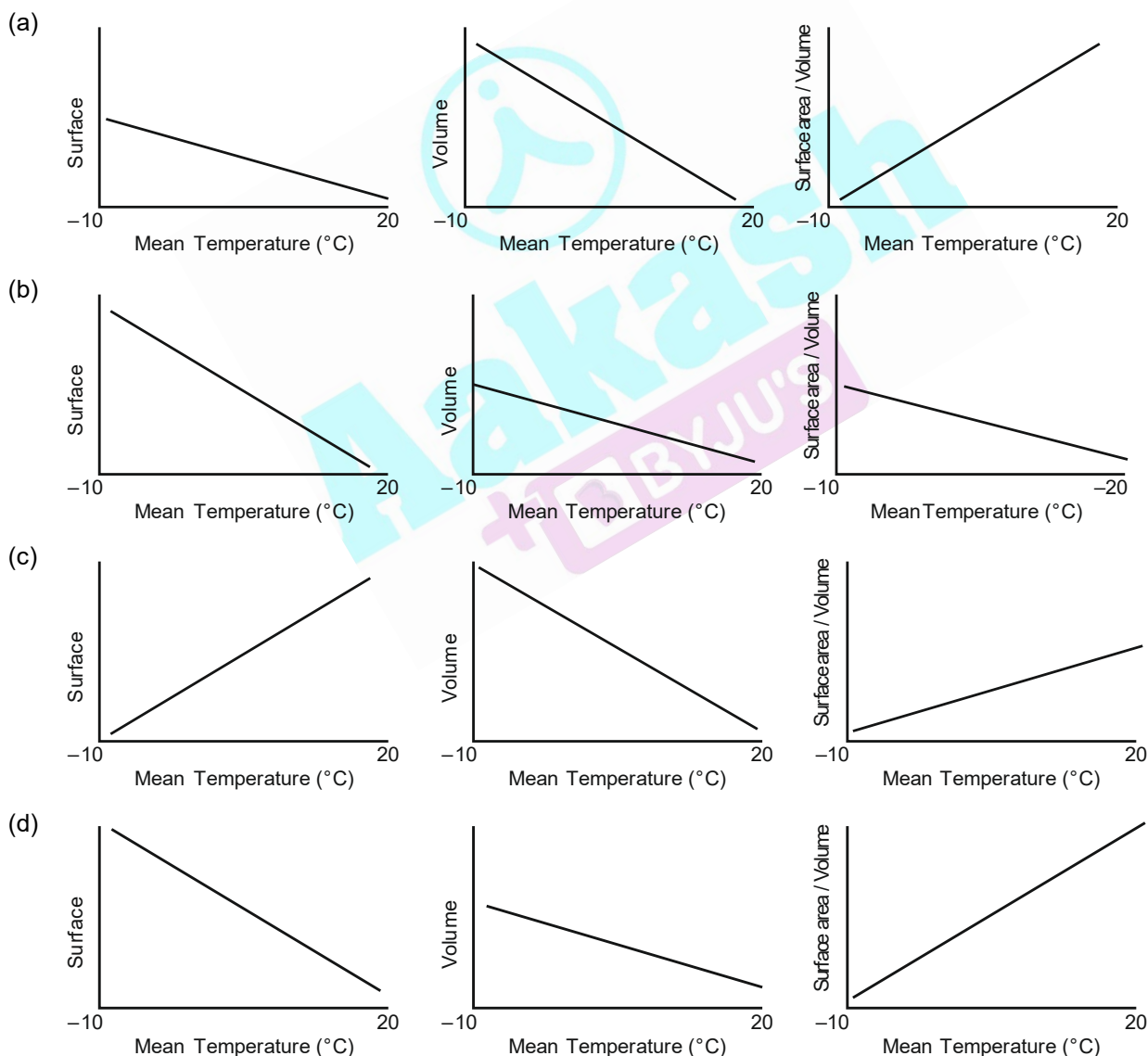
**Sol.** In alga *Dictyota*

- Fertilization occurs in external medium.
- Alternation of generations is isomorphic type
- The gametophyte is heterothallic as male and female sex organs are present on separate thalli.

So correct answer is a-T, b-T and c-F.

### ANIMAL SCIENCE (12 points)

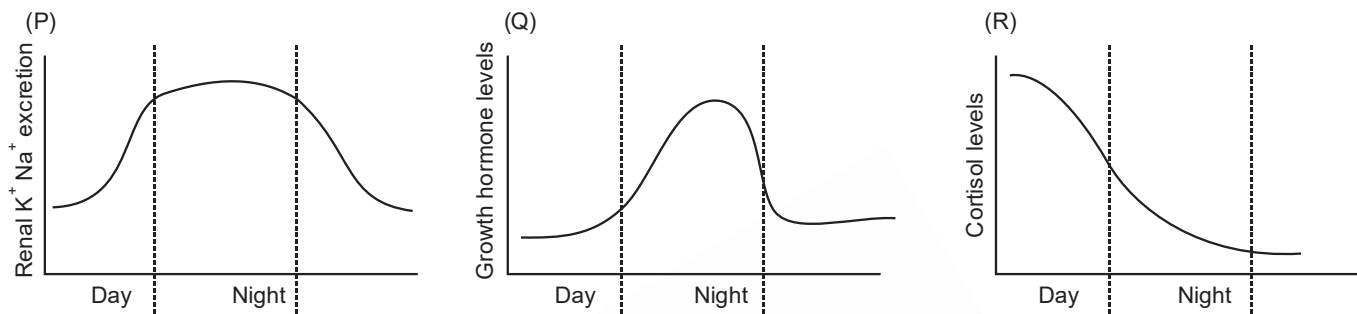
47. (2 points) Geographical variations in temperature show profound effect on evolution of life on earth. It is known that endotherms are likely to have larger bodies in colder climates at higher latitudes. Which of the following set of graphs correctly depicts this? Choose the right combination of graphs and put a tick mark (✓) in the appropriate box.



**Answer (c)**

**Sol.** The correct answer is option (c) because in the given condition surface area is decreasing but volume is increasing in the colder climate at higher latitude. If we plot a graph between surface area and mean temperature on x and y axis respectively, it will show a graph having a straight line with negative slope in a decreasing temperature while in increasing temperature it will show a straight line with positive slope. Graph between volume and increasing mean temperature will show a straight line with negative slope. The surface volume ratio will increase in increasing temperature.

48. (3.5 points) (A) Circadian rhythms of three biological processes/hormones are depicted in graphs P-R.

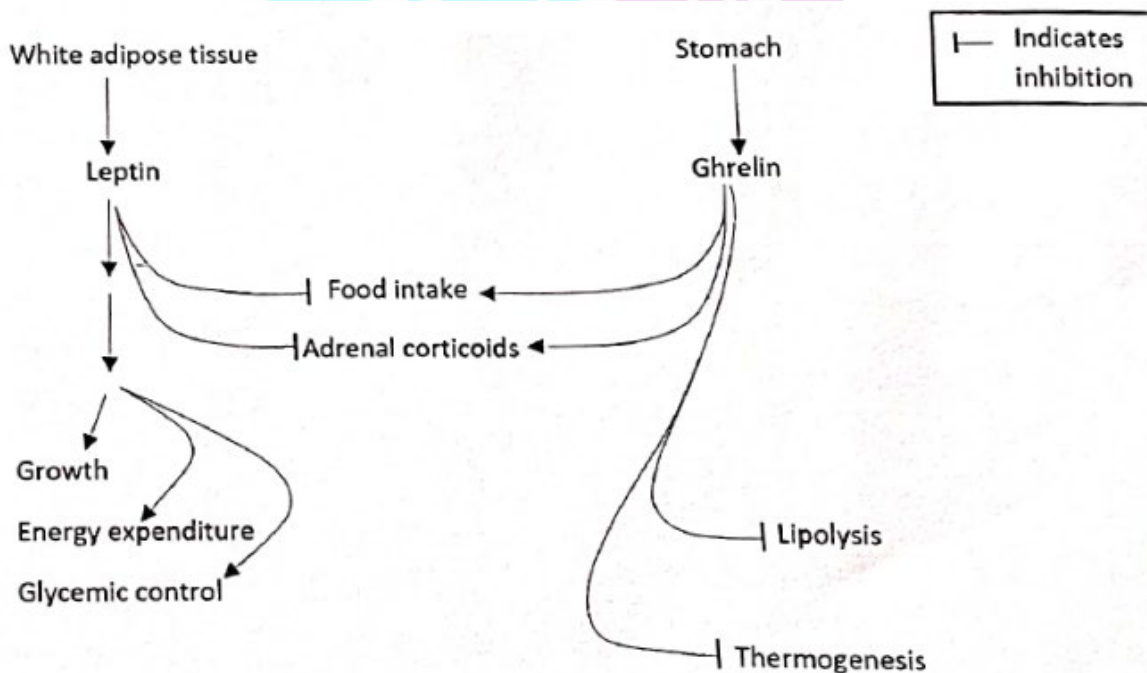


Match the type of animal to each graph and fill in the correct options in the blanks.

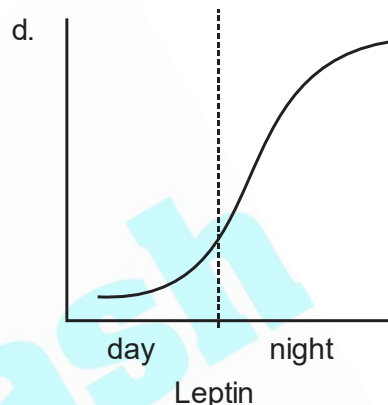
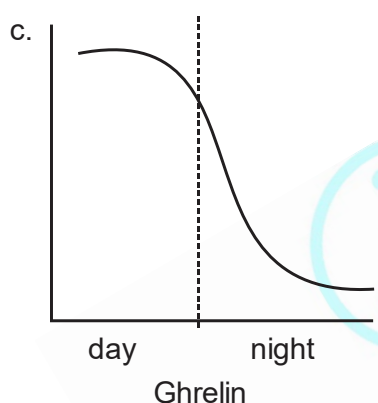
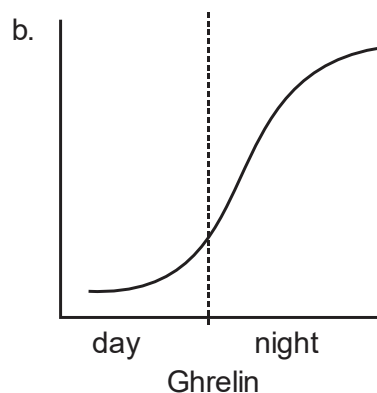
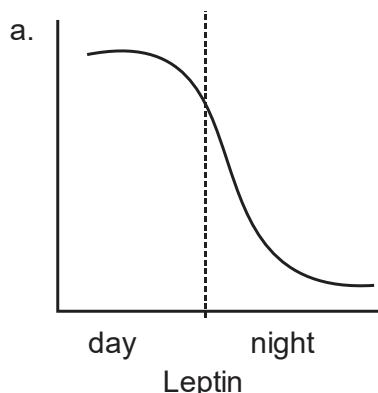
Options for type of animal :

- Nocturnal only
- Diurnal only
- Either diurnal or nocturnal

(B) Leptin and ghrelin are hormones associated with various physiological functions, especially energy balance. The modes of actions of these hormones are shown below.



Indicate whether each of the following graphs represents the correct or incorrect pattern in nocturnal animals by putting tick marks (✓) in the appropriate boxes.



**A. Sol.** Graph (P) represents nocturnal only i.e. (a)

Graph (Q) represents diurnal only i.e. (b)

Graph (R) represents diurnal only

**B. Sol.** w.r.t. nocturnal animals graph (a) and graph (b) are correct while graph (c) and (d) are incorrect.

Leptins inhibit food intake and levels of adrenal corticoids so, in nocturnal animals, its levels should be very low in night hours.

Ghrelin requires for food intake and increases adrenal corticoids levels hence, its level remain high during night hours.

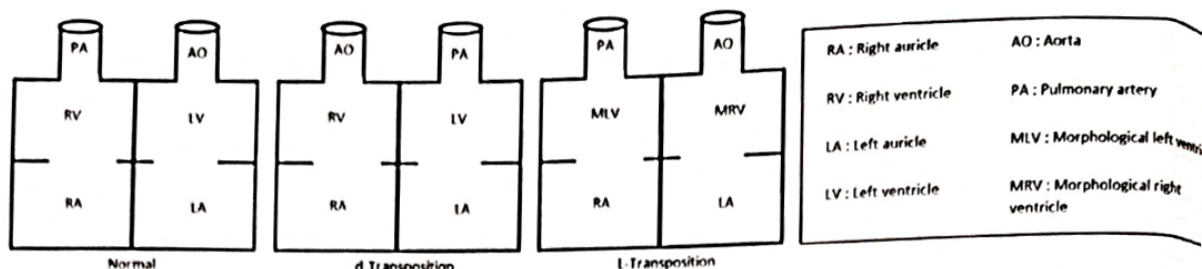
49. **(2.5 points)** Mammalian heart acts as double circulation pump in which two circulatory pathways occur simultaneously. However due to some defects or abnormalities in different parts of heart, a person or new born may face several symptoms and if not corrected can lead to different health issues.

A few of these conditions are described below.

- (I) Aortic valve stenosis: In this condition instead of thin and flexible three cusps of aortic valve, a person carries one or two thick and stiff cusps leading to narrowing or obstruction of aortic blood flow
- (II) Atrial septal defect: In this condition the septal division between right and left atrium is incomplete
- (III) Co-arctation of aorta: In this condition the aorta is narrowed or constricted
- (IV) d-Transposition of great vessels: This is a condition in which the pulmonary artery emerges from left ventricle and aorta emerges from right ventricle
- (V) L-Transposition: In this condition the lower chambers of the heart namely right ventricle and left ventricle are fully reversed and great vessels are also reversed

A list of symptoms/outcomes is given below.

- Lethal for new born unless corrected
- Enlarged left ventricle
- Body receives fully oxygenated blood
- High blood pressure
- Tightness in chest
- Body receives fully deoxygenated blood
- Bluish skin colour

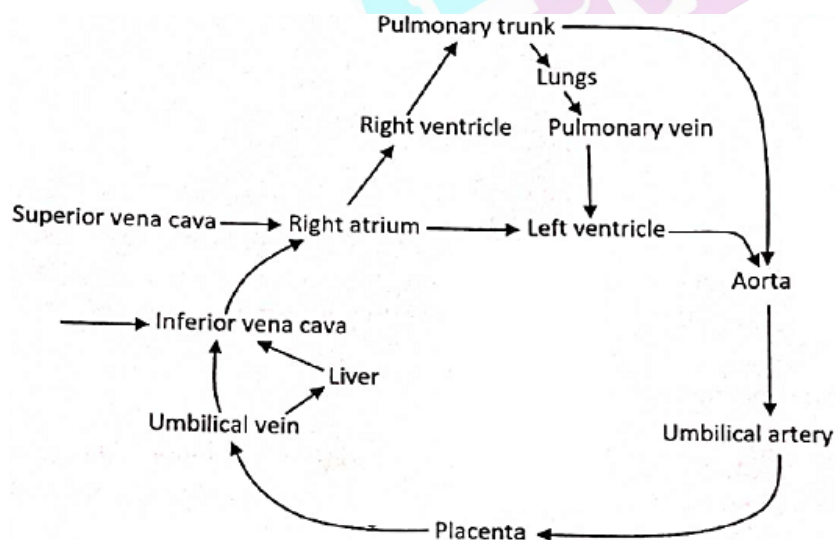


Match the symptoms/outcomes with each condition and fill in the blanks with the appropriate numbers.

**Sol.**

	Condition	Symptoms/Outcomes
(1)	Aortic valve stenosis	Enlarged left ventricle, tightness in chest.
(2)	Atrial septal defect	Bluish skin colour.
(3)	Co-arctation of aorta	High blood pressure.
(4)	d-transposition of great vessels	Body receives fully deoxygenated blood, lethal for new born unless corrected.
(5)	L-transposition	Body receives fully oxygenated blood.

50. (2 points) Study the fetal blood circulation path shown below.



Assign appropriate symbols ( $>$ ,  $<$ ,  $=$ ) to the relation between given blood vessels with respect to oxygen saturation level found. Only a completely correct sequence will be given points.

**Sol.** In fetal circulation, oxygen saturation levels vary among different blood vessels due to their respective roles in oxygenation and deoxygenation of tissues.

The correct sequence of oxygen saturation level is

Umbilical vein > Inferior vena cava > Pulmonary trunk > Pulmonary vein > Aorta > Umbilical artery = Superior vena cava.

51. (2 points) The sympathetic nervous system is best known for its role in responding to dangerous or stressful situations and parasympathetic nervous systems controls various involuntary physiological processes, including but not limited to those illustrated in the table below:

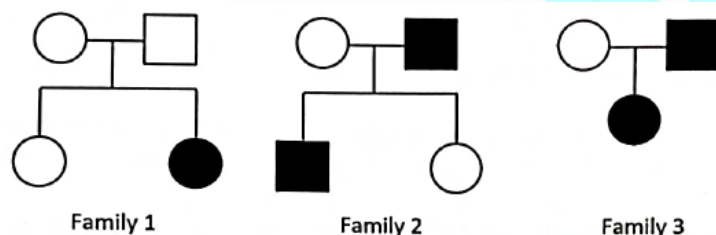
Physiologic functions	Effects	
Cardiovascular	Decreased cardiac output (a)	Increased cardiac output (b)
Pulmonary	Bronchial dilation (a)	Bronchial constriction (b)
Pupillary	Pupillary dilation (a)	Pupillary constriction (b)
Musculoskeletal	Muscular relaxation (a)	Muscular contraction (b)

**Sol.** The correct physiological functions and their effect w.r.t. sympathetic and parasympathetic nervous system are

	Cardiovascular	Pulmonary	Pupillary	Musculoskeletal
Sympathetic nervous system	b	a	a	b
Parasympathetic nervous system	a	b	b	a

### GENETICS & EVOLUTION (12.5 points)

52. (2 points) The following are three pedigrees showing the inheritance pattern of a commonly occurring trait that is monogenic.



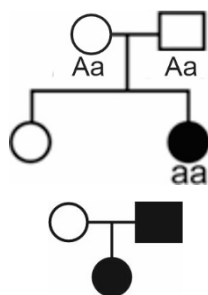
Indicate whether each of the following statements regarding the inheritance of the polymorphic trait as true or false by putting tick marks (✓) in the appropriate boxes.

- The inheritance pattern is X-linked recessive.
- The mother in family 1 is heterozygous for the gene governing the trait.
- In family 3 if the parents had a second child, the probability that it is a son showing the trait is  $\frac{1}{4}$ .
- If the trait was rare the inheritance pattern could be X-linked dominant.

**Answer (b, c)**

**Sol.** For family 1 as the daughter is affected which receives X-chromosome from the father but the father is unaffected which depicts the fact that the disorder analysed for family 1 is not X-linked recessive trait. For family 2 and 3 the trait can be X-linked recessive as the affected male can receive the X trait from the carrier mother in family 2 and the affected female get the X trait from affected father and carrier mother. Thus, option (a) is incorrect as it is not true for all the families.

Option (b) is correct as if we consider the trait exhibited in family 1 as autosomal recessive the mother will be heterozygous.



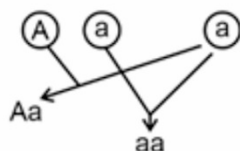
Option (c) is correct as

If it is considered as autosomal recessive then

Parents :

Aa x aa

Gametes



F<sub>1</sub> gen. :

So, the probability that it is a son =  $\frac{1}{2}$

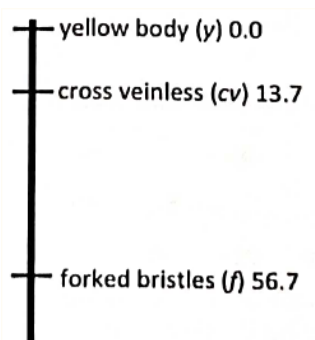
and the probability that it is carrying the disorder =  $\frac{1}{2}$

∴ The probability having a son showing the trait =  $\frac{1}{2} \times \frac{1}{2} = \frac{1}{4}$

Option (d) is incorrect as if the X-linked trait is dominant the father of affected daughter should be affected in family 1; the affected son's mother should be affected in family 2. Only the inheritance in family three could be X-linked dominant.

Option	T/F
a	F
b	T
c	T
d	F

53. (2 point) A genetic map was made for three X-linked mutation of *Drosophila*, yellow body, crossveinless and forked bristles. This is represented as:



Flies with the genotype,  $y\ cv\ +/+ +$  is crossed to males of the genotype  $y\ cv\ f/Y$ . What percentage of the progeny is expected to have the phenotype yellow body crossveinless and normal (wild type) bristles?

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.

**Sol.** Parents:

$y$	$y$
$cv$	$cv$
$+$	$f$

×

Gametes:  $y\ cv\ +$     $y\ +\ +$     $+ \ cv\ +$     $+\ +\ +$     $y\ cv\ f$     $\rightarrow$

$F_1$  gen:

	$y\ cv\ +$	$y\ +\ +$	$+ \ cv\ +$	$+\ +\ +$
$y\ cv\ f$	$yy\ cv\ cv\ f\ +$ yellow, normal crossveinless	$yy\ cv\ +\ f\ +$	$+y\ cv\ cv\ f\ +$	$+y\ cv\ +\ f\ +$
$\rightarrow$	$ycv+/y$ yellow, normal crossveinless	$y++/y$	$+cv+/y$	$+++/y$

Probability of yellow body, crossveinless and normal bristles

$$= \frac{2}{8} = \frac{1}{4} = 25\%$$

54. (2 points) In a beehive it was observed that there exist two kinds of bees – Non-hygienic and hygienic. Hygienic worker bees uncap sealed cells and remove bodies of dead larvae from the hive. The genotypes of the female and male hygienic bees are  $uurr$  and  $ur$  respectively. Non-hygienic bees can be completely or partially non-hygienic depending on their genotypes.

The 'uu' is the genotype for 'uncap' phenotype while the 'rr' is for 'remove' phenotype.

The genotypes of the female and male non-hygienic bees are  $U\_R\_$  and  $UR$  respectively. In a situation where non-hygienic female bees homozygous for both genes are crossed with hygienic male bees, then:

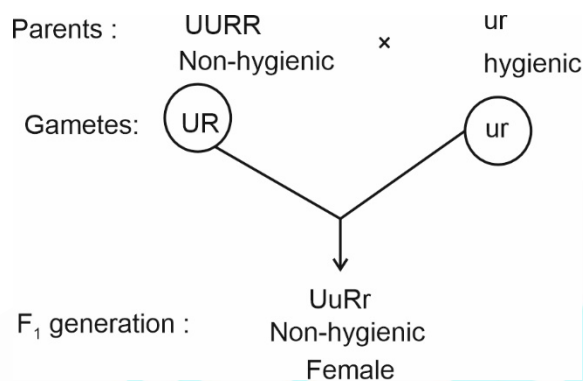
(Indicate whether each of the following statements is true or false by putting tick marks (✓) in the appropriate boxes.)

- All the female bees in the  $F_1$  generation will be hygienic bees.
- Backcrossing of  $F_1$  female progeny with non-hygienic males results in 50% hygienic and 50% non-hygienic female bees.
- $F_1$  female progeny when crossed with hygienic males results in 25% of bees being completely non-hygienic female bees.
- A cross between  $F_1$  females and hygienic males results in 25% of female bees being partially non-hygienic i.e. these bees remove the dead pupae if the cells are uncapped.

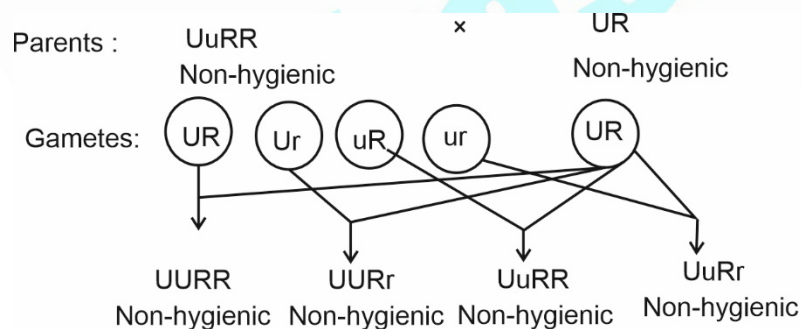
**Answer**

Option	T/F
a	F
b	F
c	T
d	F

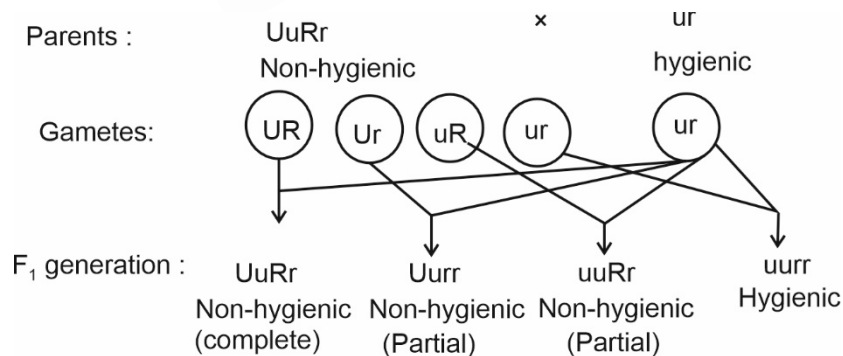
**Sol.**



Option a is incorrect as all the female bees in  $F_1$  generation are non-hygienic in nature.



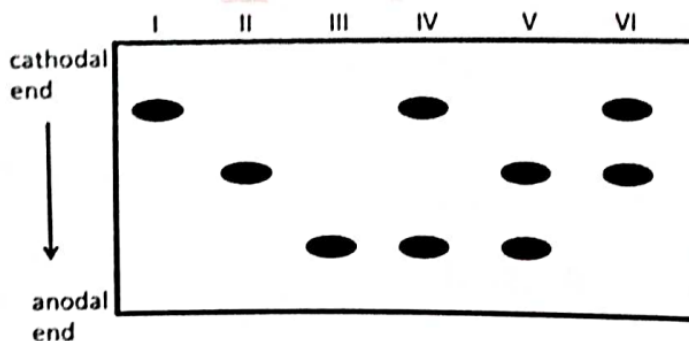
Option b is incorrect as all the females are non-hygienic



Option c is correct because 25% of female bees with genotype  $UrRr$  will be completely non-hygienic.

Option d is incorrect as 50% of the female bees are partially non-hygienic

55. (3 points) Allozymes are variants of an enzyme that are functionally same but differ structurally and coded for by different alleles of a gene. Allozyme variation can be detected by protein electrophoresis. The following allozyme patterns observed for the enzyme alcohol dehydrogenase (ADH) in an insect population.



The percentage of individuals in a population showing the different allozyme patterns were analyzed. The observations are summarized below:

Pattern	I	II	III	IV	V	VI
%	25.0	9.0	4.0	15.0	12.0	35.0

Answer the following :

(A) Is the population in a state of Hardy -Weinberg equilibrium? Yes/ No

(B) Name each of the alleles as A, B, C, D... For example if there is 1 allele name it as A, if 2 alleles are present name it as A and B and so on. At what frequency is each of the alleles present in the population? Give answers to 3 decimal places.

*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*

**Sol.**

Pattern	Alleles	Genotype	Frequency	Percentage
I	A	AA	$p^2$	25%
II	B	BB	$q^2$	9%
III	C	CC	$r^2$	4%
IV	A and C	AC	$2pr$	15%
V	B and C	BC	$2qr$	12%
VI	A and B	AB	$2pq$	35%

If there are 100 insects in a population, then

number of 'A' allele in AA individuals = 50

number of 'A' allele in AC individuals = 15

number of 'A' allele in AB individuals = 35

Total number of 'A' alleles = 100

Total number of alleles in population = 200

$$\text{Frequency of 'A' allele} = \frac{100}{200} = 0.500$$

Number of 'B' allele in BB individuals = 18

Number of 'B' allele in BC individuals = 12

Number of 'B' allele in AB individuals = 35

Total number of 'B' alleles = 65

$$\text{Frequency of 'B' alleles} = \frac{65}{200} = 0.325$$

Number of 'C' allele in CC individuals = 8

Number of 'C' allele in AC individuals = 15

Number of 'C' allele in BC individuals = 12

Total number of 'C' alleles = 35

$$\text{Frequency of 'C' alleles} = \frac{35}{200} = 0.175$$

If population is in Hardy-Weinberg equilibrium then  $p^2 = \frac{25}{100} \Rightarrow p = 0.5$

$$q^2 = \frac{9}{100} \Rightarrow q = 0.3$$

$$c^2 = \frac{4}{100} \Rightarrow c = 0.2$$

But, actual frequencies of 'A', 'B' and 'C' alleles are deviating from the above mentioned frequencies *i.e.*

$p = 0.5$ ,  $q = 0.3$  and  $c = 0.2$

Hence, population is not in Hardy-Weinberg equilibrium

56. (1.5 points) A synthetic inducible operon was developed in *E. coli*. The operon encodes enzymes for degradation of the herbicide Basta. The operon is activated when a regulatory protein R, complexed with Basta, binds to a DNA element (called RBS) upstream to the promoter. There are no other components of this synthetic operon.

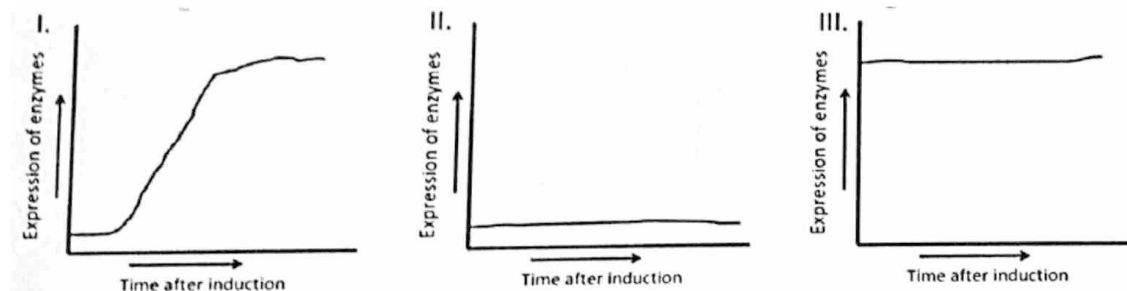
Three different mutants were generated:

Mutant 1: Null mutant for the gene expressing the R protein

Mutant 2: Expresses a mutant R protein to which Basta cannot bind

Mutant 3: Expresses a mutant R protein which can bind to RBS even in the absence of Basta

The following are three plots representing the activity of the operon following induction with Basta:



Identify the expression profile (I to III) for each of the above three mutants and fill in the blanks with the correct graph number.

**Sol.** Null mutation in a gene leads to the production of a non-functional enzyme or no enzyme at all.

In case I as there is a null mutation in gene R leads to the non-functional or no enzyme at all it won't be able to complex with BASTA and thus reduce the expression of or inhibits the expression of the operon.

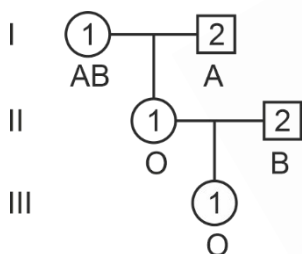
In case II as the R protein is not able to complex with BASTA then the operon will be unable to express.

Therefore, in both the cases graph II will be observed with no expression.

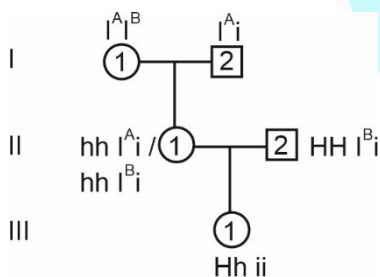
In case III as R protein can bind to RBS it will show the enhanced expression of enzyme which results in the occurrence of graph III.

Mutant	Graph
1	II
2	II
3	III

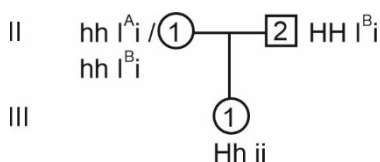
57. (2 points) 'Bombay phenotype' is a rare blood type that describes individuals whose RBCs lack the H antigen. H antigen is needed for the final production of antigens A and B. Following is a pedigree showing inheritance of blood groups. Write the possible genotype/s in terms of both 'I' and 'II' alleles for the individual/s with blood group O when the person with blood group B is homozygous for II.



Sol.



Since the individual II(1) is having O blood group even if the parents are AB and A so it means that the organism has  $hh I^A i / hh I^B i$  genotype which infers the fact that it exemplifies Bombay phenotype.



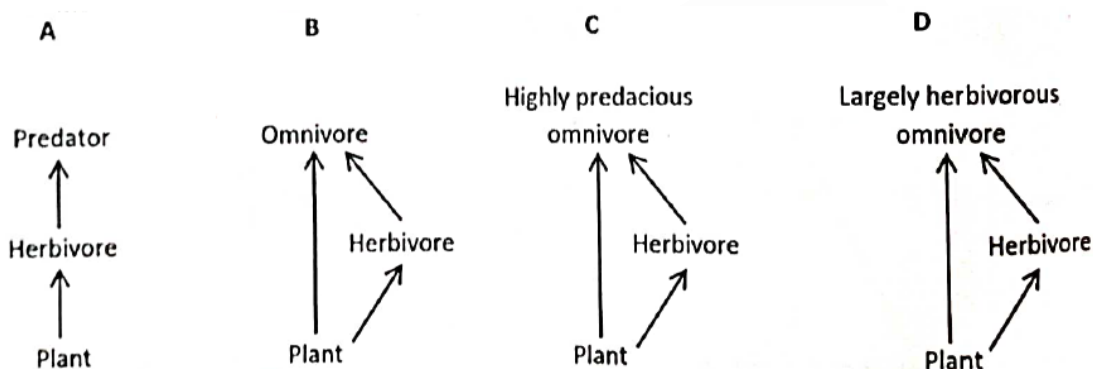
So the genotype of III (1) is  $Hh ii$ .

## **ECOLOGY (5 points)**

58. **(2 points)** Omnivore is widespread among insects, both in natural and in agricultural system. It is possible to use insect omnivores as biological control agents in the modern agriculture system. Four possible interventions could be done by introducing the following:

- Predator
- Omnivore
- Highly predacious omnivore and
- Largely herbivorous omnivore

A – D represent four trophic relationships between plant, herbivore and predator, with and without different kinds of omnivores.



Arrange the four interventions as most effective to least effective for obtaining agricultural produce by filling in the appropriate alphabet in the blanks. *Note that only a completely correct sequence will be given points.*

**Answer (A > C > B > D)**

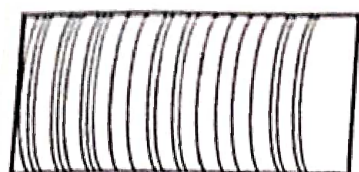
**Sol.** The correct sequence of interventions as most effective for obtaining agricultural produce is

A > C > B > D

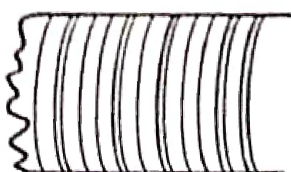
- A simple food chain will promote good agricultural yield
- Highly predacious omnivores largely affected the herbivores organism.
- Omnivores organism will feed on both trophic level and lead to less agricultural produce than previous one.
- Largely herbivores omnivores feed on the plant and lead to decreased agricultural produce.

59. **(3 points)** To determine when a wood house in a remote island was built, a dendrochronologist gathered and analysed the following specimens in 2023:

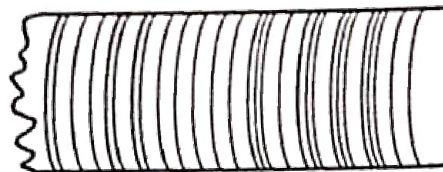
- Sample from a house beam
- Sample of a living tree of the same species
- Sample of standing dead tree of the same species



(i)



(ii)



(iii)

(A) The ring patterns were as shown above (irregular lines indicate the bark). Estimate the year in which the wood was cut and used for building the house. Fill in the blank with the year.

(B) Determine the year of death of the tree in figure iii. Fill in the blank with the year.

**Answer (A) 2018**

**(B) 2023**

**Sol.** One annual ring includes one circle of autumn wood and one circle of spring wood formed in one year of life span.

As per the given data, the year of death of tree (iii) is 2023 and it has 28 annual rings.

In sample (i) the number of annual rings is 23.

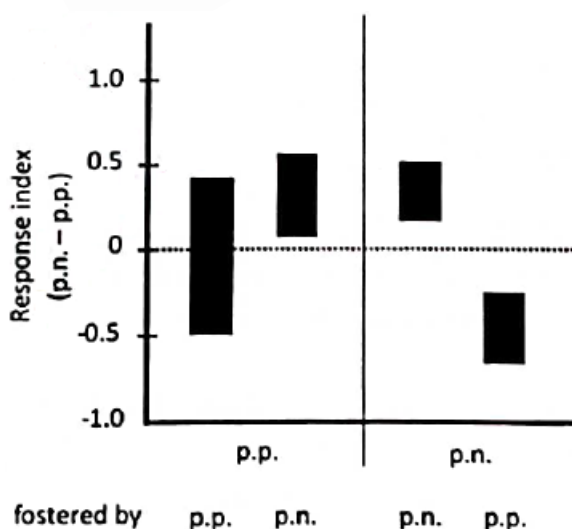
That means the tree was cut five years before 2023, i.e. in 2018.

A. In 2018, the wood was cut and used for building the house.

B. Year of death of the tree in figure (iii) is 2023 (for actual calculation of age of tree, chemical characterisation of bark is performed).

### **ETHOLOGY (7 points)**

60. **(2 points)** Cichlids in African Great Lakes are genetically quite similar but differ in colours, which can influence female mate choice. Females of these fish brood their young in their mouths and continuously guard their free swimming offspring till adulthood. Two species of cichlids differing in colours (red and blue) were studied in cross-fostering experiments. Offspring of *P. pundamilia* (blue) were fostered by females of *P. nyererei* (red) and vice versa. Mate choice made by female offspring when they became adults was studied by presenting them with males of both the colours. The following preference data was obtained. It was also observed that this mate choice recognition was highly disrupted in dark.



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

- (a) The mate preference in the adult cichlid female is an innate behaviour.
- (b) The phenotype of the mother acted as a model for learning cues for mate selection.
- (c) The behaviour shown by mature offspring is an example of imprinting.
- (d) For cichlids swimming at some depths in eutrophic ponds, the mate choice recognition is likely to be hampered.

**Sol.** (a) is incorrect statement because adult cichlid identify their mates according to their colour. Colour identification they learnt during their growth periods. Hence it is learnt behaviour.

(b) is correct statement as phenotype of mother helps them to learn cues for mate selection.

(c) is correct statement because after birth or hatching, the newborn follows another animal that it recognises as its mother, this is called imprinting.

(d) is correct statement because mate choice recognition is disrupted in dark. So, at certain depth in eutrophic ponds the mate choice recognition in cichlid may be hampered.

61. **(2.5 points)** The grey cheeked mangabey monkey is found in the forests of East Africa. It lives in troops and defends a group territory. Comparative features between two calls – ‘whoop-gobble’ and ‘scream’ used by the mangabeys are tabulated.

Call	Sound pressure 5m from monkey	Frequency (Hz)
Whoop-gobble	75 dB	300 – 400
Scream	78 dB	1000 – 3000

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

- (a) Scream vocalization is used by the monkeys in intergroup signaling.
- (b) Using scream for communication within a troop could attract predators relative to the whoop-gobble call.
- (c) Scream has a broad range of frequency and hence can be carried over long distances.
- (d) Whoop-gobble is generally used during agonistic encounters within a group.
- (e) Whoop-gobble could be used for communication across groups for spacing between troops.

**Sol.** (a) is incorrect because whoop-gobble vocalisation is used in intergroup signalling.

(b) is incorrect statement.

(c) is incorrect because screaming is for comparatively shorter distance while whoop-gobble is carried over long distances.

(d) is incorrect because during agonistic encounter within a group usually screaming is used which is louder than whoop-gobble.

(e) is correct for long duration for communication across groups.

62. **(2.5 points)** Unlike almost every other gull species, the kittiwake nests exclusively on tiny ledges on coastal cliffs. This cliff habitat invaded by the kittiwake creates very different selection pressures than the open breeding areas used by most other gulls. A few examples of altered selection pressures are listed below.

- (i) Absence of predators.
- (ii) Limited number of nest sites.
- (iii) Absence of other gull species in the colony.
- (iv) Absence of nest materials at nesting sites.
- (v) Narrowness of ledge.

Certain behavioural adaptations help these birds exploit these habitats. Match each of the following behavioral adaptation listed below with the selection pressure that they counter and fill in the table with the correct alphabets.

*(Note that only a completely row will be given points)*

- A. Juveniles hide beaks and not run when threatened.
- B. Alarm call rarely given.
- C. Nest with mud base and deep cup.
- D. No removal of egg shells.
- E. Territory establishment only at future nest site.
- F. Territory very small.
- G. Young feed from throat to avoid dropping of food.
- H. No species-specific long call given.
- I. Stealing

**Sol.**

	Behavioural adaptations		Selection pressure
(A)	Juveniles hide beaks and not run when threatened.	(v)	Narrowness of ledge.
(B)	Alarm call rarely given.	(i)	Absence of predators.
(C)	Nest with mud base and deep cup.	(v)	Narrowness of ledge.
(D)	No removal of egg shells.	(i)	Absence of predators.
(E)	Territory establishment only at future nest site.	(ii)	Limited number of nest sites.
(F)	Territory very small.	(ii)	Limited number of nest sites.
(G)	Young feed from throat to avoid dropping of food	(v)	Narrowness of ledge.
(H)	No species-specific long call given	(iii)	Absence of other gull species in the colony.
(I)	Stealing	(iv)	Absence of nest materials at nesting sites.

**BIOSYSTEMATICS (2 points)**

63. (2 points) Based on the lateral openings in the skull called temporal fenestrae, vertebrates can be classified as Diapsida (two pairs of openings) or Synapsida (one pair of opening). Animals with keratinised skin appendages are termed as Sauropsida.

The presence or absence of these three features (P, Q and R) is indicated in the given table by '+' and '-' respectively for five animals (1 – 5).

	Animal	Sauropsida (P)	Diapsida (Q)	Synapsida (R)
1.	Testudomorpha	+	-	-
2.	Rhynchocephalia	+	+	-
3.	Caiman	+	+	-
4.	Budgerigar	+	+	-
5.	Echidna	-	-	+

Based on the data given, construct the most parsimonious cladogram to classify these animals and draw the cladogram in the given box. All the animals (1 - 5) and features (P - R) need to be indicated in the cladogram.

*Note that only a completely correct cladogram will be given points.*

**Sol.**

