

Indian National Biology Olympiad (INBO) - 2024

Homi Bhabha Centre for Science Education (HBCSE-TIFR)

Question Paper

Date: 4th February, 2024

Maximum Marks: 300

Duration: 2 hours

INSTRUCTIONS

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.

Before starting, ensure that you have received a copy of the question paper containing a total of 32 numbered pages.

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.

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.

SCORING KEY

NO. OF CORRECT ANSWERS: X

NO. OF INCORRECT ANSWERS: Y

SCORE: SECTION A: 3X – Y

SECTION B: 3X

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.

Options:

- a. i only b. ii and iii only c. i and iv only d. ii and iv
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 phosphorylated amino acid residue recognizing kinase.
 - v. An interaction stabilizing the half-life of the 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

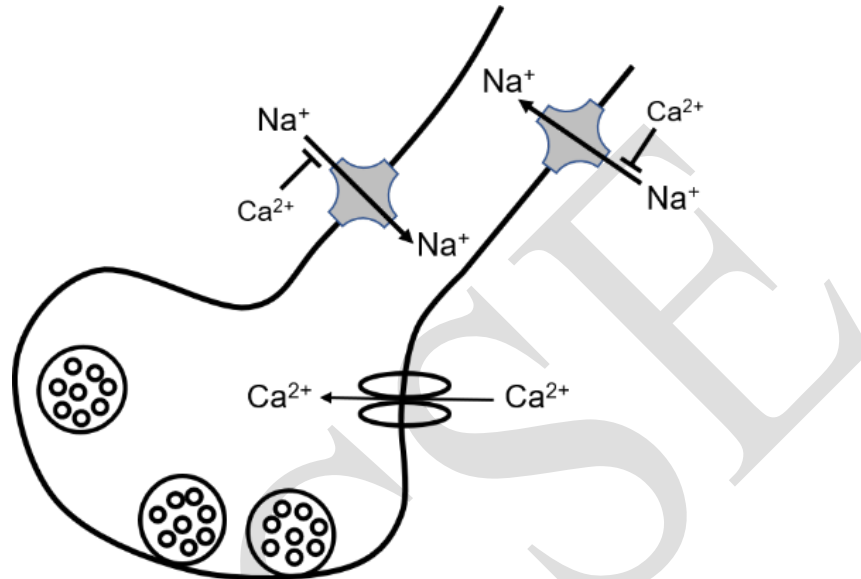
3. (1 point) Acquired immune system produces different types of antibodies upon exposure to an antigen. The type of antibody produced varies based on the time from the initial exposure to antigen, the duration after the initial exposure, and secondary or every subsequent exposure to the same antigen.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

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?

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

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?

- Glycerol is more hydrophilic than sucrose.
- Water from the glycerol solution enters the cells leaving a hypertonic solution of glycerol outside.
- Glycerol has greater cell membrane permeability than sucrose.
- Sucrose being a disaccharide requires a specific carrier protein to pass through the erythrocyte membrane.

6. (1 point) The neurotransmitter acetylcholine is made in the cytosol and then transported into synaptic vesicles, where its concentration is more than 100-fold higher than in the cytosol. When synaptic vesicles are isolated from neurons, they can take up additional acetylcholine added to the solution in which they are suspended, but only when ATP is present. Na⁺ ions

are not required for acetylcholine uptake, but, curiously, raising the pH of the solution in which the synaptic vesicles are suspended increases the rate of acetylcholine uptake. Furthermore, transport is inhibited when drugs are added that make the membrane permeable to H^+ ions. Which of the following set of statements are consistent with the observation?

- i. Acetylcholine is being transported into the vesicle by H^+ -acetylcholine antiport system.
- ii. H^+ gradient that drives the uptake is generated by an ATP driven H^+ pump.
- iii. Raising the pH of the solution surrounding the vesicles increases the H^+ gradient.
- iv. Transport of acetylcholine into the vesicle is a secondary active transport process.

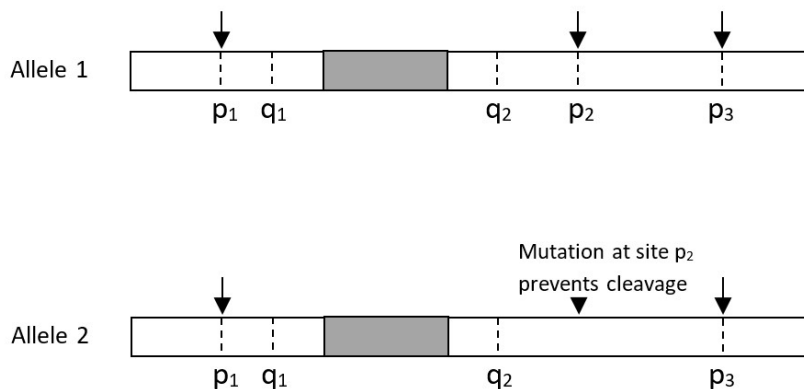
- a. i, ii and iii only
- b. ii and iv only
- c. i, ii and iv only
- d. i, ii, iii and iv

7. (1 point) A Polymerase Chain Reaction (PCR) with all the required components including the 'Forward' and 'Reverse' primers results in ~ 1 billion copies of double stranded DNA molecules after 30 cycles of optimized thermal cycling programme.

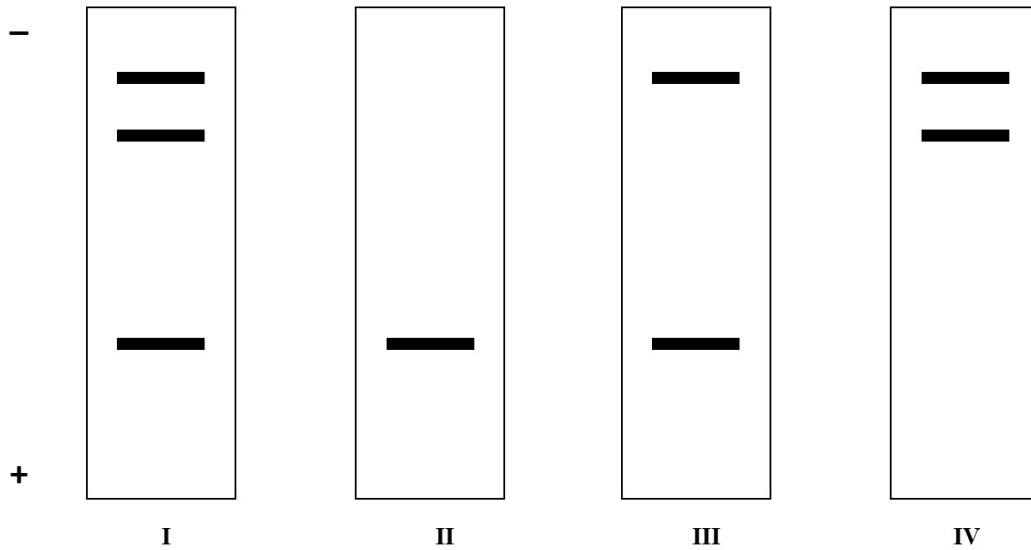
A research scholar designed PCR primers to amplify a 300 bp region of the *gyrA* gene from genomic DNA of *E. coli*. During the PCR reaction set up, he forgot to add the 'Reverse' primer in the PCR reaction mixture. Which of the following is correct?

- a. The DNA polymerization will not take place at all, and thus there will be no new DNA copies synthesized.
- b. The DNA strand complementary to the 'Forward' primer will be synthesized during every cycle of PCR and therefore only half a billion copies of the 300 bp target amplicon will be formed.
- c. Only arithmetic increase in the copy number of complementary strand of the 'Forward primer' will take place, resulting in 300 bp single-stranded DNA molecules.
- d. Single stranded DNA fragments longer than the intended 300 bp would be synthesized during DNA polymerization.

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:



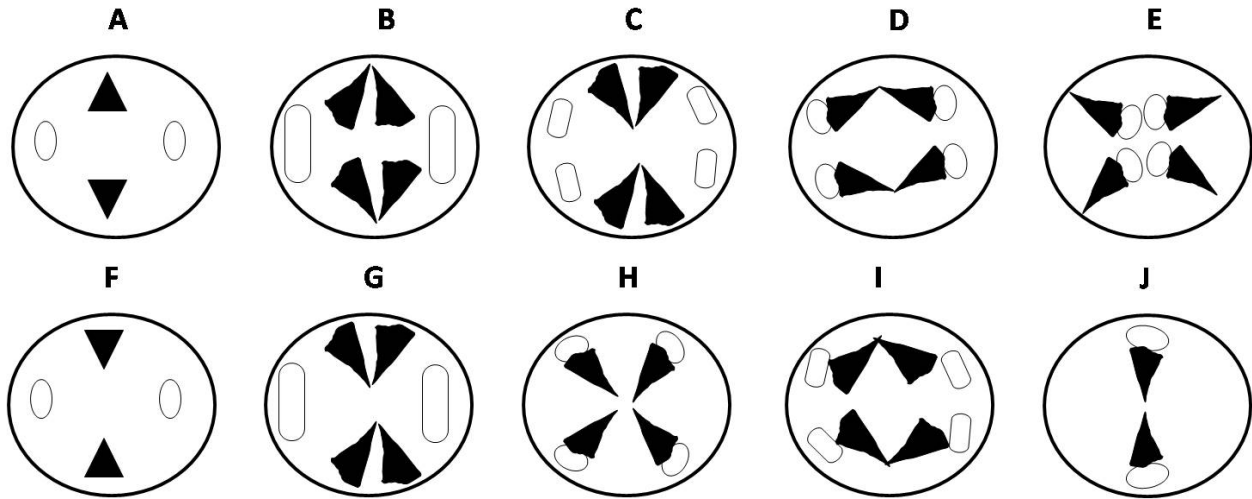
The resulting patterns obtained when the DNA sample was completely digested with (i) only enzyme P and (ii) only enzyme Q respectively would be:

- a. I and III respectively
- b. III and II respectively
- c. I and IV respectively
- d. IV and II respectively

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

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→B→I→D→H

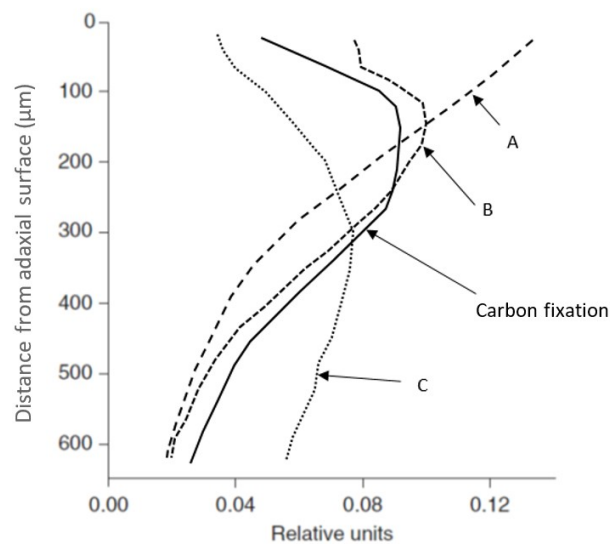
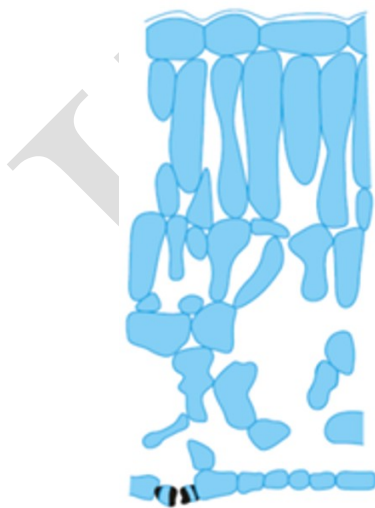
b. F→G→C→H→J

c. F→B→C→E→J

d. A→G→I→E→D

11. (1 point) The figure below depicts a cross section of a spinach leaf (approximately 650 μm 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.

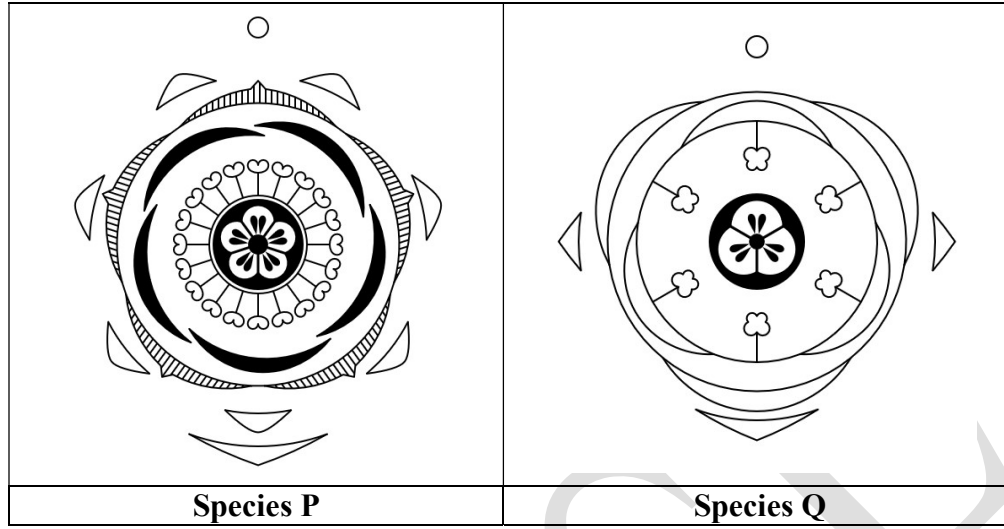
a. A-I, B-II, C-III

b. A-III, B-I, C-II

c. A-I, B-III, C-II

d. A-II, B-I, C-III

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 monothecous 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?

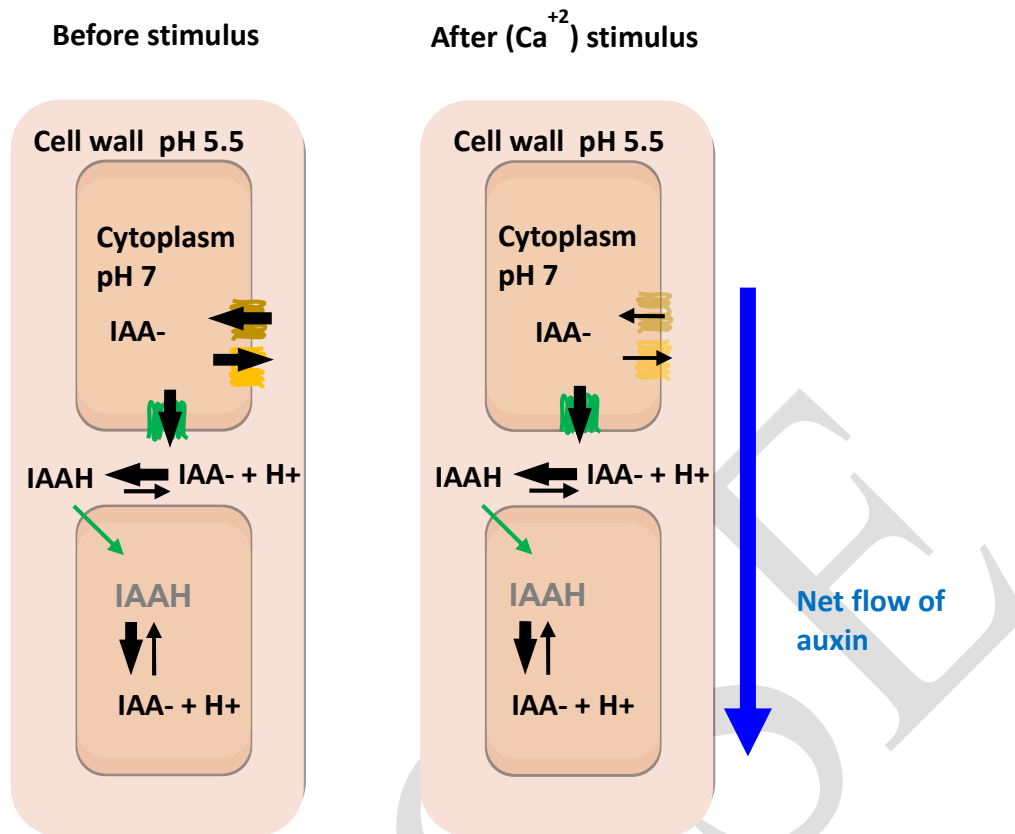
- a. I, II, IV and V
- b. I, II, III and V
- c. III, IV and V
- d. I, II, III and IV

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, & iii only
- b. ii & iv only
- c. i & iii only
- d. iii & iv only

14. (1 point) Auxin is a charged anion (IAA^-) in the cytoplasm (pH 7). In the more acidic cell wall (pH 5.5) some auxin is uncharged (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 Ca²⁺ 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.

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:

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

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

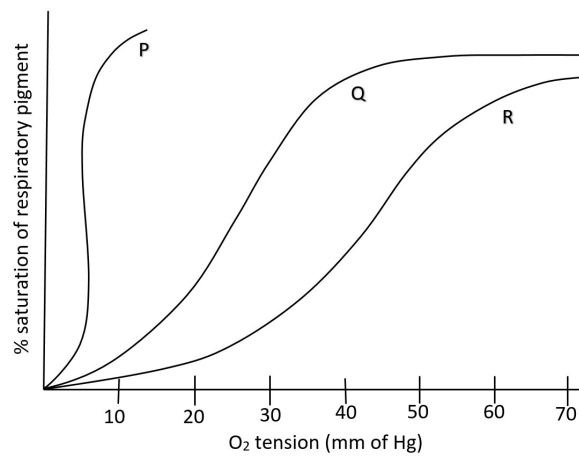
17. (1 point) All aquatic animals whether marine, brackish or freshwater need to regulate their internal osmotic potential against the external one. Although the standard Na^+/K^+ -ATPase pump operates at the basolateral cell membranes in these animals, the kinetic properties can vary based on the environment. 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.

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 Cl^- channels on the sensory neurons causing 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.

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



Which of the following correctly explains the observed patterns?

- Animal R is metabolically less active than animal Q.
- 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.
- Animal Q is likely to be found at higher altitude as compared to animal P.
- Animal P is likely to be found in highly anoxic conditions as compared to animal R.

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?

- The measurement of clearance of creatinine can be employed for the precise assessment of GFR in humans.
- The measurement of clearance of inulin can be employed for the precise assessment of GFR in humans.
- The measurement of clearance of creatinine can be employed for the precise estimation of GFR in non-primate mammals.
- The measurement of clearance of inulin can be employed for the precise assessment of GFR in non-primate mammals.
- 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 |

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 |

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.

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

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

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.

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.

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.

The following statements are made about plasma therapy:

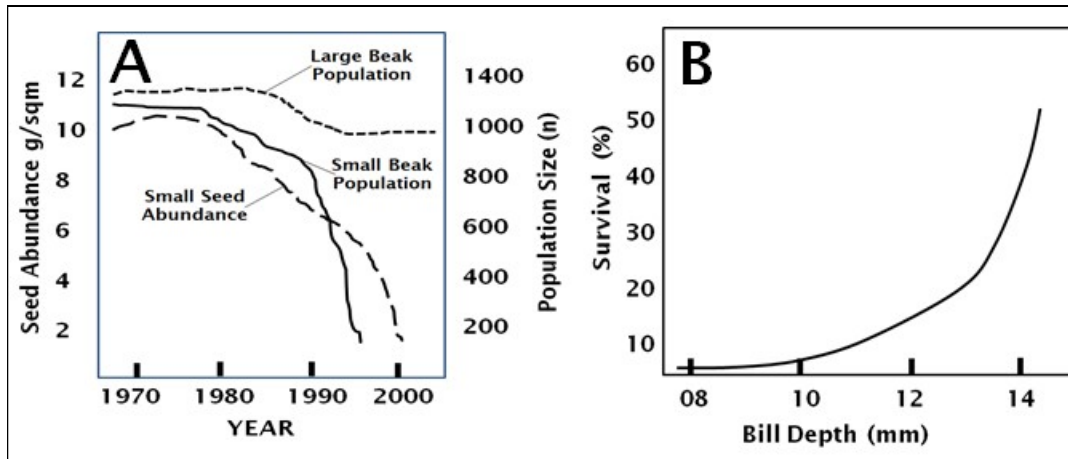
- i. Person who caught infection after being vaccinated and then recovered are likely to be better donors than those who were not vaccinated
- ii. The donor's plasma should have high levels of antigen for the treatment to be effective.
- iii. In plasma therapy a person with AB Rh⁺ blood group will be 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

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.



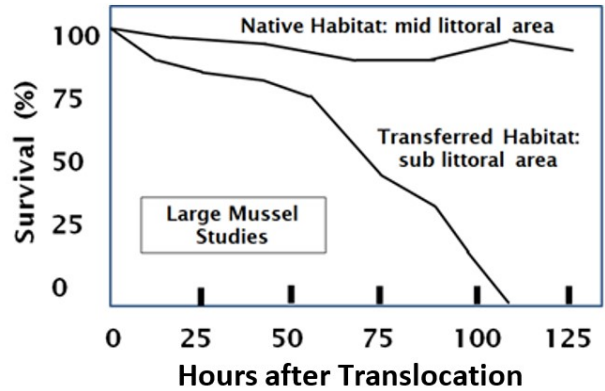
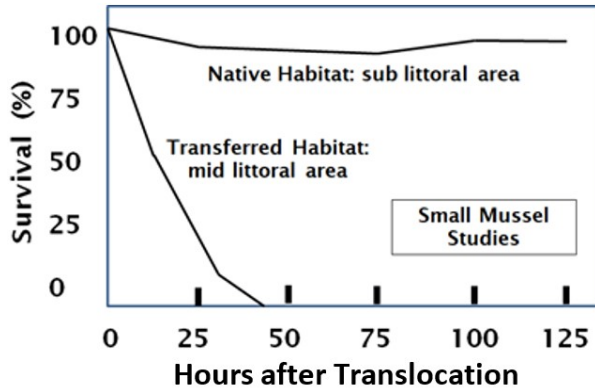
Which type of selection process is occurring under such an unfavorable condition?

- 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.

29. (1 point) Herbivores have evolved to feed effectively, while plants have countered with a wide variety of anti-herbivore defenses. 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

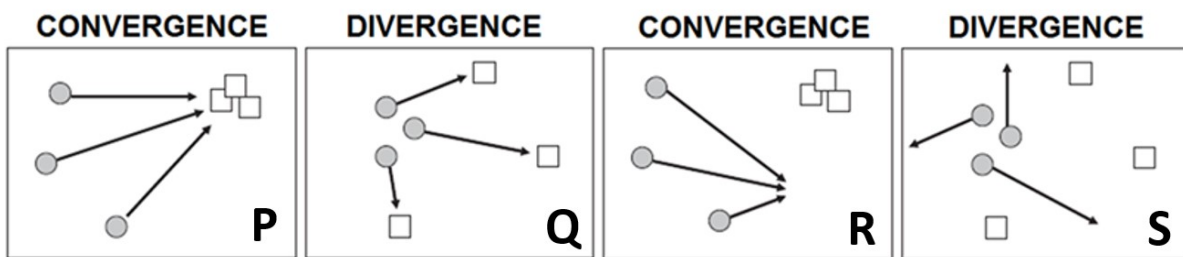
30. (1 point) The mussels are widespread species on the rocky shore of West Coast of India. Small sized mussel species occur abundantly on the sub littoral areas while large sized mussel species occur abundantly on the mid littoral area. Experiments were carried out where their locations were interchanged. 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?

- i. In the sub littoral area, heavy wave action restricts the size of mussels and prevents predators from eliminating small mussels.
 - ii. In mid littoral area, predators eliminate most of the small mussels leading to survival of large mussels.
 - iii. Prey individuals can survive when translocated to a site where they do not normally occur if they are protected from predators.
 - iv. 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

31. (1 point) In the following diagram, four possible outcomes of Restoration programs are shown. The 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.



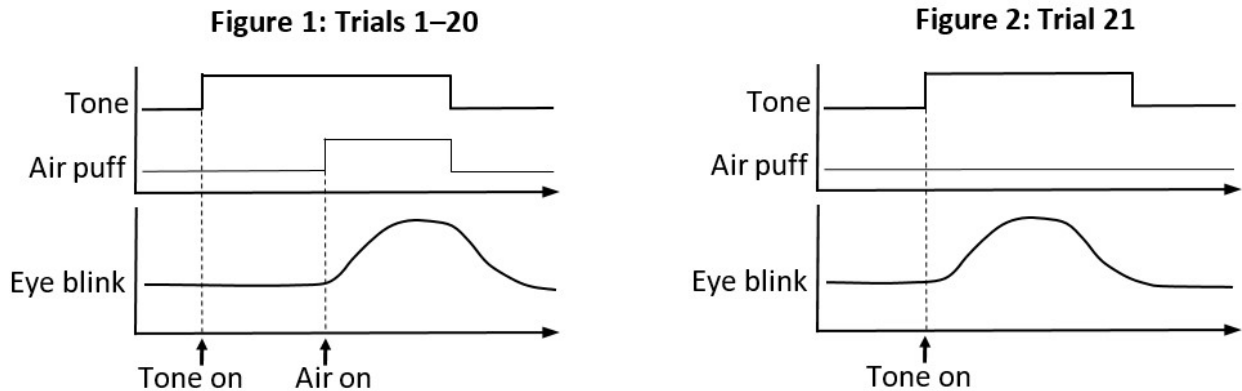
Mark appropriately the correct statement with reference to restoration goal accomplishment:

- a. 'P' is the best expected outcome since the restoration leads to single type of ecosystem from different existing states.
- b. 'Q' is a good outcome since the restoration leads to the reference ecosystems which are all of different types.

- c. 'R' is a good restoration program. Although, it largely deviates from the reference ecosystem, the three arrows are in single direction of restoration.
- d. 'S' is an unexpected but desirable restoration program where restoration leads to different and diverse type of 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 trials 1 – 20 are shown in Figure 1 and that of trial 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.

33. (1 point) Culturally learned behaviours or information within a community are acquired through some form 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.

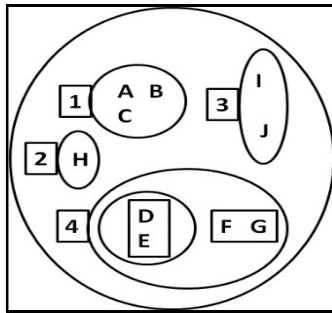
Options:

- a. i, ii and iii only
- c. iii and iv only

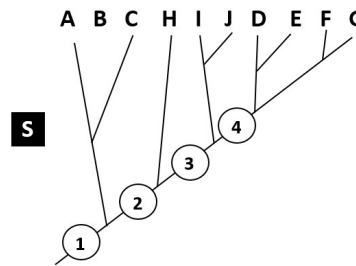
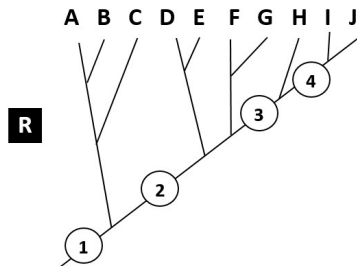
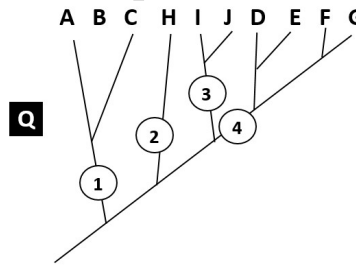
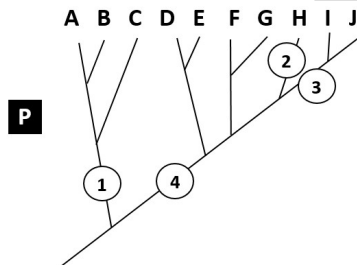
- b. ii and iv only
- d. i, ii, iii and iv

BIOSYSTEMATICS (1 point)

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?



- a. P
- c. R

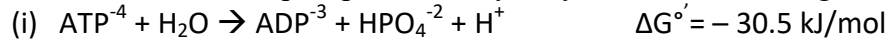
- b. Q
- d. S

***** END OF SECTION A *****

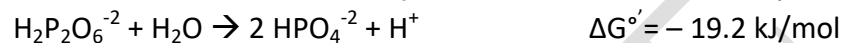
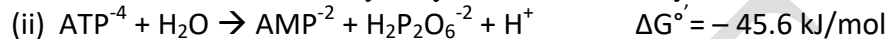
SECTION B

CELL BIOLOGY (14.5 points)

35. (2 points) Adenosine triphosphate (ATP) is a commonly used energy coin in living systems. 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.

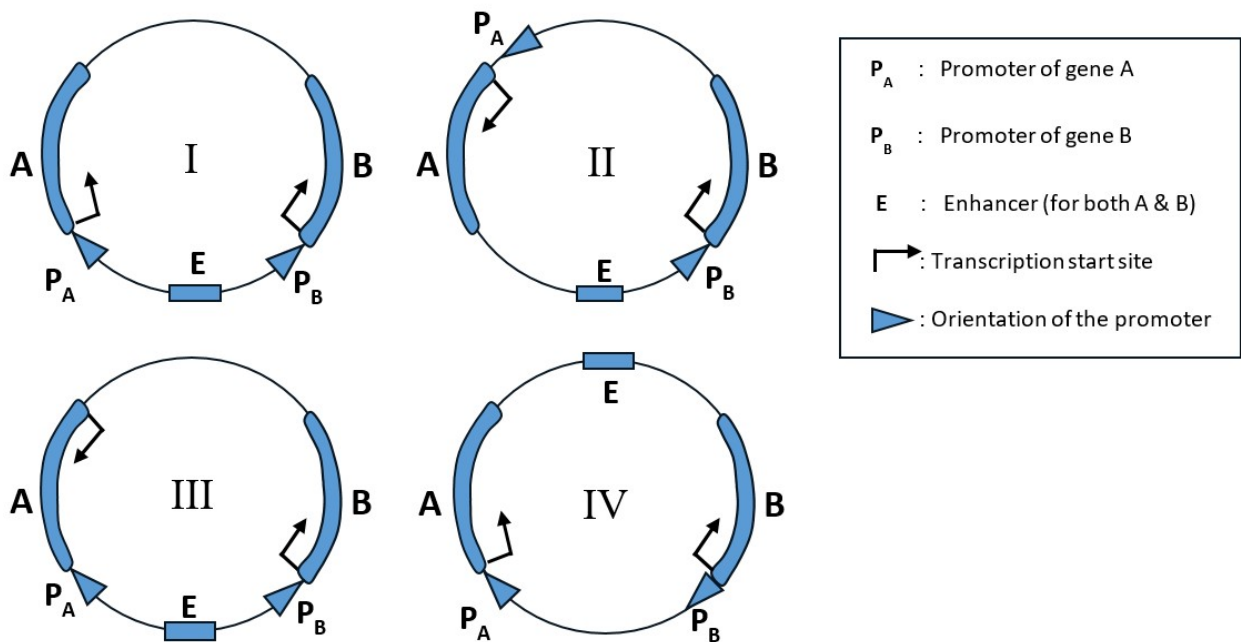
- a. ATP is a thermodynamically unstable molecule.
- b. Hydrolysis of ATP in living systems does not require a catalyst.
- c. Since phosphate is a resonance stabilised molecule, the reaction is favoured towards hydrolysis.
- d. Since H^+ generated is quickly neutralised to maintain homeostasis, ATP hydrolysis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

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.

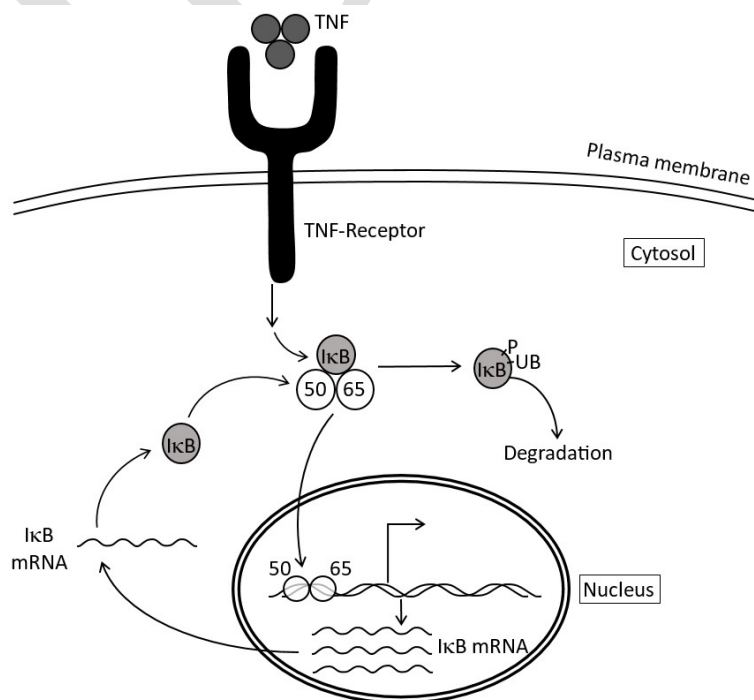
A few statements about these herbicides are listed. Mark each of the statements as true or false by putting tick marks (✓) in the appropriate boxes.

- 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.

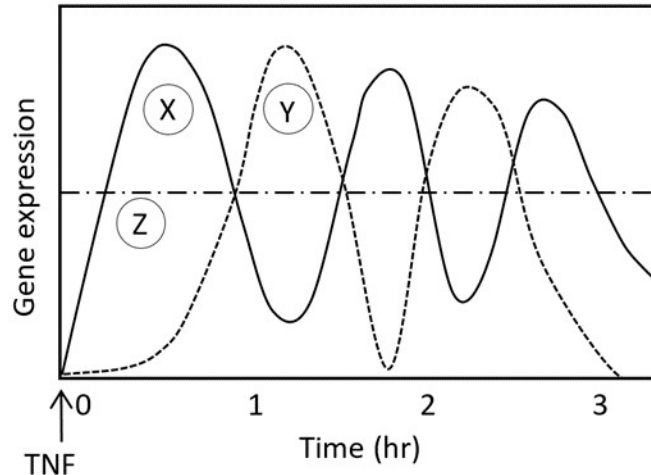
37. (2 points) Two eukaryotic genes A and B are cloned in an expression plasmid vector. Below are the four different constructs that were made. Indicate the expected outcomes for each construct by putting tick marks (✓) in the appropriate boxes. *Note that only a completely correct row will be given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



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- κ B (Nuclear Factor Kappa B) by TNF- α (Tumor Necrosis Factor-alpha). NF- κ B is a heterodimer of two subunits, p50 and p65, and it is retained in the cytoplasm by its inhibitor I κ B- α . TNF signaling phosphorylates I κ B- α leading to its degradation by ubiquitination. As a result, free NF- κ B and its translocation into the nucleus, where it binds to a responsive promoter and activates gene expression. Activation of NF- κ B by the TNF is transient in nature because one of the genes that NF- κ B activates is the gene for I κ B- α itself.

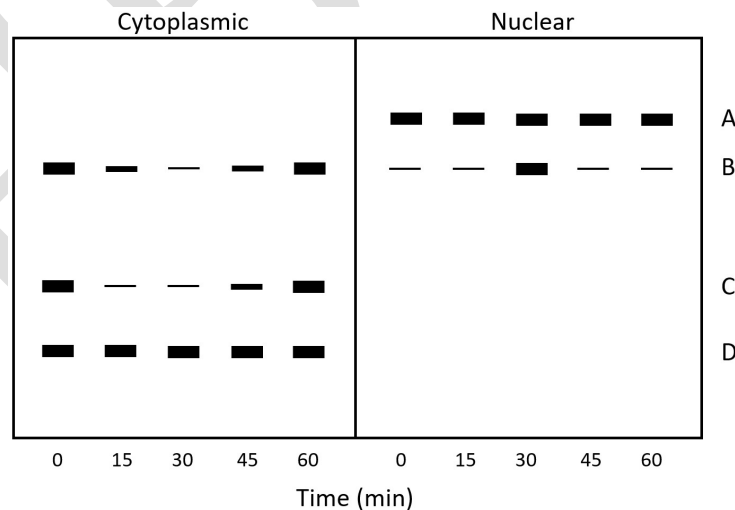


(A) In one experiment, activation of NF- κ B by TNF was studied in a macrophage cell line. The following were the results of gene expression of NF- κ B responsive gene and the expression of I κ B- α gene. Z in the graph represents expression of a housekeeping gene.



Indicate which one is NF- κ B responsive gene and which one is the I κ B- α 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 κ B- α proteins. Also, antibodies against α -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 κ B- α , α -actin and lamin respectively. Fill in the appropriate alphabet (A, B, C or D) in the table.

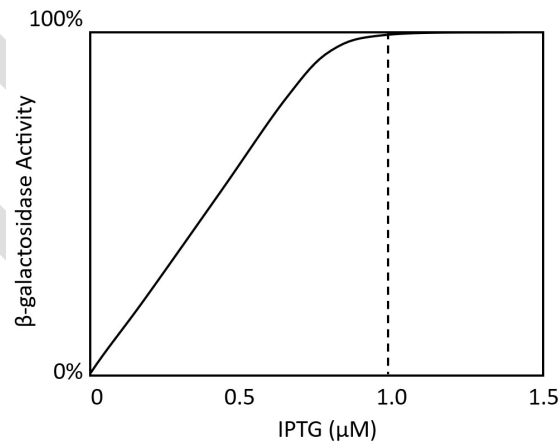
(C) Experiments (1 – 4) were also conducted by adding either inducer or inhibitors of following activities and measuring the TNF – dependent NF- κ B activated gene expression. Indicate the expected effect of each experiment by putting tick marks (✓) in the appropriate boxes.

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.

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:

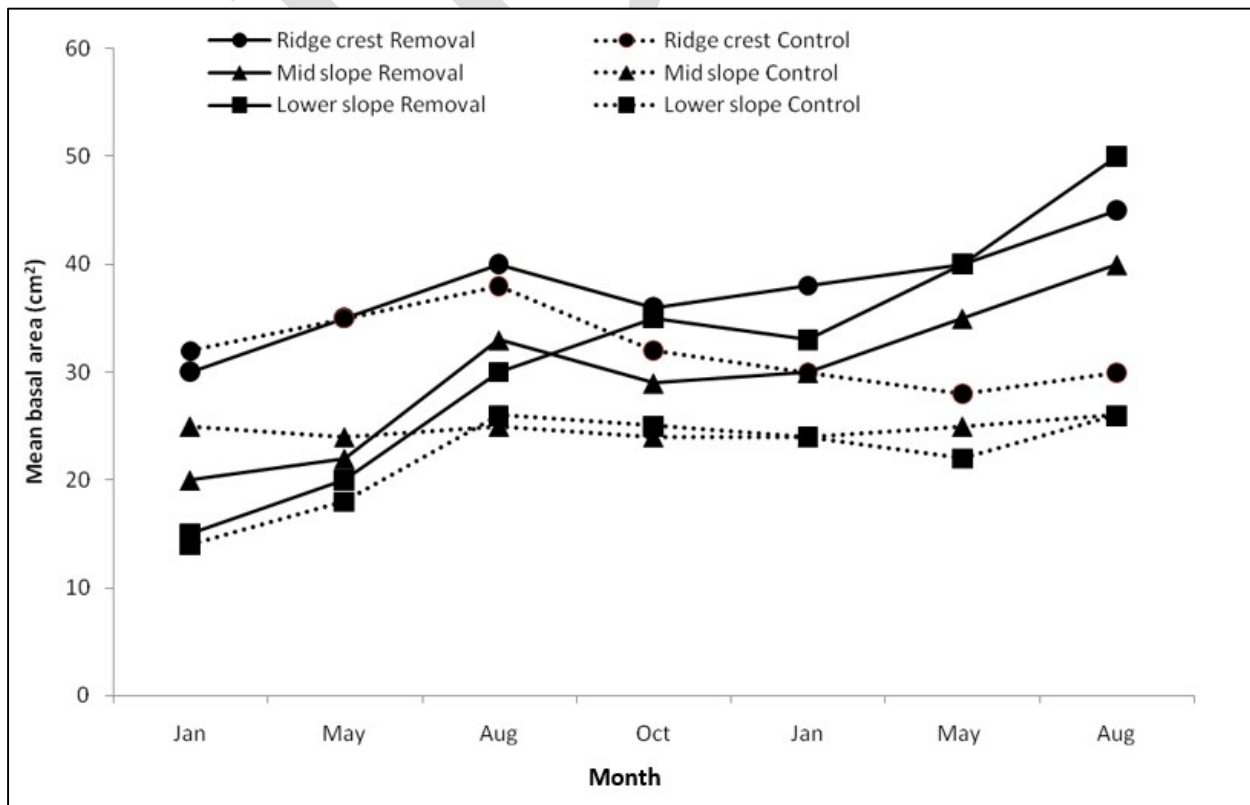


Assume that IPTG freely permeates in the cell and its concentration in the medium and the cell equilibrates fast. Also assume that each lac-repressor (a tetramer) binds to 4 IPTG molecules. If the *E.coli* is taken as a sphere of 1 μ m diameter, calculate the number of lac-repressor (tetrameric) molecules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

PLANT SCIENCES (13 points)

41. (2 points) For a plant in which the first stable product of CO₂ fixation is a 3-carbon compound, about 500 molecules of water are lost for every molecule of CO₂ 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 (✓) in the appropriate boxes.
- Decreased water efflux and increased CO₂ influx.
 - Low concentration of CO₂ in the air and relatively high concentration of water vapour within the leaf.
 - CO₂ molecules having a smaller diffusion coefficient than water.
 - The plasma membrane, cytoplasm and chloroplast envelope adding to the resistance in the CO₂ diffusion pathway.
42. (2.5 points) 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.
43. (2 points) *Stipa neomexicana* is a C₃ 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 neighboring 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 marks (✓) in the appropriate boxes.

- The removal of other species allows the growth of *Stipa neomexicana* throughout the crest.
- 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*.

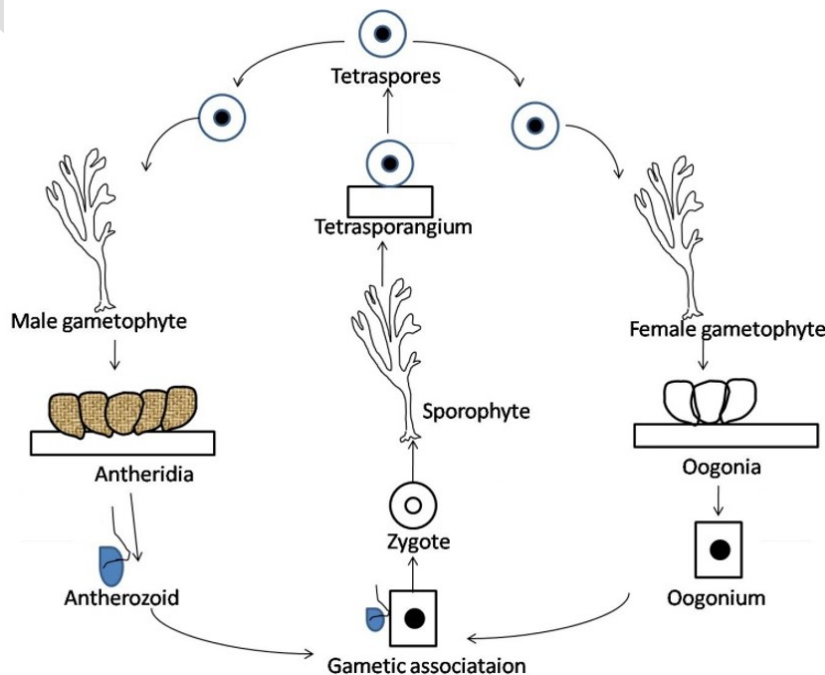
44. (3 points) Auxins play an important role in the growth of plants. The distribution of auxin and the resulting changes in the shoot growth were being observed in the plant kept near a window (plant 1) and the shoot of a fallen potted plant exhibiting negative gravitropism (plant 2). Complete the table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

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 the 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 MPa m^{-1} and the pressure due to weight of a standing column of water is 0.01 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.

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

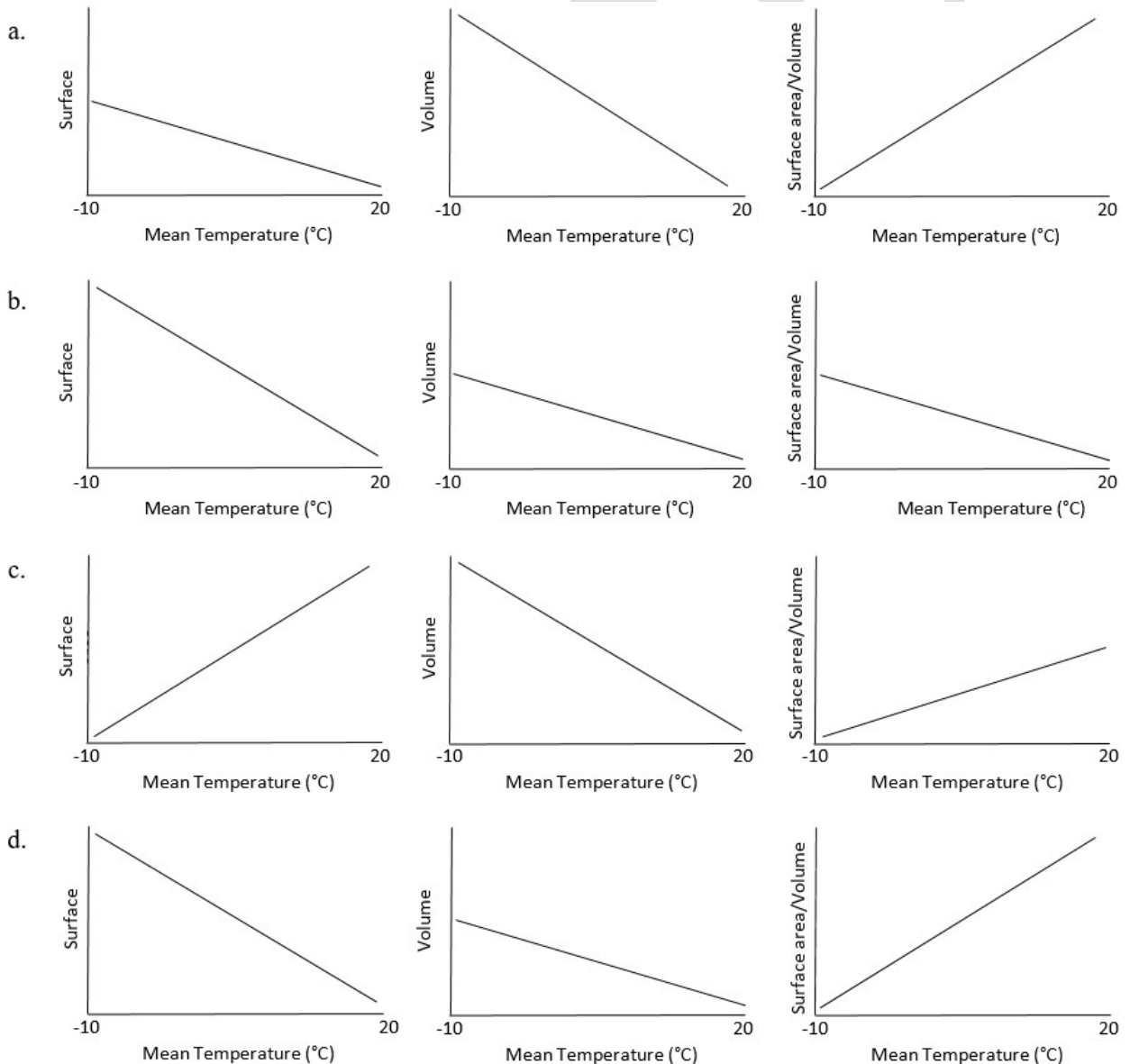


Based on the figure, mark the following statements as true or false by putting tick marks (✓) in the appropriate boxes.

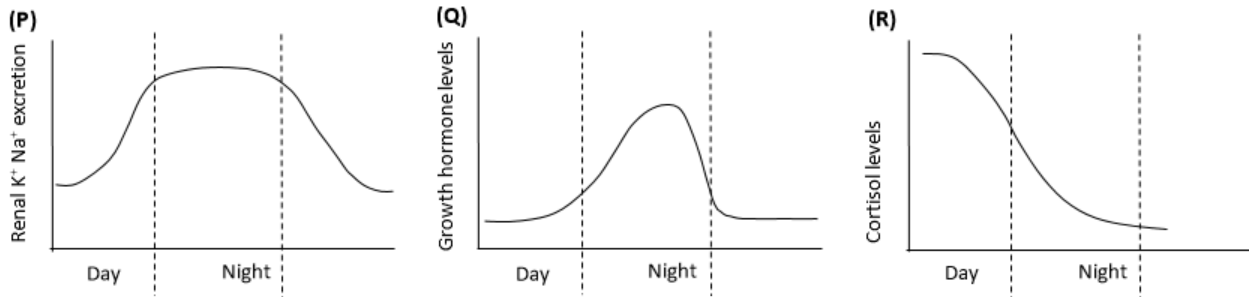
- Fertilization is external.
- Alternation of generations is isomorphic.
- Gametophyte is homothallic.

ANIMAL SCIENCES (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.



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

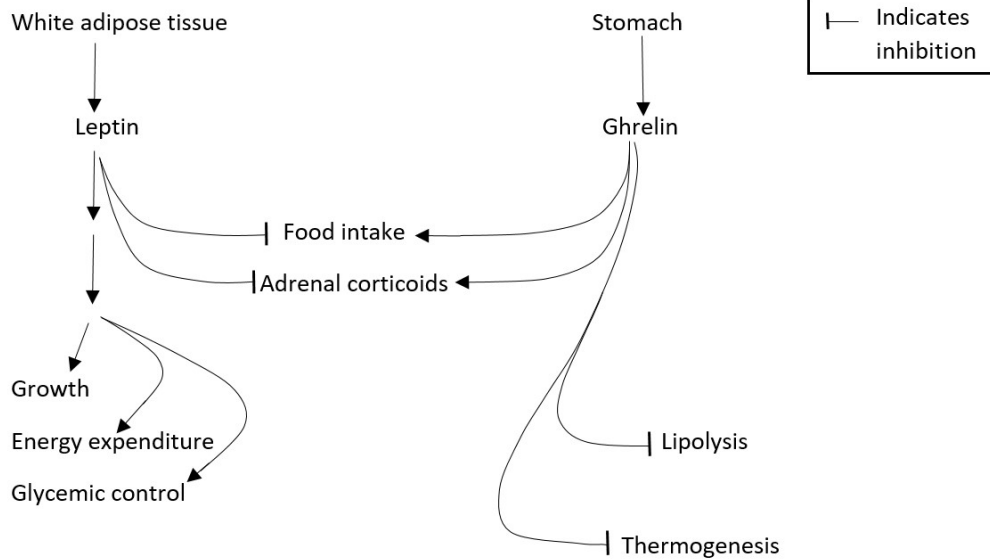


Match the type of animal to each graph and fill in the correct options in the blanks.

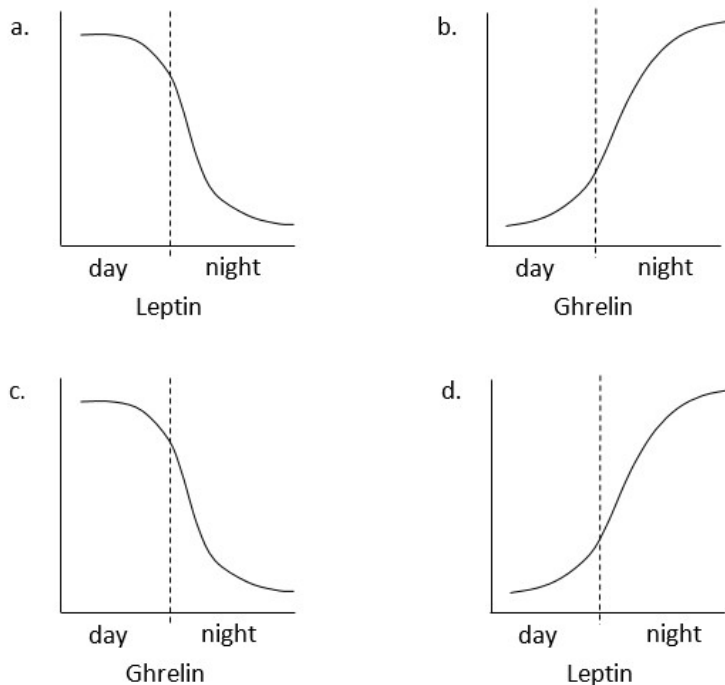
Options for type of animal:

- 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.

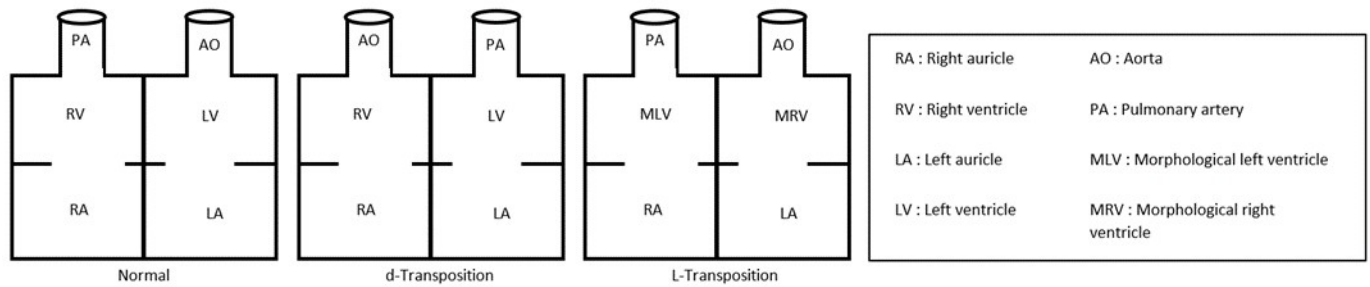


49. (2.5 points) Mammalian heart acts as double circulation pump in which two circulatory pathways occur simultaneously. However due to some defects or abnormalities in different parts of heart, a person or new born may face several symptoms and if not corrected can lead to different health issues. A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

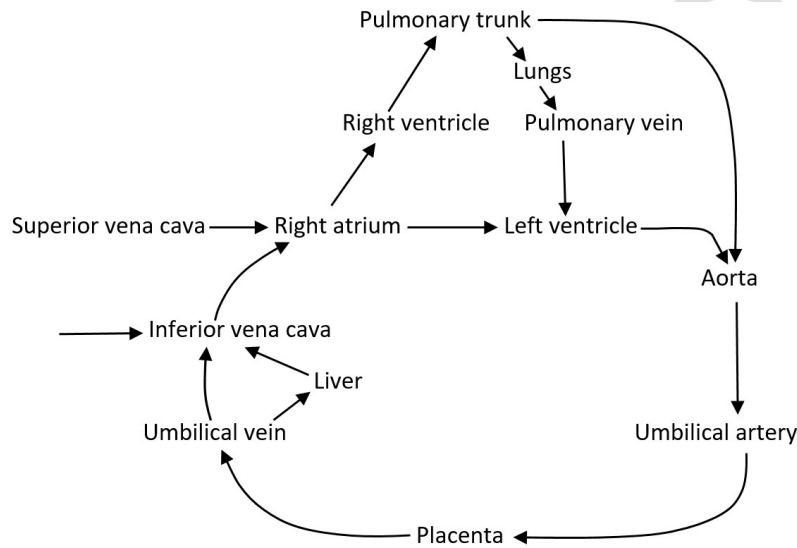
A list of symptoms/outcomes is given below.

- i. Lethal for new born unless corrected
- ii. Enlarged left ventricle
- iii. Body receives fully oxygenated blood
- iv. High blood pressure
- v. Tightness in chest
- vi. Body receives fully deoxygenated blood
- vii. Bluish skin colour



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

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.*

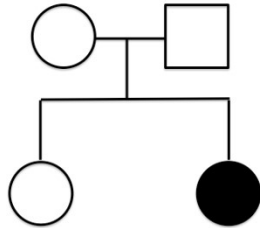
51. (2 points) The sympathetic nervous system is best known for its role in responding to dangerous or stressful situations and parasympathetic nervous systems controls various involuntary physiological processes, including but not limited to those illustrated in the table below:

| 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) |

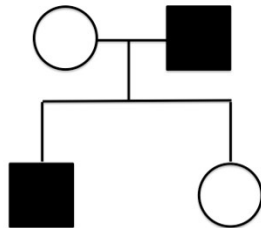
Associate physiological functions with either the sympathetic or parasympathetic nervous system and fill in the choices using alphabets (either 'a' or 'b') in the respective boxes in the table.

GENETICS & EVOLUTION (12.5 points)

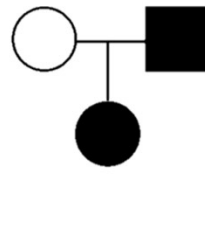
52. (2 points) The following are three pedigrees showing the inheritance pattern of a commonly occurring trait that is monogenic.



Family 1



Family 2

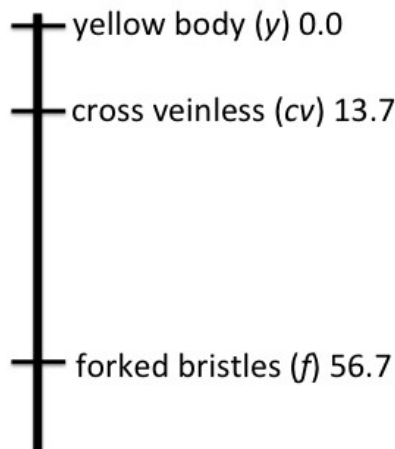


Family 3

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.

53. (2 points) 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.

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.

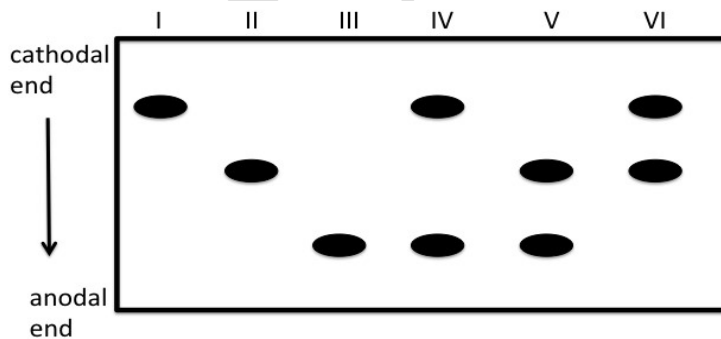
The ‘uu’ is the genotype for ‘uncap’ phenotype while the ‘rr’ is for ‘remove’ phenotype.

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 F1 generation will be hygienic bees.
- Backcrossing of F1 female progeny with non-hygienic males results in 50% hygienic and 50% non-hygienic female bees.
- F1 female progeny when crossed with hygienic males results in 25% of bees being completely non-hygienic female bees.
- A cross between F1 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.

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



The percentage of individuals in a population showing the different allozyme patterns was 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.

- 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.

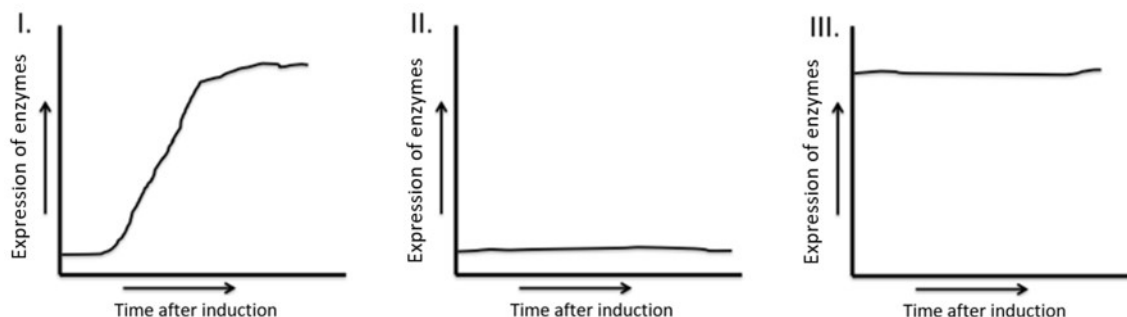
Three different mutants were generated:

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

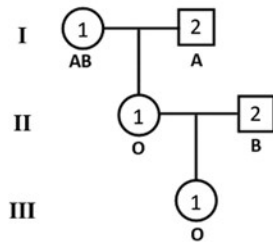
The following are three plots representing the activity of the operon following induction with Basta:



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

- 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

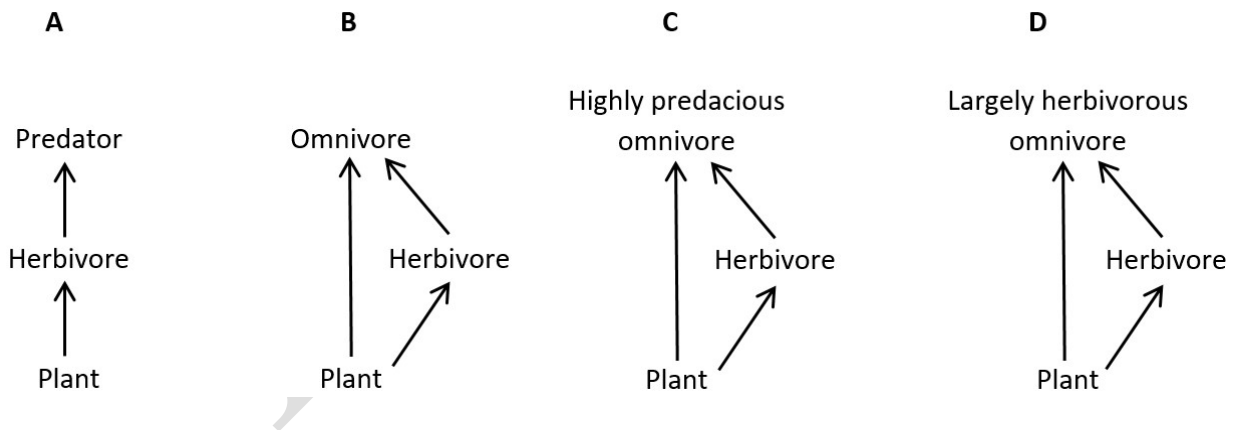
in terms of both 'I' and 'H' alleles for the individual/s with blood group O when the person with blood group B is homozygous for H.



ECOLOGY (5 points)

58. (2 points) Omnivory is widespread among insects, both in natural and in agricultural systems. It is possible to use insect omnivores as biological control agents in the modern agricultural system. Four possible interventions could be done by introducing the following:
- Predator
 - Omnivore
 - Highly predacious omnivore and
 - Largely herbivorous omnivore

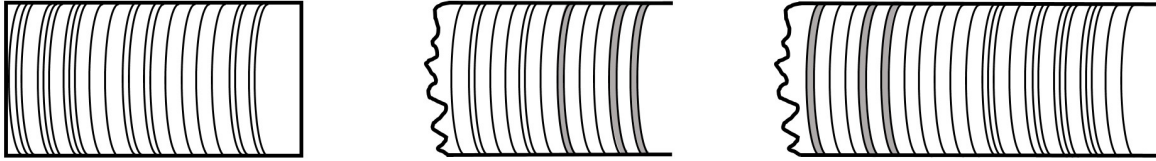
A – D represent four trophic relationships between plant, herbivore and predator, with and without different kinds of omnivores.



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.*

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

- ii. Sample of a living tree of the same species
- iii. Sample of a standing dead tree of the same species



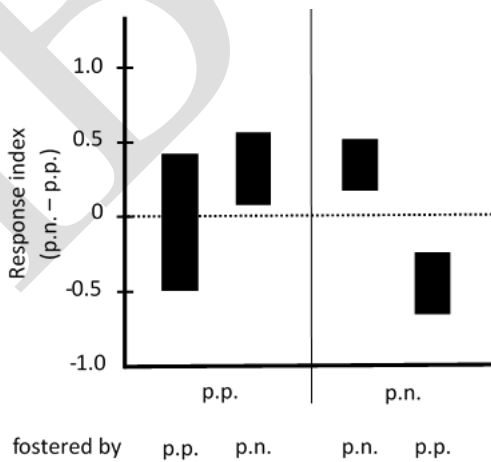
- i.
- ii.
- iii.

(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.

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.

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.

- Scream vocalization is used by the monkeys in intergroup signaling.
 - Using scream for communication within a troop could attract predators relative to the whoop-gobble call.
 - Scream has a broad range of frequency and hence can be carried over long distances.
 - Whoop-gobble is generally used during agonistic encounters within a group.
 - Whoop-gobble could be used for communication across groups for spacing between troops.
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.
- Absence of predators.
 - Limited number of nest sites.
 - Absence of other gull species in the colony.
 - Absence of nest materials at nesting sites.
 - Narrowness of ledge.

Certain behavioral 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 correct row will be given points)

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

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.*

***** END OF SECTION B *****