

# Indian National Biology Olympiad (INBO) - 2025

Homi Bhabha Centre for Science Education (HBCSE-TIFR)

## Question Paper

Date: 2<sup>nd</sup> February, 2025

Maximum Marks: 300

Duration: 2 hours

ROLL NO.     –     –

### 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 26 numbered pages.**

Use **ONLY** a blue/black pen to mark your answers.

#### Section A

- Section A consists of 27 questions carrying 1 point each.
- All 27 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.

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 73 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.

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### SCORING KEY

**NO. OF CORRECT ANSWERS: X**

**NO. OF INCORRECT ANSWERS: Y**

**SCORE: SECTION A: 3X – Y**

**SECTION B: 3X**

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## SECTION A

### CELL BIOLOGY (4 points)

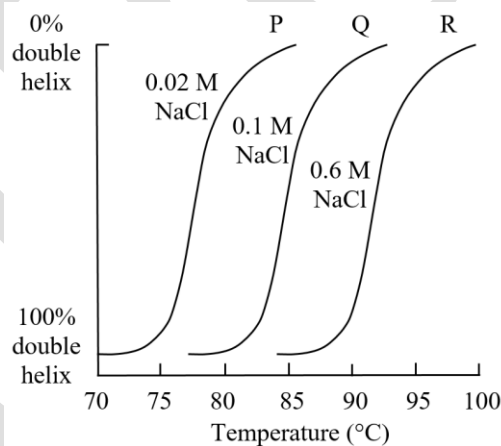
1. (1 point) tRNA is a single stranded molecule that folds into a clover-leaf like secondary structure. Which of the following factors play a role in its folding?
- Hydrophobicity of the bases
  - Hydrogen bonding among the bases
  - Phosphodiester bonds
  - Temperature

Options:

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

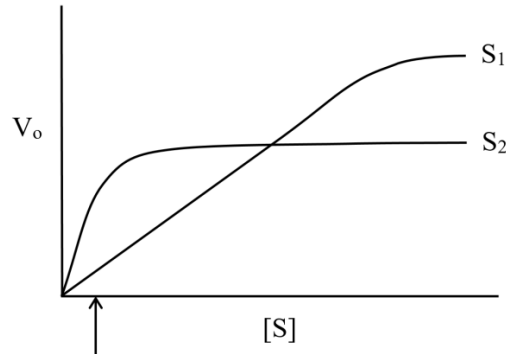
2. (1 point) When the ciliated tracheal epithelium in isolation is treated with a microtubule depolymerizing drug, which of the following observations is most likely to be made?
- The number of cilia per unit epithelial surface area will decrease.
  - The directional beating of the cilia will be lost.
  - Cilia will become rigid and beat randomly.
  - The cilia will reduce to 1/4<sup>th</sup> of its original size.

3. (1 point) The graph depicts the effect of different salt concentrations on the physical state of a bacterial DNA fragment. Select the most appropriate option that applies to this data.



- Increasing salt concentration increases the thermolability of the DNA strand.
- Repulsion between like charges in DNA is more pronounced in condition P as compared to conditions Q and R.
- Increasing salt concentration leads to increased hydrogen bonding between the DNA strands.
- If one measures absorbance of the DNA strands at 260nm, R is likely to show greatest absorbance at any temperature between 70 – 100°C as compared to P and Q.

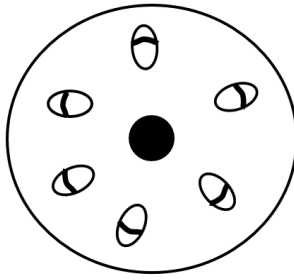
4. (1 point) Amino acid glutamine is required for cancer cells to survive and proliferate. Enzyme glutaminase breaks down glutamine into glutamate and ammonia. Glutaminase was obtained from two different sources,  $S_1$  and  $S_2$ . Their kinetic properties are shown in the graph. The arrow indicates the concentration of glutamine in the cell environment. Based on the kinetics, can any of these enzymes be considered for possible cancer treatment?



- Enzyme from  $S_1$  can be used more effectively for cancer treatment as it shows higher  $V_{max}$  than  $S_2$ .
- Enzyme  $S_2$  is better for cancer treatment as it shows lower  $K_M$  value for the substrate.
- Both enzymes cannot be used as production of ammonia will be detrimental to the neighbouring normal cells.
- Both enzymes are equally effective as both are active at concentrations found in the cell environment.

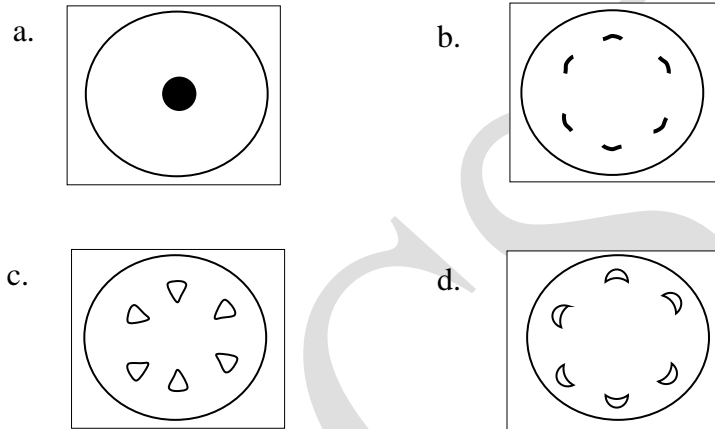
### **PLANT SCIENCES (7 points)**

5. (1 point) Plants have constitutive leaf angles that are generally fixed and do not vary much among different growth environments. Several species however have the ability to actively adjust their leaf angles. Leaf angle is defined as the angle between the leaf blade plane and the horizontal plane. Which of the following condition is likely to decrease the leaf angle of a plant?
- Environmental stress such as temperature rise.
  - Environmental stress such as drought.
  - Sustained flooding leading to plant submergence.
  - Plants growing with dense canopy overhead.
6. (1 point) In an experiment, carbon dioxide labelled with radioactive carbon ( $^{14}\text{CO}_2$ ) was supplied to a leaf of potted plant for a particular time interval. The pot was kept in a well-lit place during this experiment. After few hours, a transverse section (T. S.) of the stem (region just above the petiole attachment) was obtained and observed under a microscope as shown below.



T.S. of the stem as observed under a microscope

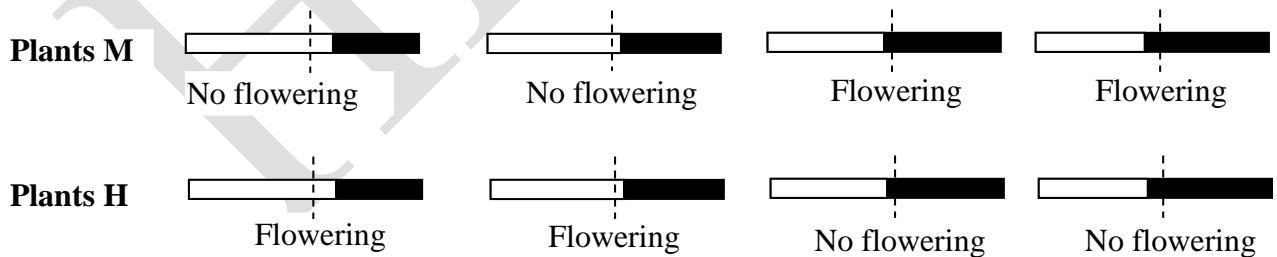
The section was subsequently dried and exposed to an X-ray film in a dark room for a week. After development of the film, which one of the following patterns would be observed?



7. (1 point) How many molecules of  $\text{CO}_2$  need to be fixed to complete one Calvin cycle and regenerate RuBP?

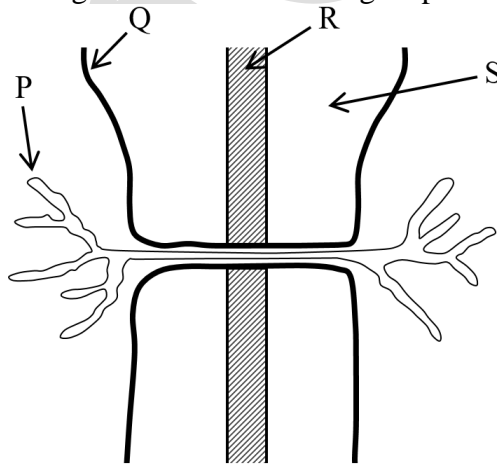
- a. 1                      b. 2                      c. 3                      d. 4

8. (1 point) The observations regarding flowering in two plants Maryland mammoth tobacco plants (M) and Henbane *Hyoscyamus niger* (H) plants grown in artificially varying day and night lengths are shown below. The dashed vertical line indicates 14 hr.



Based on the observations, select the correct option.

- a. Both M and H are short day plants.
  - b. M is a short day plant while H is a long day plant.
  - c. M is a long day plant while H is a short day plant.
  - d. M is a long day plant while H is a day neutral plant.
9. (1 point) Several mechanisms have evolved in plants that avoid self-pollination. In a plant, one such mechanism is seen in the growing pollen tube. If the incompatibility gene is expressed during the development of pollen tube, the style and stigma block further growth of pollen tube. This mechanism, operative between pollen tube and style-stigma, respectively is:
- a. haploid and diploid genome incompatibility.
  - b. diploid and diploid genome incompatibility.
  - c. haploid and haploid genome incompatibility.
  - d. diploid and haploid genome incompatibility.
10. (1 point) In *Mirabilis* plant, inheritance of leaf colour is due to plastids. If pollen grains from a variegated branch are used to pollinate the stigma of a flower from a green branch, it will result in plants with:
- a. only green leaves.
  - b. only variegated leaves.
  - c. green, yellow and variegated leaves
  - d. both green and variegated leaves.
11. (1 point) Plasmodesmata are microscopic channels that connect adjacent plant cells allowing for transport of molecules. Longitudinal section through a plasmodesma is shown below.

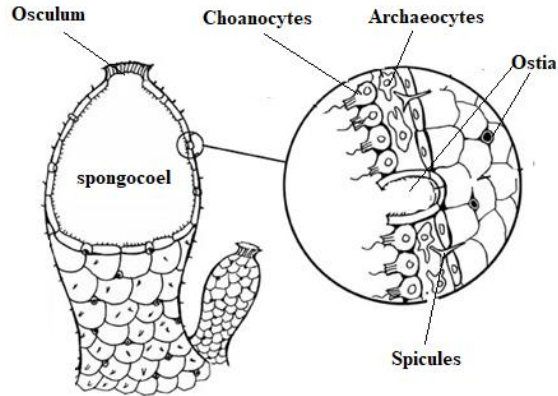


The structures designated as P – S, respectively, are:

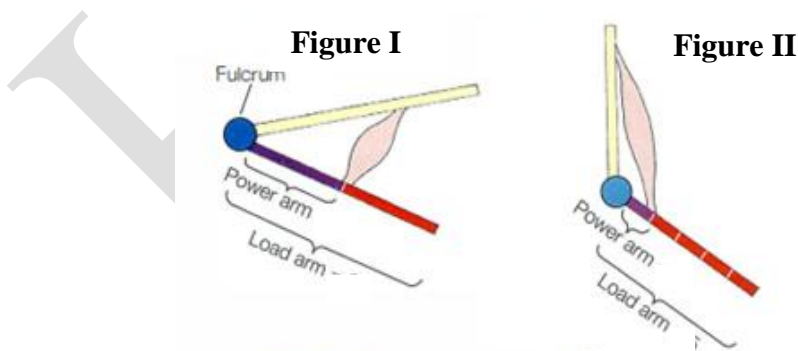
- a. plasmalemma, middle lamella, primary cell wall, secondary cell wall
- b. Golgi bodies, primary cell wall, lignin, secondary cell wall
- c. Golgi bodies, plasma membrane, primary cell wall, secondary cell wall
- d. endoplasmic reticulum, plasma membrane, middle lamella, primary cell wall

**ANIMAL SCIENCES (3 points)**

12. (1 point) Marine sponges exhibit filter feeding wherein the water is taken into their body. The cells such as archaeocytes and choanocytes (collar cells) are instrumental in the process of digesting the ingested food. The waste is removed through the outward movement of water. Which of the following correctly depicts the sequence of events during the ingestion and digestion in a sponge?



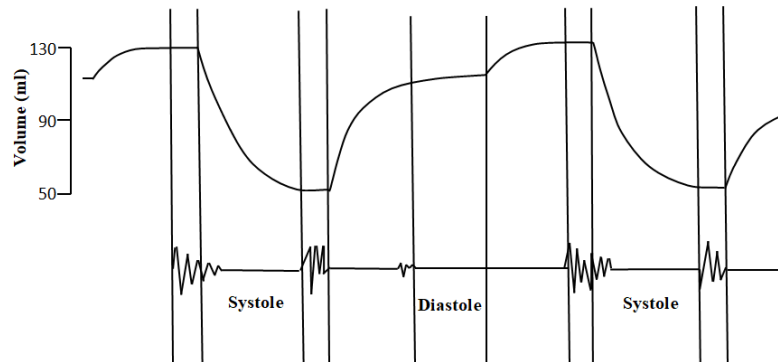
- Food particles → Osculum → Archaeocytes → Choanocytes → Intracellular digestion → distributed to other cells of the body → Undigested food expelled through ostia
  - Food particles → Ostia → Archaeocytes → Choanocytes → Intracellular digestion → distributed to other cells of the body → Undigested food expelled through osculum
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13. (1 point) Bones constitute a system of levers that are moved around joints by the muscles. Two representative figures are shown below (I and II)



The length ratio of the power arm and load arm determines whether a particular lever can exert a stronger force over a short distance or is better at translating force into large movements. Systems I and II in the human body with the load arm to power arm ratios of 2:1 and 5: 1 are respectively found in:

- Arm and skull
- Leg and arm
- Hip and neck
- Jaw and leg

14. (1 point) The changes in the ventricular volume over a cardiac cycle in a healthy human are represented below.



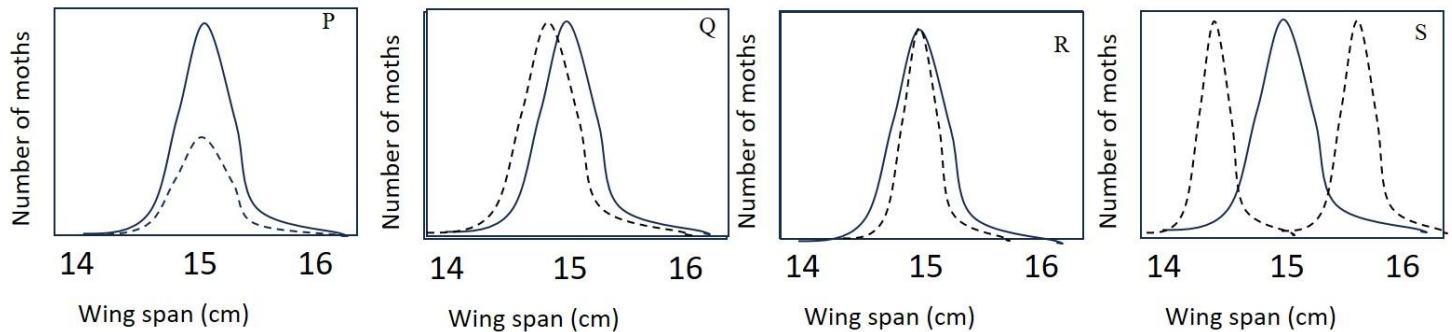
Which of the following would represent the correct trend (relationship) in the aortic pressure (P), atrial pressure (Q) and ventricular pressure (R) at the start of left ventricular ejection of blood?

- a.  $R > P > Q$   
 b.  $P > Q > R$   
 c.  $P > R > Q$   
 d.  $P = R > Q$

### **GENETICS & EVOLUTION (4 points)**

15. (1 point) TONPG is a compound which is toxic to *E. coli*. This is transported into the cell by lactose permease, the protein encoded by *lac Y* gene of the lactose operon. TONPG is not cleaved by  $\beta$ -galactosidase (encoded by *lac Z* gene). TONPG can be used to isolate mutants of the lactose operon. Which one of the following mutants can be isolated using TONPG?
- a. Mutants of *lac Z*, which do not make  $\beta$ -galactosidase.  
 b. Mutants of *lac Y*, which do not make permease.  
 c. Mutants of the *lac I* gene which do not make a functional repressor protein.  
 d. Constitutive mutants in the operator region of the lactose operon.
16. (1 point) Two genotypes of a bacterial species, M and N, were found to grow at 10% (growth rate = 1.10) and 5% (growth rate = 1.05), respectively, per generation at 37° C in LB media. In an experiment,  $10^3$  bacterial cells of each genotype were taken together in a flask and the growth was observed for 500 generations under non-limiting nutrient conditions at 37°C in LB media. Assuming no new mutations would arise during the experiment, which one of the following statements is true regarding this experiment?
- a. After 500 generations, the number cells corresponding to genotype M will be 2 times more than genotype N.  
 b. The frequency of genotype N decreases progressively and eventually; genotype M will approach 100% and genotype N will approach 0% of the total population.  
 c. Genotype M will never approach 100% and genotype N will never approach 0% as both genotypes exhibit positive growth rate of  $> 1$ .  
 d. The genotype proportions would stabilize after some generations and reach an equilibrium.

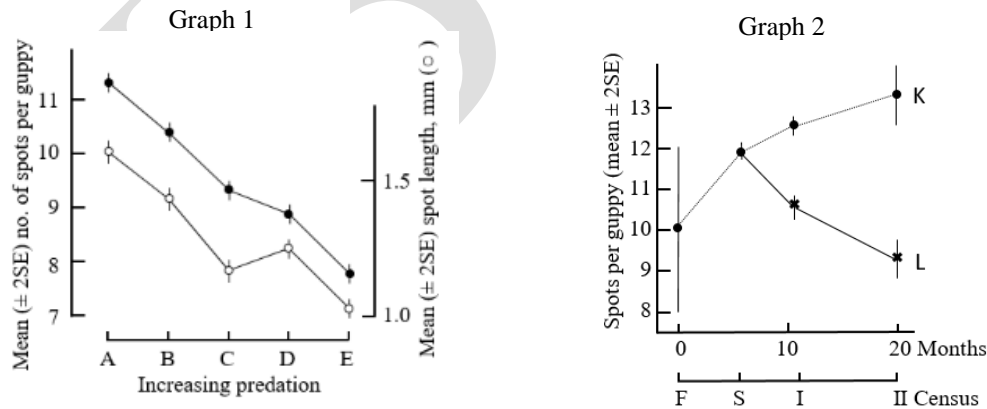
17. (1 point) The following figure shows how the wing span of a polyphemus moth species migrated/diversified to four unconnected geographies (P, Q, R, and S) respond to different environmental conditions they encounter during a year.



Which of them is/are example/s of microevolution? *In the figure, continuous line represents the wing span size (in cm) distribution of the population. The dotted line represents the same observed after one year.*

- a. P only
- b. P and R only
- c. Q, R and S only
- d. Q and S only

18. (1 point) A study was carried out on spot pattern of male guppies in five streams (A – E) where other fish were the main predators. The findings are shown in graph 1. Graph 2 shows the results of laboratory experiments where a founder population F was kept initially without predators. At time point S, predators were added to population L but not to population K. Observations over time are depicted.



Which of the following can be deduced from the findings?

- i. The variation in the spot pattern in the guppy population K and L is most likely the effect of age as observed in graph 2.
- ii. Both graphs indicate disruptive selection.
- iii. This is an example of counter selection against spot colour due to predation.
- iv. The result of the study supports directional selection.



Options:

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

**ECOLOGY (7 points)**

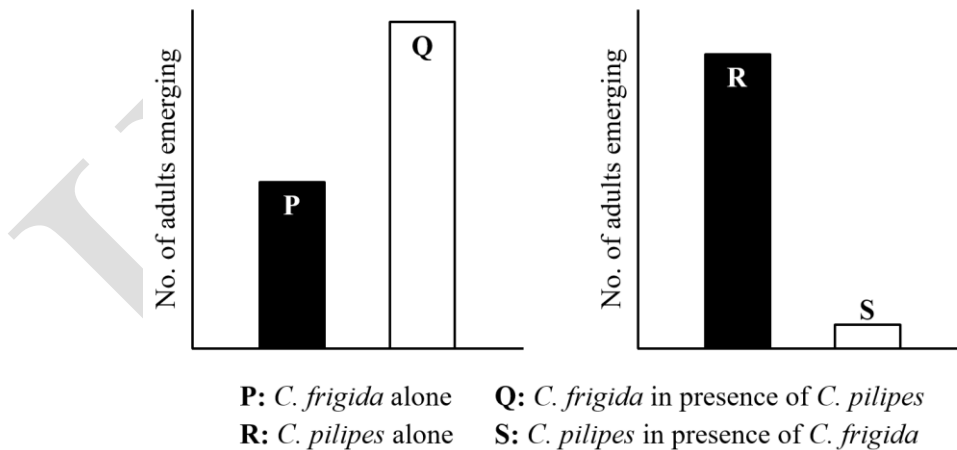
19. (1 point ) Edge effects are changes in population or community structure that occur at the boundary between two habitats, also known as ecotone. Which of the following is/are correct about an ecotone?

- i. Ecotone is the zone of minimal diversity of species.
- ii. Species completely different from the adjacent two habitats are likely to be found in ecotone.
- iii. If the ecotone is between a forest and an agricultural land, it is beneficial for forest due to influx of fertilizer chemicals.
- iv. An ecotone such as a wetland serves as a buffer by protecting adjacent ecosystems.

Options:

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

20. (1 point) The seaweed flies, *C. frigida* and *C. pilipes* feed on brown seaweeds commonly found on rocky shores. Both these flies were grown in the laboratory and fed on brown seaweed. When grown independently and in the presence of each other, the following data was obtained.



The interaction between the two species is:

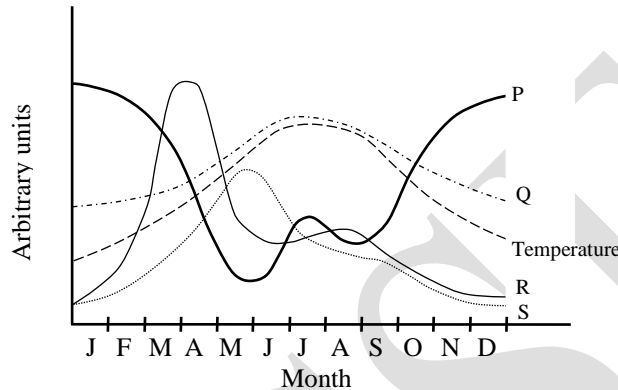
- a. Competitive exclusion
- b. Intraspecific competition
- c. Amensalism
- d. Asymmetric competition

21. (1 point) If volcanic eruptions take place and a land becomes barren, the correct order of succession would be:

- a. Lichens → Bryophytes → Shrubs → Trees → Climax community.
- b. Shrubs → Small trees → Biggers trees → Climax community.

- c. Algae → Bryophytes → Shrubs → Climax community.
- d. Lichens → Big trees → Climax community.

22. (1 point) The dry matter estimated at given instance is called a standing crop biomass. The lines P, Q, R and S in the figure below represent the changes over a year in abiotic factors namely nutrients, temperature and light as well standing crop of phytoplankton and zooplankton in a freshwater lake. Temperature is the only abiotic factor that is labeled.



Only during the period of May to July, standing crop biomass of producer and primary consumer forms an inverted pyramid. Which two lines represent phytoplankton and zooplankton respectively?

- a. R and P
- b. R and S
- c. Q and P
- d. S and P

23. (1 point) Solbrig and Simpson carried out a study on dandelion (*Taraxacum officinale*) over four years. The characteristic feature of this weed is that it produces seeds apomictically (without sexual reproduction). Therefore, in any given locality, the genetic lines present are few and each lineage is a clone of one genetic type. They identified four genetic types, P, Q, R and S, on 3 grasslands situated close to each other. These grasslands were facing different amounts of disturbances. The following table shows different proportions of the four genetic lines present at each site.

	Habitat	Percentage of genetic lines present			
		P	Q	R	S
1.	Trampled, dry grassland mown every week, bare ground patches	73	13	15	0
2.	Moderately trampled, mown every week, in shade	53	32	14	1
3.	Wet, shaded, mown once a year	17	8	11	64

Which genetic type of dandelions is most likely to be a K-selected population?

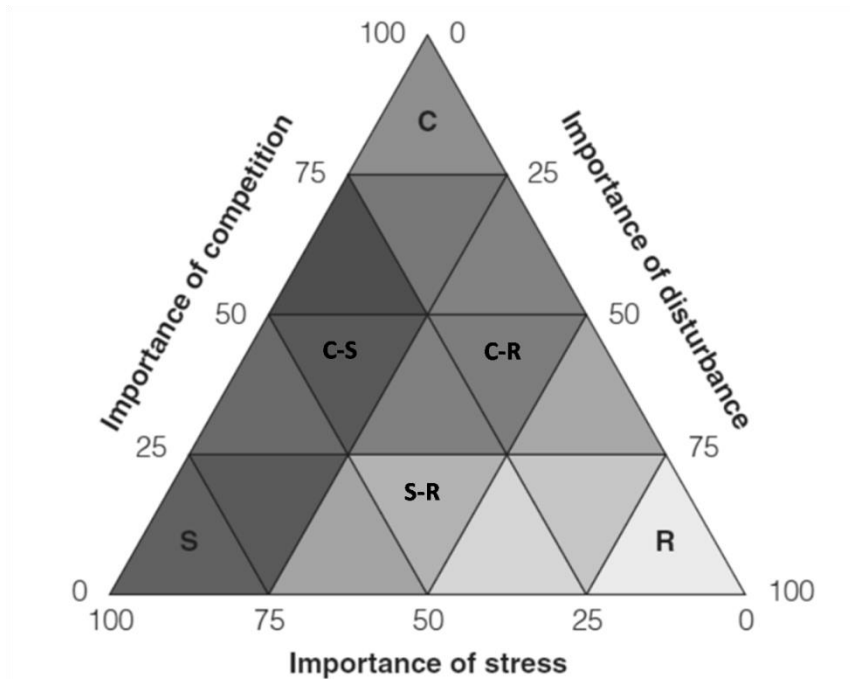
- a. P      b. Q      c. R      d. S

24. (1 point) A study on species diversity was carried out at Sulpaneshwar Wildlife Sanctuary (X), Jambughoda Wildlife Sanctuary (Y) and Purna Wildlife Sanctuary (Z). Species diversity is a collective function of species richness and evenness. A list of species and their abundance is given in table below. Arrange these different habitats in decreasing order of species diversity.

Species	Abundance		
	X	Y	Z
A	10	12	10
B	30	6	10
C	6	18	10
D	0	8	10
E	10	11	10
F	1	3	0
G	3	2	10

- a. Habitat Y, Habitat Z and Habitat X  
b. Habitat X, Habitat Y and Habitat Z  
c. Habitat Z, Habitat Y and Habitat X  
d. Habitat Y, Habitat X and Habitat Z

25. (1 point) Following triangle diagram represents environmental conditions and distinctive strategies or life histories among plants. Expansion for C: competitive, S: stress-tolerant and R: ruderal (growing on waste ground), C-S: stress tolerant competitors, C-R: Competitive ruderals and S-R: Stress tolerant ruderals. The percentage of the C-S-R for species X, Y and Z are given in table below. Classify species X, Y and Z. Select the most appropriate option

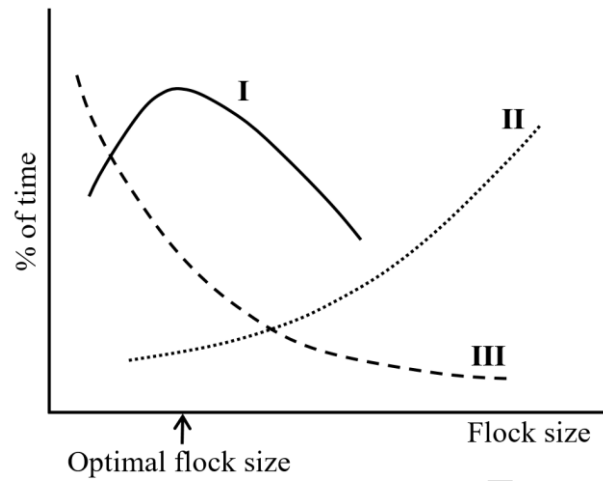


Species	C	R	S
X	14	78	8
Y	25	10	65
Z	20	40	40

- a. X-Ruderal, Y-Stress-tolerant competitors and Z - Stress tolerant ruderals
- b. X - Competitive, Y- Ruderal and Z- Competitive ruderals
- c. X-Stress tolerant competitors, Y- Competitive and Z- Stress tolerant competitors
- d. X- Stress tolerant competitors, Y- Competitive ruderals and Z- Stress tolerant ruderals

**ETHOLOGY (1 point)**

26. (1 point) A group of scientists were studying the factors influencing winter flocks of small birds. The survival of birds in a flock is considered to be dependent on two main risks namely starvation and predation. The bird's time budget is divided into three types of behaviours associated with these risks – scanning (for predators), feeding and fighting (for food). A graph depicting the three behaviours is shown in three curves I, II and III.



I, II and III respectively represent:

- fighting, feeding and scanning
- scanning feeding and fighting
- fighting, scanning and feeding
- feeding, fighting and scanning

**BIOSYSTEMATICS (1 point)**

27. (1 point) Three traits for four phylogenetically different animals (P, Q, R and S) are shown.

Animal	Egg size	Progeny	Parental care
P	•	•	●
Q	●	●	•
R	•	●	•
S	●	•	●

P, Q, R and S respectively most likely are:

- mouse, chicken, zebrafish, honeybee
- human, zebrafish, honeybee, chicken
- zebrafish, frog, wasp, chicken
- mouse, honeybee, zebrafish, human

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

## SECTION B

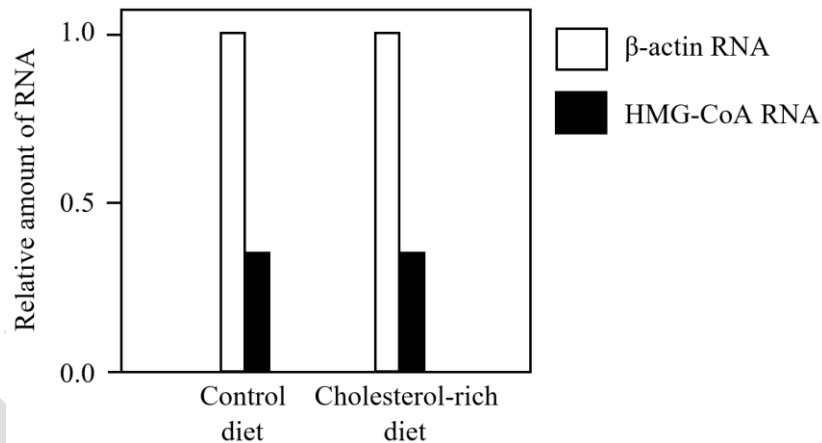
### CELL BIOLOGY (18 points)

28. (2 points) Consider a protein with a molecular weight of 88 kDa. Calculate the molecular weight of the protein coding region of the corresponding mRNA. Assume the molecular weight of an amino acid to be 110 Da and the average molecular weight of a ribonucleotide residue to be 340 Da.

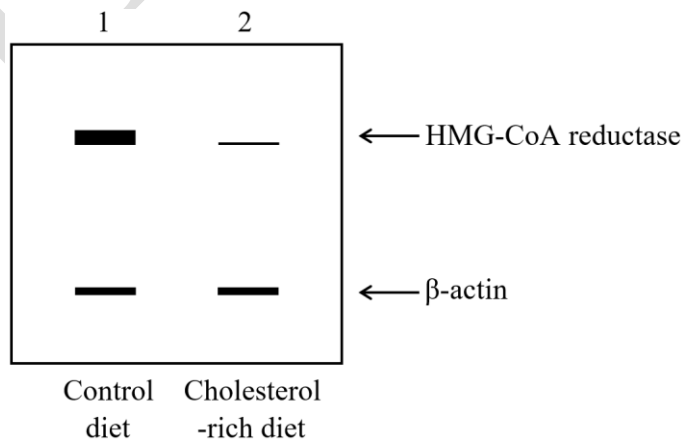
*Note that the final answer for question will be given marks only if calculations are shown in the box given and the final answer is filled in the blank.*

29. (2.5 points) HMG-CoA reductase is a key rate limiting enzyme in cholesterol biosynthetic pathway. The effect of cholesterol on HMG-CoA reductase was studied by feeding mice with control diet and to a separate group with cholesterol rich diet.

Part I. Total RNA was isolated and level of specific mRNA was measured by RT-PCR.



Part II. From the same experiment as described in Part I, proteins were also isolated and separated on SDS-PAGE and immunoblotted using specific antibodies against  $\beta$  – actin and HMG-CoA reductase. The result of the western blot is shown below



Based on the above results, indicate whether each of the following statements is true, false or cannot be concluded by putting tick marks (✓) in the appropriate boxes.

- a. Cholesterol feeding reduces the transcription of all genes in mice.
  - b. Cholesterol feeding inhibits translation of all mRNA.
  - c. Cholesterol feeding reduces the level of HMG-CoA reductase.
  - d. Cholesterol feeding induces the degradation of HMG-CoA reductase.
  - e. Cholesterol feeding inhibits translation of HMG-CoA reductase mRNA.
30. (2 points) In a hypothetical restriction mapping experiment, a sample of DNA was completely digested with two restriction enzymes *EcoRI* and *HaeIII* added to the same tube. DNA separation using agarose gel electrophoresis showed three bands of sizes 1.5 kb, 2.5 kb and 3.0 kb. Indicate whether each of the following is possible or not possible by putting tick marks (✓) in the appropriate boxes.
- a. The sample is a 7 kb circular DNA with *EcoRI* and *HaeIII* having two unique sites each.
  - b. The sample is a linear DNA with *HaeIII* having a site located at 5.5 kb from one end and an *EcoRI* site located at 2.5 kb from the other end.
  - c. The sample is a linear DNA with *EcoRI* and *HaeIII* sites 1 kb apart.
  - d. The sample is a 11 kb linear DNA with two unique *EcoRI* and *HaeIII* sites each.

31. (2 points) Consider the following:

I) Bacteriophage genome,  $10^5$  bp long, was fragmented to obtain unique (non-repeating) fragments of 500 bp length each.

II) Bacterial DNA,  $5 \times 10^6$  bp long, was also fragmented to obtain unique (non-repeating) fragments of 500 bp length each.

Equal quantity of each sample was denatured and allowed to re-associate separately under the same experimental conditions. During the re-association, the following parameters were tested.

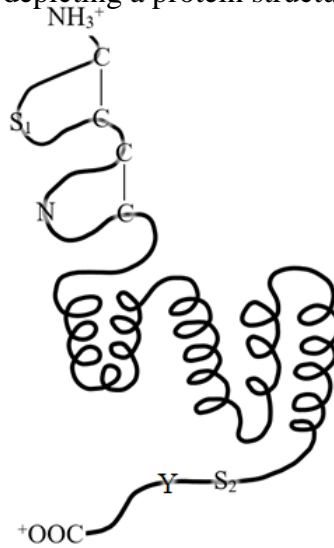
- i)  $S_1$  Nuclease digestion (specific for ssDNA)
- ii) Hypochromicity

At any point of time during the re-association:

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

- a. 'I' will show higher nuclease digestion value than 'II'.
- b. 'II' will show lower hypochromicity than 'I'.
- c. Both 'I' and 'II' will show equal reduction in absorbance at 260 nm but different nuclease digestion values.
- d. Both 'I' and 'II' will show equal nuclease digestion values, but different absorbance values at 260 nm.

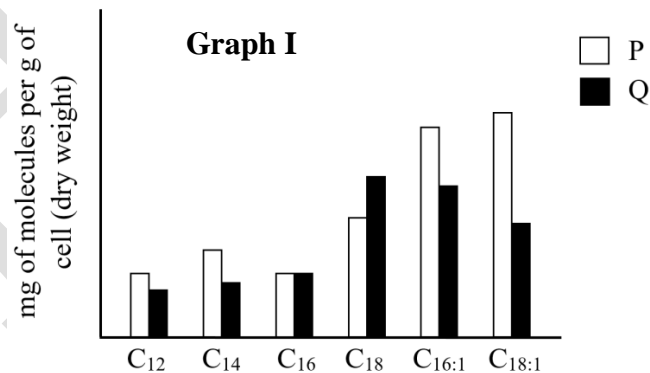
32. (3 points) Following is a cartoon depicting a protein structure:



Here C, S, N and Y represent Cysteine, Serine, Asparagine and Tyrosine respectively. Place tick marks (✓) in the appropriate boxes to indicate the correct options for each of the question A – C. (Note: Only a completely correct row will be given points.)

- (A) Location of the protein
- (B) Likely site of phosphorylation
- (C) Likely site of glycosylation

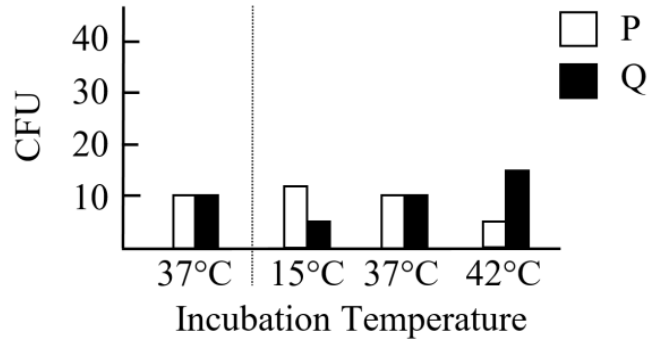
33. (2.5 points) Two bacterial species, P and Q, when analysed for the membrane lipid composition, revealed the following results (graph I):



When cells were cultured at 37°C and then shifted either to 15°C or 42°C temperatures, the data for colony-forming units (CFUs) obtained is depicted in graph II. (CFU is a measure of number of viable bacteria in a sample.)



**Graph II**



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

- Fatty acids of lower molecular weight are likely to impart more fluidity to the membrane.
- Unsaturated fatty acids are likely to provide more fluidity to the membrane that is required for cells to grow at higher temperatures.
- Culture P performs better at lower temperature as it has greater energy storage in the form of fatty acids.
- Membrane of bacteria P with more fluidity is likely to outperform Q at all temperatures.
- Weaker hydrogen bonding and increased membrane permeability will be observed in organism P at higher temperatures.

34. (2 points) A geneticist was studying the cell cycle in the root tip cells of a plant. She microscopically observed that 15 cells were in prophase, 7 cells were in prometaphase, 8 cells were in metaphase, 7 were in anaphase, 5 were in telophase and 88 were in interphase. The overall cell cycle for this particular species was recorded to be 23 hours. The time span that the cells are in the mitotic phase is:

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

35. (2 points) Arachidonic acid is a 20-carbon polyunsaturated fatty acid (20:4 all cis<sup>5,8, 11, 14</sup>eicosatetraenoic acid). It is found in the membrane and during inflammatory stimulus, it is released by the action of phospholipase A2. It acts as a precursor for prostaglandins and leukotrienes through the catalytic action of cyclooxygenases.

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

- It contributes to the fluidity of the membrane.
- It acquires a U-shaped structure.
- Its structure is favourable for cyclization catalyzed by cyclooxygenases.
- The redness and swelling at the site of inflammation is reduced by prostaglandins.

**PLANT SCIENCES (13.5 points)**

36. (2 points) There are two gardens – one in city A and the other in city B. Both these gardens had plant species X and Y. While the garden in city A had butterflies, that in city B did not have any insects or birds. The plant species X in the garden of city A set fruits successfully, whereas the plants of the same species in the garden of city B did not set any fruits. Interestingly, plants of species Y set fruits successfully in both the gardens of city A and B. Based on this observation, the types of flowers of the plant species X and Y were interpreted as follows:

- i. X = Dioecious, Y = Hermaphrodite
- ii. X = Monoecious, Y = Dioecious
- iii. X = Hermaphrodite, Y = Unisexual
- iv. X = Dioecious, Y = Monoecious

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

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

37. (2 points) A flower that lacks any of the four whorls is described as an incomplete flower. If any of the whorls essential for reproduction is/are missing, it is described as an imperfect flower. In some members of the cucumber family, plants growing in a poor environment produce imperfect flowers while those growing in a good (resource-rich) environment can produce both imperfect or perfect flowers.

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

- a. A flower that is incomplete is also imperfect.
- b. A flower lacking calyx and corolla both can be described as perfect.
- c. The cucumber plant growing in poor conditions is likely to produce staminate flowers.
- d. The imperfect flowers produced by cucumber plants in good conditions are likely to be carpellate flowers.

38. (2 points) Diagrammatic representations of part of a mitochondrion and a chloroplast depicting the locations of  $H^+$ -ATPase are shown in figures I and II respectively.

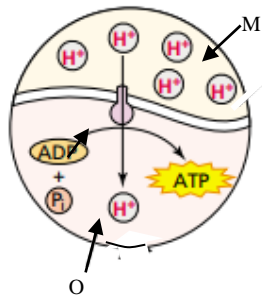


Figure I

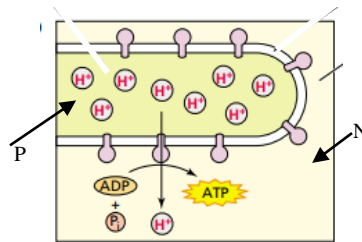


Figure II

What do M, N, O and P in the figures represent?

(Choose from the options below and fill in the blanks with the respective alphabet.)

Options:

- a. Granum    b. Lamellae    c. Stroma    d. Cristae    e. Intermembrane space  
f. Thylakoid membrane    g. Matrix    h. Outer membrane    i. Inner membrane  
j. Lumen

39. (4 points) The following is a description of seven types of flowers.

- i) Flowers with conspicuous yellow-pigmented nectar guide
- ii) Nocturnal nectar-producing flowers
- iii) Large, pale-coloured flowers
- iv) Flowers with strong fragrance
- v) Large flowers with bell-shaped concave structures of petals lacking in colours
- vi) Inconspicuous flower with feathery stigma
- vii) Flowers having brightly-coloured petals with nectar but lacking fragrance

Based on their characteristics, assign the type/s of flower/s (i – vii) that is/are likely to be pollinated by each of the agent listed in the table. Indicate your answers by filling the number/s of flower type (i – vii) against each agent. (*Note: only a completely correct row will be given points.*)

40. (3.5 points) Consider two flaccid plant cells P and Q with solute potentials  $-0.732$  MPa and  $-0.82$  MPa respectively. These cells were immersed in separate beakers each containing  $0.2M$  sucrose solution ( $\Psi_s = -0.65$  MPa), then answer the following questions.

(A) Complete the table with the values of solute, water and pressure potentials of the cells P and Q after immersion. Express the values in MPa, up to three decimal places. (*Only a completely correct row will get points*)

(B) What would be the difference in the pressure potentials of the two cells at equilibrium after immersion in the sucrose solution?

(C) If cells P and Q are now placed next to each other, then the movement of water will be:

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

- a.  $P \rightarrow Q$                       b.  $Q \rightarrow P$                       c. No net movement

### **ANIMAL SCIENCES (11 points)**

41. (4 points) During exercise, the cardiovascular and respiratory systems work together to deliver oxygen to the muscles and remove carbon dioxide. Consider the following data for an individual during moderate exercise:

- Heart rate (HR): 150 beats per minute (bpm)
- Stroke volume (SV): 80mL/beat

- Oxygen consumption by tissues per litre of blood ( $VO_2$ ): 180 mL  $O_2$ /L
- Tidal volume ( $V_T$ ): 600 mL
- Respiratory rate (RR): 20 breaths/min
- Alveolar ventilation : 80%

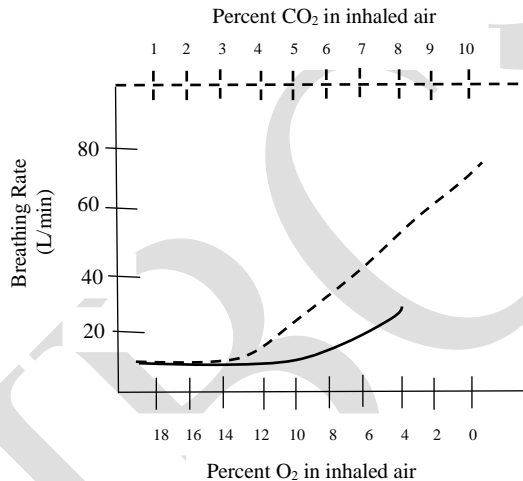
(A) Calculate the total amount of oxygen delivered to the tissues per minute (in mL  $O_2$ /min).

*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.*

(B) Calculate the alveolar ventilation in mL/min.

*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.*

42. (2 points) The changes in the breathing rate in response to changes in  $CO_2$  and  $O_2$  levels in inhaled air for dogs is shown in figure I.

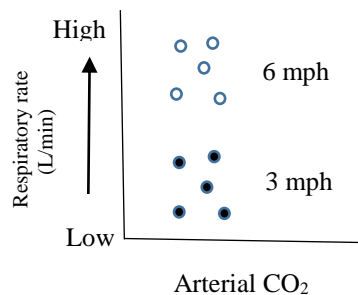


**Figure I**

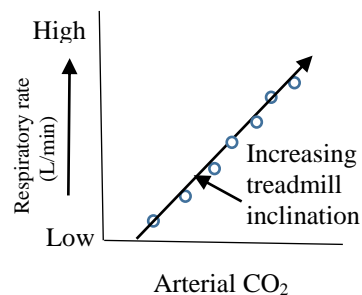
In related respiratory physiology experiments, dogs were prepared for measuring their respiratory rate (L/min) and they were trained to run on a treadmill. Blood samples were taken for measurement of  $CO_2$  levels.

Experiment 1: Dog runs on the treadmill set at two different speeds. The respiratory rate is plotted as a function of arterial  $CO_2$  concentration

Experiment 2: Dog runs on the treadmill at the same speed, but the slope of the treadmill is elevated, increasing the work load.



**Experiment 1**



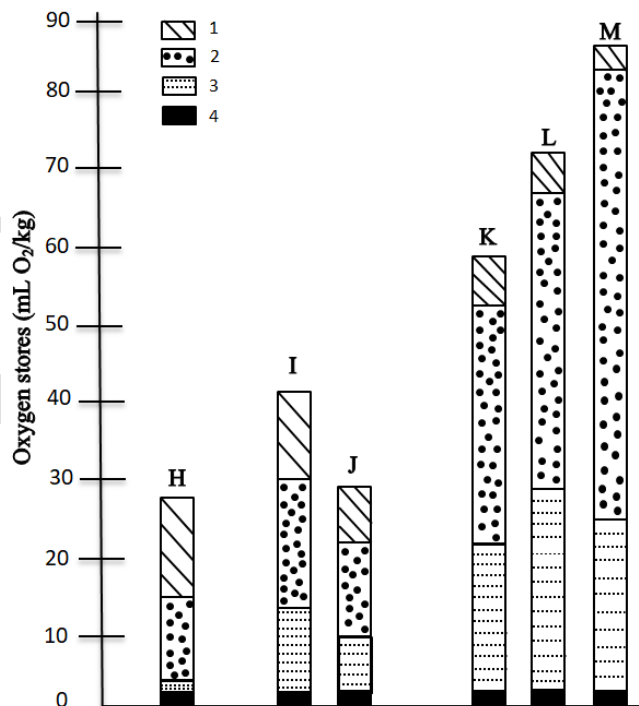
**Experiment 2**

Based on the given data, indicate whether each of the following statements is correct or incorrect by putting tick marks (✓) in the appropriate boxes.

- Experiment 1 suggests that the rising levels of CO<sub>2</sub> in the blood during exercise is the feedback signal that stimulates the increase in respiratory rate.
- Arterial levels of CO<sub>2</sub> are the metabolic signals that regulate respiration in response to work load.
- Breathing is more sensitive to increased CO<sub>2</sub> content in inhaled air than to the decreased O<sub>2</sub> content.
- Breathing rate shows a continuous inverse trend in relation to the O<sub>2</sub> content of inhaled air at all levels.

43. (2 points) A comparison of the total oxygen stores in various parts of the body for five species of marine mammals and human are shown in the bar graphs. The animals are as follows:

- Humans (H)
- Otariid seals such as Northern fur seal (I) and Steller sea lion (J) that dive for short periods of time at moderate depths.
- True seals such as Harbor seal (K), Ribbon seal (L) and Weddell seal (M) that dive for relatively long periods at much greater depths.

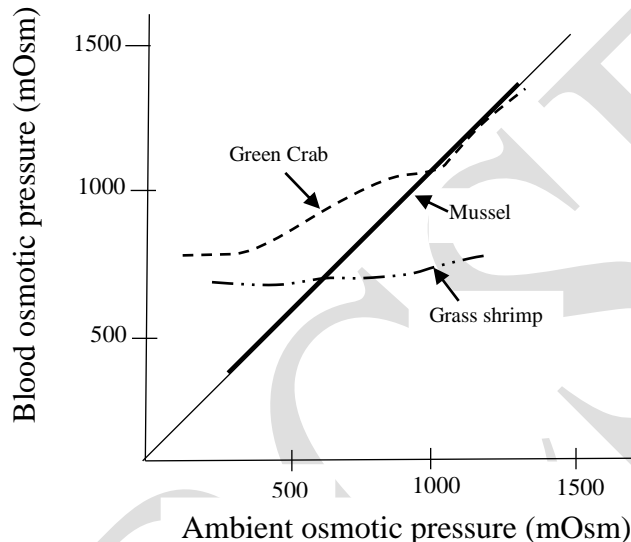


1, 2, 3 and 4 most likely respectively represent oxygen stores in which of the following parts? Choose the correct option and put a tick mark (✓) in the appropriate box.

- Blood; lungs; body fluids other than blood; myoglobin

- b. Myoglobin; lungs; body fluids other than blood; blood
- c. Lungs; blood; myoglobin; body fluids other than blood
- d. Myoglobin; lungs; blood; body fluids other than blood

44. (3 points) The osmotic pressure of blood plasma as a function of the ambient osmotic pressure for three species of marine invertebrates namely the blue mussel, the green crab and a species of grass shrimp is shown in the graph. The thin solid line is a line of equality between blood osmotic pressure and ambient osmotic pressure.



Based on the graph, choose from the list of options regarding the type of animal and fill in the respective blanks with the correct option number. *Only a completely correct answer for each blank will be awarded points.*

Options:

- (i) Short range conformer
- (ii) Strict osmotic conformer
- (iii) Conformer at only high ambient osmotic pressure
- (iv) Conformer at only lower ambient osmotic pressure
- (v) Regulator at only high ambient osmotic pressure
- (vi) Regulator at only lower ambient osmotic pressure
- (vii) Homeotherm
- (viii) Wide range regulator

### **GENETICS & EVOLUTION (11 points)**

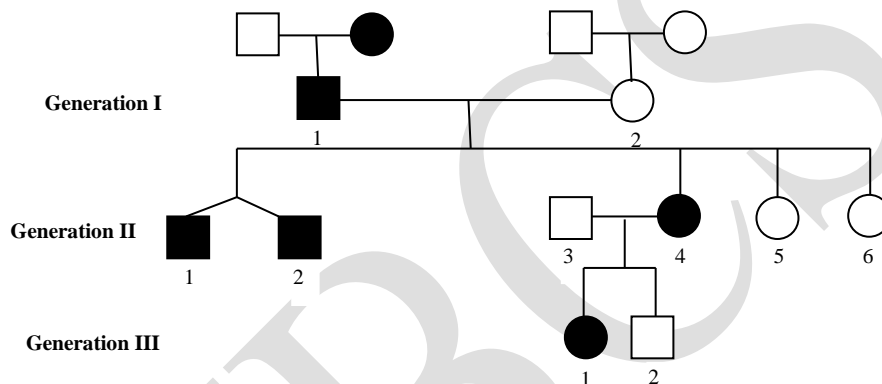
45. (2 points) Sex determination in the Indian blue peafowl (*Pavo cristatus*) follows the ZZ-ZW pattern wherein the blue peafowl is ZW and the male is ZZ. The cameo plumage which produces brown feathers results from a Z-linked allele ( $Z^{ca}$ ) that is recessive to the wild-type

blue allele ( $Z^{ca+}$ ). Consider the following crosses (I) Female with blue plumage crossed with a cameo male (II) Cameo female crossed with blue homozygous male.

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

- All the F1 females in cross I will be cameo while 50% of the male progeny will have blue plumage.
- Of the F2 females of cross I, 50% will have blue plumage and 50% will be cameo.
- The proportion of blue males in the F1 generation of both crosses I and II is identical.
- The F2 progeny of cross II will have blue females, blue males and cameo females in the ratio 1:2:1 respectively.

46. (2 points) A pedigree representing the transmission of brachydactyly (short fingers) in a family is shown below. Persons with short fingers are indicated by filled circles (females) and filled squares (males). None of the grandparents of generation II is a carrier for the trait.



(A) The mode of inheritance of the trait is:

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

Options:

- X-linked recessive
- X-linked dominant
- Autosomal recessive
- Autosomal dominant

(B) What is the probability (%) that II-6 is heterozygous for the trait?

(C) What is the probability (%) that III-1 is heterozygous for the trait?

(D) If II-3 and II-4 have another biological child, then what is the probability (%) of that child being a daughter with brachydactyly?

47. (2 points) Albinism in humans is inherited as an autosomal recessive trait. Calculate the probability of a couple (both heterozygous for the trait) having three children – one with normal pigmentation and two with albinism.

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

48. (2 points) Following are four sequences taken from HIV RNA such that:

**I:** Victim who got infected with HIV after blood transfusion

**II:** Suspect 1 HIV patient whose blood was suspected to be transfused in the victim

**III:** Suspect 2 HIV patient whose blood was suspected to be transfused in the victim

**IV:** Unrelated person infected with HIV

**I:** G T G C T T C A C C G A C G C C C C G C G

**II:** A A G C T T C A C C G G C G C T C C A C A

**III:** G T G C T T C A C C G A C G C T C C A C A

**IV:** A A G C T T C A T A G G A G C T T C A A A

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

- In the above sequence of 21 nucleotides, only 4 nucleotides can provide information about the possible culprit.
- Of the 21 nucleotides, 5 nucleotides indicate that the unrelated person can be considered as an outgroup.
- The RNA virus has continued to evolve in the suspects as well as the victim even after the victim was infected.
- A total of 10 nucleotides in the sequence provide no information about the outgroup or the possible suspects.

49. (3 points) In a genetic study involving corn (*Zea mays*), three genes, **gene a, b, and c** are located on the same chromosome. A geneticist performs a three-point test cross to determine the distances between these genes. The following data shows the number of offspring with different genotypes:

Genotypes			Number of offspring
a <sup>+</sup>	b <sup>+</sup>	c <sup>+</sup>	180
a	b	c	175
a <sup>+</sup>	b	c	55
a	b <sup>+</sup>	c <sup>+</sup>	50
a <sup>+</sup>	b	c <sup>+</sup>	15
a	b <sup>+</sup>	c	20
a <sup>+</sup>	b <sup>+</sup>	c	3
a	b	c <sup>+</sup>	2

Construct the genetic map involving genes a, b, and c indicating the correct order and genetic distance in centimorgans (cM) and draw the map in the given box. *Only a completely correct map will be given points.*

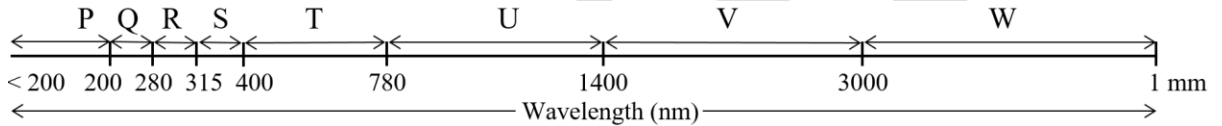


**ECOLOGY (7 points)**

50. (2 points) In order to study how populations of species can invade communities from which they are previously absent, several attempts have been made by ecologists to establish different species of birds to new habitats/islands. Colonization success of birds into these habitats depends on several factors. Indicate whether each of the following factors has a positive effect or not on the success rate of colonization by putting tick marks (✓) in the appropriate boxes.

- The number of release attempts.
- Repeated releases at one or a few sites as compared to releases at many different sites.
- Species with greater natality to mortality ratio.
- Migratory life history of birds that cover large distances between summer and winter quarters.

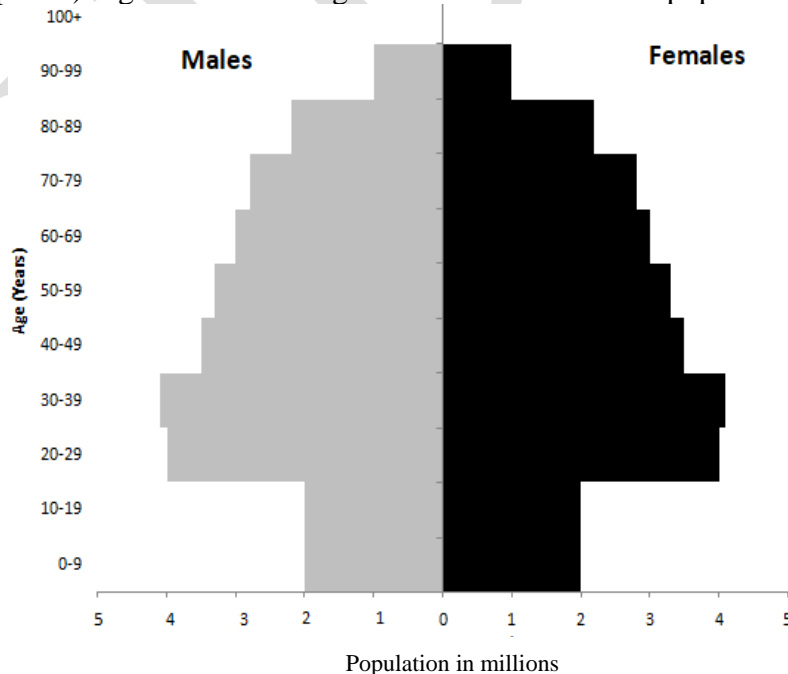
51. (3 points) The entire spectrum of electromagnetic radiation is shown below.



A few biologically important properties are listed below. Assign the correct range/s of the spectrum to each of them and fill in the blanks with the respective alphabet/s (P to W).

- Floral induction
- Both heat and human vision
- Germicidal

52. (2 points) Figure shows the age distribution for human population for the country X.



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

- The age distribution indicates equal birth and death rate for this population.
- The individuals in the populations were producing just enough offspring to approximately replace losses due to death.
- The age pyramid indicates expanding population.
- Under ideal conditions, the population of the reproductive stage will double in 10 years.

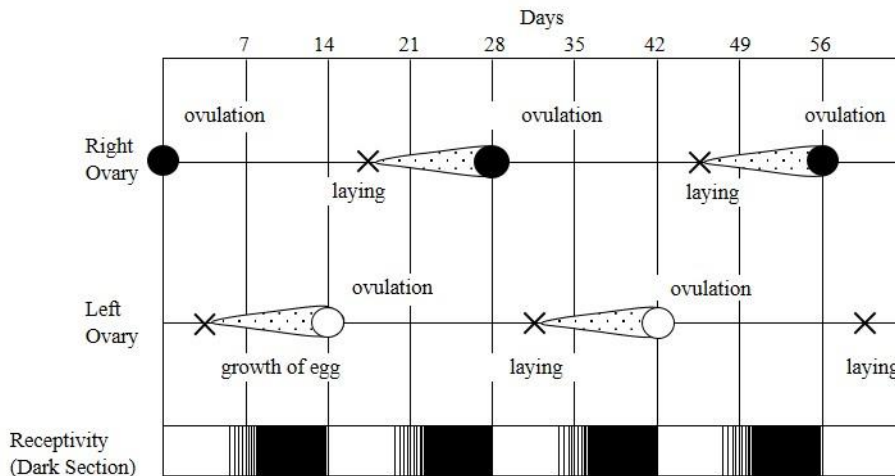
**ETHOLOGY (6.5 points)**

53. (4.5 points) In colonies of eusocial insects such as bees, although the workers never mate, they are able to lay unfertilized eggs which, being haploid develop into drones. If in a colony where the queen mates only once, predict the preference of the various members for other members with respect to the following conditions:

- Queen's preference for her daughter's sons versus her own sons.
- Non egg laying worker's preference for their sister's sons versus their own brothers.
- Egg-laying worker's preference for her brothers versus their own sons.

Complete the table by filling in the respective values of genetic relatedness ( $r$ ) for the relationships 1 and 2 in each condition (i, ii and iii) and also indicate the preference by inserting the appropriate symbol ( $>$ ,  $<$  or  $=$ ).

54. (2 points) Studies on the copulatory receptivity of *Anolis* lizards were carried out during the breeding season in these lizards. The figure depicts the physiological and behavioural observations during the reproductive season of female *Anolis*. These lizards lay shelled fertilized eggs, which hatch into young ones.



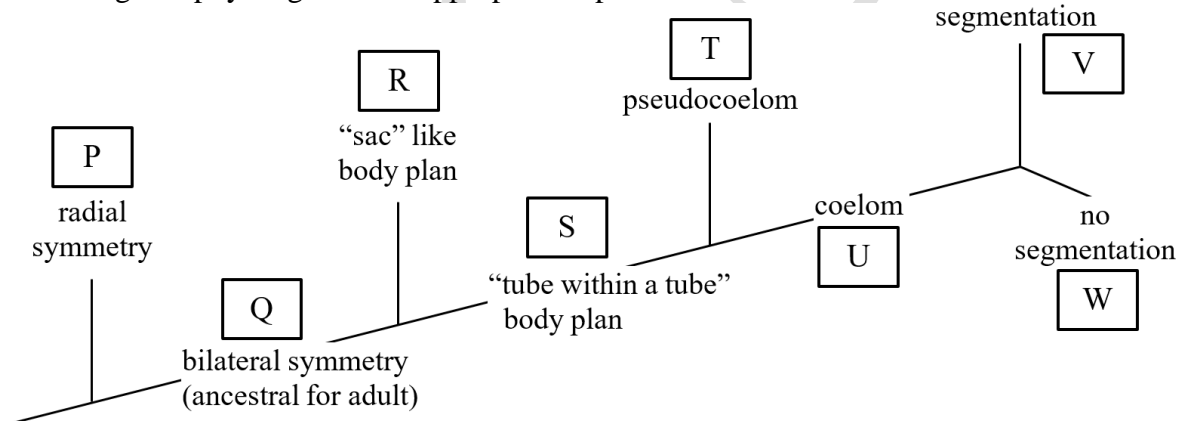
Indicate whether each of the following is true or false by putting tick marks (✓) in the appropriate boxes.

- a. A female is uniformly receptive to territorial males throughout the breeding season.
- b. Fertilization is only possible for the egg that is released from the right ovary due to the differential response of the female to copulation.
- c. A female lizard lays eggs one at a time every 12 – 16 days.
- d. Female receptivity is coordinated with egg laying to maximise the chances of fertilization.

**BIOSYSTEMATICS (6 points)**

55. (2 points) A few statements about various vertebrate clades are made. Indicate whether each of the following is true or false by putting tick marks (✓) in the appropriate boxes.
- a. Horses and monkeys can be placed in a monophyletic clade of placental mammals.
  - b. Marsupials and placental mammals can be placed in a monophyletic clade of Mammalia.
  - c. Monophyletic clade of Amniota includes monotremes and reptiles.
  - d. Monophyletic clade of therians consists of primates and ungulates only.

56. (4 points) A classification of animals is shown below with important evolutionary traits. Place the given phyla against the appropriate alphabet.



Indicate the position of the following phyla (1 – 4) in the cladogram and fill in the respective alphabet (P – W) in the blanks.

1. Echinoderms
2. Mollusks
3. Roundworms
4. Arthropods

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