

## INSTRUCTIONS SHEET – INBO 2020

The question paper is divided into Sections A and B. All answers should be **written in the answer sheet 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 39 numbered pages.**

### Section A

- Section A consists of 28 questions carrying 1 point each.
- All 28 questions are of multiple choice type, with only one correct answer for each question.
- Mark the correct answer with '✓' in the answer sheet 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 27 questions with a total of 72 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 INBO (THEORY): SECTION A:  $3X - Y$**

**SECTION B:  $3X$**

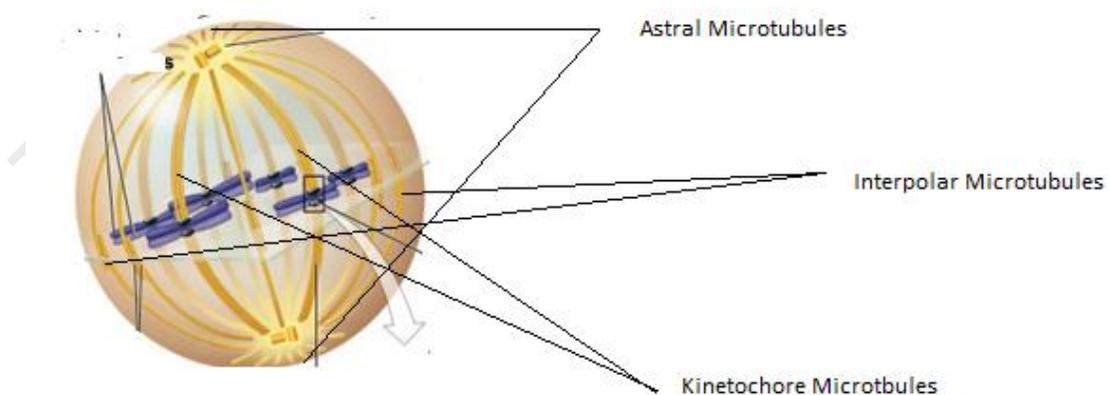
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# INDIAN NATIONAL BIOLOGY OLYMPIAD – 2020

## SECTION A

### CELL BIOLOGY (7 points)

1. (1 point) Lipid rafts are cholesterol-rich and glycosphingolipid-rich microdomains in the plasma membrane. Integral membrane proteins required for immune signaling and cell-cell communication are found in rafts. A few statements regarding lipid rafts are given below.
- The raft microdomains are more fluid than rest of the membrane.
  - Integral membrane proteins present in lipid rafts require a specific modification.
  - The raft microdomains do not freely mix with rest of the membrane and can induce protein clustering.
  - Lipid rafts help in preferential endocytosis of clustered signalling proteins.
- Pick the combination of correct statements.
- i, ii and iii
  - i, ii and iv
  - ii and iii only
  - i and iii only
2. (1 point) Kinesin-5 motors are tetrameric motors that bind to anti-parallel microtubules and slide them apart. The microtubules in a mitotic spindle can be divided into three groups (i) kinetochore microtubules (ii) astral microtubules and (iii) interpolar microtubules as shown below.

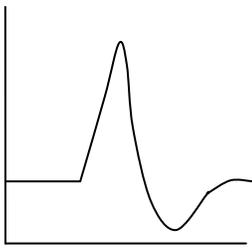
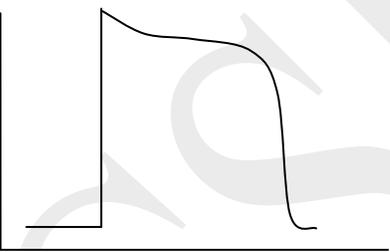
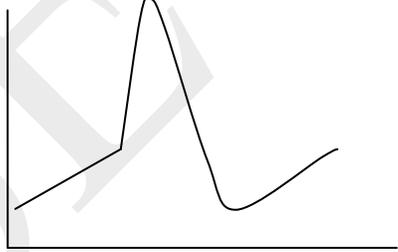


During mitosis, Kinesin-5 is most likely to be present on \_\_\_\_\_ microtubules and is expected to play a crucial role during \_\_\_\_\_. Choose the correct option to complete the given statement.

- kinetochore and prophase
- interpolar and anaphase
- astral and anaphase
- interpolar and metaphase

3. (1 point) A few cell types and action potentials are shown below.

Cell Types
A1. Pacemaker Cells
A2. Nerve Cells
A3. Cardiac Myocytes

Action potentials		
		
B1.	B2	B3

Match the action potentials to the respective cell type and choose the combination of correct pairs.

- A1-B2, A2-B1, A3-B3
- A1-B3, A2-B1, A3-B2
- A1-B1, A2-B2, A3-B3
- A1-B3, A2-B2, A3-B1

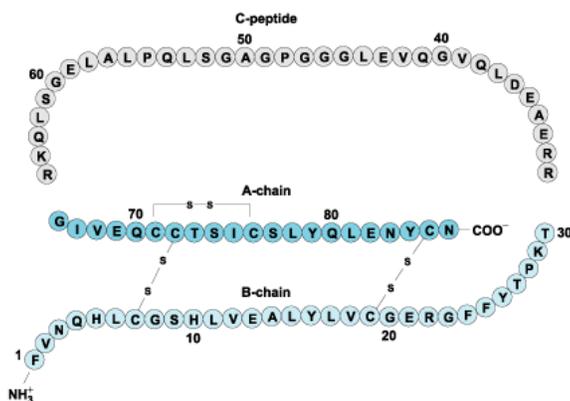
4. (1 point) Which of the following statements regarding surface area to volume ratio is/are true?

- Large surface area to volume ratio eliminates the need for a circulatory system.
- Large surface area to volume ratio helps in faster exchange of nutrients.
- Large surface area to volume ratio helps in faster rate of diffusion of nutrients inside cells.

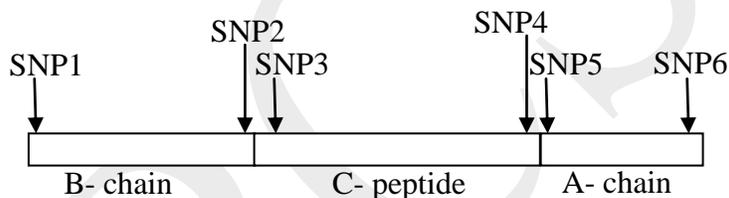
Choose the correct option.

- (i) only
- (i) and (ii) only
- (ii) and (iii) only
- (i), (ii) and (iii)

5. (1 point) Insulin peptides and the bonds between them are shown in the figure below. The release of 'C' peptide is important for the production of mature functional insulin and the signaling mediated by it.



As shown below, different Single Nucleotide Polymorphism (SNP) event/s introduced an additional site for restriction enzyme RE1 in the insulin gene. These SNPs did not change the C- peptide release. However, the mature insulin produced was non-functional.



Which SNP event/s in the insulin gene can be the most likely explanation of the above observation?

- Only SNP1
- SNP1 & 5
- SNP 3 & 4
- Only SNP6

6. (1 point) A growth factor, promoting cell growth activates a distinct cascade of phosphorylation events mediated by protein kinase enzymes. The ATP dependant phosphorylation of the target by a kinase can regulate the function of target proteins. Several statements made in this regard are given below:

- Energy released from ATP hydrolysis by the kinase helps in activation of the target protein.
- ATP hydrolysis-mediated phosphorylation often brings structural changes in the target protein.
- Phosphorylation can facilitate new protein-protein interactions to target proteins.
- Phosphorylation of the target protein must activate it.

Which of the statements is/are true?

- 1 and 4.

- b. 2 and 3.
- c. 3 only.
- d. 2 and 4.

7. (1 point) A circular plasmid DNA with ampicillin resistance gene, having a unique site for the restriction enzyme 'X', was digested completely with 'X' to generate cytosine residues at the 5' end of the overhangs. After treatment with a second enzyme, which is not a restriction enzyme, the digested DNA was used in a self-ligation reaction. When the ligation mixture was transformed in bacteria, no colonies were obtained on ampicillin containing selection media. Following statements are made about the second enzyme and its function.

- 1. It is a kinase which phosphorylates the 5' end of the cytosine residues.
- 2. It is a phosphatase which removes 5' phosphate from the cytosine residue.
- 3. It is a methylase which attaches  $-CH_3$  group exclusively to the 5' cytosine residue.
- 4. It is a deaminase which removes the  $-NH_2$  group from the 5' cytosine residue.

Pick the option that correctly explains the failure of colony formation.

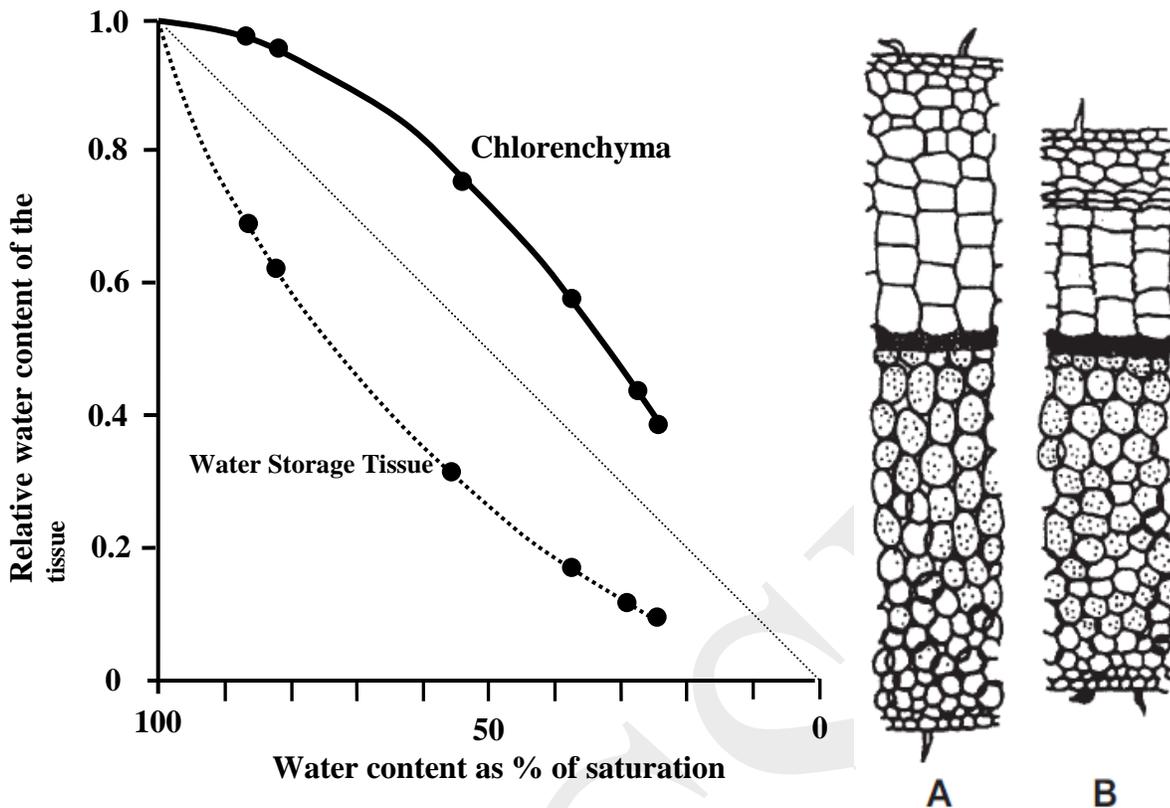
- a. 1 & 3
- b. 2 & 4
- c. 1 & 4
- d. 3 & 2

### **PLANT SCIENCES (5 points)**

8. (1 point) Toluidine is a metachromatic stain that can impart different colors to different plant tissues. The primary cell walls turn pink while secondary cell walls turn blue. Which of the following is likely to result?

- a. Collenchyma cell walls will turn pink.
- b. Xylem vessels will turn pink.
- c. Phloem walls will turn blue.
- d. Chlorenchyma wall will turn blue.

9. (1 point) The graph below shows the change in the relative water content of different tissues with change in the total water content of the leaf of *Peperomia trichocarpa*. The cross sections A and B next to it represent water saturated leaves and the leaves on drying respectively. Based on this information indicate which of the following statements are true.



- (i) Total water retained in the chlorenchyma is always more than that in water storage tissue at different levels of desiccation.
- (ii) At about 50% water content, the loss of water from the water storage tissue is about 75%.
- (iii) Major change in leaf thickness occurs due to shrinkage in the water storage tissue.
- (iv) 75% water loss in the chlorenchyma is seen when the total water content falls by 75%.

Choose from the options given below.

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

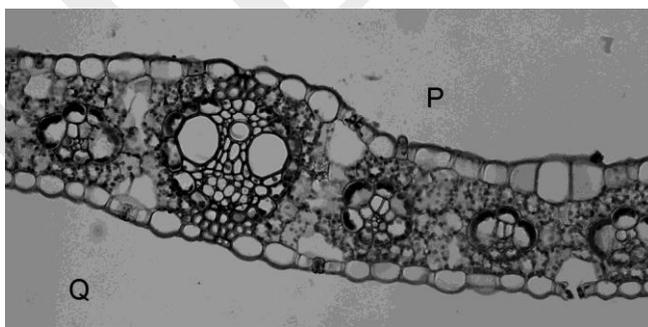
10. (1 point) Active biological life is substantially dependent on functional membranes. The lipids of these membranes must be present in a viscous-fluid state for the proteins and protein complexes anchored within them to fulfil their functions. The melting point and viscosity of the lipids depend on the length of the component fatty acids and their degree of unsaturation. The following table provides information on the melting points of major fatty acids found in plant membranes and also compares the composition of mitochondrial membrane of two plant species. Study the table carefully and based on it, state which of the following statements are true.

Major Fatty Acids	Melting point (°C)	Percentage weight of total fatty acid content	
		Pea Shoot (Chilling-resistant)	Maize shoot (Chilling-sensitive)
Palmitic acid (16:0)	63.1	12.8	28.3
Stearic acid (18:0)	69.6	2.9	1.6
Oleic acid (18:1)	13.4	3.1	4.6
Linoleic acid (18:2)	-5.0	61.9	54.6
Linoleic acid (18:3)	-11.0	13.2	6.8

- (i) The shorter the fatty acid chain, the lesser is the viscous-fluid state of lipids at lower temperatures.
- (ii) The higher the degree of unsaturation in a fatty acid, higher is the viscous-fluid state of lipids at lower temperatures.
- (iii) Chilling-sensitive plants have a higher percentage of unsaturated fatty acids in their mitochondrial membranes as compared to saturated fatty acids.
- (iv) Chilling-sensitive plants have a lower unsaturated to saturated fatty acid ratio compared to chilling-resistant plants.

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

11. (1 point) Amit found a permanent slide in an old cupboard of his school laboratory. As the corner of the slide was broken, the label was incomplete. He could only read 'T.S. of....' He started observing the slide under the microscope. He observed the section as shown in the picture below.

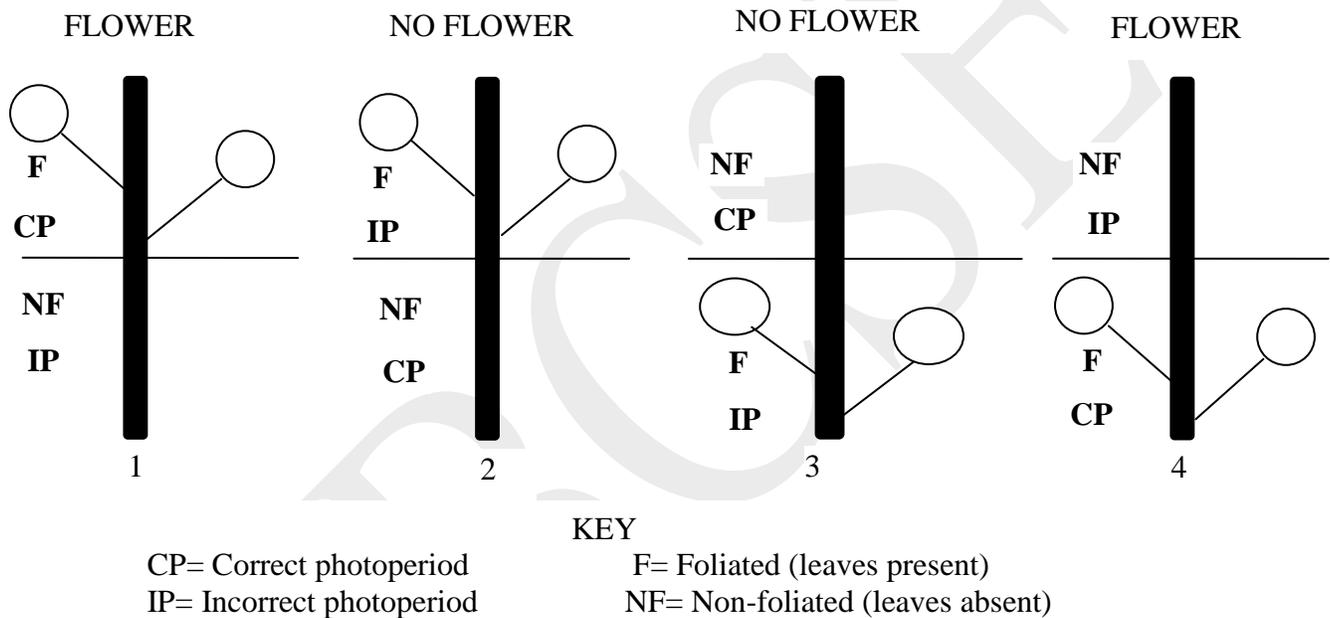


Based on his observations, state which of the following statements is/are true.

- i. It is a transverse section of a floating hydrophytic leaf.
- ii. The epidermal region towards 'P' can be considered as the adaxial side.
- iii. The plant must be monocotyledonous.
- iv. If water dries up, the leaf will curl downwards towards 'Q'.
- v. There is no prominent mid-vein present in this leaf.

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

12. (1 point) In order to study various factors affecting flowering of plants, an experiment was performed on four sets of plants. In these sets, either the upper or the lower parts of the plants were defoliated and separated by a light barrier. Either the upper or lower part of the plant was exposed to the correct photoperiod. As shown in the diagram, plants in sets 1 and 4 showed flowering.



For testing which of the following hypotheses was the above experimental set up designed?

- a. If the plant is exposed to incorrect photoperiod, flowering will not occur.
- b. There is no effect of light barrier on the plant flowering process.
- c. Vegetative growth of a plant is a more crucial factor for flowering as compared to light.
- d. Only if plant leaves are exposed to the correct photoperiod, flowering will occur.

**ANIMAL SCIENCES (7 points)**

13. (1 point) Select the correct combination of the following taxa which have been sequentially arranged in the order from most inclusive (most general) to least inclusive (most specific).

- 1) Insecta
- 2) Arthropoda
- 3) Hymenoptera

- 4) Ecdysozoa
- 5) Bilateria
- 6) *Apis*

- a. 4-5-2-1-3-6
- b. 5-4-2-1-3-6
- c. 5-2-4-1-3-6
- d. 6-3-1-2-4-5

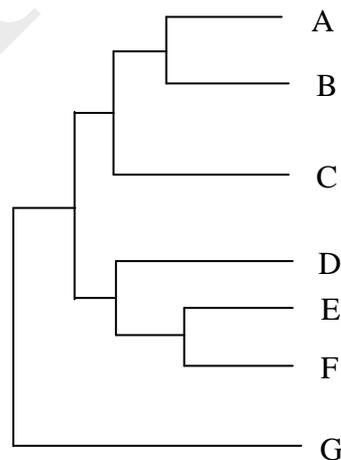
14. (1 point) Which of the following statements best defines a portal system?

- a. Part of the circulatory system where arteries subdivide into large number of branches of capillaries and again join with another artery.
- b. A system of blood supply between heart and liver.
- c. A system of veins which begins and ends with a bed of capillaries.
- d. Part of the lymphatic circulatory system found in higher chordates where blood from organs is forwarded to open sinus through a network of capillaries.

15. (1 point) Which of the following structural modifications are **NOT** essential in terrestrial mammals for cursorial (rapid running) adaptation?

- a. Reduction in the number of digits and phalanges.
- b. Modification for articulation of bones to restrict movement in one plane.
- c. Fusion of bones of the sole and palm.
- d. Prehensile limbs with opposable digits.

16. (1 point) The cladogram shows phylogenetic relationship amongst seven vertebrate species A - G. Species G is amphibious and adapted to both terrestrial and aquatic habitats. Species A and F are exclusively aquatic while B, C, D, E are terrestrial. The most logical explanation for the mode of evolution of A and F will be



- a. Disruptive selection
- b. Convergent evolution
- c. Divergent evolution
- d. Co-evolution

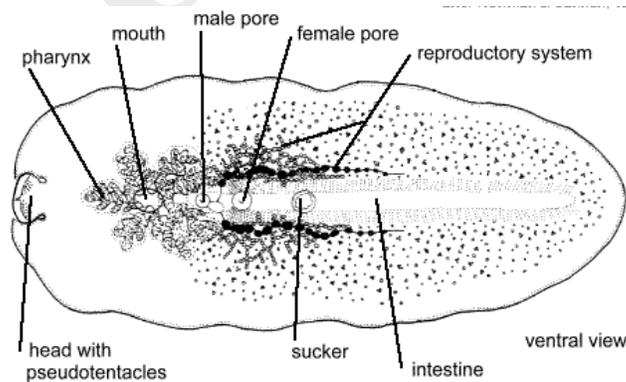
17. (1 point) The urine osmotic concentrations and urine/plasma salt concentration ratios for four animals (human, P, Q and R) are given in the table.

	Urine max. osmotic concentration (osm/lt.)	Urine/plasma salt concentration ratio
Human	1.4	4
P	5.5	14
Q	3.1	10
R	0.52	2

P, Q & R respectively most likely represent:

- a. Cat, fish, beaver
- b. Beaver, pig, white rat
- c. Kangaroo rat, beaver, mouse
- d. Kangaroo rat, cat, beaver

18. (1 point) The internal structures of a marine life form, *Pseudoceros bifurcus* are shown in the figure. Mark the correct interpretation.

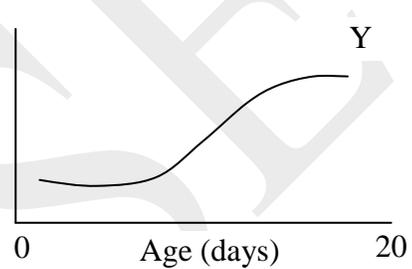
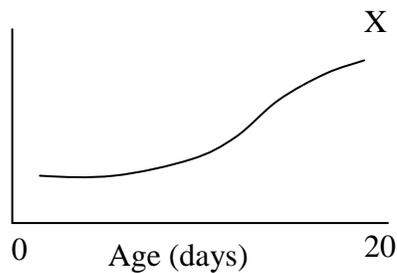


*Pseudoceros bifurcus*

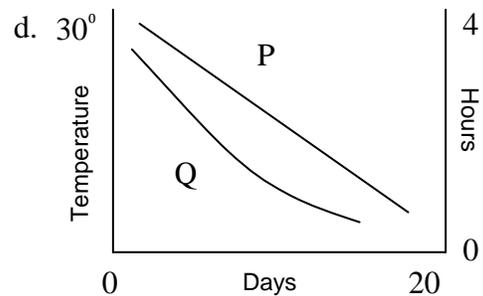
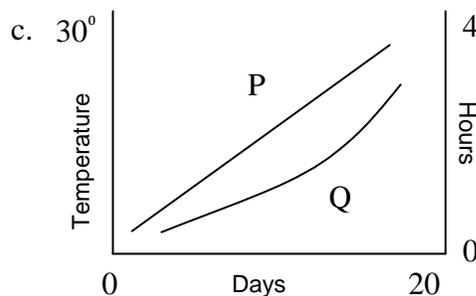
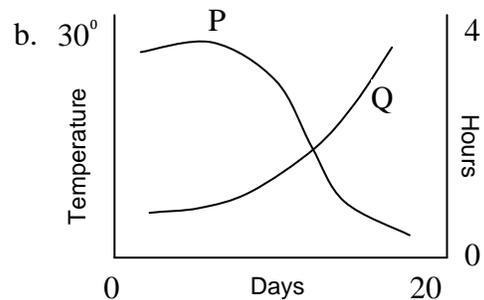
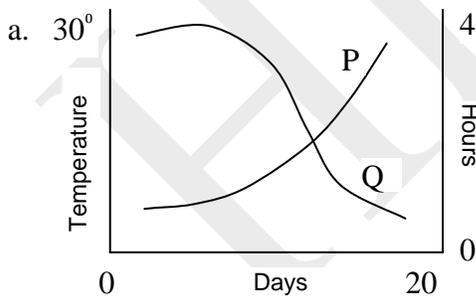
The animal is most likely is:

- a. a cnidarian as it shows tissue level organization with bilateral symmetry.
- b. a free-living platyhelminth as it shows bilateral symmetry and has an acoelomate body plan.
- c. a free-living platyhelminth as it shows non-segmented body plan and absence of circulatory system.
- d. a parasitic platyhelminth as it shows suckers, hermaphroditism and absence of sense organs.

19. (1 point) The rate of metabolic heat production (X) and whole body insulation (Y) during development in white-footed mice are shown.



Which of the following graphs correctly depicts the adaptive response of these mice towards effective survival at lower temperatures (P) and the time that the animal can spend out of its nest (Q) during the development over 20 days?



**GENETICS & EVOLUTION (3 points)**

20. (1 point) Crossing-over is absent during meiosis in males of *Drosophila melanogaster*. At what stage of meiosis does segregation of alleles occur in these males?

- a. Prophase
- b. Anaphase I
- c. Metaphase I
- d. Anaphase II

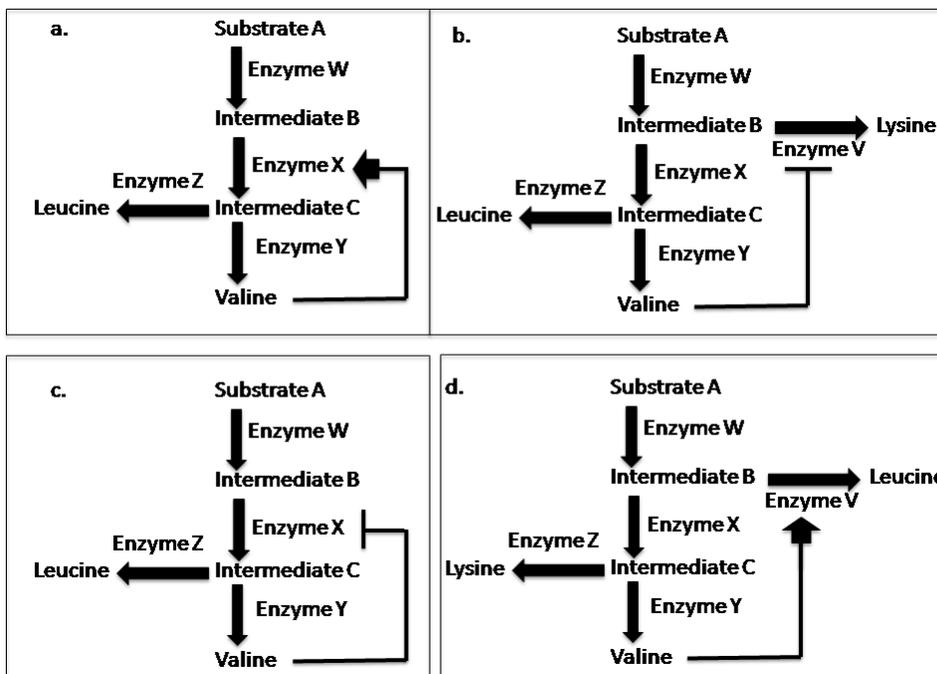
21. (1 point) Wild type (K12) strains of *E. coli* can grow on minimal medium (MM) as they can synthesize all components including amino acids for their growth. MM is made up of a few salts i.e.  $\text{Na}_2\text{HPO}_4$ ,  $\text{KH}_2\text{PO}_4$ ,  $\text{NH}_4\text{Cl}$ ,  $\text{NaCl}$  and a carbon source like glucose.

While K12 can grow on MM containing all amino acids, it fails to grow if only valine is added to MM. In order to find out the amino acid(s) which allow/s K12 to grow in the presence of valine, different combinations of amino acids were added to the medium and growth of K12 was monitored. A part of the result is shown below:

MM containing amino acids	Growth of K12
Valine + leucine + lysine	Yes
Valine + lysine + isoleucine	No
Valine + leucine + arginine	Yes
Valine + arginine + alanine	No

Which one of the following pathways correctly explains the above observations?

[Note: the pathways are hypothetical]



22. (1 point) A *Drosophila* mutant that cannot fly is isolated in an Indian laboratory. The mutant phenotype is recessive and has been mapped to gene 'M'. Three European labs in UK, Spain and Germany independently isolated mutants with the same phenotype. In order to test if these mutants also resulted from mutation in gene 'M', the following crosses were made and the phenotype of the F<sub>1</sub> progeny analyzed:

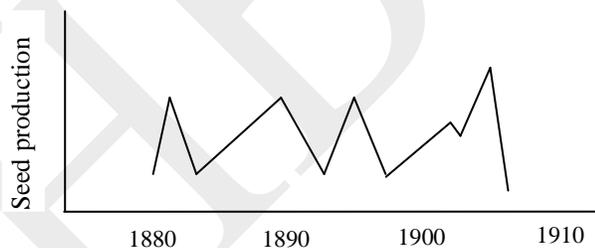
Crosses	Phenotype of F <sub>1</sub>
India x UK	Cannot fly
India x Spain	Can fly
India x Germany	Can fly
UK x Spain	Can fly
UK x Germany	Can fly
Germany x Spain	Cannot fly

Based on the above findings, which of the European mutants is most likely to map to gene "M"?

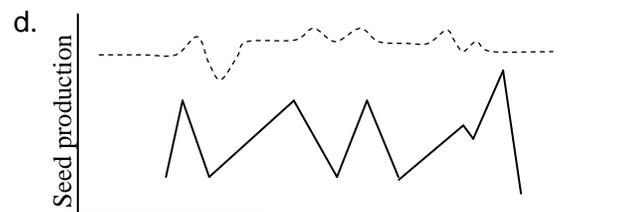
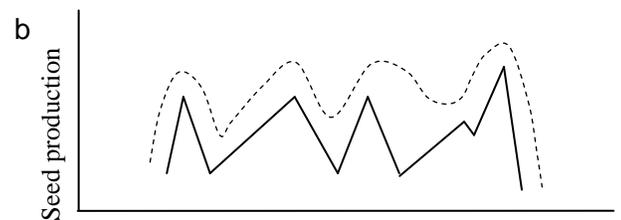
- a. UK only
- b. Spain only
- c. Germany only
- d. Both Germany and Spain

**ECOLOGY (3 points)**

23. (1 point) Seed production record of beechnut trees over a span of 30 years is shown:



Which of the following graphs represents the most likely tree growth ring pattern (dotted lines) for these trees?



24. (1 point) Sea turtles show the following life history characteristics:

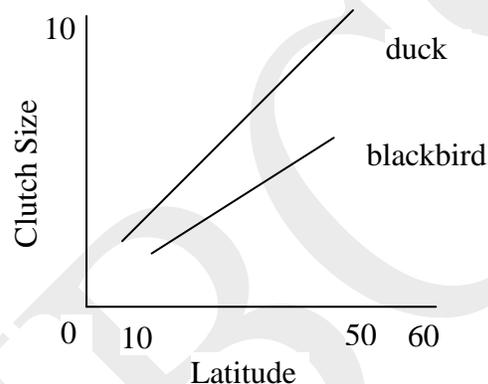
- i. They live for many years.
- ii. They produce massive number of eggs at a time.
- iii. They show limited parental care.

Which of the following statements is true for sea turtles?

- a. They show r-strategy because characters i and iii are typical of r - strategy of life history.
- b. Sea turtles show K-strategy because characters i and ii are typical K -strategy of life history.
- c. They show mixed K-r strategy as character iii is typical of a K-strategist while i and ii of r-strategist.
- d. Sea turtles show mixed K-r strategy as feature i is observed in K-strategy while ii and iii are observed in r- strategy.

25. (1 point) Life history of a species includes the pattern of growth, development and reproduction.

Clutch sizes of two species of birds in relation to the latitude are shown in the given graph.



Which of the following statements is/are correct?

- i. Large climate variation can lead to decrease in population below the carrying capacity thus leading to a large clutch size.
- ii. At high latitudes, longer day lengths in summer can give optimum time to support a large clutch.
- iii. Greater mortality in winter can lead to more food for survivors in the next summer.
- iv. Given time and resources are limited at higher latitudes, birds maximize fitness by producing large brood sizes.

Choose from the given options.

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

**BIOSYSTEMATICS (3 points)**

26. (1 point) An invertebrate possessing the following features was found in a sample collected from a freshwater ecosystem.

- No antero-posterior axis
- Presence of gastro-vascular cavity
- No circulatory system
- No organ system

The organism most likely is a:

- a. cnidarians.
- b. poriferan.
- c. platyhelminth.
- d. rotifer.

27. (1 point) Match the following animal groups with their attributes.

<b>Animal Groups</b>	<b>Attributes</b>
A) Annelids	(i) Pseudocoelom and ventral nerve cord
B) Rotifers	(ii) True coelom and ventral nerve cord
C) Birds	(iii) Ventral heart and endothermy
D) Reptiles	(iv) Dorsal heart and ventral nerve cord
	(v) Ventral heart and ectothermy

- a. A- ii, B- i, C- iii, D- iv
- b. A-ii, B- i, C- iii , D- iv
- c. A- ii, B- i, C- iii, D- v
- d. A- i, B- ii, C- v, D- iii

28. (1 point) Which of the following features is common to both cnidarians and platyhelminthes?

- a. Absence of organ system.
- b. Self-fertilization.
- c. Digestive system with a single opening.
- d. Ability to absorb nutrients across their body wall.

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

**INDIAN NATIONAL BIOLOGY OLYMPIAD – 2020**

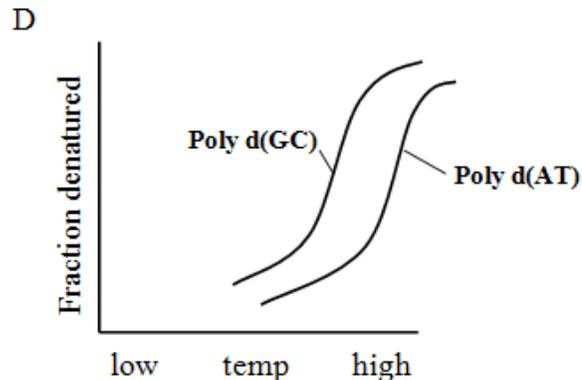
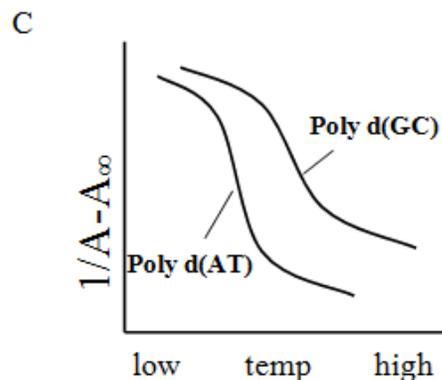
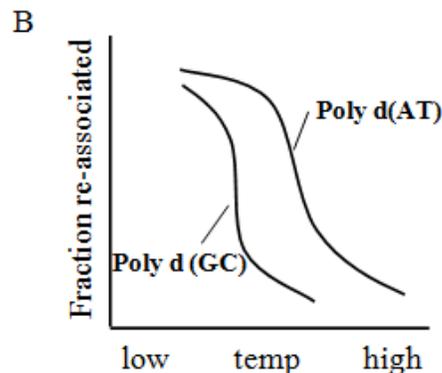
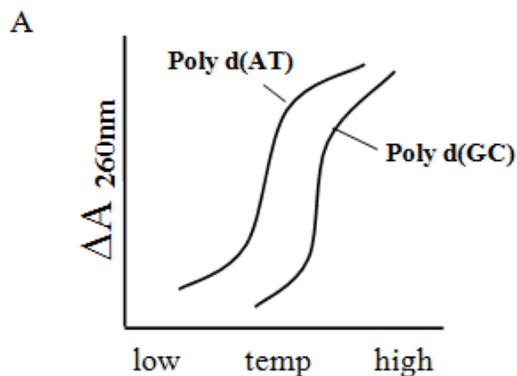
**SECTION B**

**NOTE:**

- Write all answers in the **ANSWERSHEET ONLY**.
- Only the answer sheets will be collected at the end of the examination.

**CELL BIOLOGY (17 points)**

29. (2 points) Under normal physiological conditions, DNA is present in the form of double helix and absorbss maximally in the UV region. When these conditions change, it starts unwinding and the hydrogen bonds that hold the two strands together break. This process is called as DNA denaturation or DNA melting. Melting can affect the absorptive properties of the molecule. Two DNA molecules are considered namely poly d(AT) and poly d(GC) of a short defined length. Which of the following graph/s correctly depict/s the denaturation/renaturation of these molecules? Note that  $A_{\infty}$  indicates absorbance of native dsDNA molecule at 260nm. A indicates absorbance of the same sample under study at 260nm.



Mark each graph as either correct or incorrect by putting tick marks (✓) in the appropriate boxes.

Graph	Correct	Incorrect
A.		
B.		
C.		
D.		

30. (2 points) In a cell, two biomolecules A and B are known to form dimers A-B only when they are present in equal numbers. These biomolecules A, B and dimers A-B are known to disintegrate with half-lives of 30 minutes, 60 minutes and 30 minutes respectively. Suppose at  $t=0$ , the number of biomolecules A and B are 1000 and 500 respectively, then the number of A-B dimers at  $t=90$  minutes will be:

Answer: \_\_\_\_\_

31. (3 points) Assume that the average intake of calories per day for humans is 2072 kcal and 50% of that is utilized for producing ATP. Energy obtained from the hydrolysis of ATP is used for all important cellular processes. Assume that the molecular weight of ATP is 500 g/mol and energy released by the hydrolysis of ATP is -14 kcal/mol.

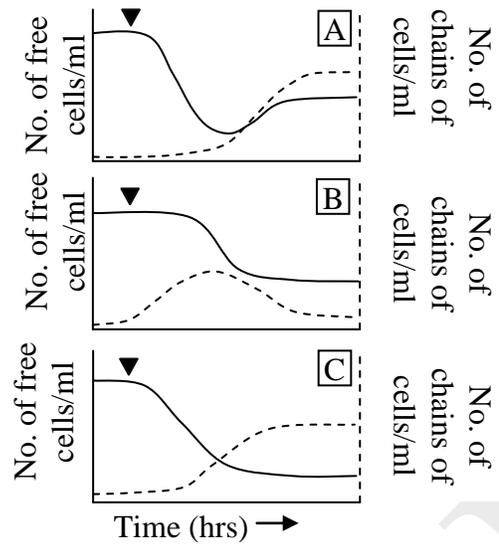
(A) If ATP has to be synthesised entirely, how much of it will be theoretically synthesized in a day?

Answer: \_\_\_\_\_ kg

(B) Suppose that the total weight of ATP present in human body is 0.1 moles. In this case, how many times a day will each ATP get recycled?

Answer: \_\_\_\_\_ times per day

32. (2 points) Since metastatic cancer breaks the rules of multicellularity, a researcher was using yeast as a model system to understand the process. In a drug screen, three compounds showed the following effect on the growth of yeast cells (Black arrow indicates additions of drug). Choose the order in which the researcher would rank the three drugs to predict the best efficacy of cancer treatment (from best to worst)

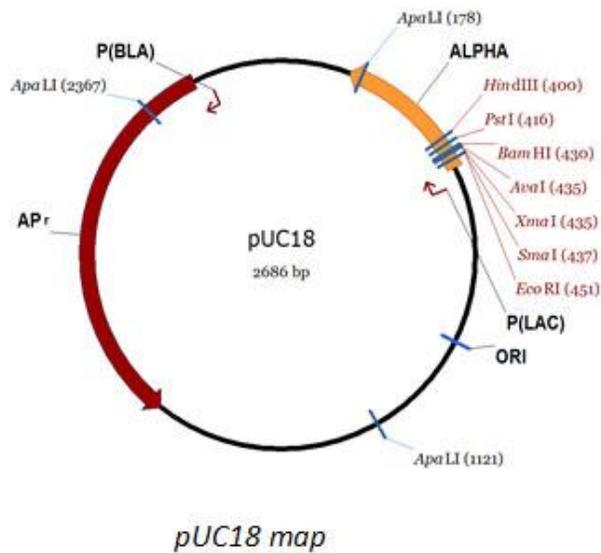


Choose the correct option and put a tick mark (✓) in the appropriate box.

- a.  $B > C > A$
- b.  $C > B > A$
- c.  $A > B > C$
- d.  $C > A > B$

a.	b.	c.	d.
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

33. (2 points) You were cloning the genome of a new DNA virus into the Hind III site of pUC18 vector, whose map is given below. P(LAC) and  $AP_r$  in the figure denote promoter of beta-galactosidase gene and ampicillin resistance gene respectively.



You plated out your transformants on ampicillin plates containing X-gal and picked one blue colony and one white colony. When you checked the size of the insert into each plasmid (isolated from blue and white colonies), you were surprised to find that the plasmid from blue colony had an insert of 60 bp, while the plasmid from white colony did not appear to contain any insert at all.

Indicate which of the following explanations are true or false by putting tickmarks (✓) in the appropriate boxes in the table. .

No.	Explanation	True	False
1	In the plasmid from blue colony, the insert was in frame and hence did not disrupt the coding of alpha fragment of beta-galactosidase.		
2	The plasmid from white colony had a very large insert (more than 50 kbp).		
3	In the plasmid-containing blue colony, the insert was cloned at site other than Multiple Cloning Site (MCS).		
4	The MCS in the plasmid from white colony was degraded by exonuclease contamination.		

34. (6 points) A student was performing enzyme purification in the laboratory for the first time. She began with 1200 mg of crude protein extract containing an enzyme of interest. At the beginning as well as at every purification step, she determined:

- i. Total protein content
- ii. Total units of enzyme present (also known as Activity)
- iii. Specific activity of enzyme (Units/mg protein).

(A) In a very efficient purification process, which of the following is expected to happen? Choose the correct option and put a tick mark (✓) in the appropriate box.

- a. i to increase, ii to remain constant, iii to increase.
- b. i and ii to increase, iii to remain constant.
- c. i to decrease, ii and iii to increase.
- d. i, ii and iii to increase.

a.	b.	c.	d.

(B) Data (protein content and activity) obtained by her during the process is given in the table. Complete the table by filling in the specific activity, % yield of activity and purification factor values. *Note that only an entirely correct row will be given points.*

Step	Protein (mg)	Activity (U)	Specific activity (U/mg)	% Yield of activity	Purification factor
0	1200	800	0.67	-	-
1	600	600			1.5
2	200	180			
3	30	150			
4	20	148			

(C) Which of the above is the least effective purification step? Choose the correct option and put a tick mark (✓) in the appropriate box.

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

a.	b.	c.	d.

(D) Which of the above is the most effective purification step? Choose the correct option and put a tick mark (✓) in the appropriate box.

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

a.	b.	c.	d.

(E) Which step is indicative that enzyme of interest is partially inactivated? Choose the correct option and put a tick mark (✓) in the appropriate box.

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

d. 4

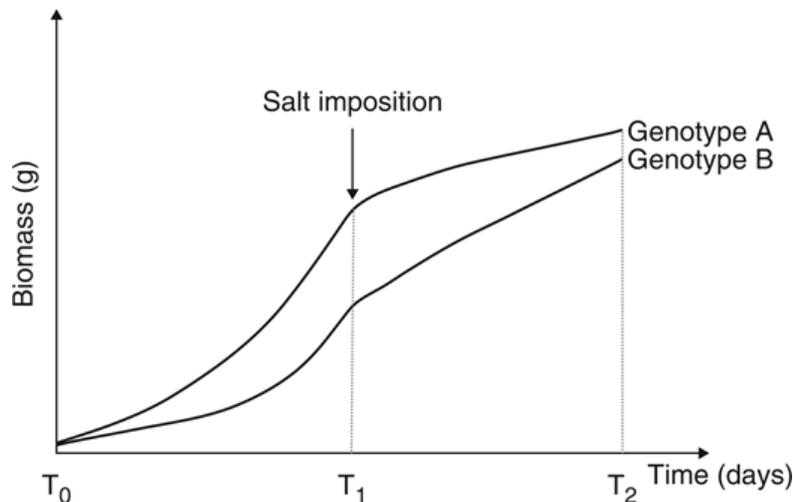
a.	b.	c.	d.

**PLANT SCIENCES (9.5 points)**

35. (2.5 points) *Fagus sylvatica* is a large tree which can reach heights of more than 50 m. The characteristics of sun and shade leaves of *Fagus sylvatica* are typical of the relationship between sun and shade leaves in plants. Some of these characteristics are listed in the table. Fill the appropriate symbols '>', '=' or '<' to indicate the relationships between them. Some answers have already been given.

Characteristic	Sun leaves	Relationship	Shade leaves
Leaf surface area (cm <sup>2</sup> )	Su		Sh
Thickness of leaf (μm)	Su		Sh
Chlorophyll (a+b) concentration [Chl/leaf (w/w)]	Su	<	Sh
Net Photosynthesis (mg CO <sub>2</sub> .dm <sup>-2</sup> .h <sup>-1</sup> )	Su		Sh
Light compensation point (W.m <sup>-2</sup> )	Su		Sh
Dark respiration (mg.dm <sup>-2</sup> .h <sup>-1</sup> )	Su		Sh
Light saturation of net photosynthesis (μmol.m <sup>-2</sup> .s <sup>-1</sup> )	Su	<	Sh

36. (2 points) An experiment was set up to study the responses of two genotypes – A and B to salinity stress. The shoot biomass of the two species was measured at time T<sub>0</sub>. The salinity was imposed at the 3<sup>rd</sup> leaf stage. The fresh weights in g of the entire plants were recorded at definite time intervals between T<sub>0</sub> to T<sub>2</sub>. The results obtained are depicted graphically.



Which of the following statements are true?

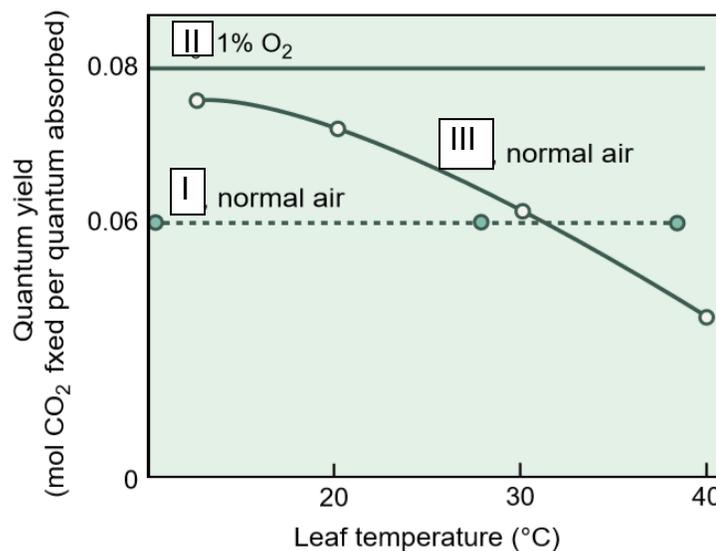
- i. There is a decrease in plant growth rate after salt imposition.
- ii. Genotype A is more sensitive to salinity than Genotype B.
- iii. Genotype B is more sensitive to salinity than Genotype A.
- iv. When growth is measured by biomass from  $T_0$  to  $T_2$ , Genotype A appears to be more salt tolerant.
- v. When growth is measured only from  $T_1$  to  $T_2$ , Genotype B appears to be more salt tolerant.

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

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

a.	b.	c.	d.	e.

37. (2 points) Following figure shows the effect of leaf temperature on quantum yield in three different plants.



Identify the types of plants I, II and III respectively and choose the correct option. Put a tick mark (✓) in the appropriate box.

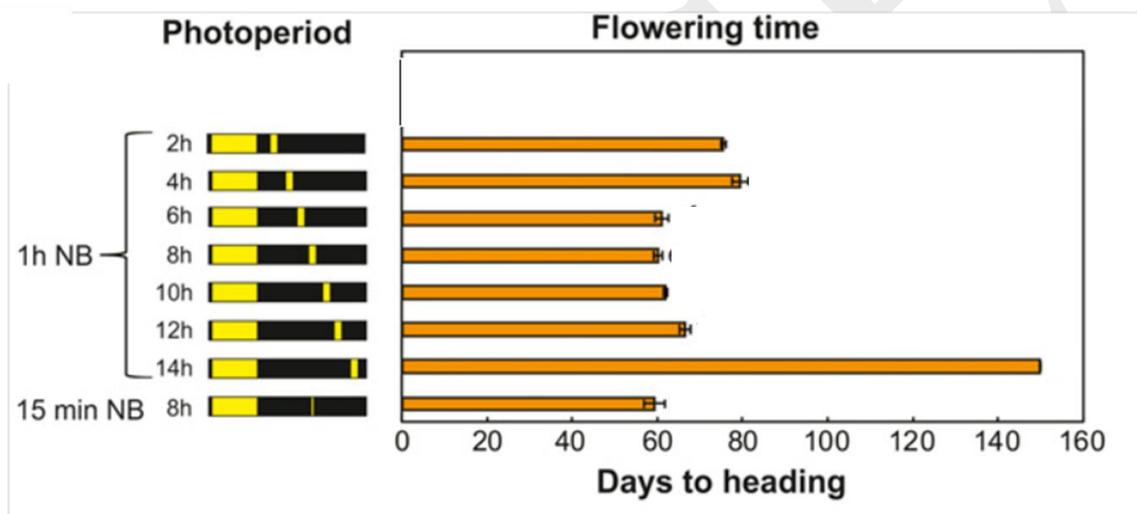
- a. C4, C3 and CAM plants.
- b. CAM, C4 and C3 plants.
- c. C3, CAM and C4 plants.

d. C4, C3 and C3 plants.

a.	b.	c.	d.

38. (3 points) Photoperiodic flowering responses vary in different species. Short-day (SD) plants and long-day (LD) plants show accelerated flowering in SD and LD respectively. The plants (X) under their optimum day-night cycle start showing flowering and heading at about 53<sup>rd</sup> day.

Shown in the diagram is the response of these plants grown under different light and dark regime with 1 hr night breaks (NB) after 2-14 hours of darkness.



(A) Choose the most appropriate statement and fill in the blanks only in that statement with 'long or short' and the number of hours respectively.

- I. Plant X is a \_\_\_\_\_ day plant with critical day period \_\_\_\_\_ hr or less.
- II. Plant X is a \_\_\_\_\_ day plant with critical day period \_\_\_\_\_ hr or more.
- III. Plant X is a \_\_\_\_\_ day plant with critical night period \_\_\_\_\_ hr or less.
- IV. Plant X is a \_\_\_\_\_ day plant with critical night period \_\_\_\_\_ hr or more.

(B) In plants where NB is given after 14 hr of night period:

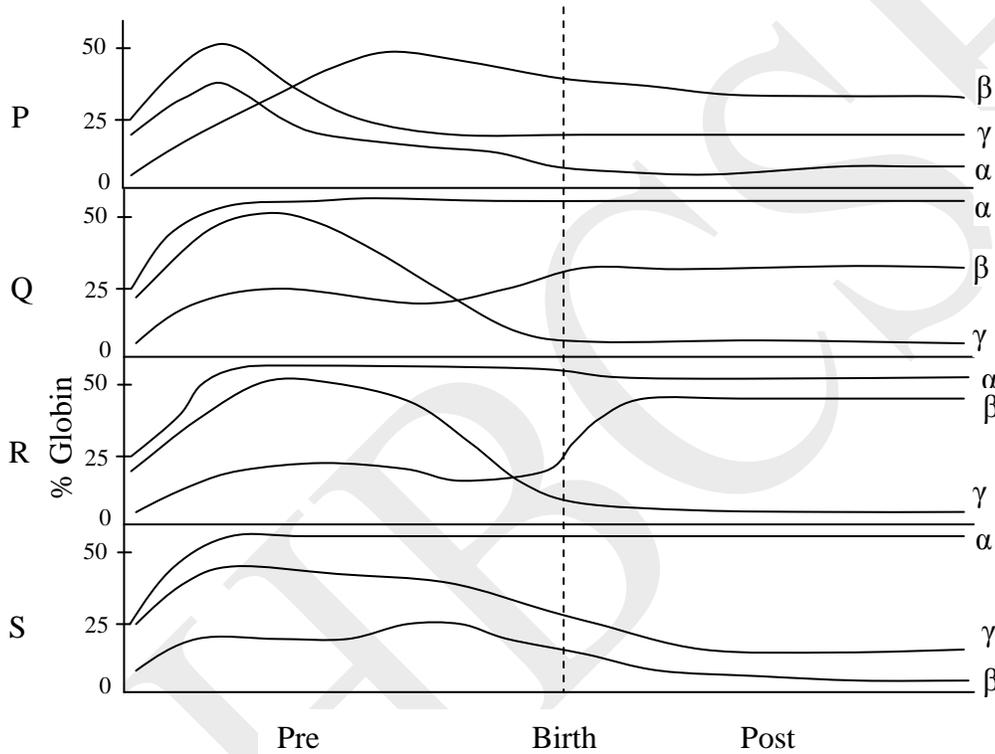
Choose the correct option and put a tick mark (✓) in the appropriate box.

- a. Pfr predominates in the cells and promotes transcription of inhibitory RNA for flowering.
- b. Pr predominates in the cells and promotes transcription of inhibitory RNA for flowering.
- c. Pfr predominates in the cells and promotes transcription of RNA for flowering.
- d. Pr predominates in the cells and promotes transcription of RNA for flowering.

a.	b.	c.	d.

**ANIMAL SCIENCES (7 points)**

39. (2 points) In a healthy individual, erythropoiesis is contributed by the yolk sac, spleen and liver during embryonic stages and by the bone marrow in the adult stage. The  $\beta$  and  $\gamma$  globin have reciprocal levels in fetal versus adult stages whereas  $\alpha$  globin is constantly high in both stages of human life. Thalassemia is related to defective expression of genes controlling the expression of  $\alpha$ ,  $\beta$  and  $\gamma$  globin genes. Match the graphs with the types of thalassemia.



Choose from the options and fill in the blanks.

Graph P: \_\_\_\_\_

Graph Q: \_\_\_\_\_

Graph R: \_\_\_\_\_

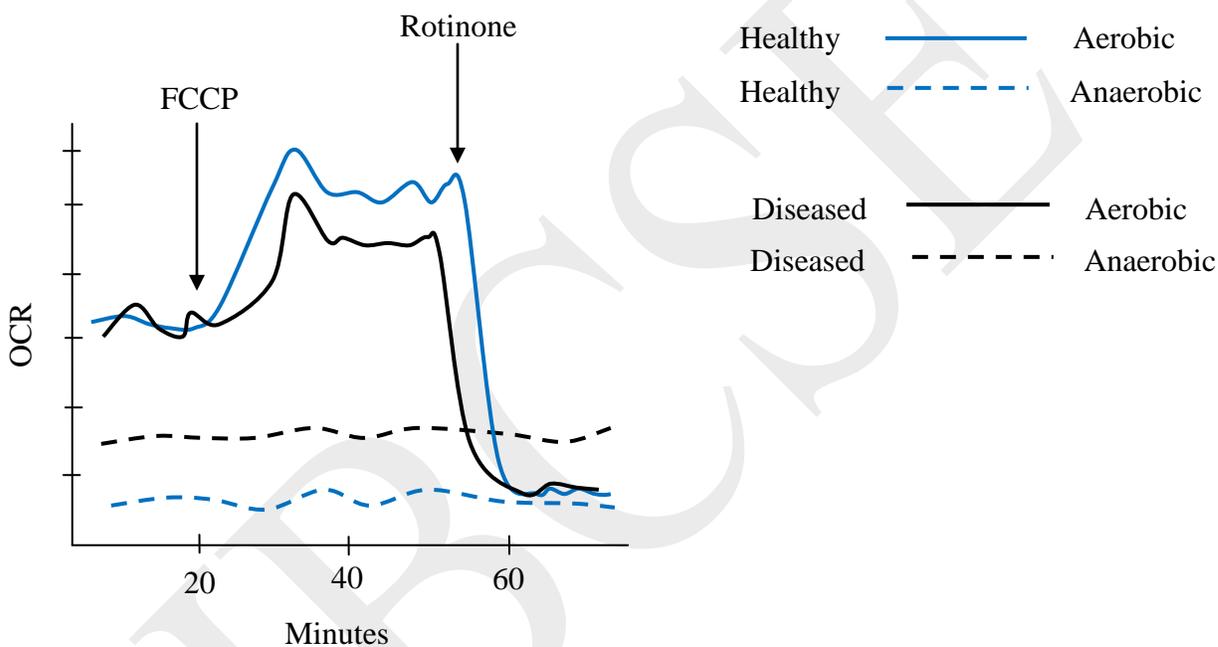
Graph S: \_\_\_\_\_

Options:

a. Beta thalassemia minor (one gene mutated)

- b. Normal (healthy)
- c. Beta thalassemia major
- d. alpha thalassemia major

40. (3 points) Seahorse XF analyzer is an instrument for assessment of mitochondrial health by measuring the oxygen consumption rate (OCR) in real time. The given graph depicts basal aerobic and anaerobic respiration of healthy and diseased cells of liver in culture. Dosing the cells with FCCP maximizes mitochondrial respiratory capacity whereas, Rotinone, blocks complex I causing inhibition of oxidative phosphorylation. Anaerobic respiration indicates the spare respiratory capacity of the liver cells.



Based on this study, indicate whether each of the interpretations listed is correct or incorrect by putting tick marks (✓) in the appropriate boxes.

- I. Adding glucose to diseased liver cells shall proportionately increase oxygen consumption rate.
- II. Poor FCCP response in diseased cells suggests a stronger mitochondrial membrane potential.
- III. Less number of mitochondria could be the reason for poor FCCP response in diseased cells.
- IV. Identical response of control and diseased cells to Rotinone suggests cessation of anaerobic respiration as well.
- V. Addition of glucose to diseased liver cells will improve spare respiratory capacity.
- VI. Cessation of aerobic respiration could be the reason for identical response to Rotinone in control and diseased cells.

Interpretation	Correct	Incorrect
I.		
II.		
III.		
IV.		
V.		
VI.		

41. (2 points) The relationship for mammals between physiological variables & body mass (Mb in kg) are given.

$$\text{Blood volume (lt)} = 0.055 \cdot \text{Mb}^{0.99}$$

$$\text{Heart weight} = 0.0058 \cdot \text{Mb}^{0.99}$$

$$\text{Lung ventilation rate (lt/hr)} = 20 \cdot \text{Mb}^{0.75}$$

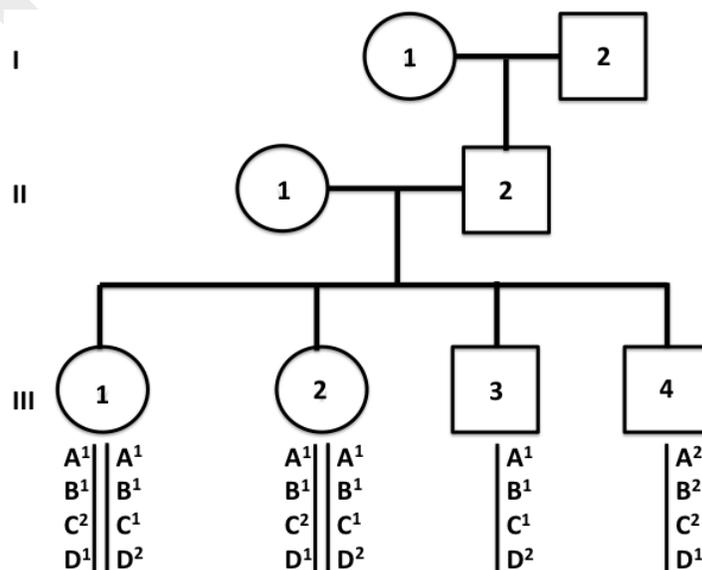
$$\text{Respiration frequency (min}^{-1}\text{)} = 53.5 \cdot \text{Mb}^{-0.26}$$

Mark the following statements as true (T) or false (F).

- As the body size increases, the respiration frequency increases. \_\_\_\_\_
- Lung ventilation rate is inversely proportional to the body size. \_\_\_\_\_
- In mammals, blood volume usually tends to be ten times more than the heart weight. \_\_\_\_\_
- As the animal size increases, the relative increase in blood volume is greater than the relative increase in heart weight. \_\_\_\_\_

### GENETICS & EVOLUTION (17 points)

42. (2 points) Consider the pedigree given below in which the genotypes at four different loci for the children in generation III have been shown. The symbols  $A^1/A^2$ ,  $B^1/B^2$ ,  $C^1/C^2$  and  $D^1/D^2$  represent alleles for the locus A, B, C and D, respectively. The symbols parallel to a straight line indicate that they are located on the same chromosome.



Based on the above information, indicate whether each of the following statements is true or false with respect to the four loci that have been represented by putting tick marks (✓) in the appropriate boxes.

- a. The represented loci are present on the X- chromosome.
- b. The genotype of individual II (1) is  $A^1/A^2 B^1/B^2 C^1/C^2 D^1/D^2$ .
- c. The genotype of individual II (2) can be represented as

$$\left| \begin{array}{l} A^2 \\ B^2 \\ C^2 \\ D^1 \end{array} \right.$$

d. Based on the genotype of individual II (2), the alleles present on one of the chromosomes of individual I (1) can be correctly predicted.

Statements	True	False
a.		
b.		
c.		
d.		

43. (2 points) Natural selection occurs when some genotypes in a population have different survival, fertility or reproduction. Following data shows the frequency of two alleles and their relative fitness (W) for 4 different populations.

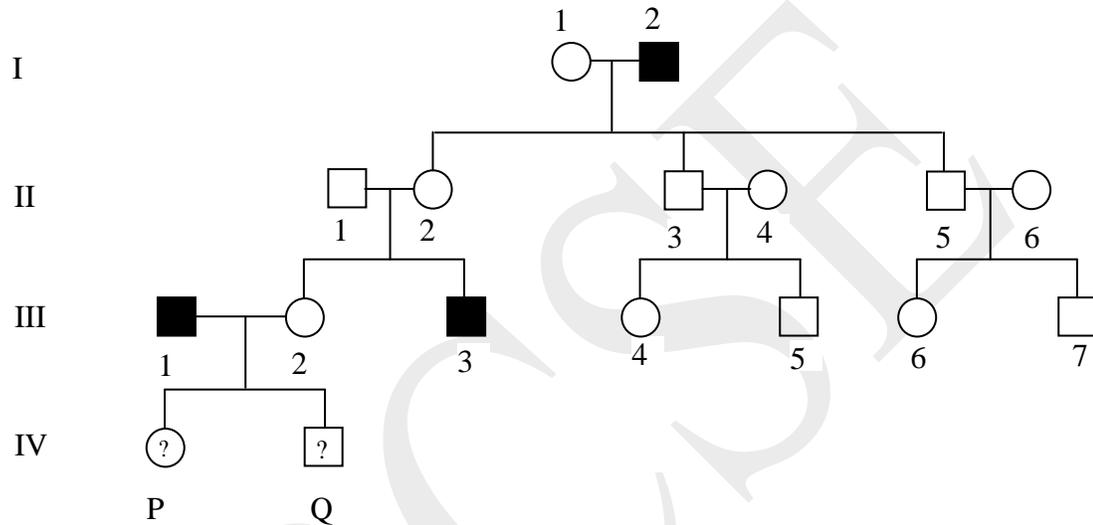
- Population (i)  $f(A_1) = 0.2$   $W_{11} = 1.0$   
 $f(A_2) = 0.8$   $W_{12} = 1.0$   
 $W_{22} = 1.0$
- Population (ii)  $f(A_1) = 0.8$   $W_{11} = 1.0$   
 $f(A_2) = 0.2$   $W_{12} = 1.0$   
 $W_{22} = 0.4$
- Population (iii)  $f(A_1) = 0.2$   $W_{11} = 0.4$   
 $f(A_2) = 0.8$   $W_{12} = 1.0$   
 $W_{22} = 0.4$
- Population (iv)  $f(A_1) = 0.8$   $W_{11} = 1.0$   
 $f(A_2) = 0.2$   $W_{12} = 0.4$   
 $W_{22} = 1.0$

State which of these populations are likely to show each of the following with respect to the alleles.

Fill in the blanks with the correct population (i – iv).

- a. Disruptive selection: \_\_\_\_\_
- b. Stabilizing selection: \_\_\_\_\_
- c. Directional selection: \_\_\_\_\_
- d. Not under any selection: \_\_\_\_\_

44. (3 points) Study the pedigree below for a rare human skin disease.



(A) II1 individual does not carry the allele associated with the affected phenotype. The most likely mode of inheritance is:

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

- a. Autosomal dominant
- b. Autosomal recessive
- c. X-linked recessive
- d. X-linked dominant

a.	b.	c.	d.
✓			

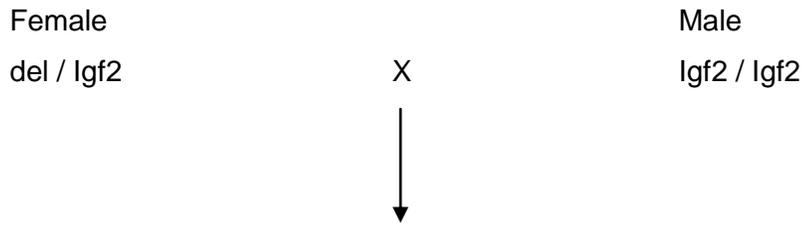
(B) If individuals III1 and III2 had a son, what is the probability that the son will be affected?

Answer: \_\_\_\_\_

(C) Who in the pedigree has the same mitochondrial (mt) DNA as III3? Give all correct answers. (Only a completely correct answer will be given points.)

Answer: \_\_\_\_\_

45. (2 points) Insulin-like growth factor is an important hormone required for growth and is synthesized by gene *Igf2*. Del indicates deletion of the *Igf2* gene. Study the following cross.



Normal-sized male and female offspring  
 $del_f / Igf2_m, Igf2_f / Igf2_m$

If F1 is sib-mated as shown,



Half the progeny small-sized  
 $del_f / Igf2_f, del_f / Igf2_m, Igf2_m / Igf2_f, Igf2_m / Igf2_m$

The above results can be best explained as:

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

- a. Incomplete dominance
- b. Incomplete penetrance
- c. Maternal imprinting
- d. Paternal imprinting

a.	b.	c.	d.

46. (2 points) In a human population, there are 16% individuals with blood group O while the percentage of people with blood group A is 20%. Assuming that the population is in the Hardy-Weinberg equilibrium for blood group locus, answer the following questions.

(A) Which of the following option represents the Hardy-Weinberg equation for the human population?

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

- a)  $(p+q)^3=1$       b)  $(p+q+r)^2 = 1$       c)  $(p+q+r)^3 = 1$       d)  $(p + q + r + s)^2 = 1$

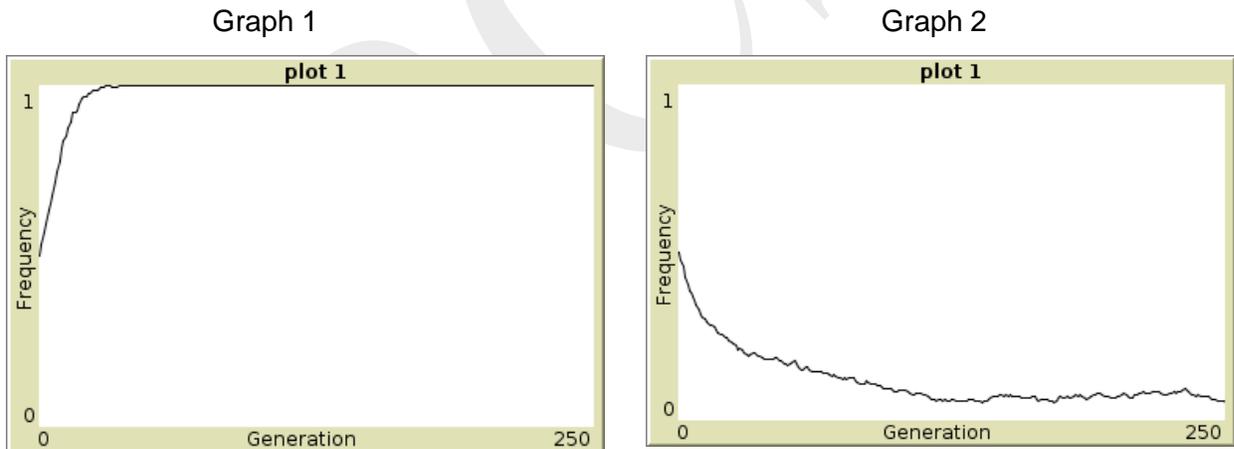
a.	b.	c.	d.

(B) Calculate the allele frequency of allele A in this population.

Answer: \_\_\_\_\_

47. (3 points) Each of the two graphs below shows the allele frequency of an allele of a locus that determines the coat colour of the rock pocket mouse<sup>3</sup>. The black coat colour allele is dominant over white coat colour allele. Depending on the type of landscape within the habitat – dark rocky outcrops versus light whitish sand, the chances of mice being predated by hawks changes.

(A) Based on the rate of change of allele frequencies over generations, identify the type of allele and the type of background from the given options that is likely to show changes in the allele frequencies in each of the graphs:



Choose the correct options from the table and fill in the blanks.

Option	Type of allele	Type of background
a	White coat colour	Dark rocky outcrops
b	White coat colour	Light whitish sand
c	Black coat colour	Dark rocky outcrops
d	Black coat colour	Light whitish sand

Answer:

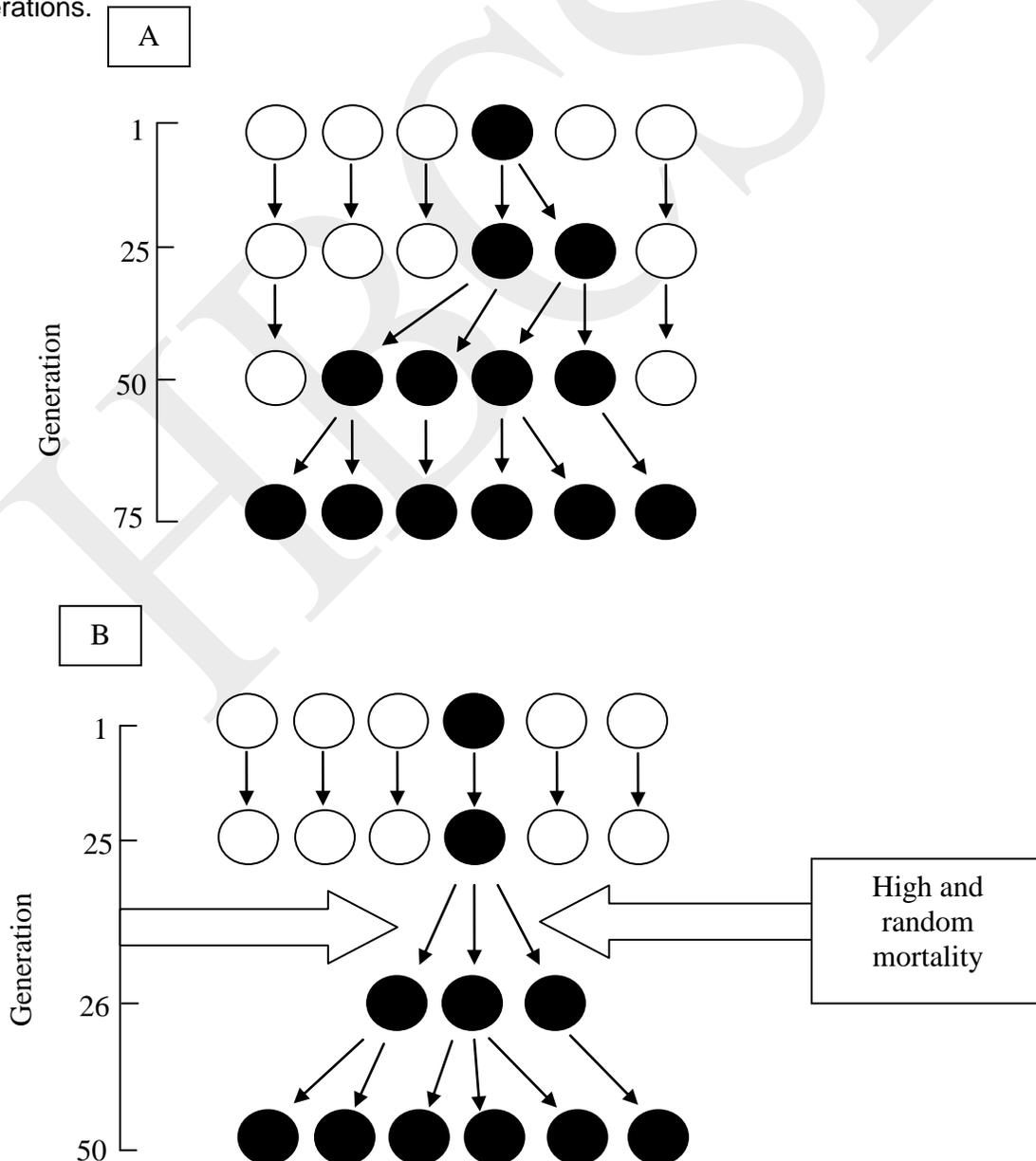
Graph 1: \_\_\_\_\_

Graph 2: \_\_\_\_\_

(B) At generation 0, if there were 100 mice each of homozygous dominant, heterozygous dominant and homozygous recessive in the population, what would be the numbers of each type of mice after 250 generations if there was no selection on any coat colour? (Assume the carrying capacity to be 400 mice)

Answer: \_\_\_\_\_

48. (3 points) The figure depicts two modes (A and B) of evolutionary change in the genetic makeup of a population over a span of 50 - 75 generations. Two allelic variants of individuals in the population have been symbolized either as dark solid circles or as open empty circles. Arrows indicate differential reproductive success for transferring alleles to the gene pool of successive generations.



(A) The best description of these evolutionary changes are:

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

- a. A: Natural selection, B: Artificial selection
- b. A: Natural selection, B: Genetic drift
- c. A: Genetic drift, B: Artificial selection
- d. A: Sexual selection of altered mate choice, B: Selection through recombination events

a.	b.	c.	d.

(B) Which of the following is **NOT** true for 'B'?

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

- a. Evolutionary changes are not gradual.
- b. Evolutionary process led to reduction of genetic diversity.
- c. Evolutionary changes have occurred on the basis of fitness.
- d. Genetic uniformity in the population at the 50<sup>th</sup> generation is not through mutation and selection.

a.	b.	c.	d.

(C) Which of the following is **NOT** true for 'A'?

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

- a. Evolutionary changes are gradual.
- b. Evolutionary changes have occurred on the basis of fitness.
- c. Selection is operating through reproductive success of one genotype.
- d. Population is stabilized with new mutational events.

a.	b.	c.	d.

**ECOLOGY (7 points)**

49. (3 points) Asiatic Lions are found in the Gir National Park in India and are social big cats wherein a male is seen in a pride of 5-6 females. This is unlike tigers or leopards that are solitary big cats. A

ratio of Male:Female :: 1:3 is considered as a healthy sex ratio in Asiatic lions. A new habitat was identified to translocate the lions. This forest had about 688 herbivores (spotted deer, black buck, neelgai, chinkara, etc) with an annual 10% increase in their population and a 2% mortality. Translocation experiment of adult (6 year old) Asiatic Lions was conducted and four adults (01 male and 03 females) were translocated. Their breeding score in subsequent years is as follows:

In 1 <sup>st</sup> year	Total Male cubs	Dead male cubs	Total Female cubs	Dead Female cubs
Females				
A	-	-	-	-
B	1	1	-	-
C	-	-	-	-
In 2 <sup>nd</sup> Year				
A	1	1	1	-
B	1	1	2	-
C	-	-	1	-
In 3 <sup>rd</sup> year				
A	2	-	2	
B	2	2	2	2
C	2	-	-	-

After about 6 years 02 additional adult males were translocated to the same territory. Mark the following statements as true or false putting tick marks (✓) in the appropriate boxes.

		True	False
1	Introduction of second batch of lions shall prevent the population bottleneck and improve genetic quality but shall also increase territorial conflicts.		
2	The final tally of total lions will be 12 with identical sex ratio of male : female at the end of 3 years.		
3	About 80 herbivores per lion are ideally considered as a healthy prey base in the wilderness. At the end of second stint of translocation of 2 adult males, there be sufficient food available for the existing total population.		

50. (4 points) The optimized life history is one that balances between the competing demands of survival and reproduction such that best fitness is achieved.

(A) If a reproductive adult animal can produce 'B' number of offspring, 'S' is its own survival probability and 'S<sub>o</sub>' is the survival (upto 1 year) probability of its offspring, what is the total fitness (F) of the adult animal? Choose the correct option and put a tick mark (✓) in the appropriate box.

- a.  $F = S_o B / S$
- b.  $F = S + S_o B$
- c.  $F = S / S_o B$
- d.  $F = S - S_o B$

a.	b.	c.	d.

(B) 'S' can be split into 2 factors namely:

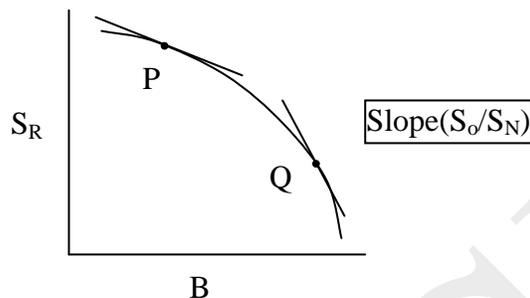
$S_R$ - survival related to reproduction

$S_N$ - survival not related to reproduction

After rearranging the equation for fitness, one gets:

$$S_R = (F/S_N) - (S_o/S_N)B$$

When  $S_R$  is plotted against B, the following graph is obtained.



Mark the correct interpretation/s of the graph. Choose the correct option/s and put tick mark/s (✓) in the appropriate box/es.

- When adults have a high probability of survival (P), the best strategy is to invest in offspring.
- When offspring survival is relatively poor, they produce larger number every year.
- When adults have a low probability of survival as compared to offspring (Q), adult should produce few eggs each year and increase their own reproductive life span.
- Q indicates high probability of survival of offspring while P indicates low probability of survival of offspring as compared to adults.

a.	b.	c.	d.

**ETHOLOGY (7.5 points)**

51. (2.5 points) A zeitgeber is any external or environmental cue that entrains or synchronizes an organism's biological rhythms to the Earth's 24-hour light/dark cycle and 12-month cycle. The picture given is an actogram depicting activity pattern of a migratory bird, Black-headed bunting, maintained in captivity. Each activity cage was provided with 2 perches mounted with an infrared motion sensor that continuously detected the bird's movement in its cage and transmitted it to a computerized data acquisition system.



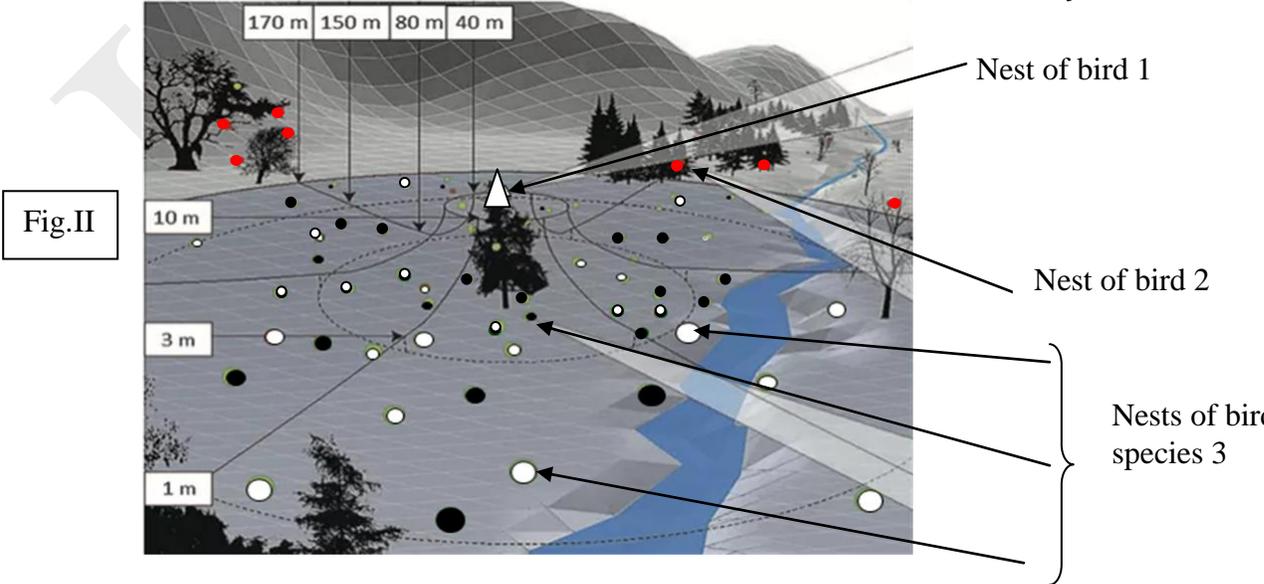
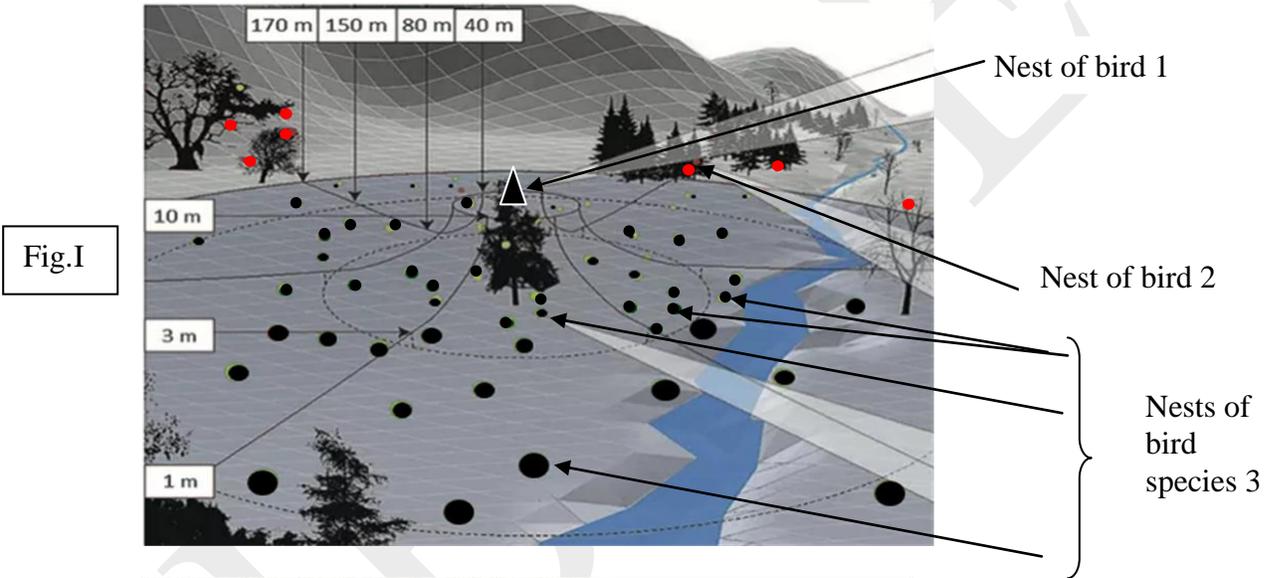
Based on the actogram, indicate whether each of the interpretations listed is correct or incorrect by putting tick marks (✓) in the appropriate boxes.

- Birds are more active during night time in the pre-migratory season as compared to post-migratory season.
- The nocturnal activity pattern of male birds will change and become more like non-migratory if they are injected with testosterone.
- The shift from non-migratory to migratory phase involves gross progressive increment in activity pattern.
- Zeitgeber timings 0 or 24 appear to be the same and indicates midnight.
- Evening injection of thyroxine in the migratory season could possibly partially or completely negate the activity at night.

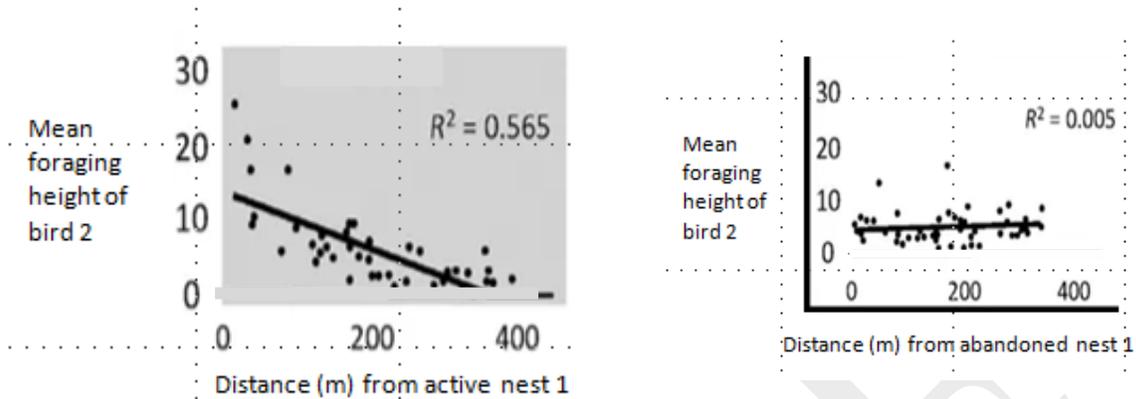
Interpretation	Correct	Incorrect
a.		
b.		

c.		
d.		
e.		

52. (5 points) In the south Arizona forest, the nesting sites of three bird species showed a characteristic spatial pattern shown in the figures I and II. The triangle indicates nest of bird 1, red circles indicate nests of bird 2 and black circles indicate nests of bird 3. The filled circles and triangle indicate active nests while unfilled ones the abandoned or inactive nests. There was a distinct difference in the distribution of nests of bird species 3 depending on whether the nest of bird 1 was active (figure I) or inactive (abandoned), figure II. The circles indicate the height above ground. The radius of the largest circle is approximately 170 meters.



Nest of bird 1 is at about 15 meters on the tree top and bird 1 can launch either a horizontal or descending pursuit to catch the prey. The foraging height of bird 2 shows the following relationship with the nest of bird 1:

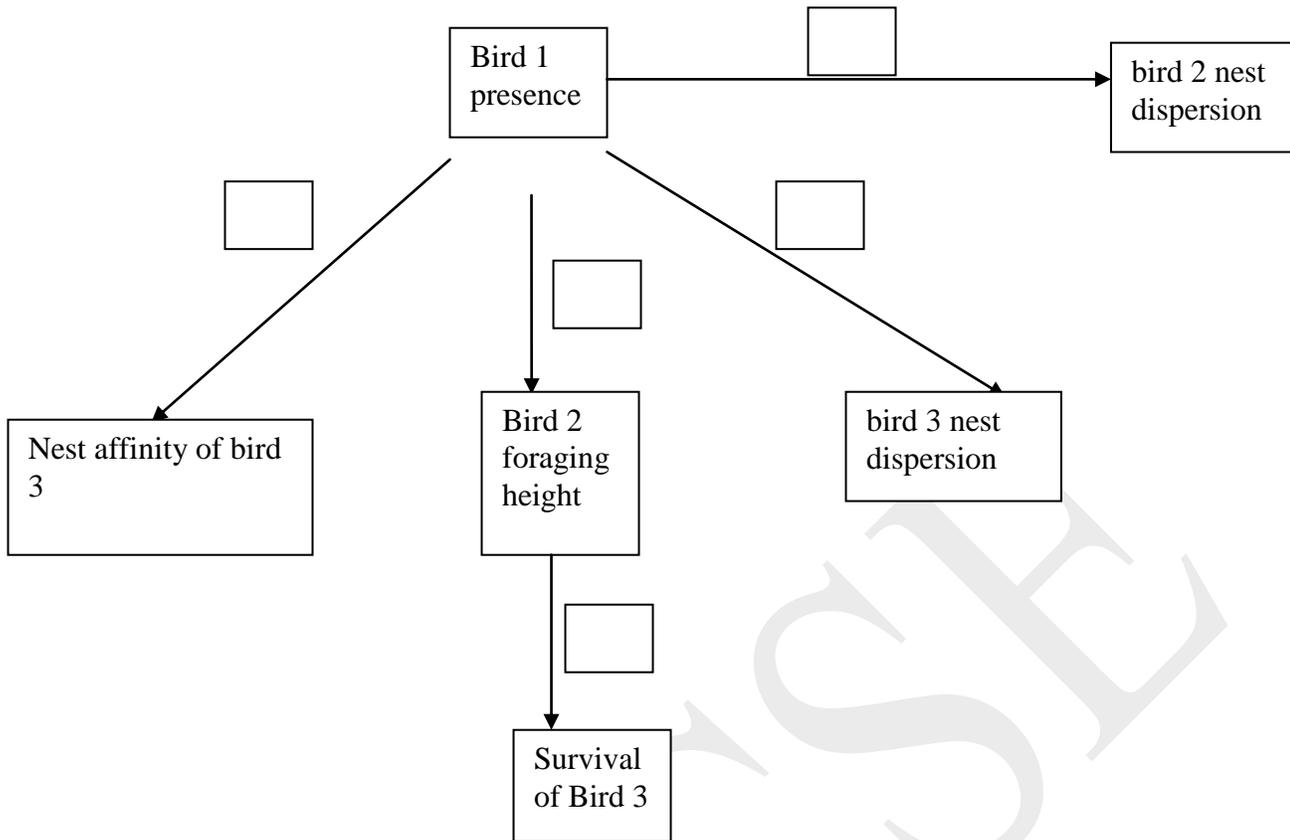


(A) State whether each of the results/hypotheses listed below is consistent or not consistent with the available data. Indicate your answers by putting tick marks (✓) in the appropriate boxes.

- a. The eggs and nestlings of bird 3 are likely to be the food of bird 2.
- b. Nesting success of bird species 3 is very high in the presence of nest of bird 1.
- c. Bird 2 can prey on both birds 1 and 3.
- d. Bird 3 shows nest preference near bird 1 which is likely to be the predator of bird 2.
- e. Bird 2 is likely to be the predator of bird 3 but prey of bird 1.

Results/Hypotheses	Consistent	Not consistent
a.		
b.		
c.		
d.		
e.		

(B) Indicate the relationship between the following by + or -. + indicates “will have effect” and – indicates “will not have effect”.



**BIOSYSTEMATICS (7 points)**

53. (2 points) A circulatory system comprising of a typical circuit of 'heart-sinuses-gills-heart' without the involvement of capillaries can be found in some of the following animal groups.

- (i) Cnidaria
- (ii) Nematoda
- (iii) Arthropoda
- (iv) Protochordata
- (v) Flightless birds
- (vi) Mollusca
- (vii) Annelida

Choose the correct combination from the options and put a tick mark (✓) in the appropriate box.

- a. i, iv, v and vi
- b. ii, iii and vii
- c. ii, iii, v and vi
- d. iii, iv and vi

a.	b.	c.	d.
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

54. (2 points) Duck-billed platypus is classified as a mammal although it is oviparous and possesses mammary glands without nipples. Which of the following essential character/s qualify platypus for its inclusion under the class Mammalia?

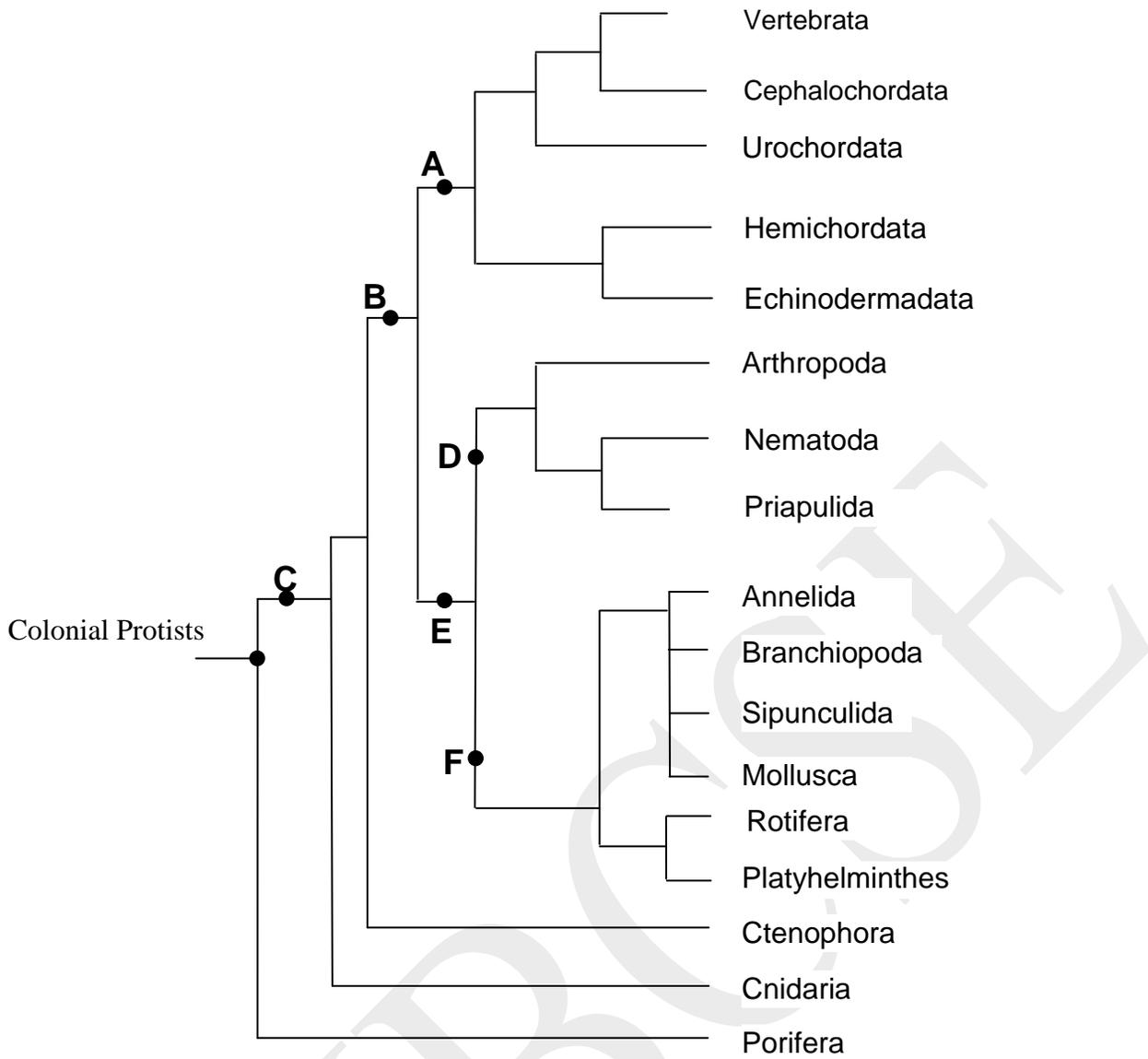
- 1) Presence of diaphragm
- 2) Presence of thecodont dentition (thecodont: teeth lodged in socket)
- 3) Dicondylic skull (possessing two occipital condyles)
- 4) Presence of sweat glands
- 5) Endothermy
- 6) Presence of four-chambered heart
- 7) Presence of pinna
- 8) Body covered by fur
- 9) Milk production
- 10) Presence of seven cervical vertebrae

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

- a. 1, 2, 4, 7, 8, 10
- b. 1, 3, 5, 6, 8, 9, 10
- c. 3, 4, 5, 6, 10
- d. 1, 3, 5, 6, 7, 8

a.	b.	c.	d.

55. (3 points) Major evolutionary divergence is based on embryonic, morphological and molecular criteria. Following is a list of events during embryonic development that depicts evolutionary relationships with various phyla. Match the listed events during embryogenesis of various organisms of the phyla with A to F in the figure shown.



Choose from the options given below and fill in the blanks.

- (i) Spiral cleavage
- (ii) Radial symmetry
- (iii) Moulting
- (iv) Anus from blastopore
- (v) Three germinal layers
- (vi) Mouth from blastopore

Answer:

- A: \_\_\_\_\_
- B: \_\_\_\_\_
- C: \_\_\_\_\_
- D: \_\_\_\_\_
- E: \_\_\_\_\_
- F: \_\_\_\_\_

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