

# INDIAN NATIONAL BIOLOGY OLYMPIAD- 2019

## INSTRUCTIONS

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.

### Section A

- Before starting, ensure that you have received a copy of this Question Paper containing a total of 39 pages (39 sides on 20 sheets).
- Section A consists of 26 questions carrying 1 point each.
- All 26 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 30 questions with a total of 74 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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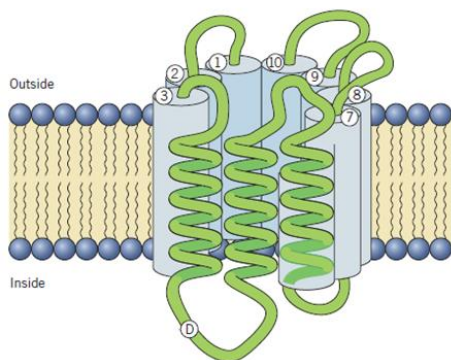
**INDIAN NATIONAL BIOLOGY OLYMPIAD – 2019**

**SECTION A**

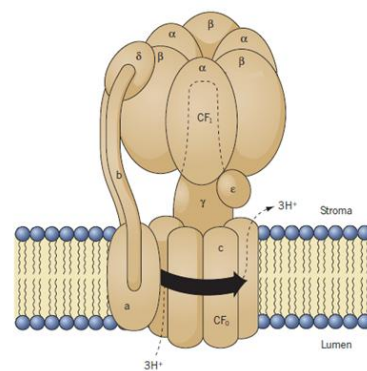
**CELL BIOLOGY (7 points)**

1. (1 point) When human genome was sequenced, the annotated number of genes was found to be ~20,000. Based on complexity of humans, however, it was expected that there would be more than 100,000 genes. Which of the following statements would explain this discrepancy?
  - a. The current methods of sequencing are inefficient to identify the large number of genes.
  - b. Enhanced somatic recombination in humans takes place to generate more number of genes.
  - c. Large number of genes in humans undergo alternative splicing to generate proteome diversity.
  - d. Fewer genes through frame shift translation can generate more number of proteins.
  
2. (1 point) Molecular chaperones promote folding of proteins using energy from ATP. In the presence of ATP, chaperones assume an open conformation. This exposes pockets (P) in the chaperone which bind and enclose regions of nascent polypeptides that might promote aggregation. Imagine that life evolved in benzene instead of water, leading to the same set of amino acids and proteins as we have in biology now. In such a hypothetical scenario, which of the following amino acids is most likely to be found lining P of chaperones?
  - a. Isoleucine
  - b. Glutamine
  - c. Arginine
  - d. Cysteine
  
3. (1 point) Consider a diploid organism with  $2n$  value of 4. How many chromosomes and DNA molecules respectively are present in the G1 and G2 phases of a somatic cell of this organism? (consider only nuclear DNA)
  - a. G1: 4 and 4; G2: 4 and 4
  - b. G1: 4 and 4; G2: 4 and 8
  - c. G1: 4 and 4; G2: 8 and 4
  - d. G1: 4 and 4; G2: 8 and 8

4. (1 point) Chloroplasts, according to the theory of endosymbiosis, represent originally free-living prokaryotes that were taken inside eukaryotic cells and lost their ability to exist independently. Which of the following is least likely to be encoded by the chloroplast genome based on this theory?
- Chloroplast DNA Polymerase
  - Chloroplast RNA Polymerase
  - Chloroplast ribosomal subunits
  - Chloroplast tRNA
5. (1 point) Of the sunlight that reaches the surface of the earth, biological processes mostly make use of light of wavelength between 400nm to 700nm. Which of the following transitions, critical for life, will occur in the molecules absorbing photons in this range of wavelengths?
- Vibrational transitions
  - Rotational transitions
  - Electronic transitions
  - Nuclear transitions
6. (1 point) ATPases are protein complexes which are found on different membranes of the cell. The following diagrams show the structure of two major types of ATPases, the P-type ATPase and F-type ATPase.



P-type ATPase



F-type ATPase

Which of the following statement/s regarding the ATPases is/are true?

- ATPases are always involved in the synthesis of ATP.
- The P-type ATPase is formed from a single polypeptide.

- iii. The F-type ATPase is a multiprotein complex.
- iv. Both the above types of ATPases are directly involved in the active transport of ions.

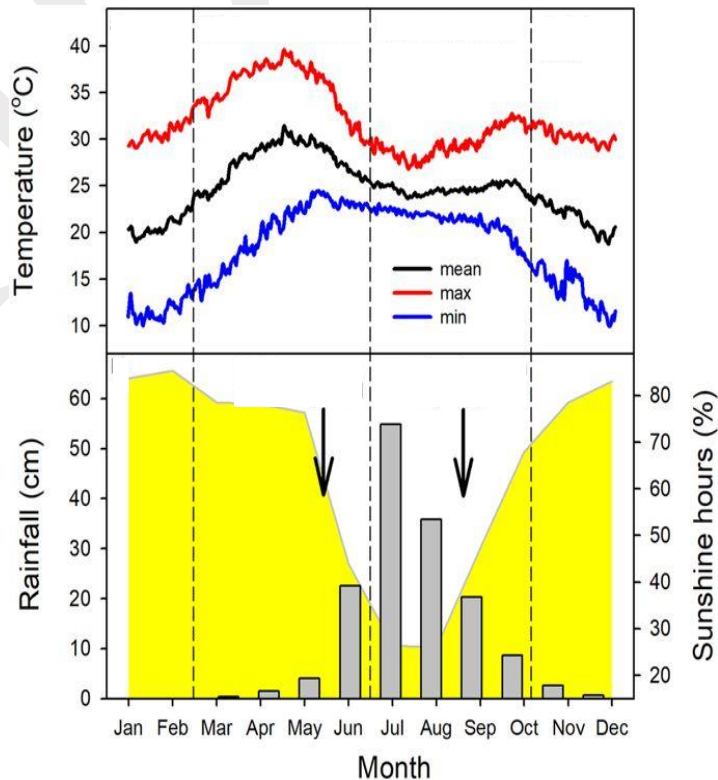
- a. i only
- b. ii and iii
- c. i and iv
- d. iv only

7. (1 point) A scientist was analysing a particular DNA sequence in humans and its relation to a disease. Which of the following data is most supportive of the scientist's hypothesis that the particular sequence is NOT related to the disease?

	Percent of diseased individuals having the sequence	Percent of non-diseased individuals having the sequence
A	48%	52%
B	65%	35%
C	90%	10%
D	20%	80%

**PLANT SCIENCES (5 points)**

8. (1 point) The graph below represents the annual temperature, rainfall and sunshine at a tropical site in India.



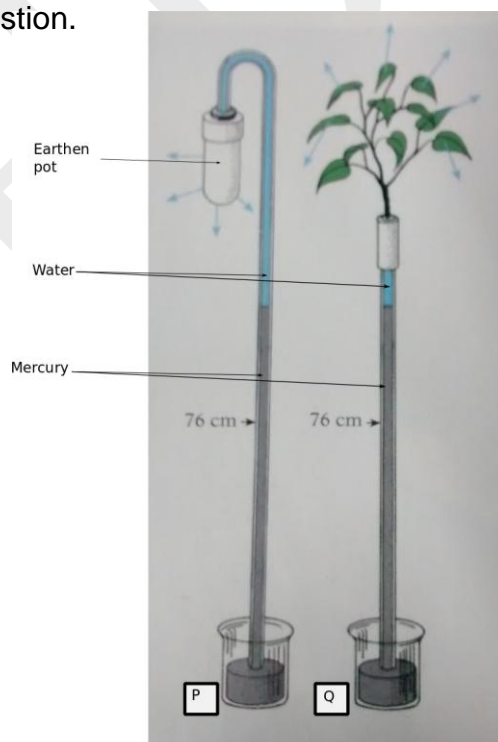
(Top panel: The three lines indicate the maximum, mean and minimum temperature.

Bottom panel: The grey bars indicate amount of rainfall and the curve indicates the sunshine hours.)

Trees growing in this region flush (put out) new leaves during the months of March and April. This is the hottest and driest time of the year. Which of the following could be the reasons for this phenomenon?

- i. New leaves avoid insect herbivory which is accompanied by the rains.
  - ii. New leaves with highest photosynthesis efficiency would be able to maximise the sunshine hours.
  - iii. New leaves lose least water and hence are more efficient during the dry period.
  - iv. New leaves are more tolerant than mature leaves to abiotic stresses like high temperature.
- a. i and ii only  
b. ii and iv only  
c. iii and iv only  
d. i, ii, iii and iv

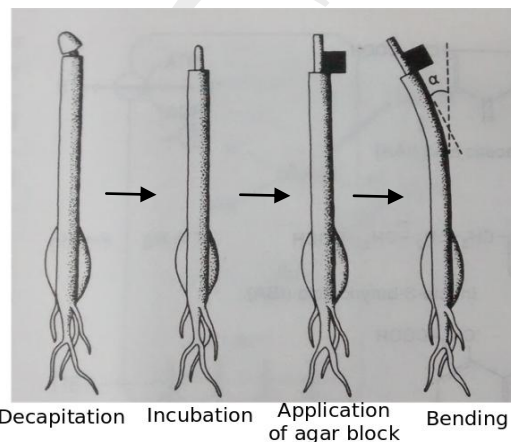
9. (1point) Observe the experimental set-up shown here carefully and answer the following question.



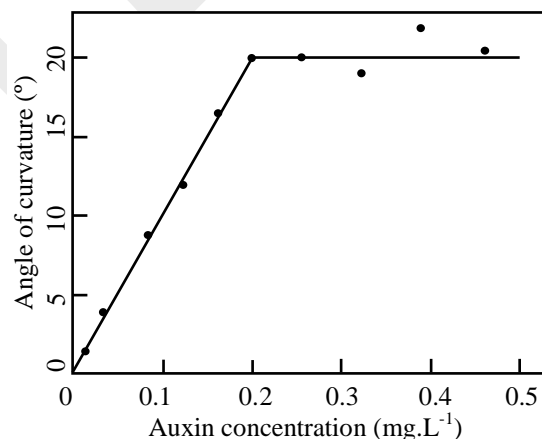
Which of the following hypotheses is the experimental set-up designed to test?

- a. The amount of water required by a plant increases with increase in the rate of evaporation of water through transpiration.
- b. The process of transpiration can generate enough pressure to pull water up the column.
- c. The increase in the atmospheric pressure increases the rate of transpiration in plants.
- d. The process of water transport through stem requires an unbroken column of liquid.

10.(1 point) In the coleoptile-bending assay developed by Went in 1928, a coleoptile is decapitated and kept for a few hours. A block of agar soaked in a known concentration of plant hormone, auxin, is then kept on one side of the decapitated coleoptile. The entire set-up is kept in the dark throughout the procedure. After a few hours, the curvature of the tip is measured. The pictures below show the schematic of the four steps of the assay.



The graph below shows the effect of concentration of auxin on the bending or curvature.



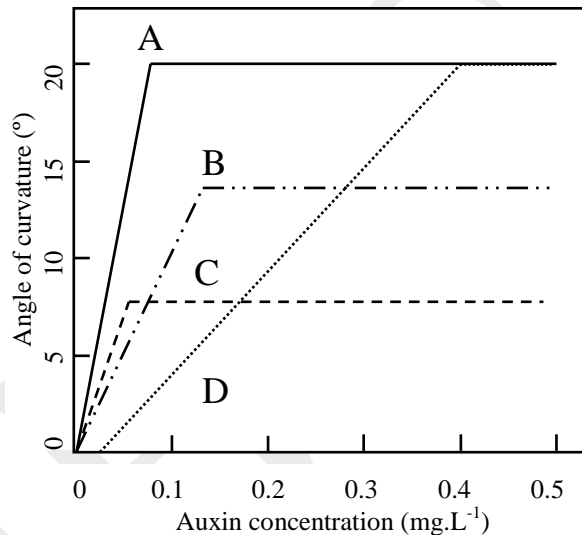
This graph could be used to estimate concentration of auxin in a sample by measuring the angle of curvature or bending due to the block soaked in the sample.

Answer the questions 10 and 11 based on the above experiment.

Which of the following cases could lead to the overestimation of auxin in the sample?

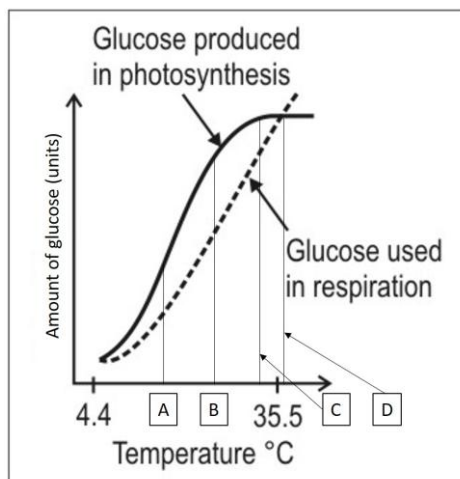
- a. If the agar block with unknown auxin is loaded without any incubation after decapitation.
- b. If agar block is kept exactly on the top of the coleoptile instead of on one side.
- c. If the size of the agar block is reduced to half.
- d. If the duration between the application of agar block and measuring of bending is reduced.

11.(1 point) How will the graph look if there is reduction in the sensitivity of the coleoptile to the auxin?



- a. A
- b. B
- c. C
- d. D

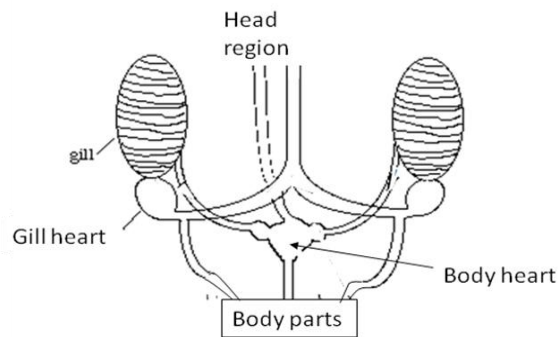
12.(1 point) Photosynthesis results in the production of glucose in plants which is then utilized for plant growth. Growth of a plant at different temperatures is shown in the graph. Given all other conditions are the same, at what temperature will the plant grow the fastest?



- a. A
- b. B
- c. C
- d. D

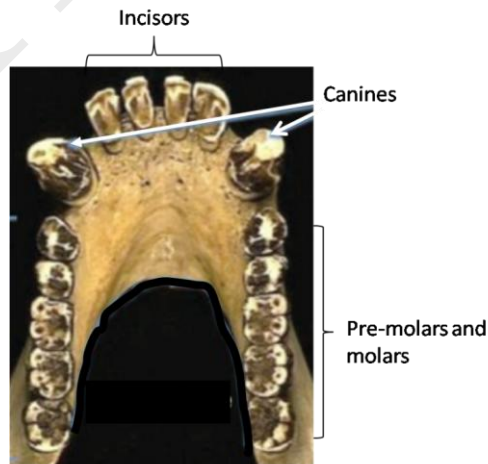
**ANIMAL SCIENCES (2 points)**

13.(1 point) The squid and octopus are molluscs that are known to be among the most active aquatic invertebrates. The circulatory system of a squid is shown below. It shows two types of hearts, namely the gill hearts and body heart. The correct path of blood through this circulatory system is:



- a. Body parts and head → gill heart → gills → body heart → Body parts and head
- b. Body parts → body heart → gills → gill heart → Body parts and head
- c. Body parts → body heart → gills → gill heart → body heart → Body parts and head
- d. Body parts and head → gills → gill heart → body heart → Body parts and head

14. (1 point) The following is a jaw structure that belongs to either an ape or to a most recent ancestor of human. Which of the following is the correct statement?





- a. It most likely represents ancestral human jaw as the arrangement of molars and premolars matches with ancestral human skull.
- b. It most likely represents ape because of a peculiar jaw shape and distance between the teeth.
- c. It most likely represents ancestral human as the number of incisors and canines matches with the ancestral human skull.
- d. The jaw cannot be of an ape as apes are herbivores and lack canines.

**GENETICS & EVOLUTION (2 points)**

15. (1 point) Three siblings have the following blood groups: B Rh positive; A Rh negative; and O Rh positive. Based on this information what will be the parents' genotype for the two blood group loci? (*Note: Rh positive allele is dominant represented by +.*)

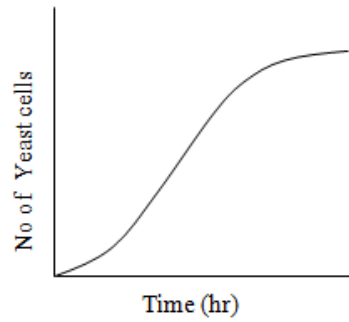
- a.  $I^A I^B + -$  and  $I^A i + -$
- b.  $I^B i + +$  and  $I^A i + -$
- c.  $I^B i + -$  and  $I^A i - -$
- d.  $I^A I^B + +$  and  $ii + -$

16. (1 point) In natural populations, individual allele frequencies are changing all the time. Several factors can be responsible for change in allele frequency. Among these, the only factor that produces adaptive evolutionary changes is:

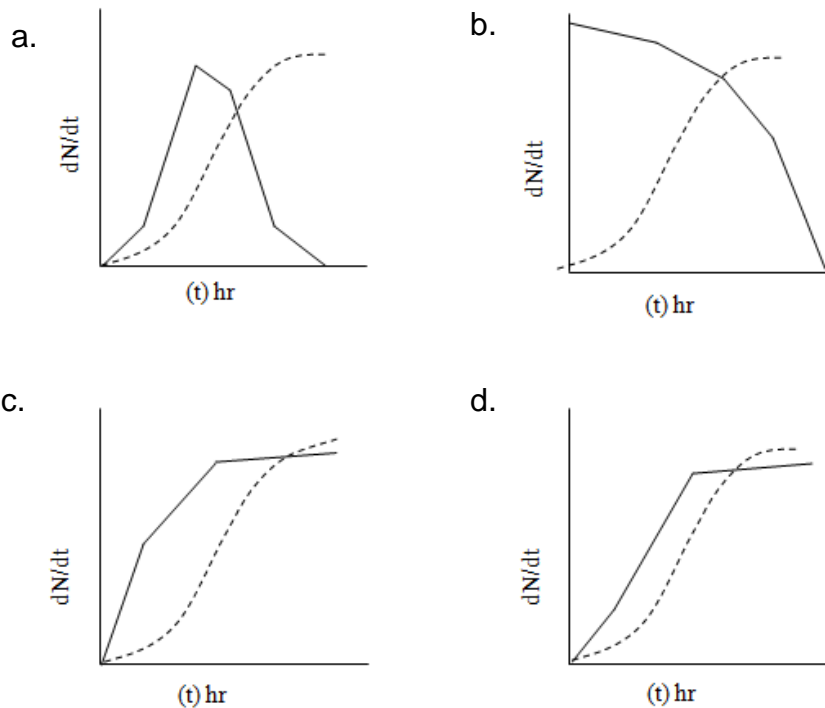
- a. random mutation.
- b. immigration and emigration.
- c. natural selection.
- d. genetic drift.

**ECOLOGY (3 points)**

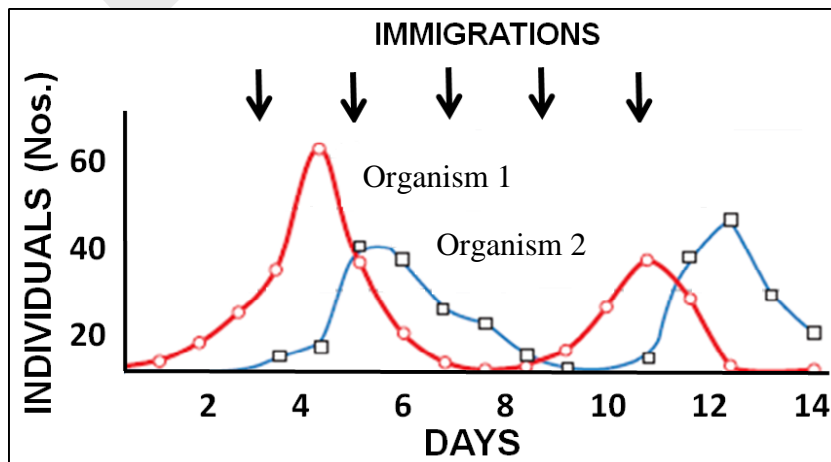
17. (1 point) In order to understand the interaction of biotic and abiotic components on the life forms, experiment can be set to study the growth curve. When yeast cells were grown in a media, a sigmoidal curve was obtained as shown below.



If the above curve is converted into growth rate curve, where change in cell number per unit time is plotted against time, the graph obtained will be:



18. (1 point) In the following diagram, the interaction between two organisms 1 and 2 is shown in laboratory culture. At different intervals, individuals of both the species were introduced into culture to maintain their population density (like natural immigration process).



Which of the following statement/s is/are true for this interrelationship?

- i. If immigration is not there, population of both species will get exhausted within 6 to 10 days.
- ii. Organism 1 is most likely the predator of organism 2.
- iii. The graph shows normal curve of prey – predator relationship. Therefore, in this experiment, immigration of species from external source is not essential for coexistence of species.
- iv. Organism 1 and 2 share a mutualistic relationship with each other.

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

19.(1 point) Intrinsic rate ( $r$ ) of natural increase in number, generation time in days and net reproduction rate ( $R_0$ ) for 3 animals are given:

$r$	Average generation time	$R_0$
(i) 0.0125	141.8	5.9
(ii) 0.101	55.6	275
(iii) 0.111	30.9	30.9

(i), (ii) and (iii) most likely are:

- a. rat, beetle and louse respectively.
- b. louse, beetle and rat respectively.
- c. rat, louse and beetle respectively.
- d. beetle, rat and louse respectively.

**ETHOLOGY (4 points)**

20.(1 point) Approximately 9% of all bird species breed cooperatively, where non-reproducing subordinate “helpers” assist in raising the offspring of others. Helpers forego their own reproduction to provide energetically costly assistance in rearing the

offspring of the breeding couple. Other confounding factors are known to affect the behavior of “helping”. Effect of one such factor, namely, shortage of territory (indicated as Yes or No) is shown in the graph.



- The graph indicates that if territory is not limited, there are greater chances that the birds will act as helpers.
- The behavior of “helping” by non-related individuals is more pronounced when enough territory is available.
- The birds show low preference for “helping” behavior when nesting sites are limited.
- The graph indicates that unrelated birds are more likely to provide “help” to breeders when the territory availability is limited.

21. (1 point) The table below shows the number of study sites predicted to be occupied or unoccupied by tigers, based on a mathematical model of their habitat use and the actual observed presence or absence of tigers in those study sites based on rigorous field surveys. Assuming the field studies are accurate, answer questions 21 and 22.

		Observed from field surveys	
		Present	Absent
Predicted occupancy from habitat use model	Present	26	6
	Absent	9	43

What percentage of all the study sites was correctly predicted by the habitat model?

- 41.7
- 74.3
- 82.1
- 87.7

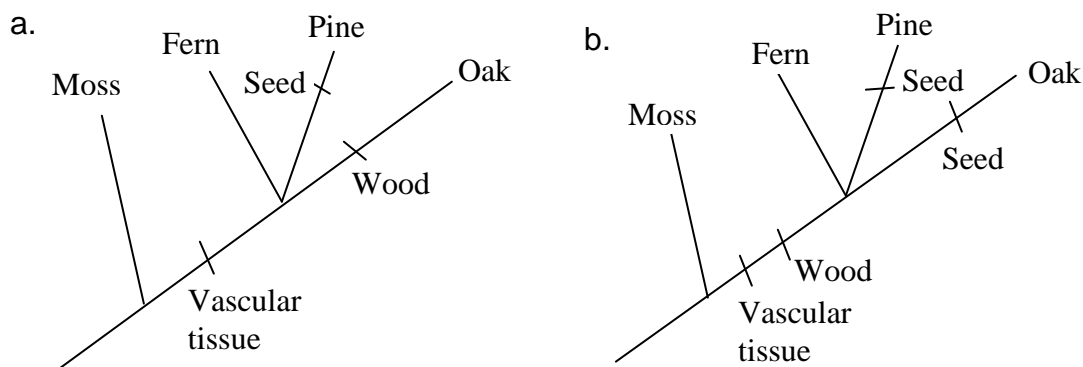
22. (1 point) Which statement best describes the accuracy of the habitat model?
- The model was better at predicting tiger presence than tiger absence.
  - The model was better at predicting tiger absence than tiger presence.
  - The model equally good at predicting tiger presence and tiger absence.
  - The model was unable to predict either tiger presence or tiger absence.

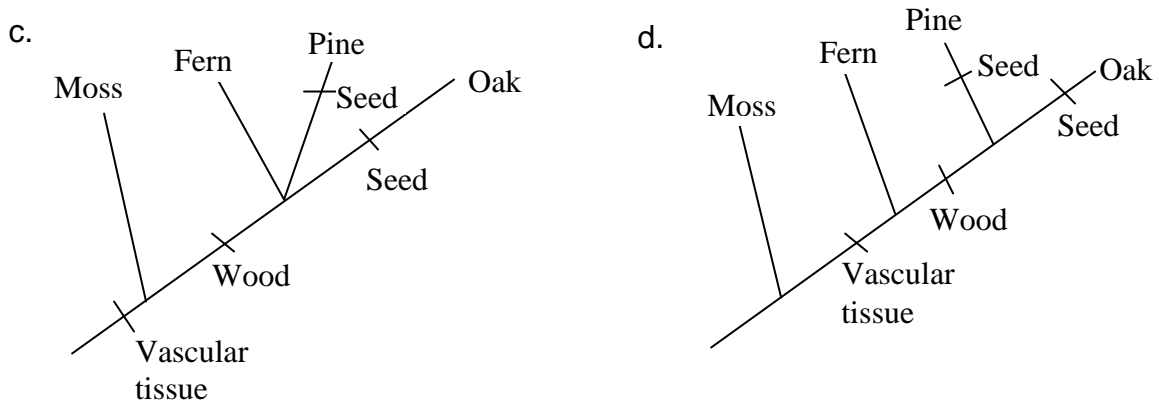
23. (1 point) To estimate the probability of a bird surviving from one year to the next in the wild, birds are often 'ringed' with a numbered aluminium ring attached to their leg. This allows researchers to track birds year after year to estimate survival probability. The impact of the ring itself on the survival of the bird is difficult to quantify because it is almost impossible to estimate accurately the survival of birds without rings. Which of the following choices would be the most suitable to try and estimate the impact of rings on bird survival in the wild?

- Use a radio transmitter on some birds without rings to estimate survival probability of birds, and compare with survival of ringed birds.
- Estimate the survival of captive birds without rings, and compare with the survival of ringed birds in the wild.
- Use rings of different weights on different birds of the same species, and examine the impact of ring weight on survival by extrapolation method.
- Use plastic rings instead of aluminium rings and compare survival probabilities of birds with different kinds of rings.

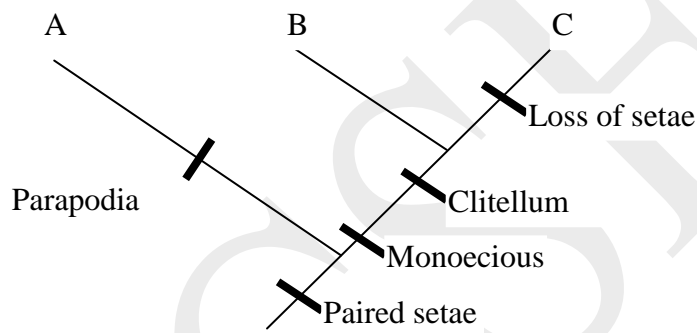
**BIOSYSTEMATICS (3 points)**

24. (1 point) Considering characters such as vascular tissue, wood and seed, which of the following correctly depicts evolutionary relationship but is not parsimonious?





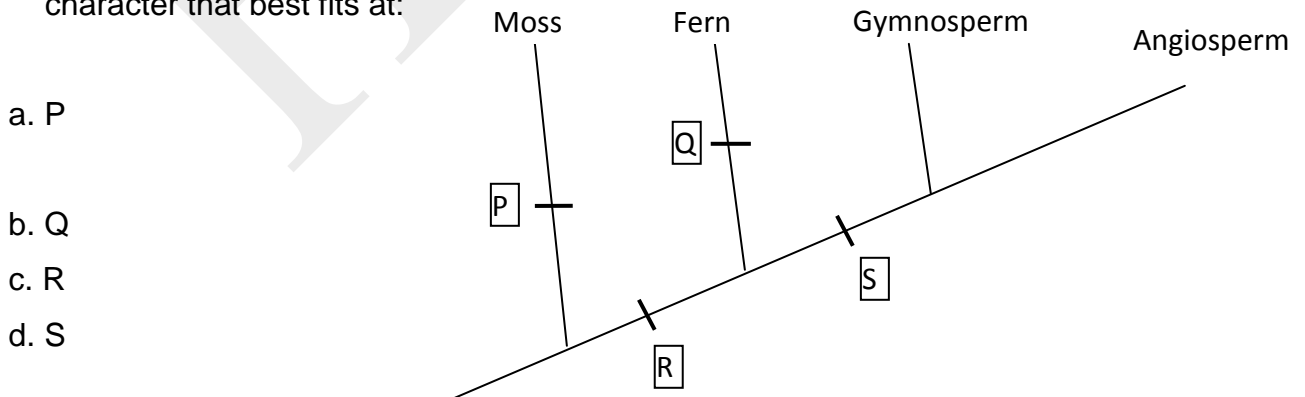
25. (1 point) A cladogram depicting the evolutionary relationships of two classes of annelids is shown below.



A, B and C respectively indicate:

- a. Polychaeta, Hirudinea and Oligochaeta
- b. Oligochaeta, Polychaeta and Hirudinea
- c. Hirudinea, Oligochaeta and Polychaeta
- d. Polychaeta, Oligochaeta and Hirudinea

26. (1 point) The 'free living and independent sporophyte as well as gametophyte' is a character that best fits at:



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

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

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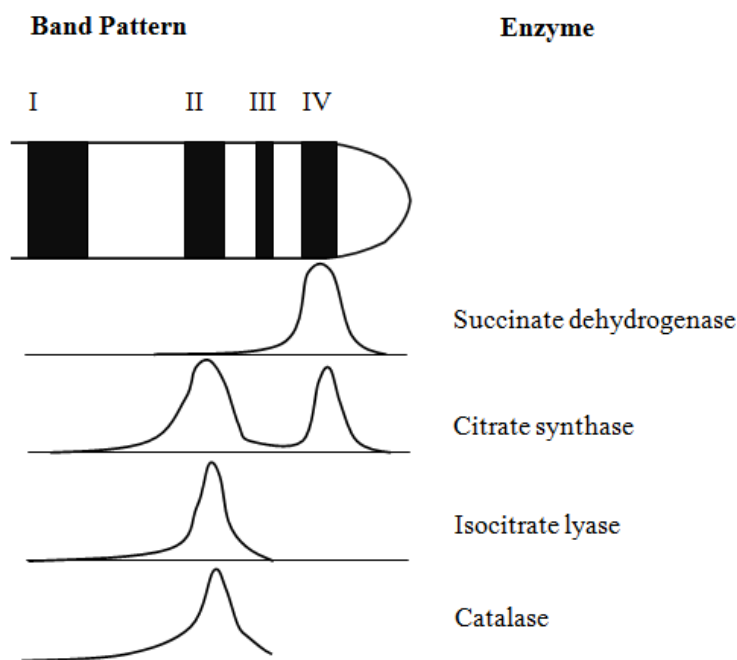
**SECTION B**

**NOTE:**

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

**CELL BIOLOGY (19.5 points)**

27.(2 points) In an experiment, endosperm of 5-day germinating seeds of *Ricinus communis* (castor bean seeds) were homogenized in an isotonic medium (0.4 moles/lit sucrose). The resulting organelle suspension was layered onto a density gradient column and centrifuged for 4 hrs at 1,00,000 g. Organelles move into the gradient until they have reached a position equivalent to their own density. Determination of protein contents revealed 4 distinct bands (I-IV) along the gradient. Some marker enzymes in each of these bands when tested showed following results:



Bands I-IV represent:

(Choose from the options below and fill in the blanks with the correct alphabet a – e for each band.)

Band I: \_\_\_\_\_

Band II: \_\_\_\_\_

Band III: \_\_\_\_\_

Band IV: \_\_\_\_\_

Options:

- a. Nuclei
- b. Protoplastids
- c. Mitochondria
- d. Cytosol
- e. Microbodies

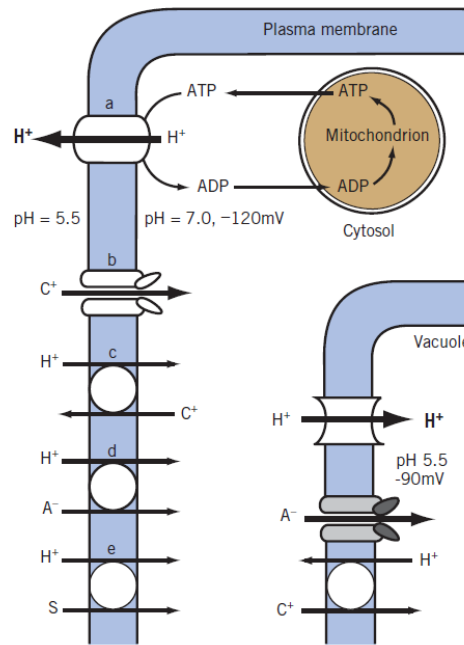
28.(2.5 points) One of the hallmarks of living systems is that they have highly efficient catalysts called enzymes. Enzymes have many unique properties unlike chemical catalysts. Indicate whether each of the following statements is true or false by putting a tick mark (✓) in the appropriate box.

- i. They catalyze the reaction by lowering  $\Delta G^0$  of the reaction.
- ii. Active site of the enzyme binds to transition state of the reaction.
- iii. All enzyme substrate complexes formed are covalent in nature.
- iv. Some RNA molecules also catalyze reactions.
- v. All enzymes lose their catalytic activity at temperatures as high as 90°C.

Statement	True	False
i.		
ii.		
iii.		
iv.		
v.		



29.(2 points) The diagram below shows a schematic of a membrane ATPase proton pump and its interaction with other structures involved in solute exchange across the membrane. Study the diagram and the statements given and state which of them is/are true. ( $C^+$  indicates cation,  $A^-$  indicates anion while S indicates uncharged solute.)



- I. The plasma membrane ATPase directly contributes to potential difference across the plasma membrane.
- II. The ATPase – proton pump (a) acts as a uniport system.
- III. The proton motive force generated due to the activity of the plasma membrane ATPase makes it difficult for the anions to passively diffuse into the cytosol.

Put a tick mark (✓) in the appropriate box.

- a. I only
- b. II and III only
- c. I and II only
- d. I, II and III

a.	b.	c.	d.

30.(3 points) cAMP activates lac-operon through binding to Catabolite Repressor Protein (CRP) protein. CRP-cAMP complex binds upstream in the lac-promoter. This facilitates binding of RNA polymerase if the lac-operator is free (not bound to lac-repressor). Glucose inhibits induction of lac-operon by lowering the levels of cAMP.

The cAMP is produced from ATP by an enzyme adenylate cyclase. Following are some of the results from famous research papers published in 1971 and 1974 by Peterkofsky and Gazdar:

Experiment 1: Effect of glucose on in-vivo activity of adenylate cyclase.

*E.coli* were grown in synthetic medium, and 1mM sugar solutions (table 1) were added. In vivo activity of adenylate cyclase was measured by formation of cAMP.  $\alpha$ -methylglucoside is a glucose derivative which cannot enter into glycolysis.

Table 1:

Additions	p moles of cAMP formed/2mins
None	828
Glucose	80
Gluconic acid	866
$\alpha$ -methylglucoside	84

Experiment 2: Effect of glucose on in-vitro activity of adenylate cyclase.

Cultures of *E.coli* B were grown in different concentrations of glucose. Cells were harvested and lysed and adenylate cyclase activity was measured.

% glucose in medium	Adenylate cyclase activity
0.03%	0.41
0.3%	0.39
3.0%	0.82

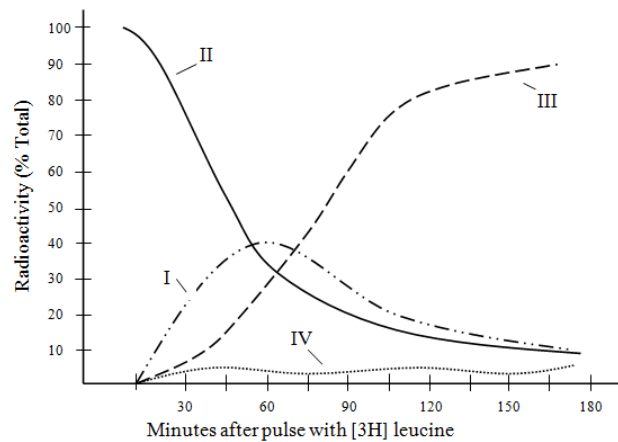
Analyse the above results and state whether the following statements are true or false by putting tick marks (✓) in the appropriate boxes.

- i. Metabolism of glucose is not essential for inhibition of adenylate cyclase.
- ii. Glucose directly binds to adenylate cyclase and inhibits it.

- iii. Possibly transport of glucose or glucose like molecules in intact cell is important for inhibition of adenylate cyclase.

Statement	True	False
i.		
ii.		
iii.		

31.(4 points) Pulse-chase analysis is a method for examining any cellular process occurring over time by exposing (the pulse) the cells to radioactively labeled compound and then replacing the labeled compound with unlabelled one. Radioactively labeled leucine [ $^3\text{H}$ -leucine] is used to study the function of insulin synthesis of pancreatic  $\beta$  cells. Following results were obtained when  $\beta$  cells were exposed to  $^3\text{H}$ -leucine for 30 minutes and intermittently aliquoted. The four graphs obtained most likely indicate:



- a. I: Radioactivity due to insulin inside the Golgi.
- b. I: Extracellular radioactivity due to insulin.
- c. I: Radioactivity due to pro-insulin inside secretory vesicles.
- d. II: Cytoplasmic radioactivity due to pro-insulin.
- e. II: Radioactivity due to pro-insulin inside the Rough ER.
- f. III: Radioactivity due to insulin inside secretory vesicles.
- g. III: Radioactivity due to pro-insulin inside the Golgi apparatus.

- h. IV: Radioactivity due to C-peptide inside Golgi apparatus.
- i. IV: Radioactivity due to pro-insulin in Rough ER.

Choose from the options and fill in the blanks with the alphabet indicating the correct answer.

Graph I: \_\_\_\_\_

Graph II: \_\_\_\_\_

Graph III: \_\_\_\_\_

Graph IV: \_\_\_\_\_

32. (2 points) Transformation of bacteria is often used in recombinant DNA technology to introduce a plasmid into *E.coli* cell. Success of the process depends upon when each molecule of the recombinant plasmid is successful in transforming each bacterium. In an experiment  $1 \times 10^{-9}$ g of a 3000 bp plasmid was used to transform the *E.coli* cells. Consequently,  $1 \times 10^8$  transformed *E.coli* cells were obtained. Calculate the % efficiency of the transformation process. Consider that the molecular weight of 1bp = 660.

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

33. (2 points) Consider a mitochondrial DNA that has a molecular weight of  $9.9 \times 10^6$ . How many proteins with non-overlapping sequences would be coded by this genome? (Assume that all nucleotides would be coding.)

(Consider: average molecular weight of a protein to be 30,000; mean molecular weight of an amino acid residue to be 100; average molecular weight of a nucleotide to be 330).

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

34. (2 points) Given below are some details regarding the disease Phenylketonuria (PKU). The alleles P and Q code for different versions of the Phenylalanine Hydroxylase

(PAH) enzyme, whose function is to break down phenylalanine (Phe). High concentrations of phenylalanine result in Phenylketonuria.

Genotype	PAH activity	Concentration of Phe	PKU Disease
PP	100%	60 uM	No
PQ	30%	120 uM	No
QQ	0.3%	600 ~ 2400 uM	Yes

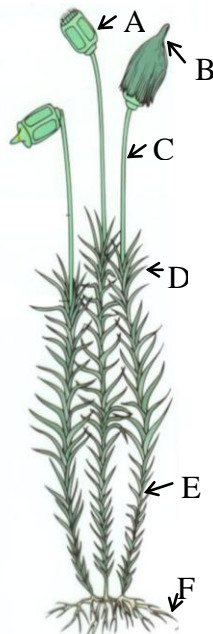
From the given information, which of the following statements about the alleles P and Q in terms of PAH activity is true? Put a tick mark (✓) in the appropriate box.

- a. P is dominant over Q.
- b. Q is dominant over P.
- c. P shows incomplete dominance over Q.
- d. Q shows incomplete dominance over P.

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

**PLANT SCIENCES (14 points)**

35.(4 points) The diagram below shows different parts of a moss (bryophyte). Different parts have been labeled from A to F.



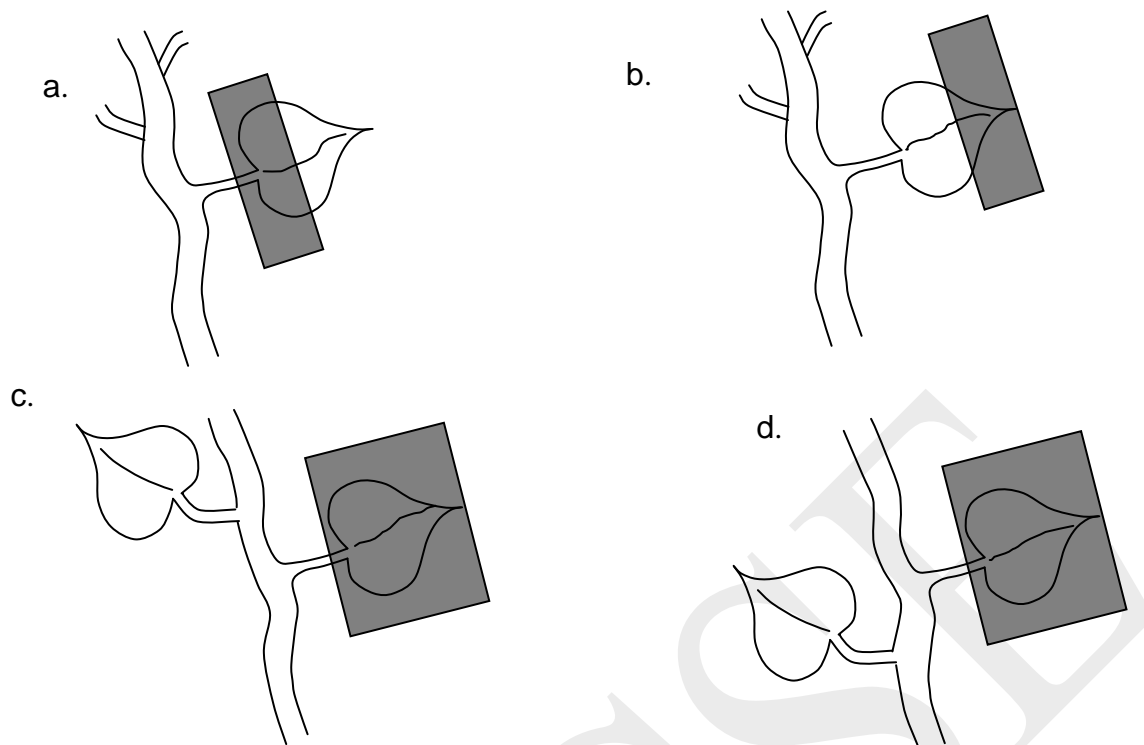
(A) Complete table 1 by indicating the ploidy levels of each of the plant parts A – F. (Only a fully correct row will be given marks).

Table 1	
Ploidy level	Plant parts
Haploid (n)	
Diploid (2n)	

(B) Analyze statements given in table 2 and state whether they are true or false by putting tick marks (✓) in the appropriate boxes.

Table 2			
Statement		True	False
I.	Parts A and D are photosynthetic.		
II.	Part F is unicellular and unbranched.		
III.	Part C shows the presence of stomata.		
IV.	Sexually reproducing structures are found in part A.		

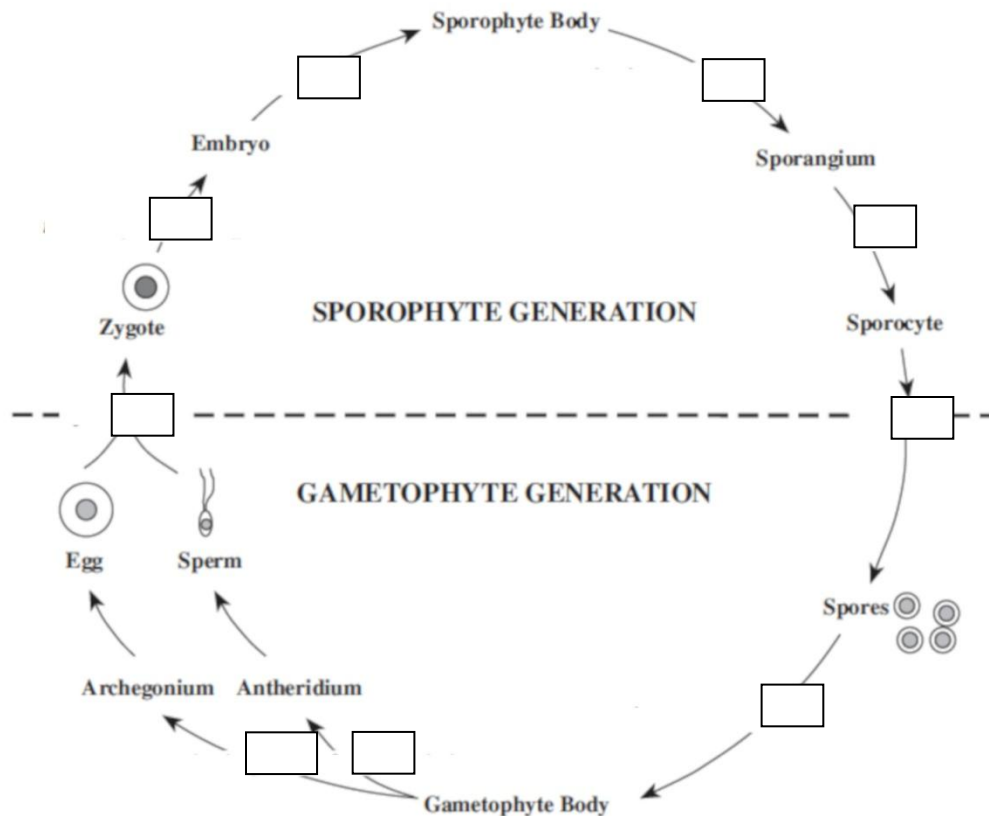
36. (2 points) Cocklebur is a short day plant with critical period of 15 hours. In these plants, leaves exposed to non-inducing photoperiod actively inhibit flowering while, leaves exposed to inducing photoperiod, synthesize flowering hormone which travels upwards towards the apex of the plant stem. In which of the following situations, will there be flowering? (Note that the black papers shown in the figures cover the leaves throughout the day.)



Put tick marks (✓) in the appropriate boxes.

Situations	Flowering will be observed	Flowering will not be observed
a.		
b.		
c.		
d.		

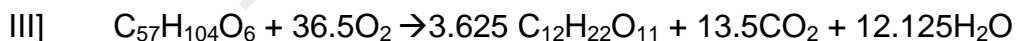
37. (3 points) The life cycle of plants is characterized by meiosis, mitosis and fertilization followed by growth and development at different stages. The following diagram depicts the haplodiplontic life-cycle typically found in pteridophytes. In the diagram place A for meiosis, B for mitosis and C for fertilization in the different boxes given below so as to depict the correct life cycle. (*Entirely correct answers in the sporophyte and gametophyte generation will be given 1.5 point each.*)



38. (3 points) Respiration in three types of plant tissues/parts are listed below:

- M. Respiration of growing leaf cells
- N. Respiration of mature lemon fruit
- O. Respiration of sprouting mustard seeds

Respiratory quotient (RQ) is defined as the ratio between  $\text{CO}_2$  release and  $\text{O}_2$  uptake measured at the same time. RQ can provide information on the nature of substrate used for respiration and relative rate of completing respiratory processes. This can be demonstrated by balanced equations. Three such equations are given below:



Match the different respiring plant tissues (M - O) to the appropriate respiratory Process/es (I - III).

M: \_\_\_\_\_

N: \_\_\_\_\_

O: \_\_\_\_\_



39. (2 points) In an experiment to study photosynthesis in spinach, following 4 sets were prepared.

**Set P:** Intact chloroplasts were separated from spinach leaves. Then the mixture of intact chloroplasts, NADP and ADP were exposed to light for some time. Then chlorophyll was selectively removed from the mixture and  $^{14}\text{CO}_2$  was introduced to the system in dark.

**Set Q:** It was exactly like set P but without addition of NADP and ADP.

**Set R:** Intact chloroplasts, NADP and ADP mixture was exposed to light with  $^{14}\text{CO}_2$  simultaneously.

**Set S:** Similar to set R but maintained in dark.

Match the following  $^{14}\text{CO}_2$  fixed (counts/min) to each of the above sets and fill in the blanks:

- i. 9000                      ii. 20, 000                      iii. 1,34,000                      iv. 2,00,000

Answer:

Set P: \_\_\_\_\_

Set Q: \_\_\_\_\_

Set R: \_\_\_\_\_

Set S: \_\_\_\_\_

**ANIMAL SCIENCES (9 points)**

40. (2 points) Biochemical changes that occur during hyperventilation and breath retention can be predicted. The levels of 4 parameters under normal condition are given. Indicate the changes that will occur during (i) hyperventilation and (ii) holding the breath by writing 'increase', 'decrease' or 'no change'.

*(Only an entirely correct row will be given points.)*

	pH	kPa pCO <sub>2</sub>	kPa pO <sub>2</sub>	mmol/L HCO <sub>3</sub> <sup>-</sup>
Normal	7.4	4.49	16.5	20.9
Hyperventilation				
Holding breath				

41.(2.5 points) *Cambarus aculabrum* is an obligatory cave dweller crayfish species. It shows several peculiar traits that have adaptive significance. Which of the following is/are likely to be observed in these animals? Put tick marks (✓) in the appropriate boxes.

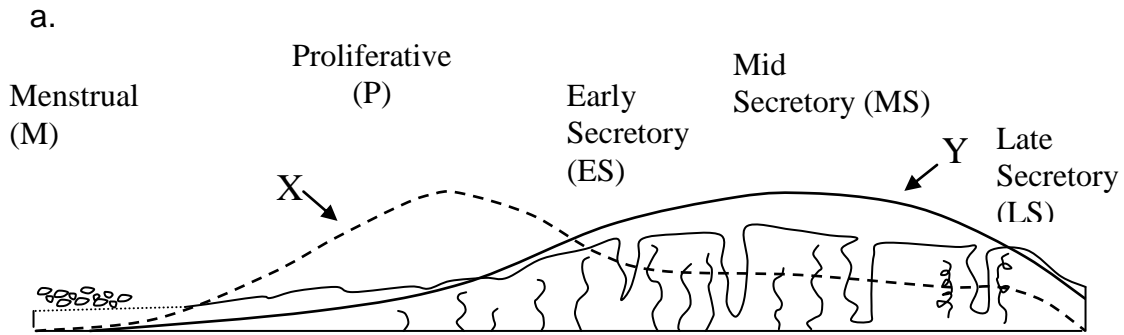
- i. Highly reduced body pigmentation.
- ii. Well-developed and enlarged eyes.
- iii. Highly developed sensory organs such as antennae.
- iv. Reduced ambulatory appendages.
- v. Lower rate of metabolism.

Traits	Likely to be observed	Not likely to be observed
i.		
ii.		
iii.		
iv.		
v.		

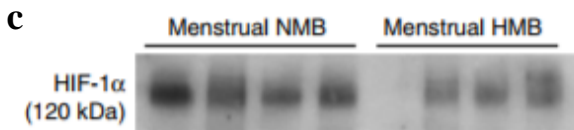
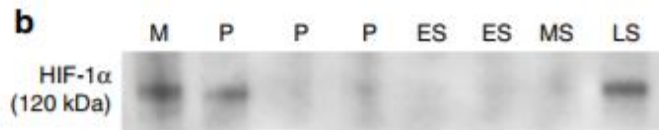
42.(2.5 points) Hormonal secretions bring about sequential changes in the female reproductive system. Menses refers to regression of corpus luteum, triggering an inflammatory response in the endometrium followed by bleeding. Possible role of hypoxia inducing factor (HIF) in the menstrual bleeding has been proposed for several years. In hypoxic conditions,  $\alpha$  subunit of this protein binds with  $\beta$ -subunit and induces transcription of growth factor that plays a role in the recovery of the injured tissue.

When oxygen is abundant,  $\alpha$  subunit of HIF-1 $\alpha$  is hydroxylated by propyl hydroxylase (PHD) enzyme. This triggers its rapid degradation by proteosome.

Pimonidazole is another endometrial tissue marker for hypoxia. When reduced, it can bind to cellular biomolecules such as proteins and can be detected. The human menstrual cycle is shown below.



In a study, the role of hypoxia and HIF levels were studied in females with normal menstrual bleeding (NMB) and heavy menstrual bleeding (HMB). Results of Western Blot are shown below.



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

- It is likely that hypoxia leads to vasoconstriction thus helping prevent blood loss from the site of injury.
- Graphs X and Y respectively refer to progesterone and oestrogen levels.
- Hypoxia is likely to be present during late secretory phase and menstrual phase.
- It is likely that in HMB females, PHD is upregulated.
- Endometrial tissues from NMB females are likely to show less staining with Pimonidazole as compared to HMB females.

Statement	True	False
a.		
b.		
c.		
d.		
e.		

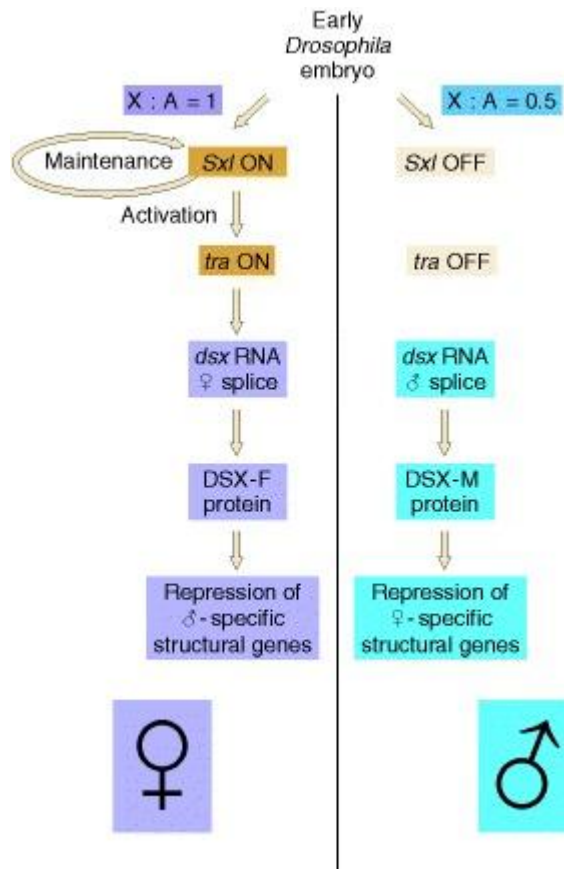
43. (2 points) Consider a hypothetical situation of a mammal on earth living in a CO<sub>2</sub> rich environment. It inspires CO<sub>2</sub> and expires O<sub>2</sub>. This animal has evolved respiratory pigment proteins P to carry CO<sub>2</sub> in the blood and Q to carry O<sub>2</sub> in the blood. Which of the following structural characteristics in the carrier protein is/are evolutionarily favourable? Put tick mark/s (✓) in the appropriate box/es.

- a. Affinity of P for CO<sub>2</sub> will decrease with increasing pH
- b. Affinity of Q for O<sub>2</sub> will increase with increasing pH
- c. Affinity of P for CO<sub>2</sub> will increase with increasing pH
- d. Affinity of Q for O<sub>2</sub> will decrease with increasing pH
- e. Affinity of P for CO<sub>2</sub> will decrease with decreasing pH
- f. Affinity of Q for O<sub>2</sub> will increase with decreasing pH

a.	b.	c.	d.	e.	f.

**GENETICS & EVOLUTION (15 points)**

44. (2.5 points) In *Drosophila*, sex determination is based on the ratio of X-chromosome to autosomal (X:A) ratio. Although, Y chromosome is not involved in determination of sex, it is essential for the process of spermatogenesis. The diagram below summarizes the molecular pathway of the process of sex determination in *Drosophila*.



The activation of *Sxl* gene is triggered by a protein dimer transcription factor known as NUM-NUM dimer. NUM protein monomer is transcribed by a X chromosome gene while a similar protein DEM is coded by an autosomal gene. NUM-DEM dimer or DEM-DEM dimer do not function as transcription factors.

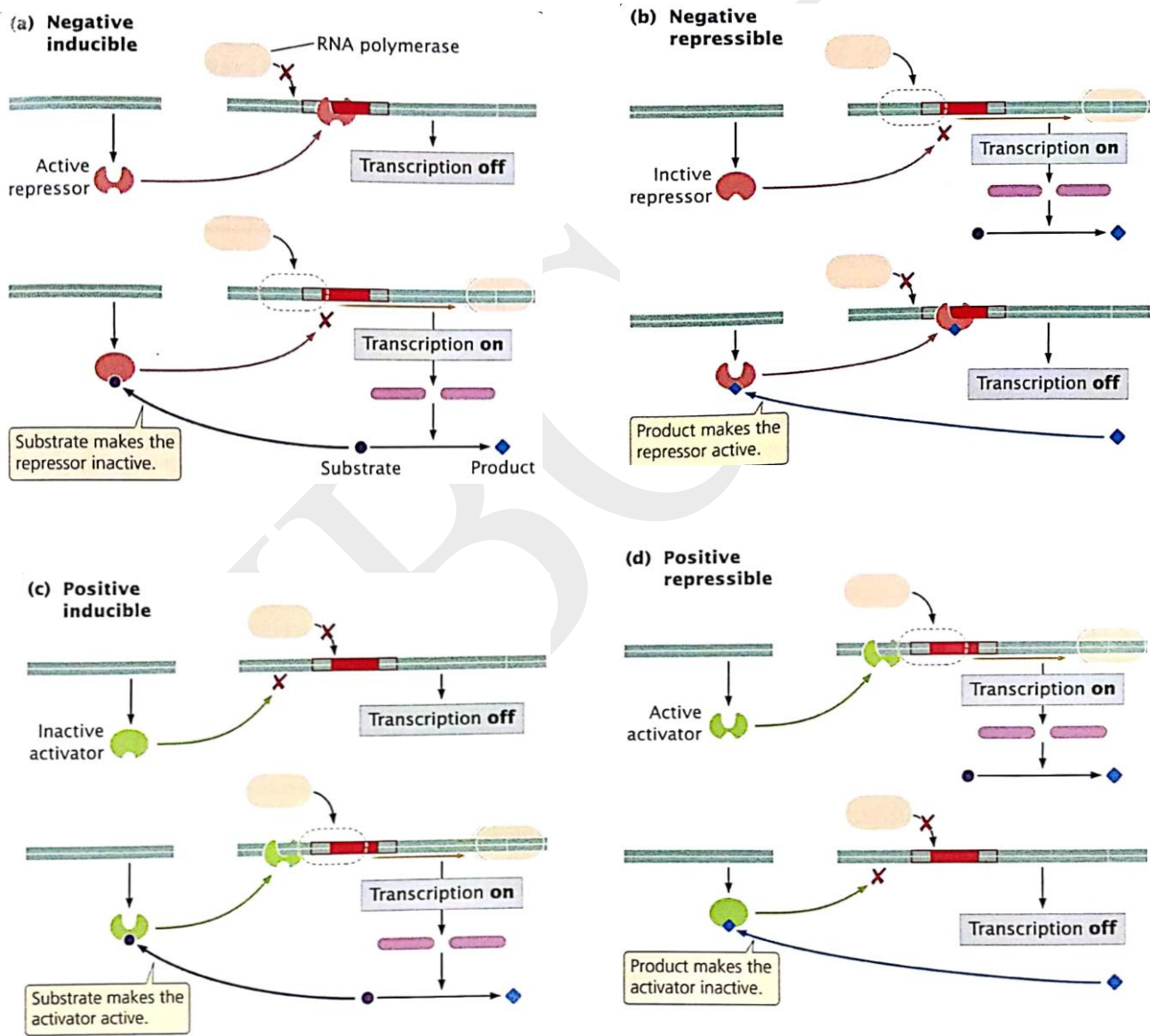
Based on the information, predict the sex and the fertility of the *Drosophila* embryos in the following conditions and put tick marks (✓) in the appropriate boxes in the table.

Sex chromosomes	Autosomes	Other Mutations	Sexual Phenotype			
			Fertile Female	Sterile Female	Fertile Male	Sterile Male
XX	AA	<i>tra</i> <sup>-</sup> / <i>tra</i> <sup>-</sup>				
XY	AA	Over expression of NUM protein monomer				
XO	AA	Over expression of DEM protein				
XY	AA	<i>tra</i> <sup>-</sup> / <i>tra</i> <sup>-</sup>				
XYY	AAA	Over expression of NUM protein monomer				

45. (4 points) There are four different ways operons could be regulated namely:

- a. Negative inducible (NI)
- b. Negative repressible (NR)
- c. Positive inducible (PI)
- d. Positive repressible (PR)

The diagram below summarizes these mechanisms. Identify the appropriate regulation mechanism/s that would be optimum for a bacterial cell to use in the situations described below and write down the correct alphabet/s in the blanks.



Situation 1: A molecule P can be synthesised by the cell but it prefers obtaining it from its environment if it is available.

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

Situation 2: A molecule when present in the environment can negatively affect the growth of the cell, but the cell can degrade it to harmless products by specialised enzymes.

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

Situation 3: A molecule is a by-product of an essential biochemical pathway, if it accumulates above permissible limit inside the cell it has negative effects on the growth of the cell.

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

Situation 4: A molecule only when produced in excess, needs to be converted into another molecule for future use.

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

46. (2 +1.5 +1 = 4.5 points) In an experiment, the following three strains of the same bacterial species were used:

Strain 1 is *phe*<sup>+</sup> *trp*<sup>+</sup> *met*<sup>-</sup> *his*<sup>-</sup>

Strain 2 is *phe*<sup>-</sup> *trp*<sup>-</sup> *met*<sup>+</sup> *his*<sup>+</sup>

Strain 3 is *phe*<sup>+</sup> *trp*<sup>+</sup> *met*<sup>+</sup> *his*<sup>+</sup>

These three strains were individually plated on two different sterile growth media P and Q.

P is a complete medium that contains all essential nutrients required for growth.

Q is a minimal media that contains only sugars (as carbon source) and minerals required for growth.

These plates were then incubated to check for growth.

(A) Indicate whether you will observe the bacterial growth in these media using symbols + and -. (Only an entirely correct row will be given points.)

Media	Strain 1	Strain 2	Strain 3
P			
Q			

In order to study whether gene transfer occurs between these bacteria, which of the following is the correct experimental set up? Put a tick mark (✓) in the appropriate box.

- Mix strains 1 and 2 and grow the cells in minimal media.
- Mix strains 2 and 3 and grow the cells in complete media.
- Mix strains 1 and 2 initially, then add strain 3 and grow the cells in complete media.
- Mix strains 1 and 3 and grow the cells in minimal media.

a.	b.	c.	d.

(B) Which of the following results will support the assumption that the gene transfer occurred? Put a tick mark (✓) in the appropriate box.

(Points will be awarded only if part A is correct.)

- Strain 1 became  $phe^+ trp^+ met^+ his^+$
- Strain 2 became  $phe^+ trp^+ met^+ his^+$
- Strain 3 became  $phe^- trp^- met^- his^-$
- Any of the strains became  $phe^- trp^- met^- his^-$

- i only
- ii only
- i or ii
- iii or iv

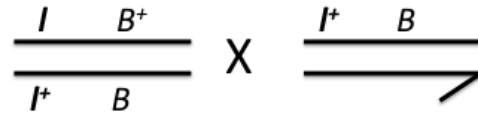
a.	b.	c.	d.

47. (2 points) The eye of a wild type *Drosophila melanogaster* has about 700 ommatidia giving it an oval shape. In Bar mutants (*B*) the number of ommatidia is reduced giving it a bean shape when heterozygous or a slit like structure when homozygous. The bar gene is X-linked. The mutant allele (*B*) is dominant over the wild type allele (*B*<sup>+</sup>).



*Drosophila* also has recessive alleles of genes (*l*) that cause lethality of the organism during early embryonic development. The normal allele of this gene is denoted as *l*<sup>+</sup>. In a stock of *Drosophila* one such allele is present on the X-chromosome and is 20cM away from the *bar* gene.

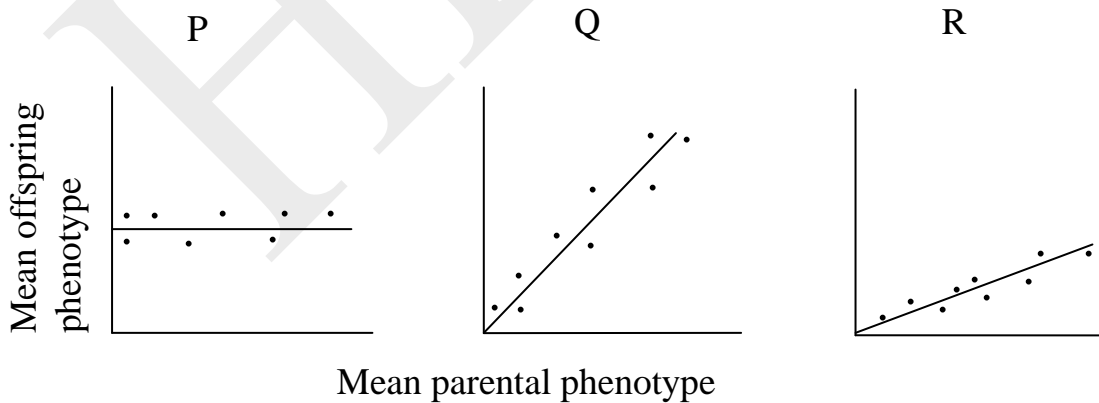
The following cross was carried out:



300 progeny were analyzed. Based on the information given above, calculate the expected number of progeny with different phenotypes and their sex and fill in the values in the boxes in the table.

	Bar eyed	Wild type
Males		
Females		

48. (2 points) Many of the traits observed in human populations are polygenic. Apart from being polygenic, they are frequently influenced by environmental factors. The proportion of total phenotypic variation that is due to genetic differences is known as heritability. This heritability can be estimated by comparing phenotypes of parents and offspring. Three situations are given below:



Arrange the graphs in the order of increasing environmental effect on offspring phenotype. (Only an entirely correct order will be given points.)

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

## **ECOLOGY (10.5 points)**

49.(2 points) Radioactive carbon  $^{14}\text{C}$  constitutes a very small proportion of total atmospheric  $\text{CO}_2$ . There is only about 1 radioactive carbon atom for every million stable  $^{12}\text{C}$  atoms in atmosphere. Knowing the half life of  $^{14}\text{C}$  to be 5600 years, what will be the expected ratio of  $^{14}\text{C}:^{12}\text{C}$  in the fossil skeleton that is 11,200 years old?

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

50.(2 points) Renewable energy is greener than fossil fuels. Nonetheless, it does have some impact on the ecosystem. In Western Ghats of India, several turbines are installed in order to harness wind energy. When scientists did the survey of the region after some years of installation, they found some changes in fan-throated lizards, a natural inhabitant. The males of this species possess a flap under the throat which becomes brightly coloured as they reach sexual maturity. They found that

- (i) these flaps were much less coloured now.
- (ii) the density of these lizards had increased in the area and
- (iii) these lizards showed reduced tendency to escape when they were approached.

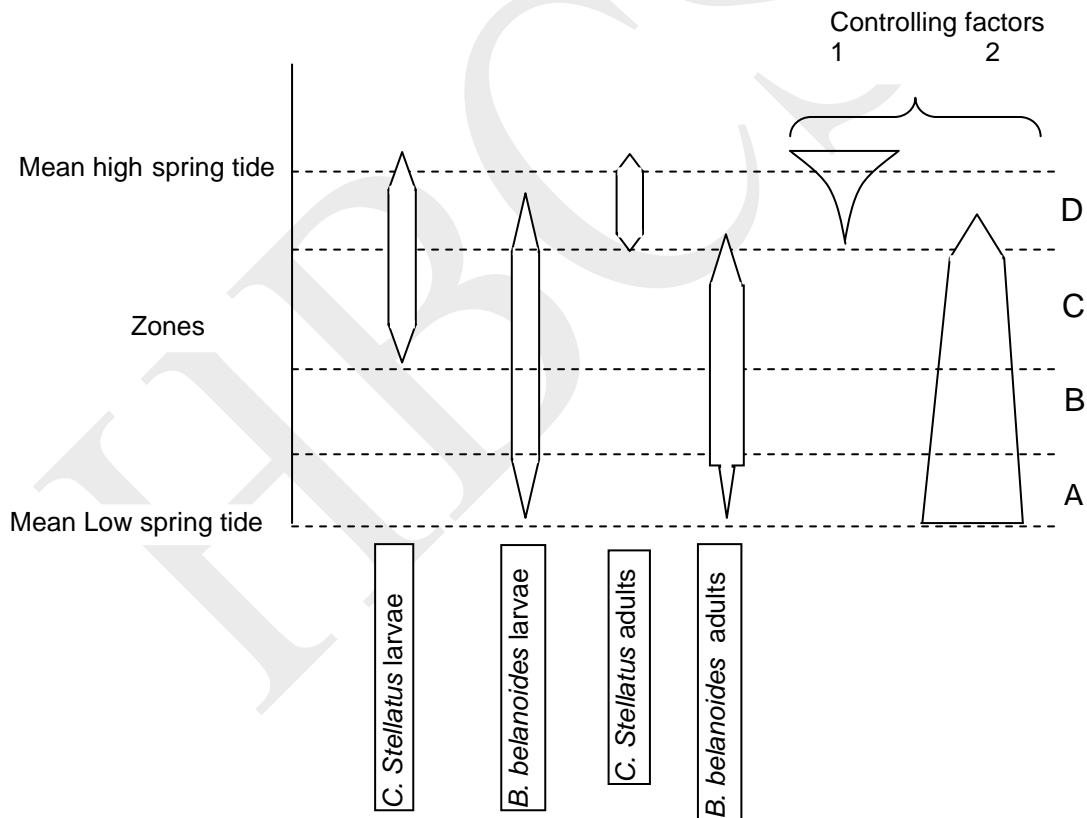
Indicate whether each of the following could be the cause or result of these findings.

Put tick marks (✓) in the appropriate boxes.

- a. Observation (i) and (ii) suggest that reduced colour of the flap may have helped lizards better camouflage with nature and hence increased their survival chances.
- b. Observation (iii) suggests that the new environment has reduced predator pressure on lizards.
- c. The reduced colouration [observation (i)] could be due to decrease in prey which had carotenoid-like pigments in their body.
- d. Observation (ii) clearly indicates that there is more abundant prey available in the habitat than before.

Statement	Cause/Result	Not a cause/result
a.		
b.		
c.		
d.		

51. (3 points) In order to understand interspecific relationships in different environments, a study on two barnacle species namely, *C. stellatus* and *B. balanoides* was conducted in the intertidal zone. The results are shown as kite diagram. The diagram indicate the zones occupied by barnacles of different stages as well as controlling factors acting on the two species.



Study the kite diagram and assign appropriate zone/s (A – D) to the following descriptions:

(Only an entirely correct answer to each description(I-VI) will be given points.)

I. Zone of competitive exclusion: \_\_\_\_\_

II. Realised niche of *B. balanoides*: \_\_\_\_\_

- III. Zone of highest interspecific competition: \_\_\_\_\_
- IV. Dessication as a major controlling factor: \_\_\_\_\_
- V. Predation selection pressure on *B. balanoides*: \_\_\_\_\_
- VI. Potential niche of *C. stellatus*: \_\_\_\_\_

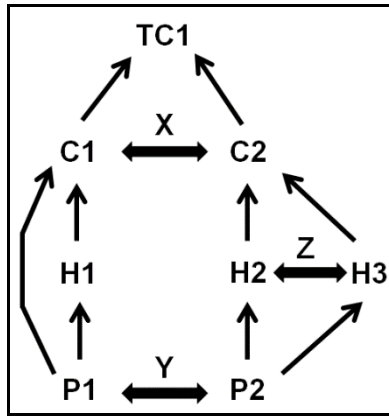
52. (1.5 points) The sac fungus *Cryphonectria endothia* can infect chestnut tree native to China. However, when it infects the tree, its growth is kept in check by a variety of natural factors. The same fungus infects another species of chestnut native to America, through the bores made by the birds and the mycelium grows, eventually encircling the trunk leading to death of the tree. If *Cryphonectria endothia* gets infected by a particular strain of virus, it regulates the fungus by altering its RNA content such that further damage to the chestnut tree is prevented. What kinds of interactions are taking place between the following species? Choose from the options below and fill in the blanks with the appropriate alphabet.

- i. *Cryphonectria endothia* and chestnut tree native to China: \_\_\_\_\_
- ii. *Cryphonectria endothia* and chestnut tree native to America: \_\_\_\_\_
- iii. *Cryphonectria endothia* and virus: \_\_\_\_\_

Options:

- a. Host-parasite interaction
- b. Host-pathogen interaction
- c. Commensalism
- d. Amensalism
- e. Mutualism

53. (2 points) In the following flow chart, the vertical interlinking of trophic levels is shown from Producers (P), Herbivores (H), Secondary Carnivores (C) and Tertiary Carnivore (TC). Within trophic levels, horizontal interactions are also seen which are marked here as X, Y and Z interactions.



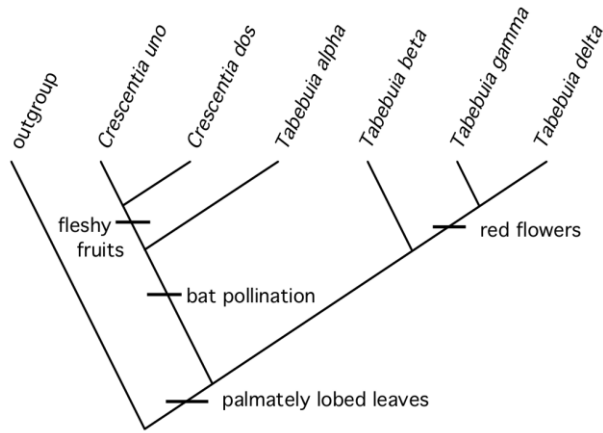
Indicate whether each of the following statements is correct or incorrect by putting tick marks (✓) in the appropriate boxes.

- a. Interaction X indicates interspecific competition between species primarily for resources.
- b. Interaction Y is a competition between two species within trophic level for space.
- c. The preference of C2 either for H2 or H3 will decide the type and extent of interaction Z between H2 and H3.
- d. In this food chain TC1 is a true carnivore while C1 and C2 are omnivores.

Statement	Correct	Incorrect
a.		
b.		
c.		
d.		

**BIOSYSTEMATICS (6 points)**

54.(2 points) *Bignoniaceae* is a family of flowering plants known for ornamental tubular flowers. Genus *Crescentia* and genus *Tabebuia* both belong to this family. Classification of plants of these two genera is shown below.

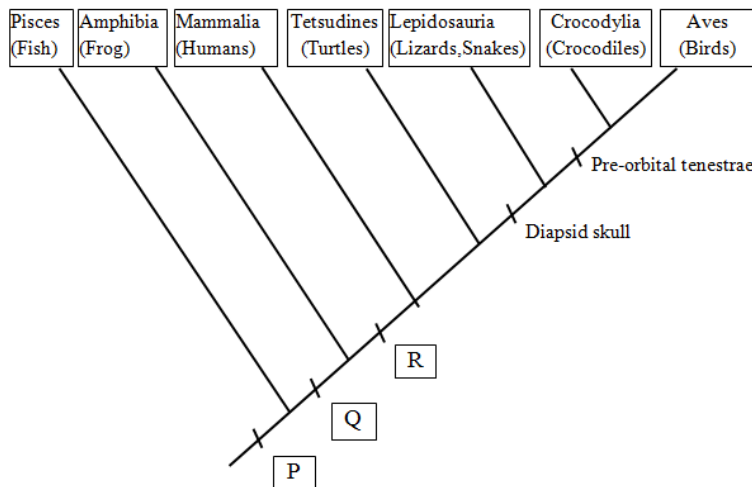


Indicate whether each of the following statements is true or false by putting tick marks (✓) in the appropriate boxes.

- a. All *Tabebuia* species are monophyletic.
- b. Bat pollination is a characteristic feature of only *Crescentia* species.
- c. Outgroup species would show either unlobed or compound leaves.
- d. *T. beta* is more closely related to *T. alpha* than to *T. delta*.

Statement	True	False
a.		
b.		
c.		
d.		

55. (2 points) Animal classification is shown in the form of a cladogram.



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

- a. Tetsudines, Lepidosauria and Crocodylia together form a monophyletic taxon 'Reptilia'.
- b. The homeotherms form a polyphyletic taxon.
- c. The trait 'Q' is most likely to be amniotic egg.
- d. The taxon that contains mammals, reptiles and birds along with their most recent common ancestor is a monophyletic clade.

Statement	True	False
a.		
b.		
c.		
d.		

56. (2 points) Given is a sketch of an organism that an archaeologist found.

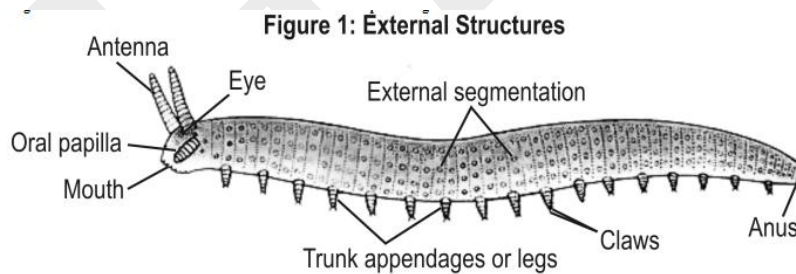
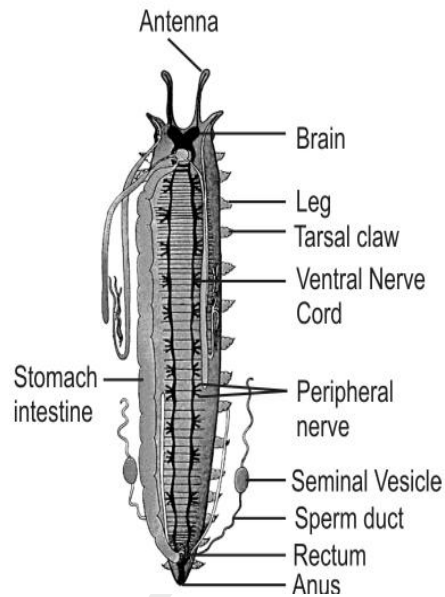


Figure 2: Internal Structures



The interpretation of its morphological and anatomical features is provided in the table below.

Phyla/Class	Worm-like body	Organ differentiation	External body segmentation	Nerve cord	External legs	Circulatory system	Vertebral column
Nematoda	Yes						
Annelida	Yes	Yes	Yes	Ventral			
Arthropoda		Yes		Ventral	Yes	Open	
Reptilia		Yes		Dorsal	Yes	Closed	Yes

This organism is likely to be a link between:

(Fill in the blanks with the correct Phyla/Class.)

Answer: Phyla/Class \_\_\_\_\_ and Phyla/Class \_\_\_\_\_.

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