

INSTRUCTIONS SHEET – INBO 2015

The question paper is divided into Section A and Section 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

- Section A consists of 30 questions carrying 1 point each.
- All 30 questions are of multiple choice type, with only one correct answer for each question.
- Mark the correct answer with '✓' on 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 28 questions with a total of 70 points.
- The points for the questions in Section B vary depending on the number of answers and the complexity of the question. These points have been indicated along with the question.
- Contradictory answers will not be considered for marking.

SCORING KEY

NO. OF CORRECT ANSWERS: X

NO. OF INCORRECT ANSWERS: Y

SCORE INBO (THEORY): SECTION A: 3X – Y

SECTION B: 3X

INDIAN NATIONAL BIOLOGY OLYMPIAD – 2015

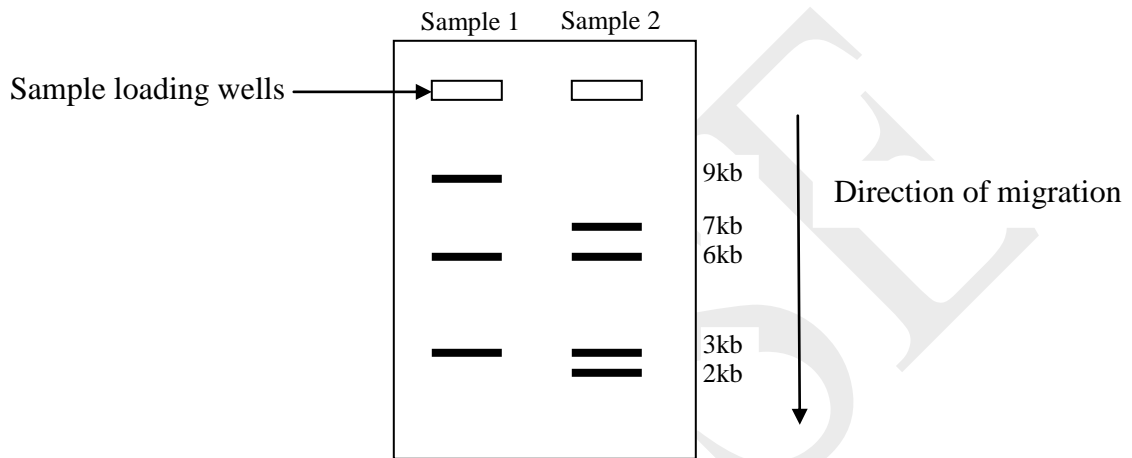
SECTION A

CELL BIOLOGY (7 points)

1. (1 point) A highly reductionist attribute of a living system is observed in self-replicating molecules. Autocatalytic RNA is the best example of this. However, if a biological system in the form of primordial cell has to be designed from chemical system, in addition to self-replicating molecules, it requires energy capturing and generating systems as well. Which of the following components would be the most important in organizing a self-propagating biological system?
 - a. Enzymes
 - b. Plasma Membrane
 - c. Mitochondria
 - d. Chloroplasts

2. (1 point) Yeast artificial chromosomes (YACs) are genetically engineered chromosomes derived from the DNA of yeast, *Saccharomyces cerevisiae*. YACs are used as cloning vectors to transfer large fragments of DNA. Which of the following is/are essential to generate a yeast artificial chromosome (YAC) vector?
 - I. Telomeric sequences
 - II. Centromeric sequences
 - III. Autonomously replicating sequences
 - a. III only
 - b. I and III only
 - c. II and III only
 - d. I, II and III

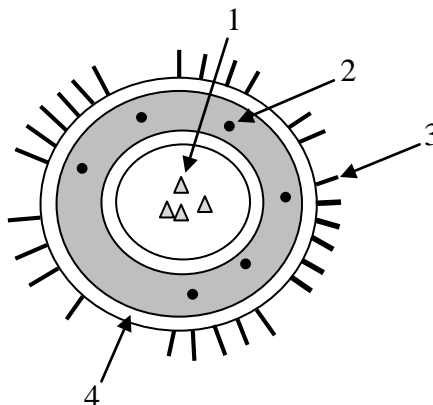
3. (1 point) Restriction endonucleases are enzymes which cut DNA at specific sequences. Two samples of DNA (sample 1 and sample 2) of 18kb each were cut using three different restriction enzymes simultaneously. When the digested samples were run on agarose gel, the following pattern was obtained. Note that each DNA sample has one recognition sequence for each of the three enzymes.



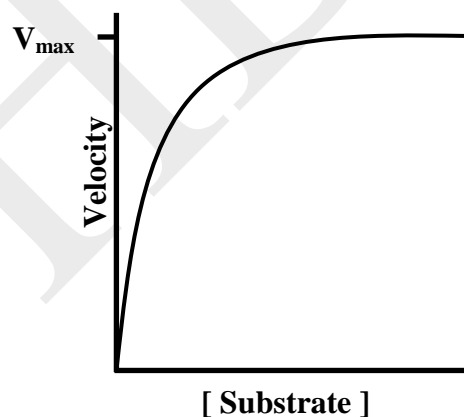
Which of the following could explain the results?

- The concentration of sample 1 used is more than the concentration of sample 2.
- Sample 2 seems to be contaminated with DNA from sample 1.
- The sample 2 was loaded much later than sample 1.
- Sample 1 is circular DNA while sample 2 is a linear piece of DNA.

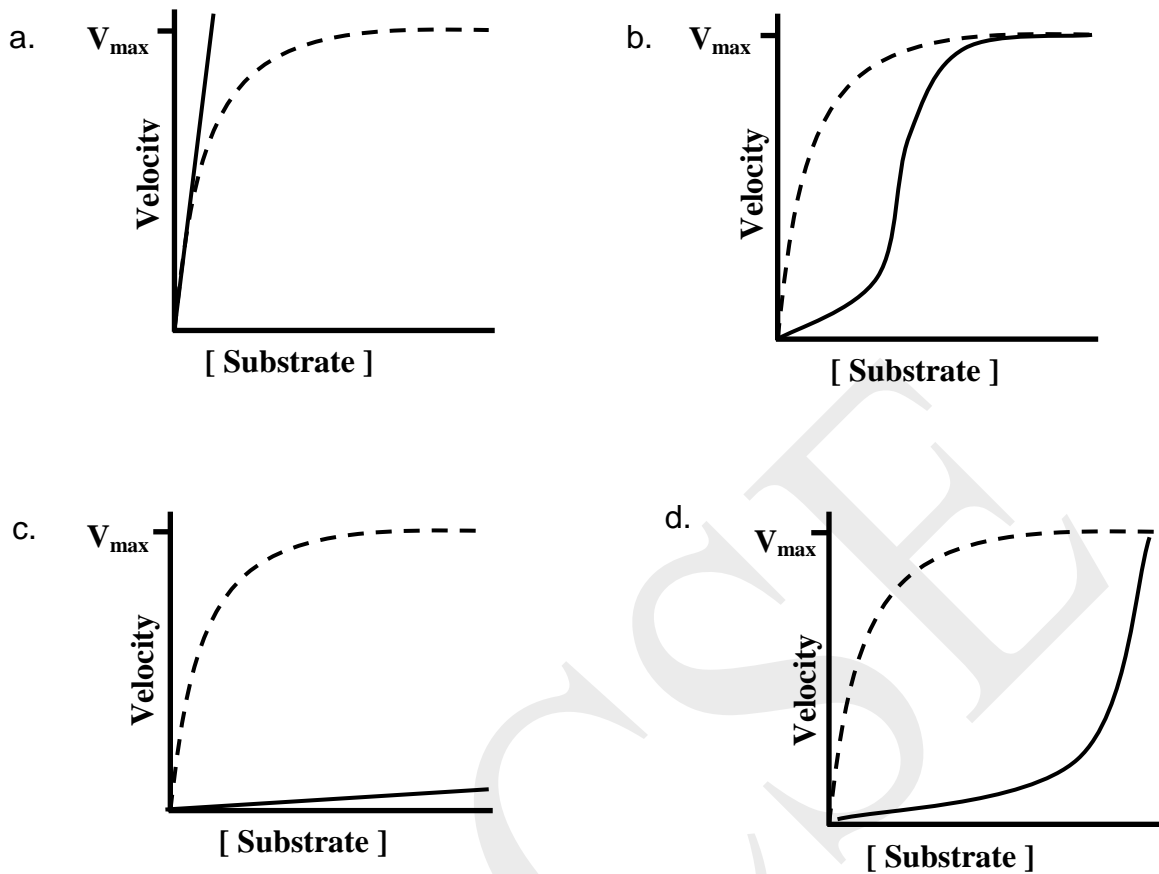
4. (1 point) Liposomes are vesicles used to entrap drugs for targeted delivery to specific organs. Following is a schematic representation of a liposome. 1, 2, 3 and 4 would be:



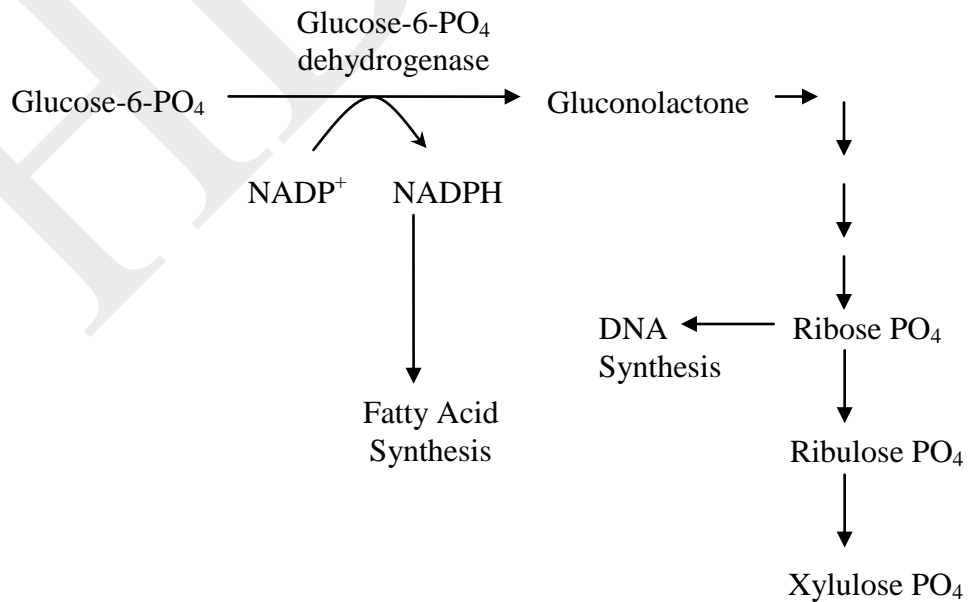
- a. 1: Water soluble drug
2: Water insoluble drug
3: Homing peptide
4: Polar head of lipid
 - b. 1: Hydrophobic drug
2: Hydrophilic drug
3: Water soluble drug
4: Protein coat
 - c. 1: Homing peptide
2: Hydrophobic drug
3: Hydrophilic proteins
4: Polar head groups of proteins
 - d. 1: Hydrophobic drug
2: Phospholipids
3: Hydrophilic drug
4: Hydrophilic proteins
5. (1 point) A typical graph obtained for an enzyme catalyzed reaction that takes place in a human body is shown below.



Which of the following correctly represents the same reaction in which no enzyme is used? Broken line represents the enzyme catalyzed reaction for comparison.



6. (1 point) In addition to glycolysis, there also exists another “glucose direct oxidation” pathway in the cell cytoplasm. This pathway is depicted below.



Enzymes of this pathway will be found abundantly in:

- i. Bone marrow cells
 - ii. Liver cells
 - iii. Adipose tissue
 - iv. Skeletal muscles
- a. i and iii only
 - b. iii and iv only
 - c. i, ii and iii only
 - d. ii and iv only
7. (1 point) Red blood cells also possess the same pathway that is shown in Question no. 6. What is the role of this pathway in these cells?
- i. To provide pentose sugars required for nucleic acid synthesis.
 - ii. To provide reducing equivalents required for fat synthesis.
 - iii. To provide extra energy by direct glucose oxidation.
 - iv. To generate NADPH that can provide protection against reactive oxygen species.
- a. i and iv only
 - b. iii and iv only
 - c. i, ii and iii only
 - d. iv only

PLANT SCIENCES (5 points)

8. (1 point) The ABC model postulates that the organ identity in each whorl of a flower is determined by the combination of the following five genes:
- Apetala 1 (AP1)
Apetala 2 (AP2)
Apetala 3 (AP3)

Pistillata (PI)

Agamous (AG)

The table below indicates the normal expression pattern of these genes in the whorls of a wild flower. As shown in the table, the expression of AP1 or AP2 in a whorl leads to the suppression of AG in that same whorl and vice versa.

AP1 or AP2 (A)		AG (C)	
Sepals	Petals	Stamens	Carpels
1	2	3	4
Outermost whorl			Innermost whorl

Which of the following patterns will develop (from outermost whorl to the innermost whorl) if only the activity of genes AP3 and PI is lost?

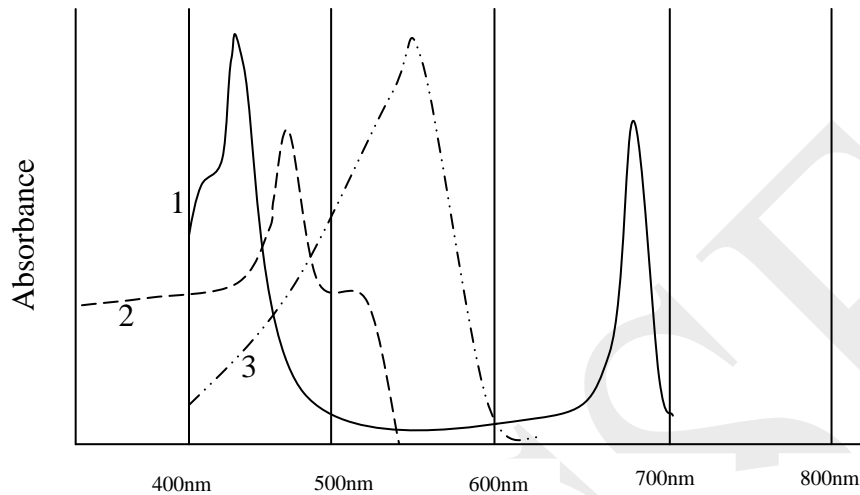
- Sepals, Petals, Petals, Carpels
 - Sepals, Stamens, Stamens, Carpels
 - Sepals, Sepals, Carpels, Carpels
 - Sepals, Sepals, Petals, Carpels
9. (1 point) With reference to the table in the previous question (Question no. 8), which of the following patterns will develop (from outermost whorl to the innermost whorl) if only the activity of genes AP1 and AP2 is lost?
- Petals, Petals, Stamens, Carpels
 - Carpels, Stamens, Stamens, Carpels
 - Petals, Stamens, Stamens, Carpels
 - Stamens, Stamens, Carpels, Carpels
10. (1 point) A CAM plant was supplied with $^{14}\text{CO}_2$ in the evening at 7 pm and the radiolabeled carbon (^{14}C) was monitored over time. The correct pathway followed by the ^{14}C will be:

- a. During night: oxaloacetic acid_(cytosol) → oxaloacetic acid_(vacuole) → malate_(vacuole)
 During day: malate_(cytosol) → CO₂_(cytosol) → carbohydrates_(chloroplast)
- b. During night: oxaloacetic acid_(cytosol) → malate_(cytosol) → malic acid_(vacuole)
 During day: malate_(cytosol) → CO₂_(chloroplast) → Calvin cycle intermediates_(chloroplast) → carbohydrates_(chloroplast)
- c. During night: oxaloacetic acid_(cytosol) → malic acid_(chloroplast)
 During day: CO₂_(cytosol) → Calvin cycle intermediates_(chloroplast) → carbohydrates_(chloroplast)
- d. During night: oxaloacetic acid_(cytosol) → oxaloacetic acid_(vacuole)
 During day: malate_(cytosol) → Calvin cycle intermediates_(chloroplast) → carbohydrates_(chloroplast)

11. (1 point) Assuming that the number of chromosomes in the endosperm of a gymnosperm is 80, the number of chromosomes before and immediately after fertilization in each of the following structures will be:

	Structures	Before fertilization	After fertilization
a.	Integument	80	160
	Cells of archegonia	80	80
	Nucellus	160	160
b.	Integument	80	80
	Cells of archegonia	40	40
	Nucellus	80	80
c.	Integument	80	80
	Cells of archegonia	40	40
	Nucellus	40	120
d.	Integument	160	160
	Cells of archegonia	80	80
	Nucellus	160	160

12. (1 point) Absorption spectra of some photosynthetic pigments are given below. These pigments show specific absorption patterns in a spectrum. Identify pigments 1, 2 and 3.



- a. 1: Chlorophyll a 2: Phycobilin 3: Carotene
 b. 1: Chlorophyll a 2: Carotene 3: Phycoerythrin
 c. 1: Carotene 2: Chlorophyll a 3: Phycoerythrin
 d. 1: Phycoerythrin 2: Carotene 3: Chlorophyll a

ANIMAL SCIENCES (7 points)

13. (1 point) Characters like enlarged paws of forelimbs, reduced eyes and thickened skin protecting tapered nose are shared between the North American mole (eutherian) and the Australian mole (marsupial). This is explained by:

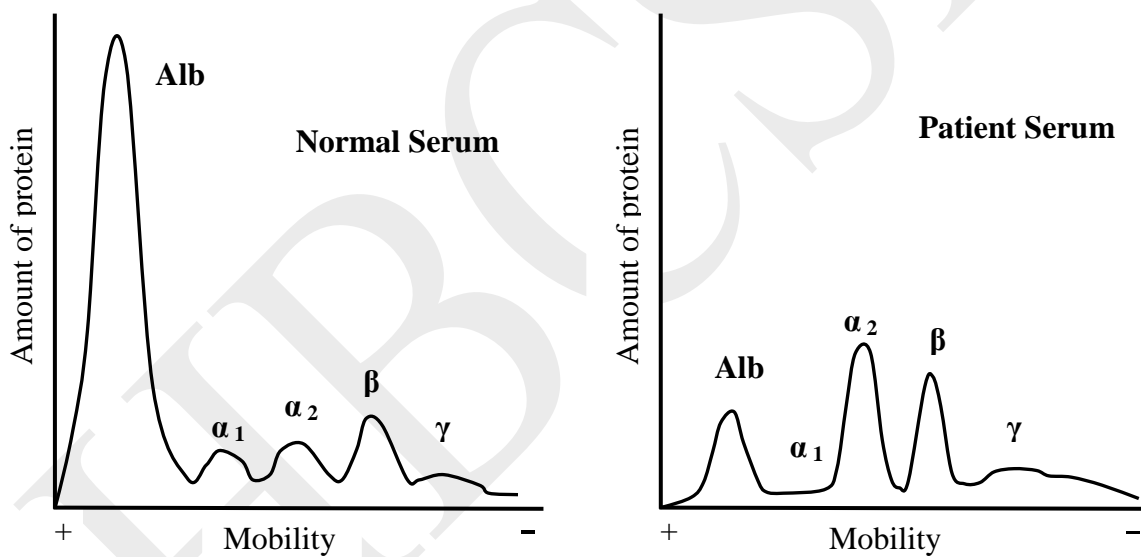
- a. Reproductive isolation
 b. Convergent evolution
 c. Genetic drift
 d. Co-evolution

14. (1 point) The long up-curved tusks of wild boar serve the purpose of:

- i. Digging out tubers

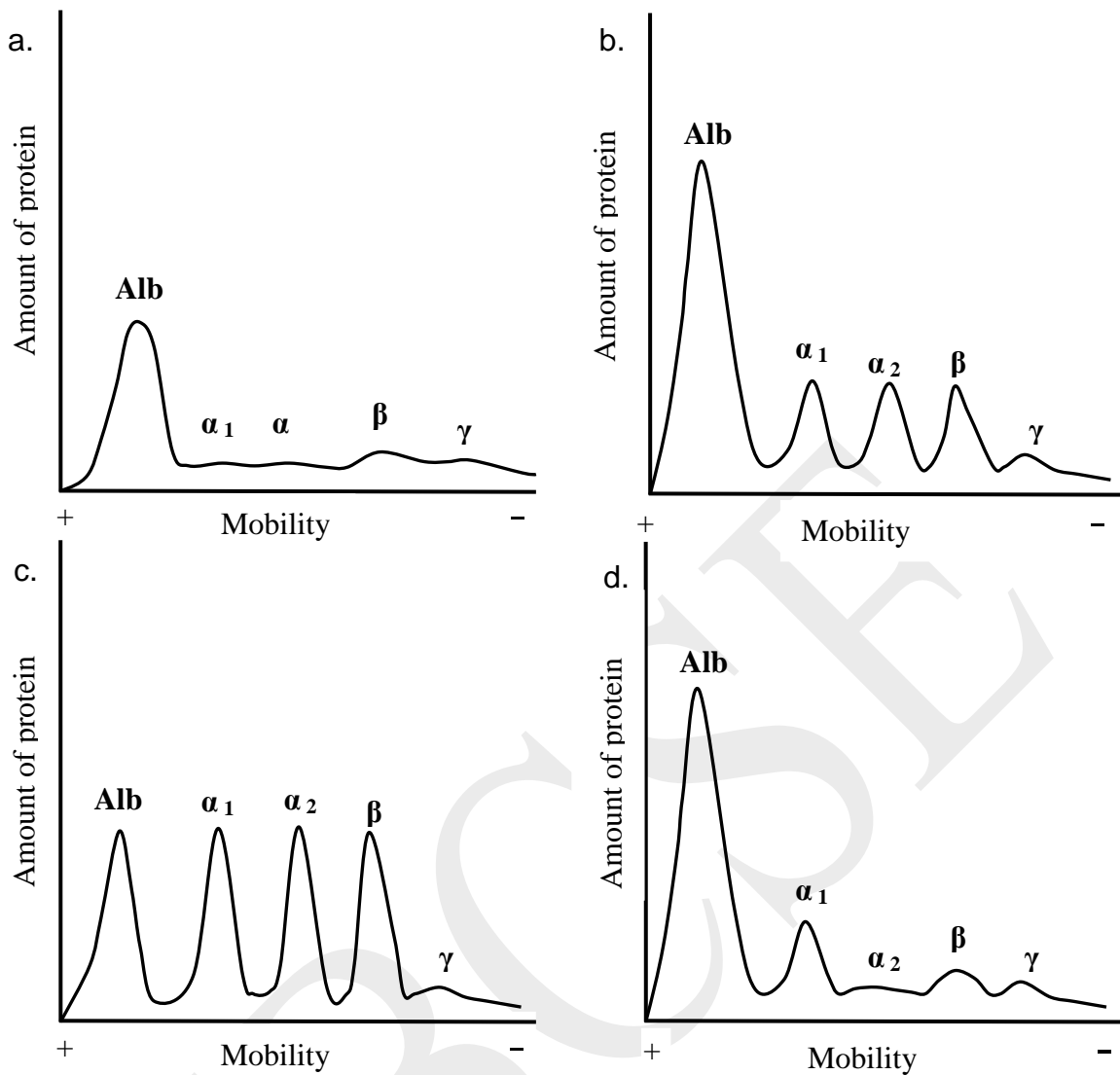
- ii. Piercing the body of prey
 - iii. Defence
 - iv. Intimidating rival males
- a. i, ii and iii
 - b. ii, iii and iv
 - c. i, iii and iv
 - d. only i and iii

15.(1 point) The electrophoretic patterns of serum proteins from a healthy individual and a patient with advanced nephrosis are shown below.



(Alb: albumin, α_1 , α_2 , β and γ are types of globulins)

Choose the graph that corresponds to the urinary protein profile of the patient.



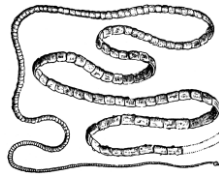
16. (1 point) A digestive system comprising solely of mouth, oesophagus, intestine and anus is found in:

- a. a nematode
- b. a snail
- c. an insect
- d. an earthworm

17. (1 point) Protostomes and deuterostomes are taxonomically best distinguished based on:

- a. body symmetry
- b. embryonic development pattern
- c. segmentation pattern
- d. presence or absence of coelom

18. (1 point) The figures depict representative illustrations of three categories of animals with segmented bodies.



A : Tapeworm



B: Nereid worm



C: Centipede

Which of these animal/s show metameric segmentation?

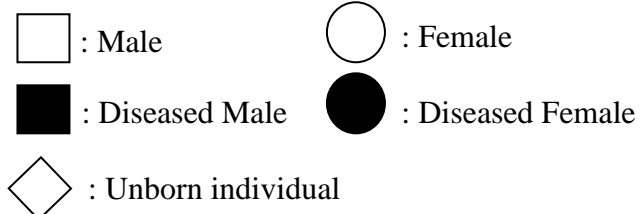
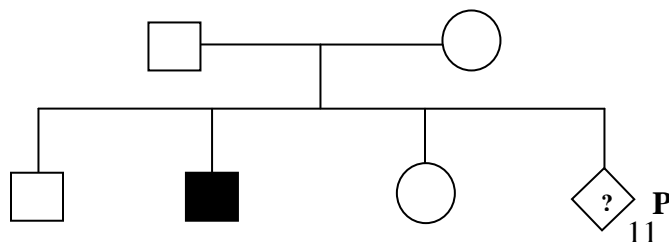
- B only
- A and B
- B and C
- A and C

19. (1 point) With reference to the previous question (Question no. 18), which of the following statements are true?

- Metameric design involves segments possessing elements of the excretory, nervous and circulatory systems.
 - Metameric design is possible in radially symmetrical animals.
 - Metameric design is determined by the mode of respiration and circulation in the animal.
 - Metameric design makes every segment indispensable for survival.
- i and ii
 - ii, iii and iv
 - i and iv
 - ii and iii only

GENETICS & EVOLUTION (4 points)

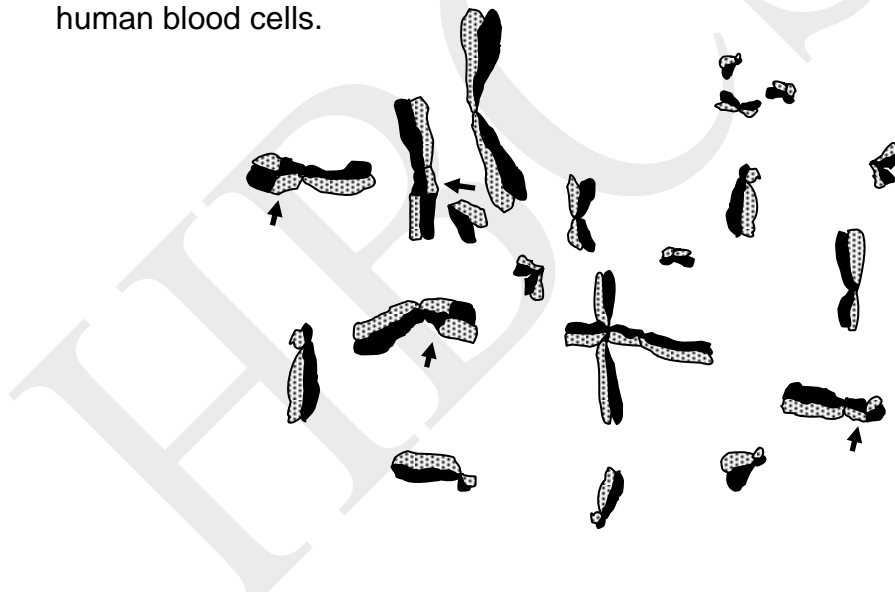
20. (1 point) Study the following pedigree.



Mark the correct interpretation.

- a. If the pedigree depicts autosomal recessive trait, then the probability of child 'P' to be diseased is $\frac{1}{2}$.
- b. If the pedigree depicts X-linked recessive trait, then the probability of child 'P' to be diseased is $\frac{1}{4}$.
- c. If the pedigree depicts sex-linked trait, then there is a 50% chance that individual 'P' will be normal.
- d. The pedigree depicts X-linked dominant trait and the individual 'P' will be normal if female.

21.(1 point) Dividing chromosomes can be labeled with a thymine analogue, bromodeoxy-uridine. After differential staining, the chromosomes can be seen as darkly stained (old) strands and lightly stained (new) strands. The following chromosomes were observed and photographed while studying division of human blood cells.



From the picture, which of the following can be deduced?

- I. The chromosomes belong to metaphase stage.
- II. The cell division was taking place in mature red blood cells.
- III. Parts of the chromatids were exchanged by crossing over.
- IV. The different colours of the two sister chromatids confirm that DNA replication is semi-conservative.

Options:

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

22. (1 point) Two different mutant flies of *Drosophila melanogaster* were discovered during a mutagenesis experiment.

In case of the first mutation, when an affected male was crossed with an affected female, 40 normal and 80 affected flies were obtained.

In case of the second mutation, when a normal male was crossed with a normal female, 120 normal and 40 affected files were obtained.

Which of the following can be deduced from these observations?

- I. The first mutation was dominant.
- II. The second mutation was dominant.
- III. In case of the first mutation, the homozygous mutants did not survive.
- IV. In case of the second mutation, if a homozygous normal male was crossed with an affected female then all the progeny would be normal.

Options:

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

23. (1 point) Three genes 'a', 'b' and 'c' are located on the same chromosome. The distance between 'a' and 'b' was 20 mu, 'b' and 'c' was 10 mu while 'a' and 'c' was 30 mu.

In one member of a population, it was noticed that the expression of gene 'b' was missing. When the map distance between 'a' and 'c' was calculated, it still showed 30 mu.

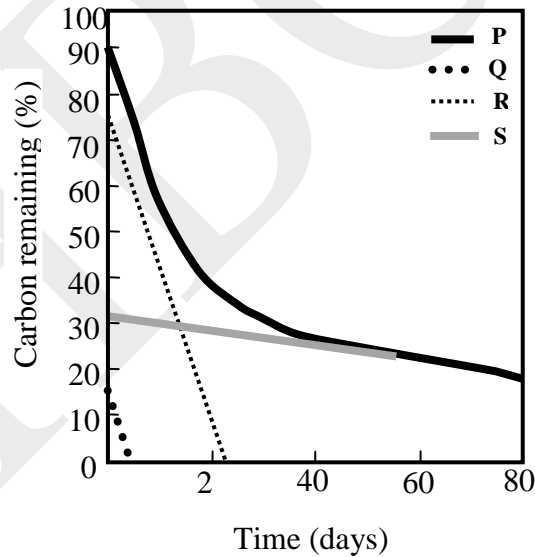
Choose the probable explanations.

- I. The gene 'b' had a point mutation.
- II. The gene 'b' was silenced epigenetically.
- III. Segmental inversion occurred in the gene 'b'.
- IV. The gene 'b' was replaced by another DNA segment of the same size.

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

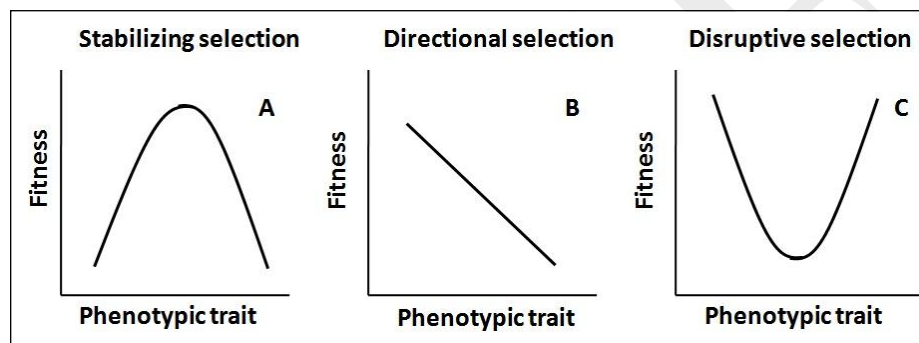
ECOLOGY (4 points)

24. (1 point) The following graph depicts the rates of decay (mass loss) of different classes of carbon present in hay that was left to decompose on the soil surface. Based on the information given, P, Q, R and S most likely are:

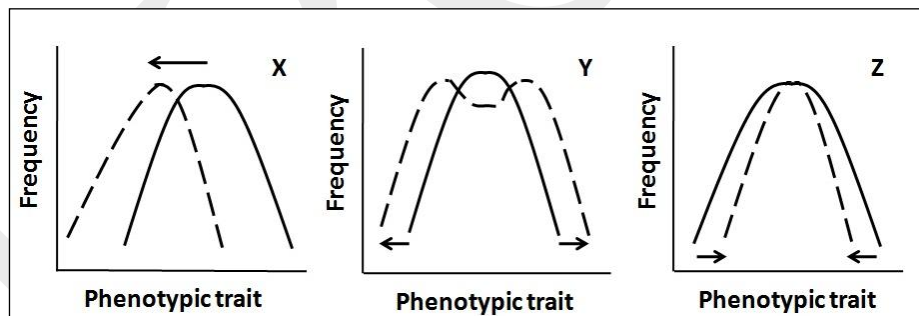


- a. P: Cellulose and hemicellulose, Q: Proteins, R: Organic carbon, S: Lignin
- b. P: Lignin, Q: Cellulose, R: Pectin, S: Starch
- c. P: Total organic carbon, Q: Proteins, R: Cellulose, S: Lignin
- d. P: Lignin, Q: Nucleic acids, R: Proteins, S: Cellulose

25. (1 point) Which of the following is referred to as “chemosynthesis-powered” ecosystem?
- Grassland ecosystem
 - Deep sea ecosystem
 - Inter-tidal ecosystem
 - Forest ecosystem
26. (1 point) Natural selection can act on characters with quantitative variations in ways as depicted in A, B and C.



This can lead to the results depicted in the graphs X, Y and Z.

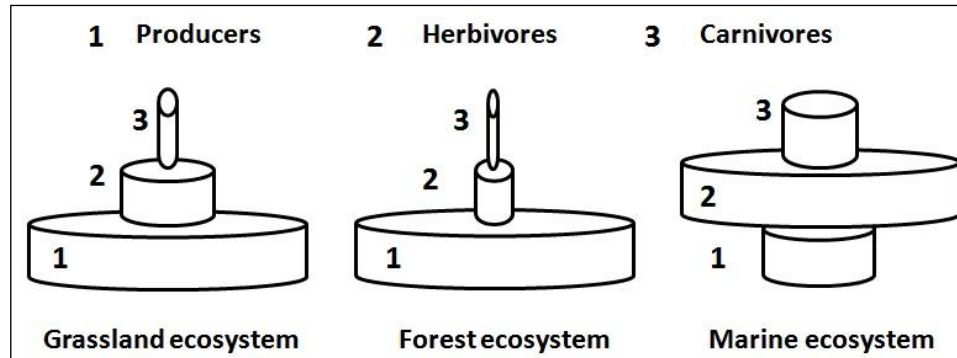


The bold lines show the distribution of phenotypes in the population before and the broken lines show the effect of the selection.

The changes in the phenotypic traits observed in X, Y, Z are respectively due to:

- A, B and C
- C, A and B
- B, C and A
- C, B and A

27. (1 point) Typical pyramids of biomass (g/m^2) of three different ecosystems are shown below.



In a marine ecosystem, an inverted pyramid is observed. The possible reason for this is:

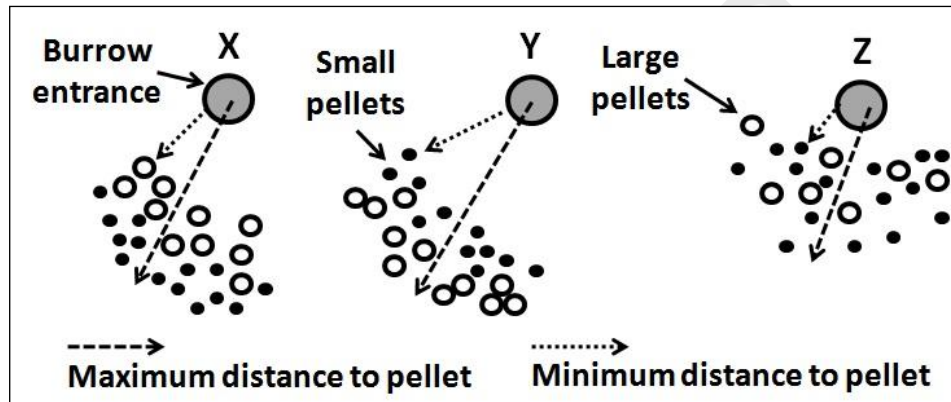
- The dominant producers in a marine ecosystem are bacteria and protists which divide rapidly to generate sufficient biomass to support herbivores.
- In a marine ecosystem, the plants are represented by algae in the inter-tidal area which constitute less biomass compared to the other trophic levels.
- Unlike terrestrial ecosystems where carnivores regulate the population of herbivores resulting in higher producer biomass, there is no predatory control in a marine ecosystem.
- In a marine ecosystem, the herbivore population is very high hence the producer biomass remains low.

ETHOLOGY (2 points)

28. (1 point) Fiddler crabs are semi-terrestrial animals found on sea shores. The crabs pick up chunks of sediment from the ground with the help of their claws. They sift and eat the edible portions from this. Once all the nutrients have been removed from the sediment, they deposit it as small balls outside their burrow.

They then spread the burrowing pellets of different sizes at variable distances from the burrow entrance. This is used as a reproductive dominance strategy for mate selection.

The following diagram shows three such burrows of the same depth and disposition of small and large pellets by crabs X, Y and Z.



Which of the following statements is likely to best explain female mate choice among the three crabs X, Y and Z?

- Female would choose crab "Y" because disposition of large pellets farther from the burrow and put in clumps indicates a male with greater strength.
- Female would choose crab "X" because disposition of more number of smaller pellets farther from the burrow may indicate an active male.
- Female would choose crab "Z" because disposition of mixed pellets randomly makes visual interaction with the male possible and hence chances of better mate selection.
- Female would be equally attracted to X or Y but not to Z since the minimum and maximum distance to pellets are lesser in Z as compared to that in X or Y.

29. (1 point) The Eastern Phoebe is a medium-sized flycatcher song bird. There are two different song forms which the adult males regularly sing. Males use these vocalizations to announce territory, but more often to attract a mate.

These birds produce specific complex songs without learning. A few statements regarding song formation in these birds are made.

- i. If the bird is deafened in its early life, it will not be able to produce the final complex song accurately.
- ii. If the bird is reared in isolation, it will still be able to produce a mature song.
- iii. In a stable environment, non-learners such as Eastern Phoebe will have a selective advantage over learners since the process of learning is an energy demanding one.

The correct statement/s is/are:

- a. i and iii
- b. Only ii
- c. Only iii
- d. ii and iii

BIOSYSTEMATICS (1 point)

30. (1 point) Among the following components required to construct a phylogenetic tree, which one needs to be determined first?

- a. Polyphyletic status
- b. Derived character state
- c. Outgroup member
- d. Ancestral character state

***** 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 (11 points)

31. (2 points) For organisms P, Q, R and S, key features along with their habitats and number of genes they possess are given in the table.

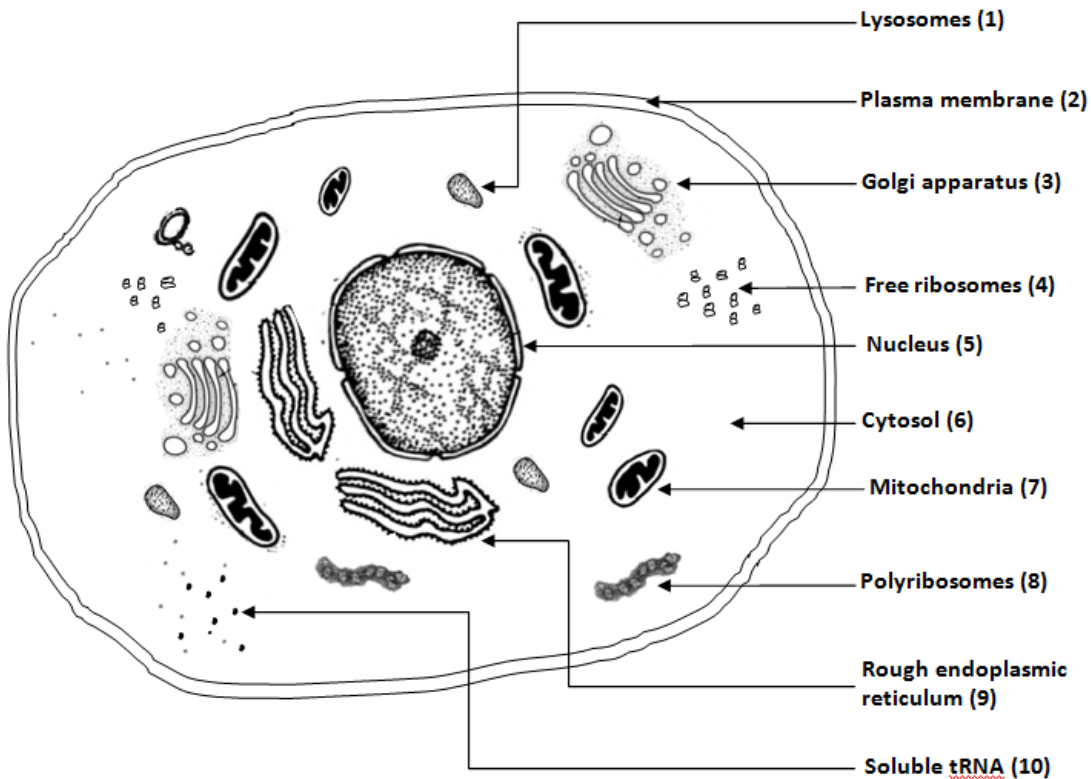
Organism	Key feature 1	Habitat 2	No. of genes 3
P	Organotrophic	Human genital tract	468
Q	Lithotrophic	Hydrothermal vent	1544
R	Aerobic	Volcanic region	2620
S	Aerobic heterotrophic	Soil	19000

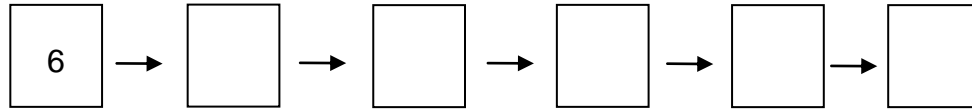
Indicate whether each of the following statements is true or false by putting tick marks (✓) in the appropriate boxes.

- A. Organism P cannot be a eubacterium owing to its habitat and small number of genes.
- B. Organism S can be either a prokaryote or eukaryote.
- C. Organism R is most likely to be archaebacterium due to feature 2.
- D. Organism Q can only be eubacterium owing to features 1 and 2.

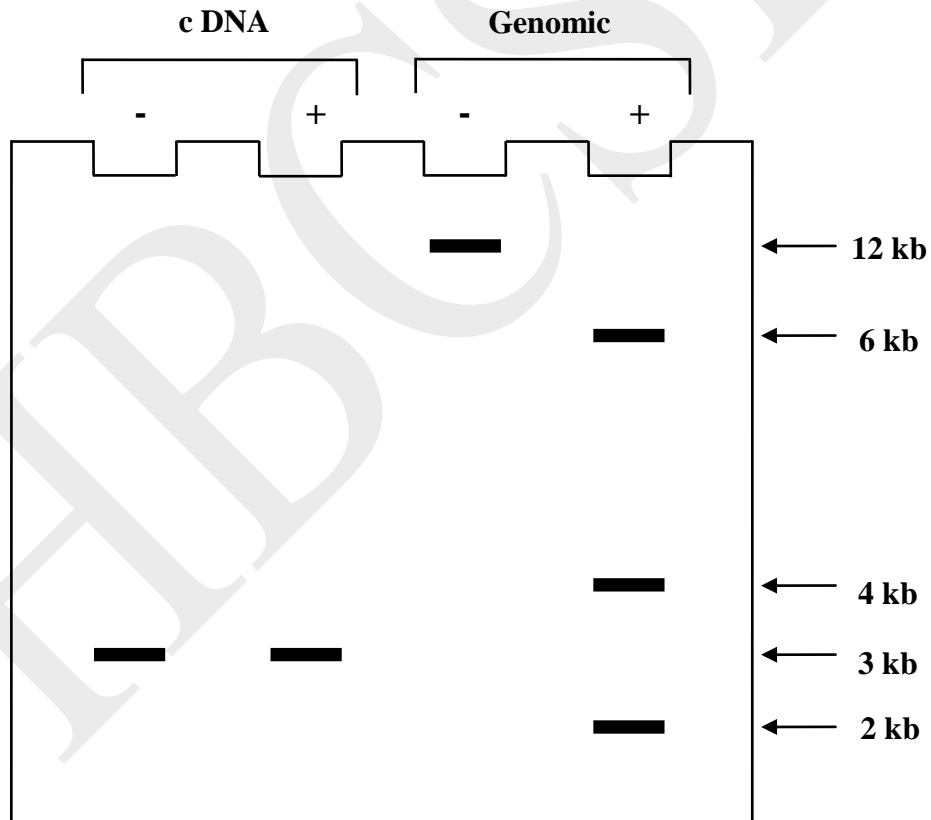
Statements	True	False
A		
B		
C		
D		

32. (2.5 points) A research student was studying the kinetics of synthesis of a trans-membrane cellular receptor using ^{35}S -labeled cysteine. He fractionated cellular components using differential centrifugation at different time intervals. The different cellular components are shown in the following schematic diagram of a cell. Indicate the order in which the radioactivity will be detected by putting the corresponding fraction number in the boxes.





33. (1.5 points) A researcher prepared cDNA clones and genomic DNA clones of a particular gene. She then isolated DNA from both these clones and completely digested them with EcoRI. The digests were analyzed by gel electrophoresis followed by hybridization using probes specific for that particular gene. Following are the results obtained after autoradiography. ('+' indicates the addition of restriction enzyme and '-' indicates absence of the enzyme.)



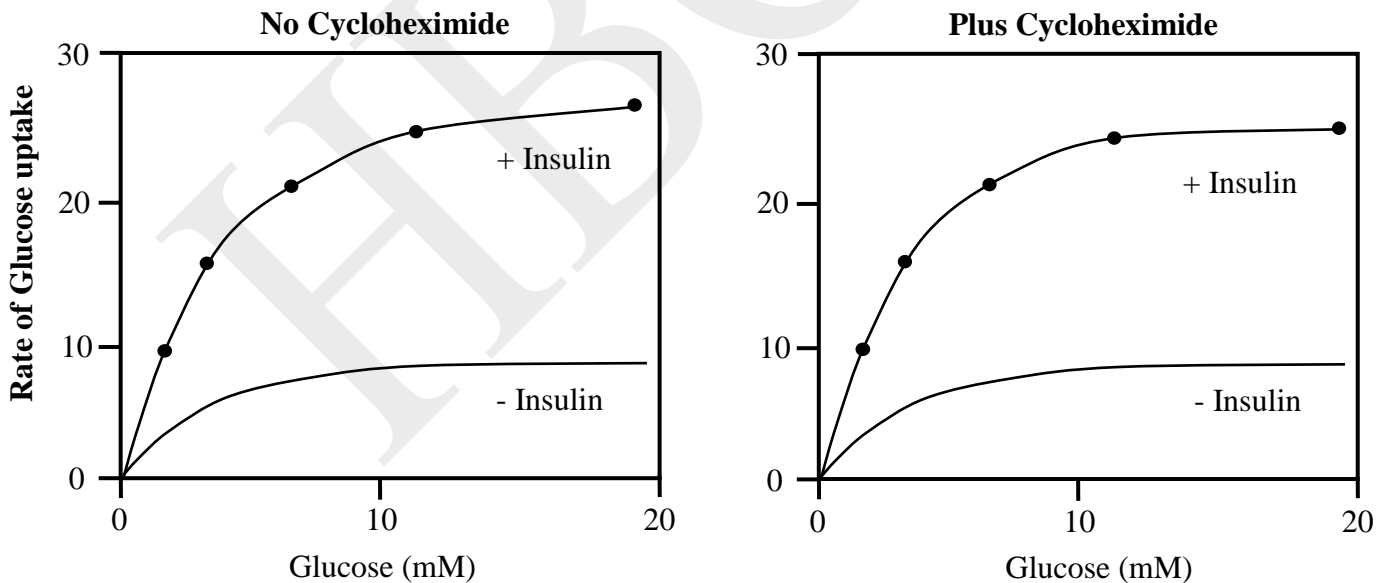
Indicate whether each of the following statements is true or false by putting tick marks (✓) in the appropriate boxes.

A. The cDNA clones lack EcoRI cleavage site.

- B. The extra sequences in genomic clones are located at the two ends of coding sequences.
- C. The gene is a spilt gene and the EcoRI sites are present in the introns.

Statements	True	False
A		
B		
C		

34. (2 points) A student was studying the mechanism of glucose uptake in fat cells in response to insulin. In fat cells, glucose is transported by glucose transporter GLUT4. Effect of cycloheximide (a translation inhibitor) on glucose uptake in the presence and absence of insulin showed the following results.



Cytochalasin B is a potent competitive inhibitor of glucose uptake and it binds to GLUT4. Therefore, radioactive cytochalasin B can be used to find the number of transporters in the fat cells. Following are the results:

Membrane fraction of fat cells	Bound ³ H cytochalasin B (counts per minute/mg vesicle protein)	
	- Insulin	+ insulin
Plasma membrane	890	4480
Internal membrane	4070	80

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

- A. Insulin induced uptake of glucose in fat cells is independent of ongoing protein synthesis.
- B. The Km of GLUT4 is increased by insulin.
- C. Insulin increases the total number of GLUT4 in the cells.
- D. Insulin induces redistribution of GLUT4 transporters within the cells.

Statements	True	False
A		
B		
C		
D		

35. (1 point) In 1958, Meselson and Stahl carried out experiments to support the semi-conservative mode of DNA replication using double stranded heavy DNA labeled with ¹⁵N. As part of this experiment, if one starts with heavy double stranded DNA molecule and allows replication to occur in media containing ¹⁴N, then after how many rounds of replication would one get a 1:7 proportion of hybrid and light dsDNA molecules?



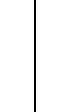




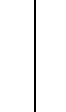


Answer: _____

36. (2 points) The restriction enzyme EcoRI is sometimes called a '6-cutter' since its recognition sequence GAATTC is six nucleotides long. If a linear DNA 8192 kb long is completely digested with EcoRI, what would be the number of fragments one would get assuming random distribution of nucleotide bases?

Answer: _____

PLANT SCIENCES (10 points)

37. (2 points) In an experiment, two sets of sucrose solutions of varying concentrations were prepared (Set 1 and Set 2). In set 1, a drop of methylene blue solution was added to each tube to make the solutions coloured. In set 2, plant tissue samples of equal weight and surface area were added one per tube. After 2 hours, a drop of colored solution from set 1 was added to the test tube of corresponding concentration of set 2. The results are shown below.

Test tube no.	I	II	III	IV	V
Molarity of sucrose solution (M)	0.05	0.10	0.15	0.20	0.25
Water potential (bars)	P	Q	R	S	T
Control sucrose solution containing methylene blue (Set 1)					
↓ Transfer of drop to test solution					
Test solution (Set 2)					

Note that arrows in each tube indicate the movement of the drop.

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

- A. Weight of the tissue in test tube I of set 2 will be greater after 2 hours than that at the beginning.
- B. Water potential (T) of test tube V of set 1 will be highest.
- C. The results show that the process underway in test tube II of set 2 is:
Osmosis → increased concentration of sucrose in test tube → increase in density → rising of drop to surface.
- D. The results will not change if sucrose solutions are replaced by sodium chloride solution and the same concentrations are maintained.

Statements	True	False
A		
B		
C		
D		

38. (3 points) Schematic drawings of two plant structures are depicted in Figures 1 and 2. Assign the correct number/s from the figures for each of the following descriptions:

- 1. Metaxylem: _____
- 2. Pith: _____
- 3. In mature dicot root, this region is enlarged and serves for food (starch) storage. : _____
- 4. These cells remain meristamatic and give rise to lateral roots. _____

5. Apoplastic pathway is hindered because of this structure: ____

Figure 1

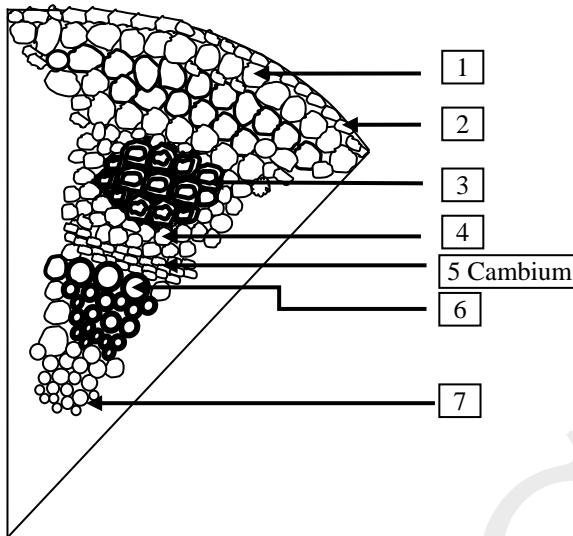
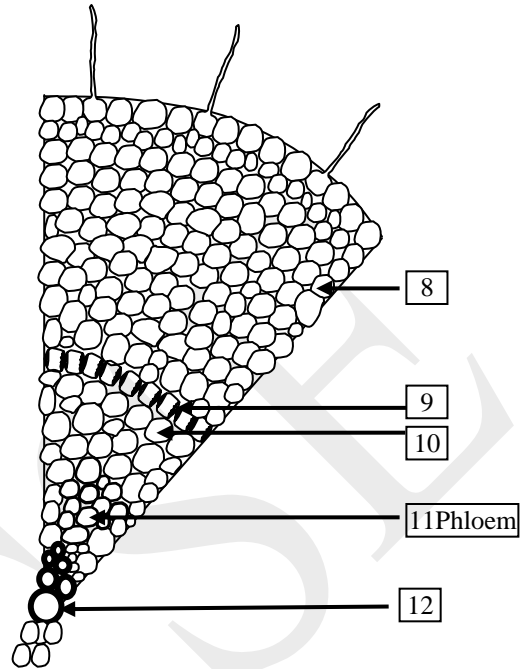


Figure 2



39. (2 points) In plants, two types of photosystems, namely Photosystem I (PSI) and Photosystem II (PSII) exist. PSII is predominantly found in the grana structures. The light harvesting complexes (LHCs) are pigment-protein complexes that gather the light energy and pass on to the reaction centres of PSI and II. The region of LHC facing stroma is rich in negatively charged amino acids. They attract positively charged structures from membrane and lead to stacking or grana formation. However, if these amino acids get phosphorylated, the charges are neutralised, stacking disappears and LHCs are free to move laterally towards PS I.

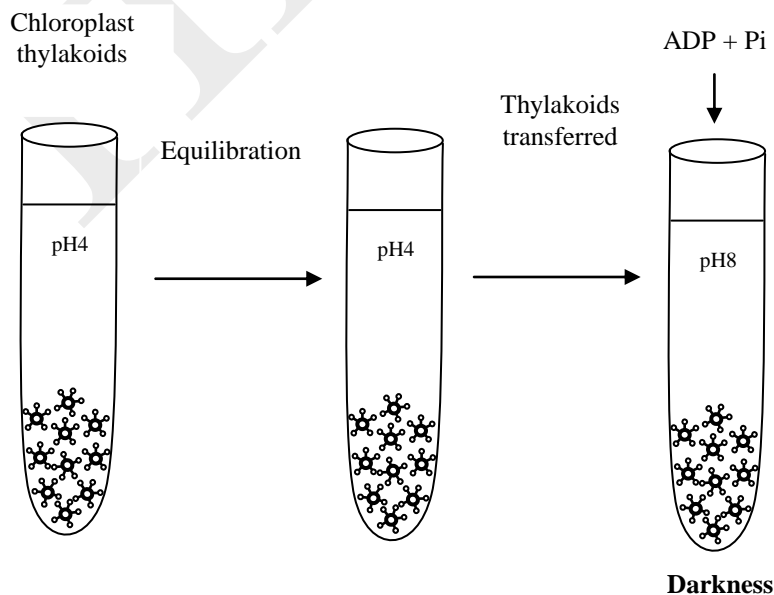
When plant is exposed to bright light, LHC-kinase gets activated while in far red light, LHC-phosphatase gets activated.

State whether the following interpretations are correct or incorrect by putting tick marks (✓) in the appropriate boxes.

- A. If the Sun plants are shifted to shade conditions where the light is rich in far red region and kept there for long duration, destacking of the grana will be favoured.
- B. Phosphorylated LHC will be more abundantly found in unstacked region.
- C. As compared to Sun plants, shade plants will predominantly show increased stacking of the thylakoid membranes.
- D. Uneven illumination of both PS I and II can still lead to effective photosynthesis in plants.

Interpretations	Correct	Incorrect
A		
B		
C		
D		

40. (2 points) In an experiment carried out by Jagendorf and co-workers, isolated chloroplast thylakoids were equilibrated in acid medium at pH 4. The thylakoids were then transferred to a buffer at pH 8 that contained ADP and Pi in darkness.



What result/s would one expect? Indicate by putting tick marks (✓) in the appropriate boxes.

- A. ADP and Pi will combine to form ATP even in the absence of electron transport.
- B. ATP will not be generated as there is no light to build up proton gradient across the thylakoid membrane.
- C. The flow of H⁺ ions from the lumen of thylakoid into stromal side will generate ATP as the stromal side of thylakoid is alkaline.
- D. ATP will be generated in higher amounts if the same experiment is carried out in light.

Results	Expected	Not expected
A		
B		
C		
D		

41. (2 points) The cyclic biochemical pathways that accomplish the fixation and reduction of CO₂ in chloroplasts are carried out by three different methods, C3 cycle, C4 cycle and CAM pathway.

The following statements compare these three different pathways.

- i. C3 cycle is most energy efficient under specific/optimum conditions but it has the lowest water use efficiency (500 molecules of H₂O are lost for fixing every molecule of CO₂). It suffers from photorespiration, a diametrically opposite process resulting in the loss of fixed CO₂.
- ii. Both C4 cycle and CAM pathway are adapted for hot and dry habitats and are identical except for the fact that CAM was reported in the members of family Crassulaceae first.

- iii. C4 cycle has CO₂ concentrating mechanism to prevent the damage caused by photorespiration but it utilizes much more energy than C3 cycle.
- iv. CAM pathway fixes CO₂ as a C4 compound and it has the highest water use efficiency.

The correct statements are:

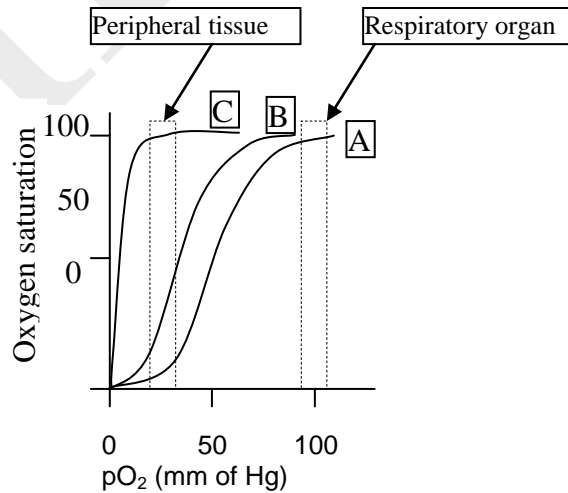
Indicate by putting a tick mark (✓) in the appropriate box.

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

a.	b.	c.	d.

ANIMAL SCIENCES (10 points)

42. (2 points) Typical oxygen saturation curves of three protein molecules A,B and C are shown.

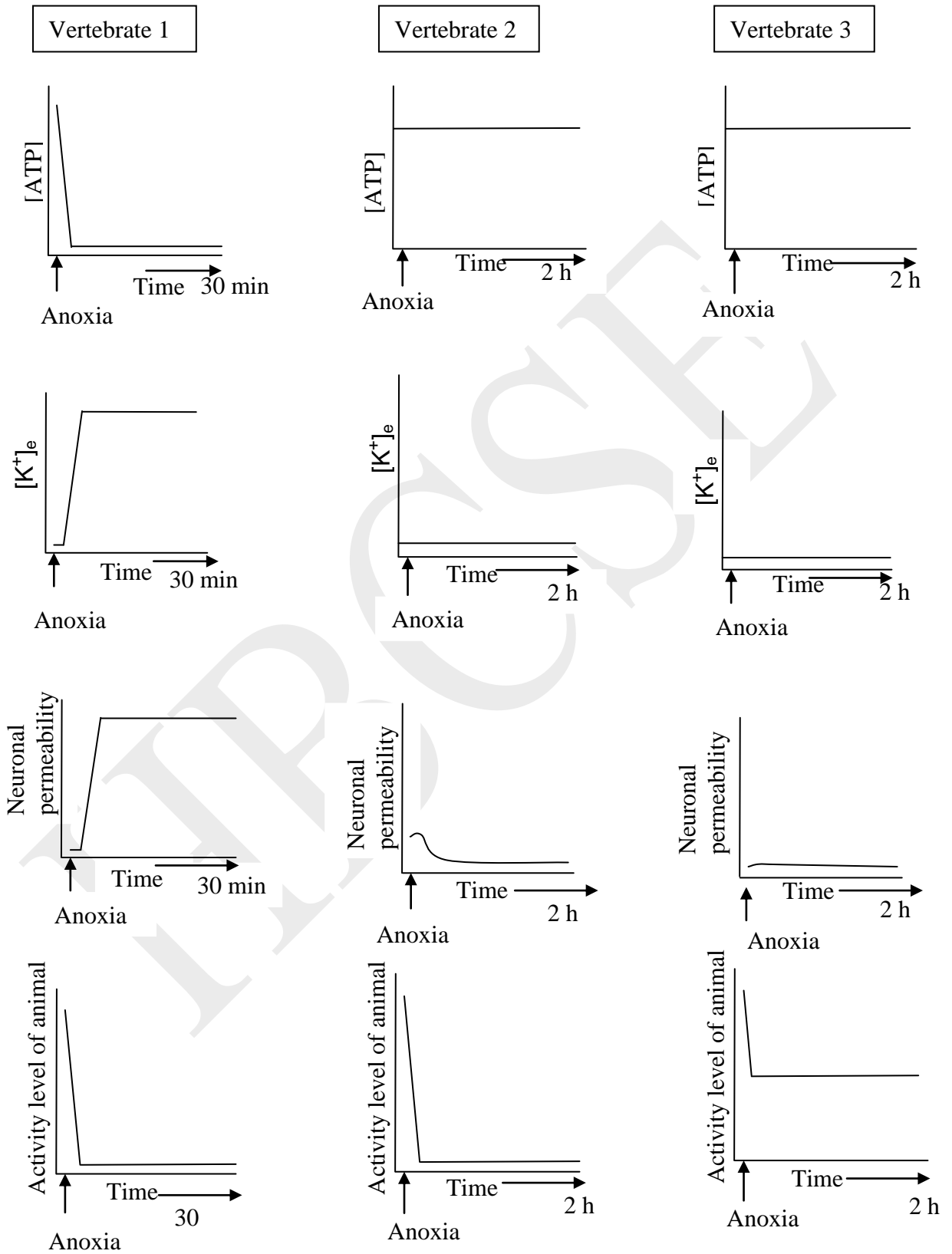


Indicate whether each of the following statements is true or false by putting tick marks (✓) in the appropriate boxes.

1. Curves indicate that protein A is a more efficient storage protein for O₂ as compared to B and C.
2. Protein A shows co-operative binding pattern which suggests that it contains more than 1 subunits.
3. Under severe hypoxic conditions, proteins A and B will work more efficiently as transport proteins than C.
4. In humans, the adult and the fetal hemoglobin molecules would show curves similar to A and B respectively.

Statements	True	False
1		
2		
3		
4		

43. (3 points) Due to its high rate of O₂ consumption, brain is one of the first organs to fail in anoxia. However, some vertebrates can survive for long durations without oxygen. Also, these adaptive features may vary in different animals. Various changes that occur in brain tissues for animals 1, 2 and 3 are depicted in the following graphs.

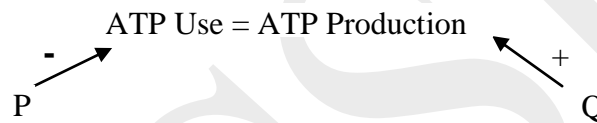


Indicate which of the vertebrates is/ are:

(Fill in the blanks with the appropriate vertebrate numbers)

- a. Anoxia tolerant: _____
- b. Anoxia intolerant: _____
- c. Anoxia tolerance or intolerance cannot be predicted: _____

44. (3 points) Many of the anoxia tolerant animals can finely balance their ATP utilization with its production. Various processes are involved in maintaining this balance.



'-' indicates reduction in ATP use

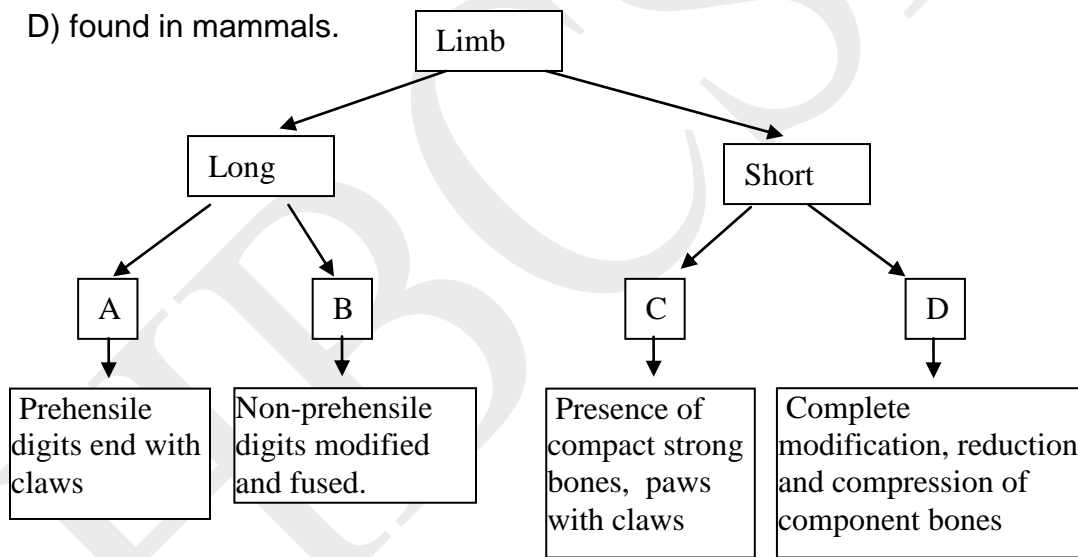
'+' indicates ATP production

Categorize each of the following processes as either P or Q. Put tick marks (✓) in the appropriate boxes.

- a. Suppression of nervous activity
- b. Lactate production buffered by shell and bone calcium carbonate
- c. Triggered glycolysis
- d. Moving to cooler water
- e. Diminution of vision and hearing function
- f. Peripheral vasoconstriction

Processes	P	Q
a.		
b.		
c.		
d.		
e.		
f.		

45. (2 points) The chart shows different types of limb modifications (A, B, C and D) found in mammals.



Assign these modifications (A to D) to the animals with the following lifestyles.

1. Animal prefers to run on ground. _____
2. Animals swim in aquatic habitat. _____
3. Animals live a subterranean life. _____
4. Climbing animals living in and moving through trees. _____

GENETICS & EVOLUTION (16.5 points)

46. (1.5 points) Human cells contain 22 pairs of autosomes and a single pair of sex chromosomes. Maternally and paternally derived chromosomes can be passed on to gametes in any combination.

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

- A. Assuming no crossing over, number of different types of gametes produced by an individual would be $n \times 23^2$ where n denotes the number of reproductive cycles.
- B. Since crossing over adds to dissimilarity, number of different types of gametes produced by one individual would be $>2^{23}$.
- C. Assuming no crossing over, different kinds of zygotes that can be produced in a single mating will be $2^{23} \times 2^{23}$.

Statements	True	False
A		
B		
C		

47. (2.5 points) The normal pair of sex chromosomes in humans is XX in females and XY in males. Any deviation from this normal pattern is likely to result in the defective function of body systems. The X chromosome affects many non-reproductive functions. At least one copy is essential for survival and promotes development of female pattern. While the Y chromosome is a determinant of male type development, it can also affect a few somatic characteristics such as height. In clinical usage, presence of Barr bodies is indicated as 'chromatin +' and absence as 'chromatin -'.

For each of the following descriptions, match the most appropriate genotype, by choosing from the options and fill in the table.

- A. 'Chromatin –' female phenotype with non-functional ovaries.
- B. 'Chromatin +' male phenotype with tall stature, poorly developed secondary sex characteristics.
- C. Female phenotype with normal female reproductive function but with mental retardation.
- D. Male phenotype with unusually tall stature but normal sexual development and fertility.
- E. Normal female phenotype with ovo-testicular development internally.

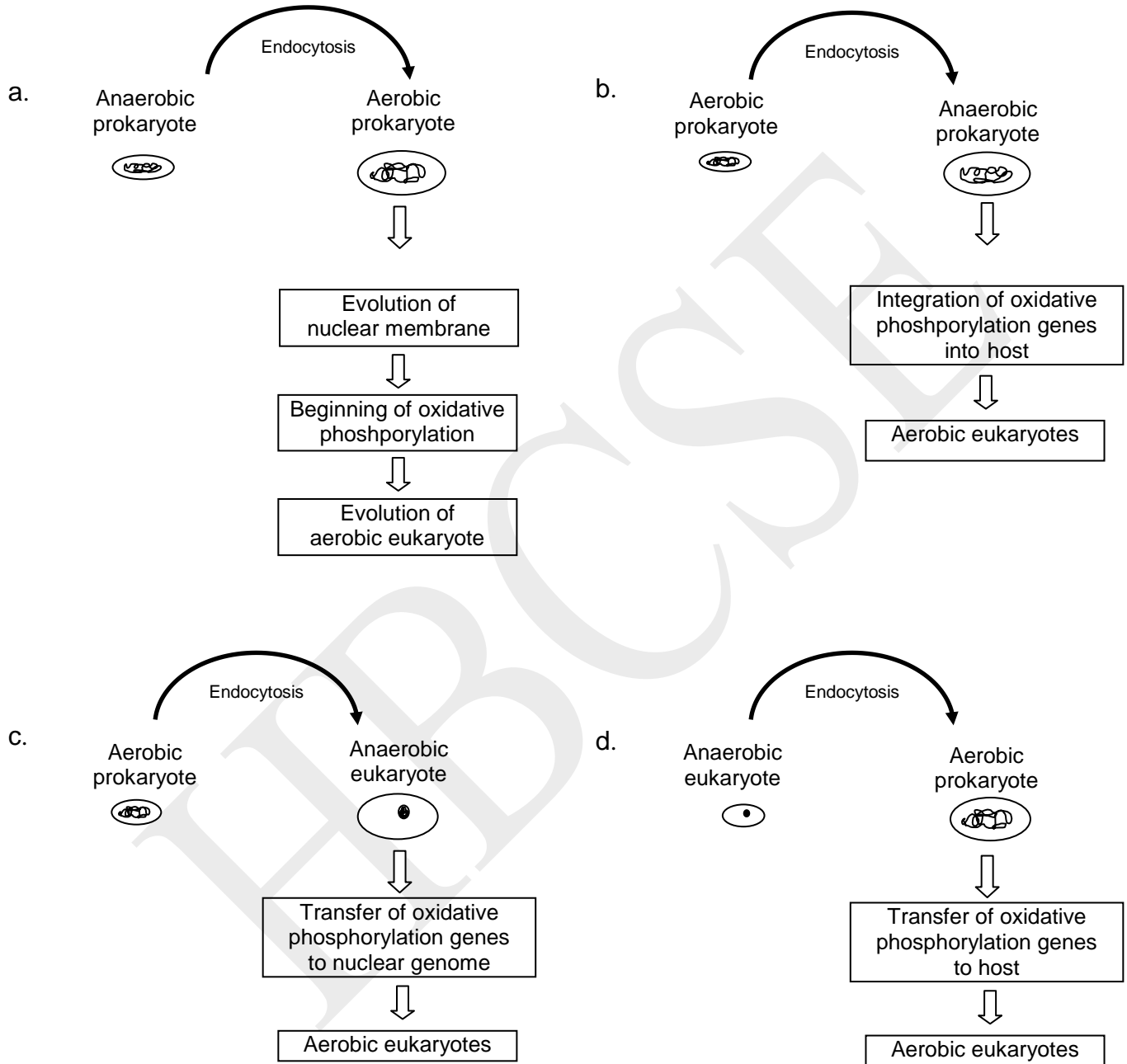
Options:

- 1. XX/XY chimera
- 2. XO
- 3. YO
- 4. XXX
- 5. XXY
- 6. XYY

Description	Genotype
A	
B	
C	
D	
E	

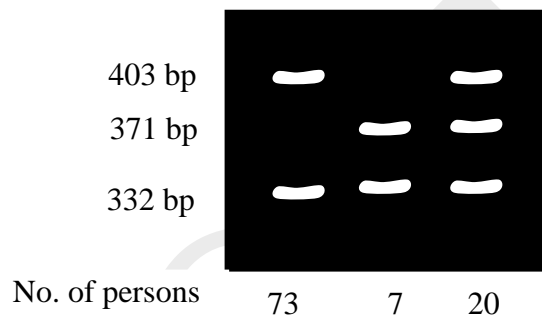
48. (2 points) According to the 'Endosymbiont' hypothesis, the first aerobic eukaryote must have evolved around 1.5 billion years ago when earth's atmosphere started accumulating O₂ in significant quantities. Choose the

correct path that depicts this hypothesis and put a tick mark (✓) in the appropriate box.



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

49. (2 points) Scientists working on HIV-1 strain infection in humans, found a gene CCR5 of special interest. This gene, located on chromosome 3, makes a person susceptible to viral infection. A mutant allele of this gene contains 32 bp deletion (CCR5 Δ 32) which confers resistance to the infection. A population of 100 individuals was studied for this gene. The gene of interest was amplified by PCR, restriction digested and run on agarose gel to yield the following profile.



Calculate the frequency of CCR5 Δ 32 gene in this population.

Answer: _____

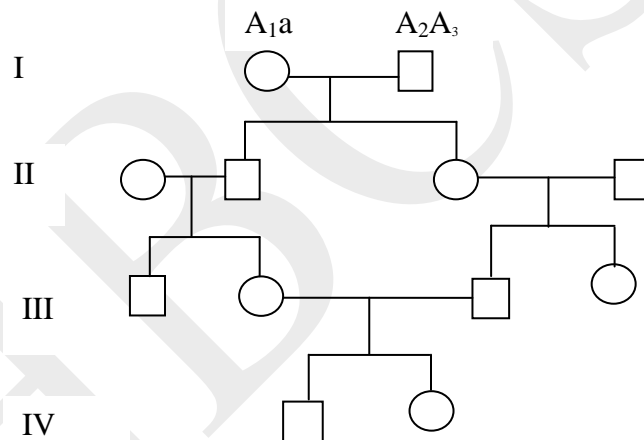
50. (2 points) Tay-Sachs is an autosomal recessive genetic disorder. It is a life threatening disease of the nervous system where babies cannot live past the age of couple of years. Genetic studies of an island population totally isolated from mainland revealed that 26% individuals were carriers and 2% babies were detected with homozygous recessive alleles. Indicate whether each of the following statements is true or false by putting tick marks (✓) in the appropriate boxes.

- The population on this island is in Hardy Weinberg equilibrium at the time of study since it accounts for the expected relationship of $p + q = 1$.
- The gene frequency of dominant allele will remain unchanged in future generations as there is no gene flow to or from this island.
- The frequency of Tay-Sachs allele will be 0.13 for the next generation.

D. After several generations the deleterious allele will get totally wiped out from the population.

Statements	True	False
A		
B		
C		
D		

51. Consider a genetic disease that is very rare in a population and is autosomal recessive. Suppose that the female of the first generation in the following pedigree has genotype A_1a at a disease locus while male is A_2A_3 .



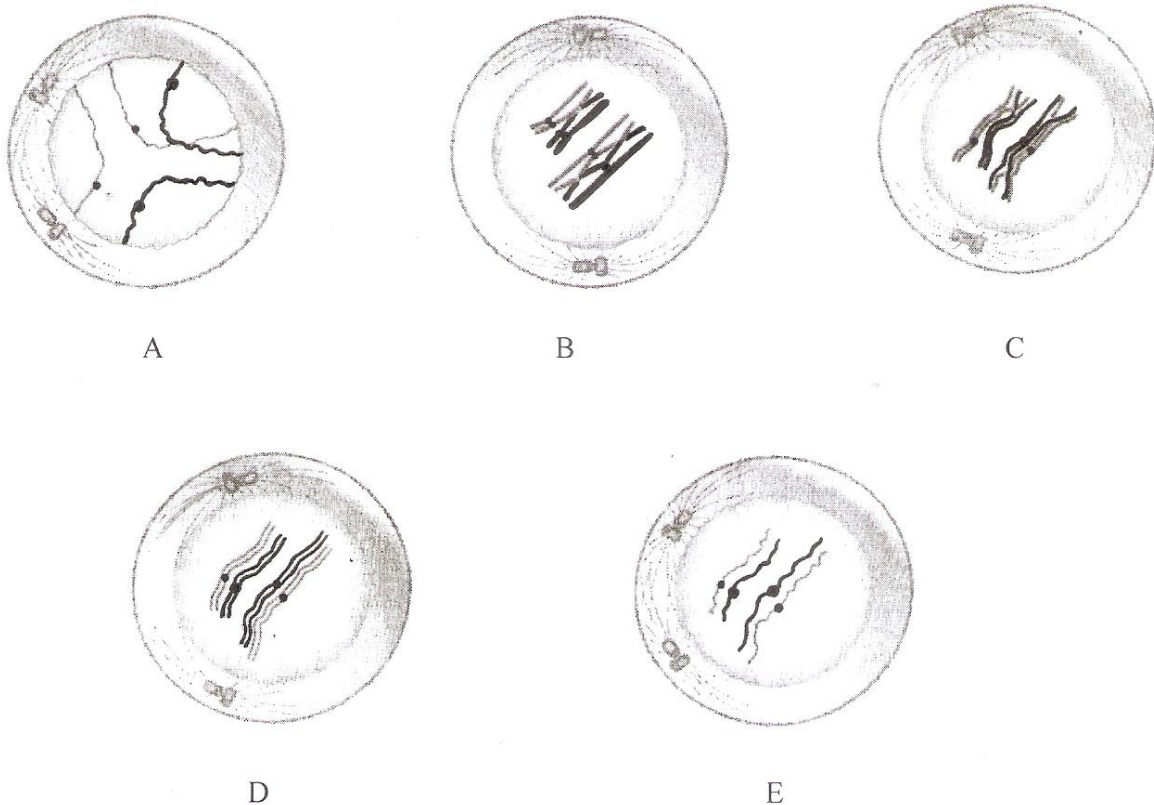
i. (2 points) What is the probability that the female in generation IV will be diseased?

Answer: _____

ii. (2 points) What is the probability that the great grandchild will inherit two copies of the same normal allele from the great grand parents?

Answer: _____

52. (2.5 points) The following figures depict different sub-stages of meiotic prophase I.

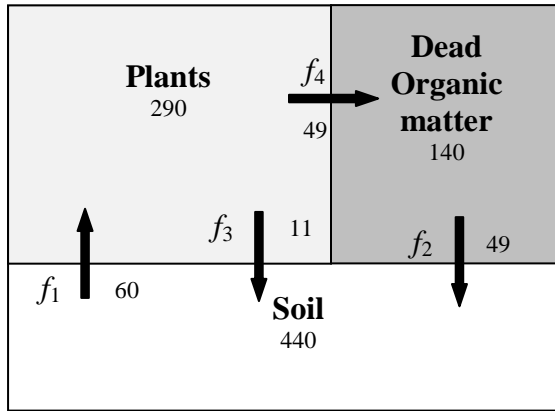


Arrange the sub-stages in the correct sequence:



ECOLOGY (8 points)

53. (2 points) The diagram given below is a simple representation of the cycling of calcium through a forest ecosystem. The ecosystem is represented by three compartments, plants, soil and dead organic matter. The pool size of each compartment is in units of kg/ha. The flux rates are represented by arrows linking the various compartments and are in units of kg/ha/yr. The arrows f_1 to f_4 indicate the different processes involved.



The processes occurring in the above diagram are: (Choose from the options and write appropriate numbers.)

f_1 : _____

f_2 : _____

f_3 : _____

f_4 : _____

Options:

1. Leaching
2. Plant uptake
3. Net mineralization
4. Litterfall
5. Sedimentation

54. Consider an ecosystem consisting of a producer, primary consumer and decomposers. Following terms are defined for this ecosystem.

- A. Total light incident
- B. Light incident on the producers
- C. Light reflected back and lost
- D. Amount lost in respiration by producer
- E. Biomass gained by producer
- F. Biomass eaten by herbivore
- G. Biomass excreted as faeces
- H. Biomass used for respiration by herbivore

I. Biomass of primary consumer that is available for next trophic level

(I) (0.5 point) What will be the % photosynthetic efficiency of such an ecosystem?

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

a. $[(D+E+F)/(B+C)] \times 100$

b. $[E/(A+B - C)] \times 100$

c. $[(D+E)/B] \times 100$

d. $[E/(A+B+C)] \times 100$

a.	b.	c.	d.

Give formulae for calculating the following.

(II) (0.5 point) Percent exploitation efficiency (the proportion of production on one trophic level that is consumed by members of the next trophic level) of the herbivore.

Answer: _____%

(III) (0.5 point) Percent assimilation efficiency of the primary consumer.

Answer: _____%

(IV) (0.5 point) Percent trophic efficiency (transfer of biomass between trophic levels) of this ecosystem.

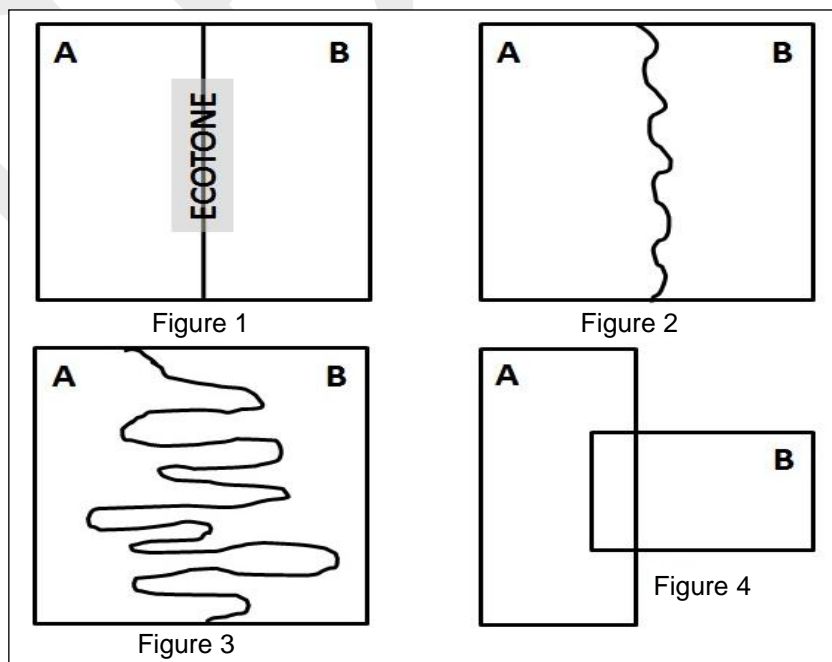
Answer: _____%

(V) (2 points) Indicate whether each of the following equations holds true or not by putting tick marks (✓) in the appropriate boxes.

- a. $H+I = F - G$
- b. $A = B+C$
- c. $D+E+F = \text{Gross productivity of producer}$
- d. $E = I+H$

Equation	Holds True	Does not hold true
a.		
b.		
c.		
d.		

55. (2 points) An ecotone is a transition area between two biomes. It is where two communities meet and integrate. It may be narrow or wide, and it may be local or regional. Following diagram depicts four different ecosystems with variable types of ecotones.



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

- A. Figure 1 shows definitive ecotones where there is a distinct barrier clearly distinguishing the habitats and therefore, no overlaps in diversity. This is an example of grassland and forest ecosystems.
- B. Figure 2 has marginal undulating boundary which suggest almost complete distinction. This can be exemplified by a forest and river ecosystems.
- C. Figure 3 has merging ecotones and therefore, there is no distinction of habitats and diversity. This is an example of ocean and terrestrial ecosystems.
- D. Figure 4 shows almost non overlapping ecotones. Most of the habitats and diversity would be distinct except for the overlapping regions. This is an example of oceanic and riverine.

Descriptions	True	False
A		
B		
C		
D		

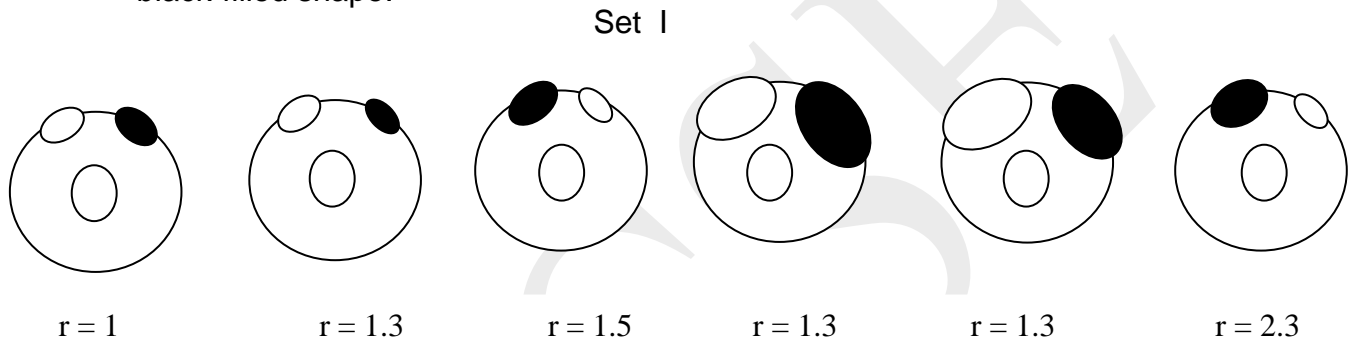
ETHOLOGY (6.5 points)

56. A well known example of fixed action pattern (FAP) is that of Herring gulls that lay eggs in shallow nests on the ground. If an egg rolls out of the nest, it is retrieved by the parent. This behavior is exhibited even if the egg is replaced with a dummy egg.

In a series of experiments called 'titration technique', ethologists Barends and Kruijt investigated whether the position of an egg in the nest and /or size had any effect on its retrieval.

(I) (2.5 points) The diagram below shows the titration method in which a series of experiments were carried out using varying sizes of eggs for determining whether there is any side preference for retrieval of eggs by the parent bird (Set I).

The big circle represents the nest with one real egg in the centre of the nest and two dummy eggs on the rim. 'r' is the ratio of the sizes of the dummies on the nest rim. The dummy chosen by the parent bird in each trial is indicated by black-filled shape.



Based on the results of the experiments in set I determine whether each of the statement is true or false. Indicate by putting tick marks (✓) in the appropriate boxes.

- A. There is a side preference for the left whenever the left egg is of a bigger size.
- B. The choice of position is random and does not depend on the size.
- C. There is a side preference for the right. This preference is maintained even when there is a marginal difference in sizes.
- D. Egg retrieval based on position is not a genetic trait but a learned behavior based on past experience.
- E. The egg retrieval choice is based on the relative sizes of eggs and not on the absolute sizes.

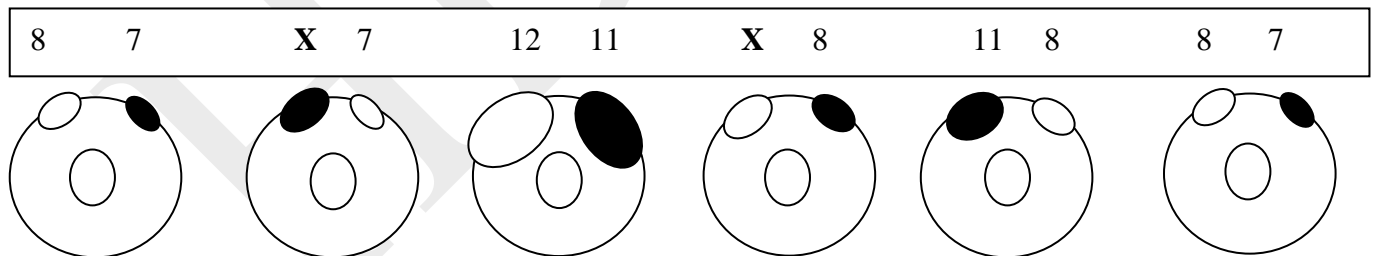
Statements	True	False
A		
B		
C		
D		
E		

(II) (2 points) Results of another set of experiments are shown below (Set II).

Analyse them with respect to the conclusions of the previous experiments. You need to determine the egg size 'X' by analyzing the outcomes of each experiment in this set.

The big circle represents the nest with one real egg in the centre of the nest and two dummy eggs on the rim. The numbers 7, 8, 11, 12 and X refer to the size of the dummies on the nest rim (in arbitrary units). The dummy chosen by the parent bird in each trial is indicated by black-filled shape.

Set II



Calculate X if the size of the dummy egg 'X' is an integer.

Answer: _____

57. (2 points) Niko Tinbergen, one of the founders of ethology, emphasised that we can understand how and why a biological phenomenon occurs, in terms of its proximate and ultimate causation.

When male African lions take over a pride consisting of females and their dependent offspring, they often kill all the young in the pride. The adult females then immediately come into estrus, mate with the new males and produce a new cohort of offspring.

Analyse the following statements and indicate with tick marks (✓) in the appropriate boxes whether each statement is true or false.

- A. A proximate causal explanation for the incoming males to kill the existing young is to reduce the future competition with their own cubs.
- B. An ultimate causal explanation of why the females in the pride come into estrus synchronously is that when the young male offspring leave the pride in a group, they would survive better and have greater reproductive success.
- C. An ultimate causal explanation of why the new males repeatedly mate with the estrus females is that their actual time of ovulation and peak receptivity is concealed.
- D. A proximate causal explanation of concealed ovulation is protection of their newborn cubs from being killed by non-paternal males since the paternity is uncertain.

Statements	True	False
A		
B		
C		
D		

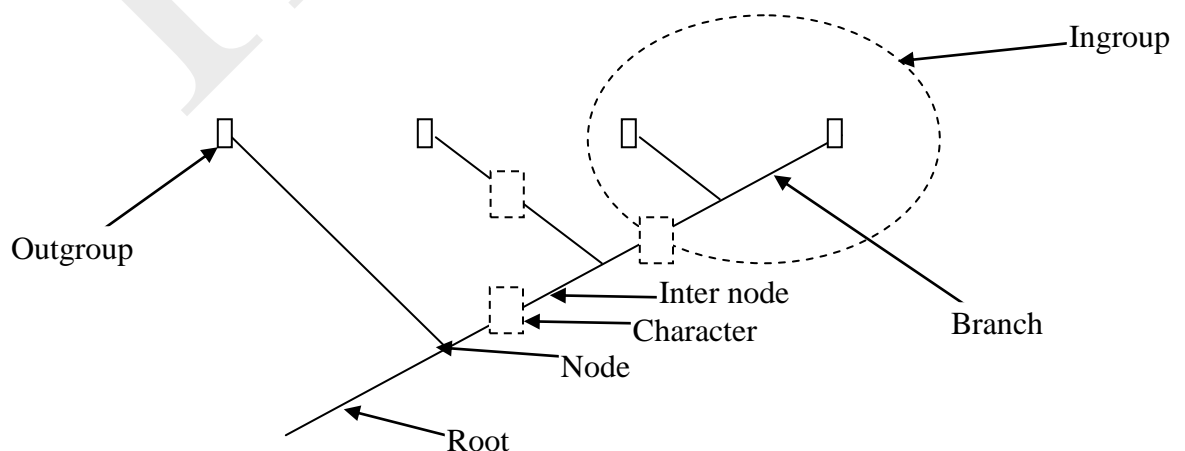
BIOSYSTEMATICS (8 points)

58. Animals can be grouped or classified based on the presence and absence of external as well as internal key characters.

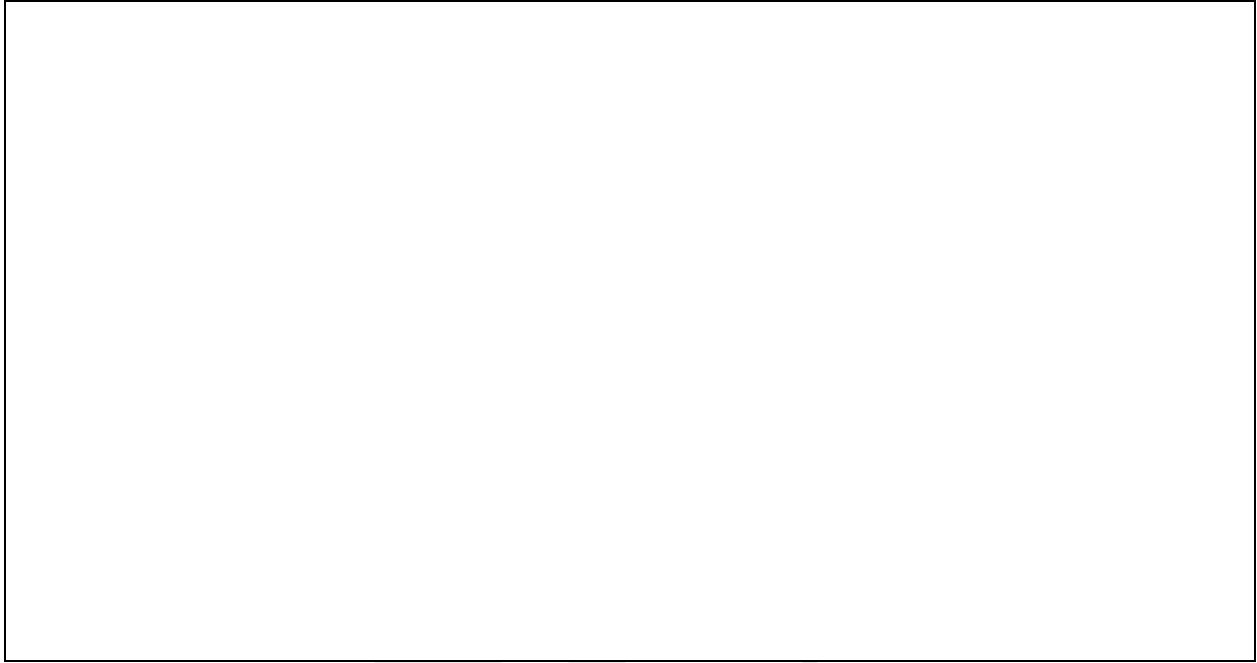
(I) (3.5 points) A few animal groups are listed in the given table. Fill in the table with 1 for presence and 0 for absence against the specific characters for each group of animals. **Only an entirely correct row will be given 0.5 point.**

Sr. No.	Class/group	Bony skeleton	Four chambered heart	Four Appendages	Mammary glands	Jaws	Post orbital fenestrae
1	Outgroup	0	0	0	0	0	0
2	Sharks						0
3	Ray-finned fishes						0
4	Amphibia						0
5	Primates						0
6	Rodents						0
7	Crocodiles						1
8	Aves						1

Cladogram is a tree-shaped diagram used to illustrate evolutionary relationships between groups of animals by analyzing certain characters, or physical features. A representation of a typical cladogram is shown below.



(II) (2.5 points) Construct the most parsimonious cladogram for the eight groups of animals given in the table and indicate the characters at the appropriate nodes / internodes /branches of the cladogram.



(III) (1 point) Which of the following organisms can be considered as the outgroup in the above cladogram? Choose the correct option and put a tick mark (✓) in the appropriate box.

- i. Lancelet
- ii. Insects
- iii. Lamprey
- iv. Tunicates

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

a.	b.	c.	d.

(IV) (1 point) Which of the following organisms can be considered as outgroup in the above cladogram if the character 'jaws' is replaced by 'vertebrae'? Choose the correct option and put a tick mark (✓) in the appropriate box.

- i. Lancelet
- ii. Insects
- iii. Lamprey
- iv. Tunicates

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

a.	b.	c.	d.

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