

CBSE Class 12 Biology Question Paper 2026 with Solution PDF-Set 57-3-3

Question Paper with Solutions

Conducted by the Central Board of Secondary Education (CBSE)



Time Allowed: 3 hours

Maximum Marks: 70

General Instructions

- (i) This question paper contains **33** questions. **All** questions are **compulsory**.
- (ii) Question paper is divided into **five** sections – Sections **A, B, C, D** and **E**.
- (iii) **Section A** – questions number **1** to **16** are Multiple Choice Type Questions. Each question carries **1** mark.
- (iv) **Section B** – questions number **17** to **21** are Very Short Answer Type Questions. Each question carries **2** marks.
- (v) **Section C** – questions number **22** to **28** are Short Answer Type Questions. Each question carries **3** marks.
- (vi) **Section D** – questions number **29** and **30** are Case-Based questions. Each question carries **4** marks. Each question has subparts with internal choice in one of the subparts.
- (vii) **Section E** – questions number **31** to **33** are Long Answer Type Questions. Each question carries **5** marks.
- (viii) There is no overall choice. However, an internal choice has been provided in Sections B, D and E of the question paper. A candidate has to write answer for only **one** of the alternatives in such questions.
- (ix) Kindly note that there is a separate question paper for Visually Impaired Candidates.
- (x) Wherever necessary, neat and properly labelled diagrams should be drawn.

Section A (16 marks)

Questions no. 1 to 16 are Multiple Choice Type Questions, carrying 1 mark each. Choose the best option.
 $16 \times 1 = 16$

1. In a human, the average gene consists of (i) ___ bases and the largest known human gene contains (ii) ___ bases.

Select the correct option to fill in the blanks (i) and (ii):

[1 mark]

- (A) (i) 800; (ii) 1.6 million
- (B) (i) 300; (ii) 2400
- (C) (i) 8000; (ii) 1.2 million
- (D) (i) 3000; (ii) 2.4 million

Correct Answer: (D) (i) 3000; (ii) 2.4 million

Solution:

Concept:

- Human genes differ greatly in size; the average human gene contains about 3000 bases.
- The dystrophin gene is the largest known human gene in the NCERT account, containing about 2.4 million bases.

Step 1: Fill the average-size blank Blank (i) asks for the average size of a gene, not the number of genes in the human genome. The required figure is approximately 3000 bases. A gene can contain coding as well as non-coding regions, so its full length is not simply the length of a protein-coding sequence.

Step 2: Check both entries of each option Blank (ii) requires 2.4 million bases for the dystrophin gene. Option (A) gives 800 and 1.6 million, option (B) gives 300 and 2400, and option (C) gives 8000 and 1.2 million; none matches the two required values together.

Step 3: Conclusion The blanks are (i) 3000 bases and (ii) 2.4 million bases. Hence, the correct option is (D).

Quick Tip to Solve: Recall the pair: average human gene, 3000 bases; dystrophin gene, 2.4 million bases.

2. Which of the following is a carrier for the disease Amoebiasis?

[1 mark]

- (A) Culex mosquito
- (B) Female Anopheles mosquito
- (C) Snail
- (D) Housefly

Correct Answer: (D) Housefly

Solution:

Concept:

- Amoebiasis is caused by the protozoan parasite *Entamoeba histolytica*, which infects the large intestine.
- Infective cysts enter the body through contaminated food or drinking water; houseflies can mechanically carry the parasite from faecal matter to food.

Step 1: Identify the mode of transmission A carrier in this question is the organism that transfers the pathogen to food. A housefly can pick up the parasite from the faeces of an infected person and deposit it on exposed food or food products. Eating the contaminated food can transmit amoebiasis.

Step 2: Eliminate the other carriers *Culex* mosquitoes are associated with filariasis, while female *Anopheles* mosquitoes transmit malaria. A snail is not the carrier responsible for the faecal-to-food transmission of amoebiasis described here. Thus the mosquito and snail choices do not fit this disease.

Step 3: Conclusion Housefly is the carrier for amoebiasis. Hence, the correct option is (D).

Quick Tip to Solve: Separate the pathogen from its carrier: *Entamoeba* causes amoebiasis, while houseflies contaminate food.

3. What does I in restriction enzyme Hind S₂I indicate?

[1 mark]

- (A) It cuts after the first nucleotide in the restriction site.
- (B) It is the first enzyme isolated from strain S₂ of bacterium.
- (C) Only one enzyme can be used to digest a plasmid from S₂ strain.
- (D) Only one restriction enzyme has been isolated from this bacteria.

Correct Answer: (B) It is the first enzyme isolated from strain S₂ of bacterium.

Solution:

Concept:

- Restriction-enzyme names identify the source bacterium and strain, followed by a Roman numeral.
- The terminal Roman numeral indicates the order in which the enzyme was isolated from that particular bacterial strain.

Step 1: Read the terminal Roman numeral In the printed enzyme name Hind S₂I, the terminal I is a Roman numeral. It denotes the first restriction enzyme isolated from the indicated S₂ bacterial strain. It does not give a nucleotide position within the recognition sequence.

Step 2: Test the alternative interpretations Option (A) confuses the isolation order with the site of

cleavage. Option (C) incorrectly treats the numeral as a limit on enzymes usable for plasmid digestion. Option (D) claims that only one restriction enzyme has been isolated; the numeral I establishes order, not the total number of enzymes that may exist or be isolated.

Step 3: Conclusion I indicates the first enzyme isolated from strain S_2 of the bacterium. Hence, the correct option is (B).

Quick Tip to Solve: Read the final Roman numeral in a restriction-enzyme name as isolation order, never as a cutting position.

4. Select the correct option for the pair of plants pollinated by water.

[1 mark]

- (A) Vallisneria and Hydrilla
- (B) Zostera and Water lily
- (C) Water lily and Parthenium
- (D) Water hyacinth and Water lily

Correct Answer: (A) Vallisneria and Hydrilla

Solution:

Concept:

- Hydrophily is pollination in which water carries pollen from the male reproductive structure to the stigma.
- An aquatic habitat alone does not establish hydrophily: many aquatic plants have flowers above water and use other pollinating agents.

Step 1: Identify the water-pollinated pair Both *Vallisneria* and *Hydrilla* are examples of water-pollinated plants. In *Vallisneria*, female flowers reach the water surface on long stalks and released male flowers are carried by water currents to them.

Step 2: Check the remaining pairs *Zostera* is water-pollinated, but water lily is not. Water lily and water hyacinth have flowers emerging above the water and are pollinated by insects or wind rather than by water. *Parthenium* is wind-pollinated. Therefore each of (B), (C), and (D) contains a plant that does not satisfy the stated condition.

Step 3: Conclusion The water-pollinated pair is *Vallisneria* and *Hydrilla*. Hence, the correct option is (A).

Quick Tip to Solve: Check the pollen carrier for both plants; living in water does not mean that water transfers their pollen.

5. Some statements regarding drugs and alcohol are given below :

- (i) Adolescents are more vulnerable to peer pressure.
- (ii) Drug addiction leads to increased tolerance level of the receptors present in our body.
- (iii) Alcohol affects the central nervous system.
- (iv) Excessive use of drugs helps to increase energy.
- (v) Anabolic steroids decrease aggressiveness.

Choose the option with correct statement(s).

[1 mark]

- (A) Statements (i), (iv) and (v) are correct
- (B) Statements (i), (ii) and (iii) are correct
- (C) Only statements (i) and (v) are correct
- (D) Only statement (iii) is correct

Correct Answer: (B) Statements (i), (ii) and (iii) are correct

Solution:

Concept:

- Peer influence and curiosity can make adolescence a vulnerable period for drug and alcohol abuse.
- Repeated drug use can increase tolerance, so progressively larger doses may be required to produce the earlier response.

Step 1: Evaluate statements (i), (ii), and (iii) Statement (i) is correct because adolescents are particularly susceptible to peer pressure. Statement (ii) is correct: repeated use can increase the tolerance level of receptors in the body. Statement (iii) is also correct because alcohol affects the central nervous system and can impair coordination and judgement.

Step 2: Evaluate statements (iv) and (v) Statement (iv) is incorrect: excessive drug use harms health and does not provide a general, sustained increase in energy. Statement (v) is incorrect because anabolic-steroid abuse can increase aggressiveness rather than decrease it. Options (A) and (C) include false statements, while option (D) wrongly excludes the true statements (i) and (ii).

Step 3: Conclusion Statements (i), (ii), and (iii) are correct. Hence, the correct option is (B).

Quick Tip to Solve: Check the two traps first: excessive drugs harm health, and anabolic steroids can increase aggression.

6. What would be the minimum possibility of a dominant trait being expressed in an offspring after a monohybrid test cross? [1 mark]

- (A) 25%
- (B) 50%
- (C) 75%
- (D) 100%

Correct Answer: (B) 50%

Solution:

Concept:

- A monohybrid test cross mates an individual showing a dominant trait with a homozygous recessive individual, aa .
- The dominant-looking parent can be AA or Aa , where A is dominant and a is recessive.

Step 1: Test the homozygous dominant possibility For $AA \times aa$, the first parent produces only A gametes and the tester only a gametes. All offspring are Aa , so all express the dominant trait: the probability is 100%.

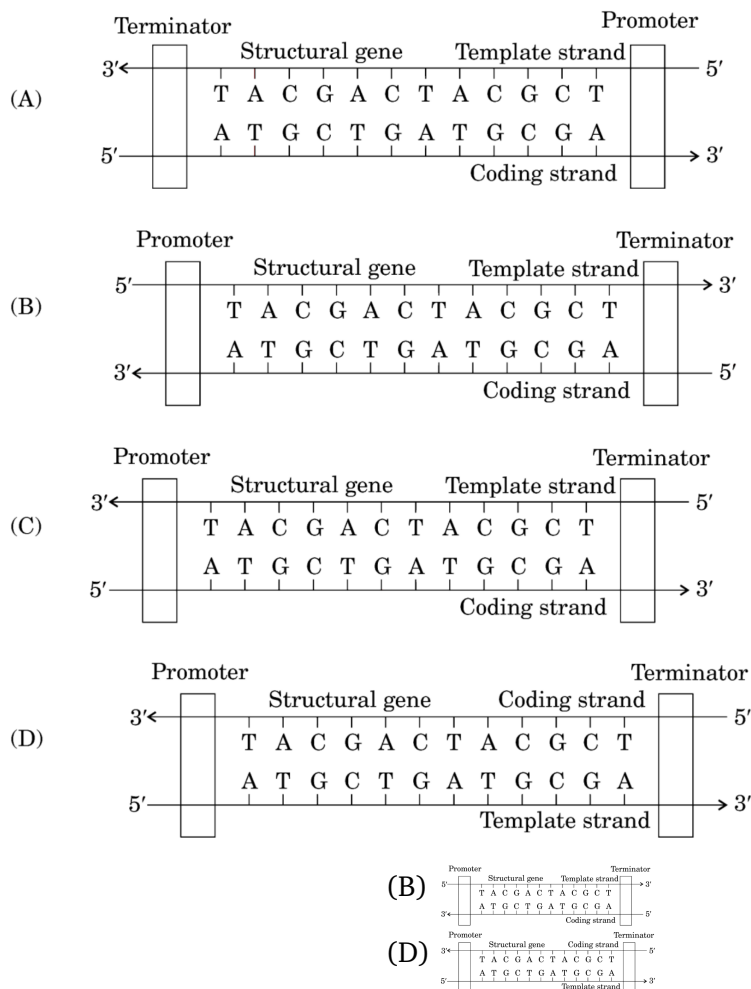
Step 2: Test the heterozygous possibility For $Aa \times aa$, the first parent forms A and a gametes in equal proportions. The offspring are $\frac{1}{2}Aa$ and $\frac{1}{2}aa$, giving dominant and recessive phenotypes in a 1 : 1 ratio. Thus 50% is the smaller of the two possible dominant-trait probabilities. The 25% and 75% values are not the dominant-phenotype probabilities for either test cross.

Step 3: Conclusion The minimum probability is 50%, obtained when the dominant parent is heterozygous. Hence, the correct option is (B).

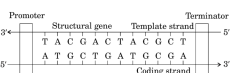
Quick Tip to Solve: For a test cross, compare $Aa \times aa$ with $AA \times aa$; do not use the 3:1 ratio from a heterozygote self-cross.

7. Four different transcription units are shown below. Choose the option with the correct image.

[1 mark]



Correct Answer: (C)



Solution:

Concept:

- RNA polymerase reads the template strand in the $3' \rightarrow 5'$ direction and synthesises RNA in the $5' \rightarrow 3'$ direction.
- The promoter lies upstream, towards the $5'$ end of the coding strand; the terminator lies downstream, towards its $3'$ end.

Step 1: Follow the promoter-to-terminator direction In option (C), the promoter is at the left and the terminator at the right. Moving from left to right, the upper template strand runs $3' \rightarrow 5'$ and the lower coding strand runs $5' \rightarrow 3'$. These antiparallel orientations allow RNA synthesis to proceed towards the terminator.

Step 2: Reject the inconsistent arrangements In (A), promoter and terminator are reversed relative to the labelled template polarity. In (B), the labelled template runs $5' \rightarrow 3'$ from promoter to terminator, which is the wrong reading direction. In (D), the template and coding labels are interchanged relative to the required polarities. Complementary base pairing by itself is therefore insufficient; the strand

labels and regulatory sites must also agree.

Step 3: Conclusion Option (C) shows the correct transcription unit. Hence, the correct option is (C).

Quick Tip to Solve: Start at the promoter: the template must read 3-prime to 5-prime as you move towards the terminator.

8. Foetal ejection reflex in human female triggers the release of which hormone?

[1 mark]

- (A) Oxytocin from foetal pituitary gland
- (B) hCG from placenta
- (C) Progesterone from corpus luteum
- (D) Oxytocin from maternal pituitary gland

Correct Answer: (D) Oxytocin from maternal pituitary gland

Solution:

Concept:

- Parturition is induced by a neuroendocrine mechanism involving signals from the fully developed foetus and the placenta.
- The foetal ejection reflex stimulates oxytocin release from the maternal posterior pituitary; oxytocin strengthens uterine contractions.

Step 1: Trace the reflex pathway Signals from the mature foetus and placenta induce mild uterine contractions, called the foetal ejection reflex. This reflex triggers the release of oxytocin from the mother's pituitary gland. Stronger contractions then promote further oxytocin release through positive feedback until delivery.

Step 2: Check the hormone and its source Option (A) names the correct hormone but incorrectly assigns its release to the foetal pituitary. Placental hCG in (B) supports early pregnancy, while progesterone in (C) helps maintain pregnancy; neither is the hormone released by this reflex to intensify labour contractions.

Step 3: Conclusion The reflex triggers oxytocin release from the maternal pituitary gland. Hence, the correct option is (D).

Quick Tip to Solve: In a labour-reflex question, check both the hormone and the source: oxytocin is released from the maternal pituitary.

9. Match the items given in Column I with Column II and select the correct option.

Column I	Column II
a. Earthworm	i. Aquatic Ecosystem
b. Zooplankton	ii. Detritivore
c. Phytoplankton	iii. Pyramid of Biomass in Sea
d. Inverted pyramid	iv. Primary Producer

[1 mark]

(A) a-i, b-ii, c-iii, d-iv

(B) a-ii, b-iii, c-iv, d-i

(C) a-ii, b-iv, c-i, d-iii

(D) a-ii, b-i, c-iv, d-iii

Correct Answer: (D) a-ii, b-i, c-iv, d-iii

Solution:

Concept:

- Detritivores fragment detritus, whereas primary producers make organic food by photosynthesis.
- Zooplankton are animal plankton of aquatic ecosystems. In the sea, the standing biomass of producers can be smaller than that of consumers, giving an inverted biomass pyramid.

Step 1: Match the organisms to their roles Earthworm feeds on and fragments detritus, so a matches ii (Detritivore). Zooplankton live in aquatic ecosystems, so b matches i. Phytoplankton photosynthesise and form the producer level of aquatic food chains, so c matches iv (Primary Producer).

Step 2: Match the pyramid and test the codes The pyramid of biomass in the sea is commonly inverted: phytoplankton have a small standing crop but rapid turnover. Thus d matches iii. Option (A) misidentifies earthworm, (B) pairs the inverted pyramid with the general ecosystem entry, and (C) incorrectly calls zooplankton primary producers.

Step 3: Conclusion The correct matching is a-ii, b-i, c-iv, d-iii. Hence, the correct option is (D).

Quick Tip to Solve: First pair earthworm with detritivore and phytoplankton with producer, then use the inverted sea-biomass pyramid to select the code.

10. A gene having non-coding introns and coding exons is known as:

[1 mark]

(A) Pseudogene

(B) Structural gene

(C) Split gene

(D) Oncogene

Correct Answer: (C) Split gene

Solution:

Concept:

- A split gene has coding exons interrupted by non-coding introns, a common organisation of eukaryotic genes.

- During RNA processing, introns are removed from the primary transcript and exons are joined by splicing to form mature RNA.

Step 1: Identify the interrupted coding arrangement The important feature in the question is the presence of both introns and exons within a gene. Because introns interrupt the coding regions, the gene is described as split. Splicing removes the intervening introns from the transcript and joins the exons.

Step 2: Distinguish the other terms A pseudogene is a generally non-functional gene-like sequence; this does not define an intron-exon arrangement. A structural gene specifies a functional RNA or protein, but that broad term does not describe the interruption of exons by introns. An oncogene is associated with cancer development. These terms therefore do not specifically name the feature asked about.

Step 3: Conclusion A gene containing non-coding introns and coding exons is called a split gene. Hence, the correct option is (C).

Quick Tip to Solve: Use the cue 'introns interrupt exons': an interrupted coding sequence identifies a split gene, and splicing joins its exons.

11. Golden rice is a promising transgenic crop. When released for cultivation, it will help in: [1 mark]

- (A) Producing petrol-like fuel
- (B) Reduction of Vitamin A deficiency in humans
- (C) Pest resistance
- (D) Herbicide tolerance

Correct Answer: (B) Reduction of Vitamin A deficiency in humans

Solution:

Concept:

- Genetic engineering can improve the nutritional quality of a food crop, an application called biofortification.
- Golden rice accumulates β -carotene in its edible endosperm. This pigment is a precursor of vitamin A in the human body.

Step 1: Connect the engineered nutrient to human nutrition The golden colour of the rice comes from carotenoid accumulation. Its β -carotene can be converted to vitamin A after consumption, so the intended nutritional benefit is to help reduce vitamin A deficiency in people who depend heavily on rice as a staple food.

Step 2: Separate nutritional improvement from other traits Production of petrol-like fuel is not the purpose of golden rice. Pest resistance and herbicide tolerance are possible traits of other genetically modified crops, but they do not explain the defining nutritional feature of golden rice. The answer must identify the vitamin-related benefit rather than a general use of transgenic crops.

Step 3: Conclusion Golden rice can help reduce vitamin A deficiency in humans. Hence, the correct option is (B).

Quick Tip to Solve: Link 'golden' to β -carotene and then to vitamin A; do not confuse nutritional enrichment with pest resistance.

12. Which of the following is not a symptom of Ascariasis?

[1 mark]

- (A) Intestinal blockage
- (B) Muscular pain and fever
- (C) Anaemia
- (D) Skin ulcers

Correct Answer: (D) Skin ulcers

Solution:

Concept:

- Ascariasis is caused by the intestinal roundworm *Ascaris*. Infection occurs when food or water contaminated with its eggs is ingested.
- The listed manifestations of ascariasis include internal bleeding, muscular pain, fever, anaemia and blockage of the intestinal passage.

Step 1: Check the listed symptoms Adult worms inhabit the intestine, and a heavy worm load can block the intestinal passage, so option (A) is a symptom. Muscular pain and fever, named together in (B), and anaemia in (C) are also recognised manifestations of ascariasis in the NCERT account.

Step 2: Apply the negative wording The question asks which condition is **not** a symptom. Skin ulcers are not among the characteristic manifestations of ascariasis, whereas all three other options match the stated symptom list. Therefore the external skin lesion is the exception sought here.

Step 3: Conclusion Skin ulcers are not a characteristic symptom of ascariasis. Hence, the correct option is (D).

Quick Tip to Solve: Underline 'not', then match intestinal blockage, muscular pain with fever, and anaemia to ascariasis; the remaining skin lesion is the answer.

13. For Questions number 13 to 16, two statements are given, one labelled as Assertion (A) and the other labelled as Reason (R). Select the correct answer to these questions from the codes (A), (B), (C) and (D) as given below.

Assertion (A): Repetitive sequences are stretches of DNA sequences that are thought to have no direct coding functions.

Reason (R): They shed light on chromosome structure, dynamics and evolution. [1 mark]

(A) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of the Assertion (A).

(B) Both Assertion (A) and Reason (R) are true, but Reason (R) is not the correct explanation of the Assertion (A).

(C) Assertion (A) is true, but Reason (R) is false.

(D) Assertion (A) is false, but Reason (R) is true.

Correct Answer: (B) Both Assertion (A) and Reason (R) are true, but Reason (R) is not the correct explanation of the Assertion (A).

Solution:

Concept:

- Repetitive DNA consists of nucleotide sequences repeated many times in the genome and is generally described as having no direct coding function.
- A true reason explains an assertion only if it accounts for why the assertion holds; two related true facts need not have that relationship.

Step 1: Evaluate the assertion The assertion states the NCERT description of repetitive sequences: these stretches of DNA are thought to have no direct coding functions. Thus Assertion (A) is true. Absence of a direct coding function does not mean that these regions are useless to the genome or to its study.

Step 2: Evaluate the reason Repetitive sequences provide information about chromosome structure, dynamics and evolution. Thus Reason (R) is also true; it states the biological and investigative significance of these sequences.

Step 3: Test the explanatory link Providing insight into chromosomes does not explain why a sequence lacks a direct coding function. The reason describes its significance, rather than the cause of its non-coding nature. This rules out code (A); codes (C) and (D) each incorrectly declare one of the true statements false.

Step 4: Conclusion Both statements are true, but the reason is not the correct explanation of the assertion. Hence, the correct option is (B).

Quick Tip to Solve: After judging both statements true, ask whether the reason explains the non-coding nature itself; usefulness in chromosome studies does not do so.

14. Assertion (A): Net Primary Productivity (NPP) is always less than Gross Primary Productivity (GPP).

Reason (R): A portion of Gross Primary Productivity (GPP) is used by plants for respiration. [1 mark]

(A) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of the Assertion (A).

(B) Both Assertion (A) and Reason (R) are true, but Reason (R) is not the correct explanation of the Assertion (A).

(C) Assertion (A) is true, but Reason (R) is false.

(D) Assertion (A) is false, but Reason (R) is true.

Correct Answer: (A) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of the Assertion (A).

Solution:

Concept:

- Gross primary productivity (GPP) is the rate of total organic matter production by photosynthesis in an ecosystem.
- Net primary productivity (NPP) is the rate of organic matter production remaining after respiratory loss: $NPP = GPP - R$, where R is the respiratory expenditure of producers in the same units.

Step 1: Evaluate the assertion Plants use some of their photosynthetic production for respiration. After this positive respiratory loss is subtracted, the remaining net production is less than the gross production. Thus the assertion is true in the ecological context of primary productivity.

Step 2: Evaluate the reason The reason states that plants use a portion of GPP for respiration. This is true because producers require energy for maintenance and other life processes, so all of the organic matter produced cannot remain as new biomass.

Step 3: Establish the explanatory link The relationship $NPP = GPP - R$, with $R > 0$, directly gives $NPP < GPP$. Respiratory use is therefore the reason for the difference. Code (B) wrongly denies this explanation, while (C) and (D) incorrectly treat one statement as false.

Step 4: Conclusion Both statements are true, and the reason correctly explains the assertion. Hence, the correct option is (A).

Quick Tip to Solve: Write $NPP = GPP - R$ before choosing the code: the subtracted respiratory loss both proves and explains the assertion.

15. Assertion (A): Activated sludge contains large population of bacteria.

Reason (R): These bacteria help in anaerobic digestion of human waste in biogas plant. [1 mark]

- (A) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of the Assertion (A).
- (B) Both Assertion (A) and Reason (R) are true, but Reason (R) is not the correct explanation of the Assertion (A).
- (C) Assertion (A) is true, but Reason (R) is false.
- (D) Assertion (A) is false, but Reason (R) is true.

Correct Answer: (C) Assertion (A) is true, but Reason (R) is false.

Solution:

Concept:

- Activated sludge is the sediment of microbial flocs formed after aerobic secondary treatment of sewage.
- Aerobic treatment uses oxygen-consuming microbes, whereas anaerobic digestion and methane production require anaerobic microorganisms.

Step 1: Evaluate the assertion During aeration, bacteria grow rapidly in flocs associated with fungal filaments and consume organic matter. When these flocs settle in the settling tank, they form activated sludge. It therefore contains a large bacterial population, so Assertion (A) is true.

Step 2: Evaluate the reason The bacteria responsible for forming activated sludge are predominantly aerobic. Anaerobic digestion of human waste in a biogas plant involves anaerobic microbes, including methane-producing methanogens. It is incorrect to attribute that role to these aerobic activated-sludge bacteria, so Reason (R) is false.

Step 3: Test the explanatory relation The bacterial abundance in activated sludge results from growth during aeration and subsequent settling. A statement about anaerobic biogas digestion cannot explain it. Options (A) and (B) incorrectly accept the reason, while option (D) incorrectly rejects the assertion.

Step 4: Conclusion Assertion is true, but Reason is false. Hence, the correct option is (C).

Quick Tip to Solve: Link activated sludge with aeration and microbial flocs; link biogas production with anaerobic methanogens.

16. Assertion (A): DNA cannot pass through cell membrane of a bacterial cell.

Reason (R): DNA is a hydrophilic molecule.

[1 mark]

- (A) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of the Assertion (A).
- (B) Both Assertion (A) and Reason (R) are true, but Reason (R) is not the correct explanation of the Assertion (A).
- (C) Assertion (A) is true, but Reason (R) is false.
- (D) Assertion (A) is false, but Reason (R) is true.

Correct Answer: (A) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of the Assertion (A).

Solution:

Concept:

- DNA has a negatively charged phosphate backbone and is hydrophilic, so it interacts readily with water.
- The hydrophobic interior of a bacterial cell membrane prevents the free passage of large, charged DNA molecules.

Step 1: Evaluate the assertion Under ordinary conditions, foreign DNA does not pass freely through an untreated bacterial cell membrane. The assertion refers to this natural barrier to DNA uptake, so it is true. Artificial transformation requires the cells to be made competent.

Step 2: Evaluate the reason DNA is hydrophilic because its charged phosphate groups interact with water. It does not readily dissolve in the hydrophobic interior of the lipid membrane. The reason is therefore true.

Step 3: Connect the reason with the assertion DNA's hydrophilic nature explains why it cannot pass freely across the membrane. Thus the reason directly explains the assertion. Option (B) misses this causal link, while options (C) and (D) wrongly declare one of the two statements false. Treatments used to make competent cells enable uptake and do not negate the ordinary membrane barrier.

Step 4: Conclusion Both statements are true, and the reason correctly explains the assertion. Hence, the correct option is (A).

Quick Tip to Solve: For DNA uptake questions, connect the charged, hydrophilic DNA backbone with the membrane's hydrophobic barrier.

Section B (10 marks)

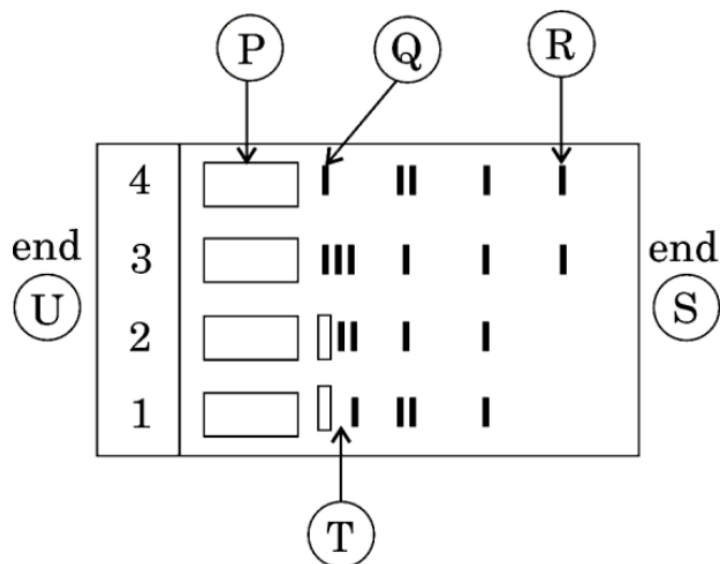
17(a). (i) Given below is the schematic representation of the process of electrophoresis. Identify the alphabets representing the:

(I) Anode end, and

(II) Lightest/Smallest DNA in matrix.

(ii) What is Agarose gel and why is it used in this process?

[2 marks]



Solution:

Concept:

- Negatively charged DNA migrates through agarose gel towards the positively charged anode in an electric field.
- Agarose forms a porous molecular sieve; smaller DNA fragments move through its pores more readily and migrate farther than larger fragments.

Step 1: Identify the anode and smallest fragment (i) The loading wells lie at the left of the diagram, near end U, and the separated bands extend towards the right. Since DNA moves towards the positive electrode, the anode end is S. The band labelled R lies farthest from the loading wells, so R represents the lightest or smallest DNA fragment. A band near the wells, such as Q, has travelled a shorter distance and represents a larger fragment under the same conditions.

Step 2: Explain the nature and role of agarose (ii) Agarose is a natural polymer extracted from seaweeds. It forms a gel matrix with pores through which DNA fragments move during electrophoresis. The matrix provides a sieving effect, separating DNA fragments according to their size: smaller fragments travel farther, whereas larger fragments encounter greater resistance and remain closer to the wells.

Step 3: Conclusion (i) Anode end: S; lightest/smallest DNA fragment: R. (ii) Agarose is a seaweed-derived natural polymer used as a porous sieving matrix to separate DNA fragments by size.

Quick Tip to Solve: First locate the wells: the anode is in the direction of band migration, and the smallest fragment is farthest from the wells.

17(b). After performing gel electrophoresis, a student observes that DNA fragments are not visible.

(i) Suggest a reason for this and explain how fragments can be made visible.

(ii) Also explain how a specific DNA fragment can be collected from the gel for further use. [2 marks]

Solution:

Concept:

- DNA fragments are colourless and cannot be seen directly in an unstained gel under ordinary visible light.
- Ethidium bromide staining followed by ultraviolet illumination reveals DNA bands; elution recovers a selected fragment from the gel.

Step 1: Make the separated fragments visible (i) A likely reason is that the student has not stained the DNA or has not examined the stained gel under ultraviolet light. Separation by electrophoresis does not itself make DNA visible. Stain the gel with ethidium bromide and expose it to ultraviolet radiation. The dye associated with DNA fluoresces, so the separated DNA fragments appear as bright orange-coloured bands at their respective positions in the gel.

Step 2: Recover the desired fragment (ii) Identify the band corresponding to the required DNA fragment and cut that band out of the agarose gel. Extract the DNA from the excised gel piece by elution, separating the DNA from the agarose matrix. The recovered, purified fragment can then be used in a subsequent procedure, such as joining it to a cloning vector to form recombinant DNA.

Step 3: Conclusion Stain with ethidium bromide and view under UV light to reveal DNA bands. Cut out the selected band and recover its DNA by elution for further use.

Quick Tip to Solve: Remember the sequence: stain, illuminate with UV, identify the desired band, excise it, and elute its DNA.

18(a). (i) Rearrange the following in correct order of their appearance on Earth between 2 million years and 40,000 years ago:

Homo Neanderthalensis, *Australopithecus*, *Homo erectus*, *Homo habilis*

(ii) Which one of the above:

(I) had the largest brain size?

(II) ate fruits?

[2 marks]

Solution:

Concept:

- The NCERT account of human evolution places australopithecines before *Homo habilis*, followed by *Homo erectus* and the Neanderthals.
- Brain capacity and diet distinguish these hominid forms; a chronological sequence must be based on their appearance rather than the order given in the question.

Step 1: Arrange the hominids chronologically (i) Begin with *Australopithecus*, the early upright

hominid that lived in East African grasslands. It precedes *Homo habilis*, which had a brain capacity of about 650–800 cm³. Next comes *Homo erectus*, with a brain capacity of about 900 cm³, followed by *Homo neanderthalensis*. Thus the order is *Australopithecus*, *Homo habilis*, *Homo erectus*, and *Homo neanderthalensis*.

Step 2: Identify the requested brain size and diet (ii) (I) Among the four listed forms, *Homo neanderthalensis* had the largest brain, about 1400 cm³. (II) *Australopithecus* mainly ate fruits. Although australopithecines used stone weapons for hunting, NCERT describes their diet as predominantly fruit-based; the reference to hunting should not be confused with a mainly meat-based diet.

Step 3: Conclusion (i) *Australopithecus*, then *Homo habilis*, then *Homo erectus*, then *Homo neanderthalensis*. (ii) Largest brain: *Homo neanderthalensis*; fruit-eater: *Australopithecus*.

Quick Tip to Solve: Recall the sequence Australopithecus–habilis–erectus–Neanderthal, and attach the fruit diet to the first form.

OR

18(b). (i) What is natural selection?

(ii) Explain the type of natural selection that promotes evolutionary change. Give an example.

[2 marks]

Solution:

Concept:

- Natural selection acts on existing heritable variation: individuals with advantageous traits leave more surviving offspring in a particular environment.
- Directional selection favours one extreme phenotype and shifts the population mean towards that extreme over generations.

Step 1: (i) Define natural selection Natural selection is the differential survival and reproduction of individuals possessing favourable heritable variations. Better-adapted individuals contribute more offspring to the next generation, so their advantageous traits become more common. Fitness here means reproductive success in the prevailing environment.

Step 2: (ii) Explain directional selection with an example Directional selection favours individuals at one extreme of the range of variation, progressively shifting the population towards that phenotype. For example, during industrial melanism, soot darkened tree trunks and reduced lichens. Dark peppered moths were better camouflaged from predatory birds than light moths, survived more frequently and produced more offspring. Consequently, the frequency of dark moths increased. Selection favoured pre-existing variation; pollution did not deliberately produce a useful colour change.

Step 3: Conclusion Natural selection favours heritable traits that increase reproductive success. Directional selection promotes a shift towards one extreme, as illustrated by the increase of dark peppered moths in polluted areas.

Quick Tip to Solve: Link directional selection to one favoured extreme and a shifting population mean; use dark moths on soot-covered trunks as the example.

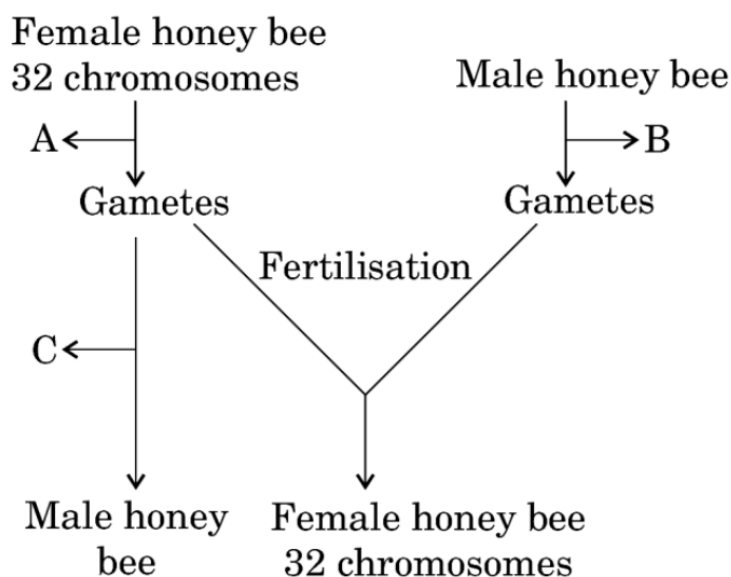
19. Study the schematic cross between male and female honey bee given below and answer the questions that follow.

(a) Identify the cell division 'A' and 'B' that leads to gamete formation.

(b) Name the process 'C' that leads to development of honey bee.

(c) What type of sex-determination pattern is this?

[2 marks]



Solution:

Concept:

- In honey bees, females are diploid with $2n = 32$ chromosomes, whereas males are haploid with $n = 16$ chromosomes.
- Fertilisation restores diploidy; parthenogenesis is development from an unfertilised egg.

Step 1: (a) Identify the divisions A and B A is **meiosis**: the diploid female produces haploid eggs, reducing the chromosome number from 32 to 16. B is **mitosis**: the haploid male produces haploid sperm by mitotic division, retaining 16 chromosomes. A reduction division is not required in the already haploid male.

Step 2: (b) Identify the process C C is **parthenogenesis**. The diagram shows a female gamete developing into a male honey bee without fertilisation. Because no sperm contributes chromosomes, the developing male remains haploid. In contrast, fusion of an egg and a sperm produces a diploid female with 32 chromosomes.

Step 3: (c) Name the sex-determination pattern This is **haplodiploid sex determination**. Sex depends on whether the developing individual has one or two sets of chromosomes: an unfertilised haploid egg forms a male, whereas a fertilised diploid egg forms a female.

Step 4: Conclusion A: meiosis; B: mitosis; C: parthenogenesis. The pattern is haplodiploid sex determination.

Quick Tip to Solve: Trace the unfertilised egg to the male: it immediately identifies parthenogenesis and the haploid male in honey bees.

20(a). A person complains of persistent itching in the groin region and scalp. The person also shows dry and scaly lesions on skin, nails, etc.

(i) Identify the disease.

(ii) Name its two causative agents.

(iii) Mention its mode of transmission.

[2 marks]

Solution:

Concept:

- Ringworm is a superficial fungal infection producing dry, scaly skin lesions and intense itching; it can affect skin, nails and scalp.
- Dermatophyte fungi spread through infective material from infected individuals, contaminated articles or soil, and grow well in warm, moist regions.

Step 1: (i) Identify the disease The disease is **ringworm**. Persistent itching together with dry and scaly lesions on the skin, nails and scalp is characteristic of this fungal infection. Warm, moist skin folds, such as the groin, favour fungal growth. Despite its name, the disease is not caused by a worm.

Step 2: (ii) Name two causative agents Two causative fungal genera are *Microsporum* and *Trichophyton*. These fungi infect superficial keratin-containing tissues, which explains involvement of the skin, hair-bearing scalp and nails.

Step 3: (iii) Describe transmission Infection is acquired by contact with an infected person or contaminated articles such as towels, clothes and combs. Ringworm can also be acquired from soil containing the fungi. Thus, sharing personal articles can transfer infective fungal material to another person's skin or scalp.

Step 4: Conclusion The disease is ringworm, caused by fungi such as *Microsporum* and *Trichophyton*; it spreads through contact with infected persons, contaminated personal articles or soil.

Quick Tip to Solve: Combine itching and scaly lesions with warm, moist skin folds to identify ringworm, then name fungal genera rather than a worm.

OR

20(b). A girl develops sneezing, watery eyes and difficulty in breathing every time she visits a flower garden.

(i) Identify the condition.

(ii) Name the immune component responsible for this condition.

(iii) Name the chemical released.

(iv) State one medicine used to treat such a condition.

[2 marks]

Solution:

Concept:

- Allergy is an exaggerated immune response to otherwise harmless environmental substances called allergens, such as pollen.

- IgE antibodies participate in allergic responses, and mast cells release mediators such as histamine that produce the symptoms.

Step 1: (i) Identify the condition The girl has a **pollen allergy**. Repeated exposure in a flower garden is associated with sneezing, watery eyes and breathing difficulty because airborne pollen acts as an allergen in a sensitised individual. The repeated association with exposure supports an allergic response.

Step 2: (ii) Name the immune component The responsible immune component is **IgE**, or immunoglobulin E. Allergen-specific IgE is associated with mast cells; on subsequent exposure, the allergen triggers release of stored chemical mediators from these cells.

Step 3: (iii) Name the released chemical **Histamine** is released from mast cells. It contributes to increased vascular permeability and other local responses responsible for the watery eyes, nasal symptoms and breathing difficulty during an allergic reaction.

Step 4: (iv) State a medicine An **antihistamine** is used to treat such an allergic condition. It reduces the effects of histamine and therefore helps relieve the associated allergic symptoms.

Step 5: Conclusion (i) Pollen allergy; (ii) IgE antibodies; (iii) histamine; (iv) an antihistamine.

Quick Tip to Solve: Recall the sequence pollen allergen, IgE, mast-cell histamine release and antihistamine treatment to answer all four parts.

21. A child is born with a genetic disorder due to the deletion of a gene.

(a) Name such a gene studied by you. Explain how gene therapy can help in treating such a condition.

(b) Mention one challenge associated with this therapy.

[2 marks]

Solution:

Concept:

- Gene therapy introduces a functional gene into appropriate patient cells to compensate for a defective or missing gene.
- The ADA gene encodes adenosine deaminase, an enzyme necessary for normal immune function; its deletion can cause ADA deficiency.

Step 1: (a) Identify the gene and explain treatment The example is the **adenosine deaminase (ADA) gene**. Its deletion causes ADA deficiency, impairing immune function. For gene therapy, lymphocytes are collected from the patient's blood and grown in culture outside the body. A functional ADA cDNA is introduced into these lymphocytes using a retroviral vector. The genetically modified lymphocytes are then returned to the patient, where expression of the introduced gene enables them to produce functional ADA enzyme and helps restore immune function.

Step 2: (b) State a challenge The genetically modified lymphocytes are not immortal: they survive for a limited period. Therefore, this treatment does not provide a permanent supply of corrected cells, and the patient requires periodic infusions of genetically engineered lymphocytes. Introducing a working gene into these cells compensates for the enzyme deficiency but does not correct every cell in the child's body.

Step 3: Conclusion Deletion of the ADA gene can be treated by introducing functional ADA cDNA into cultured patient lymphocytes and reinfusing them. A major challenge is the need for repeated infusions because these corrected lymphocytes have a limited lifespan.

Quick Tip to Solve: Remember the ADA sequence: isolate lymphocytes, culture them, introduce ADA cDNA using a retrovirus, reinfuse, and repeat as cells die.

Section C (21 marks)

22. Draw a neat diagram of a maize grain showing the internal structure and label any five parts.

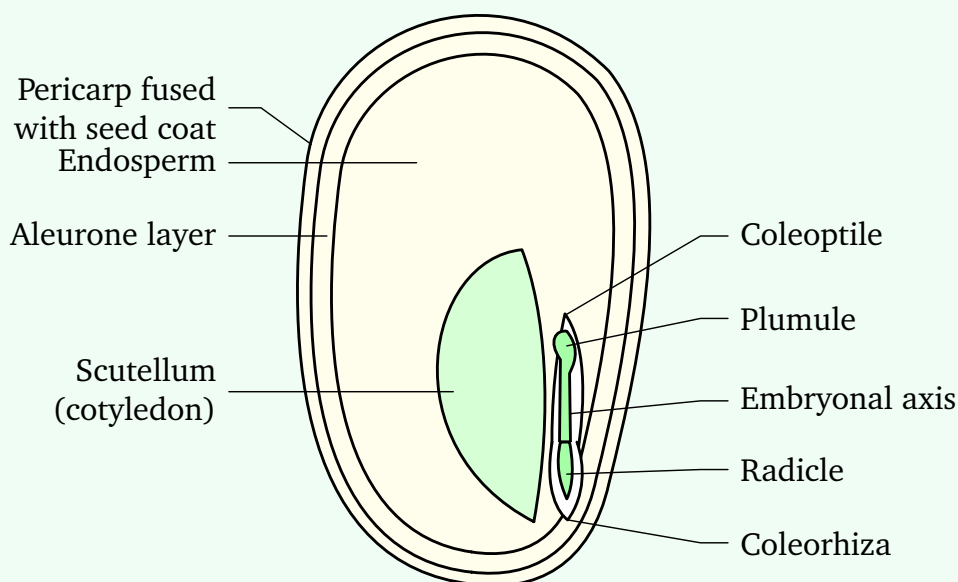
[3 marks]

Solution:

Concept:

- Maize is a monocotyledonous, endospermic grain. Its fruit wall (pericarp) is fused with the thin seed coat, forming the outer covering.
- The large endosperm stores food. Its peripheral protein-rich layer is the aleurone layer, while the embryo lies toward one side near the lower end.
- The embryo has one cotyledon, the scutellum, and an embryonal axis bearing the plumule and radicle. The coleoptile and coleorhiza protect the plumule and radicle respectively.

Step 1: Draw the grain in longitudinal section Draw the outer fused pericarp and seed coat enclosing the grain. Show a narrow aleurone layer just inside this covering and a large central endosperm. Place the embryo toward one side of the lower portion, with the shield-shaped scutellum between the endosperm and the embryonal axis. The diagram below shows the internal relationships; the embryo is enlarged to make its parts clear.



Longitudinal section of a maize grain (schematic)

Step 2: Label the embryo and storage tissue Label the scutellum as the single cotyledon. At the upper end of the embryonal axis show the plumule within the coleoptile; at its lower end show the radicle enclosed by the coleorhiza. The endosperm must occupy most of the grain, rather than being drawn as part of the embryo. The labelled outer covering, aleurone layer, endosperm, scutellum and plumule already provide five distinct parts; the remaining embryo labels make the structure complete.

Step 3: Conclusion The labelled longitudinal section shows the internal structure of maize grain, including the fused pericarp and seed coat, aleurone layer, endosperm, scutellum, plumule, radicle and their protective sheaths.

Quick Tip to Solve: Place the scutellum next to the endosperm, then draw the plumule above the radicle; label their sheaths as coleoptile and coleorhiza respectively.

23. In vitro fertilization (IVF) is a popular method these days that is helping childless couples to bear a child.

(a) Write the different steps that are carried out in this technique.

(b) Would you consider gamete intra fallopian transfer as a type of IVF? Justify your answer. [3 marks]

Solution:

Concept:

- In vitro fertilisation (IVF) means fertilisation outside the body under laboratory conditions similar to those in the body. It is followed by embryo transfer (ET).
- In vivo fertilisation takes place inside the female reproductive tract. The site where the gametes fuse distinguishes IVF from gamete intrafallopian transfer (GIFT).

Step 1: Collect gametes and carry out fertilisation: part (a) Ova are collected from the wife or a suitable female donor, and sperms are collected from the husband or a suitable male donor. In the laboratory, the ova and sperms are brought together under suitable conditions so that fertilisation produces a zygote. Thus, fusion of the gametes occurs outside the woman's body. The zygote is then allowed to undergo early cleavage in culture.

Step 2: Transfer the developing embryo: part (a) The zygote or early embryo with up to eight blastomeres is transferred into the fallopian tube; this is zygote intrafallopian transfer (ZIFT). An embryo with more than eight blastomeres is transferred into the uterus; this is intrauterine transfer (IUT). These are alternative transfer sites selected according to the developmental stage. Further development and implantation allow pregnancy to continue within the woman.

Step 3: Distinguish GIFT from IVF: part (b) GIFT is not a type of IVF. In GIFT, an ovum collected from a donor is transferred into the fallopian tube of a woman who cannot produce ova but can provide a suitable environment for fertilisation and further development. Fertilisation then takes place inside her body, that is, in vivo. The transfer involves an unfertilised gamete rather than a zygote or embryo formed by laboratory fertilisation.

Step 4: Conclusion IVF comprises gamete collection, fertilisation and early development in the laboratory, followed by embryo transfer. GIFT is distinct because fertilisation occurs inside the fallopian tube, not in vitro.

Quick Tip to Solve: Ask where sperm and ovum fuse: outside the body indicates IVF; transfer of an unfertilised ovum followed by fusion inside the body indicates GIFT.

24. (a) Describe the experiment conducted by T.H. Morgan on *Drosophila melanogaster* involving eye colour and body colour.

(b) How did the results deviate from Mendelian inheritance pattern?

(c) Explain the two genetic terms used by Morgan for his observations.

[3 marks]

Solution:

Concept:

- Mendel's law of independent assortment predicts independent inheritance of two gene pairs when the genes are unlinked. Morgan tested inheritance of pairs of traits in *Drosophila melanogaster*.
- Genes located on the same chromosome are physically associated. Crossing over between homologous chromosomes can separate their alleles and produce new combinations.

Step 1: Describe Morgan's dihybrid cross: part (a) Morgan crossed yellow-bodied, white-eyed female fruit flies with brown-bodied, red-eyed males. The body-colour and eye-colour genes under study were located on the X chromosome. He obtained the F_1 generation and intercrossed the F_1 progeny, then examined the combinations of body colour and eye colour in the F_2 offspring. Comparing the parental combinations with the new combinations allowed him to test whether the two genes assorted independently.

Step 2: Identify the departure from independent assortment: part (b) The two genes did not segregate independently, so Morgan did not obtain the Mendelian dihybrid phenotypic ratio of 9 : 3 : 3 : 1. The parental combinations, yellow body with white eyes and brown body with red eyes, were much more frequent than the non-parental combinations. The low proportion of recombinants showed that the two genes were tightly linked rather than behaving as independently assorting gene pairs.

Step 3: Explain linkage and recombination: part (c) **Linkage** is the physical association of two genes on the same chromosome, which makes their parental allele combinations tend to be inherited together. **Recombination** is the generation of non-parental combinations of genes or alleles. For linked genes, crossing over between non-sister chromatids of homologous chromosomes during meiosis can generate these new combinations. Closely situated genes show stronger linkage and less recombination than genes farther apart on the same chromosome.

Step 4: Conclusion Morgan's body-colour and eye-colour cross produced an excess of parental combinations and a departure from independent assortment. He described the association of genes as linkage and the production of non-parental combinations as recombination.

Quick Tip to Solve: Remember the sequence: parental combinations in excess indicate linkage; the less frequent new combinations are recombinants produced through crossing over.

25. Answer the following questions:

(a) Explain the different ways by which apomictic seeds can be developed.

(b) Mention one advantage of apomictic seeds for farmers.

[3 marks]

Solution:

Concept:

- Apomixis is a form of asexual reproduction that mimics sexual reproduction by producing seeds without fertilisation.
- An apomictic embryo may originate from an unreduced egg or directly from a diploid maternal cell of the ovule; sexual fusion is not needed to form that embryo.

Step 1: (a) Describe embryo formation from a diploid egg In some flowering plants, the diploid egg cell is formed without reduction division, so it retains the maternal chromosome number. This unreduced egg develops directly into an embryo without being fertilised by a male gamete. Thus, meiosis and fertilisation are bypassed in the formation of the apomictic embryo.

Step 2: (a) Describe embryo formation from nucellar cells In plants such as Citrus and mango, some diploid nucellar cells surrounding the embryo sac begin to divide. They protrude into the embryo sac and develop directly into embryos. Each embryo formed from a nucellar cell is of maternal origin and develops without fertilisation. More than one embryo can consequently occur within a seed; the occurrence of several embryos in a seed is called polyembryony.

Step 3: (b) Explain the benefit for farmers If apomixis is introduced into a hybrid crop, the favourable combination of characters of the hybrid can be maintained in its seed progeny. The embryo is produced asexually, so the hybrid characters do not segregate as they would during normal sexual seed formation. Farmers can therefore use seeds harvested from the hybrid crop for repeated sowing while retaining its desirable traits, reducing the need to buy costly hybrid seed every season.

Step 4: Conclusion Apomictic seeds can develop through an unfertilised diploid egg or through embryos formed directly from nucellar cells. Their agricultural advantage is the maintenance of desirable hybrid characters, allowing farmers to reuse hybrid seeds.

Quick Tip to Solve: State the embryo's origin in each route: an unreduced egg in one and a diploid nucellar cell in the other. Link the farmer's benefit to the absence of segregation of hybrid characters.

26. (a) What is meant by translation in protein synthesis?

(b) Explain charging of tRNA (aminoacylation of tRNA) and mention its importance in the process of translation.

[3 marks]

Solution:

Concept:

- The sequence of codons in messenger RNA (mRNA) specifies the sequence of amino acids in a polypeptide. A ribosome is the site of translation.
- Transfer RNA (tRNA) acts as an adaptor: its anticodon recognises an mRNA codon, while its amino acid attachment site carries the corresponding amino acid.

Step 1: (a) Define translation Translation is the process in which amino acids are polymerised into a polypeptide according to the sequence of codons in mRNA. At the ribosome, charged tRNAs recognise the appropriate codons through complementary codon–anticodon pairing and deliver their amino acids. Peptide bonds join successive amino acids to form the growing polypeptide chain.

Step 2: (b) Explain aminoacylation of tRNA Before translation, an amino acid is activated using energy from ATP and attached to its specific tRNA by the enzyme aminoacyl-tRNA synthetase. The amino acid is linked to the terminal adenosine at the 3' CCA end of the tRNA. The resulting aminoacyl-tRNA is called a charged tRNA, and this preparatory process is called charging or aminoacylation of tRNA. The enzyme's specificity ensures that the correct amino acid is attached to the appropriate tRNA.

Step 3: (b) Explain why charging is essential Charging supplies the ribosome with amino acids carried by their proper adaptors, so the amino acids can be placed in the order specified by the mRNA. It also stores energy from ATP in the linkage between the amino acid and tRNA. This activated linkage provides energy for peptide-bond formation during chain elongation. Thus, charging contributes both to the accuracy of translation and to the energy required to link amino acids into a protein.

Step 4: Conclusion Translation converts the codon sequence of mRNA into an amino acid sequence. ATP-dependent attachment of each amino acid to its specific tRNA prepares the correct, activated aminoacyl-tRNA needed for accurate polypeptide synthesis.

Quick Tip to Solve: For charging, name all three essentials: the specific amino acid and tRNA, aminoacyl-tRNA synthetase, and ATP. Then connect charging to accuracy and peptide-bond formation.

27. Study the following cases:

Case I: A person bitten by a rabid dog is immediately given an injection of antitoxin for rabies.

Case II: A child is given rabies vaccine as a preventive measure.

(a) Identify the type of immunity provided in both the cases.

(b) Differentiate between the two types of immunity.

(c) What is a vaccine? How does it help in preventing a disease?

[3 marks]

Solution:

Concept:

- Active immunity results when the body's own immune system responds to an antigen and produces specific antibodies and memory cells.
- Passive immunity results from the transfer of ready-made antibodies. It provides rapid protection but does not itself generate immunological memory in the recipient.

Step 1: (a) Identify the immunity in each case **Case I: Artificially acquired passive immunity.** The injection described supplies ready-made protective antibodies against rabies, so the person need not first produce these antibodies.

Case II: Artificially acquired active immunity. The rabies vaccine introduces antigens that stimulate the child's own immune system to produce a specific protective response.

Step 2: (b) Compare the two responses Passive immunity acts immediately because antibodies are supplied directly, but its protection is temporary as the transferred antibodies are gradually broken down. It does not itself produce memory cells in the recipient. Active immunity develops more slowly during the initial response because the body must recognise the antigen and activate specific lymphocytes. It is generally longer lasting because memory cells are formed, enabling a faster and stronger response on subsequent exposure to the same antigen.

Step 3: (c) Define a vaccine and explain its action A vaccine is a preparation containing antigenic material of a pathogen, such as killed or weakened microorganisms or their antigenic proteins, that stimulates protective immunity. Its antigens activate specific lymphocytes, leading to antibody production and the formation of memory B and T cells. If the actual pathogen enters later, these memory cells produce a rapid, intensified secondary immune response that helps eliminate it before the disease develops. Thus, vaccination uses the specificity and memory of the immune system to prevent disease.

Step 4: Conclusion Case I provides artificial passive immunity through supplied antibodies, whereas Case II provides artificial active immunity through vaccination. Passive protection is immediate and temporary; active protection develops through the recipient's own response and creates immune memory.

Quick Tip to Solve: Identify what is injected: ready-made antibodies imply passive immunity; pathogen antigens in a vaccine imply active immunity and memory-cell formation.

28. (a) What is the carrying capacity of a species in a habitat?

(b) Explain the growth curve that takes this capacity into account.

[3 marks]

Solution:

Concept:

- Carrying capacity, denoted by K , is the maximum population size of a species that the resources of a habitat can sustain.
- Logistic growth incorporates resource limitation: $\frac{dN}{dt} = rN \left(\frac{K - N}{K} \right)$, where N is population size, t is time and r is the intrinsic rate of natural increase.

Step 1: (a) Define carrying capacity A habitat has finite food, water, space and other resources. Its carrying capacity is the maximum number of individuals of a particular species that it can support sustainably under the prevailing environmental conditions. It is represented by K ; it depends on both the species and the habitat.

Step 2: (b) Explain the phases of logistic growth When a small population establishes itself in a habitat with limited resources, it first shows a lag phase. It then increases rapidly in an acceleration phase. As population density rises, competition for the limited resources intensifies and the growth rate slows during the deceleration phase. Finally, the population approaches the carrying capacity and enters an asymptote or stationary phase. A plot of population size against time therefore gives an S-shaped or sigmoid curve.

Step 3: Relate the curve to its equation The Verhulst–Pearl logistic equation is

$$\frac{dN}{dt} = rN \left(1 - \frac{N}{K} \right).$$

When N is small compared with K , the resource-limitation factor is close to one and growth can be rapid. As N approaches K , this factor approaches zero. At $N = K$, net population growth is zero because the available resources support no further sustained increase.

Step 4: Conclusion The carrying capacity K is the sustainable population limit of the habitat. Logistic growth accounts for this limit and produces a sigmoid curve that levels off at K .

Quick Tip to Solve: Link the flat upper part of the sigmoid curve to $N = K$: the logistic growth factor then becomes zero.

Section D (8 marks)

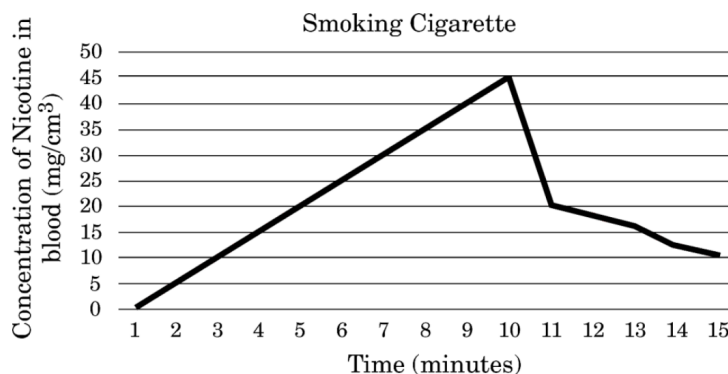
Questions No. 29 and 30 are Case-Based questions. Each question has 3 sub-questions with internal choice in one sub-question.

29(a)(i). Read the following passage and answer the question that follow:

The data below shows the concentration of nicotine smoked by a smoker taking 10 puffs/minute.

With reference to the above graph, explain the concentration of nicotine in the blood at 10 minutes.

[1 mark]



Solution:

Concept:

- The ordinate of the plotted line gives the blood nicotine concentration at the time shown on the horizontal axis.
- Repeated inhalation of tobacco smoke allows nicotine to enter the blood through the lungs and accumulate during smoking.

Step 1: Read the value at ten minutes Locate 10 minutes on the time axis and trace vertically to the plotted line. The intersection is at the highest point of the curve and corresponds to 45 mg cm^{-3} on the concentration axis.

Step 2: Explain the peak The smoker has been taking repeated puffs, so nicotine has continued to

enter the blood. By ten minutes its uptake has produced the maximum concentration shown in this graph. After this point the plotted concentration falls; the value at ten minutes must be read at the peak, rather than from the following descending segment.

Step 3: Conclusion At 10 minutes, the nicotine concentration reaches its plotted maximum of approximately 45 mg cm^{-3} , due to nicotine uptake during repeated smoking.

Quick Tip to Solve: For the ten-minute reading, move up from 10 to the peak and then across to the vertical axis; retain the printed unit.

OR

29(a)(ii). Read the following passage and answer the question that follow:

The data below shows the concentration of nicotine smoked by a smoker taking 10 puffs/minute.

How will this affect the concentration of carbon monoxide and haem-bound oxygen at 10 minutes?

[1 mark]

Solution:

Concept:

- Tobacco smoke contains carbon monoxide, which enters the blood when smoke is inhaled.
- Carbon monoxide binds strongly to haemoglobin, reducing the amount of haemoglobin available to carry oxygen.

Step 1: Identify the change in carbon monoxide By ten minutes, repeated inhalation of cigarette smoke increases the carbon monoxide concentration in the blood. This accompanies exposure to tobacco smoke; the nicotine curve itself does not give a numerical carbon monoxide concentration.

Step 2: Explain the effect on oxygen transport Carbon monoxide forms carboxyhaemoglobin by occupying oxygen-binding sites on haemoglobin. Consequently, the concentration of haem-bound oxygen decreases and the blood transports less oxygen to body tissues.

Step 3: Conclusion At ten minutes, blood carbon monoxide increases, whereas haem-bound oxygen decreases, lowering the oxygen-carrying capacity of blood.

Quick Tip to Solve: Remember the opposite directions: more carbon monoxide binding to haemoglobin means less haemoglobin-bound oxygen.

29(b). Read the following passage and answer the question that follow:

The data below shows the concentration of nicotine smoked by a smoker taking 10 puffs/minute.

How does cigarette smoking result in high blood pressure and increase in heart rate?

[1 mark]

Solution:

Concept:

- Nicotine is an active constituent of tobacco and stimulates the adrenal glands.

- The adrenal medulla releases the catecholamines adrenaline and noradrenaline, which produce sympathetic effects.

Step 1: Trace the hormonal trigger Nicotine absorbed from cigarette smoke reaches the blood and stimulates the adrenal glands to release adrenaline and noradrenaline into the circulation.

Step 2: Connect the hormones to cardiovascular effects These hormones stimulate cardiac activity, increasing the rate and force of heart contraction. They also cause constriction of blood vessels in several vascular beds, increasing resistance to blood flow. Their combined effects raise blood pressure and increase heart rate.

Step 3: Conclusion Cigarette smoking supplies nicotine, which stimulates adrenal release of adrenaline and noradrenaline; these hormones raise blood pressure and heart rate.

Quick Tip to Solve: Use the sequence nicotine, adrenal glands, adrenaline/noradrenaline, increased blood pressure and heart rate.

29(c). Read the following passage and answer the question that follow:

The data below shows the concentration of nicotine smoked by a smoker taking 10 puffs/minute. To which class of compounds does nicotine belong? Name one other drug from the same class.

[2 marks]

Solution:

Concept:

- Alkaloids are naturally occurring nitrogen-containing organic compounds, many obtained from plants and having physiological effects.
- A chemical class groups compounds by their chemical nature; drugs in the same chemical class need not have the same effects on the nervous system.

Step 1: Identify the class of nicotine Nicotine is a tobacco alkaloid. Thus the requested class of compounds is alkaloids. Its stimulating action describes a physiological effect, whereas alkaloid identifies its chemical class.

Step 2: Give another drug from that class Morphine is another alkaloid. It is obtained from the latex of the opium poppy, *Papaver somniferum*, and belongs to the opioid group of drugs. Although morphine has effects different from those of nicotine, both are nitrogen-containing plant alkaloids; they therefore satisfy the same chemical-class criterion asked in the question.

Step 3: Conclusion Nicotine belongs to the alkaloids. Morphine is another drug belonging to this class.

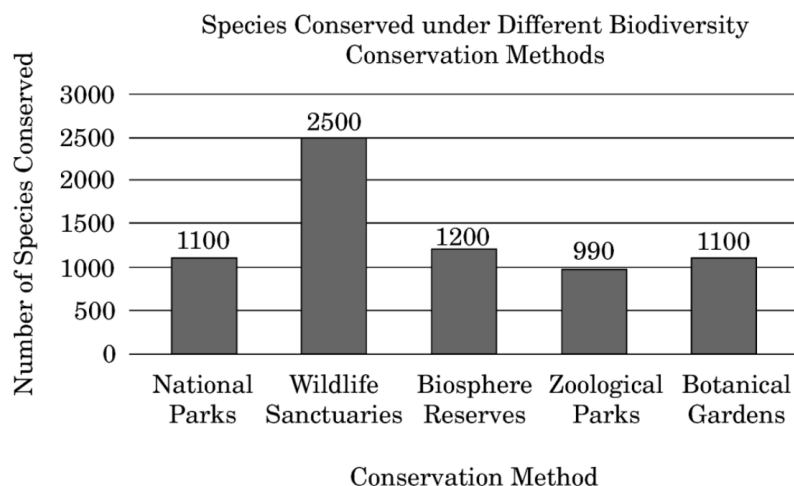
Quick Tip to Solve: When asked for the class of compounds, answer alkaloids and name morphine; distinguish chemical class from stimulant or depressant action.

30. Read the following passage and answer the questions that follow:

India is one of the megadiverse countries housing around 8.1 per cent of global species diversity, although its land area is only 2.4 per cent of the world's land area. Many of the species are highly threatened due to human activities like deforestation, mining and habitat fragmentation. Laws like Wildlife (Protection) Act, 1972 were enacted by the Government of India to preserve our biological wealth. Various conservation measures are being implemented to save the threatened species.

The following bar graph shows the number of species conserved under different biodiversity conservation methods.

[4 marks]



Study the graph and answer the questions.

30(a). Which method conserves the highest number of species? Is it *ex situ* or *in situ* conservation?

[1 mark]

Solution:

Concept:

- The tallest bar represents the conservation method with the largest number of conserved species.
- In situ conservation protects species within their natural habitats, whereas ex situ conservation protects them outside those habitats.

Step 1: Compare the species counts The wildlife sanctuaries bar reaches 2500 species. It is higher than biosphere reserves at 1200, national parks and botanical gardens at 1100 each, and zoological parks at 990. Thus the largest count belongs to wildlife sanctuaries.

Step 2: Classify the conservation method Wildlife sanctuaries protect wild organisms within the natural habitats where they live. This preserves species along with their habitat and ecological interactions, so it is an example of in situ conservation.

Step 3: Conclusion Wildlife sanctuaries conserve the highest number of species, 2500, and represent in situ conservation.

Quick Tip to Solve: Read the number above the tallest bar, then classify its method by whether organisms remain in their natural habitat.

30(b). Which other methods shown in the diagram are opposite to the one identified by you in question (a)? How are these two conservation approaches different? [2 marks]

Solution:

Concept:

- In situ conservation protects species within their natural habitats and conserves the ecological community along with them.
- Ex situ conservation protects threatened organisms outside their natural habitats under human care and management.

Step 1: Identify the opposite approach in the graph Wildlife sanctuaries use in situ conservation. The opposite approach in the graph is ex situ conservation, practised by zoological parks for animals and botanical gardens for plants. These organisms are maintained outside their original natural habitats.

Step 2: Compare where and how conservation occurs In situ conservation maintains populations in their natural ecosystems and protects their habitats and ecological interactions, as in wildlife sanctuaries. Ex situ conservation maintains organisms outside their natural habitats under managed conditions, enabling specialised care, propagation or captive breeding.

Step 3: Conclusion Zoological parks and botanical gardens practise ex situ conservation: protection outside natural habitats. In situ conservation protects species within their natural habitats.

Quick Tip to Solve: Classify each method by its location: natural habitat means in situ, while a managed collection outside it means ex situ.

30(c)(i). Write two features of Biodiversity hotspots. [1 mark]

Solution:

Concept:

- A biodiversity hotspot is a region with exceptional biodiversity, including many endemic species, that faces a serious threat of habitat loss.
- Endemic species are naturally restricted to a particular geographical region and do not occur naturally elsewhere.

Step 1: State the biological feature Hotspots show very high species richness and a high degree of endemism. They contain many species, including a large proportion confined to that region, making the region especially important for biodiversity conservation.

Step 2: State the threat feature Hotspots face severe habitat loss and destruction. Their distinctive biodiversity is therefore highly threatened; loss of the remaining habitat can cause the extinction of species found nowhere else.

Step 3: Conclusion Two features are exceptionally high species richness with high endemism, and a high degree of threat from habitat loss or destruction.

Quick Tip to Solve: Remember both sides of a hotspot: exceptional endemic diversity and exceptional threat from habitat loss.

30(c)(ii). To which category do sacred groves belong and how do they help in bio-conservation?

[1 mark]

Solution:

Concept:

- In situ conservation protects organisms in their natural habitats together with their ecological communities.
- Sacred groves are forest patches protected by local communities because of religious beliefs and cultural traditions.

Step 1: Classify sacred groves Sacred groves belong to in situ conservation because the plants, animals and other organisms remain protected within their original forest habitats rather than being moved into artificial collections.

Step 2: Explain their conservation role Religious and cultural restrictions discourage tree felling and disturbance within these groves. They preserve natural vegetation and provide refuges for many organisms, including rare and threatened species, thereby conserving biodiversity and its gene pool.

Step 3: Conclusion Sacred groves are an in situ conservation method. Community protection of these forest patches preserves natural habitats and provides refuges for rare and threatened species.

Quick Tip to Solve: Link the community's protection of a forest patch to preservation of species in their own natural habitat.

Section E (15 marks)

31(a). (i) Explain any two basic principles/core techniques on which biotechnology is based.

(ii) Describe any three key tools used in Recombinant DNA technology.

[5 marks]

Solution:

Concept:

- Modern biotechnology combines genetic engineering with the maintenance of sterile conditions for growing selected cells on a large scale.
- Recombinant DNA technology requires enzymes to cut and join DNA, a vector to carry it, and a suitable host to multiply and express the introduced gene.

Step 1: (i) Explain genetic engineering Genetic engineering involves changing the chemistry of genetic material, DNA or RNA, introducing it into a host organism, and thereby altering the host's phenotype. A useful gene can be isolated from a donor, joined to a carrier DNA molecule and transferred into a recipient cell. Once maintained and expressed in the recipient, the introduced gene confers the desired characteristic or enables production of a useful product. This allows selected genes to be transferred without bringing all the unwanted genes of the donor along with them.

Step 2: (i) Explain sterile bioprocessing The second core technique is the maintenance of a sterile, contamination-free environment in chemical engineering processes. Only the desired microorganism

or eukaryotic cell is allowed to grow in large quantities for producing products such as antibiotics, vaccines and enzymes. Sterility prevents unwanted microbes from competing with the production organism or contaminating its product. Controlled nutrient supply, temperature, pH and aeration in a bioreactor support efficient large-scale growth and product formation.

Step 3: (ii) Describe the enzymes Restriction endonucleases act as molecular scissors: they recognise specific DNA sequences, commonly palindromic recognition sites, and cut DNA at defined positions. Cutting donor DNA and the vector with the same suitable enzyme can generate compatible ends. DNA ligase then seals the sugar-phosphate backbones, joining the desired DNA fragment to the vector to form recombinant DNA. DNA polymerase synthesises DNA using a template and is useful when DNA must be amplified. Thus, these enzymes provide the cutting, joining and copying activities needed for DNA manipulation.

Step 4: (ii) Describe the cloning vector A cloning vector carries the foreign DNA into the host and enables it to be replicated. Plasmids and bacteriophages are commonly used vectors. An origin of replication allows replication inside the host; a selectable marker helps identify cells that have taken up the vector; and suitable cloning sites allow insertion of the desired DNA. For example, an antibiotic-resistance marker permits transformed bacterial cells to be selected on a medium containing that antibiotic.

Step 5: (ii) Describe the competent host A suitable host cell, such as *Escherichia coli*, receives the recombinant vector and supplies the cellular machinery for its replication and, when required, expression of the foreign gene. The host must be made competent to take up DNA. Bacterial cells may be treated with divalent calcium ions, incubated with recombinant DNA on ice and briefly heat-shocked to facilitate DNA entry. Selected transformed cells are then cultured to obtain many copies of the recombinant DNA or the required gene product.

Step 6: Conclusion The two core techniques are genetic engineering and sterile, controlled bioprocessing. Three key tools of recombinant DNA technology are DNA-manipulating enzymes, cloning vectors and competent host cells; together they allow a desired gene to be isolated, transferred, multiplied and expressed.

Quick Tip to Solve: Remember the tools as cut and join (enzymes), carry (vector), and multiply or express (host); keep these separate from the two core principles.

31(b). “Early and accurate diagnosis of diseases is vital in medical technology.”

(i) Name the conventional methods of diagnosis and their disadvantages.

(ii) Which three diagnostic techniques have been developed through Biotechnology? Explain how each one helps in detecting diseases.

[5 marks]

Solution:

Concept:

- Early diagnosis requires detection of a pathogen or disease-associated molecule even when it is present in a very small amount and symptoms have not appeared.
- PCR amplifies a specific nucleic-acid sequence; nucleic-acid probes recognise complementary sequences; ELISA uses specific antigen–antibody interactions.

Step 1: (i) Identify conventional diagnostic methods and their limitations Conventional methods include serum and urine analysis, such as routine biochemical tests. These methods often cannot detect a disease at an early stage, when the concentration of the pathogen or its products is very low. By the time sufficient pathogen multiplication has occurred to produce detectable changes and visible symptoms, the disease may already be established. Thus, their main disadvantage in this context is inadequate sensitivity for very early diagnosis.

Step 2: (ii) Explain detection by polymerase chain reaction Polymerase chain reaction (PCR) makes many copies of a selected DNA sequence by repeated cycles of denaturation, primer annealing and extension. Even a minute amount of pathogen nucleic acid can therefore yield a detectable amplification product, enabling detection before symptoms become evident. For an RNA virus such as HIV, reverse transcription first converts viral RNA to complementary DNA, which is then amplified. PCR also helps detect mutations in genes associated with cancer and other genetic disorders.

Step 3: Explain detection using recombinant DNA technology and probes A labelled single-stranded DNA or RNA probe is designed to be complementary to a specific gene sequence. DNA from the patient is denatured to single strands, and the probe is allowed to hybridise with it. In the NCERT example, a radioactive probe binds to its complementary normal sequence, and the hybrid is detected by autoradiography. A clone containing a mutated sequence that prevents complementary pairing does not bind that probe and hence does not appear on the photographic film. Sequence-specific hybridisation thus helps identify disease-associated genetic changes.

Step 4: Explain detection by ELISA Enzyme-linked immunosorbent assay (ELISA) is based on specific antigen–antibody binding. Infection can be detected by testing for the pathogen’s antigens or for antibodies made by the patient against that pathogen. An enzyme-linked component produces a measurable colour reaction after addition of its substrate, revealing the specific binding event. This makes even small quantities of the relevant antigen or antibody detectable, although antibody detection depends on antibodies having developed after infection.

Step 5: Conclusion Conventional serum and urine analyses may miss early disease. The three biotechnology-based techniques are PCR, recombinant DNA technology using labelled probes, and ELISA; they detect disease through nucleic-acid amplification, complementary sequence recognition, and antigen–antibody recognition, respectively.

Quick Tip to Solve: Link each technique to its key action: PCR copies, probes pair with complementary sequences, and ELISA detects antigen–antibody binding.

32(a). (i) Describe the series of experiments conducted by Frederick Griffith. Comment on the significance of the result obtained.

(ii) State the contribution of Avery, MacLeod and McCarty.

[5 marks]

Solution:

Concept:

- Transformation is a heritable change in a cell caused by uptake of genetic material from another cell.
- In pneumococcus, the smooth (S) strain has a polysaccharide capsule and is virulent; the rough (R) strain lacks the capsule and is non-virulent.
- Selective destruction of proteins, RNA or DNA tests which substance is essential for the transforming activity.

Step 1: (i) Describe Griffith's experimental material and controls Frederick Griffith worked with *Streptococcus pneumoniae*, the bacterium that causes pneumonia. The S strain forms smooth colonies because it possesses a polysaccharide coat; the R strain forms rough colonies and lacks this coat. He injected mice with different preparations of these bacteria and compared their survival. Live S bacteria killed the mice, whereas live R bacteria did not kill them. These experiments established the difference in virulence of the two strains.

Step 2: Describe the heat-killed and mixed injections Mice injected with heat-killed S bacteria survived, showing that dead S bacteria alone did not cause the disease. However, mice injected with a mixture of live R bacteria and heat-killed S bacteria died. Griffith recovered living S bacteria from the dead mice.

Step 3: State the significance of transformation A substance from the dead S bacteria had transformed some living R bacteria into living, virulent S bacteria capable of synthesising the smooth polysaccharide coat. This new character was inherited by their descendants. Griffith therefore demonstrated a transfer of hereditary information through a transforming principle. His work established transformation, but he did not determine the chemical identity of the transforming substance.

Step 4: (ii) Explain Avery, MacLeod and McCarty's contribution Oswald Avery, Colin MacLeod and Maclyn McCarty investigated the biochemical nature of Griffith's transforming principle. They purified proteins, RNA and DNA from heat-killed S bacteria and tested the fractions for their ability to transform R bacteria. The DNA fraction could produce transformation. Treatment with proteases, which digest proteins, or with RNases, which digest RNA, did not abolish transformation. Treatment with DNase, which digests DNA, abolished transforming activity. They therefore concluded that DNA was the transforming principle and the hereditary material responsible for this change, rather than protein or RNA.

Step 5: Conclusion Griffith demonstrated heritable transformation of non-virulent R bacteria into virulent S bacteria by material from heat-killed S cells. Avery, MacLeod and McCarty identified DNA as that transforming material through biochemical purification and enzyme-treatment experiments.

Quick Tip to Solve: Remember the decisive comparisons: live R plus dead S yields living S; only DNase abolishes transformation in the biochemical test.

32(b). The following questions are based on haemophilia.

(i) Work out the crosses between:

(I) Normal female and Haemophilic male

(II) Carrier female and Normal male

(III) Carrier female and Haemophilic male

(ii) Write the conclusions you draw from these crosses. Comment on the type of inheritance of the disease.

(Use: X - Normal, X^h - Haemophilic)

[5 marks]

Solution:

Concept:

- Haemophilia is an X-linked recessive disorder. Using the question's notation, X carries the normal allele and X^h carries the haemophilia allele; Y lacks the corresponding allele.
- Females are XX (normal, non-carrier), XX^h (unaffected carrier), or X^hX^h (haemophilic). Males are XY (normal) or X^hY (haemophilic).
- Each offspring receives one sex chromosome from each parent. A father contributes his X chromosome to daughters and his Y chromosome to sons; the mother contributes an X chromosome to both.

Step 1: (i)(I) Cross a normal female with a haemophilic male The normal female is non-carrier, so the parental cross is

$$XX \times X^hY.$$

All her eggs carry X , whereas the male produces X^h -bearing and Y -bearing sperm in equal proportions. Fertilisation gives XX^h daughters and XY sons in a 1 : 1 ratio. Thus all daughters are phenotypically normal carriers and all sons are normal. No child is haemophilic. The two identical egg entries in the Punnett square show that either maternal X chromosome has the normal allele.

Egg / Sperm	X^h	Y
X	XX^h Carrier daughter	XY Normal son
X	XX^h Carrier daughter	XY Normal son

Cross (I): $XX \times X^hY$. Each offspring cell represents one-quarter of all children.

Step 2: (i)(II) Cross a carrier female with a normal male The parental cross is

$$XX^h \times XY.$$

The eggs carry either X or X^h ; the sperm carry either X or Y . The four equally likely genotypes are XX , XX^h , XY and X^hY , in a 1 : 1 : 1 : 1 ratio. Among daughters, half are normal non-carriers and half are unaffected carriers. Among sons, half are normal and half are haemophilic. Consequently, 25% of all children are expected to be affected, and every affected child in this cross is a son. These are probabilities for each birth, not a fixed sequence of births.

Egg / Sperm	X	Y
X	XX Normal daughter	XY Normal son
X^h	XX^h Carrier daughter	X^hY Haemophilic son

Cross (II): $XX^h \times XY$. Each offspring cell represents one-quarter of all children.

Step 3: (i)(III) Cross a carrier female with a haemophilic male The parental cross is

$$XX^h \times X^hY.$$

The maternal gametes are X and X^h , while the paternal gametes are X^h and Y . Their combinations give XX^h , X^hX^h , XY and X^hY , in a 1 : 1 : 1 : 1 ratio. Half the daughters are unaffected carriers and half are haemophilic. Half the sons are normal and half are haemophilic. Thus 50% of all children are expected to be affected: 25% affected daughters and 25% affected sons.

Egg / Sperm	X^h	Y
X	XX^h Carrier daughter	XY Normal son
X^h	X^hX^h Haemophilic daughter	X^hY Haemophilic son

Cross (III): $XX^h \times X^hY$. Each offspring cell represents one-quarter of all children.

Step 4: (ii) Infer the pattern of inheritance A male expresses haemophilia with a single X^h , because he is hemizygous for this X-linked gene. A heterozygous female is an unaffected carrier because her normal allele masks the recessive allele. A female is affected only when both her X chromosomes carry the haemophilia allele, as in cross (III); therefore affected females are much rarer than affected males. An affected father never transmits his haemophilia allele directly to a son, since sons receive his Y . He transmits it to every daughter. With a normal non-carrier mother, those daughters are carriers,

and they can transmit the allele to their sons. This father-to-daughter-to-grandson route illustrates criss-cross inheritance. A carrier mother can transmit the allele to either sons or daughters, with a probability of one-half for each child.

Step 5: Conclusion Haemophilia shows X-linked recessive inheritance. Cross (I) produces only carrier daughters and normal sons; cross (II) produces haemophilia in half the sons and no daughters; cross (III) produces haemophilia in half the sons and half the daughters. The expected overall affected proportions are respectively 0%, 25% and 50%.

Quick Tip to Solve: First write the father's X chromosome in every daughter and his Y in every son. Then combine each with the mother's possible X chromosomes, keeping percentages within each sex distinct from percentages of all children.

33(a). (i) Draw a neat sectional view of seminiferous tubule of a human testes showing spermatogenesis. Label any five stages.

(ii) Explain the hormonal regulation of spermatogenesis process in humans.

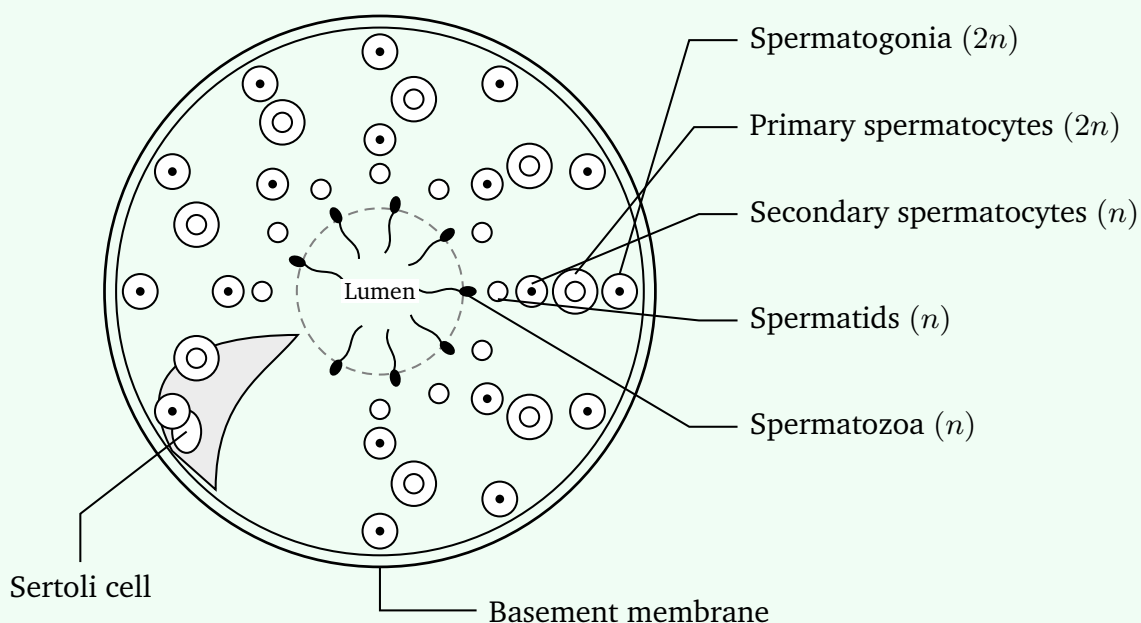
[5 marks]

Solution:

Concept:

- Spermatogenesis is the formation of haploid spermatozoa from diploid spermatogonia in the seminiferous tubules of the testes, beginning at puberty.
- Developing germ cells progress from the basement membrane towards the lumen. Meiosis reduces the chromosome number from $2n = 46$ to $n = 23$; spermiogenesis changes spermatids into spermatozoa.
- The hypothalamus, anterior pituitary, Leydig cells and Sertoli cells coordinate sperm formation through GnRH, LH, FSH and androgens.

Step 1: (i) Draw and label the stages in the tubule The sectional view shows the five successive stages: spermatogonia, primary spermatocytes, secondary spermatocytes, spermatids and spermatozoa. Spermatogonia lie next to the basement membrane; progressively more mature cells lie closer to the central lumen. Sertoli cells extend through the germinal epithelium and nourish developing germ cells. Sperm heads lie towards the epithelium while their tails project into the lumen before release.



Sectional view of a seminiferous tubule showing five stages of spermatogenesis.

Step 2: Explain the sequence shown in the section Spermatogonia ($2n$) multiply by mitosis. Some grow into primary spermatocytes ($2n$), which complete meiosis I to form two haploid secondary spermatocytes (n). Each secondary spermatocyte undergoes meiosis II, producing two haploid spermatids; thus one primary spermatocyte forms four spermatids. Spermatids differentiate into spermatozoa by **spermiogenesis**, without another cell division. Their subsequent release from Sertoli cells into the tubule lumen is **spermiation**.

Step 3: (ii) Trace the hormonal control At puberty, the hypothalamus increases secretion of gonadotropin-releasing hormone (GnRH). GnRH acts on the anterior pituitary and stimulates release of the gonadotropins luteinising hormone (LH) and follicle-stimulating hormone (FSH).

LH pathway: LH acts on the interstitial or Leydig cells of the testes, stimulating synthesis and secretion of androgens, chiefly testosterone. These androgens stimulate and maintain spermatogenesis within the seminiferous tubules.

FSH pathway: FSH acts on Sertoli cells, stimulating secretion of factors that support developing germ cells and help in spermiogenesis. Thus the two pituitary hormones act through different testicular cells and cooperate in sperm production.

Step 4: Conclusion The labelled progression is spermatogonia $\rightarrow$ primary spermatocytes $\rightarrow$ secondary spermatocytes $\rightarrow$ spermatids $\rightarrow$ spermatozoa, from the tubule wall towards the lumen. GnRH stimulates pituitary LH and FSH; LH acts on Leydig cells to produce androgens, while FSH acts on Sertoli cells to support sperm development.

Quick Tip to Solve: Draw the least mature cells next to the basement membrane and sperm tails towards the lumen. Remember LH–Leydig–androgens and FSH–Sertoli–spermiogenesis.

33(b). Medical Termination of Pregnancy (MTP) plays an important role in reproductive health.

(i) What is MTP?

(ii) Under what conditions is it legally permitted in India? Mention any two points.

(iii) In which stage of pregnancy is MTP considered legally and medically safe?

(iv) Explain any two risks/concerns associated with this process.

[5 marks]

Solution:

Concept:

- Medical termination of pregnancy (MTP), or induced abortion, is the intentional termination of an established pregnancy before full term.
- MTP protects reproductive health when performed for legally permitted reasons by a registered medical practitioner under the prescribed conditions.
- The first trimester, up to 12 weeks of pregnancy, is considered relatively safe for MTP.

Step 1: (i) Define MTP MTP is the voluntary or intentional termination of pregnancy before full term. Unlike contraception, which prevents pregnancy from becoming established, MTP ends an existing pregnancy.

Step 2: (ii) State two legally permitted conditions Subject to the requirements of the MTP Act, termination is permitted in the following situations.

First condition: Continuing the pregnancy would endanger the woman's life or cause grave injury to her physical or mental health.

Second condition: There is a substantial risk that the child, if born, would have a serious physical or mental abnormality.

The required medical opinion, consent, gestational conditions and approved facilities must also be satisfied; these grounds do not authorise unrestricted termination.

Step 3: (iii) Identify the relatively safe stage MTP is considered relatively safe during the **first trimester, that is, up to 12 weeks of pregnancy**, when performed by a qualified medical practitioner with proper facilities and legal safeguards. Termination in the second trimester is medically riskier. This is a statement of relative medical safety; later termination is legally permitted in specified circumstances.

Step 4: (iv) Explain two risks or concerns **Unsafe procedures:** MTP performed by unqualified persons or in unhygienic conditions can cause severe bleeding, infection or injury to the reproductive organs and may endanger the woman's life.

Misuse for sex selection: Prenatal sex determination followed by termination solely because the foetus is female is an unlawful and discriminatory misuse. It contributes to an adverse sex ratio.

Step 5: Conclusion MTP may protect maternal health or prevent birth in cases of serious foetal abnormality. It is relatively safer up to 12 weeks, subject to legal safeguards. Unsafe procedures and sex-selective misuse are major concerns.

Quick Tip to Solve: Answer the four parts in order: definition, two permitted grounds, first trimester, then one medical risk and one social concern. Keep the 12-week safety statement distinct from the legal upper limit.