CBSE Class 12 Biology Question Paper 2026 with Solution PDF-Set 57-3-1

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. 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 controlled by a neuroendocrine mechanism involving the mother and the fully developed foetus.
- The foetal ejection reflex stimulates release of oxytocin from the maternal posterior pituitary; oxytocin strengthens uterine contractions.

Step 1: Trace the reflex Signals from the fully developed foetus and placenta induce mild uterine contractions, called the foetal ejection reflex. This reflex acts on the maternal neuroendocrine system and triggers oxytocin release.

Step 2: Check the source and alternatives Maternal oxytocin causes stronger uterine contractions, which stimulate further oxytocin release through positive feedback until delivery. Option (A) incorrectly identifies the foetal pituitary. Placental hCG in (B) maintains the corpus luteum early in pregnancy, while progesterone in (C) supports pregnancy; neither is the hormone released by this reflex.

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

Quick Tip to Solve: Link foetal ejection reflex to maternal oxytocin, then to stronger uterine contractions.

2. Which of the following is not a functional unit of an ecosystem? [1 mark]

(A) Energy flow

(B) Decomposition

(C) Stratification

(D) Productivity

Correct Answer: (C) Stratification

Solution:

Concept:

- Ecosystem functions include productivity, decomposition, energy flow and nutrient cycling.

- Stratification describes the vertical arrangement of organisms in distinct layers and is a structural feature.

Step 1: Separate structure from function Productivity is the rate of biomass production. Decomposition breaks down dead organic matter, and energy flow transfers energy through trophic levels. Thus options (A), (B) and (D) describe processes that make the ecosystem function.

Step 2: Identify the structural feature Stratification is the spatial distribution of species at different heights, such as trees, shrubs and herbs in a forest. It describes how the community is arranged rather than a functional process. The word "not" therefore selects stratification.

Step 3: Conclusion Stratification is not a functional unit of an ecosystem. Hence, the correct option is (C).

Quick Tip to Solve: For a NOT question, classify each term as an ecosystem process or a spatial structural feature.

3. Match Column I with Column II and select the correct option:

Column I: a. Primers, b. Insertional inactivation, c. Bioreactor, d. Downstream processing

Column II: i. β-galactosidase, ii. To separate and purify products, iii. Chemically synthesized oligonucleotides, iv. Large scale production of specific product of activity of microbes [1 mark]

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

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

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

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

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

Solution:

Concept:

- Primers are chemically synthesised short oligonucleotides that provide a starting point for DNA synthesis.
- Insertional inactivation can disrupt a reporter gene, such as the gene encoding β-galactosidase.
- Bioreactors support large-scale biological production; downstream processing separates and purifies the product.

Step 1: Match the molecular tools Primers match chemically synthesized oligonucleotides, so a–iii. Insertion of foreign DNA into the reporter gene can inactivate β-galactosidase activity, allowing recombinants to be identified, so b–i.

Step 2: Match production and recovery A bioreactor provides controlled conditions for large-scale production of a specific microbial product, so c–iv. Downstream processing includes separation and purification after production, so d–ii. Option (B) reverses these last two matches, while (C) and (D) incorrectly link primers with the enzyme.

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

Quick Tip to Solve: Match bioreactor with production and downstream processing with purification before checking the codes.

4. 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:

- Biofortification improves the nutritional quality of a food crop.
- Golden rice is engineered to accumulate β-carotene, a precursor of vitamin A, in its edible endosperm.

Step 1: Connect the engineered trait to nutrition The golden colour is associated with carotenoid accumulation in the grain. Humans can convert dietary β-carotene into vitamin A, so consumption can help address vitamin A deficiency.

Step 2: Eliminate unrelated applications Golden rice is a nutritional improvement, not a crop selected for production of petrol-like fuel as in (A). Pest resistance and herbicide tolerance, in (C) and (D), are other possible transgenic traits but do not explain the purpose of golden rice.

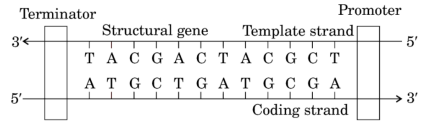
Step 3: Conclusion Golden rice helps reduce vitamin A deficiency in humans. Hence, the correct option is (B).

Quick Tip to Solve: Remember golden rice as provitamin A-enriched endosperm; distinguish nutrition from pest-control traits.

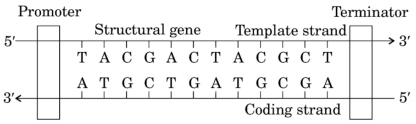
5. Four different transcription units are shown below. Choose the option with the correct image.

[1 mark]

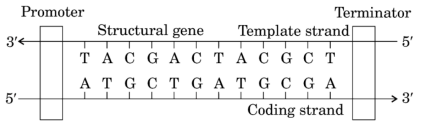
(A)



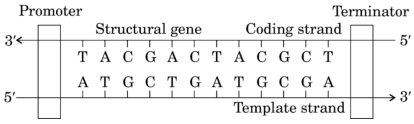
(B)



(C)



(D)



(A) Terminator on left, Promoter on right; template strand 3' to 5' at top with TACGACTACGCT; coding strand 5' to 3' at bottom

(B) Promoter on left, Terminator on right; template strand 5' to 3' at top with TACGACTACGCT; coding strand 3' to 5' at bottom

(C) Promoter on left, Terminator on right; template strand 3' to 5' at top with TACGACTACGCT; coding strand 5' to 3' at bottom

(D) Promoter on left, Terminator on right; coding strand 3' to 5' at top with TACGACTACGCT; template strand 5' to 3' at bottom

Correct Answer: (C) Promoter on left, Terminator on right; template strand 3' to 5' at top with TACGACTACGCT; coding strand 5' to 3' at bottom

Solution:

Concept:

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

Step 1: Check the correct orientation With the promoter on the left, transcription proceeds towards the terminator on the right. The template must therefore run from $3'$ on the left to $5'$ on the right, with the antiparallel coding strand running from $5'$ to $3'$. Diagram (C) has all these relationships.

Step 2: Test the other diagrams In (A), the promoter and terminator are reversed relative to the labelled template polarity. In (B), the template runs $5' \to 3'$ from promoter to terminator, which is the wrong reading direction. In (D), the strand labels are swapped, again giving a template that runs $5' \to 3'$ towards the terminator. Thus neither correct base pairing alone nor the presence of a promoter is sufficient.

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

Quick Tip to Solve: Start at the promoter and read the labelled template towards the terminator: it must run 3-prime to 5-prime.

6. Appearance of antibiotic-resistant bacteria is an example of evolution due to: [1 mark]

(A) Adaptive radiation

(B) Divergent evolution

(C) Artificial selection

(D) Anthropogenic action

Correct Answer: (D) Anthropogenic action

Solution:

Concept:

- Natural selection increases the frequency of heritable variants that survive and reproduce better under a selection pressure.
- Anthropogenic action means human activity that alters selection pressures, including the use of antibiotics.

Step 1: Explain the origin of resistance in the population A bacterial population may contain heritable variants resistant to an antibiotic. When the antibiotic is used, susceptible bacteria are eliminated or inhibited, while resistant bacteria survive and multiply, making resistance more common.

Step 2: Identify the relevant human action Human use of antibiotics creates the selection pressure, so the example illustrates anthropogenic action. Adaptive radiation and divergent evolution refer to different patterns of diversification and are not the specific explanation here. Artificial selection usually involves humans deliberately choosing organisms to breed for desired traits; antibiotic resistance arises through selection under the pressure humans introduce.

Step 3: Conclusion The appearance of antibiotic-resistant bacteria illustrates evolution due to anthropogenic action. Hence, the correct option is (D).

Quick Tip to Solve: Ask who introduced the selection pressure: human antibiotic use points directly to anthropogenic action.

7. Identify the statements that correctly describe Darwin's Theory of Evolution.

(i) Overproduction of organisms leads to competition.

(ii) Variation is inherited and causes evolution.

(iii) Acquired characters are inherited.

(iv) Survival depends on favourable traits.

(v) New species arise due to accumulation of favourable variations.

Choose the correct option. [1 mark]

(A) (i), (ii), (iv) and (v) are correct

(B) (ii), (iii) and (iv) are correct

(C) All are correct

(D) Only (i) and (iv) are correct

Correct Answer: (A) (i), (ii), (iv) and (v) are correct

Solution:

Concept:

- Darwinian natural selection acts on heritable variation in populations facing competition for limited resources.
- Favourable inherited variations improve survival and reproductive success; their accumulation can lead to new species.

Step 1: Evaluate the Darwinian statements Overproduction produces competition for limited resources, so (i) is correct. In the context of Darwinian evolution, inherited variations contribute to evolutionary change, making (ii) correct. Favourable traits influence survival, so (iv) is correct, and accumulation of favourable heritable variations can lead to speciation, so (v) is correct.

Step 2: Reject inheritance of acquired characters Statement (iii), that acquired characters are inherited, belongs to Lamarck's explanation rather than Darwin's theory. Therefore options (B) and (C), which include (iii), fail. Option (D) includes two valid statements but omits the other valid statements (ii) and (v).

Step 3: Conclusion Statements (i), (ii), (iv) and (v) correctly describe Darwin's theory. Hence, the correct option is (A).

Quick Tip to Solve: Exclude acquired-character inheritance first, then retain competition, heritable variation and natural selection.

8. 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*, which lives as an endoparasite in humans.
- Its characteristic symptoms include internal bleeding, muscular pain, fever, anaemia and blockage of the intestinal passage.

Step 1: Match the listed symptoms Intestinal blockage can result from the worms in the intestine. Muscular pain and fever, and anaemia, are also recognised symptoms of ascariasis. Thus options (A), (B) and (C) all describe symptoms of this disease.

Step 2: Identify the exception Skin ulcers are not a characteristic symptom of ascariasis. The question asks for the symptom that is absent from the standard list, so the three recognised symptoms must be excluded from selection.

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

Quick Tip to Solve: For ascariasis, recall the intestinal worm and its blockage, anaemia, fever and muscular pain; then select the exception asked for.

9. Every trophic level has a certain mass of living material at a particular time. What is it called? [1 mark]

(A) Standing crop

(B) Primary productivity

(C) Standing state

(D) Ecological efficiency

Correct Answer: (A) Standing crop

Solution:

Concept:

- Standing crop is the living material present at a trophic level at a particular time; it is measured as biomass or as the number of organisms per unit area.
- A stock measured at an instant differs from productivity, which measures the rate of production of organic matter.

Step 1: Identify the quantity described The question specifies a mass of living material at one trophic level at a particular time. This is a snapshot of the organisms present, rather than the rate at which new material is being produced.

Step 2: Distinguish the other terms Primary productivity is a rate of biomass production by producers. Standing state refers to the quantity of nutrients present at a given time. Ecological efficiency expresses transfer between trophic levels. None of these terms denotes the stated mass of living material.

Step 3: Conclusion The living material present is called the standing crop. Hence, the correct option is (A).

Quick Tip to Solve: Link living biomass at an instant to standing crop, nutrients at an instant to standing state, and production per unit time to productivity.

10. The smallest part of DNA molecule that can be changed by point mutation is: [1 mark]

(A) Oligonucleotide

(B) Codon

(C) Gene

(D) Nucleotide

Correct Answer: (D) Nucleotide

Solution:

Concept:

- A nucleotide is the basic repeating unit of DNA and consists of a nitrogenous base, deoxyribose sugar and phosphate.
- A point mutation alters a single base-pair position in DNA; on one strand this corresponds to a change at a single nucleotide.

Step 1: Identify the smallest affected unit In a point substitution, one base at a particular position is replaced by another. Therefore a single nucleotide position is sufficient to undergo the change; an entire multi-nucleotide sequence need not be replaced.

Step 2: Compare the remaining options A codon contains three nucleotides, an oligonucleotide contains several, and a gene contains a much longer sequence. Each can contain the site of a point mutation, but none is the smallest unit among the given choices.

Step 3: Conclusion The smallest listed part is a nucleotide. Hence, the correct option is (D).

Quick Tip to Solve: For a point mutation, focus on one nucleotide position; a changed codon or gene is the larger sequence containing that position.

11. 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:

- Adolescence is a period of vulnerability to peer pressure, including pressure to experiment with drugs or alcohol.
- Repeated drug use increases tolerance, so larger doses may be needed for the same response; alcohol affects the central nervous system.

Step 1: Evaluate statements (i), (ii) and (iii) Statement (i) is true because the wish to conform to peers can influence adolescent behaviour. Statement (ii) correctly describes increased tolerance with repeated drug exposure. Statement (iii) is also true: alcohol acts on the central nervous system and can impair judgement and coordination.

Step 2: Evaluate statements (iv) and (v) Statement (iv) is false: excessive drug use harms health and is not a means of increasing useful energy. Statement (v) is false because anabolic steroid abuse can increase aggression, rather than decrease it. Options (A) and (C) include false statements, while (D) incorrectly 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: Reject any combination containing (iv) or (v): excessive drug use is harmful, and anabolic steroid abuse can increase aggression.

12. 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 organ to the receptive stigma.
- Aquatic habitat alone does not establish hydrophily: many aquatic plants have flowers exposed above water and use other pollinating agents.

Step 1: Identify water-pollinated plants *Vallisneria* and *Hydrilla* are freshwater examples of water-pollinated plants. In *Vallisneria*, the female flower reaches the water surface and male flowers or pollen are brought to it by water currents.

Step 2: Check each alternative pair *Zostera* is water-pollinated, but water lily is not, so (B) fails. Water lily and water hyacinth are aquatic plants whose flowers are pollinated by agents such as insects or wind, rather than water. Thus (C) and (D) also fail; *Parthenium* does not supply a pair of hydrophilous plants in (C).

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

Quick Tip to Solve: Test the pollen carrier, not the habitat: water lily and water hyacinth live in water but are not examples of hydrophily.

13. 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:

- During secondary sewage treatment, vigorous aeration promotes aerobic microbial flocs that consume organic matter and reduce biochemical oxygen demand.
- The settled flocs form activated sludge. Methanogenic microorganisms carry out anaerobic digestion

and produce methane in biogas systems.

Step 1: Evaluate the Assertion Activated sludge is the sediment of microbial flocs formed after the aerated effluent enters a settling tank. These flocs contain large populations of bacteria associated with fungal filaments. The Assertion is therefore true.

Step 2: Evaluate the Reason The bacteria characterising activated sludge are aerobic organisms from the aeration tank. Anaerobic digestion and methane production involve anaerobic microorganisms, including methanogens, rather than these aerobic floc bacteria. When sludge enters an anaerobic digester, anaerobes digest its bacteria and fungi. Thus the Reason's attribution to these bacteria is false.

Step 3: Test the explanatory link The large bacterial population results from microbial growth during aerated sewage treatment. The claimed role in anaerobic digestion does not explain it. Since the Reason itself is false, neither of the codes requiring both statements to be true applies.

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

Quick Tip to Solve: Separate aerobic flocs in the aeration tank from anaerobic methanogens in the digester before judging this Assertion-Reason pair.

14. Assertion (A): Ecosystems require a constant supply of energy to synthesize the molecules they require.

Reason (R): This is to counteract the universal tendency towards increasing disorderliness as per Second Law of Thermodynamics. [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:

- Ecosystems are open systems that need a continuing input of energy to maintain life processes and the synthesis of organised biological molecules.
- The second law of thermodynamics describes the tendency for total entropy, or disorder, to increase. Maintaining local biological order requires energy expenditure.

Step 1: Evaluate the Assertion Organisms continually synthesise and maintain complex molecules. Energy also becomes unavailable for biological work as heat during transfers and transformations. A continuing energy input is therefore required by the ecosystem, so the Assertion is true.

Step 2: Evaluate the Reason The tendency towards increasing disorder is consistent with the second

law of thermodynamics. Energy must be supplied to sustain organised living structures and processes against this tendency. Hence the Reason is true. The ecosystem does not violate the law: local order is maintained while entropy increases in the surroundings.

Step 3: Establish the explanatory link The Reason directly states why the energy supply in the Assertion is necessary: ongoing synthesis and maintenance of organised molecules require energy to counter the tendency towards disorder. Thus the two true statements are causally linked, excluding the code for an unrelated Reason.

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

Quick Tip to Solve: Link continuous energy input to the maintenance of biological order; ecosystems maintain local order without violating the second law.

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15. 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:

- The bacterial plasma membrane is a lipid bilayer with a hydrophobic interior.
- DNA is hydrophilic because of its polar, negatively charged phosphate backbone; it cannot diffuse freely through this lipid barrier.

Step 1: Evaluate Assertion (A) The assertion is true in the context of introducing foreign DNA into a bacterial cell. Untreated cells do not allow DNA to pass freely across their plasma membrane; they must be made competent for efficient DNA uptake.

Step 2: Evaluate Reason (R) The reason is true. DNA is a hydrophilic macromolecule and interacts readily with water through its charged phosphate groups.

Step 3: Test the explanatory link DNA's hydrophilic nature prevents its free passage through the hydrophobic interior of the membrane. Thus R directly explains A. Option (B) incorrectly denies this link, while (C) and (D) incorrectly declare one of the statements false.

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

Quick Tip to Solve: Link hydrophilic DNA to the membrane's hydrophobic interior to identify why competence is needed for DNA uptake.

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16. 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 sequences present in many copies in the genome.
- A sequence's protein-coding role and its usefulness in understanding chromosome organisation or evolution are different properties.

Step 1: Evaluate Assertion (A) A is true in the NCERT description. Repetitive sequences are stretches of DNA repeated many times that are thought to have no direct coding functions. They are not described as ordinary genes encoding proteins.

Step 2: Evaluate Reason (R) R is also true. Studying these sequences provides information about chromosome structure, dynamics and evolution; their patterns can reveal relationships and changes in genomes.

Step 3: Check whether R explains A The usefulness of repetitive sequences in studying chromosomes does not explain why they lack a direct coding function. The statements describe two distinct aspects of repetitive DNA. Thus (A) incorrectly claims a causal explanation, while (C) and (D) incorrectly reject a true statement.

Step 4: Conclusion Both A and R are true, but R is not the correct explanation of A. Hence, the correct option is (B).

Quick Tip to Solve: After judging both statements true, ask whether chromosome-study usefulness actually explains the absence of a coding function.

Section B (10 marks)

17(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 fungal infection of skin, scalp and nails, characterised by dry, scaly lesions and intense itching.
- Fungal infections spread through contact with infected material; warmth and moisture favour fungal growth in skin folds.

Step 1: Identify the disease in part (i) Persistent itching accompanied by dry, scaly lesions on the skin and nails indicates **ringworm**. The groin region is a favourable site because moisture and warmth promote fungal growth. Despite its name, ringworm is not a disease caused by a worm.

Step 2: Name two causative agents in part (ii) Two causative fungal genera are *Microsporum* and *Trichophyton*. Both cause superficial infections of keratinised tissues. *Epidermophyton* is another genus that can cause ringworm.

Step 3: Explain transmission in part (iii) Infection is acquired through contact with an infected person or contaminated articles such as towels, clothes and combs. The fungi may also be acquired from soil. Sharing personal articles can transfer infective fungal material onto the skin or scalp.

Step 4: Conclusion (i) Ringworm. (ii) *Microsporum* and *Trichophyton*. (iii) Contact with infected people, contaminated personal articles or soil.

Quick Tip to Solve: Pair itchy, dry and scaly lesions with fungal ringworm; name fungal genera and a contact route of transmission.

OR

17(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 an otherwise harmless environmental substance called an allergen.
- IgE antibodies participate in allergic responses; activated mast cells release histamine and other mediators that produce symptoms.

Step 1: Identify the condition in part (i) The girl is suffering from **allergy**, most likely triggered by pollen in the flower garden. The repeated association with garden visits indicates exposure to an environmental allergen, producing sneezing, watery eyes and breathing difficulty in a sensitised individual.

Step 2: Name the immune component in part (ii) The immune component is **immunoglobulin E (IgE)**. Allergen-specific IgE associated with mast cells helps trigger their activation when the sensitised person encounters the allergen again.

Step 3: Name the chemical released in part (iii) **Histamine** is released from mast cells during the allergic response. It contributes to inflammation, increased vascular permeability and the characteristic allergic symptoms.

Step 4: State a medicine in part (iv) An **antihistamine** is used to reduce the effects of histamine and relieve allergic symptoms. This targets the chemical mediator responsible for much of the response.

Step 5: Conclusion (i) Allergy to pollen. (ii) IgE antibodies. (iii) Histamine. (iv) An antihistamine.

Quick Tip to Solve: Follow the chain pollen allergen, IgE, mast-cell histamine, antihistamine to answer all four parts in order.

18(a). (i) Mention any two characteristics of Neanderthal man that lived near East and Central Asia.
(ii) Identify the following hominids with respect to human evolution:
(I) Brain capacity 900 cc, probably ate meat.
(II) First human-like with brain capacity 650 - 800 cc. [2 marks]

Solution:

Concept:

- Human evolutionary forms can be identified using characteristic brain capacities together with evidence about their habits.
- NCERT associates *Homo habilis* with a brain capacity of 650–$800\,\text{cm}^3$, and *Homo erectus* with about $900\,\text{cm}^3$.

Step 1: State two Neanderthal characteristics for part (i) Neanderthal man had a brain capacity of about $1400\,\text{cm}^3$ and used animal hides to protect the body. These are two characteristic features of the Neanderthals that lived near East and Central Asia. They also buried their dead, another recognised feature of their behaviour.

Step 2: Identify hominid (I) in part (ii) A brain capacity of about $900\,\text{cm}^3$, together with the statement that the hominid probably ate meat, identifies ***Homo erectus***. Both the capacity and the dietary clue agree with this identification.

Step 3: Identify hominid (II) in part (ii) The first human-like hominid with a brain capacity of 650–$800\,\text{cm}^3$ is ***Homo habilis***. It is distinguished from *Homo erectus* by this smaller brain-capacity range; in the NCERT account it probably did not eat meat. Here $1\,\text{cc} = 1\,\text{cm}^3$.

Step 4: Conclusion (i) Neanderthals had a brain capacity of about $1400\,\text{cc}$ and used hides to protect their bodies. (ii) (I) *Homo erectus*; (II) *Homo habilis*.

Quick Tip to Solve: Remember the capacity sequence: habilis 650–800, erectus 900, Neanderthal 1400 cc, then match the behavioural clue.

OR

18(b). The allele for brown eyes (B) is dominant over blue eyes (b). In a population, 36% of individuals have blue eyes. Assuming Hardy-Weinberg equilibrium, calculate:
(i) Frequency of allele B
(ii) Percentage of heterozygous individuals
(iii) Percentage of individuals that are homozygous dominant
(Working to be shown) [2 marks]

Solution:

Concept:

- In Hardy-Weinberg equilibrium, allele frequencies satisfy $p + q = 1$, where p is the frequency of B and q is the frequency of b.
- The genotype frequencies are p^2 for BB, $2pq$ for Bb, and q^2 for bb. Blue eyes appear only in the

homozygous recessive genotype bb.

Step 1: (i) Calculate the allele frequencies The proportion of blue-eyed individuals is the genotype frequency, not the frequency of the recessive allele itself. Therefore,

$$q^2 = \frac{36}{100} = 0.36, \qquad q = \sqrt{0.36} = 0.60.$$

Hence the frequency of allele B is $p = 1 - q = 1 - 0.60 = 0.40$.

Step 2: (ii) Calculate the heterozygous proportion Heterozygous individuals have genotype Bb and brown eyes. Their frequency is $2pq = 2(0.40)(0.60) = 0.48$, so their percentage is $0.48 \times 100 = 48\%$.

Step 3: (iii) Calculate the homozygous dominant proportion Homozygous dominant individuals have genotype BB. Their frequency is $p^2 = (0.40)^2 = 0.16$, giving 16%. The genotype percentages check as $16 + 48 + 36 = 100\%$.

Step 4: Conclusion (i) Frequency of $B = 0.40$; (ii) heterozygous individuals $= 48\%$; (iii) homozygous dominant individuals $= 16\%$.

Quick Tip to Solve: Start with the recessive phenotype: its frequency is q^2, so take the square root before calculating p and $2pq$.

19. What did Henking observe in his experiments on insects that led to the discovery of sex chromosome? How did his observation contribute to our understanding of sex determination?

[2 marks]

Solution:

Concept:

- Sex chromosomes are chromosomes whose presence or combination is associated with the determination of sex. Their distribution during gamete formation can produce different types of gametes.
- Henking's observation of an unusual nuclear structure in insect spermatogenesis was an early clue to the chromosomal basis of sex determination.

Step 1: Describe Henking's observation In 1891, Henking traced a particular nuclear structure during spermatogenesis in some insects. He observed that only half of the sperm received this structure, whereas the other half did not. Because he could not establish its nature or function, he named it the X body.

Step 2: Explain its contribution to sex determination Subsequent work showed that the X body was a chromosome, hence the name X chromosome. The two kinds of sperm provided a basis for understanding chromosomal sex determination. In an XX–XO system, an egg carrying X fertilised by an X-bearing sperm produces an XX female, whereas fertilisation by a sperm lacking X produces an XO male. Here O denotes the absence of a sex chromosome, not a separate chromosome. Thus, different sex-chromosome complements can determine the sex of the offspring.

Step 3: Conclusion Henking found an X body in only half the sperm. Its later identification as the X chromosome helped establish the role of sex chromosomes in determining sex.

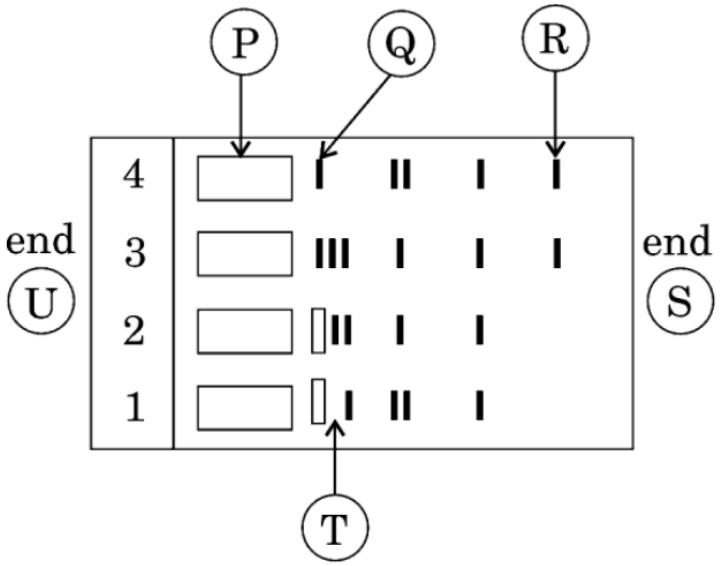
Quick Tip to Solve: Separate Henking's actual finding, the X body in half the sperm, from its later identification and role in sex determination.

20(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:

- DNA has a net negative charge because of its phosphate backbone. In an electric field, DNA fragments migrate through the gel towards the positively charged anode.
- Agarose gel is a porous molecular sieve. Smaller DNA fragments pass through its pores more readily and travel farther than larger fragments during the same run.

Step 1: (i) Identify the labelled end and DNA fragment The loading wells are shown on the left of the diagram, near end U. DNA bands have migrated from the wells towards the right, so the positive anode end is S. Among the labelled DNA bands, R points to the band farthest from the loading wells; it therefore represents the lightest or smallest DNA fragment. Q and T point to bands closer to the wells and hence do not indicate the smallest fragment.

Step 2: (ii) Describe agarose and its role Agarose is a natural polymer obtained from seaweeds. It forms a porous, jelly-like gel when prepared in an appropriate buffer. This gel provides the supporting matrix through which DNA moves during electrophoresis. Its molecular-sieving effect separates DNA fragments according to size: smaller fragments migrate faster and farther, while larger fragments are retarded more strongly.

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

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

OR

20(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 normally be seen directly in an unstained agarose gel. A DNA-binding stain allows the separated fragments to be detected.
- Ethidium bromide-stained DNA fluoresces under ultraviolet light. Elution is the recovery of a selected DNA fragment from an excised piece of gel.

Step 1: (i) Explain the missing bands and make them visible One possible reason is that the gel has not been stained with a suitable DNA-binding dye, such as ethidium bromide. Even if separation has occurred, the unstained DNA remains invisible to the unaided eye. Stain the gel with ethidium bromide and expose it to ultraviolet radiation. The dye associated with DNA then fluoresces, revealing the separated DNA fragments as bright orange bands. Viewing a stained gel only in ordinary light would also fail to reveal these fluorescent bands properly.

Step 2: (ii) Recover the required DNA fragment Identify the band corresponding to the desired DNA fragment and cut out the piece of agarose containing that band. Extract the DNA from this gel piece by elution and purify it to remove agarose and other contaminants. The recovered DNA fragment can then be used for further procedures, such as ligation into a cloning vector.

Step 3: Conclusion (i) Unstained DNA may be invisible; ethidium bromide staining followed by ultraviolet illumination reveals the bands. (ii) Excise the desired band and recover the DNA by elution.

Quick Tip to Solve: Remember the sequence: stain, view under ultraviolet light, excise the selected band, and elute its DNA for further use.

21. GEAC is a regulatory body under the Ministry of Environment, Forest and Climate Change in India.
(a) Write the full form of GEAC.
(b) Mention two of its important functions related to biotechnology. [2 marks]

Solution:

Concept:

- Genetic engineering requires regulatory assessment because genetically modified organisms and their products can affect human health and the environment.
- GEAC evaluates the acceptability of genetic modification work and the safety of introducing genetically modified organisms for use or release.

Step 1: (a) Expand GEAC GEAC stands for Genetic Engineering Appraisal Committee. The name Genetic Engineering Approval Committee is also used in the NCERT account of this regulatory body.

Step 2: (b) State two important functions First, it examines the validity and acceptability of research

involving genetic modification and appraises biotechnology activities requiring regulatory clearance, particularly their biosafety aspects. Second, it assesses the safety of introducing genetically modified organisms and their products for public use or environmental release, including evaluating possible effects on people and the environment before giving the necessary approval. These functions provide regulatory oversight of genetic engineering and its applications.

Step 3: Conclusion GEAC is the Genetic Engineering Appraisal Committee (NCERT: Genetic Engineering Approval Committee). Its functions include evaluating genetic modification research and assessing the safety of introducing GM organisms for public use or release.

Quick Tip to Solve: For the two functions, remember two checks: validity of genetic modification research and safety of introducing GM organisms.

Section C (21 marks)

22. 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 of the egg.
- An apomictic embryo may arise from an unreduced egg or directly from a diploid somatic cell of the ovule. It therefore retains the maternal genetic constitution.

Step 1: (a) Explain embryo development from an unreduced egg In some species, the diploid egg cell is formed without reduction division, so the chromosome number is not halved by meiosis. This diploid egg develops into an embryo without fertilisation. The embryo is thus produced without fusion of male and female gametes, and a seed containing it develops. This is an apomictic route through an unreduced egg.

Step 2: (a) Explain embryo development from somatic ovular cells In many varieties of citrus and mango, some diploid nucellar cells surrounding the embryo sac start dividing, protrude into the embryo sac and develop into embryos. This direct formation of embryos from somatic cells is called adventive embryony. Several such embryos may develop in one ovule, so the resulting seed can contain more than one embryo, a condition called polyembryony.

Step 3: (b) State the advantage for farmers If a desirable hybrid is made apomictic, its favourable combination of characters can be preserved in successive seed generations because the apomictic embryos do not arise through meiosis and fertilisation. Farmers can collect and sow seeds from the hybrid crop repeatedly without segregation of the hybrid characters. This reduces the need to buy expensive fresh hybrid seed each season.

Step 4: Conclusion Apomictic embryos develop from an unreduced diploid egg without fertilisation or from somatic ovular cells such as nucellar cells. Apomixis can preserve hybrid characters and allow

farmers to reuse hybrid seed.

Quick Tip to Solve: Separate the two embryo origins: diploid egg and diploid nucellus. Link the farmer's benefit specifically to preserving hybrid characters without segregation.

23. (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:

- Translation is the polymerisation of amino acids into a polypeptide whose amino acid sequence is specified by the sequence of codons in messenger RNA (mRNA).
- Transfer RNA (tRNA) acts as an adaptor: its anticodon recognises a complementary mRNA codon and its amino acid acceptor end carries the corresponding amino acid.

Step 1: (a) Define translation Translation is the synthesis of a polypeptide on ribosomes according to the genetic information carried by mRNA. The ribosome reads successive mRNA codons, and tRNAs bring the corresponding amino acids. These amino acids are joined by peptide bonds in the order specified by the mRNA, producing the primary structure of the protein.

Step 2: (b) Explain charging of tRNA Charging, or aminoacylation, is the attachment of a specific amino acid to its corresponding tRNA. In the presence of ATP and the specific enzyme aminoacyl-tRNA synthetase, the amino acid is first activated. The enzyme then links it to the amino acid acceptor end, the $3'$ end, of the appropriate tRNA. The product is called aminoacyl-tRNA or charged tRNA. The enzyme's specificity ensures that the appropriate amino acid is attached to its matching tRNA.

Step 3: Explain why charging is essential A charged tRNA delivers its amino acid to the ribosome while its anticodon pairs with the corresponding mRNA codon. Charging therefore connects codon recognition to the correct amino acid, allowing the mRNA message to determine the polypeptide sequence. The energy used during amino acid activation is retained in the aminoacyl-tRNA linkage and is used in peptide-bond formation when amino acids are brought together on the ribosome. Uncharged tRNA cannot supply an amino acid for chain elongation.

Step 4: Conclusion Translation converts the codon sequence of mRNA into an amino acid sequence. ATP-dependent aminoacylation loads the correct amino acid onto each tRNA and provides activated amino acids for peptide-bond formation.

Quick Tip to Solve: For charging, name all three essentials: amino acid, matching tRNA and ATP-dependent aminoacyl-tRNA synthetase; then connect charging to accuracy and peptide-bond formation.

24. (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:

- Resources such as food and space are finite in a habitat. Their availability limits the population size that the habitat can support.
- The logistic growth model includes carrying capacity K: $\frac{dN}{dt} = rN\left(\frac{K-N}{K}\right)$, where N is population size, t is time and r is the intrinsic rate of natural increase.

Step 1: (a) Define carrying capacity The carrying capacity, denoted by K, is the maximum population size of a species that a particular habitat can support sustainably with its available resources under the prevailing environmental conditions. It depends on limiting resources such as food, water and space; a habitat cannot support unrestricted population growth indefinitely.

Step 2: (b) Identify and explain the growth curve The logistic or Verhulst–Pearl growth curve takes carrying capacity into account. A population growing in a habitat with limited resources initially shows a lag phase, followed by a phase of rapid, approximately exponential increase while resources are plentiful. As population density rises, competition for resources increases and the growth rate slows. Finally the population approaches the upper limit K, producing a stationary phase. A plot of population size against time is therefore sigmoid or S-shaped.

Step 3: Relate the equation to the resource limit The logistic equation is

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

When N is much smaller than K, the factor $1 - N/K$ is close to 1, so growth is nearly exponential. As N approaches K, this factor approaches zero and growth slows. At $N = K$, net population growth is zero: additions to the population balance losses. Thus the model describes the effect of environmental resistance on a growing population.

Step 4: Conclusion Carrying capacity K is the sustainable upper population limit of a habitat. Logistic growth produces an S-shaped curve that levels off as the population approaches K.

Quick Tip to Solve: In the logistic equation, substitute $N = K$: the growth rate becomes zero. This immediately explains why the S-shaped curve levels off at carrying capacity.

25. 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 fusion of an ovum and a sperm outside the female body under suitable laboratory conditions. It is followed by embryo transfer (ET).
- The site of fertilisation distinguishes IVF from an in vivo technique: in vivo fertilisation occurs inside the female reproductive tract.

Step 1: (a) Collect the gametes and carry out fertilisation Ova are collected from the wife or a female donor, and sperms are collected from the husband or a male donor. The ovum and sperms are brought together under simulated physiological conditions in the laboratory. Fertilisation produces a zygote, which is cultured so that it begins cleavage and develops into an early embryo.

Step 2: (a) Transfer the zygote or embryo The zygote or an early embryo with up to eight blastomeres is transferred into the fallopian tube; this is zygote intra-fallopian transfer (ZIFT). An embryo with more than eight blastomeres is transferred into the uterus; this is intrauterine transfer (IUT). Further development and implantation occur in the female reproductive tract, and pregnancy can then continue normally.

Step 3: (b) Distinguish GIFT from IVF No. In gamete intra-fallopian transfer (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 development. Fertilisation takes place inside her body. Because there is no fertilisation outside the body, GIFT is an assisted reproductive technique but is not a type of IVF.

Step 4: Conclusion IVF comprises collection of gametes, laboratory fertilisation, embryo culture and embryo transfer. GIFT is not IVF because fertilisation in GIFT occurs in vivo, in the fallopian tube.

Quick Tip to Solve: Identify the site of fertilisation first: laboratory fertilisation indicates IVF; transfer of an unfertilised ovum into the tube indicates GIFT.

26. Draw a neat diagram of a maize grain showing the internal structure and label any five parts. [3 marks]

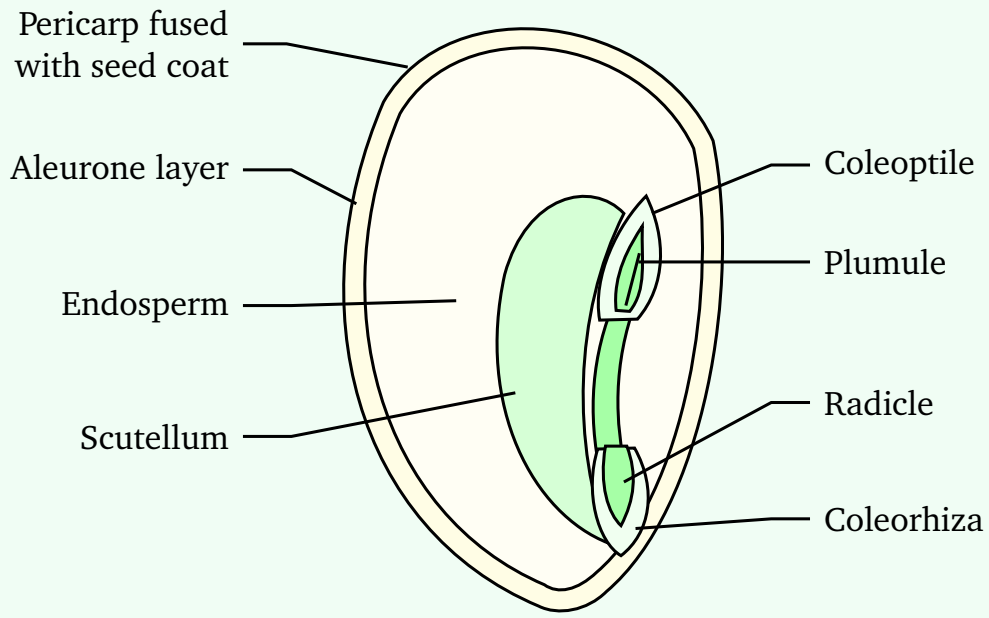
Solution:

Concept:

- A maize grain is a caryopsis: its fruit wall (pericarp) is fused with the seed coat. It is an endospermic, monocotyledonous seed.
- Most of the grain contains food-storing endosperm. The embryo lies at one side and has a single, shield-shaped cotyledon called the scutellum and an embryonal axis.

Step 1: Draw the enclosing layers and endosperm The longitudinal section below shows the thin

pericarp fused with the seed coat surrounding the grain. Inside it, the outer protein-rich aleurone layer encloses the bulky, starchy endosperm. The endosperm is retained in the mature maize grain and supplies stored food during germination. The scutellum is positioned between the endosperm and the embryonal axis, as shown.



Longitudinal section of a maize grain (schematic).

Step 2: Identify the embryo and its protective sheaths The scutellum is the single cotyledon of the embryo. The upper end of the embryonal axis bears the plumule, which is enclosed by the protective coleoptile. The lower end bears the radicle, enclosed by the coleorhiza. These paired structures must be distinguished: plumule and radicle are the developing shoot and root, whereas coleoptile and coleorhiza are their respective protective sheaths. The figure labels more than the five requested parts.

Step 3: Conclusion The labelled longitudinal section shows the pericarp with seed coat, aleurone layer, endosperm, scutellum, plumule, coleoptile, radicle and coleorhiza of a maize grain.

Quick Tip to Solve: Place the scutellum against the endosperm, then label plumule inside coleoptile above and radicle inside coleorhiza below.

27. Cow dung and water are mixed and fed into a biogas plant to allow digestion of biowastes. The person performing this process says that there is no need to provide an inoculum.

(a) Do you agree with him? Justify your answer.

(b) What happens to the biowaste inside the digester?

(c) Name the useful by-products obtained from this process and mention how they are used. [3 marks]

Solution:

Concept:

- Biogas production depends on anaerobic microbial decomposition of organic wastes. Methanogenic microbes produce methane during the final stages of this process.
- Cattle dung naturally contains methanogens, such as *Methanobacterium*, associated with the cattle rumen; thus dung itself supplies these microbes to the plant.

Step 1: (a) Explain why a separate inoculum is unnecessary Yes, the person's statement is correct. Cow dung already contains methanogenic microbes, including *Methanobacterium*. Mixing the dung with water introduces these organisms along with the organic material into the biogas plant. Therefore the dung itself acts as the microbial inoculum, and no separate inoculum needs to be added.

Step 2: (b) Describe digestion inside the plant In the oxygen-free digester, anaerobic microorganisms break down the organic constituents of the biowaste into simpler substances. Methanogens act on the products of this breakdown and generate methane-rich biogas, which collects in the gas holder above the slurry. Carbon dioxide and small amounts of other gases also form. As digestion proceeds, the partially decomposed slurry is displaced towards the outlet.

Step 3: (c) State the useful products and their uses The useful gaseous product is **biogas**, containing mainly methane together with carbon dioxide and small quantities of other gases. It is used as a fuel for cooking and lighting. The other useful product is the **spent or digested slurry**; it is rich in plant nutrients and is used as organic manure in agricultural fields. Thus the same process supplies fuel and recycles nutrients from cattle waste back to the soil.

Step 4: Conclusion Cow dung supplies its own methanogenic inoculum. Anaerobic digestion yields methane-rich biogas for fuel and digested slurry for manure.

Quick Tip to Solve: Link each output to its use: the methane-rich gas is fuel, whereas the nutrient-rich outlet slurry is manure.

28. (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:

- Genes on the same chromosome are linked and tend to be inherited together; independently assorting genes produce the Mendelian dihybrid phenotypic ratio $9:3:3:1$.

- Crossing over between homologous chromosomes during meiosis can produce new combinations of alleles, called recombinants.

Step 1: (a) Describe Morgan's cross Morgan crossed yellow-bodied, white-eyed female *Drosophila melanogaster* with brown-bodied, red-eyed males. He then intercrossed their F_1 progeny and studied the combinations of body colour and eye colour in the next generation. These two genes occur on the same X chromosome. The offspring showed a much higher proportion of parental combinations of characters than new, non-parental combinations.

Step 2: (b) Compare the outcome with independent assortment For two independently assorting gene pairs, a dihybrid cross is expected to yield the Mendelian $9:3:3:1$ phenotypic ratio in the F_2 generation. Morgan did not obtain this expected distribution: yellow body with white eyes and brown body with red eyes tended to remain associated. Thus, these genes did not segregate into gametes independently; their physical association on the same chromosome caused an excess of parental combinations.

Step 3: (c) Define the two terms **Linkage** is the physical association of genes on the same chromosome, causing their tendency to be inherited together. **Recombination** is the generation of non-parental gene combinations. Crossing over between homologous chromosomes during meiosis can separate linked alleles and generate these new combinations. Strongly linked genes show a low frequency of recombination, while genes farther apart on the chromosome show a higher frequency.

Step 4: Conclusion Morgan's cross showed an excess of parental combinations instead of the expected Mendelian dihybrid pattern. He explained the association of genes by linkage and the production of non-parental combinations by recombination.

Quick Tip to Solve: For Morgan's experiment, connect same chromosome with linkage and new allele combinations with recombination; do not treat the two genes as independently assorting.

Section D (8 marks)

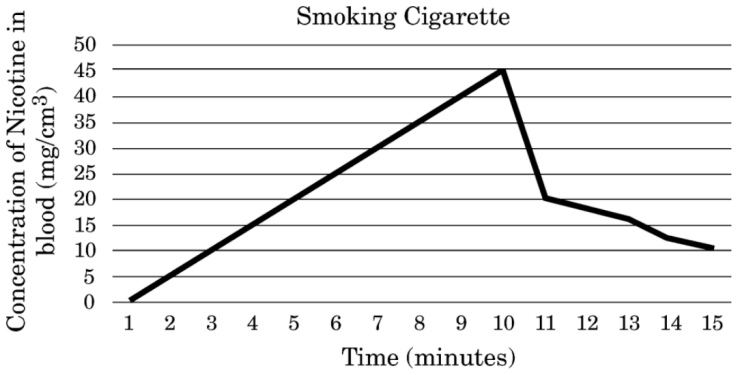
Questions No. ***29*** *and* ***30*** *are Case-Based questions. Each question has* ***3*** *sub-questions with internal choice in one sub-question.*

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:

- A graph gives the concentration at a particular time by matching that time on the horizontal axis to the corresponding height on the vertical axis.
- Nicotine from inhaled tobacco smoke is absorbed into the bloodstream; repeated puffs increase its concentration while intake exceeds removal.

Step 1: Read the plotted value at ten minutes Locate 10 minutes on the time axis and move vertically to the peak of the curve. The peak corresponds to $45\,\text{mg/cm}^3$ on the concentration scale printed in the graph.

Step 2: Explain the rise to the peak The smoker repeatedly inhales nicotine while taking puffs. Its absorption and accumulation in the blood cause the concentration to rise up to ten minutes. This is the highest concentration shown; the subsequent falling curve represents a decrease after this peak.

Step 3: Conclusion At ten minutes, nicotine reaches its maximum plotted blood concentration of about $45\,\text{mg/cm}^3$, owing to repeated nicotine intake during smoking.

Quick Tip to Solve: Read the value directly above ten minutes: the point is at the peak, not on the sharp decrease between ten and eleven minutes.

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 bloodstream during inhalation.
- Carbon monoxide binds strongly to haemoglobin, forming carboxyhaemoglobin and reducing the amount available to carry oxygen.

Step 1: Identify the effect of continued smoking By ten minutes, repeated inhalation of cigarette smoke increases the amount of carbon monoxide entering the blood. This effect is due to carbon monoxide in the smoke; nicotine is a different constituent of tobacco smoke.

Step 2: Relate carbon monoxide to haem-bound oxygen Carbon monoxide has a much greater affinity for haemoglobin than oxygen. Its binding occupies haemoglobin binding sites and lowers the proportion of haemoglobin carrying oxygen. Therefore, the oxygen-carrying capacity of blood decreases.

Step 3: Conclusion At ten minutes, carbon monoxide in the blood increases, while haem-bound oxygen decreases because more haemoglobin is bound to carbon monoxide.

Quick Tip to Solve: Keep the direction of both changes explicit: smoking increases carbon monoxide and reduces 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 a constituent of tobacco that stimulates the adrenal glands.
- The adrenal medulla releases adrenaline and noradrenaline, hormones that increase cardiovascular activity.

Step 1: Trace nicotine's hormonal effect During cigarette smoking, nicotine is absorbed into the blood. It stimulates the adrenal glands to release adrenaline and noradrenaline into the bloodstream.

Step 2: Connect these hormones with circulation Adrenaline and noradrenaline increase the rate and force of heart contraction and promote the cardiovascular response associated with sympathetic stimulation. The faster heartbeat and increased vascular tone raise blood pressure. Thus the cardiovascular effects follow the nicotine-triggered release of these hormones.

Step 3: Conclusion Cigarette smoking supplies nicotine, which stimulates the release of adrenaline

and noradrenaline from the adrenal glands; these hormones increase heart rate and blood pressure.

Quick Tip to Solve: Remember the causal sequence: nicotine, then adrenal hormones, then increased heart rate and blood pressure.

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 of which are obtained from plants and have strong physiological effects.
- Nicotine is an alkaloid present in tobacco; the chemical class of a drug is distinct from the physiological effect it produces.

Step 1: Identify the chemical class of nicotine Nicotine belongs to the class of compounds called **alkaloids**. Tobacco leaves contain nicotine, which acts on the nervous system and also stimulates adrenal hormone release. The requested class is a chemical grouping: identifying nicotine only as a stimulant would describe an effect rather than give this chemical class.

Step 2: Give another drug in that class **Morphine** is another alkaloid. It is obtained from the latex of the opium poppy, *Papaver somniferum*, and acts as an opioid analgesic. Although morphine and nicotine have different physiological actions, both are nitrogen-containing compounds belonging to the alkaloid class.

Step 3: Conclusion Nicotine is an **alkaloid**; **morphine** is another drug belonging to the same chemical class.

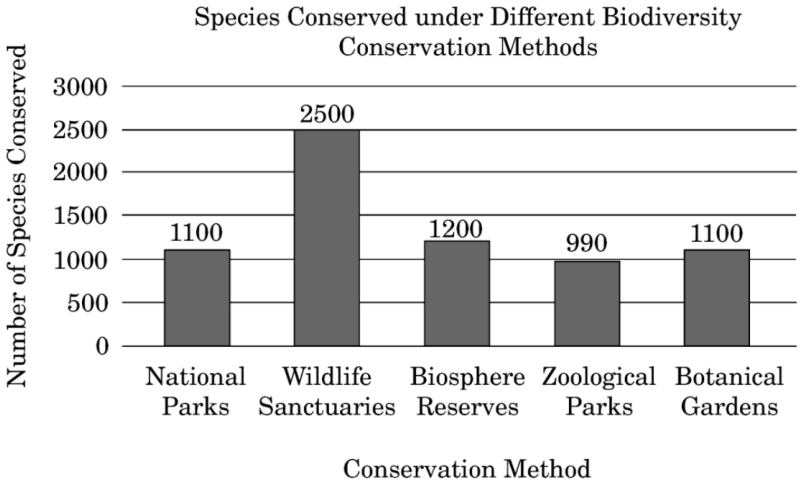
Quick Tip to Solve: Answer the class and the example separately: alkaloid is the chemical class, and morphine is a valid example even though its action differs from nicotine.

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 method conserving the greatest number of species in the supplied data.
- In situ conservation protects species within their natural habitats, whereas ex situ conservation protects them outside those habitats.

Step 1: Compare the heights of the bars The wildlife sanctuaries bar reaches 2500 species, higher than biosphere reserves at 1200, national parks and botanical gardens at 1100 each, and zoological parks at 990. Thus, the maximum in this graph belongs to wildlife sanctuaries.

Step 2: Classify the conservation method Wildlife sanctuaries protect wild organisms within their natural habitats, along with the habitat conditions and ecological relationships needed for survival. They therefore represent in situ conservation.

Step 3: Conclusion **Wildlife sanctuaries**, conserving 2500 species in the graph, have the highest number. This is **in situ conservation**.

Quick Tip to Solve: First read the tallest bar, then classify the location: protection within the natural habitat means in situ conservation.

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 organisms within their natural habitats and ecosystems.
- Ex situ conservation protects organisms outside their natural habitats under human care.

Step 1: Identify the opposite methods Wildlife sanctuaries identified in part (a) represent in situ conservation. The opposite methods in the graph are zoological parks and botanical gardens. They maintain animals and living plant collections, respectively, outside their original natural habitats and hence represent ex situ conservation.

Step 2: Compare the approaches In situ conservation preserves species in their own habitats, along with their natural communities and ecological interactions; national parks, wildlife sanctuaries and biosphere reserves are examples. Ex situ conservation maintains selected species in managed facilities outside those habitats, where their care and reproduction can be controlled. Thus, the location of protection distinguishes the approaches.

Step 3: Conclusion **Zoological parks and botanical gardens** are ex situ methods. In situ protection occurs **within natural habitats**; ex situ protection occurs **outside natural habitats**.

Quick Tip to Solve: Classify by location: sanctuaries protect natural habitats; zoos and botanical gardens maintain organisms outside them.

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

Solution:

Concept:

- Species richness is the number of different species present in a region.
- Endemism means that a species is naturally restricted to a particular geographical region and is not naturally found elsewhere.

Step 1: State the feature of species richness Biodiversity hotspots have exceptionally high species richness: a large variety of species occurs within the region. Their protection can therefore conserve many different species in a relatively limited area.

Step 2: State the feature of endemism Hotspots also have a high degree of endemism, containing many species restricted to that region. Destruction of their habitats could eliminate species that cannot be conserved by protecting a different geographical region. Hotspots are also under severe threat from habitat loss, which makes conservation there especially urgent.

Step 3: Conclusion The two features are **very high species richness** and **a high degree of endemism**.

Quick Tip to Solve: Recall the pair richness and endemism: many species occur there, and many occur nowhere else naturally.

OR

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

[1 mark]

Solution:

Concept:

- Sacred groves are patches of forest traditionally protected by local communities because of religious and cultural beliefs.
- In situ conservation preserves organisms in their natural habitat, along with the surrounding biological community.

Step 1: Identify the conservation category The organisms of a sacred grove remain within the naturally occurring forest patch. They are not transferred to an artificial collection or captive facility. Sacred groves therefore belong to in situ conservation.

Step 2: Explain how community protection saves biodiversity Traditional beliefs restrict activities such as tree cutting and hunting in these forest patches. This protection preserves natural habitats and shelters diverse species, including rare and threatened plants and animals. Sacred groves can thus act as refuges for biodiversity even when surrounding areas undergo disturbance.

Step 3: Conclusion Sacred groves represent **in situ conservation**. Community protection preserves forest habitats and provides refuges for **rare, threatened and other native species**.

Quick Tip to Solve: Link sacred groves with community-protected forests: the organisms stay in their natural habitat, so the category is in situ.

Section E (15 marks)

31(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:

- Bacterial transformation is a heritable change caused by the uptake of genetic material from another bacterial cell.
- In *Streptococcus pneumoniae*, the smooth (S) strain has a polysaccharide coat and is virulent; the rough (R) strain lacks this coat and is non-virulent.
- Selective enzymatic destruction of a substance tests whether it is essential for the transforming activity.

Step 1: (i) Compare the living strains Griffith injected living S-strain pneumococci into mice; the mice died of pneumonia. The bacteria formed smooth colonies because of their polysaccharide coat. When he injected living R-strain pneumococci, the mice survived. The R strain formed rough colonies and was non-virulent. These experiments established the different disease-causing abilities of the two

strains.

Step 2: Test the effect of killing the S strain Griffith killed S-strain bacteria by heating and injected these heat-killed bacteria into mice. The mice survived. Thus the dead S bacteria alone could not cause the disease, even though living S bacteria could.

Step 3: Mix the two preparations He then injected a mixture of heat-killed S bacteria and living R bacteria. The mice died, and living S-strain bacteria were recovered from their bodies. Neither heat-killed S bacteria nor living R bacteria alone had killed mice, so the death with the mixture required an explanation: some living R bacteria had acquired the ability to form the S-strain coat and had become virulent.

Step 4: Explain the significance of transformation Griffith proposed that a transforming principle from the heat-killed S bacteria transformed the living R bacteria into living S bacteria. The acquired change was inherited by their descendants. His experiments therefore demonstrated transfer of hereditary information between bacterial cells. They established the phenomenon of transformation, but did not identify the chemical nature of the transforming principle.

Step 5: (ii) Identify the transforming principle Avery, MacLeod and McCarty purified biochemical components from heat-killed S bacteria and tested their ability to transform R bacteria. They found that the DNA fraction could bring about transformation. Treating the preparation with proteases, which digest proteins, or RNase, which digests RNA, did not prevent transformation. In contrast, treatment with DNase, which digests DNA, abolished the transforming activity. The loss of transformation specifically when DNA was destroyed showed that DNA, rather than protein or RNA, was the transforming principle and the genetic material responsible for the inherited change.

Step 6: Conclusion Griffith demonstrated transformation of living R bacteria into virulent S bacteria by material from heat-killed S bacteria. Avery, MacLeod and McCarty identified this transforming genetic material as DNA.

Quick Tip to Solve: Recall the four injections as living S, living R, dead S, and dead S plus living R; then connect loss of transformation after DNase treatment specifically to DNA.

OR

31(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; the Y chromosome does not carry a corresponding allele.
- A normal non-carrier female is XX, a carrier female is XX^h, and an affected female is X^hX^h. A normal male is XY, while an affected male is X^hY.
- Each offspring receives one sex chromosome from each parent. A daughter receives her father's X chromosome, whereas a son receives his father's Y chromosome. Punnett squares combine the possible eggs and sperm.

Step 1: Cross the normal female with the haemophilic male (i)(I) The parents are $XX \times X^hY$. The female produces eggs carrying X, while the male produces equal proportions of X^h-bearing and Y-bearing sperm. Combining these gametes gives

$$XX \times X^hY \longrightarrow \tfrac{1}{2}XX^h + \tfrac{1}{2}XY.$$

Thus, all daughters are XX^h, phenotypically normal carriers, and all sons are XY, normal. No child is haemophilic in this cross. The fractions refer to all offspring, assuming equal probabilities of sons and daughters; the two identical maternal rows below show that every egg carries X.

Egg / Sperm	X^h	Y
X	XX^h	XY
X	XX^h	XY

Cross I: normal female and haemophilic male

Step 2: Cross the carrier female with the normal male (i)(II) The parents are $XX^h \times XY$. The female produces X and X^h eggs in equal proportions, and the male produces X and Y sperm in equal

proportions. Each of the four combinations has probability $\frac{1}{4}$:

$$XX \text{ (normal daughter)}, \quad XX^h \text{ (carrier daughter)},$$

$$XY \text{ (normal son)}, \quad X^hY \text{ (haemophilic son)}.$$

Among daughters, half are non-carriers and half are carriers; none is affected. Among sons, half are normal and half are haemophilic. Therefore, haemophilic sons constitute one-quarter of all offspring, not one-half of all offspring.

Egg / Sperm	X	Y
X	XX	XY
X^h	XX^h	X^hY

Cross II: carrier female and normal male

Step 3: Cross the carrier female with the haemophilic male (i)(III) The parents are $XX^h \times X^hY$. The eggs carry X or X^h, and the sperm carry X^h or Y, each with equal probability. The four equally probable offspring are

$$XX^h \text{ (carrier daughter)}, \quad X^hX^h \text{ (haemophilic daughter)},$$

$$XY \text{ (normal son)}, \quad X^hY \text{ (haemophilic son)}.$$

Half the daughters and half the sons are affected. Thus, half of all offspring are haemophilic: one-quarter are affected daughters and one-quarter are affected sons. The remaining daughters are carriers and the remaining sons are normal.

Egg / Sperm	X^h	Y
X	XX^h	XY
X^h	X^hX^h	X^hY

Cross III: carrier female and haemophilic male

Step 4: Infer the inheritance pattern from the crosses (ii) A male expresses haemophilia when his single X chromosome carries the recessive allele. A heterozygous female remains phenotypically normal because her normal allele masks the recessive allele; she can nevertheless transmit X^h to her children. A female expresses the disease only when both her X chromosomes carry the haemophilia allele, requiring an affected father and a mother who supplies X^h, as demonstrated by cross III.

An affected father passes X^h to every daughter but to no son: sons receive his Y chromosome. Hence there is no direct father-to-son transmission. A carrier mother can transmit the affected X to sons, and an affected father's allele can pass through a carrier daughter to a grandson, giving the characteristic criss-cross pattern. The requirement of only one affected allele in males explains why the disease is more frequent in males. These observations identify X-linked recessive inheritance.

Step 5: Conclusion Cross I gives carrier daughters and normal sons only. Cross II gives normal daughters, carrier daughters, normal sons and haemophilic sons in a $1:1:1:1$ ratio. Cross III gives carrier daughters, haemophilic daughters, normal sons and haemophilic sons in a $1:1:1:1$ ratio. Haemophilia follows X-linked recessive inheritance, with no direct father-to-son transmission.

Quick Tip to Solve: First assign the father's X to every daughter and his Y to every son; then add either maternal X. Always distinguish the percentage of affected sons from the percentage of affected children.

32(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 alteration of genetic material with controlled cultivation of selected organisms to obtain useful products.
- Recombinant DNA technology requires enzymes to manipulate DNA, a vector to carry and replicate it, and a competent host to receive it.

Step 1: (i) Explain genetic engineering Genetic engineering changes the chemistry of genetic material, DNA or RNA, and introduces the altered material into a host organism to change its phenotype. In recombinant DNA technology, a desired gene is isolated, joined to a suitable vector and transferred into a host. The host can multiply the introduced gene and, when suitable expression signals are present, produce the desired gene product. Unlike selection alone, this technique permits the introduction of a specific useful gene into another organism.

Step 2: (i) Explain maintenance of sterile conditions The second core technique is maintaining a sterile, contamination-free environment during chemical engineering processes so that only the desired microorganism or eukaryotic cell grows in large quantities. Nutrients, temperature, pH and aeration are controlled in a bioreactor. Preventing unwanted microbial growth allows the selected cells to manufacture products such as antibiotics, vaccines or enzymes reliably and on a large scale.

Step 3: (ii) Describe enzymes for DNA manipulation Restriction endonucleases act as molecular scissors: they recognise particular DNA sequences and cut DNA at specific sites. Cutting the donor DNA and vector with a suitable restriction enzyme can generate complementary sticky ends that pair with one another. DNA ligase then seals the sugar-phosphate backbones by forming phosphodiester bonds, producing recombinant DNA. Thus, restriction enzymes and the joining enzyme make controlled cutting and joining possible.

Step 4: (ii) Describe cloning vectors A cloning vector, such as a bacterial plasmid or bacteriophage, carries the desired DNA into a host and permits its multiplication. An origin of replication enables

replication of the vector and its inserted DNA. A selectable marker helps identify cells that have received the vector, while suitable unique recognition sites allow insertion of the foreign DNA without cutting the vector at many positions. A vector therefore acts as both a carrier and a means of cloning the inserted gene.

Step 5: (ii) Describe a competent host A competent host is a cell capable of taking up recombinant DNA; bacteria such as *Escherichia coli* are commonly used. Because DNA does not readily cross the cell membrane, bacterial cells can be treated with divalent calcium ions and subjected to heat shock to facilitate uptake. After entry, the host supplies the machinery for replication and, under appropriate conditions, expression of the introduced gene. Selected transformed cells are then multiplied.

Step 6: Conclusion The two core techniques are genetic engineering and maintenance of sterile conditions for large-scale culture. The three key tool groups are DNA-manipulating enzymes, cloning vectors and competent host cells.

Quick Tip to Solve: Keep the two principles separate from the three tools: modify genes and maintain pure cultures; then cut/join DNA, carry it in a vector and introduce it into a host.

OR

32(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 molecular change before clear symptoms develop.
- Biotechnology improves detection through nucleic-acid amplification, complementary nucleic-acid hybridisation and specific antigen-antibody interactions.

Step 1: (i) Identify conventional methods and their limitations Conventional methods include analysis of blood serum and urine and observation of symptoms. Their limitation is that very early detection is often not possible: the initial pathogen concentration may be below the detection threshold, and symptoms may appear only after considerable multiplication. Relying on these methods alone can therefore delay diagnosis and treatment.

Step 2: (ii) Explain polymerase chain reaction Polymerase chain reaction (PCR) amplifies a specific DNA sequence from a very small initial sample. Repeated cycles of DNA denaturation, primer annealing and extension by a thermostable DNA polymerase generate many copies of the target sequence, making it detectable. This reveals a pathogen present at low concentration, even before obvious symptoms develop. PCR-based tests are used for infections such as HIV; for an RNA target, reverse transcription first produces DNA that can be amplified. PCR also helps detect mutations associated with genetic disorders or cancer.

Step 3: (ii) Explain recombinant DNA technology using probes Recombinant DNA technology provides labelled nucleic-acid probes for recognising a specific pathogen sequence or a disease-associated gene sequence. A single-stranded DNA or RNA probe is designed to be complementary to the target. The sample DNA is made single-stranded, and the probe hybridises with a matching sequence by complementary base pairing. A radioactive label, for example, allows the hybrid to be detected by autoradiography. A suitably designed probe can distinguish normal and mutated sequences: a mismatch can prevent hybridisation under the chosen conditions, so their signals differ.

Step 4: (ii) Explain enzyme-linked immunosorbent assay Enzyme-linked immunosorbent assay (ELISA) depends on the specificity of antigen-antibody binding. Infection may be detected by identifying antigens derived from the pathogen or antibodies produced by the patient against it. In an appropriate assay, an enzyme-linked antibody participates in detection of the bound target. Addition of the enzyme's substrate produces a measurable colour change when the relevant target is present. This provides a sensitive signal for diagnosis.

Step 5: Conclusion PCR, recombinant DNA technology using labelled probes, and ELISA detect disease through amplification, complementary hybridisation and antigen-antibody binding, respectively, overcoming limitations of conventional early diagnosis.

Quick Tip to Solve: Match each technique to its mechanism: PCR amplifies nucleic acid, a probe recognises a complementary sequence, and ELISA recognises an antigen-antibody reaction.

33(a). Oogenesis is a discontinuous process that begins before birth and is completed after puberty.
(i) Trace the development of a gamete mother cell till its release from the ovary during ovulation.
(ii) Name the two pituitary hormones that play an important role in the process. [5 marks]

Solution:

Concept:

- Oogenesis produces the female gamete from a diploid oogonium. It includes multiplication, growth and meiotic maturation, with long pauses in meiosis.
- Unequal cytokinesis conserves most of the cytoplasm in one large functional cell; the other product is a small polar body.
- Follicle development and ovulation are regulated by the anterior pituitary gonadotropins, follicle-stimulating hormone (FSH) and luteinising hormone (LH).

Step 1: (i) Multiplication and meiotic arrest before birth During foetal development, millions of diploid oogonia, or gamete mother cells, are formed in each ovary through mitotic multiplication. Oogonia grow and enter meiosis I, becoming primary oocytes. Each primary oocyte has $2n = 46$ chromosomes. It becomes arrested in prophase I, so the first meiotic division does not finish during foetal life. No new oogonia are normally formed after birth.

Step 2: (i) Formation and growth of ovarian follicles Each primary oocyte becomes surrounded by a layer of granulosa cells, forming a primary follicle. Many follicles degenerate between birth and puberty. From puberty onwards, selected surviving follicles develop during ovarian cycles. A primary follicle acquires more layers of granulosa cells and a theca to become a secondary follicle. Further

development produces a tertiary follicle containing a fluid-filled cavity called the antrum. Its theca becomes differentiated into an inner theca interna and an outer theca externa.

Step 3: (i) Completion of meiosis I The primary oocyte in the developing tertiary follicle grows and completes meiosis I shortly before ovulation. The division is unequal, forming a large haploid secondary oocyte and a small first polar body. Both have $n = 23$ chromosomes, but the secondary oocyte retains most of the nutrient-rich cytoplasm. The tertiary follicle matures into a Graafian follicle, and the secondary oocyte is surrounded by the zona pellucida and follicular cells.

Step 4: (i) Release of the secondary oocyte at ovulation The secondary oocyte begins meiosis II and becomes arrested at metaphase II. At mid-cycle, the LH surge causes the mature Graafian follicle to rupture and release the secondary oocyte from the ovary; this release is ovulation. Thus, the released cell is a secondary oocyte, rather than an ovum that has already completed meiosis II. Meiosis II is completed only when fertilisation occurs, producing the ovum and a second polar body. This explains why oogenesis is discontinuous.

Step 5: (ii) Name the pituitary hormones and their roles The two hormones are **follicle-stimulating hormone (FSH)** and **luteinising hormone (LH)**, both secreted by the anterior pituitary. FSH promotes growth and maturation of ovarian follicles and stimulates oestrogen secretion by their granulosa cells. The mid-cycle surge of LH triggers ovulation and promotes formation of the corpus luteum from the ruptured follicle.

Step 6: Conclusion (i) The developmental sequence is oogonium, primary oocyte arrested in prophase I, and secondary oocyte formed by unequal meiosis I. The secondary oocyte is released at ovulation while arrested in metaphase II. (ii) The two pituitary hormones are **FSH and LH**.

Quick Tip to Solve: Pair each pause with its cell: the primary oocyte pauses in prophase I before birth, while the ovulated secondary oocyte pauses in metaphase II until fertilisation.

OR

33(b). (i) Draw a labelled two-celled structure of male gametophyte of an angiosperm.

(ii) Name the three layers that surround the cytoplasm of a male gametophyte starting from innermost to outermost layer.

(iii) Which organic material makes the outermost layer? Mention its advantage.

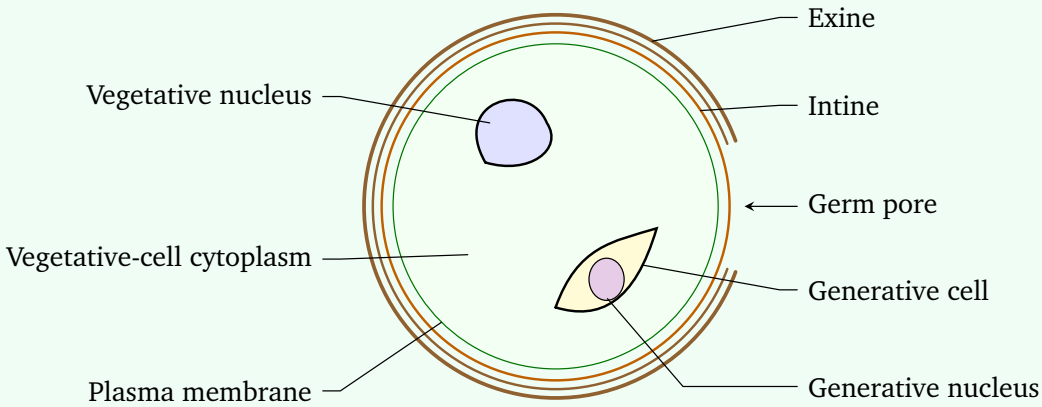
(iv) Why is the outermost layer of male gametophyte not continuous? [5 marks]

Solution:

Concept:

- The pollen grain is the male gametophyte of an angiosperm. At the two-celled stage it contains a large vegetative cell and a smaller generative cell.
- The living cytoplasm is enclosed by the plasma membrane. Outside it are the inner pollen-wall layer, intine, and the outer pollen-wall layer, exine.
- Exine contains sporopollenin and protects the pollen grain. Its apertures, called germ pores, permit the emergence of the pollen tube during germination.

Step 1: (i) Draw and identify the two cells In the labelled diagram, the large vegetative cell occupies most of the pollen grain and contains abundant food reserves and a large, irregularly shaped vegetative nucleus. The small generative cell lies within the cytoplasm of the vegetative cell; it has its own cytoplasm, boundary and nucleus. It is usually spindle-shaped. The generative cell subsequently divides mitotically to form two male gametes, whereas the vegetative cell forms the pollen tube. Thus, the two-celled stage must show a generative *cell*, not merely a second free nucleus.



Two-celled pollen grain showing the vegetative and generative cells and a germ pore.

Step 2: (ii) State the layers from inside to outside Starting immediately outside the cytoplasm, the order is **plasma membrane, intine, exine**. The plasma membrane encloses the living protoplast. Intine is the thin, continuous inner wall, composed of cellulose and pectin. Exine is the tough outer wall. Thus, the question's three enclosing layers include the plasma membrane, although the pollen *wall* itself has only two layers, intine and exine.

Step 3: (iii) Name the material and explain its advantage The outermost layer, exine, is made of **sporopollenin**, one of the most resistant organic materials known. It withstands high temperatures and strong acids and alkalis, and no enzyme that degrades it is known. This exceptional resistance protects the pollen grain against adverse environmental conditions during dispersal. It also accounts for the good preservation of pollen grains as fossils.

Step 4: (iv) Explain the interruption in exine Exine is interrupted at one or more **germ pores**, where sporopollenin is absent. These apertures provide sites through which the pollen tube emerges when a compatible pollen grain germinates on the stigma. The intine is continuous and extends out through a germ pore during pollen-tube formation. Without an aperture in the resistant exine, the growing tube would lack this exit route.

Step 5: Conclusion A two-celled pollen grain has one vegetative cell and one generative cell. Its enclosing layers, from innermost to outermost, are **plasma membrane, intine and exine**. Sporopollenin gives exine exceptional resistance, while its germ pores allow pollen-tube emergence.

Quick Tip to Solve: Label both the generative cell and its nucleus; then trace outward from the cytoplasm as membrane, intine, exine. Leave a germ-pore gap only in the exine.