

CBSE Class 12 Biology Question Paper 2026 with Solution PDF-Set 57-7-1 - Compartment



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. The undifferentiated sheath that encloses the radicle and root cap in a monocot embryo, is known as : [1 mark]

- (A) Coleoptile
- (B) Coleorrhiza
- (C) Epiblast
- (D) Scutellum

Correct Answer: (B) Coleorrhiza

Solution:

Concept:

- A monocot embryo has a single cotyledon called the scutellum and protective sheaths around its embryonal axis.
- The radicle and root cap are enclosed by the coleorrhiza, whereas the plumule is protected by the coleoptile.

Step 1: Identify the organ protected The question specifies the radicle together with its root cap. These form the embryonic root end, so the required structure must be the sheath associated with the root rather than the shoot.

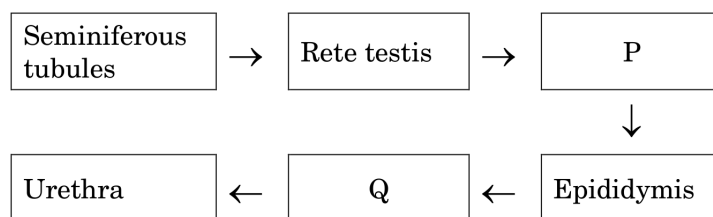
Step 2: Distinguish the other structures The coleoptile encloses the shoot apex and young leaves. The scutellum is the shield-shaped cotyledon, not a root sheath. The epiblast is a small embryonic outgrowth and does not enclose the radicle and root cap. Thus the other three options describe different structures.

Step 3: Conclusion The sheath is the coleorrhiza. Hence, the correct option is (B).

Quick Tip to Solve: Associate coleorrhiza with the radicle (root) and coleoptile with the plumule (shoot).

2. The path of the sperm transport is shown below. Identify P and Q and select the correct option.

[1 mark]



- (A) P – Vasa efferentia, Q – Ureter
(B) P – Ejaculatory duct, Q – Vas deferens
(C) P – Vasa efferentia, Q – Vas deferens
(D) P – Vas deferens, Q – Vasa efferentia

Correct Answer: (C) P – Vasa efferentia, Q – Vas deferens

Solution:

Concept:

- Sperm produced in seminiferous tubules pass through the rete testis and vasa efferentia before entering the epididymis.
- The epididymis continues into the vas deferens; the ejaculatory duct subsequently opens into the urethra.

Step 1: Locate P before the epididymis The vasa efferentia leave the testis and open into the epididymis. Therefore the structure between the rete testis and the epididymis, labelled P, is the vasa efferentia.

Step 2: Locate Q and reject the distractors Sperm leave the epididymis through the vas deferens, so Q is the vas deferens. The ureter carries urine from a kidney to the urinary bladder and is not a sperm duct. The ejaculatory duct lies farther along the pathway, not between the rete testis and epididymis. Reversing the two ducts also contradicts their anatomical order.

Step 3: Conclusion P is vasa efferentia and Q is vas deferens. Hence, the correct option is (C).

Quick Tip to Solve: Trace away from the testis: rete testis, vasa efferentia, epididymis, then vas deferens.

3. Morgan hybridised *Drosophila* white-eyed and yellow-bodied female with red-eyed and brown-bodied male (wild type) and intercrossed their F₁ progeny. He observed that the two genes :

[1 mark]

- (A) Did not segregate independent of each other.
- (B) Showed very low percentage of parental gene combinations.
- (C) Segregated independently of each other.
- (D) Showed very high percentage of recombinations.

Correct Answer: (A) Did not segregate independent of each other.

Solution:

Concept:

- Linkage is the tendency of genes located on the same chromosome to be inherited together.
- Closely linked genes produce more parental combinations and fewer recombinant combinations than independently assorting genes.

Step 1: Recognise the linked traits Morgan studied the inheritance of eye colour and body colour in *Drosophila*. The genes for white eyes and yellow body are located close together on the same X chromosome, so their transmission is linked.

Step 2: Compare the proposed outcomes Because these genes tend to travel together, they do not assort independently. The parental combinations are frequent and the recombinant combinations are infrequent. Thus the claims of very few parental combinations, independent segregation, or very high recombination contradict the observed close linkage.

Step 3: Conclusion The two genes did not segregate independently of each other. Hence, the correct option is (A).

Quick Tip to Solve: For closely linked genes, look for high parental frequency and low recombination frequency.

4. Select the option that has only termination codons.

[1 mark]

- (A) UAA, UGA, UAG
- (B) UAA, UUU, UGG
- (C) UAA, UAG, UAC
- (D) UUU, UCC, UGG

Correct Answer: (A) UAA, UGA, UAG

Solution:

Concept:

- A termination codon signals the end of translation rather than specifying an amino acid.
- The three stop codons in the standard genetic code are UAA, UAG and UGA.

Step 1: Recall the complete stop-codon set A ribosome terminates polypeptide synthesis when a stop codon is recognised by a release factor. UAA, UAG and UGA are all termination signals; their order within a listed option does not affect their identity.

Step 2: Check every option Option (A) contains all three stop codons and no sense codon. In (B), UUU codes for phenylalanine and UGG for tryptophan. In (C), UAC codes for tyrosine. In (D), UUU, UCC and UGG specify phenylalanine, serine and tryptophan respectively. These alternatives therefore cannot contain only termination codons.

Step 3: Conclusion Only UAA, UGA and UAG are termination codons. Hence, the correct option is (A).

Quick Tip to Solve: Memorise UAA, UAG and UGA as the three stop codons; UGG codes for tryptophan.

5. Choose the correct option that refers to adaptive radiation.

[1 mark]

- (A) Evolution of different species from a common ancestor to other geographical areas
- (B) Migration of members of different species to a common geographical area
- (C) Power of adaptation in an individual to a variety of environments
- (D) Evolution by anthropogenic action

Correct Answer: (A) Evolution of different species from a common ancestor to other geographical areas

Solution:

Concept:

- Adaptive radiation is the diversification of a common ancestral stock into species adapted to different habitats or ecological niches.
- It illustrates divergent evolution: related organisms develop different adaptations as they occupy different ways of life.

Step 1: Identify the common-ancestor pattern The defining feature is the origin of multiple related species from a common ancestor, followed by diversification into different habitats or niches. Darwin's finches illustrate this pattern through their different feeding adaptations.

Step 2: Evaluate the alternatives Option (A) expresses diversification from a common ancestor and is the intended description. Migration of unrelated species into one area does not establish common ancestry or diversification. An individual adapting during its lifetime is not the evolution of multiple species. Anthropogenic action describes a possible human influence on evolution, not the definition of adaptive radiation.

Step 3: Conclusion Evolution of different species from a common ancestor is the relevant pattern. Hence, the correct option is (A).

Quick Tip to Solve: Look for one ancestral stock branching into several species with different ecological adaptations.

6. P and Q are required in the extension step of PCR to extend the primer sequences from the 3' end of each primer. Choose the option which correctly fills the blanks P and Q. [1 mark]

- (A) P – Ribonucleoside triphosphate, Q – DNA polymerase
- (B) P – Deoxyribonucleotide triphosphate, Q – Thermolabile Taq-polymerase
- (C) P – Deoxynucleotides, Q – Thermostable DNA-polymerase
- (D) P – Deoxyribonucleoside monophosphate, Q – Thermostable DNA-polymerase

Correct Answer: (C) P – Deoxynucleotides, Q – Thermostable DNA-polymerase

Solution:

Concept:

- During PCR extension, DNA polymerase adds complementary deoxyribonucleotides to the free 3-prime hydroxyl end of a primer.
- PCR uses a thermostable DNA polymerase, such as Taq polymerase, so the enzyme tolerates repeated high-temperature denaturation.

Step 1: Identify the building blocks P New DNA is assembled from deoxyribonucleotide triphosphates. The printed term deoxynucleotides in option (C) refers to these DNA building blocks. Ribonucleoside triphosphates are substrates for RNA synthesis, while deoxyribonucleoside monophosphates are not the incoming activated substrates used in PCR.

Step 2: Identify the enzyme Q The enzyme must remain functional through repeated heating cycles. Taq DNA polymerase is thermostable, not thermolabile. It extends an annealed primer using the template sequence, producing a DNA strand in the 5-prime to 3-prime direction. Therefore the pairing of deoxynucleotides with thermostable DNA polymerase is appropriate.

Step 3: Conclusion P is deoxynucleotides and Q is thermostable DNA polymerase. Hence, the correct option is (C).

Quick Tip to Solve: PCR needs DNA building blocks plus a heat-stable enzyme; reject any option calling Taq thermolabile.

7. Identify the microbe that is responsible for producing large-holes in Swiss cheese. [1 mark]

- (A) *Propionibacterium sharmanii*
- (B) *Saccharomyces cerevisiae*
- (C) *Penicillium notatum*
- (D) *Acetobacter aceti*

Correct Answer: (A) *Propionibacterium sharmanii*

Solution:

Concept:

- Microorganisms used during cheese ripening can generate gases and characteristic flavours.
- *Propionibacterium sharmanii* produces carbon dioxide during Swiss-cheese manufacture; the gas forms the characteristic large holes.

Step 1: Connect the holes with gas production The large holes in Swiss cheese arise from carbon

dioxide generated during microbial fermentation and ripening. As the gas accumulates within the cheese, it creates the characteristic cavities.

Step 2: Identify the organism and distinguish the others Propionibacterium sharmanii is associated with this carbon dioxide production. Saccharomyces cerevisiae is commonly used in bread making and alcoholic fermentation. Penicillium notatum is associated with penicillin production, whereas Acetobacter aceti converts alcohol into acetic acid in vinegar manufacture. None of these is the named Swiss-cheese organism.

Step 3: Conclusion The organism is Propionibacterium sharmanii. Hence, the correct option is (A).

Quick Tip to Solve: Connect Swiss-cheese holes with carbon dioxide produced by Propionibacterium sharmanii.

8. Tetanus antitoxin, when injected into the human body, immediately provides which kind of immunity? Choose the correct option. [1 mark]

- (A) Innate immunity
- (B) Passive immunity
- (C) Autoimmunity
- (D) Active immunity

Correct Answer: (B) Passive immunity

Solution:

Concept:

- Passive immunity is protection supplied by ready-made antibodies obtained from another source.
- Active immunity requires the recipient to mount an immune response and therefore takes time to develop.

Step 1: Identify the injected material Tetanus antitoxin contains preformed antibodies against the toxin released by the tetanus bacterium. These antibodies can neutralise toxin immediately; the recipient does not first have to manufacture them.

Step 2: Distinguish the alternatives This transferred antibody protection is passive immunity. Innate immunity is present from birth, autoimmunity is an attack against self tissues, and active immunity develops when the body responds to an antigen. Thus none of these three alternatives describes the immediate action of antitoxin.

Step 3: Conclusion Tetanus antitoxin immediately provides passive immunity. Hence, the correct option is (B).

Quick Tip to Solve: Ready-made antibodies mean passive protection; an antigen that stimulates antibody production gives active immunity.

9. Cry proteins coded by the gene Cry IAb controls which one of the following pests?

[1 mark]

- (A) Cotton bollworm
- (B) Corn borer
- (C) Tobacco budworm
- (D) Mosquito

Correct Answer: (B) Corn borer

Solution:

Concept:

- Different cry genes of *Bacillus thuringiensis* encode insecticidal proteins with different target specificities.
- The cry IAb gene encodes a protein effective against corn borer.

Step 1: Match the gene to its target The relevant NCERT pairing is cry IAb with corn borer. A Bt plant expressing this gene produces a toxin that acts on the susceptible insect after ingestion and activation in its gut.

Step 2: Check the competing pests Cotton bollworms are associated with cry IAc and cry IIAb in the standard examples. Tobacco budworm and mosquito are not the prescribed target of cry IAb in this question. The presence of several Bt toxins does not make their target pests interchangeable.

Step 3: Conclusion The pest controlled by the Cry IAb protein is corn borer. Hence, the correct option is (B).

Quick Tip to Solve: Keep the gene-pest pair together: cry IAb controls corn borer, whereas cry IAc and cry IIAb control cotton bollworms.

10. If a new habitat is being colonized, out of the four processes affecting population growth, which are the two factors that contribute to an increase in population density?

(i) Immigration (ii) Natality (iii) Emigration (iv) Mortality

Options :

[1 mark]

- (A) (i) and (ii)
- (B) (ii) and (iii)
- (C) (iii) and (iv)
- (D) (i) and (iv)

Correct Answer: (A) (i) and (ii)

Solution:

Concept:

- Population density increases through natality and immigration and decreases through mortality and emigration.
- Natality adds newborn individuals; immigration adds individuals arriving from another population.

Step 1: Identify the additions Immigration, listed as (i), brings individuals into the newly colonised

habitat. Natality, listed as (ii), produces new individuals within the population. Both therefore increase the number of individuals per unit area.

Step 2: Eliminate processes that remove individuals Emigration, listed as (iii), is movement out of the habitat; mortality, listed as (iv), is loss through death. Each lowers population density. Option (B) includes emigration, option (C) contains only losses, and option (D) includes mortality, so these pairs cannot both increase density.

Step 3: Conclusion Immigration and natality, (i) and (ii), increase population density. Hence, the correct option is (A).

Quick Tip to Solve: Classify each process by direction: births and arrivals add individuals; deaths and departures remove them.

11. During the decomposition process, mineralisation by micro-organisms leads to the release of which nutrients into the soil? [1 mark]

- (A) Inorganic nutrients from humus
- (B) Both organic and inorganic nutrients from detritus
- (C) Organic nutrients from humus
- (D) Inorganic nutrients from detritus and formation of humus

Correct Answer: (A) Inorganic nutrients from humus

Solution:

Concept:

- Humification forms dark, amorphous humus that is resistant to rapid microbial decomposition.
- Mineralisation releases inorganic nutrients when microorganisms further degrade organic matter, including humus.

Step 1: Identify the product of mineralisation Mineralisation is the conversion of organically bound nutrients into inorganic mineral forms by microorganisms. In the decomposition sequence, further degradation of humus releases inorganic nutrients into the soil for reuse by plants.

Step 2: Separate mineralisation from other processes Option (C) calls the released nutrients organic, which contradicts mineralisation. Option (B) does not identify its inorganic end product alone. Option (D) combines nutrient release with formation of humus; the latter is humification rather than mineralisation. Option (A) gives the correct source and product.

Step 3: Conclusion Mineralisation releases inorganic nutrients from humus into the soil. Hence, the correct option is (A).

Quick Tip to Solve: Distinguish the two terms by their products: humification makes humus; mineralisation releases inorganic nutrients.

12. Genetically modified tobacco plants were produced using *Agrobacterium* vectors. Which properties of *Agrobacterium* help in carrying nematode-specific genes into the host plant? [1 mark]

- (A) Infectious for monocot plants; has Ti plasmid
- (B) Infectious for dicot plants; has Ti plasmid
- (C) Infectious for plants and animals; has Ti plasmid
- (D) Infectious for monocots and dicots; has cry genes

Correct Answer: (B) Infectious for dicot plants; has Ti plasmid

Solution:

Concept:

- *Agrobacterium tumefaciens* naturally transfers a segment of its Ti plasmid DNA into plant cells.
- A disarmed Ti plasmid can act as a vector carrying a desired gene into a dicotyledonous plant such as tobacco.

Step 1: Identify the host and delivery mechanism Tobacco is a dicot plant. *Agrobacterium* infects dicot plants in the standard transformation example, and its Ti plasmid provides the DNA-transfer system. After disarming the tumour-causing region, the vector can introduce nematode-specific sequences into the host.

Step 2: Check the remaining choices Option (A) specifies monocots rather than the relevant dicot host. Option (C) incorrectly extends the stated infection property to animals. Option (D) replaces the Ti-plasmid vector property with cry genes, which encode Bt insecticidal proteins and do not explain *Agrobacterium*-mediated transfer.

Step 3: Conclusion Infection of dicot plants and possession of a Ti plasmid enable the transfer. Hence, the correct option is (B).

Quick Tip to Solve: For *Agrobacterium*-mediated tobacco transformation, link the dicot host with the disarmed Ti plasmid vector.

13. Assertion (A): Apomictic embryos are genetically identical to the parent plant.

Reason (R): Apomixis is the production of seeds without fertilisation.

[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:

- Apomixis is a form of asexual reproduction that produces seeds without fertilisation.
- Apomictic embryos develop without the normal sexual fusion and segregation that generate variation.

Step 1: Judge Assertion (A) The assertion is true. In apomixis, an embryo can arise from an unreduced egg or a maternal somatic cell, as in nucellar embryony. It therefore retains the parental genetic constitution rather than acquiring a new combination from two parents.

Step 2: Judge Reason (R) The reason is true: apomixis means seed formation without fertilisation. It mimics sexual seed production while following an asexual route of embryo formation.

Step 3: Test the explanatory link The asexual production of an embryo without fertilisation explains why apomictic progeny preserve the parental genotype. Thus the reason correctly explains the assertion; the codes treating either statement as false, or denying this explanatory link, do not apply.

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

Quick Tip to Solve: In apomixis, connect asexual seed formation with preservation of the maternal genotype before selecting the assertion-reason code.

14. Assertion (A): Determining the sex of an unborn child followed by MTP is an illegal practice.

Reason (R): Amniocentesis is a practice to test the presence of genetic disorders.

[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:

- Amniocentesis examines amniotic fluid and foetal cells to detect genetic or chromosomal disorders.
- Prenatal sex determination followed by termination for sex selection is the illegal misuse described in the assertion.

Step 1: Judge Assertion (A) The assertion is true in the context of the question: determining the sex of an unborn child and then using MTP for sex selection is an illegal practice. This is the misuse of prenatal diagnostic techniques addressed in reproductive health.

Step 2: Judge Reason (R) The reason is also true. Amniocentesis is used to detect genetic disorders in the developing foetus by examining material obtained from the amniotic fluid. This states its legitimate diagnostic purpose and is independent of the misuse described in the assertion.

Step 3: Test the explanatory link Its ability to detect genetic disorders does not explain why sex determination followed by sex-selective termination is illegal. The illegality concerns sex selection and misuse of diagnosis. Therefore the two true statements do not have the explanatory relationship required for option (A); options (C) and (D) wrongly make one statement false.

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

Quick Tip to Solve: After judging both statements, ask whether the reason explains the ban on sex selection, rather than merely describing a diagnostic test.

15. Assertion (A): Mucosa-associated lymphoid tissues are specialised immune barriers located on the skin.

Reason (R): MALT constitutes about 50 percent of the lymphoid tissue in a human body. [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: (D) Assertion (A) is false, but Reason (R) is true.

Solution:

Concept:

- Mucosa-associated lymphoid tissue (MALT) is lymphoid tissue associated with the mucosal lining of the respiratory, digestive and urogenital tracts.
- The skin is a physical barrier of innate immunity; MALT is associated with mucous membranes.

Step 1: Judge the assertion The assertion is false. MALT is located within the lining of the major respiratory, digestive and urogenital tracts, where mucosal surfaces encounter foreign substances. It is not located on the skin.

Step 2: Judge the reason The reason is true: MALT constitutes about 50 percent of the lymphoid tissue in the human body.

Step 3: Check the assertion-reason relation Since the assertion is false while the reason is true, neither option (A) nor (B), which require both to be true, applies. Option (C) reverses the truth values.

Step 4: Conclusion The assertion is false, but the reason is true. Hence, the correct option is (D).

Quick Tip to Solve: Use the word mucosa to locate MALT in tract linings; do not confuse it with the skin barrier.

16. Assertion (A): Vector DNA and foreign DNA are cut by the same restriction enzyme.

Reason (R): Vector DNA and foreign DNA, cut with same enzyme, produces complementary sticky ends. [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:

- Restriction endonucleases recognise specific DNA sequences and cut DNA at defined positions.
- Using the same suitable restriction enzyme on vector and foreign DNA produces compatible complementary sticky ends, which can pair before ligation.

Step 1: Judge the assertion The assertion is true in the recombinant DNA procedure described. The vector DNA and foreign DNA are cut with the same restriction enzyme so that their ends are compatible.

Step 2: Judge the reason The reason is true. A suitable enzyme making staggered cuts generates single-stranded overhangs, called sticky ends, on both DNA molecules. Corresponding overhangs have complementary base sequences and can hydrogen-bond to one another.

Step 3: Check the explanatory connection Complementary sticky ends allow the foreign DNA to pair with the opened vector; DNA ligase then seals the sugar-phosphate backbone. Thus the reason explains why the same enzyme is used. Options (B), (C) and (D) fail because the reason is true and directly explains the true assertion.

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

Quick Tip to Solve: Link same restriction enzyme to compatible sticky ends, then distinguish base pairing from sealing by DNA ligase.

Section B (10 marks)

17(a). How is it possible in *Oxalis* and *Viola* plants, to produce assured seed sets even in the absence of pollinators? [2 marks]

Solution:

Concept:

- Cleistogamous flowers remain closed, so their anthers and stigma are not exposed to external pollinating agents.
- Autogamy is transfer of pollen from anther to stigma of the same flower and can occur within a closed flower.

Step 1: Identify the flower type *Oxalis* and *Viola* produce cleistogamous flowers in addition to open, chasmogamous flowers. The cleistogamous flowers never open; their reproductive organs remain enclosed within the flower.

Step 2: Explain assured self-pollination In a cleistogamous flower the anthers and stigma lie close together. When the anthers dehisce, pollen grains come into contact with the stigma of that same flower. This brings about autogamy without insects, wind or any other external pollen carrier.

Step 3: Connect pollination with seed formation The pollen germinates on the stigma and the pollen tube carries the male gametes to the embryo sac, allowing fertilisation and subsequent seed development. Therefore, absence of pollinators does not prevent seed set in these closed flowers.

Step 4: Conclusion *Oxalis* and *Viola* achieve assured seed set through cleistogamous flowers, which undergo autogamy even in the absence of pollinators.

Quick Tip to Solve: For assured seed set, name cleistogamy and explain how close anthers and stigma ensure autogamy.

OR

17(b). Write the ploidy of the cells of the nucellus, MMC (Megaspore Mother Cell), the functional megaspore and female gametophyte. [2 marks]

Solution:

Concept:

- Ploidy describes the number of chromosome sets: diploid cells have two sets, denoted $2n$, and haploid cells have one set, denoted n .
- Meiosis reduces the chromosome number; mitosis normally maintains it during development of the female gametophyte.

Step 1: State the sporophytic cell ploidy The nucellus is part of the diploid sporophyte, so its cells are $2n$. The megaspore mother cell (MMC), which differentiates within the nucellus, is also diploid, $2n$, before undergoing meiosis.

Step 2: Follow the reduction division The MMC undergoes meiosis to produce four haploid megas-

pores. Usually three degenerate and one survives as the functional megaspore. The functional megaspore is therefore haploid, n .

Step 3: State the gametophytic ploidy The functional megaspore develops through mitotic divisions into the female gametophyte or embryo sac. Its gametophytic ploidy is n . This does not imply that the fusion product of the two polar nuclei is haploid: after their fusion, the secondary nucleus in the central cell is $2n$.

Step 4: Conclusion Nucellus cells: $2n$; MMC: $2n$; functional megaspore: n ; female gametophyte: n .

Quick Tip to Solve: Place the chromosome-number reduction at MMC meiosis; the subsequent gametophyte-forming mitoses retain n .

18. How can childless couples get help by the following assisted reproductive technologies?

(a) GIFT

(b) ICSI

[2 marks]

Solution:

Concept:

- Assisted reproductive technologies help infertile couples by transferring gametes or facilitating fertilisation under specialised medical care.
- GIFT acts by transfer of a donor ovum into a fallopian tube; ICSI acts by direct injection of a sperm into an ovum.

Step 1: (a) Explain GIFT GIFT stands for gamete intrafallopian transfer. An ovum collected from a donor is transferred into the fallopian tube of a woman who cannot produce ova but can provide suitable conditions for fertilisation and further development. Fertilisation can then take place within her reproductive tract, enabling her to bear a child.

Step 2: (b) Explain ICSI ICSI stands for intracytoplasmic sperm injection. A single sperm is directly injected into an ovum in the laboratory to achieve fertilisation. This is useful when sperm cannot effectively fertilise the ovum on their own, such as in certain cases of male infertility. The resulting embryo is subsequently transferred into the female reproductive tract for further development.

Step 3: Conclusion GIFT helps by transferring a donor ovum into the woman's fallopian tube; ICSI helps by directly injecting a sperm into an ovum to form an embryo for subsequent transfer.

Quick Tip to Solve: Remember the intervention sites: GIFT transfers a gamete into a tube; ICSI injects a sperm into the egg cytoplasm.

19(a). Name the scientist who proposed the central dogma in molecular biology. Give its schematic representation. [2 marks]

Solution:

Concept:

- The central dogma describes the usual flow of genetic information from a nucleic acid to a functional protein.
- Transcription copies information from DNA into RNA; translation uses the message in RNA to assemble a polypeptide.

Step 1: Name the scientist Francis Crick proposed the central dogma in molecular biology. It relates the information stored in the sequence of bases in DNA to the sequence of amino acids in a protein.

Step 2: Give the schematic representation The central dogma is represented as



DNA serves as the template for RNA synthesis. The messenger RNA then carries the coded information to ribosomes, where translation produces the polypeptide. DNA also undergoes replication to pass genetic information to daughter cells; this is distinct from the DNA-to-RNA-to-protein expression pathway.

Step 3: Conclusion Francis Crick proposed the central dogma: DNA to RNA by transcription, then RNA to protein by translation.

Quick Tip to Solve: Write the two process names above the arrows: transcription before RNA and translation before protein.

OR

19(b). Write four criteria to be fulfilled by a molecule to act as a genetic material. [2 marks]

Solution:

Concept:

- A genetic material must store hereditary information, pass it on, and permit its expression in the organism.
- Hereditary continuity requires stability, while evolution requires occasional heritable changes.

Step 1: State replication and stability requirements First, the molecule must be able to generate its replica, that is, undergo replication so that genetic information can pass to daughter cells or offspring. Second, it must be chemically and structurally stable so that the stored information is preserved across generations.

Step 2: State variation and expression requirements Third, the molecule must provide scope for slow changes, or mutations, that are required for evolution. Fourth, it must be able to express itself in the form of Mendelian characters, directing the processes that produce the inherited traits. Stability does not mean an absolute inability to change: faithful inheritance and occasional mutation must both be

possible.

Step 3: Conclusion The four criteria are replication, chemical and structural stability, scope for slow mutations, and expression as Mendelian characters.

Quick Tip to Solve: Recall four verbs for genetic material: copy, persist, change slowly, and express.

20. (a) Define stratification in an ecosystem.

(b) How is stratification represented in a forest ecosystem?

[2 marks]

Solution:

Concept:

- Organisms occupy different positions within an ecosystem according to their habitat requirements.
- Stratification describes a vertical pattern of distribution, with different organisms occupying different heights or depths.

Step 1: Define stratification in part (a) Stratification is the vertical distribution of different species occupying different levels in an ecosystem. It describes the layering of the community along the vertical direction. Species in different layers experience different conditions, including the amount of light that reaches them.

Step 2: Describe forest stratification in part (b) In a forest, trees occupy the top vertical strata, shrubs form the second layer, and herbs and grasses occupy the bottom layers close to the ground. The tall trees form the upper canopy, while shorter plants grow beneath it. Thus the forest community is arranged in distinct vertical layers rather than all plant species occupying the same height.

Step 3: Conclusion Stratification is vertical layering of species; in a forest the main layers are trees above, shrubs beneath them, and herbs and grasses near the ground.

Quick Tip to Solve: Describe the forest from top to bottom: trees, then shrubs, then herbs and grasses.

21(a). (i) Name the source plant of heroin drug. How is it obtained from the plant?

(ii) Write the effects of heroin on the human body.

[2 marks]

Solution:

Concept:

- Heroin is an opioid drug derived from morphine, a natural compound obtained from the poppy plant.
- Heroin acts as a depressant: it slows down body functions through its effects on the nervous system.

Step 1: Identify the plant and origin in part (i) The source plant is the poppy, *Papaver somniferum*. Morphine is extracted from the latex of this plant, and heroin is obtained by acetylation of morphine. Heroin is therefore also called diacetylmorphine; it is not extracted directly as heroin from the plant latex.

Step 2: State the effects in part (ii) Heroin is a depressant and slows down body functions. It produces drowsiness and sedation, and depresses the activity of the central nervous system, including breathing. It is highly addictive and can produce dependence; severe respiratory depression in overdose can be fatal. The key effect to state here is the slowing of body functions, rather than stimulation or increased alertness.

Step 3: Conclusion Heroin comes from morphine extracted from the latex of *Papaver somniferum*, followed by acetylation. It is an addictive depressant that slows body functions.

Quick Tip to Solve: Link poppy latex to morphine, morphine acetylation to heroin, and heroin to slowed body functions.

OR

21(b). What is ‘withdrawal syndrome’? List any two symptoms it is characterised by.

[2 marks]

Solution:

Concept:

- Continued use of an addictive drug or alcohol can produce dependence: the body becomes accustomed to its regular presence.
- Withdrawal symptoms appear when the regular intake of the substance is abruptly discontinued.

Step 1: Define withdrawal syndrome Withdrawal syndrome is the group of unpleasant physical and psychological symptoms experienced by a dependent person when the regular dose of a drug or alcohol is abruptly stopped. It reflects dependence on the substance; it is not the immediate pleasurable effect produced by taking it.

Step 2: State two characteristic symptoms Two symptoms of withdrawal syndrome are **anxiety** and **shakiness (tremors)**. Anxiety is marked by uneasiness or nervousness, while shakiness involves involuntary trembling. Their appearance after stopping regular intake is the defining context of withdrawal.

Step 3: Conclusion Withdrawal syndrome is the unpleasant response to abrupt discontinuation of a regularly used addictive substance in a dependent person. Two characteristic symptoms are anxiety and shakiness.

Quick Tip to Solve: Link the symptoms to stopping the regular dose; distinguish withdrawal from the effects during drug intake.

Section C (21 marks)

22. (a) Draw a diagram of L.S. of an anatropous ovule of an angiosperm. Label the following parts :

(i) Nucellus

(ii) Outer integument

(iii) Antipodal cells

(iv) Polar nuclei

(b) How does endosperm in angiosperms become triploid?

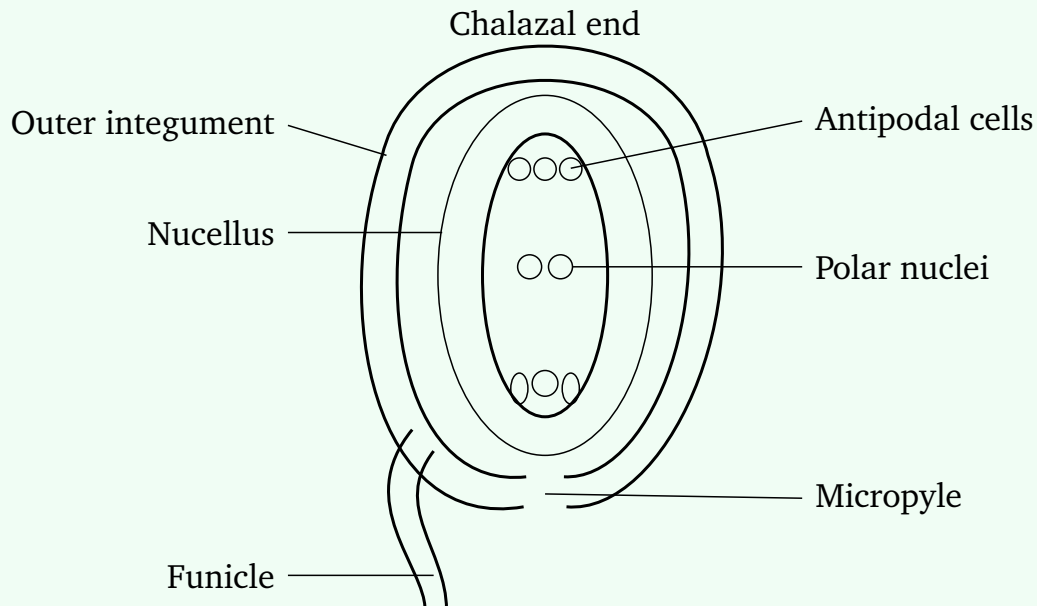
[3 marks]

Solution:

Concept:

- An anatropous ovule is inverted, bringing its micropyle close to the funicle; the embryo sac lies within the nucellus and is protected by integuments.
- In a typical angiosperm embryo sac, two haploid polar nuclei occupy the central cell and three antipodal cells lie at the chalazal end.
- Triple fusion combines one haploid male gamete with the two haploid polar nuclei to form the triploid primary endosperm nucleus.

Step 1: Part (a): Draw and label the ovule The longitudinal section below shows an inverted ovule attached to its funicle, with the micropyle beside the attachment. The outer integument surrounds the inner integument and nucellus. Within the nucellus, the embryo sac contains antipodal cells towards the chalazal end and two polar nuclei in the central cell. The four requested structures are labelled explicitly.



L.S. of an anatropous ovule (schematic)

Step 2: Part (b): Explain the triploid condition During double fertilisation, one male gamete fuses with the egg to form the zygote. The other male gamete, carrying n chromosomes, fuses with the two

polar nuclei, each carrying n chromosomes, in the central cell. Thus

$$n + n + n = 3n.$$

This event is called **triple fusion**. It produces the triploid primary endosperm nucleus; the resulting primary endosperm cell divides repeatedly to form the endosperm. Hence its triploidy comes from two maternal haploid chromosome sets and one paternal haploid set.

Step 3: Conclusion The labelled L.S. shows the anatropous ovule. Endosperm becomes triploid through triple fusion: one male gamete (n) fuses with two polar nuclei ($n + n$), giving $3n$.

Quick Tip to Solve: Place antipodals at the chalazal end and polar nuclei centrally; count all three haploid nuclei in triple fusion.

23. Define test cross. How does test cross help to determine the genotype of an individual? Explain with the help of an example. [3 marks]

Solution:

Concept:

- A dominant phenotype can have either a homozygous dominant or a heterozygous genotype; phenotype alone does not distinguish them.
- A test cross mates the individual showing the dominant phenotype with a homozygous recessive individual, so the offspring reveal the gametes produced by the tested parent.

Step 1: Define a test cross A test cross is a cross between an individual showing a dominant phenotype, whose genotype is to be determined, and a homozygous recessive individual for the same trait. The recessive parent contributes only the recessive allele; consequently the phenotype of each offspring indicates which allele came from the tested parent.

Step 2: Test a homozygous dominant tall pea plant For pea-plant height, let T denote the dominant allele for tallness and t the recessive allele for dwarfness. Cross the unknown tall plant with a dwarf plant (tt). If the tall plant is TT , it produces only T gametes:

$$TT \times tt \longrightarrow \text{all } Tt \text{ (tall)}.$$

Thus a homozygous dominant parent gives only tall offspring under Mendelian inheritance.

Step 3: Test a heterozygous tall pea plant If the tall plant is Tt , it produces T and t gametes in equal proportions. The dwarf parent produces only t gametes:

$$Tt \times tt \longrightarrow \frac{1}{2}Tt \text{ (tall)} + \frac{1}{2}tt \text{ (dwarf)}.$$

The expected phenotypic and genotypic ratios are both 1 : 1. The appearance of dwarf progeny establishes that the tall parent carries t , and is therefore heterozygous. An adequately large all-tall progeny supports the homozygous dominant genotype; a small sample alone may miss recessive offspring by chance.

Step 4: Conclusion A test cross reveals an unknown dominant genotype by crossing it with a homozygous recessive individual: $TT \times tt$ gives all tall progeny, whereas $Tt \times tt$ gives tall and dwarf progeny in an expected 1 : 1 ratio.

Quick Tip to Solve: The recessive tester contributes only t, so a dwarf offspring proves that the unknown tall parent supplied t.

24. Explain the Hardy-Weinberg principle with the help of an algebraic equation.

[3 marks]

Solution:

Concept:

- The Hardy-Weinberg principle states that allele frequencies in a population remain constant from generation to generation in the absence of disturbing evolutionary influences.
- For two alleles A and a , let their frequencies be p and q , respectively. Since these are the only two alleles, $p + q = 1$.

Step 1: State genetic equilibrium In a large, randomly mating population, the gene pool remains constant across generations when mutation, migration, natural selection and genetic drift do not disturb it. This constancy of allele frequencies is called genetic equilibrium. Random mating combines alleles without favouring any particular genotype.

Step 2: Obtain the algebraic equation Both male and female gametes carry A with probability p and a with probability q . Random fertilisation therefore produces AA with frequency p^2 , Aa with frequency $pq + qp = 2pq$, and aa with frequency q^2 . Thus, the total genotype frequency is

$$(p + q)^2 = p^2 + 2pq + q^2 = 1.$$

Here p^2 and q^2 represent the two homozygous classes, while $2pq$ represents heterozygotes.

Step 3: Interpret the equation The same allele frequencies are recovered in the next generation: the frequency of A is $p^2 + pq = p(p + q) = p$, and that of a is $q^2 + pq = q$. A change in allele frequencies indicates a disturbance of equilibrium and hence evolutionary change.

Step 4: Conclusion Hardy-Weinberg equilibrium is expressed as $p + q = 1$ and $p^2 + 2pq + q^2 = 1$: allele and genotype frequencies remain constant under the stated conditions.

Quick Tip to Solve: Always define p and q as allele frequencies, then identify all three genotype terms.

25. (a) How does the human body respond to an allergen? Which type of antibody is produced during allergic reactions?

(b) Name the types of drugs that help in reducing the symptoms of allergic reactions.

(c) Name the chemicals released in the body during an allergic reaction.

[3 marks]

Solution:

Concept:

- An allergy is an exaggerated immune response to an otherwise harmless environmental antigen, called an allergen; examples include pollen and dust mites.
- Allergic responses involve IgE antibodies and the release of inflammatory mediators from mast cells.

Step 1: (a) Explain the response and identify the antibody The body mounts an exaggerated immune response when a susceptible person encounters an allergen. It produces immunoglobulin E, or IgE, against the allergen. These antibodies become associated with mast cells. On subsequent exposure, the allergen interacts with mast-cell-bound IgE, triggering the release of chemical mediators. This produces symptoms such as sneezing, a running nose, watery eyes or difficulty in breathing, depending on the tissue involved.

Step 2: (b) Name the drugs that reduce symptoms Antihistamines, adrenaline and steroids help reduce the symptoms of allergic reactions. Antihistamines oppose the effects of histamine; adrenaline can counter severe allergic responses, while steroids suppress inflammation. These drugs act on the reaction or its effects and help relieve symptoms.

Step 3: (c) Name the chemicals released Mast cells release histamine and serotonin during an allergic reaction. These chemical mediators contribute to inflammatory changes in the affected tissues and thus account for many of the characteristic allergic symptoms. The antibody involved is therefore distinct from the chemicals released by the responding cells.

Step 4: Conclusion (a) An exaggerated immune response with IgE production; (b) antihistamines, adrenaline and steroids; (c) histamine and serotonin.

Quick Tip to Solve: Keep the three lists separate: IgE is the antibody, histamine and serotonin are mediators, and antihistamines are drugs.

26. Explain any three different approaches used in the treatment of a person suffering from Adenosine Deaminase deficiency.

[3 marks]

Solution:

Concept:

- Adenosine deaminase (ADA) is essential for normal immune-system function. Its deficiency causes severe combined immunodeficiency and can be approached by replacing cells, replacing the enzyme, or supplying a functional gene.
- Gene therapy introduces a functional copy of a defective gene into suitable cells so that the required protein can be produced.

Step 1: 1. Bone marrow transplantation Transplantation of suitable healthy donor bone marrow supplies cells capable of producing functional immune cells. This approach seeks to restore immune function by replacing the defective blood-cell-forming system. It is one of the established approaches used for ADA deficiency, although successful and complete correction is not guaranteed in every case.

Step 2: 2. Enzyme replacement therapy Functional ADA enzyme is given to the patient by injection to compensate for the missing or deficient enzyme. The administered enzyme supports the required biochemical function, but does not correct the defective gene. Consequently, treatment has to be repeated; its effect is not a permanent genetic correction.

Step 3: 3. Gene therapy using lymphocytes Lymphocytes are isolated from the patient's blood and grown in culture outside the body. A functional ADA cDNA is introduced into these lymphocytes using a retroviral vector. The genetically modified lymphocytes are then returned to the patient. Because these lymphocytes are not immortal, periodic infusions of modified cells are required. Introducing a functional ADA gene into cells at an early embryonic stage could provide a permanent correction.

Step 4: Conclusion Three approaches are bone marrow transplantation, enzyme replacement by ADA injections, and gene therapy by introducing functional ADA cDNA into the patient's lymphocytes.

Quick Tip to Solve: For each approach, state what is supplied: healthy marrow, functional enzyme, or a functional ADA gene.

27. (a) Name the type of interaction seen in each of the following examples.

(i) An orchid growing on branch of mango tree

(ii) Wasp pollinating fig inflorescence

(b) Also explain the above interactions shown by (i) and (ii).

[3 marks]

Solution:

Concept:

- An interspecific interaction is described by its effect on each partner: benefit is denoted by +, harm by –, and no significant effect by 0.
- Commensalism has the outcome (+, 0), whereas mutualism has the outcome (+, +).

Step 1: (a)(i) Identify the orchid interaction An orchid growing on a mango branch shows commensalism. The orchid is an epiphyte: it uses the tree as a place on which to grow, gaining support and access to better light above the ground. It does not obtain its food by extracting nutrients from the mango tree.

Step 2: (b)(i) Explain the effect on both partners The orchid benefits from its elevated position, while the mango tree is neither benefited nor harmed in this textbook example. Thus the effects are positive for the orchid and neutral for the mango tree, giving (+, 0). The interaction is consequently different from parasitism, in which the host would be harmed.

Step 3: (a)(ii) and (b)(ii) Identify and explain the fig-wasp interaction A wasp pollinating a fig inflorescence shows mutualism. The female wasp uses the fig inflorescence as a site for laying eggs; the developing larvae obtain nourishment from some of the developing seeds. In return, the wasp

carries pollen and pollinates the fig flowers, enabling seed production. Since both the fig and the wasp benefit, this is a (+, +) interaction. The association is highly specific, with a fig species associated with its pollinating wasp species.

Step 4: Conclusion (i) Orchid-mango: commensalism, (+, 0). (ii) Fig-pollinating wasp: mutualism, (+, +).

Quick Tip to Solve: For each example, state the benefit to one organism and then explicitly state the effect on its partner.

28. 'Indo-Burma' is considered as a hotspot. What is meant by the term 'hotspots' in biodiversity? List two criteria used for determining a 'hotspot'. Name any two hotspots of India. [3 marks]

Solution:

Concept:

- A biodiversity hotspot is a region with exceptionally high species richness and endemism that also faces severe habitat loss and threat.
- Endemic species are naturally restricted to a particular geographical region; richness alone does not establish hotspot status.

Step 1: Define a biodiversity hotspot A hotspot is a priority region for conservation because it contains a large concentration of species, especially species found nowhere else, and its natural habitats have undergone extensive destruction. Losing such a region can therefore cause the global extinction of its endemic species. Indo-Burma is one such region.

Step 2: State the two qualifying criteria The two criteria are high endemism and severe habitat loss. More precisely, a region must contain at least 1,500 endemic species of vascular plants, and it must have lost at least 70 percent of its original natural vegetation. These are separate requirements: the first identifies irreplaceable biological diversity, while the second identifies the degree of threat to it. A species-rich region with little habitat loss does not qualify merely because many species occur there.

Step 3: Name two hotspots represented in India Two hotspots that include parts of India are the Western Ghats and Sri Lanka hotspot, and the Himalaya hotspot. These names refer to broader biogeographical regions; their boundaries need not coincide with national boundaries. The Indian Western Ghats and the Indian Himalayan region form the Indian portions of these respective hotspots.

Step 4: Conclusion Hotspots combine high endemism with major habitat loss. The criteria are at least 1,500 endemic vascular plant species and loss of at least 70 percent of original vegetation. Examples: Western Ghats and Sri Lanka, and Himalaya.

Quick Tip to Solve: Remember both selection tests: exceptional endemic plant diversity and severe loss of original vegetation.

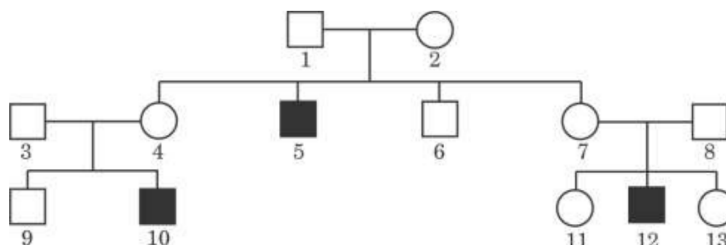
Section D (8 marks)

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

29(a). Haemophilia is a sex-linked recessive disease. Study the pedigree analysis given below showing the inheritance of the disease in a family and answer the questions that follow :

Analyse the given pedigree chart to explain why Haemophilia is considered a sex-linked recessive disorder.

[1 mark]



Solution:

Concept:

- Let X^H carry the normal allele and X^h carry the recessive haemophilia allele.
- A male X^hY is affected; a heterozygous female $X^H X^h$ is an unaffected carrier.

Step 1: Use the affected sons of unaffected parents Unaffected parents 1 and 2 have affected son 5. Likewise, unaffected mothers 4 and 7 have affected sons 10 and 12. Expression in offspring of unaffected parents supports recessive inheritance: these mothers can carry the allele without expressing the disorder.

Step 2: Relate the pattern to the X chromosome The affected individuals shown, 5, 10 and 12, are males. A son receives his only X chromosome from his mother; a single recessive X^h is therefore expressed in him. The pattern is consistent with transmission through carrier females and expression predominantly in males.

Step 3: Conclusion The pedigree supports X-linked recessive inheritance: unaffected carrier females transmit the recessive allele to affected sons.

Quick Tip to Solve: Point to the actual pedigree numbers: unaffected mother 2 has affected son 5, and the pattern repeats in 4 and 7.

29(b). Haemophilia is a sex-linked recessive disease. Study the pedigree analysis given below showing the inheritance of the disease in a family and answer the questions that follow :

(i) The possibility of a human female becoming a haemophilic is extremely rare. Explain.

(ii) Why do the sons of a haemophilic father never suffer from this disease?

[2 marks]

Solution:

Concept:

- Haemophilia is X-linked recessive: $X^H X^h$ females are carriers, while $X^h X^h$ females and $X^h Y$ males are affected.
- A father contributes his X chromosome to daughters and his Y chromosome to sons; the mother contributes an X to either sex.

Step 1: (i) Explain why affected females are rare A female becomes haemophilic only when both her X chromosomes carry the recessive allele, giving $X^h X^h$. She must receive one affected X from a haemophilic father and another affected X from a carrier or haemophilic mother. The combination of a haemophilic father with a mother carrying the same rare allele is uncommon. By contrast, a male needs only one X^h from his mother because his Y chromosome carries no corresponding normal allele to mask it.

Step 2: (ii) Explain transmission from father to son A haemophilic father has genotype $X^h Y$. His sons inherit his Y chromosome, not his affected X^h , so he cannot transmit haemophilia directly to them. With a homozygous normal mother, $X^H X^H$, all sons are $X^H Y$ and normal. The printed statement refers to this lack of paternal transmission: a son could still be haemophilic if he inherits X^h from a carrier or affected mother.

Step 3: Conclusion (i) A female requires two recessive alleles, one from each parent. (ii) Sons receive their father's Y, so they do not inherit his haemophilia allele; their risk depends on the maternal X.

Quick Tip to Solve: Track the chromosome rather than the parent's disease: father-to-son inheritance supplies Y, whereas the son's X always comes from his mother.

29(c)(i). Haemophilia is a sex-linked recessive disease. Study the pedigree analysis given below showing the inheritance of the disease in a family and answer the questions that follow :

Write the possible genotype of the individuals 2 and 5.

[1 mark]

Solution:

Concept:

- Haemophilia is an X-linked recessive disorder; let X^H carry the normal allele and X^h the haemophilia allele.
- An affected son receives his only X chromosome from his mother and his Y chromosome from his father.

Step 1: Identify individual 2 Individual 2 is an unaffected female, but her son 5 is affected. Son 5 must have received an X^h chromosome from her. Since she herself is unaffected, she must also possess a normal X^H allele; hence she is a heterozygous carrier.

Step 2: Identify individual 5 Individual 5 is represented by a shaded square, indicating an affected male. A male has one X and one Y chromosome; the recessive disease allele on his single X chromosome is expressed, so his genotype is X^hY .

Step 3: Conclusion Individual 2: X^HX^h (carrier female); individual 5: X^hY (haemophilic male).

Quick Tip to Solve: For an affected son, trace his X chromosome back to his mother, never to his father.

OR

29(c)(ii). Haemophilia is a sex-linked recessive disease. Study the pedigree analysis given below showing the inheritance of the disease in a family and answer the questions that follow :

Why is haemophilia categorised as a Mendelian disorder?

[1 mark]

Solution:

Concept:

- Mendelian disorders arise from mutation or alteration of a single gene.
- Alleles of an X-linked gene segregate during gamete formation, although inheritance depends on the sex chromosomes.

Step 1: Identify the genetic basis Haemophilia is caused by a defect in a single gene controlling a blood-clotting factor. Its disease allele is recessive and is located on the X chromosome. Thus the condition has a single-gene basis rather than being caused by a change in chromosome number.

Step 2: Relate this to inheritance The normal and defective alleles segregate into gametes and are transmitted from parents to offspring. A carrier female may transmit the defective allele to a son, in whom it is expressed because he has only one X chromosome. This predictable single-gene transmission places haemophilia among Mendelian disorders.

Step 3: Conclusion Haemophilia is a Mendelian disorder because it results from a mutation in a single gene and its alleles follow Mendelian segregation.

Quick Tip to Solve: Classify a single-gene disorder as Mendelian even when the gene is on a sex chromosome.

30(a). Sewage is generated in large quantities in the urban areas. It is treated in sewage treatment-plants (STPs) to make it less polluted before discharging into any natural water body. Observe the flow chart given below and answer the questions that follow :

Name the two products obtained after primary treatment of sewage.

[1 mark]

Primary effluent is passed into large aeration tank



Effluent is passed into settling tank to form the sediment (activated sludge)

Solution:

Concept:

- Primary sewage treatment removes suspended solids by physical processes such as filtration and sedimentation.
- Sedimentation separates the settled solid fraction from the liquid supernatant.

Step 1: Identify the settled product During primary treatment, floating debris is removed and grit and other suspended solids are allowed to settle. The solids that settle to the bottom form the primary sludge.

Step 2: Identify the liquid product The liquid remaining above the settled primary sludge is the primary effluent. It contains dissolved and fine organic matter and passes to the aeration tank for secondary biological treatment. Activated sludge is formed later, during secondary treatment, so it is not the sludge asked for here.

Step 3: Conclusion The two products are primary sludge and primary effluent.

Quick Tip to Solve: Distinguish primary sludge from activated sludge by the treatment stage in which each forms.

30(b). Sewage is generated in large quantities in the urban areas. It is treated in sewage treatment-plants (STPs) to make it less polluted before discharging into any natural water body. Observe the flow chart given below and answer the questions that follow :

What happens to the activated sludge when it is passed into an anaerobic sludge digester? Explain.

[2 marks]

Solution:

Concept:

- Activated sludge contains microbial flocs formed during aerobic secondary sewage treatment.
- Anaerobic digestion decomposes sludge without oxygen and produces a combustible mixture called

biogas.

Step 1: Digest the sludge anaerobically Most of the activated sludge is pumped into large anaerobic sludge digesters. In the absence of oxygen, anaerobic bacteria break down its organic matter. These microbes also digest the bacteria and fungi present in the sludge, thereby reducing and stabilising the organic material. A small portion of activated sludge is instead returned to the aeration tank as an inoculum.

Step 2: Explain gas production During anaerobic digestion, microbes including methanogens produce methane along with carbon dioxide and hydrogen sulphide. These gases together form biogas. The methane-rich gas mixture can be collected and used as a source of energy. Thus the digester both reduces the organic sludge load and converts some of its organic material into useful gaseous products.

Step 3: Conclusion Anaerobic microbes digest the organic matter, bacteria and fungi in activated sludge, releasing biogas containing methane, carbon dioxide and hydrogen sulphide.

Quick Tip to Solve: Link the absence of oxygen in the digester with anaerobic decomposition and methane production.

30(c)(i). Sewage is generated in large quantities in the urban areas. It is treated in sewage treatment-plants (STPs) to make it less polluted before discharging into any natural water body. Observe the flow chart given below and answer the questions that follow :

Name the two groups of microbes present in the primary effluent after it is passed into large aeration tanks. [1 mark]

Solution:

Concept:

- Aeration supplies oxygen and favours the growth of aerobic microorganisms.
- Flocs are masses of bacteria associated with fungal filaments, forming mesh-like structures.

Step 1: Identify the main growing microbes When primary effluent enters the aeration tank, it is vigorously agitated and air is pumped into it. This allows useful aerobic microbes, mainly bacteria, to grow rapidly while consuming the organic matter in the sewage.

Step 2: Identify their associated group The bacteria associate with fungal filaments to form flocs. Therefore the two groups asked for are bacteria and fungi. These flocs help lower the organic load and settle in the subsequent settling tank as activated sludge; methanogens belong to the later anaerobic digestion stage.

Step 3: Conclusion The two groups are aerobic bacteria and fungi (fungal filaments).

Quick Tip to Solve: Recall that an aeration-tank floc consists of bacteria associated with fungal filaments.

30(c)(ii). Sewage is generated in large quantities in the urban areas. It is treated in sewage treatment-plants (STPs) to make it less polluted before discharging into any natural water body. Observe the flow chart given below and answer the questions that follow :

Define BOD. What happens to the BOD when organic matter present in the wastewater increases?

[1 mark]

Solution:

Concept:

- BOD means biochemical oxygen demand and measures oxygen consumed by microbes while decomposing organic matter in water.
- A greater biodegradable organic load supports more microbial respiration and therefore greater oxygen demand.

Step 1: Define BOD Biochemical oxygen demand (BOD) is the amount of dissolved oxygen required by aerobic microorganisms to oxidise the biodegradable organic matter present in a water sample under specified test conditions. It is used as an indicator of organic pollution.

Step 2: Relate BOD to organic matter When the amount of biodegradable organic matter in wastewater increases, microbes have more substrate to decompose. They consume more oxygen in doing so, and hence the BOD increases. BOD is oxygen demand, so it should not be confused with the dissolved oxygen remaining in the water, which may decrease.

Step 3: Conclusion BOD is the oxygen required for microbial oxidation of biodegradable organic matter; increasing the organic matter increases BOD.

Quick Tip to Solve: More biodegradable waste means more microbial respiration and hence a higher oxygen demand.

Section E (15 marks)

31(a). Draw a flow chart to show hormonal control of the human male reproductive system. [5 marks]

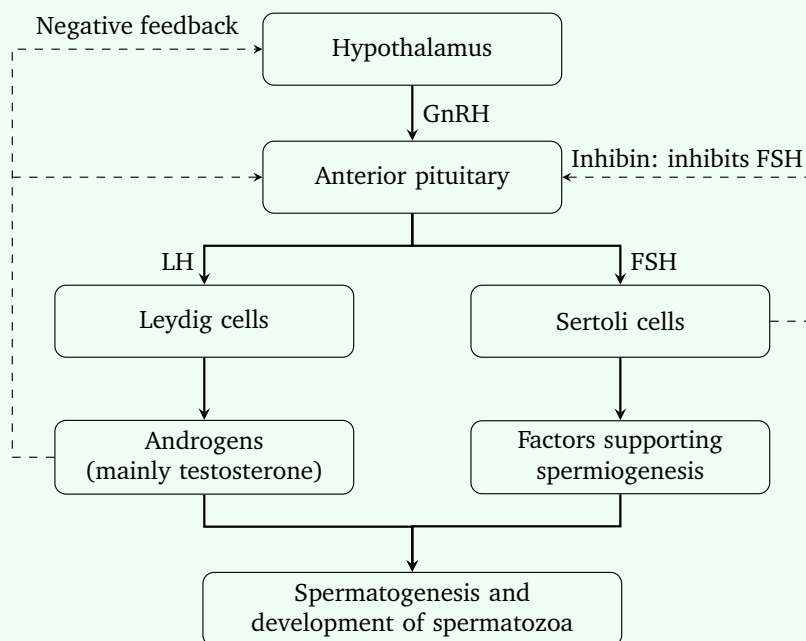
Solution:

Concept:

- Male reproductive functions are controlled by the hypothalamus, anterior pituitary and testes. At puberty, increased secretion of gonadotropin-releasing hormone (GnRH) activates this hormonal axis.
- The anterior pituitary releases two gonadotropins: luteinising hormone (LH) and follicle-stimulating hormone (FSH). Their testicular target cells and functions differ.
- Androgens support spermatogenesis, while FSH acts on Sertoli cells to promote the support required for sperm formation. Negative feedback regulates hormone secretion.

Step 1: Initiate the hypothalamus–pituitary pathway The hypothalamus secretes GnRH, which stimulates the anterior pituitary to release LH and FSH. The following flow chart shows both branches

of hormonal control. Solid arrows indicate stimulation; dashed arrows indicate negative feedback.



Hormonal control of the human male reproductive system

Step 2: Follow the LH and FSH branches LH acts on the interstitial cells, or Leydig cells, of the testes and stimulates the synthesis and secretion of androgens, mainly testosterone. These androgens stimulate spermatogenesis. FSH acts on Sertoli cells in the seminiferous tubules and stimulates the secretion of factors that help the process of spermiogenesis.

Step 3: Complete the feedback control Testosterone feeds back negatively on the hypothalamus and anterior pituitary, reducing GnRH and LH secretion when androgen levels are sufficient. Sertoli cells also secrete inhibin, which inhibits FSH secretion from the anterior pituitary.

Step 4: Conclusion GnRH activates pituitary LH and FSH release. LH acts on Leydig cells and FSH on Sertoli cells; their combined action supports sperm development, with testosterone and inhibin providing negative feedback.

Quick Tip to Solve: In the flow chart, put LH above Leydig cells and FSH above Sertoli cells; show the two branches converging on sperm development and label feedback separately.

OR

31(b). Explain the changes that the primary oocyte undergoes while in different follicular stages before ovulation. [5 marks]

Solution:

Concept:

- Oogenesis forms the female gamete. A primary oocyte is diploid, $2n = 46$, and remains arrested in prophase I of meiosis from fetal life until its further maturation after puberty.

- Follicular maturation and oocyte maturation occur together, but they are distinct: granulosa and thecal cells form the supporting follicle, while the oocyte undergoes growth and meiotic division.
- Unequal cytokinesis retains almost all the nutrient-rich cytoplasm in the developing female gamete; the small polar body receives a haploid chromosome set.

Step 1: Primary oocyte in the primary follicle During fetal development, oogonia enter meiosis I and become primary oocytes, which arrest in prophase I. Each primary oocyte becomes surrounded by a layer of granulosa cells to form a primary follicle. Thus, the cell inside a primary follicle is still a diploid primary oocyte; it has not yet completed meiosis I. Many follicles degenerate, while selected surviving follicles develop further after puberty.

Step 2: Development into a secondary follicle The primary follicle acquires additional layers of granulosa cells and a surrounding theca, becoming a secondary follicle. The granulosa cells nourish and support the enclosed oocyte. Although the follicle has increased in size and complexity, the enclosed germ cell is still called a primary oocyte and remains in prophase I. A secondary follicle must therefore not be confused with a secondary oocyte.

Step 3: Changes in the tertiary follicle A fluid-filled cavity, the antrum, develops, producing the tertiary follicle. Its theca differentiates into an inner theca interna and an outer theca externa. At this stage, the primary oocyte grows in size and completes its first meiotic division. Unequal division produces one large haploid secondary oocyte and one tiny first polar body, each with $n = 23$ chromosomes. Each chromosome still consists of two sister chromatids. Most of the cytoplasm remains in the secondary oocyte so that it retains the resources needed for early development.

Step 4: Maturation of the Graafian follicle before ovulation The tertiary follicle develops into the mature Graafian follicle. The secondary oocyte forms a new surrounding layer called the zona pellucida. It begins meiosis II and arrests at metaphase II. Consequently, the cell present just before ovulation is a haploid secondary oocyte, not a fully mature ovum. The Graafian follicle subsequently ruptures at ovulation and releases this secondary oocyte. Meiosis II is completed only if fertilisation occurs, so this completion is not a pre-ovulatory change.

Step 5: Conclusion Before ovulation, the arrested diploid primary oocyte grows and completes meiosis I during tertiary follicular development, forming a large haploid secondary oocyte and a small first polar body. The secondary oocyte, surrounded by the zona pellucida, is released from the mature Graafian follicle while arrested in metaphase II.

Quick Tip to Solve: Keep the two naming sequences separate: a secondary follicle still contains a primary oocyte; meiosis I in the tertiary follicle produces the secondary oocyte.

- 32(a).** (i) How and why is charging of tRNA essential in the process of translation?
(ii) State the function of ribosome as a catalyst in translation in bacteria.
(iii) Explain the process of binding of ribosomal units to mRNA during protein synthesis.
(iv) Where are untranslated regions located in mRNA? Mention their role.

[5 marks]

Solution:

Concept:

- Translation converts the codon sequence of mRNA into a polypeptide. tRNA acts as the adaptor: its anticodon recognises a codon, while its amino-acid attachment site carries the corresponding amino acid.
- The ribosome brings mRNA and charged tRNAs together and catalyses peptide-bond formation. Initiation assembles its two subunits at the start codon; untranslated regions flank the coding sequence and aid efficient translation.

Step 1: (i) Charging of tRNA: how it occurs and why it is needed A specific aminoacyl-tRNA synthetase activates an amino acid using ATP and attaches it to the corresponding tRNA at its 3' acceptor end. This ATP-dependent process is called charging or aminoacylation of tRNA, and the product is an aminoacyl-tRNA.

Charging supplies the correct amino acid for each codon read by the tRNA anticodon. It also stores energy in the amino acid–tRNA linkage. When charged tRNAs are brought close together on the ribosome, this activated state makes peptide-bond formation energetically favourable. Uncharged tRNA cannot supply an amino acid for the growing chain.

Step 2: (ii) Catalytic role of the bacterial ribosome The 23S rRNA of the large 50S ribosomal subunit acts as a ribozyme. Its peptidyl-transferase activity catalyses formation of the peptide bond between adjacent amino acids during elongation. Thus the catalytic component is ribosomal RNA, rather than a ribosomal protein.

Step 3: (iii) Binding of ribosomal subunits to mRNA The small ribosomal subunit first binds to mRNA. It positions the initiation codon, usually AUG, for recognition by the initiator tRNA carrying methionine (formylmethionine in bacteria). The anticodon of this initiator tRNA pairs with the start codon.

The large subunit then joins the complex, producing the functional ribosome. In bacteria, the 30S and 50S subunits form a 70S ribosome. The assembled ribosome has binding sites that hold tRNAs close together, allowing the next charged tRNA to bind and elongation to begin.

Step 4: (iv) Location and role of untranslated regions Untranslated regions (UTRs) occur at both ends of mRNA: the 5' UTR lies before the start codon, and the 3' UTR lies after the stop codon. They are parts of the mRNA but are not translated into amino acids. These regions are required for an efficient translation process, helping regulate the use of the coding sequence.

Step 5: Conclusion ATP-dependent aminoacylation provides correctly charged tRNAs; bacterial 23S rRNA catalyses peptide-bond formation. The small ribosomal subunit binds mRNA before the large subunit joins, and UTRs before the start codon and after the stop codon support efficient translation.

Quick Tip to Solve: Keep the order clear: charge tRNA, assemble the ribosome at AUG, then elongate; place both UTRs outside the start-to-stop coding region.

- 32(b). (i) State the arrangement of different genes, that in bacteria is referred to as 'operon'.
 (ii) Draw a schematic labelled illustration of *lac* operon in a switched on state.
 (iii) Describe the role of lactose in *lac* operon.

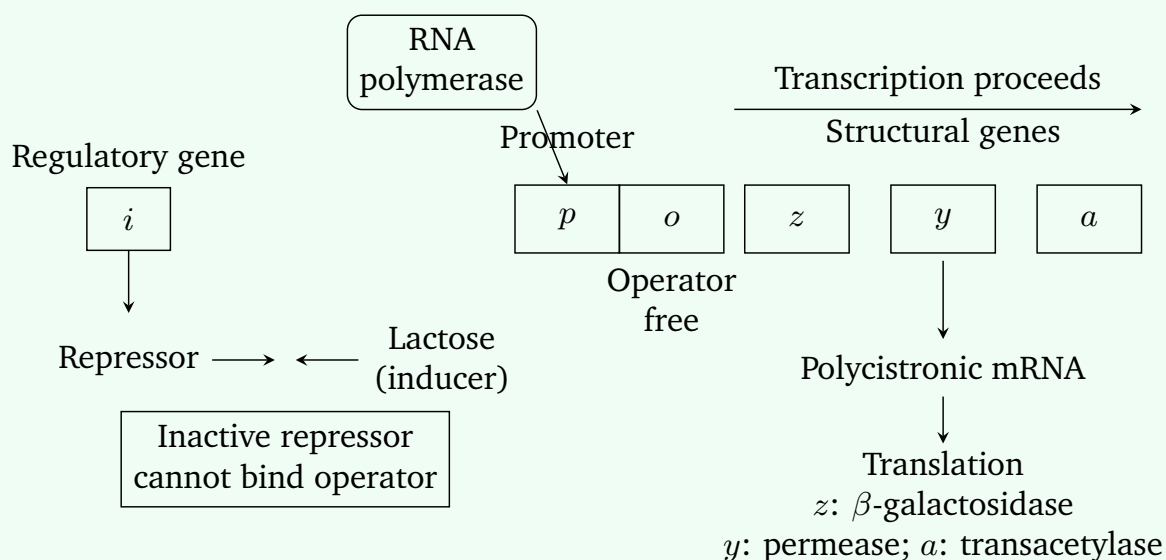
[5 marks]

Solution:**Concept:**

- An operon is a functional unit of bacterial DNA in which structural genes are controlled together by a common promoter and operator. They are transcribed as one polycistronic mRNA.
- The *lac* operon is an inducible system: its structural genes encode enzymes needed for lactose uptake and metabolism. The regulatory gene *i* produces the repressor.

Step 1: (i) Arrangement of the genes The structural genes are arranged together downstream of a common promoter and operator. In the *lac* system the order is promoter *p*, operator *o*, and structural genes *z*, *y*, *a*. RNA polymerase binds the promoter; the operator is the site at which the repressor can block transcription. A regulatory gene *i*, with its own promoter, codes for the repressor and controls this unit. Thus the three structural genes are coordinated rather than regulated separately.

Step 2: (ii) Switched-on state In the presence of lactose, the inducer binds the repressor and inactivates it. The inactive repressor cannot bind the operator. RNA polymerase therefore transcribes *z*, *y*, *a* into a polycistronic mRNA, which is translated into the three enzymes shown in the schematic. The operator is free in the switched-on state.



Switched-on lac operon: inducer inactivates the repressor and permits transcription.

Step 3: (iii) Role of lactose Lactose is both the substrate for the enzymes of the operon and its inducer. Binding of the inducer to the repressor prevents repression, permitting synthesis of β -galactosidase, permease and transacetylase. β -galactosidase hydrolyses lactose into glucose and galactose, while permease increases entry of lactose into the cell. In the absence of inducer, the active repressor binds the operator and prevents effective transcription. The system therefore produces lactose-metabolising enzymes when their substrate is available.

Step 4: Conclusion An operon comprises structural genes under common promoter-operator control. Lactose induces the *lac* operon by inactivating its repressor, allowing transcription of *z*, *y*, *a* and production of the corresponding enzymes.

Quick Tip to Solve: Remember the on-state sequence: lactose binds repressor, operator becomes free, then *z*, *y* and *a* are transcribed.

33(a)(I)(i). State the role of selectable markers in rDNA technology.

[1 mark]

Solution:

Concept:

- A cloning vector carries a selectable marker whose expression permits cells containing the vector to be identified during selection.
- Transformation is uptake of foreign DNA by a host cell; only some cells in a treated population undergo it.

Step 1: Recognise the transformed cells Selectable markers help identify and eliminate non-transformants and selectively permit the growth of transformants. They therefore distinguish cells that have taken up the vector from cells that have not.

Step 2: Explain selection For example, a vector carrying an antibiotic-resistance gene allows transformed bacteria to grow on medium containing that antibiotic. Susceptible non-transformants fail to grow. This selects vector-bearing cells; identifying a recombinant insert may require an additional screening step.

Step 3: Conclusion Selectable markers enable selection of transformants and elimination of non-transformants after introduction of the vector.

Quick Tip to Solve: Link the marker to survival during selection: vector-bearing cells grow, while non-transformants are eliminated.

33(a)(I)(ii). Name two such selectable markers which are considered to be useful for *E. coli* cloning vector.

[1 mark]

Solution:

Concept:

- Antibiotic-resistance genes serve as selectable markers because their expression allows transformed bacteria to survive on a selective medium.
- The commonly illustrated cloning vector pBR322 carries two distinct antibiotic-resistance markers.

Step 1: Name the first marker The ampicillin-resistance gene, denoted amp^R , is a useful selectable marker in an *E. coli* cloning vector. It permits selection on medium containing ampicillin.

Step 2: Name the second marker The tetracycline-resistance gene, denoted tet^R , is another useful selectable marker. It permits selection on medium containing tetracycline. In both cases the marker is

the resistance gene carried by the vector, rather than the antibiotic itself.

Step 3: Conclusion The two selectable markers are the ampicillin-resistance gene amp^R and tetracycline-resistance gene tet^R .

Quick Tip to Solve: Name the resistance genes, not just the antibiotics: use amp-R and tet-R as your memory pair.

33(a)(I)(iii). State two significances of 'Ori' in *E. coli* cloning vector.

[1 mark]

Solution:

Concept:

- The origin of replication, or ori, is a specific DNA sequence at which replication starts in a host cell.
- A cloning vector must replicate along with the foreign DNA linked to it so that copies of the inserted DNA are produced.

Step 1: Initiation of replication The ori is the site from which DNA replication begins in the *E. coli* host. Any DNA fragment linked to this sequence can therefore be replicated within the host cell as part of the vector.

Step 2: Control of copy number The ori also controls the copy number of the linked DNA, that is, how many copies of the vector and its inserted DNA are maintained per host cell. Thus, choosing an appropriate ori helps obtain the desired number of copies of the foreign DNA.

Step 3: Conclusion The two significances of ori are initiation of DNA replication and control of the copy number of the linked DNA in the host.

Quick Tip to Solve: For ori, remember two separate functions: where replication starts and how many copies are maintained.

33(a)(II). How have biotechnologists effectively used *Agrobacterium tumefaciens* in plants and retroviruses in animals? Explain.

[2 marks]

Solution:

Concept:

- Natural DNA-transfer mechanisms of pathogens can be adapted to introduce desired genes into host cells.
- A disarmed vector retains its gene-transfer ability while the genes responsible for disease are removed or inactivated.

Step 1: Use of *Agrobacterium* in plants *Agrobacterium tumefaciens* naturally transfers a segment of DNA, called T-DNA, from its Ti (tumour-inducing) plasmid into plant cells. Biotechnologists disarm the Ti plasmid by removing or inactivating its tumour-causing genes and introduce the desired gene in their place. The modified Ti plasmid delivers the useful gene into plant cells without causing a tumour, producing genetically transformed plant cells.

Step 2: Use of retroviruses in animals Retroviruses naturally introduce their genetic material into animal cells and integrate a DNA copy into the host genome. Biotechnologists disarm these viruses by removing or inactivating disease-causing genes, and use the modified viruses to carry a desired gene into animal cells. Their ability to transfer genetic material is retained while their pathogenic action is eliminated.

Step 3: Conclusion Disarmed Ti plasmids of *Agrobacterium* are used as gene-transfer vectors in plants, while disarmed retroviruses deliver desired genes into animal cells.

Quick Tip to Solve: For both examples, state the natural gene-transfer ability first, then explain disarming and delivery of the desired gene.

OR

33(b). Name and describe the technique that helps in separation and isolation of DNA fragments after cutting of DNA by restriction endonucleases. [5 marks]

Solution:

Concept:

- Agarose gel electrophoresis separates DNA fragments primarily according to their size under an applied electric field.
- DNA is negatively charged because of its phosphate backbone and therefore moves towards the positive electrode, the anode.
- The gel acts as a molecular sieve; smaller DNA fragments pass through its pores more readily and travel farther than larger fragments.

Step 1: Prepare the agarose gel and load DNA The technique is agarose gel electrophoresis. Agarose, a natural polymer obtained from seaweeds, is used to prepare a gel with wells at one end. DNA fragments produced by restriction endonuclease digestion are loaded into these wells. The gel is placed in a suitable buffer, with the wells towards the negative electrode so that the DNA can migrate through the gel towards the positive electrode.

Step 2: Separate fragments using an electric field An electric potential is applied across the gel. Negatively charged DNA fragments migrate towards the anode. The agarose matrix offers resistance to their movement and acts as a sieve. Smaller fragments move more easily through the pores and therefore travel farther in a given time; larger fragments move more slowly and remain nearer the wells. Fragments of similar size collect together as bands at particular positions in the gel.

Step 3: Visualise the separated DNA bands DNA fragments cannot be seen directly in an unstained gel. The DNA is stained with ethidium bromide and the gel is exposed to ultraviolet radiation. The stained DNA appears as bright orange-coloured bands. This allows the position of the required DNA fragment to be identified by its band in the gel.

Step 4: Isolate the desired fragment by elution The gel region containing the desired DNA band is carefully cut out. The DNA is then extracted from the excised gel piece; this recovery of DNA is called elution. The purified DNA fragment obtained in this way can be used to construct recombinant DNA

by joining it to a suitable cloning vector. Thus, electrophoresis provides separation, while excision followed by elution provides isolation of the chosen fragment.

Step 5: Conclusion Agarose gel electrophoresis separates restriction-digested DNA into size-dependent bands; staining and UV exposure reveal them, and the desired band is cut out and eluted to isolate its DNA.

Quick Tip to Solve: Keep the sequence clear: load DNA, run towards the anode, visualise stained bands, cut out the desired band, and elute its DNA.