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

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 – Section **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, internal choices have been provided in some questions. 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)

Question Nos. ***1*** *to* ***16*** *are Multiple Choice Type Questions, carrying 1 mark each. Choose the best option.*

1. Identify the plant in which emasculation is not required for artificial hybridization. [1 mark]

(A) Rice

(B) Wheat

(C) Pea

(D) Papaya

Correct Answer: (D) Papaya

Solution:

Concept:

- Emasculation is the removal of anthers from a bisexual flower before they dehisce, to prevent unwanted self-pollination during artificial hybridisation.
- A unisexual female flower has no anthers; it can be used as the female parent without emasculation.

Step 1: Identify the female flower used in crossing Papaya is a dioecious plant, with male and female flowers on separate plants. A female papaya flower has a functional pistil but no pollen-producing anthers. Therefore, no anthers need to be removed before applying pollen from the chosen male parent.

Step 2: Compare the other plants Rice, wheat and pea have bisexual flowers containing both stamens and a pistil. Their anthers must be removed when the flowers are selected as female parents for a controlled cross. Bagging is still needed for a female papaya flower to prevent contamination by unwanted pollen.

Step 3: Conclusion Emasculation is not required in papaya. Hence, the correct option is (D).

Quick Tip to Solve: Ask whether the selected female flower has anthers: no anthers means no emasculation, but bagging is still necessary.

2. Which of the following is not a component of immune system? [1 mark]

(A) Lymphocytes

(B) Plasma Proteins

(C) Red Blood Cells

(D) Bone Marrow

Correct Answer: (C) Red Blood Cells

Solution:

Concept:

- The immune system includes lymphoid organs, immune cells and soluble proteins that recognise and defend against foreign agents.

- Red blood cells chiefly transport respiratory gases, whereas lymphocytes mediate specific immune responses.

Step 1: Check the immune components Lymphocytes include B cells and T cells that participate in immunity. Plasma proteins include antibodies and complement proteins involved in defence. Bone marrow is a primary lymphoid organ where blood cells are formed and B lymphocytes mature. Thus, options (A), (B) and (D) describe immune-system components.

Step 2: Identify the different function Red blood cells, or erythrocytes, contain haemoglobin and principally carry oxygen between the lungs and tissues. They are not classified as immune-system cells in this question. Do not confuse red blood cells with white blood cells, which include the defensive lymphocytes.

Step 3: Conclusion Red blood cells are not a component of the immune system among the choices given. Hence, the correct option is (C).

Quick Tip to Solve: Match erythrocytes with gas transport and lymphocytes with immunity; antibodies make plasma proteins part of defence.

3. Select the option that shows correct statements:

(i) Corpus luteum secretes progesterone.

(ii) Only FSH attains a peak level in middle of cycle.

(iii) LH surge induces rupture of graafian follicle.

(iv) Luteal phase of menstrual cycle is also called proliferative phase. [1 mark]

(A) Only (ii) is correct.

(B) (i) and (iii) are correct.

(C) Only (iv) is correct.

(D) (ii) and (iv) are correct.

Correct Answer: (B) (i) and (iii) are correct.

Solution:

Concept:

- The mid-cycle surge of luteinising hormone (LH) triggers ovulation, the release of the ovum from the Graafian follicle.
- After ovulation, the corpus luteum secretes progesterone, which supports the secretory endometrium.

Step 1: Assess the hormone statements Statement (i) is correct because the corpus luteum secretes progesterone. Statement (ii) is incorrect: both FSH and LH rise around the middle of the cycle, and the pronounced LH surge is crucial for ovulation. Therefore, the word “Only” makes statement (ii) false.

Step 2: Check ovulation and phase names Statement (iii) is correct because the LH surge induces rupture of the mature Graafian follicle. Statement (iv) is incorrect: the luteal phase corresponds to the secretory phase of the uterine cycle. The proliferative phase precedes ovulation and is associated

with the ovarian follicular phase. Options (A), (C) and (D) each select an incorrect statement.

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

Quick Tip to Solve: Pair LH surge with ovulation and progesterone with the luteal/secretory phase; the proliferative phase comes earlier.

4. Select the mismatched pair: [1 mark]

(A) Mega diversity countries in the world - 12

(B) Genetically different strains of rice in India - Less than 1000

(C) Robert May's estimation on global species diversity - 7 million species worldwide

(D) Zoological parks - Ex-situ conservation

Correct Answer: (B) Genetically different strains of rice in India - Less than 1000

Solution:

Concept:

- Genetic diversity refers to variation within a species, including different strains and varieties.
- Ex-situ conservation protects organisms outside their natural habitats, for example in zoological parks.

Step 1: Check the rice diversity statement India has more than 50,000 genetically different strains of rice, illustrating extensive genetic diversity within a single crop species. The claim "Less than 1000" is therefore inconsistent with the NCERT account of rice diversity.

Step 2: Verify the remaining pairs In the NCERT account used for this question, India is one of the world's 12 megadiversity countries, so (A) is matched. Robert May estimated global species diversity at about 7 million species, matching (C). Zoological parks maintain animals outside their natural habitats and are examples of ex-situ conservation, matching (D).

Step 3: Conclusion The mismatched pair is "Genetically different strains of rice in India – Less than 1000". Hence, the correct option is (B).

Quick Tip to Solve: Recall the NCERT figure of more than 50,000 rice strains in India; it immediately rules out "less than 1000".

5. Pomato was produced by fusing protoplasts of [1 mark]

(A) Tomato and Potato

(B) Pomegranate and Tomato

(C) Pomegranate and Potato

(D) Pomegranate, Potato and Tomato

Correct Answer: (A) Tomato and Potato

Solution:

Concept:

- A protoplast is a plant cell whose cell wall has been removed, leaving the living cell enclosed by its plasma membrane.
- Somatic hybridisation fuses protoplasts from different plant varieties or species to produce hybrid cells that can be cultured.

Step 1: Identify the somatic hybrid Pomato is the example obtained by fusing a potato protoplast with a tomato protoplast. The resulting hybrid cell combines material from these two parent plants and can be cultured to form a somatic hybrid plant.

Step 2: Eliminate the other combinations Every other option includes pomegranate, which is not a parent in the pomato example. Thus, (B) and (C) substitute the wrong parent, while (D) incorrectly adds a third parent. Protoplast fusion is a fusion of somatic cells; it should not be confused with the fusion of gametes in sexual reproduction.

Step 3: Conclusion Pomato was produced by fusing protoplasts of tomato and potato. Hence, the correct option is (A).

Quick Tip to Solve: Link "pomato" to potato plus tomato, and link protoplast fusion to somatic hybridisation rather than fertilisation.

6. In an ecosystem, different species occupy different levels and vertical distribution of species is found. This is called _____. [1 mark]

(A) Stratification

(B) Layering

(C) Fragmentation

(D) Population

Correct Answer: (A) Stratification

Solution:

Concept:

- Stratification is the vertical distribution of different species occupying different levels in an ecosystem.
- In a forest, trees form the upper level, shrubs occupy intermediate levels, and herbs and grasses occur near the ground.

Step 1: Recognise the spatial pattern The question describes species arranged at different heights within the same ecosystem. Such a vertical arrangement is called stratification. The forest example shows how different plant species occupy distinct vertical strata depending on their growth form and resource requirements.

Step 2: Distinguish the other terms "Layering" informally describes layers but is not the ecological term asked here. Fragmentation is the breaking of detritus into smaller particles by detritivores during decomposition. A population is a group of individuals of the same species in a given area, not a vertical arrangement of different species.

Step 3: Conclusion The vertical distribution of species is called stratification. Hence, the correct option is (A).

Quick Tip to Solve: When an ecology question mentions different heights or vertical levels, think of forest strata and select stratification.

7. Which of the following sacred groves is found in Meghalaya? [1 mark]

(A) Jaintia hills

(B) Bastar

(C) Chanda

(D) Sarguja

Correct Answer: (A) Jaintia hills

Solution:

Concept:

- Sacred groves are forest patches protected by local communities because of religious or cultural traditions.
- They conserve biodiversity in its natural habitat and may shelter rare or threatened species.

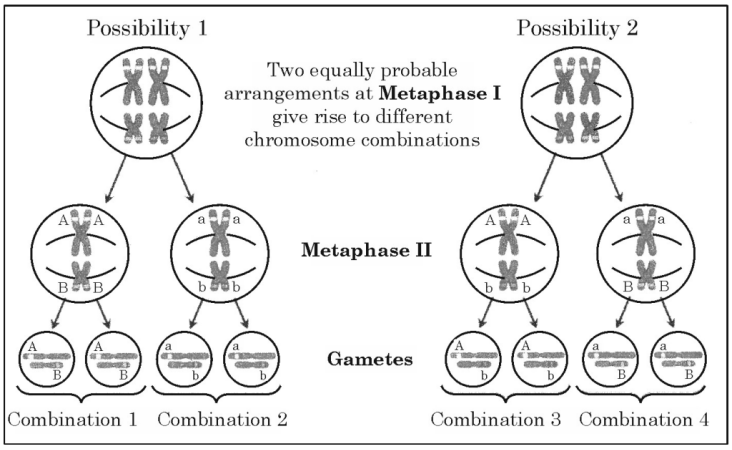
Step 1: Match the grove with its state The Khasi and Jaintia Hills of Meghalaya are well-known locations of sacred groves in the NCERT account. Traditional protection of these forest patches helps preserve the local plants, animals and their ecological relationships.

Step 2: Compare the other locations Bastar, Chanda and Sarguja are listed in the NCERT examples of sacred groves of central India, not Meghalaya. Thus, although they are also associated with sacred groves, they do not satisfy the geographical condition in this question. Select the place that belongs to the northeastern state named in the question.

Step 3: Conclusion The Jaintia hills are the sacred-grove location in Meghalaya among the given choices. Hence, the correct option is (A).

Quick Tip to Solve: Memorise Khasi and Jaintia Hills together with Meghalaya to distinguish them from central Indian sacred-grove locations.

8. In the following figure, two ways of pairing of two homologous pairs of chromosomes are shown. Which of the following phenomena is expressed? [1 mark]



(A) Linkage of genes

(B) Independent assortment of genes

(C) Multiple alleles

(D) Incomplete dominance

Correct Answer: (B) Independent assortment of genes

Solution:

Concept:

- The law of independent assortment states that the alleles of one gene pair assort independently of those of another unlinked gene pair during gamete formation.
- At metaphase I, each homologous chromosome pair can orient independently of the other pairs; homologues subsequently segregate to opposite poles.

Step 1: Read the chromosome combinations The two arrangements shown differ in the relative orientation of the two homologous pairs at metaphase I. One orientation produces the combinations AB and ab, while the other produces Ab and aB. Thus the inheritance of A or a is not tied to that of B or b.

Step 2: Distinguish the other phenomena Linkage concerns genes on the same chromosome tending to be inherited together, whereas this figure shows two different chromosome pairs. Multiple alleles means more than two alternative forms of a gene in a population. Incomplete dominance concerns an intermediate heterozygous phenotype. Neither of these describes chromosome orientation during meiosis.

Step 3: Conclusion The figure expresses independent assortment of genes. Hence, the correct option is (B).

Quick Tip to Solve: Look for independent orientations of different homologous pairs at metaphase I: these generate different allele combinations.

9. Match Column-I with Column-II and choose the correct option:

Column-I	Column-II
a. Biolistic gun	i. Bacterial cell
b. Chitinase	ii. Tumour inducing
c. Ti	iii. Animal cell
d. Ca^{++}	iv. Fungal cell
	v. Plant cell

[1 mark]

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

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

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

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

Correct Answer: (C) a-v, b-iv, c-ii, d-i

Solution:

Concept:

- Recombinant DNA technology uses different methods to introduce DNA into host cells, depending on the host and its cell wall.
- A biolistic gun delivers DNA-coated particles; chitinase digests chitin; Ti denotes tumour inducing; calcium ions help make bacterial cells competent.

Step 1: Match the plant and fungal tools A biolistic or gene gun bombards cells with DNA-coated gold or tungsten particles and is used especially for plant cells. Therefore a matches v. Fungal cell walls contain chitin, so chitinase is used to digest these walls during DNA isolation. Therefore b matches iv.

Step 2: Match the remaining entries and check the codes Ti stands for tumour inducing, as in the Ti plasmid of *Agrobacterium tumefaciens*; therefore c matches ii. Treatment with divalent calcium ions helps prepare bacterial cells to take up DNA, so d matches i. Option (A) mismatches all four entries; (B) also gives incorrect associations; (D) retains the plant-cell association but mismatches chitinase, Ti and calcium ions.

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

Quick Tip to Solve: Start with chitinase: chitin identifies a fungal wall immediately, fixing b-iv and the matching code.

10. The idea of use and disuse of organs for evolution of organism was proposed by [1 mark]

(A) Charles Darwin

(B) Thomas Malthus

(C) Hugo De Vries

(D) Lamarck

Correct Answer: (D) Lamarck

Solution:

Concept:

- Lamarck proposed that frequent use develops an organ, whereas continued disuse leads to its degeneration.
- His theory also proposed inheritance of acquired characters, so modifications acquired during an individual's lifetime would be passed to descendants.

Step 1: Identify the theory from its defining phrase The expression use and disuse is the characteristic clue to Lamarckism. For example, Lamarck explained the long neck of giraffes by repeated stretching to reach leaves, followed by inheritance of the acquired increase. This is the historical explanation being identified, rather than the modern mechanism of evolution.

Step 2: Check the other scientists Charles Darwin proposed natural selection acting on heritable variations. Thomas Malthus discussed population growth and the resulting pressure on resources, which influenced Darwin. Hugo de Vries proposed mutation theory. These contributions do not identify the use-and-disuse explanation asked for here.

Step 3: Conclusion The idea of use and disuse of organs was proposed by Lamarck. Hence, the correct option is (D).

Quick Tip to Solve: Associate use and disuse with Lamarck, natural selection with Darwin, and mutation theory with de Vries.

11. Which of the following statements about plasmids is incorrect? [1 mark]

(A) Plasmids have the ability to replicate within the bacterial cell.

(B) Their replication is controlled by chromosomal DNA.

(C) They are autonomously replicating circular extra-chromosomal DNA.

(D) They often carry antibiotic resistant genes.

Correct Answer: (B) Their replication is controlled by chromosomal DNA.

Solution:

Concept:

- Plasmids are usually small, circular, extrachromosomal DNA molecules found in bacterial cells.
- A plasmid carries its own origin of replication and can replicate independently of the bacterial chromosome; this is called autonomous replication.

Step 1: Check the statement about replication control The key distinction is between the plasmid and

the main bacterial chromosome. Plasmid replication is initiated from its own origin and is regulated by plasmid replication systems. Although it uses host cellular machinery, it is not described as replication controlled by chromosomal DNA. This makes the claim in (B) incorrect in the sense tested here.

Step 2: Verify that the remaining statements are valid Statement (A) is true because plasmids replicate inside bacterial cells. Statement (C) correctly describes their circular, extrachromosomal and autonomously replicating nature. Statement (D) is also true: many plasmids carry antibiotic-resistance genes, which can be used as selectable markers in cloning vectors. The question asks for the incorrect statement, so these true statements are eliminated.

Step 3: Conclusion The incorrect statement is that plasmid replication is controlled by chromosomal DNA. Hence, the correct option is (B).

Quick Tip to Solve: Underline incorrect, then use the plasmid's own origin of replication to distinguish autonomy from dependence on host enzymes.

12. Which connective tissue connects ovary to pelvic wall and uterus? [1 mark]

(A) Tendons

(B) Ligaments

(C) Cartilage

(D) Bone

Correct Answer: (B) Ligaments

Solution:

Concept:

- Each ovary is connected to the pelvic wall and uterus by ligaments, which support it in the female reproductive tract.
- Ligaments are fibrous connective tissue structures; tendons, cartilage and bone have different principal structural roles.

Step 1: Identify the ovarian supporting tissue The ovarian attachments described in the question are ligaments. The ovarian ligament connects the ovary to the uterus, while the suspensory ligament supports its connection to the pelvic wall. These attachments hold the ovary in position within the pelvic cavity.

Step 2: Eliminate the other connective tissues Tendons principally connect skeletal muscles to bones and are not the ovarian attachments asked for. Cartilage provides flexible structural support, for example at joints and in the external ear. Bone is a rigid, mineralised connective tissue forming the skeleton. Neither cartilage nor bone constitutes the fibrous attachments between the ovary, pelvic wall and uterus.

Step 3: Conclusion Ligaments connect the ovary to the pelvic wall and uterus. Hence, the correct option is (B).

Quick Tip to Solve: For the supporting attachments of the ovary, recall ligaments; reserve tendons for muscle-to-bone attachment.

13. Assertion (A): The population of melanized moths increased in industrial areas after Industrial Revolution.

Reason (R): In Industrial environment lichen covered trees were replaced by soot-covered trees offering better camouflage to dark coloured moths. [1 mark]

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

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

Solution:

Concept:

- Industrial melanism illustrates natural selection: environmental conditions alter the relative survival and reproductive success of existing colour variants.
- Camouflage reduces detection by predators, allowing better-camouflaged moths to leave more offspring.

Step 1: Judge the assertion The assertion is true. After the Industrial Revolution, melanized, or dark-coloured, moths increased in industrial regions because the changed surroundings favoured their survival. The change concerned the frequency of pre-existing variants in the population.

Step 2: Judge the reason The reason is true. Industrial pollution reduced lichen cover and deposited soot on tree trunks, producing a darker resting background. Dark moths were better concealed on these surfaces, whereas pale moths became more conspicuous to visually hunting birds.

Step 3: Test the explanatory relationship Better camouflage reduced predation on the dark moths, so they survived and reproduced more successfully. This selective advantage explains their increased frequency. Consequently, the statements are not merely independently true: the reason supplies the mechanism behind the assertion. Codes (B), (C) and (D) therefore do not describe the relationship.

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: Connect soot-darkened bark to reduced predation on dark moths; that causal link determines the assertion-reason code.

14. Assertion (A): The milk produced by transgenic cow 'Rosie' was nutritionally more balanced product for human babies than natural cow milk.

Reason (R): It was human protein enriched milk containing human alpha lactaglobulin. [1 mark]

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

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

- Transgenic animals contain an introduced gene that can enable production of a useful human protein.
- The transgenic cow Rosie produced human-protein-enriched milk containing human α-lactalbumin, which made it nutritionally more balanced for human babies.

Step 1: Judge the assertion The assertion is true. Rosie is the textbook example of a transgenic cow whose milk was nutritionally more balanced for human babies than ordinary cow milk because it contained an introduced human milk protein.

Step 2: Judge the reason The reason is false as written. It names human alpha lactaglobulin, whereas the protein in Rosie's milk was human α-lactalbumin. Although the description human-protein-enriched milk is correct, the incorrect identity of that protein makes the whole reason false.

Step 3: Select the assertion-reason relationship Because the assertion is true but the stated reason is false, the explanatory relationship cannot be accepted. Codes (A) and (B) require a true reason, while code (D) requires a false assertion; all three are excluded. The protein name must be checked exactly rather than treating similar-sounding milk proteins as interchangeable.

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

Quick Tip to Solve: Remember Rosie with alpha-lactalbumin; a similar-looking protein name can make an otherwise plausible reason false.

15. Assertion (A): Flocs are masses of bacteria associated with fungal filaments in secondary treatment of sewage.

Reason (R): Flocs help in digestion of solid waste by anaerobic respiration. [1 mark]

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

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

- Flocs are mesh-like masses of bacteria associated with fungal filaments, formed during secondary sewage treatment.
- Aeration supports aerobic microbes that consume organic matter and reduce the biochemical oxygen demand (BOD) of sewage.

Step 1: Judge the assertion The assertion is true. In the aeration tank, vigorous aeration and agitation promote microbial growth. Bacteria associate with fungal filaments to form flocs, which are characteristic of the biological stage of sewage treatment.

Step 2: Judge the reason The reason is false. The microbes in flocs consume organic matter aerobically, using the oxygen supplied in the aeration tank. Anaerobic digestion occurs later in sludge digesters, where anaerobic bacteria act on the sludge.

Step 3: Check the explanatory link Since the reason incorrectly assigns anaerobic respiration to flocs, it cannot explain the true assertion. Options (A) and (B) require a true reason, and option (D) requires a false assertion; all three are therefore excluded.

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

Quick Tip to Solve: Separate the aeration tank from the sludge digester: flocs act aerobically; sludge digestion is anaerobic.

16. Assertion (A): In terrestrial ecosystem much larger fraction of energy flows through grazing food chain.

Reason (R): Grazing food chain may be connected to Detritus food chain at some levels. [1 mark]

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

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

- A grazing food chain begins with living producers, whereas a detritus food chain begins with dead organic matter.
- In terrestrial ecosystems, a much larger fraction of energy passes through the detritus food chain than through the grazing food chain.

Step 1: Judge the assertion The assertion is false. In terrestrial ecosystems, much of the plant material enters the dead organic matter pool without first being grazed. Thus the detritus food chain carries the larger fraction of energy. The grazing food chain is the major conduit of energy flow in aquatic ecosystems.

Step 2: Judge the reason The reason is true. The grazing and detritus food chains can be connected at several levels. For example, an animal belonging to a grazing food chain may also feed on a detritus-feeding organism; death and waste also supply detritus.

Step 3: Check the explanatory link The true statement that the two food chains are connected does not make the assertion about terrestrial energy flow correct. Options (A), (B) and (C) all require a true assertion, so they are excluded.

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

Quick Tip to Solve: Associate terrestrial energy flow with detritus; associate the major aquatic energy conduit with grazing.

Section B (10 marks)

17(a). Define Humoral immune response. [1 mark]

Solution:

Concept:

- Humoral immunity is the antibody-mediated component of acquired immunity.
- Activated B lymphocytes differentiate into plasma cells, which secrete specific antibodies into body fluids.

Step 1: Identify the immune component When a suitable antigen stimulates B lymphocytes, they give

rise to plasma cells. These cells produce antibodies specific to that antigen, so the response has the specificity characteristic of acquired immunity.

Step 2: Explain why the response is humoral The secreted antibodies circulate in body fluids, such as blood and lymph, and bind their corresponding antigens. Because the response is mediated by antibodies present in these fluids, it is called the humoral immune response.

Step 3: Conclusion Humoral immune response is the antibody-mediated immune response in which antibodies produced by B-lymphocyte-derived plasma cells act in body fluids.

Quick Tip to Solve: For the definition, connect all three terms: B lymphocytes, antibodies and body fluids.

17(b). Name any two types of antibodies found to give humoral immune response in humans. [1 mark]

Solution:

Concept:

- Antibodies are immunoglobulins secreted by plasma cells derived from B lymphocytes.
- Human immunoglobulin classes include IgG, IgM, IgA, IgE and IgD; any two appropriate classes answer the question.

Step 1: Name one antibody class Immunoglobulin G (IgG) is a major antibody class in blood and contributes to humoral immunity by specifically recognising antigens.

Step 2: Name a second antibody class Immunoglobulin M (IgM) is another antibody class involved in humoral immunity. It is typically produced early in the primary immune response. IgG and IgM are antibody types, whereas B and T lymphocytes are cell types and would not answer this request.

Step 3: Conclusion Two types of antibodies are immunoglobulin G (IgG) and immunoglobulin M (IgM).

Quick Tip to Solve: When asked for antibody types, give immunoglobulin names such as IgG and IgM, rather than lymphocyte names.

18(a)(i). How does a farmer use dormancy of seed to his advantage? [1 mark]

Solution:

Concept:

- A dormant seed remains viable while its growth and germination are temporarily suspended.
- The resting period allows seeds to be stored and germination to be timed for favourable conditions.

Step 1: Relate dormancy to storage Dormancy prevents immediate germination of viable seeds. A farmer can therefore keep harvested seeds for a later sowing season, storing them under suitable dry conditions while retaining their usefulness as planting material.

Step 2: Relate storage to crop establishment The farmer can sow the stored seeds at a suitable time and, where needed, use an appropriate treatment to break dormancy. Germination can then occur

when moisture, temperature and other conditions support seedling establishment, instead of during an unfavourable period.

Step 3: Conclusion A farmer uses seed dormancy to store viable seeds for future sowing and to obtain germination in the favourable growing season.

Quick Tip to Solve: Link the advantage to delayed germination: storage now permits sowing and establishment in the suitable season.

18(a)(ii). Differentiate between pea seed and castor seed. [1 mark]

Solution:

Concept:

- Albuminous seeds retain endosperm in the mature seed; non-albuminous seeds do not retain it.
- Pea and castor differ in the persistence of endosperm, even though both are dicotyledonous plants.

Step 1: Describe the pea seed Pea is a non-albuminous or non-endospermic seed. The developing embryo uses up the endosperm, so the mature seed lacks persistent endosperm. Its food reserves are mainly stored in the cotyledons.

Step 2: Contrast the castor seed Castor is an albuminous or endospermic seed. A substantial endosperm remains in the mature seed and serves as a food reserve for the embryo during germination. Thus the comparison concerns the presence of endosperm at maturity, not the number of cotyledons.

Step 3: Conclusion Pea seed is non-albuminous, with food chiefly in cotyledons; castor seed is albuminous, retaining food-storing endosperm.

Quick Tip to Solve: Use the paired distinction: pea lacks persistent endosperm; castor retains it in the mature seed.

OR

18(b). Identify the stage of follicle where primary oocyte undergoes first meiotic division. Also mention the products of this division. [2 marks]

Solution:

Concept:

- Oogenesis involves meiotic divisions with unequal cytokinesis, conserving most of the cytoplasm in one functional cell.
- Completion of meiosis I reduces the chromosome number from diploid to haploid; the primary oocyte completes this division in the tertiary follicle.

Step 1: Identify the follicular stage The primary follicle develops into a secondary follicle, which then becomes a tertiary follicle with a fluid-filled antrum. Within the tertiary follicle, the primary oocyte grows and completes its first meiotic division.

Step 2: State the products of meiosis I The division produces a large haploid secondary oocyte and

a small haploid first polar body. Cytokinesis is unequal, so the secondary oocyte retains most of the nutrient-rich cytoplasm. In humans, each product has 23 chromosomes; each chromosome still consists of two sister chromatids at this stage.

Step 3: Distinguish the next meiotic event The product of this first division is the secondary oocyte, not the ovum. The secondary oocyte begins meiosis II and arrests at metaphase II; completion of meiosis II is associated with sperm entry. This distinguishes the requested first-division products from later products.

Step 4: Conclusion The primary oocyte completes meiosis I in the tertiary follicle, producing one haploid secondary oocyte and one haploid first polar body.

Quick Tip to Solve: Remember the sequence: tertiary follicle, meiosis I, secondary oocyte plus first polar body.

19(a). Study the sequence of bases in a DNA molecule that is shown below and answer the questions:

5'- GAATTC - 3'

3'- CTTAAG - 5'

What are such sequences called? Name the enzyme used that recognises such nucleotide sequences.

[1 mark]

Solution:

Concept:

- A palindromic DNA sequence reads identically when each complementary strand is read in the same direction, from $5'$ to $3'$.
- Restriction endonucleases recognise specific short DNA sequences and cleave DNA at defined sites.

Step 1: Read the strands in the same direction The upper strand reads GAATTC from left to right. Reading the lower strand from its own $5'$ end, from right to left, also gives GAATTC. Thus the equality is between the two strands read in the same chemical direction, not between opposite readings of a single strand.

Step 2: Identify the enzyme The recognition sequence GAATTC is specifically recognised by EcoRI, a restriction endonuclease. The broader enzyme class is restriction endonucleases; EcoRI is the named enzyme appropriate to the sequence printed here.

Step 3: Conclusion These are palindromic nucleotide sequences; the enzyme is the restriction endonuclease EcoRI.

Quick Tip to Solve: Compare both strands from their own 5-prime ends; GAATTC identifies EcoRI.

19(b). Study the sequence of bases in a DNA molecule that is shown below and answer the questions:

5'- GAATTC - 3'

3'- CTTAAG - 5'

How do these enzymes function? [1 mark]

Solution:

Concept:

- A restriction endonuclease recognises a specific palindromic sequence in double-stranded DNA.
- Its cleavage breaks phosphodiester bonds of the sugar-phosphate backbone, not the bonds joining a base to its sugar.

Step 1: Recognise the target The enzyme scans the DNA, recognises its particular nucleotide sequence and binds there. EcoRI recognises the GAATTC sequence shown; this specificity ensures that cleavage occurs at a defined recognition site.

Step 2: Cut both backbones EcoRI cuts between G and A on each strand when that strand is read from its own 5-prime end. These staggered cuts produce complementary single-stranded AATT overhangs, called sticky ends. Such ends can base-pair with matching ends on another DNA fragment and subsequently be joined by DNA ligase.

Step 3: Conclusion Restriction endonucleases recognise specific sequences and cleave the DNA phosphodiester backbones at defined positions; EcoRI produces sticky ends at GAATTC.

Quick Tip to Solve: Distinguish the enzyme that cuts the backbone, EcoRI, from ligase, which joins DNA fragments.

20(a). Analyse the following two cases of sex determination in different organisms:

Case I: Males have (XO) sex chromosomes and females have two copies of same sex chromosome (XX).

Case II: Females have two different sex chromosomes (ZW) and males have two copies of same sex chromosome (ZZ).

Identify the type of heterogamety in each case, giving one example of each. [2 marks]

Solution:

Concept:

- The heterogametic sex produces two kinds of gametes with respect to sex chromosomes; the homogametic sex produces one kind.
- In the XO system, O denotes the absence of a second sex chromosome, not a separate chromosome.
- The identity of the sex producing unlike gametes determines whether heterogamety is male or female.

Step 1: Case I: identify male heterogamety An XO male forms two classes of sperm: one carries an X chromosome and the other lacks a sex chromosome. An XX female forms eggs carrying X only. Fertilisation by an X-bearing sperm produces XX offspring, whereas fertilisation by a sperm lacking X produces XO offspring. The male therefore supplies the two different gamete types. This is male

heterogamety, as in a grasshopper.

Step 2: Case II: identify female heterogamety A ZW female forms two classes of eggs, one carrying Z and the other W. A ZZ male produces Z-bearing sperm only. A Z-bearing egg gives ZZ male offspring, whereas a W-bearing egg gives ZW female offspring after fertilisation. Hence the female is heterogametic. This system occurs in birds, for example the domestic hen and cock.

Step 3: Conclusion Case I: male heterogamety, exemplified by grasshopper. Case II: female heterogamety, exemplified by birds such as the domestic fowl.

Quick Tip to Solve: Identify which parent makes two kinds of sex-chromosome gametes: XO male or ZW female.

OR

20(b)(i). Differentiate between a DNA and RNA nucleotide. [1 mark]

Solution:

Concept:

- A nucleotide consists of a nitrogenous base, a pentose sugar and a phosphate group.
- DNA and RNA nucleotides differ principally in their pentose sugars and in one of their usual pyrimidine bases.

Step 1: Compare the sugars A DNA nucleotide contains 2-deoxyribose, with H at the sugar's 2-prime carbon. An RNA nucleotide contains ribose, with an OH group at the corresponding position. Both kinds contain phosphate, so phosphate does not distinguish the two.

Step 2: Compare the nitrogenous bases The usual bases in DNA nucleotides are adenine, guanine, cytosine and thymine, whereas those in RNA nucleotides are adenine, guanine, cytosine and uracil. Thus thymine occurs in the usual DNA nucleotide set, while uracil occupies its corresponding place in RNA; adenine, guanine and cytosine are shared.

Step 3: Conclusion A DNA nucleotide has deoxyribose and one of A, G, C or T; an RNA nucleotide has ribose and one of A, G, C or U.

Quick Tip to Solve: Use the sugar as the universal distinction; thymine versus uracil distinguishes the usual base sets.

20(b)(ii). Name the two types of bonds present within a single nucleotide. [1 mark]

Solution:

Concept:

- A single nucleotide contains a nitrogenous base attached to a sugar and a phosphate attached to that sugar.
- A nucleoside is the base-sugar combination; addition of phosphate gives a nucleotide.

Step 1: Identify the base-sugar bond The nitrogenous base joins the sugar's 1-prime carbon through an N-glycosidic linkage. This linkage connects the sugar to nitrogen of the base and forms the nucleoside portion of the nucleotide.

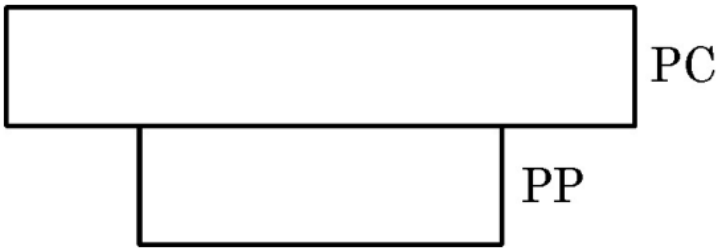
Step 2: Identify the sugar-phosphate bond The phosphate group joins a hydroxyl group of the sugar by a phosphoester linkage. A phosphodiester bond connects neighbouring nucleotides in a nucleic-acid chain, whereas the question asks for bonds within a single nucleotide. Hydrogen bonds between complementary bases are also not the required internal covalent linkages.

Step 3: Conclusion The two bonds are an N-glycosidic bond and a phosphoester bond.

Quick Tip to Solve: For one nucleotide, name base-sugar and sugar-phosphate bonds; reserve phosphodiester for the chain.

21(a)(i). Given below is a pyramid found in an ecosystem, where each bar represents the standing crop available in the trophic level.

Identify the kind of pyramid and with the help of an example explain the conditions where this kind of pyramid is possible in nature. [1 mark]



Solution:

Concept:

- A pyramid of biomass compares the standing biomass present at successive trophic levels at a particular time.
- A small standing crop can sustain a larger consumer biomass if the producers reproduce rapidly and have a high turnover rate.

Step 1: Interpret the bar widths The producer bar, PP, is narrower than the primary-consumer bar, PC. Hence the standing producer biomass is lower than the primary-consumer biomass: the diagram represents an inverted pyramid of biomass. An energy pyramid cannot have this shape because available energy decreases at successive trophic levels.

Step 2: Explain an aquatic example In an aquatic ecosystem, such as the sea, phytoplankton have a small standing biomass but reproduce and renew it rapidly. Zooplankton consume this continually replenished producer biomass and can maintain a larger standing biomass at a given moment. Thus the instantaneous biomass pyramid may be inverted even though producers support the consumers.

Step 3: Conclusion It is an inverted pyramid of biomass, found in aquatic ecosystems where rapidly renewing phytoplankton support a larger standing biomass of zooplankton.

Quick Tip to Solve: Compare standing biomass at one instant with producer turnover over time to explain the inverted shape.

21(a)(ii). Given below is a pyramid found in an ecosystem, where each bar represents the standing crop available in the trophic level.

Write any two limitations of ecological pyramids. [1 mark]



Solution:

Concept:

- Ecological pyramids present trophic structure as a simplified sequence of producer and consumer levels.
- Actual ecosystems contain interlinked feeding relationships and a decomposer pathway that simple pyramids cannot fully represent.

Step 1: Limitation 1: food webs are not represented An ecological pyramid assumes a simple food chain and does not accommodate the interconnected food web of a natural ecosystem. Organisms may draw food from several sources and participate in multiple feeding paths, but a simple sequence of bars cannot express these connections.

Step 2: Limitation 2: decomposers are excluded Saprophytes or decomposers, including many fungi and bacteria, are not assigned a place in an ecological pyramid. They nevertheless act on dead organic matter from different trophic levels and are essential for decomposition and nutrient recycling. Their exclusion omits a major functional component of the ecosystem.

Step 3: Conclusion Two limitations are that ecological pyramids do not accommodate food webs and do not include saprophytes or decomposers.

Quick Tip to Solve: Give two distinct omissions: interconnected feeding paths and the decomposer pathway.

OR

21(b)(i). In an ecosystem there was loss of biodiversity due to some project in that area.

How will biodiversity be affected? (2 points) [1 mark]

Solution:

Concept:

- Biodiversity is the variety of organisms in an ecosystem; its loss reduces the number of species and their ecological interactions.
- Diverse communities generally sustain productivity and resist environmental disturbances better than communities with fewer species.

Step 1: Identify the effect on production Loss of biodiversity can cause a decline in plant production. Fewer species remain to use the available resources and maintain the ecosystem's productive functions.

Step 2: Identify the effect on stability The ecosystem becomes less resistant to environmental disturbances such as drought. Loss of species can also increase variability in ecosystem processes, including productivity, water use and pest or disease cycles.

Step 3: Conclusion Two effects are a decline in plant production and lowered resistance to environmental disturbances such as drought.

Quick Tip to Solve: For effects of biodiversity loss, recall reduced production and reduced resistance; keep these separate from its causes.

21(b)(ii). In an ecosystem there was loss of biodiversity due to some project in that area. List two major causes of loss of biodiversity. [1 mark]

Solution:

Concept:

- Biodiversity loss results when populations cannot survive or reproduce sufficiently to replace their losses.
- Habitat loss and fragmentation, over-exploitation, alien species invasion and co-extinction are major causes of biodiversity loss.

Step 1: Explain habitat loss and fragmentation Clearing forests or converting natural habitats for development destroys the places where organisms live. Fragmentation divides a large habitat into small isolated patches, especially affecting animals that need large territories.

Step 2: Explain over-exploitation Excessive hunting, fishing or harvesting removes organisms faster than their populations can recover. Continued exploitation can reduce their numbers to extinction, as occurred with the passenger pigeon.

Step 3: Conclusion Two major causes are habitat loss and fragmentation, and over-exploitation of biological resources.

Quick Tip to Solve: Name two distinct causes: habitat destruction removes living space, whereas over-exploitation removes organisms directly.

Section C (21 marks)

22(a). Do all pollen grains remain viable for the same length of time? Support your answer with two suitable examples. [2.5 marks]

Solution:

Concept:

- Pollen viability is the period for which a pollen grain retains the ability to germinate on a compatible stigma and bring about fertilisation.
- Viability varies among plant species and also depends on environmental conditions, particularly temperature and humidity.

Step 1: Explain the variation No, all pollen grains do not remain viable for the same length of time. Pollen viability is not a fixed duration common to all flowering plants. Pollen that has lost viability cannot successfully germinate and accomplish fertilisation even if transferred to a compatible stigma.

Step 2: Give a short-lived example In cereals such as rice and wheat, pollen grains lose viability within about 30 minutes of their release. Their capacity to participate in fertilisation is therefore retained only for a very short time under ordinary conditions.

Step 3: Give a long-lived example In some members of the families Rosaceae, Leguminosae and Solanaceae, pollen grains remain viable for months. For example, the months-long viability in some Rosaceae members contrasts with the approximately 30-minute viability in rice or wheat. These two examples show that pollen longevity differs markedly among species.

Step 4: Conclusion No. Rice or wheat pollen remains viable for about 30 minutes after release, whereas pollen of some members of Rosaceae, Leguminosae or Solanaceae remains viable for months.

Quick Tip to Solve: Use one short-lived and one long-lived example: cereals, about 30 minutes; some Rosaceae members, months.

22(b). How are pollen grains stored in pollen banks? [0.5 marks]

Solution:

Concept:

- Cryopreservation preserves living biological material at very low temperature.
- Low-temperature storage greatly slows metabolic activity and maintains pollen viability for later use.

Step 1: Identify the storage method Pollen grains are collected and stored by cryopreservation in pollen banks. This permits viable pollen to be kept for later controlled pollination and crop-breeding programmes.

Step 2: State the storage temperature The pollen is stored in liquid nitrogen at $-196\,^{\circ}\mathrm{C}$. At this extremely low temperature, deterioration is greatly reduced, allowing the pollen to be preserved for years under suitable storage conditions.

Step 3: Conclusion Pollen grains are cryopreserved in liquid nitrogen at $-196\,^{\circ}\mathrm{C}$.

Quick Tip to Solve: Remember pollen-bank storage as liquid nitrogen at $-196\,^{\circ}\mathrm{C}$, not ordinary refrigeration.

23(a). What is pedigree analysis? Mention its importance in human genetics. (2 pts.) [2 marks]

Solution:

Concept:

- A pedigree records the occurrence of a particular inherited trait in members of a family over successive generations.
- Pedigree analysis uses family relationships and affected or unaffected status to trace how a trait is transmitted.

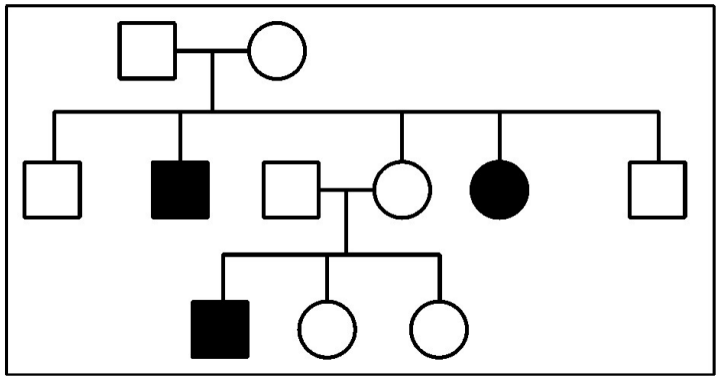
Step 1: Define pedigree analysis Pedigree analysis is the study of the inheritance of a particular trait through several generations of a family using a family-tree diagram and standard symbols. It compares the occurrence of the trait in parents, offspring and other relatives.

Step 2: State two uses in human genetics First, it helps establish the pattern of inheritance of a trait, such as dominant or recessive and autosomal or sex-linked. Second, it helps infer possible genotypes or carrier status and estimate the risk of the trait or genetic disorder appearing in future offspring, supporting genetic counselling. This is especially useful in humans because controlled experimental crosses cannot be performed.

Step 3: Conclusion Pedigree analysis traces a trait through a family over generations. It helps determine its inheritance pattern and infer carrier status or the risk of transmission to offspring.

Quick Tip to Solve: Define the family-tree study first, then give two distinct uses: identify inheritance mode and assess carrier status or offspring risk.

23(b)(i). Analyse the following pedigree and write the Pattern of inheritance. [0.5 marks]



Solution:

Concept:

- In recessive inheritance, unaffected heterozygous parents can have affected children.
- An autosomal trait can affect males and females; an affected daughter with an unaffected father excludes the usual X-linked recessive pattern.

Step 1: Check the parental and offspring phenotypes The top-generation parents are both unaffected,

but they have an affected son and an affected daughter. A recessive allele can therefore remain hidden in the parents and be expressed in their children when inherited from both parents.

Step 2: Identify the chromosomal pattern The affected daughter has an unaffected father, so the pedigree does not fit ordinary X-linked recessive inheritance. Both sexes are affected, supporting an autosomal recessive trait. If A is the normal dominant allele and a the recessive disease allele, the unaffected parents can be $Aa \times Aa$, with affected offspring aa.

Step 3: Conclusion The pedigree shows autosomal recessive inheritance.

Quick Tip to Solve: Look for unaffected parents with affected children of both sexes; an affected daughter with an unaffected father rules out ordinary X-linked recessive inheritance.

23(b)(ii). Give one example of a disease showing such an inheritance pattern. [0.5 marks]

Solution:

Concept:

- An autosomal recessive disorder is expressed when both copies of the relevant autosomal gene carry the recessive allele.
- Unaffected heterozygous carriers can produce affected sons as well as affected daughters.

Step 1: Identify the pattern from the pedigree The unaffected parents have affected offspring of both sexes. This is consistent with autosomal recessive inheritance: both parents can be carriers even though they do not express the disorder.

Step 2: Connect the pattern to a disease Sickle-cell anaemia is an autosomal recessive disorder. A person with genotype Hb^SHb^S is affected, while Hb^AHb^S is a carrier. Two carriers can therefore have an affected child, as illustrated by the pedigree.

Step 3: Conclusion One example is **sickle-cell anaemia**, an autosomal recessive disease.

Quick Tip to Solve: For an autosomal recessive pedigree, use sickle-cell anaemia as a standard NCERT example; unaffected carriers can have affected children.

24(a). How is Hardy-Weinberg expression ($p^2 + 2pq + q^2$) = 1 derived? [2 marks]

Solution:

Concept:

- In a population with two alleles A and a, let their frequencies be p and q, respectively. Since these are the only alleles, $p + q = 1$.
- Random union of gametes makes the probability of each genotype the product of the corresponding gamete allele frequencies.

Step 1: Assign frequencies to the gametes Allele A occurs in a fraction p of the gametes and allele a in a fraction q, in both the male and female gamete pools. Under random mating, the choice of one gamete is independent of the other.

Step 2: Calculate the genotype frequencies The union $A \times A$ produces AA with frequency $p \times p = p^2$. The genotype Aa can arise by $A \times a$ or $a \times A$, giving $pq + qp = 2pq$. The union $a \times a$ produces aa with frequency q^2. These three genotypes account for the entire population, so

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

In the absence of evolutionary forces, with random mating in a very large population, these allele and genotype frequencies remain constant across generations: this is Hardy-Weinberg equilibrium.

Step 3: Conclusion The Hardy-Weinberg expression is $\boxed{p^2 + 2pq + q^2 = 1}$, where p^2, $2pq$ and q^2 are the frequencies of AA, Aa and aa, respectively.

Quick Tip to Solve: Remember the factor 2 in $2pq$: a heterozygote can receive A from either the male or the female gamete.

24(b). List any two factors that disturb the genetic equilibrium. [1 mark]

Solution:

Concept:

- Genetic equilibrium means that allele frequencies in a population remain constant from generation to generation.
- Evolutionary forces that change allele frequencies disturb Hardy-Weinberg equilibrium.

Step 1: State gene migration Gene migration, or gene flow, transfers alleles between populations when individuals enter or leave and reproduce. The addition or removal of alleles can change their relative frequencies in a population.

Step 2: State genetic drift Genetic drift changes allele frequencies by chance, especially in small populations. Random differences in survival or reproduction can make an allele more or less common without any selective advantage.

Step 3: Conclusion Any two factors are **gene migration (gene flow)** and **genetic drift**.

Quick Tip to Solve: Distinguish gene flow, which moves alleles between populations, from drift, which changes their frequencies by chance.

25. Draw a neat diagram of megasporangium of an angiosperm and label any six parts. [3 marks]

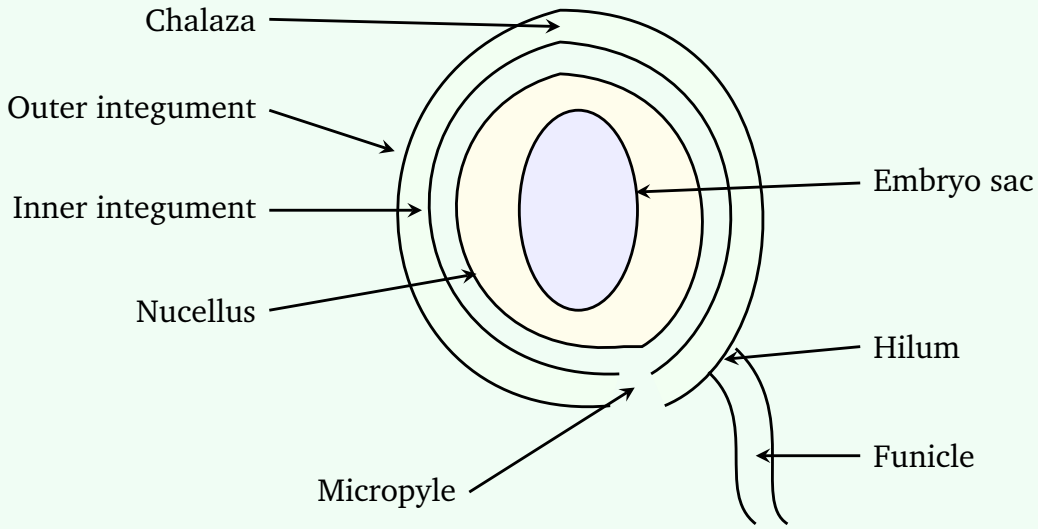
Solution:

Concept:

- The ovule is an integumented megasporangium. Its nucellus encloses the female gametophyte, or embryo sac.
- The integuments surround the nucellus but leave a small opening, the micropyle. The opposite basal region is the chalaza.

Step 1: Draw the ovule and its attachment Draw a longitudinal section of a typical anatropous ovule. Show the stalk, or funicle, and mark the hilum at its junction with the body of the ovule. In this inverted ovule, the micropylar end lies near the funicle. Outline the two protective integuments, leaving their ends separated to form the micropyle.

Step 2: Show the internal tissues and label the parts Inside the integuments draw the nucellus, the tissue that provides nourishment to the developing embryo sac. Place the embryo sac within the nucellus. Mark the chalaza at the end opposite the micropyle, where the nucellus and integuments meet. The diagram labels the outer integument, inner integument, nucellus, embryo sac, micropyle, chalaza, hilum and funicle; any six of these fulfil the question. The embryo sac is enclosed by the nucellus and is not itself an integument.



Longitudinal section of a typical anatropous ovule (schematic)

Step 3: Conclusion The labelled longitudinal section shows the angiosperm megasporangium (ovule), with its protective layers, internal tissues and attachment.

Quick Tip to Solve: Draw from outside inward: integuments, nucellus, embryo sac. Leave a micropyle and place the chalaza at the opposite end.

26(a). Mention the scientific name of the source plant and the part from which opioids are extracted.

[1 mark]

Solution:

Concept:

- Natural opiate alkaloids are obtained from the opium poppy, whose scientific name is *Papaver somniferum*.
- The latex of the unripe capsules is the plant material from which opium is obtained; morphine is an alkaloid extracted from it.

Step 1: Identify the source plant The plant is the opium poppy, *Papaver somniferum*. Write the genus

with a capital initial and the species name with a lower-case initial, and italicise both words in the scientific name.

Step 2: Identify the source part Opioids such as morphine are extracted from the latex of the poppy plant, specifically the latex of its unripe capsules. Thus the required source material is latex, rather than the seeds or leaves.

Step 3: Conclusion Source plant: *Papaver somniferum*; source part/material: **latex from its unripe capsules**.

Quick Tip to Solve: Pair opium poppy with latex: *Papaver somniferum* supplies morphine, while coca leaves supply cocaine.

26(b). How are morphine and heroin related? Mention the effect each one of them has on human body. [2 marks]

Solution:

Concept:

- Morphine is a natural opioid obtained from the latex of the opium poppy, $Papaver\ somniferum$.
- Opioids bind to specific opioid receptors in the central nervous system; their effects include pain relief and depression of nervous-system activity.

Step 1: Establish the chemical relationship Heroin is chemically diacetylmorphine. It is prepared by acetylating morphine: two acetyl groups replace the hydrogen atoms of morphine's two hydroxyl groups. Thus heroin is a derivative of morphine, rather than a different natural constituent required from another plant.

Step 2: State the effect of each opioid Morphine is a powerful analgesic and sedative. It reduces the perception of severe pain and is used medically for pain relief, including after surgery. Heroin is a depressant: it slows down body functions and depresses central nervous-system activity. It can produce drowsiness and dangerous respiratory depression and is highly addictive. The required distinction is morphine's pain-relieving action and heroin's slowing of body functions.

Step 3: Conclusion Heroin (diacetylmorphine) is obtained by acetylation of morphine. Morphine acts as a strong analgesic and sedative, whereas heroin acts as a depressant that slows body functions.

Quick Tip to Solve: Link the name diacetylmorphine to acetylation, then pair morphine with analgesia and heroin with depression of body functions.

27(a). A farmer grew two varieties of corn crop in field A and B. He grew normal corn crops in field A and GM corn crops in field B.

He observed that corn borers attacked only in field A. To control it, spores of Bt were sprayed on field A.

Name the gene in the spores responsible for control of pest. [0.5 marks]

Solution:

Concept:

- *Bacillus thuringiensis* (Bt) produces insecticidal crystal proteins encoded by cry genes.
- Different cry genes encode proteins that act against different groups of insect pests.

Step 1: Identify the pest in the field The pest specified is the corn borer. The required gene must therefore encode a Bt toxin effective against this insect, rather than simply any gene found in the bacterium.

Step 2: Match the pest to the specific gene The Bt gene $cryIAb$ encodes a toxin used to control corn borers. Bt produces the relevant crystal protein during sporulation, so a preparation containing its spores and associated crystals can supply the insecticidal protein to feeding larvae.

Step 3: Conclusion The gene is $\boxed{cryIAb}$, which encodes a Bt toxin effective against corn borers.

Quick Tip to Solve: Match corn borer to cryIAb; do not substitute cryIAc or cryIIAb, which are associated with cotton bollworm control.

27(b). A farmer grew two varieties of corn crop in field A and B. He grew normal corn crops in field A and GM corn crops in field B.

He observed that corn borers attacked only in field A. To control it, spores of Bt were sprayed on field A.

What effect will the spores of Bt have on insect pest? [1.5 marks]

Solution:

Concept:

- Bt produces a crystalline insecticidal protein as an inactive protoxin during sporulation.
- The protoxin becomes active in the alkaline gut of a susceptible insect and damages its midgut epithelium.

Step 1: Explain ingestion and toxin activation When corn-borer larvae feed on corn sprayed with the Bt preparation, they ingest spores together with the associated toxin crystals. The alkaline pH of their gut solubilises the crystals, and gut proteases process the inactive protoxin into the active toxin.

Step 2: Explain damage to the insect The active toxin binds to specific receptors on the surface of the midgut epithelial cells and creates pores in their membranes. This causes the cells to swell and lyse, damaging the gut. The susceptible insect consequently dies. The killing action is therefore due to the Bt protein associated with the spore preparation; the inactive protoxin does not damage Bt itself.

Step 3: Conclusion Bt toxin is activated in the insect's alkaline gut, forms pores in midgut epithelial

cells, causes swelling and lysis, and kills the corn-borer larvae.

Quick Tip to Solve: Write the sequence in order: ingestion, alkaline-gut activation, receptor binding, pore formation, cell lysis and insect death.

27(c). A farmer grew two varieties of corn crop in field A and B. He grew normal corn crops in field A and GM corn crops in field B.

He observed that corn borers attacked only in field A. To control it, spores of Bt were sprayed on field A.

How has corn plants of field B developed resistance against this pest? Explain. [1 mark]

Solution:

Concept:

- A transgenic crop expresses an introduced gene and acquires the trait encoded by its product.
- The $cryIAb$ gene from $Bacillus\ thuringiensis$ encodes a Bt protein effective against corn borers.

Step 1: Identify the introduced resistance gene The GM corn plants in field B have been genetically engineered by introducing the Bt $cryIAb$ gene into their genome. Their cells therefore synthesise the insecticidal Bt protein; they do not need the bacterium itself to grow inside the plant.

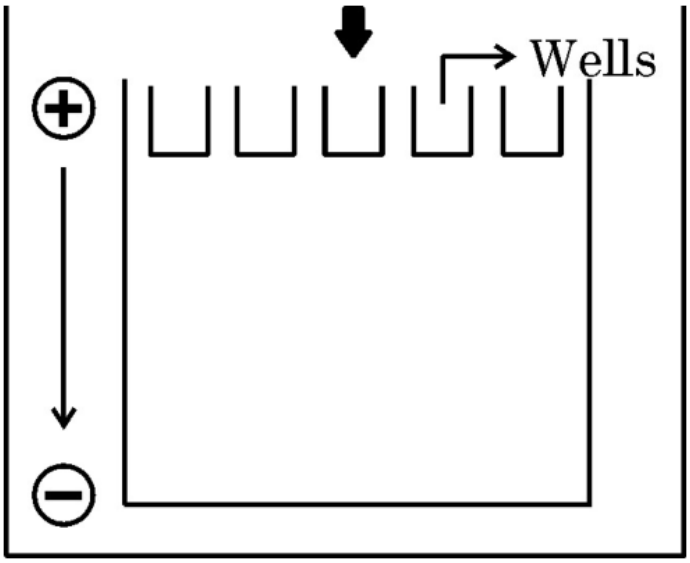
Step 2: Explain the protection against feeding larvae When a corn-borer larva feeds on the transgenic corn, it ingests the Bt protein. In the alkaline insect gut the toxin becomes active, binds to midgut epithelial cells and forms pores, causing cell damage and death of the larva. Thus the crop's resistance is due to expression of an introduced bacterial gene, rather than immunity acquired after an attack.

Step 3: Conclusion Field B corn expresses the introduced Bt $cryIAb$ gene and produces a toxin that kills feeding corn borers, providing resistance to this pest.

Quick Tip to Solve: For Bt corn, connect the specific gene cryIAb to toxin production inside the plant and death of the feeding borer.

28(a). **Observe the given picture carefully. A mixture of DNA with fragments ranging from 100 base pairs to 1800 base pairs were separated by electrophoresis on agarose gel with the following arrangement:**

What result will be obtained in staining with ethidium bromide? Explain with reasons. [1 mark]



Solution:

Concept:

- DNA carries a net negative charge because of its phosphate backbone and migrates towards the positive electrode (anode).
- Ethidium bromide binds to DNA; stained DNA bands are seen as bright orange bands under ultraviolet light.

Step 1: Inspect the polarity in the first arrangement The wells are placed near the positive electrode, while the negative electrode is at the far end of the gel. Negatively charged DNA therefore moves towards the positive electrode beside the wells, instead of travelling down the agarose gel towards the negative electrode indicated in the drawing.

Step 2: Predict the staining result DNA migrates out of the wells towards the nearby anode and may be lost into the buffer. Hence the expected separated orange DNA bands will not be obtained along the gel below the wells when the stained gel is viewed under ultraviolet light. Ethidium bromide can reveal DNA that is present, but staining cannot correct the reversed electrode arrangement.

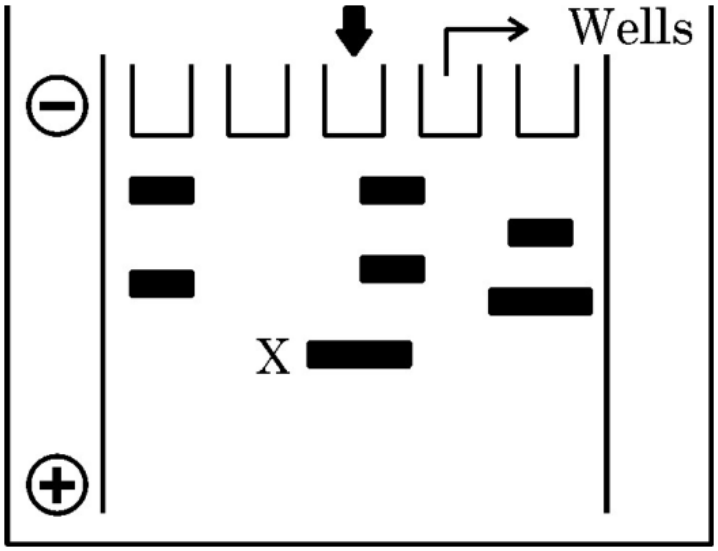
Step 3: Conclusion No properly separated DNA bands will appear down the gel: the DNA moves towards the anode near the wells, rather than through the gel in the intended direction.

Quick Tip to Solve: Before predicting band positions, locate the positive electrode: negatively charged DNA always moves towards it.

28(b). **Observe the given picture carefully. A mixture of DNA with fragments ranging from 100 base pairs to 1800 base pairs were separated by electrophoresis on agarose gel with the following arrangement:**

The above setup was modified as shown below and a band with 100 base pairs was obtained at X.

What changes were made to the previous design to get a band at 'X'. Why did the band appear at 'X'? [2 marks]



Solution:

Concept:

- Negatively charged DNA moves from the cathode (negative electrode) towards the anode (positive electrode) during electrophoresis.
- Agarose acts as a molecular sieve: under the same conditions, smaller DNA fragments move through its pores more readily and travel farther than larger fragments.

Step 1: Correct the electrode arrangement The electrical connections were reversed relative to the first diagram. The wells are now beside the negative electrode, and the positive electrode is at the opposite, lower end of the gel. DNA loaded into the wells is repelled from the negative end and migrates through the agarose towards the positive end, so the fragments can be separated within the gel.

Step 2: Explain the position of the 100-base-pair band The mixture contains fragments from 100 to 1800 base pairs. The 100-base-pair fragments are the smallest and experience the least obstruction from the agarose mesh. During the same electrophoresis time they migrate farther from the wells than the larger fragments. Fragments of the same length collect as a band, so the 100-base-pair DNA appears at X, the farthest indicated position in its lane towards the anode. Its position is due to size-dependent migration, not to a positive charge on the DNA.

Step 3: Conclusion The electrode polarity was reversed so that the wells lie near the cathode and DNA runs towards the anode through the gel. The smallest fragments, 100 base pairs long, travel farthest and form the band at X.

Quick Tip to Solve: Read a DNA gel from the wells towards the anode: in a given lane, the farthest band contains the shortest fragments.

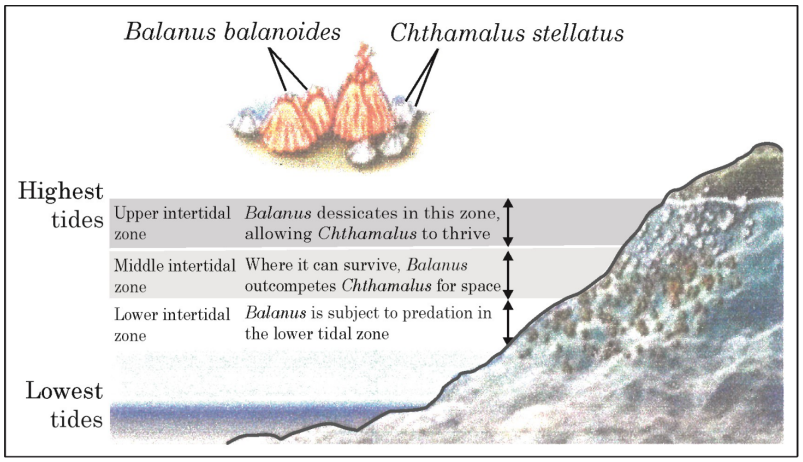
Section D (8 marks)

Question Nos. ***29*** *and* ***30*** *are case-based questions. Each question has sub-sections with internal choice in one sub-section.*

29. The diagram below shows the distribution of two barnacle species, Chthamalus and Balanus on a rocky sea shore.

When Balanus is experimentally removed, Chthamalus expands its range in lower intertidal zone.

[4 marks]



29(a). Identify and define the ecological phenomenon demonstrated by this observation. [1 mark]

Solution:

Concept:

- Interspecific competition occurs when individuals of different species use a common limiting resource, reducing the success of one or both species.
- Competitive release is the expansion of a species into a habitat or resource range from which a superior competitor had previously excluded it.

Step 1: Identify the original restriction On the rocky shore, Balanus competes with Chthamalus for attachment space. The presence of the superior competitor restricts the distribution of Chthamalus; the restriction is not simply its inability to live farther down the shore.

Step 2: Interpret removal of the competitor After Balanus is experimentally removed, Chthamalus occupies the lower intertidal region. Its expansion following removal of the competing species identifies the role of competition in limiting its earlier distribution.

Step 3: Conclusion The phenomenon is competitive release: a species expands its distribution or resource use when its competing species is removed.

Quick Tip to Solve: Look for expansion after a competitor is removed: that observation identifies competitive release.

OR

29(a). State the principle that explains the elimination of one species. [1 mark]

Solution:

Concept:

- Interspecific competition is competition between different species for the same limiting resource.
- Gause's competitive exclusion principle predicts exclusion when two species depend on exactly the same limiting resources under stable conditions.

Step 1: Identify the competing requirements Two species occupying the same ecological niche may need the same limited space or food. If one consistently uses the resource more successfully, the other cannot sustain its population alongside it indefinitely.

Step 2: State the principle precisely Gause's competitive exclusion principle states that two closely related species competing for the same limiting resources cannot coexist indefinitely; the competitively inferior species is eventually eliminated. This applies when resource requirements overlap completely and conditions remain constant.

Step 3: Conclusion Gause's competitive exclusion principle explains elimination: complete competitors cannot coexist indefinitely, and the inferior competitor is excluded.

Quick Tip to Solve: Use competitive exclusion for elimination; use competitive release for expansion after removal of a competitor.

29(b). Two different species can compete for the same resource. Give another example of it. [1 mark]

Solution:

Concept:

- Different species compete when they depend on the same resource and its availability limits their success.
- Competing species need not be closely related: overlap in resource use is the relevant condition.

Step 1: Give a different pair of competitors In some shallow South American lakes, visiting flamingoes and resident fishes compete for food. These organisms belong to different groups, but both obtain food from the same aquatic habitat.

Step 2: Identify the shared resource Both consume zooplankton. When this food resource is limited, consumption by either species reduces the amount available to the other, producing interspecific competition rather than a predator-prey interaction between the flamingoes and fishes.

Step 3: Conclusion Flamingoes and resident fishes in shallow South American lakes compete for the same food resource, zooplankton.

Quick Tip to Solve: An example of competition must name both competitors and the shared resource: flamingoes, fishes and zooplankton.

29(c). How do species avoid competition in nature? Explain with an example. [2 marks]

Solution:

Concept:

- Resource partitioning reduces competition by allowing species to use different portions of a shared resource or to use it at different places or times.
- Reduced overlap in resource use allows species with similar requirements to coexist in the same habitat.

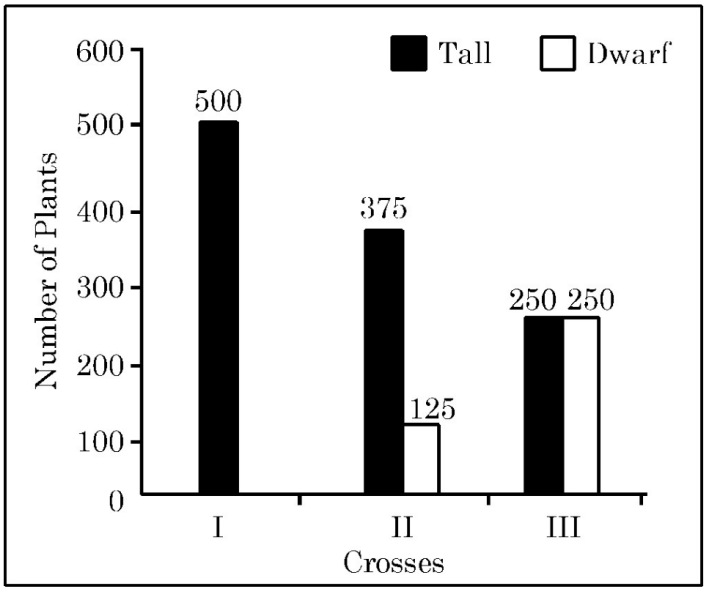
Step 1: Explain how competition is avoided Species may adopt different feeding behaviours, forage in different parts of a habitat, or use the same food at different times. This division of resource use reduces direct competition because the species no longer depend on exactly the same resource in exactly the same way. Such differentiation is called resource partitioning.

Step 2: Explain the warbler example MacArthur observed five closely related species of warblers living on the same tree. They used different foraging positions and feeding behaviours, obtaining food from different parts of the tree. Although they shared a broad habitat and similar food requirements, this partitioning reduced overlap in food collection and enabled the five species to coexist.

Step 3: Conclusion Species avoid or reduce competition by resource partitioning. For example, five species of warblers coexist on the same tree by differing in their foraging positions and feeding activities.

Quick Tip to Solve: For resource partitioning, name the shared habitat and explain how the species divide its use; warblers forage in different parts of one tree.

30. A student performed some crosses in plants and represented the result in the form of bar graphs as shown below. Each graph displays the phenotypic proportion of the progeny. Study the graphs and answer the questions: [4 marks]



30(a). What can you infer about the genotype of parents in crosses I and II? [1 mark]

Solution:

Concept:

- Let T represent the dominant allele for tallness and t the recessive allele for dwarfness; TT and Tt are tall, whereas tt is dwarf.
- A standard Mendelian monohybrid cross between pure tall and pure dwarf parents produces a uniform tall F_1; selfing the F_1 produces a $3:1$ phenotypic ratio.

Step 1: Infer the parents in cross I Cross I gives 500 tall plants and no dwarf plants. In the represented Mendelian sequence, the parental cross is homozygous tall TT with homozygous dwarf tt. Their gametes carry T and t, respectively, so all offspring are tall heterozygotes Tt.

Step 2: Infer the parents in cross II Cross II gives 375 tall and 125 dwarf plants, hence $375:125=3:1$. This is obtained by crossing two heterozygous tall plants, $Tt \times Tt$, yielding genotypes $1TT:2Tt:1tt$. The three dominant-phenotype classes are tall and the recessive class is dwarf.

Step 3: Conclusion Cross I: $TT \times tt$, homozygous tall and homozygous dwarf. Cross II: $Tt \times Tt$, two heterozygous tall parents.

Quick Tip to Solve: In the standard monohybrid sequence, all-tall F_1 follows $TT \times tt$, while a $3:1$ tall:dwarf ratio identifies $Tt \times Tt$.

OR

30(a). Which genetic cross is represented by these crosses? [1 mark]

Solution:

Concept:

- A monohybrid cross follows the inheritance of one character with two contrasting traits.
- Here the character is plant height, with tall and dwarf as its contrasting traits; T is dominant over t.

Step 1: Count the characters being studied Each bar graph records only whether the offspring are tall or dwarf. These are two forms of a single character, plant height, rather than two independent characters such as height and seed colour.

Step 2: Relate the graphs to monohybrid inheritance The all-tall progeny of cross I and the $3:1$ tall:dwarf progeny of cross II are the familiar F_1 and F_2 outcomes of Mendelian monohybrid inheritance. Cross III follows the same character in a test-cross arrangement and gives a $1:1$ ratio.

Step 3: Conclusion These crosses represent monohybrid inheritance: a monohybrid cross studies one pair of contrasting traits, tallness and dwarfness.

Quick Tip to Solve: Tall and dwarf are two traits of one character, so count characters rather than bars when identifying a monohybrid cross.

30(b). Looking at bar graph of cross III, identify the type of cross performed and its importance in genetics. [2 marks]

Solution:

Concept:

- A test cross mates an individual showing the dominant phenotype with a homozygous recessive individual to determine the former's genotype.
- Let T denote the dominant allele for tallness and t the recessive allele for dwarfness. Both TT and Tt are tall, whereas tt is dwarf.

Step 1: Interpret the equal progeny classes Cross III produces 250 tall and 250 dwarf plants, giving a tall : dwarf ratio of $250 : 250 = 1 : 1$. This is the characteristic outcome of crossing a heterozygous tall plant with a dwarf plant:

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

The tall parent supplies T and t gametes in equal proportions, while the dwarf parent supplies only t gametes.

Step 2: Explain its genetic importance Tall appearance alone cannot distinguish TT from Tt. In a test cross, a TT parent crossed with tt would yield only tall Tt offspring. The appearance of dwarf offspring in cross III reveals the recessive allele carried by the tall parent, identifying it as heterozygous. Thus the cross tests the genetic constitution of a dominant-phenotype individual.

Step 3: Conclusion Cross III is a test cross, $Tt \times tt$. Its importance is determining whether an individual with a dominant phenotype is homozygous or heterozygous; the observed $1 : 1$ ratio identifies a heterozygous tall parent.

Quick Tip to Solve: In a test cross, read the offspring as a record of the dominant parent's gametes: equal tall and dwarf classes indicate Tt.

30(c). What conclusion can you draw from the results of bar graphs of crosses I and II? Name the genetic principle illustrated. [1 mark]

Solution:

Concept:

- Under complete dominance, the dominant allele is expressed in a heterozygote and masks the recessive allele.
- Alleles retain their identity and segregate during gamete formation, so a masked recessive trait can reappear in the next generation.

Step 1: Interpret cross I Cross I shows all 500 offspring as tall. In the Mendelian monohybrid cross $TT \times tt$, the F_1 plants are all Tt: tallness is expressed and dwarfness is masked. Thus tallness is dominant over dwarfness.

Step 2: Interpret cross II Cross II shows 375 tall and 125 dwarf plants, a $3 : 1$ phenotypic ratio. Selfing the F_1, $Tt \times Tt$, gives $1TT : 2Tt : 1tt$. The recessive dwarf trait reappears because the two alleles separate during gamete formation and can reunite as tt; they do not blend or disappear.

Step 3: Conclusion Tallness is dominant and dwarfness is recessive, illustrating Mendel's law of dominance. Reappearance of dwarf plants in cross II also demonstrates the law of segregation (purity of gametes).

Quick Tip to Solve: Link the all-tall F_1 to dominance and the return of dwarf plants in the $3:1$ F_2 to segregation.

Section E (15 marks)

31(a). Trace the events from fertilization till implantation of blastocyst in human female. Also mention the site where fertilization takes place. [5 marks]

Solution:

Concept:

- Fertilisation is fusion of the haploid male and female gametes to form a diploid zygote. In humans it normally occurs at the ampullary-isthmic junction of the Fallopian tube (oviduct).
- Cleavage comprises successive mitotic divisions of the zygote into blastomeres; the developing embryo passes through the morula and blastocyst stages before implantation in the uterine endometrium.

Step 1: Arrival of gametes and penetration by a sperm Sperms deposited in the vagina travel through the cervix and uterus into the Fallopian tube. Fertilisation can occur when an ovulated secondary oocyte and viable sperms reach the ampullary-isthmic junction at the appropriate time. A sperm contacts the zona pellucida around the oocyte; enzymes released from its acrosome help it penetrate the coverings and fuse with the oocyte's plasma membrane. Sperm entry induces changes in the zona pellucida that prevent additional sperms from entering, ensuring fertilisation by only one sperm.

Step 2: Completion of meiosis and formation of the zygote Sperm entry induces the secondary oocyte to complete its second meiotic division. This unequal division produces a large haploid ovum and a small second polar body. The haploid sperm nucleus and the haploid ovum nucleus fuse (syngamy), restoring the diploid chromosome number and forming the zygote. In humans, the resulting zygote has 46 chromosomes, 23 contributed by each parent.

Step 3: Cleavage and the morula As the zygote moves along the oviduct towards the uterus, it undergoes repeated mitotic cleavage divisions, producing 2, 4, 8 and then 16 blastomeres. The embryo with 8 to 16 blastomeres is called a morula. These divisions partition the cytoplasm among smaller cells rather than producing a corresponding increase in the embryo's overall size. The morula continues dividing while travelling into the uterus.

Step 4: Formation and differentiation of the blastocyst Continued development produces a blastocyst with a fluid-filled cavity. Its blastomeres become arranged as an outer layer called the trophoblast and an inner group of cells attached to it called the inner cell mass. The inner cell mass gives rise to the embryo, whereas the trophoblast mediates attachment to the uterine lining. The blastocyst sheds its zona pellucida, allowing direct contact with the receptive endometrium.

Step 5: Attachment and implantation The trophoblast attaches to the thickened uterine endometrium and invades it. Uterine cells divide rapidly and cover the blastocyst, so it becomes embedded within

the endometrial tissue. This embedding is called implantation and leads to the establishment of pregnancy. Thus the embryo undergoes early cleavage during transport through the oviduct, but implantation takes place in the uterus.

Step 6: Conclusion Fertilisation occurs at the ampullary-isthmic junction of the Fallopian tube. The developmental sequence is zygote, cleavage stages, morula, blastocyst and finally implantation of the blastocyst in the uterine endometrium.

Quick Tip to Solve: Keep the two sites distinct: fertilisation is in the oviduct; implantation is in the endometrium. Include both trophoblast and inner cell mass at the blastocyst stage.

OR

31(b)(i). Case studies of some couples are given below. They were not able to have kids even though the parents were not taking any precautions. They also do not wish to adopt a child or take the help of donors. Study these cases and suggest an appropriate Assisted Reproductive Technology that could help them.

Case I - Female - Normal Reports. Male - Normal sperms but no connection between epididymis and vas deferens.

Case II - Female - Normal eggs but Fallopian tube blocked. Male - Normal sperms. Male reports are normal.

Case III - Female - Normal Reports. Male - Low sperm count with less motility. [3 marks]

Solution:

Concept:

- Assisted reproductive technologies overcome a specific barrier to fertilisation or embryo transfer. The technique must match the defect in each couple.
- The husband's sperm and the wife's ova can be used in all three cases, so neither adoption nor donor gametes are necessary.

Step 1: Case I: recover the husband's sperm and use ICSI Normal sperm are produced, but the missing connection between the epididymis and vas deferens prevents their passage into the ejaculate. Sperm can be recovered from the epididymis and used for intracytoplasmic sperm injection (ICSI): one sperm is injected directly into the wife's ovum in the laboratory. The resulting embryo is subsequently transferred to her reproductive tract. Simply collecting the ejaculate would not overcome the obstruction, because the normal sperm cannot reach it.

Step 2: Case II: bypass the blocked Fallopian tube Use in vitro fertilisation followed by embryo transfer into the uterus (IVF–ET with IUT). Collect the wife's normal ova and fertilise them with her husband's sperm outside the body. Culture the embryo and transfer an embryo with more than eight blastomeres into the uterus. This bypasses the blocked tube, whereas transferring gametes or a zygote into that tube would retain the obstacle.

Step 3: Case III: assist insemination using the husband's sperm Artificial insemination, particularly intrauterine insemination (IUI), is the standard approach for low sperm count. Process the husband's

semen to concentrate and select motile sperm, then introduce them into the wife's uterus. This reduces the distance they must travel and increases the number of useful sperm near the fertilisation site. If the available sperm have severely inadequate motility, ICSI is also suitable because direct injection of a selected viable sperm into the ovum bypasses the need for it to swim to and penetrate the egg.

Step 4: Conclusion Case I: sperm retrieval followed by ICSI and embryo transfer; Case II: IVF followed by IUT; Case III: artificial insemination/IUI using the husband's sperm, with ICSI suitable for severe low motility.

Quick Tip to Solve: Match the barrier to the bypass: absent sperm passage needs retrieval; a blocked tube needs uterine embryo transfer; low sperm count calls for assisted insemination.

31(b)(ii). Copper releasing intrauterine devices are very effective and popular contraceptive devices. Name any two copper releasing IUDs. Write two reasons that make them effective contraceptives.

[2 marks]

Solution:

Concept:

- Copper-releasing intrauterine devices (IUDs) are placed inside the uterus and act mainly by reducing the ability of sperm to bring about fertilisation.
- Their effectiveness involves both the local uterine response to an IUD and the action of the copper ions it releases.

Step 1: Name two copper-releasing devices Two examples are Cu-T and Cu-7. Both belong to the copper-releasing group of IUDs. Multiload 375 is another member of this group. Lippes loop is non-medicated, whereas LNG-20 is a hormone-releasing device, so these are not appropriate copper-releasing examples.

Step 2: Explain their two contraceptive actions First, an IUD increases phagocytosis of sperm within the uterus, reducing the number of sperm available for fertilisation. Second, the released copper ions suppress sperm motility and their fertilising capacity. Thus, fewer effective sperm can reach and fertilise the ovum. Suppression of ovulation is not the characteristic mechanism asked for here.

Step 3: Conclusion Examples: Cu-T and Cu-7. They increase uterine phagocytosis of sperm, and their copper ions suppress sperm motility and fertilising capacity.

Quick Tip to Solve: Give one uterine effect and one copper-ion effect: increased sperm phagocytosis, then reduced motility and fertilising capacity.

32(a)(i). Watson and Crick's discovery of double helical structure was based on which two findings. Also mention the name of the scientists associated with these findings. [2 marks]

Solution:

Concept:

- The Watson–Crick model combined structural evidence about the shape of DNA with chemical evidence about the proportions of its nitrogenous bases.
- In double-stranded DNA, complementary pairing accounts for the equality of adenine with thymine and guanine with cytosine.

Step 1: Identify the structural finding and its scientists X-ray diffraction studies of DNA supplied evidence for its helical structure and characteristic dimensions. These data were produced by Rosalind Franklin and Maurice Wilkins and helped Watson and Crick construct the double-helical model.

Step 2: Identify the base-composition finding and its scientist Erwin Chargaff found that, in double-stranded DNA, the amount of adenine equals thymine and the amount of guanine equals cytosine: $A = T$ and $G = C$. Consequently, total purines equal total pyrimidines. These regularities supported specific complementary pairing, namely A with T and G with C, rather than arbitrary pairing of bases.

Step 3: Conclusion The two findings were X-ray diffraction evidence from Rosalind Franklin and Maurice Wilkins, and the base-composition relationships $A = T$, $G = C$ established by Erwin Chargaff.

Quick Tip to Solve: Link each finding to its name: Franklin and Wilkins for X-ray structure; Chargaff for equal complementary-base amounts.

32(a)(ii). Write down the salient features of double helix structure of DNA (any three points). [3 marks]

Solution:

Concept:

- DNA consists of deoxyribonucleotide polymers whose nitrogenous-base sequence stores genetic information.
- Its double-helical model explains both the stable association of two strands and the complementarity that allows each strand to serve as a template.

Step 1: Feature 1: two antiparallel polynucleotide strands DNA contains two polynucleotide chains. Each chain has a sugar–phosphate backbone on the outside, with the nitrogenous bases projecting towards the interior. Adjacent nucleotides within a chain are linked by phosphodiester bonds. The strands have opposite polarities: if one runs in the $5' \to 3'$ direction, the other runs in the $3' \to 5'$ direction. This arrangement is described as antiparallel.

Step 2: Feature 2: specific complementary base pairing The strands are joined by hydrogen bonds between complementary bases. Adenine pairs with thymine through two hydrogen bonds, whereas guanine pairs with cytosine through three hydrogen bonds. Thus each pair contains one purine and one pyrimidine, maintaining a nearly uniform distance between the two backbones. The sequence on

one strand determines the complementary sequence on the other.

Step 3: Feature 3: a right-handed helix with regular dimensions The two chains coil into a right-handed double helix. Its pitch is approximately 3.4 nm, with about ten base pairs in each complete turn; successive base pairs are therefore separated by approximately 0.34 nm. The helix has an approximately 2 nm diameter. Stacking of successive base pairs, together with hydrogen bonding, contributes to its stability.

Step 4: Conclusion Three salient features are antiparallel sugar–phosphate strands, complementary $A-T$ and $G-C$ base pairing, and a right-handed helix with about ten base pairs per 3.4 nm turn.

Quick Tip to Solve: Organise three points as strand arrangement, base pairing and helical dimensions; keep the turn length distinct from the spacing of adjacent base pairs.

OR

32(b)(i). Given below is a stretch of DNA showing the coding strand of structural gene of transcription unit.

5'- ATG ACC GTA TTT TCT GTA GTG CCC GTA CTT CAG GCA TTA 3'

Write the corresponding template strand and m-RNA strand that will be transcribed along with its polarity. [2 marks]

Solution:

Concept:

- The template and coding DNA strands are complementary and antiparallel: A pairs with T and G pairs with C.
- RNA polymerase reads the template in the $3' \to 5'$ direction and synthesises RNA in the $5' \to 3'$ direction. The RNA sequence matches the coding strand except that U replaces T.

Step 1: Complement the coding strand The supplied coding strand runs from $5'$ on the left to $3'$ on the right. Complement each base in its given position without reversing the sequence. The corresponding template strand is

$$3' - \text{TAC TGG CAT AAA AGA CAT CAC}$$
$$\text{GGG CAT GAA GTC CGT AAT} - 5'.$$

The second line continues the same strand; the polarity is opposite to that of the coding strand.

Step 2: Transcribe the template During transcription, A in the DNA template pairs with U in RNA; T, G and C pair with A, C and G respectively. Thus the transcribed RNA is

$$5' - \text{AUG ACC GUA UUU UCU GUA GUG}$$
$$\text{CCC GUA CUU CAG GCA UUA} - 3'.$$

This is the unprocessed transcript, so all triplets of the given stretch are retained at this stage.

Step 3: Conclusion The template is the complementary DNA strand running $3' \to 5'$, and the transcribed RNA is the coding-strand sequence with every T replaced by U, running $5' \to 3'$, as written

above.

Quick Tip to Solve: Write the opposite polarity first for the template; obtain RNA directly from the coding strand by changing T to U.

32(b)(ii). Given below is a stretch of DNA showing the coding strand of structural gene of transcription unit.

5'- ATG ACC GTA TTT TCT GTA GTG CCC GTA CTT CAG GCA TTA 3'

If GUA of transcribed mRNA is an intron, then depict the sequence involved in formation of mRNA / mature / processed hnRNA strand:

(1) In a bacterium

(2) In humans [2 marks]

Solution:

Concept:

- In bacteria, the primary mRNA transcript normally functions directly in translation without the hnRNA processing characteristic of eukaryotes.
- Human hnRNA undergoes splicing, which removes introns and joins exons. A methylguanosine cap is added at the $5'$ end and a poly-A tail at the $3'$ end.

Step 1: Write the bacterial transcript In the bacterial case, no spliceosomal removal of the specified GUA segments is carried out. The entire transcribed sequence remains available as mRNA:

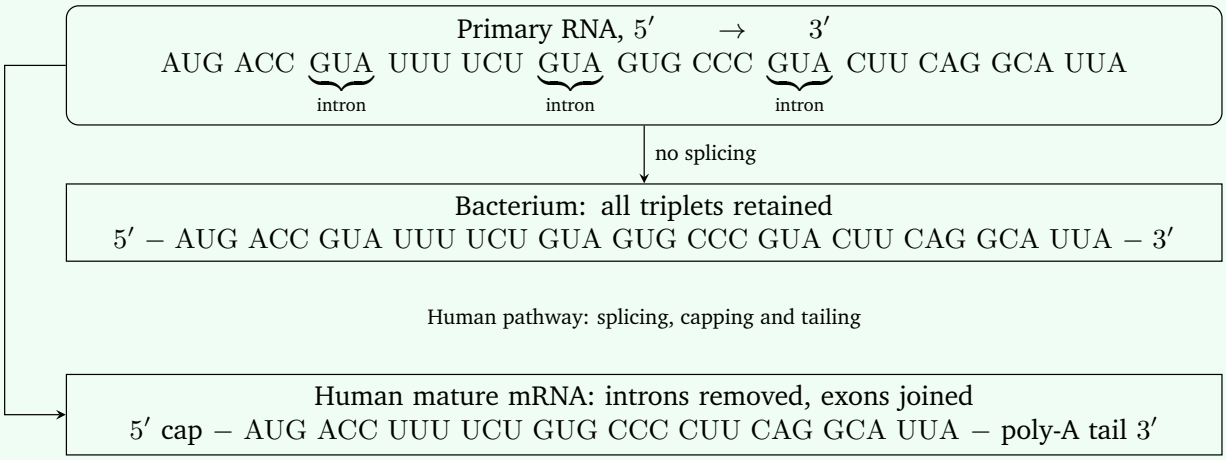
$$5' - \text{AUG ACC GUA UUU UCU GUA GUG}$$
$$\text{CCC GUA CUU CAG GCA UUA} - 3'.$$

Hence all thirteen triplets are retained in the bacterial mRNA. This reflects the textbook distinction between bacterial transcription and eukaryotic hnRNA processing.

Step 2: Process the human hnRNA GUA occurs at triplet positions 3, 6 and 9 of the primary transcript. As specified, these GUA segments are introns; remove all three and join the remaining exons in their original order. The sequence remaining after splicing is

$$5' - \text{AUG ACC UUU UCU GUG}$$
$$\text{CCC CUU CAG GCA UUA} - 3'.$$

The human mature mRNA also carries the $5'$ methylguanosine cap and the $3'$ poly-A tail. These terminal additions are distinct from the coding triplets shown.



Bacterial transcription and human processing of the given RNA sequence

Step 3: Conclusion Bacterial mRNA retains all three GUA triplets; human mature mRNA lacks them and has the joined exon sequence shown above, with a $5'$ cap and a $3'$ poly-A tail.

Quick Tip to Solve: Mark every GUA before splicing: there are three occurrences, while GUG remains because it is a different triplet.

32(b)(iii). Given below is a stretch of DNA showing the coding strand of structural gene of transcription unit.

5'- ATG ACC GTA TTT TCT GTA GTG CCC GTA CTT CAG GCA TTA 3'

How many amino acids the resulting polypeptide will have after the process of translation in humans?

[1 mark]

Solution:

Concept:

- Each sense codon is a triplet of nucleotides specifying one amino acid during translation.
- Introns are removed before human mRNA is translated; their nucleotides do not contribute amino acids to the polypeptide.

Step 1: Count the retained triplets The original transcript contains thirteen triplets. GUA occurs three times and, under the condition given in part (ii), all three occurrences are introns. Splicing therefore leaves $13 - 3 = 10$ triplets, or thirty coding nucleotides.

Step 2: Check the reading frame The retained sequence is AUG, ACC, UUU, UCU, GUG, CCC, CUU, CAG, GCA and UUA. Each is a sense codon, and AUG supplies the initiating methionine. None of these ten triplets is a stop codon. The cap and poly-A tail are not counted as coding triplets in this calculation.

Step 3: Conclusion The given processed human coding stretch specifies $\boxed{10}$ amino acids.

Quick Tip to Solve: Subtract the three GUA introns before counting codons; keep AUG because the start codon also encodes methionine.

33(a)(i). Name the protozoan species that is responsible for causing the most serious and even fatal malarial disease. [0.5 marks]

Solution:

Concept:

- Malaria is caused by protozoan parasites belonging to the genus *Plasmodium*.
- Different *Plasmodium* species cause different forms of malaria; the species associated with malignant malaria is particularly dangerous.

Step 1: Identify the parasite group The causative organism is a protozoan parasite, not the mosquito that transmits it. The disease-causing genus is *Plasmodium*.

Step 2: Select the species causing malignant malaria Among the human malarial parasites, *Plasmodium falciparum* causes the most serious form, known as malignant malaria, which can be fatal.

Step 3: Conclusion The species is *Plasmodium falciparum*.

Quick Tip to Solve: Associate the phrase most serious or fatal malaria with *P. falciparum*, and distinguish the parasite from its mosquito vector.

33(a)(ii). Name the host in which the parasite completes its sexual stages and explain the changes taking place. [2 marks]

Solution:

Concept:

- The definitive host is the host in which a parasite undergoes sexual reproduction.
- In the malarial life cycle, sexual development occurs in the female *Anopheles* mosquito, whereas asexual multiplication occurs in the human host.

Step 1: Identify the host and the ingested stage A female *Anopheles* mosquito takes a blood meal from an infected person and ingests the male and female gametocytes of *Plasmodium*. In the mosquito's gut, these gametocytes develop into male and female gametes. Thus the mosquito is the definitive host as well as the vector of malaria.

Step 2: Trace fertilisation and sporozoite formation The gametes fuse in the gut to form a zygote. The zygote develops into a motile ookinete, which penetrates the gut wall and forms an oocyst on its outer surface. Development and multiplication within the oocyst produce numerous sporozoites. When the oocyst ruptures, the sporozoites are released and migrate to the mosquito's salivary glands. They can then enter another human through the saliva during a subsequent bite.

Step 3: Conclusion Sexual reproduction is completed in the female *Anopheles* mosquito: ingested gametocytes form gametes, fertilisation produces a zygote, and subsequent development produces sporozoites that reach its salivary glands.

Quick Tip to Solve: Remember the host by fertilisation: gametes fuse inside the mosquito, making it the definitive host; sporozoites leave through its saliva.

33(a)(iii). How does the parasite damage the human body after entering the blood stream? [1.5 marks]

Solution:

Concept:

- The malarial parasite, *Plasmodium*, multiplies asexually in human liver cells and then in red blood cells (RBCs).
- Repeated rupture of infected RBCs destroys blood cells and releases haemozoin, associated with the characteristic chills and high fever.

Step 1: Trace multiplication in the liver After an infected female *Anopheles* mosquito introduces sporozoites into the bloodstream, the parasites reach the liver. They enter liver cells and multiply asexually. The infected liver cells rupture and release numerous parasites, called merozoites, which then enter red blood cells.

Step 2: Explain damage during the blood stage The parasites multiply inside RBCs, causing them to rupture. Rupture releases new parasites, which invade more RBCs, and the toxic substance haemozoin. Haemozoin release produces recurring bouts of chills and high fever. Repeated destruction of RBCs lowers their number and can cause anaemia, reducing the oxygen-carrying capacity of blood.

Step 3: Conclusion *Plasmodium* damages liver cells and repeatedly destroys RBCs; haemozoin released during RBC rupture causes chills and high fever, while RBC loss can cause anaemia.

Quick Tip to Solve: Link the blood-stage symptoms to RBC rupture: haemozoin causes chills and fever, while RBC loss causes anaemia.

33(a)(iv). Suggest two effective preventive measures to control the spread of this disease in endemic regions. [1 mark]

Solution:

Concept:

- Malaria spreads through the bite of an infected female *Anopheles* mosquito.
- Prevention therefore targets mosquito breeding and contact between mosquitoes and humans.

Step 1: Remove mosquito breeding sites Drain stagnant water around houses and regularly empty water-holding containers. This removes aquatic breeding sites and reduces the number of mosquitoes that can transmit the parasite in the community.

Step 2: Prevent mosquito bites Use insecticide-treated mosquito nets while sleeping. Nets form a barrier against mosquito bites, while the insecticide helps kill mosquitoes that contact the net, reducing transmission to people.

Step 3: Conclusion Two effective measures are elimination of stagnant-water breeding sites and use of insecticide-treated mosquito nets.

Quick Tip to Solve: Give one measure that reduces mosquito breeding and one that prevents infected mosquitoes from biting people.

OR

33(b)(i). What are bio-fertilizers? [1 mark]

Solution:

Concept:

- Bio-fertilizers are organisms that enrich the nutrient quality of the soil.
- Beneficial microorganisms improve plant nutrition by fixing atmospheric nitrogen or helping roots absorb mineral nutrients.

Step 1: State what bio-fertilizers are Bio-fertilizers are living organisms used to improve the nutrient quality and fertility of soil. The main microbial groups used are bacteria, cyanobacteria and fungi.

Step 2: Explain the defining function Their biological activities increase nutrient availability to plants. For example, *Rhizobium* in legume root nodules fixes atmospheric nitrogen, enriching the nitrogen supply available to the plant.

Step 3: Conclusion Bio-fertilizers are organisms that enrich the nutrient quality of soil, such as nitrogen-fixing *Rhizobium*.

Quick Tip to Solve: In the definition, include both the living organism and its function of enriching soil nutrients.

33(b)(ii). Name the different types of microorganisms used as bio-fertilizers in organic farming and explain how each contributes to soil fertility. [3 marks]

Solution:

Concept:

- Bacteria, cyanobacteria and fungi are the main microbial groups used as bio-fertilizers in organic farming.
- Nitrogen-fixing microbes increase the soil nitrogen supply, while mycorrhizal fungi improve the uptake of phosphorus and other resources by plant roots.

Step 1: Explain bacterial bio-fertilizers *Rhizobium* lives symbiotically in the root nodules of legumes and fixes atmospheric nitrogen into forms usable by the plant. Free-living soil bacteria such as *Azotobacter* and *Azospirillum* also fix atmospheric nitrogen. These bacteria enrich the nitrogen content of the soil, supporting the synthesis of proteins and other nitrogen-containing compounds in plants.

Step 2: Explain cyanobacterial bio-fertilizers Cyanobacteria such as *Anabaena*, *Nostoc* and *Oscillatoria* fix atmospheric nitrogen and are especially useful in paddy fields. They also add organic matter to the soil. *Anabaena* associated with the aquatic fern *Azolla* is another useful nitrogen-fixing association in rice cultivation.

Step 3: Explain fungal bio-fertilizers Mycorrhizal fungi, such as species of *Glomus*, form symbiotic associations with roots. Their hyphae absorb phosphorus from the soil and pass it to the plant, extending the effective absorbing surface of the root system. The plant supplies food to the fungus. This association also improves tolerance to drought and salinity and resistance to root-borne pathogens,

supporting plant growth in the soil.

Step 4: Conclusion Bacterial and cyanobacterial bio-fertilizers enrich soil nitrogen; mycorrhizal fungi improve phosphorus uptake. Together these microbial groups improve nutrient availability and plant growth in organic farming.

Quick Tip to Solve: Pair each group with an example and a function: bacteria and cyanobacteria fix nitrogen; mycorrhizal fungi supply absorbed phosphorus.

33(b)(iii). Write two advantages of using bio-fertilizers over chemical fertilizers. [1 mark]

Solution:

Concept:

- Bio-fertilizers use beneficial living organisms to improve nutrient availability in soil.
- They can reduce dependence on chemical fertilizers while supporting the soil's biological fertility.

Step 1: State the environmental advantage Bio-fertilizers are eco-friendly and reduce the need for chemical fertilizer inputs. This helps lower the risk of soil and water pollution associated with excessive use and runoff of chemical fertilizers.

Step 2: State the soil-fertility advantage They support long-term soil fertility through beneficial microbial activities such as nitrogen fixation and improved nutrient uptake. Their use maintains biological activity in the soil while making nutrients available to growing plants.

Step 3: Conclusion Two advantages are reduced environmental pollution from chemical fertilizer use and maintenance of soil fertility through beneficial microbial activity.

Quick Tip to Solve: Give two distinct advantages: one about reduced pollution and one about sustained biological fertility of the soil.