

CBSE Class 12 Biology Question Paper 2026 with Solution PDF-Set 57-2-3

Question Paper with Solutions

Conducted by the Central Board of Secondary Education (CBSE)



Time Allowed: 3 hours

Maximum Marks: 70

General Instructions

- (i) This question paper contains **33** questions. **All** questions are compulsory.
- (ii) Question paper is divided into **FIVE** sections – Section **A, B, C, D** and **E**.
- (iii) Section **A** – question numbers **1** to **16** are multiple choice type questions. Each question carries **1** mark.
- (iv) Section **B** – question numbers **17** to **21** are very short answer type questions. Each question carries **2** marks.
- (v) Section **C** – question numbers **22** to **28** are short answer type questions. Each question carries **3** marks.
- (vi) Section **D** – question numbers **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** – question numbers **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 student has to attempt 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 No. 1 to 16 are Multiple Choice Type Questions, carrying 1 mark each. Only one option is correct. Choose the best option.

1. *Caenorhabditis elegans* is a nematode which is

[1 mark]

- (A) Free living and non-pathogenic
- (B) Endoparasitic and pathogenic
- (C) Free living and pathogenic
- (D) Ecto-parasitic and non-pathogenic

Correct Answer: (A) Free living and non-pathogenic

Solution:

Concept:

- *Caenorhabditis elegans* is a free-living nematode used as a model organism in biological research.
- Free-living organisms live independently of a host; non-pathogenic organisms do not cause disease.

Step 1: Identify the mode of life *C. elegans* lives freely in soil-associated habitats and feeds on microorganisms. It does not require the tissues of a plant or animal host to complete its normal life cycle, so it is not an endoparasite or an ectoparasite.

Step 2: Check the pathogenicity This nematode is non-pathogenic. Thus (B) is wrong on both features, (C) incorrectly calls it pathogenic, and (D) incorrectly calls it ectoparasitic. Do not confuse it with the plant-parasitic root-knot nematode *Meloidogyne incognita*.

Step 3: Conclusion *Caenorhabditis elegans* is free living and non-pathogenic. Hence, the correct option is (A).

Quick Tip to Solve: Link *C. elegans* with a free-living model organism; link *Meloidogyne* with root-knot disease.

2. Self-incompatibility in some flowering plants is a _____ mechanism that prevents self-fertilization.

Fill in the blank with the appropriate option:

[1 mark]

- (A) Morphological
- (B) Physiological
- (C) Anatomical
- (D) Genetic

Correct Answer: (D) Genetic

Solution:

Concept:

- Self-incompatibility is a genetically controlled mechanism that prevents self-pollen from achieving fertilisation.

- Pollen-pistil recognition can inhibit pollen germination or pollen-tube growth in the pistil.

Step 1: Identify the controlling mechanism The question asks what kind of mechanism self-incompatibility is. The recognition and rejection of self-pollen are controlled by genes, even though the resulting response affects physiological processes such as pollen-tube growth.

Step 2: Distinguish the alternatives Morphological or anatomical barriers depend on flower structure, such as separation of anthers and stigma. Self-incompatibility instead operates through genetic recognition of pollen. Therefore morphological (A), physiological (B), and anatomical (C) do not give the standard classification asked here.

Step 3: Conclusion Self-incompatibility is a genetic mechanism. Hence, the correct option is (D).

Quick Tip to Solve: For self-incompatibility, identify genetic recognition of pollen; do not confuse its physiological effect with its genetic control.

3. Which of the following traits studied by Mendel in pea plant is a recessive trait?

[1 mark]

- (A) Tall stem
- (B) Green pod
- (C) Green seed
- (D) Violet flower

Correct Answer: (C) Green seed

Solution:

Concept:

- A recessive trait is masked in a heterozygote by the corresponding dominant allele.
- In Mendel's peas, yellow seed colour is dominant over green seed colour, whereas green pod colour is dominant over yellow pod colour.

Step 1: Identify the recessive seed colour For seed colour, let Y represent the dominant yellow allele and y the recessive green allele. Plants with YY or Yy have yellow seeds, while yy plants have green seeds. Thus green seed colour is recessive.

Step 2: Check the other traits Tall stem is dominant over dwarf stem, green pod is dominant over yellow pod, and violet flower is dominant over white flower. Thus (A), (B), and (D) are all dominant traits. The word green must be interpreted together with the plant part named.

Step 3: Conclusion Green seed is the recessive trait among the choices. Hence, the correct option is (C).

Quick Tip to Solve: Distinguish seed from pod: green seeds are recessive, but green pods are dominant in Mendel's pea plants.

4. Genetically modified tobacco plants were produced using *Agrobacterium* vectors. Which property of *Agrobacterium* helps in carrying nematode specific genes into the host plant? [1 mark]

- (A) Infectious for monocot plant; has Ti plasmid
- (B) Infectious for dicot plant; has Ti plasmid
- (C) Infectious for plants and animals; has Ti plasmids
- (D) Infectious for monocot and dicot plants; has cry gene

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

Solution:

Concept:

- *Agrobacterium tumefaciens* naturally infects many dicot plants and transfers T-DNA from its Ti plasmid into plant cells.
- A disarmed Ti plasmid can carry an inserted gene into a host plant without causing the normal tumour response.

Step 1: Connect the vector with tobacco Tobacco is a dicotyledonous plant. The DNA-transfer ability of *Agrobacterium*, together with its Ti plasmid, allows nematode-specific sequences inserted in the vector to be introduced into tobacco cells.

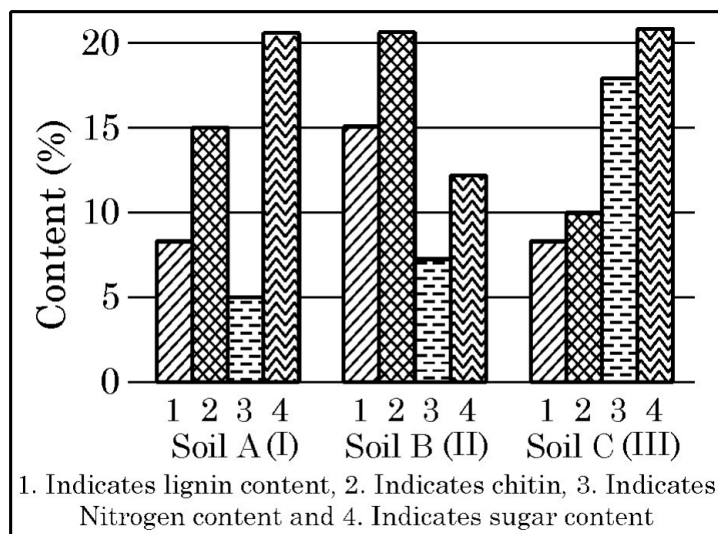
Step 2: Eliminate the mismatched properties Option (A) names monocots instead of the standard dicot hosts. Option (C) incorrectly extends the relevant infection property to animals. Option (D) names the cry gene, which is associated with *Bacillus thuringiensis*; it is not the property responsible for Ti-plasmid-mediated transfer of nematode-specific genes.

Step 3: Conclusion The relevant properties are infection of dicot plants and possession of a Ti plasmid. Hence, the correct option is (B).

Quick Tip to Solve: For an *Agrobacterium* vector, pair dicot infection with the Ti plasmid; associate cry genes with Bt.

5. Observe the contents 1, 2, 3 and 4 of soil samples I, II and III shown in the graph. If the temperature and moisture of all soil samples are identical, which soil sample(s) will show faster decomposition?

[1 mark]



- (A) Soil Sample I
- (B) Soil Sample II
- (C) Soil Sample III
- (D) Both Soil Samples II and III

Correct Answer: (C) Soil Sample III

Solution:

Concept:

- Decomposition is slower when detritus contains more resistant compounds such as lignin and chitin.
- Decomposition is faster when detritus is richer in nitrogen and water-soluble substances such as sugars, under suitable temperature and moisture.

Step 1: Read the graph by substance Bars 1 and 2 represent lignin and chitin, whereas bars 3 and 4 represent nitrogen and sugar. Sample III has much more nitrogen than either I or II, and high sugar comparable to I. It also has less chitin than I and II, and lignin comparable to I but lower than II.

Step 2: Compare the expected rates Because temperature and moisture are identical, the chemical composition decides the comparison. Sample III combines abundant readily usable nutrients with less resistant material. Sample I is poorer in nitrogen, and sample II has the highest lignin and chitin with relatively less sugar. Thus neither I nor II, nor the pair II and III, is the best choice.

Step 3: Conclusion Soil Sample III will show faster decomposition. Hence, the correct option is (C).

Quick Tip to Solve: Read bars 1 and 2 as decomposition barriers and bars 3 and 4 as favourable nutrients; compare all four before choosing.

6. Current percentage of tropical rainforests covering the Earth's land surface is

[1 mark]

- (A) 14%
- (B) 6%
- (C) 8%
- (D) 15%

Correct Answer: (B) 6%

Solution:

Concept:

- The NCERT comparison describes a major reduction in tropical rainforest cover from its earlier extent.
- Tropical rainforests once covered about 14% of the Earth's land surface; their remaining cover is described as no more than about 6%.

Step 1: Recall the comparison used in the chapter This question tests the textbook figure for the reduced extent of tropical rainforests. The relevant present-cover value in that comparison is approximately 6% of land surface, so choose the listed value nearest to that statement.

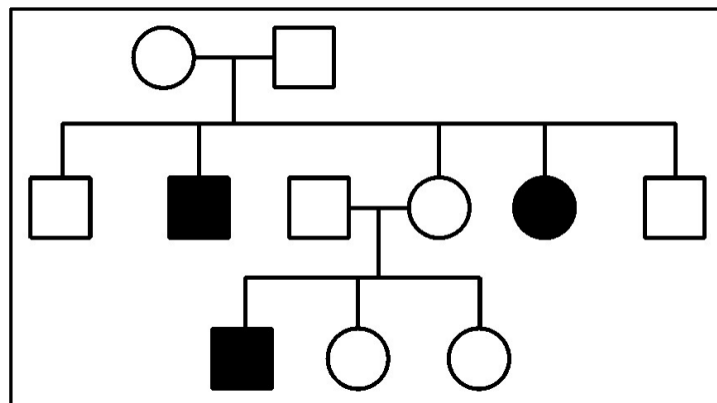
Step 2: Distinguish past and remaining cover The 14% choice refers to the former extent, not the remaining cover. Neither 8% nor 15% is the remaining-cover figure in the NCERT comparison. The denominator is Earth's land surface, rather than its entire surface including oceans.

Step 3: Conclusion The appropriate value among the printed choices is 6%. Hence, the correct option is (B).

Quick Tip to Solve: Remember the rainforest comparison as about 14% formerly and about 6% remaining, both measured against land surface.

7. Study the given pedigree and identify the disease represented.

[1 mark]



- (A) Sickle cell Anaemia
- (B) Haemophilia
- (C) Colour blindness
- (D) Down's syndrome

Correct Answer: (A) Sickle cell Anaemia

Solution:

Concept:

- In a pedigree, squares represent males, circles represent females, and filled symbols represent affected individuals.
- An autosomal recessive disorder can affect children of either sex born to unaffected carrier parents.

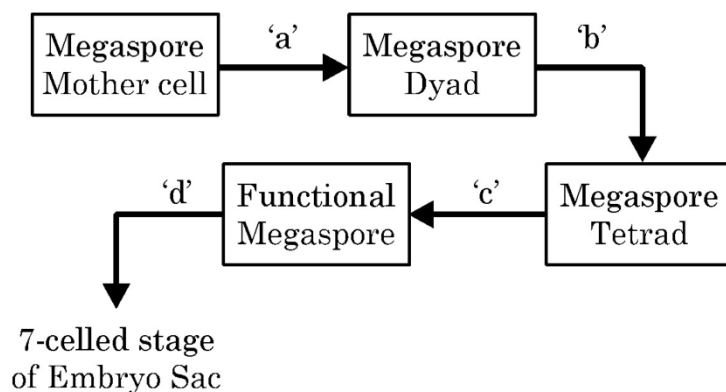
Step 1: Identify the inheritance pattern The unaffected parents in the first generation have an affected son and an affected daughter. This fits an autosomal recessive pattern: two unaffected carriers $Aa \times Aa$ can have affected aa offspring. The unaffected couple in the next generation can likewise produce an affected son if both are carriers.

Step 2: Compare the listed diseases Sickle-cell anaemia is autosomal recessive and fits the pedigree. Haemophilia and colour blindness are X-linked recessive: an affected daughter normally requires an affected father, but the father shown is unaffected. Down's syndrome results from an extra chromosome 21 and does not follow this simple recessive pedigree pattern.

Step 3: Conclusion The pedigree represents sickle-cell anaemia among the given diseases. Hence, the correct option is (A).

Quick Tip to Solve: An affected daughter with an unaffected father rules out the usual X-linked recessive pattern in this pedigree.

8. Given below are stages of embryo sac formation from megaspore mother cell. Identify the correct option for the cell division marked a, b, c and d. [1 mark]



- (A) a - Meiosis-I, b - No division, c - Mitosis, d - Meiosis-II
(B) a - Meiosis-I, b - Meiosis-II, c - No division, d - Mitosis
(C) a - Mitosis, b - Meiosis-I, c - Meiosis-II, d - No division
(D) a - No division, b - Mitosis, c - Meiosis-I, d - Meiosis-II

Correct Answer: (B) a - Meiosis-I, b - Meiosis-II, c - No division, d - Mitosis

Solution:

Concept:

- Megasporogenesis involves meiosis of a diploid megaspore mother cell to produce a tetrad of haploid megaspores.
- In the common monosporic pattern, one functional megaspore undergoes three mitotic nuclear divisions to form an eight-nucleate, seven-celled embryo sac.

Step 1: Assign the two meiotic divisions At a, the megaspore mother cell forms a dyad through meiosis I. At b, the dyad forms a tetrad through meiosis II. These successive divisions complete meiosis and produce four haploid megaspores.

Step 2: Identify selection and embryo-sac development At c, three megaspores degenerate and one remains functional; there is no cell division at this selection stage. At d, the functional megaspore develops into the embryo sac through mitotic nuclear divisions followed by organisation into seven cells. Option (B) alone gives all four assignments; (A) misplaces meiosis II, and (C) and (D) misidentify the first stage.

Step 3: Conclusion The sequence is a: meiosis I; b: meiosis II; c: no division; d: mitosis. Hence, the correct option is (B).

Quick Tip to Solve: Follow the sequence mother cell, dyad, tetrad, functional megaspore, embryo sac: two meiotic stages, selection, then mitoses.

9. What could be the reason of extinction of Abingdon Tortoise from Galapagos Islands?

[1 mark]

- (A) Intraspecific Competition
- (B) Predation
- (C) Parasitism
- (D) Interspecific Competition

Correct Answer: (D) Interspecific Competition

Solution:

Concept:

- Interspecific competition occurs when individuals of different species use the same limiting resource.
- A competitively superior introduced species may reduce the food available to a native species and contribute to its extinction.

Step 1: Identify the competing species The Abingdon tortoise is the NCERT example of competition with introduced goats in the Galapagos Islands. The goats were more efficient browsers and consumed the vegetation on which the tortoises depended, reducing the tortoises' food supply.

Step 2: Distinguish the other interactions Tortoises and goats are different species, so their competition is not intraspecific. The goats did not kill and eat the tortoises, as would occur in predation, nor did they live on or in the tortoises as parasites. The relevant interaction is competition for shared plant food.

Step 3: Conclusion Interspecific competition with introduced goats explains the extinction in this example. Hence, the correct option is (D).

Quick Tip to Solve: Associate the Abingdon tortoise with introduced goats competing for vegetation; different species means interspecific competition.

10. What conclusion can be drawn if the forelimbs of an aquatic animal and a terrestrial animal have similar anatomical structure? [1 mark]

- (A) Live in same habitat
- (B) Share common ancestors
- (C) Forelimbs perform same functions
- (D) Forelimbs are analogous

Correct Answer: (B) Share common ancestors

Solution:

Concept:

- Homologous organs share the same basic anatomical plan and evolutionary origin, even when they perform different functions.
- Homology supports common ancestry and divergent evolution; analogous organs share a function despite different basic origins.

Step 1: Interpret the structural similarity A similar underlying forelimb structure in an aquatic animal and a terrestrial animal indicates inheritance of a common structural plan from a common ancestor. Modification of this inherited plan can adapt the limbs for swimming in one lineage and movement on land in another.

Step 2: Test the remaining options Aquatic and terrestrial animals do not occupy the same habitat, so option (A) is not implied. A shared anatomical plan does not require identical functions, ruling out (C). Calling the limbs analogous in (D) would emphasise similarity of function rather than the common structural origin described here.

Step 3: Conclusion The similar forelimb anatomy indicates that the animals share common ancestors. Hence, the correct option is (B).

Quick Tip to Solve: For limb comparisons, use the underlying anatomical plan to recognise homology and infer common ancestry.

11. If any organ fails to function satisfactorily, transplantation is the only remedy to enable the patient to live a normal life. All of the following are true w.r.t. transplantation except - [1 mark]

- (A) Tissue matching is essential before undertaking any graft.
- (B) T-lymphocytes play an important role in graft rejection.
- (C) Patient takes immuno-suppressants for first few weeks only after transplantation.
- (D) Blood group matching is important before transplantation.

Correct Answer: (C) Patient takes immuno-suppressants for first few weeks only after transplantation.

Solution:

Concept:

- The immune system distinguishes self from non-self; donor tissue may therefore trigger graft rejection in a recipient.
- Cell-mediated immunity, involving T-lymphocytes, is important in rejection, and immunosuppressants reduce this response.

Step 1: Check the matching and rejection statements Tissue matching and blood group matching help select a compatible donor and reduce immune reactions, so statements (A) and (D) are correct in the context of transplantation. T-lymphocytes participate in the cell-mediated immune response responsible for graft rejection, so (B) is also correct.

Step 2: Identify the incorrect duration The transplanted organ continues to carry donor antigens after the first few weeks. A recipient generally requires continuing, long-term immunosuppressive treatment to prevent rejection; treatment is not limited to only the first few weeks. Thus statement (C) is the exception requested by the question.

Step 3: Conclusion The statement limiting immunosuppressants to the first few weeks is incorrect. Hence, the correct option is (C).

Quick Tip to Solve: Underline the word “except” and the phrase “first few weeks only”: persistent donor antigens explain why that statement fails.

12. Which of the following is used to visualize DNA bands under UV light after gel electrophoresis? [1 mark]

- (A) Acetocarmine
- (B) Safranin
- (C) Ethidium Bromide
- (D) Potassium Iodide

Correct Answer: (C) Ethidium Bromide

Solution:

Concept:

- Gel electrophoresis separates DNA fragments according to size, but the separated DNA is not directly visible to the unaided eye.

- Ethidium bromide associates with DNA and fluoresces under ultraviolet illumination, revealing the positions of DNA bands.

Step 1: Connect staining with visualisation After electrophoresis, DNA stained with ethidium bromide is observed under UV light. The stained fragments appear as bright orange-coloured bands, allowing their positions in the gel to be identified before a desired band is cut out for elution.

Step 2: Eliminate the other reagents Acetocarmine is used for staining chromosomes in cytological preparations, and safranin is commonly used to stain cells and tissues. Neither is the reagent described for fluorescent visualisation of electrophoretic DNA bands. Potassium iodide also does not provide this standard DNA-band detection method.

Step 3: Conclusion Ethidium bromide is used to visualise DNA bands under UV light. Hence, the correct option is (C).

Quick Tip to Solve: Remember the sequence for DNA bands: electrophoresis, ethidium bromide staining, UV illumination and orange fluorescence.

13. Assertion (A): DNA Ligase is used to join DNA fragments.

Reason (R): It catalyses the formation of glycosidic bonds between nucleotides.

Select the correct option:

[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 correct explanation for Assertion (A).
- (C) Assertion (A) is true, Reason (R) is false.
- (D) Assertion (A) is false, Reason (R) is true.

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

Solution:

Concept:

- DNA ligase seals breaks in the sugar-phosphate backbone and joins compatible DNA fragments through phosphodiester bonds.
- A glycosidic bond joins a nitrogenous base to its sugar within a nucleotide; it is not the backbone link between adjacent nucleotides.

Step 1: Evaluate the assertion The assertion is true. DNA ligase is used to join DNA fragments, for example a DNA insert and a vector during formation of recombinant DNA. It makes the covalent backbone continuous at the joining sites.

Step 2: Evaluate the reason The reason is false because it names the wrong bond. Ligase catalyses formation of a phosphodiester linkage between adjacent nucleotide ends, involving a 3'-hydroxyl and a 5'-phosphate. It does not join fragments by forming glycosidic bonds.

Step 3: Test the explanatory relationship A false statement about glycosidic bonds cannot explain ligase's role in joining DNA. The two options requiring a true reason are therefore excluded, as is the option that calls the assertion false.

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

Quick Tip to Solve: Match ligase with phosphodiester bonds in the backbone; match glycosidic bonds with the base-sugar link inside a nucleotide.

14. Assertion (A): Apomixis leads to production of genetically identical off-springs.

Reason (R): Apomixis involves fertilization between two genetically similar plants.

Select the correct option:

[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 correct explanation for Assertion (A).
- (C) Assertion (A) is true, Reason (R) is false.
- (D) Assertion (A) is false, Reason (R) is true.

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

Solution:

Concept:

- Apomixis is a form of asexual reproduction that mimics sexual reproduction by producing seeds without fertilisation.
- In apomictic reproduction the maternal genetic constitution can be retained, producing genetically identical offspring.

Step 1: Evaluate the assertion The assertion is true in the stated context: apomictic offspring retain the parental genotype. For example, an unreduced egg can develop into an embryo without fertilisation, or an embryo can develop from a maternal nucellar cell.

Step 2: Evaluate the reason The reason is false. Apomixis does not involve fertilisation between two genetically similar plants; its defining feature is seed formation without fertilisation. Genetic similarity between two parents would not itself make reproduction apomictic.

Step 3: Check whether the reason explains the assertion The genetic identity follows from an asexual route that preserves the maternal genotype, not from the proposed fusion of gametes. Thus neither option requiring both statements to be true fits, and the assertion cannot be classified as false.

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

Quick Tip to Solve: Use “seeds without fertilisation” as the defining test for apomixis; the presence of seeds alone does not imply sexual reproduction.

15. Assertion (A): Under a particular set of selection pressure, organisms evolve towards the most efficient reproductive strategy.

Reason (R): Populations evolve to maximise their reproductive fitness in the habitat where they live.

Select the correct option:

[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 correct explanation for Assertion (A).
- (C) Assertion (A) is true, Reason (R) is false.
- (D) Assertion (A) is false, 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:

- Reproductive fitness is an organism's relative success in contributing offspring to subsequent generations in a particular environment.
- Natural selection favours heritable reproductive strategies that improve reproductive success under the prevailing selection pressures.

Step 1: Evaluate the assertion The assertion is true. Depending on the selection pressures, different reproductive strategies may be favoured, such as producing many small offspring or fewer large offspring. Their effectiveness depends on the habitat and the survival and reproduction they permit.

Step 2: Evaluate the reason The reason is true. Populations evolve towards greater reproductive fitness in the habitat where they live because individuals carrying advantageous heritable traits contribute more descendants. This is an outcome of natural selection, not a conscious choice by organisms.

Step 3: Establish the explanatory connection A reproductive strategy that increases reproductive fitness is favoured under that habitat's selection pressures. This explains why populations evolve towards the most efficient strategy under those conditions. The reason is therefore explanatory, rather than merely a separate true statement.

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

Quick Tip to Solve: Link the efficiency of a reproductive strategy to surviving descendants in that habitat, rather than simply to the number of offspring produced.

16. Assertion (A): Microbes are used for commercial production of alcohol and beverages.

Reason (R): Yeast converts glucose into ethanol and carbon dioxide during fermentation.

Select the correct option:

[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 correct explanation for Assertion (A).
(C) Assertion (A) is true, Reason (R) is false.
(D) Assertion (A) is false, 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).

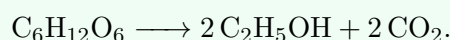
Solution:

Concept:

- Yeast, especially *Saccharomyces cerevisiae*, is used commercially to ferment sugars for production of alcoholic beverages.
- Alcoholic fermentation converts glucose into ethanol and carbon dioxide under anaerobic conditions.

Step 1: Evaluate the assertion The assertion is true. Microbes are grown on a large scale for industrial products, and yeast is used in the commercial production of alcohol and beverages such as wine and beer.

Step 2: Evaluate the reason The reason is true. During alcoholic fermentation, yeast converts glucose into ethanol and carbon dioxide. The overall conversion is:



Ethanol is the alcohol produced by this process.

Step 3: Relate fermentation to commercial production The ability of yeast to form ethanol from fermentable sugars is precisely why it is useful for making alcoholic beverages commercially. Thus the reason directly explains the assertion; it is not merely an unrelated correct fact about a microbe.

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

Quick Tip to Solve: Identify ethanol as the useful fermentation product in beverages and carbon dioxide as the gas produced alongside it.

Section B (10 marks)

17(a)(i). Name the organ that forms a connection between foetus and the uterus of a pregnant human female. [0.5 marks]

Solution:

Concept:

- The placenta is the specialised connection between the developing foetus and the maternal uterine tissue.
- Foetal chorionic villi interdigitate with maternal uterine tissue to form this exchange organ.

Step 1: Identify the maternal-foetal interface After implantation, finger-like chorionic villi develop and become surrounded by uterine tissue and maternal blood. Their close association provides a large surface for exchange between mother and foetus.

Step 2: Distinguish the connecting structures This combined maternal-foetal organ is the placenta. The umbilical cord connects the foetus to the placenta; the placenta itself forms the functional connection with the uterus.

Step 3: Conclusion The organ is the **placenta**.

Quick Tip to Solve: Name placenta for the foetus-uterus connection; reserve umbilical cord for the foetus-placenta connection.

17(a)(ii). How does it support both nutrition and hormonal regulation? [1.5 marks]

Solution:

Concept:

- The placenta functions both as an exchange organ and as an endocrine tissue during pregnancy.
- Its large villous surface brings maternal and foetal circulations close enough for exchange across the placental barrier, without their blood normally mixing directly.

Step 1: Explain the nutritional role Nutrients such as glucose and amino acids pass from the maternal blood across the placenta into the foetal blood. Oxygen is also supplied, while carbon dioxide and metabolic wastes move from the foetus towards the mother for removal. The umbilical cord carries blood between the foetus and the placenta, completing this supply route.

Step 2: Explain the hormonal role The placenta secretes human chorionic gonadotropin (hCG), human placental lactogen (hPL), oestrogens and progestogens. Early in pregnancy, hCG maintains the corpus luteum and its hormone secretion. Progestogens and oestrogens support the uterine endometrium and maintenance of pregnancy; placental hormones also promote maternal changes that support the developing foetus.

Step 3: Conclusion The placenta supplies nutrients and oxygen to the foetus and removes wastes, while acting as an endocrine tissue that secretes hormones needed to support pregnancy.

Quick Tip to Solve: Divide this answer into exchange and endocrine functions, naming both the materials exchanged and the placental hormones.

17(b)(i). Give reasons for:**All copulations do not lead to pregnancy.**

[1 mark]

Solution:**Concept:**

- Pregnancy requires fertilisation followed by implantation; copulation alone does not ensure either event.
- Fertilisation normally occurs at the ampullary-isthmic junction of the fallopian tube when a viable sperm and an ovum reach it together.

Step 1: Relate intercourse to ovulation An ovum is released during ovulation and remains available for fertilisation only for a limited time. Copulation need not occur at a time when viable sperm can meet this ovum in the fallopian tube.

Step 2: Identify the condition for conception If sperm and the ovum do not reach the ampullary-isthmic junction simultaneously while viable, fertilisation does not occur. Even after fertilisation, successful implantation of the developing blastocyst in the uterine endometrium is needed to establish pregnancy.

Step 3: Conclusion All copulations do not lead to pregnancy because viable sperm and an ovum must meet at the correct site and time for fertilisation, followed by successful implantation.

Quick Tip to Solve: For this reason question, link copulation to the simultaneous arrival of viable sperm and ovum at the ampullary-isthmic junction.

17(b)(ii). Give reasons for:**Meiosis I in spermatogenesis and oogenesis are markedly different.**

[1 mark]

Solution:**Concept:**

- Meiosis I reduces the chromosome number from diploid to haploid in both spermatogenesis and oogenesis.
- The important difference is the distribution of cytoplasm: the male division is equal, whereas the female division is unequal.

Step 1: Describe the male division In spermatogenesis, a diploid primary spermatocyte completes meiosis I to form two similar-sized haploid secondary spermatocytes. Cytoplasm is divided approximately equally, and both cells can continue meiosis II to produce spermatids.

Step 2: Contrast the female division In oogenesis, a diploid primary oocyte completes meiosis I with unequal cytokinesis, forming a large haploid secondary oocyte and a small first polar body. Most cytoplasm is retained by the secondary oocyte, preserving cellular resources for the future egg and early development.

Step 3: Conclusion Meiosis I produces two similar-sized secondary spermatocytes in males, but one

large secondary oocyte and one small first polar body in females because cytoplasmic division is unequal in oogenesis.

Quick Tip to Solve: Compare the two products of meiosis I and their sizes; chromosome reduction itself is the same in both processes.

18(a). A patient with Type I diabetes is unable to produce sufficient insulin.

How has recombinant DNA technology helped in addressing this problem?

[1.5 marks]

Solution:

Concept:

- Recombinant DNA technology allows microorganisms to produce human insulin chains using introduced human DNA sequences.
- Mature insulin contains an A chain and a B chain linked by disulphide bonds; the C-peptide of proinsulin is absent from mature insulin.

Step 1: Produce the two human insulin chains DNA sequences corresponding to the A and B chains of human insulin are prepared separately and introduced into plasmids of *Escherichia coli*. The transformed bacterial cultures express these sequences, producing the A and B chains separately. Using the mature-chain sequences avoids the need for bacterial removal of the C-peptide from human proinsulin.

Step 2: Assemble and supply functional insulin The two chains are isolated and purified, then combined by forming the appropriate disulphide bonds to make functional human insulin. Recombinant production provides a large-scale supply of human insulin that can be administered to a person with Type I diabetes to replace the deficient hormone and help regulate blood glucose.

Step 3: Conclusion Recombinant DNA technology produces functional human insulin from separately manufactured A and B chains, providing insulin replacement for patients whose own insulin secretion is insufficient.

Quick Tip to Solve: Recall the sequence: A- and B-chain DNA in bacterial plasmids, separate chain production, purification, then disulphide-bond assembly.

18(b). A patient with Type I diabetes is unable to produce sufficient insulin.

Mention its advantage over animal derived insulin.

[0.5 marks]

Solution:

Concept:

- Recombinant human insulin has the amino acid sequence of human insulin.
- Animal-derived insulin, formerly extracted from slaughtered cattle and pigs, can cause allergy or other immune reactions in some patients.

Step 1: Identify the limitation of animal insulin Insulin obtained from another animal species can

differ from human insulin in its amino acid sequence. The foreign protein preparation can therefore produce unwanted allergic or immune responses in susceptible patients.

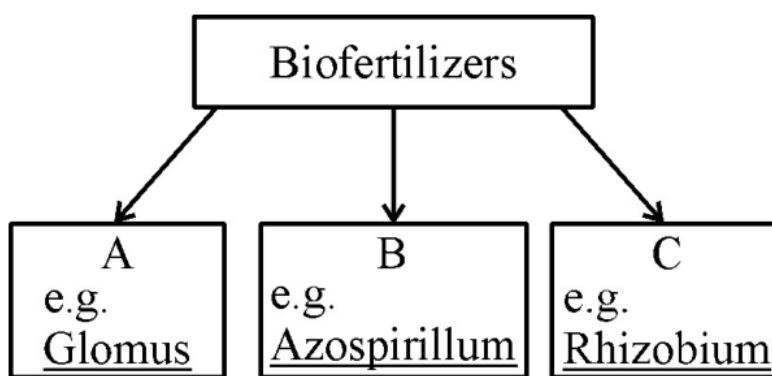
Step 2: State the recombinant advantage Recombinant human insulin corresponds to the human hormone, reducing the risk of reactions associated with animal-derived insulin. It also provides a consistent source of purified insulin without extraction from animal pancreases.

Step 3: Conclusion Recombinant human insulin is less likely to cause allergic or immune reactions than animal-derived insulin.

Quick Tip to Solve: For the comparison with animal insulin, state reduced allergy or immune reactions as the principal advantage.

19. Study the flow chart and answer the following questions:

[2 marks]



19(a). Identify A, B and C in the flow chart.

[1.5 marks]

Solution:

Concept:

- Biofertilizers are organisms that enrich soil nutrient quality through activities such as nitrogen fixation or improved mineral absorption.
- Mycorrhiza is a symbiotic association between fungi and plant roots; nitrogen-fixing bacteria can be free-living or symbiotic.

Step 1: Identify A from its fungal example A is the fungal biofertilizer group, specifically mycorrhizal fungi. Species of *Glomus* form mycorrhiza with roots. The fungal partner absorbs phosphorus from the soil and passes it to the plant.

Step 2: Identify B from its bacterial example B is the group of free-living nitrogen-fixing bacteria. *Azospirillum* enriches soil nitrogen through nitrogen fixation without forming the leguminous root-nodule association characteristic of *Rhizobium*.

Step 3: Identify C from its root association C is the group of symbiotic nitrogen-fixing bacteria. *Rhizobium* occurs in the root nodules of leguminous plants, where it fixes atmospheric nitrogen in association with the host.

Step 4: Conclusion A: mycorrhizal fungi; B: free-living nitrogen-fixing bacteria; C: symbiotic nitrogen-

fixing bacteria.

Quick Tip to Solve: Use the examples as clues: *Glomus* indicates mycorrhiza, *Azospirillum* free-living fixation, and *Rhizobium* symbiotic fixation.

19(b). Give one another example of bio-fertilizer B.

[0.5 marks]

Solution:

Concept:

- The biofertilizer category B contains free-living nitrogen-fixing bacteria.
- An alternative example must belong to the same category as the printed example, *Azospirillum*.

Step 1: Identify the category required The flow chart places *Azospirillum* under B. In the NCERT classification, B therefore represents free-living nitrogen-fixing bacteria rather than mycorrhizal fungi or root-nodule bacteria.

Step 2: Choose another member *Azotobacter* is another free-living nitrogen-fixing bacterium. It fixes atmospheric nitrogen and can enrich the nitrogen content of soil. It is a suitable different example of B, unlike *Glomus*, which is a fungus.

Step 3: Conclusion Another example of B is *Azotobacter*.

Quick Tip to Solve: When asked for another example, retain the category but replace the organism already printed in the chart.

20(a)(i). Explain the type of interaction between:

Egret and Cattle

[1 mark]

Solution:

Concept:

- Commensalism is an interaction in which one species benefits while the other is neither helped nor harmed.
- The effects on the partners in commensalism are represented as $(+, 0)$, where $+$ means benefit and 0 means no significant effect.

Step 1: Identify the egret's benefit As cattle graze and move through vegetation, they stir up insects that would otherwise remain hidden. Egrets walking close to the cattle can easily locate and capture these insects, so their feeding success increases.

Step 2: Assess the effect on cattle In this association the cattle receive no significant benefit from the egret's feeding, and are not harmed by it. Only the egret gains; the interaction is therefore distinguished from mutualism, in which both partners benefit.

Step 3: Conclusion The interaction between egret and cattle is **commensalism**: the egret benefits by feeding on insects disturbed by cattle, while cattle remain unaffected.

Quick Tip to Solve: Identify the benefit to each partner separately: egret gains food, cattle are unaffected, giving $(+, 0)$.

20(a)(ii). Explain the type of interaction between:

Cuckoo and Crow

[1 mark]

Solution:

Concept:

- Parasitism is an interaction in which one organism benefits at the expense of another, represented as (+, -).
- In brood parasitism, a bird lays its eggs in the nest of a host bird and depends on the host to incubate the eggs and rear its young.

Step 1: Identify the cuckoo's benefit The cuckoo lays its eggs in a crow's nest. The crow incubates these eggs and feeds the young cuckoo after hatching, allowing the cuckoo to avoid the energetic cost of caring for its own offspring.

Step 2: Explain the cost to the crow The crow spends time, food and energy rearing another species' offspring, with a cost to its own reproduction. Resemblance between the parasite's eggs and the host's eggs reduces the likelihood that the crow will detect and reject the cuckoo's eggs.

Step 3: Conclusion Cuckoo and crow show **brood parasitism**: the cuckoo is the beneficiary and the crow is the host whose parental care is exploited.

Quick Tip to Solve: Eggs laid in another bird's nest identify brood parasitism; name the cuckoo as parasite and the crow as host.

OR

20(b). Biodiversity exists at various levels within an ecosystem. Explain biodiversity at genetic and ecological level.

[2 marks]

Solution:

Concept:

- Biodiversity is the variety of living organisms and biological organisation, including variation at genetic, species and ecological levels.
- Genetic diversity concerns variation within a species, whereas ecological diversity concerns the variety of ecosystems in a geographical region.

Step 1: Explain genetic diversity Genetic diversity is the variation in genes among individuals or populations of the same species. Such variation produces differences in inherited characteristics and contributes to the ability of populations to respond to different environments. For example, *Rauwolfia vomitoria* populations growing in different Himalayan ranges show genetic variation in the potency and concentration of the active chemical reserpine. The many varieties of rice and mango in India also illustrate genetic diversity within their respective species.

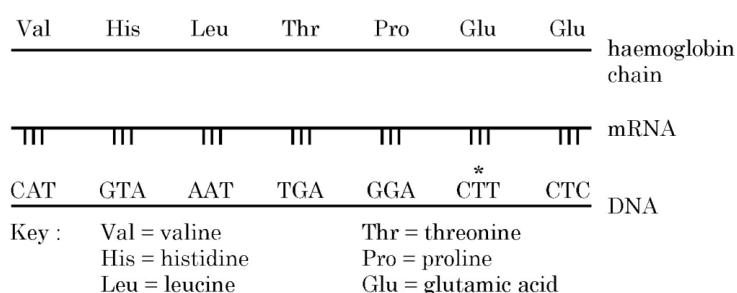
Step 2: Explain ecological diversity Ecological diversity is the variety of ecosystems, habitats and associated ecological communities in a region. Different ecosystems have different environmental conditions and biological communities. For example, India's deserts, rain forests, mangroves, coral

reefs, wetlands, estuaries and alpine meadows together give it greater ecosystem diversity than a country such as Norway.

Step 3: Conclusion Genetic diversity is variation within a species, such as variation among rice varieties; ecological diversity is the variety of ecosystems, such as deserts, forests and wetlands in a region.

Quick Tip to Solve: Ask what is varying: genes within one species indicate genetic diversity; different ecosystems indicate ecological diversity.

21(a)(i). The diagram below shows the sequence of amino acids in part of haemoglobin molecule. Key: Val = valine, His = histidine, Leu = leucine, Thr = threonine, Pro = proline, Glu = glutamic acid. If the base *T is substituted with A, in 'C*TT' of DNA strand how would it affect the haemoglobin chain? [1 mark]



Solution:

Concept:

- The DNA template is transcribed into complementary mRNA: DNA A pairs with RNA U, DNA T with RNA A, and C with G.
- A base substitution that changes the encoded amino acid is a missense mutation. The mRNA codon GAA specifies glutamic acid, whereas GUA specifies valine.

Step 1: Transcribe the altered DNA triplet The displayed DNA is the template strand, because its triplet CTT gives mRNA GAA, which encodes the glutamic acid shown. Substitution of the starred first T by A changes CTT to CAT. The corresponding change in mRNA is

DNA template: CTT $\rightarrow$ CAT, mRNA: GAA $\rightarrow$ GUA.

Step 2: Translate the new codon GUA codes for valine instead of glutamic acid. Counting the amino acids from the left of the printed chain, the affected glutamic acid occupies position six. The substitution changes this one amino acid without shifting the reading frame or changing the seventh residue.

Step 3: Conclusion Valine replaces glutamic acid at the sixth position of the haemoglobin β -chain, producing the sickle-cell haemoglobin variant, HbS.

Quick Tip to Solve: The printed DNA is the template: complement CTT to GAA first, then CAT to GUA, before identifying the amino acid.

21(a)(ii). Name the condition and the effects associated with the above substitution.

[1 mark]

Solution:

Concept:

- Substitution of valine for glutamic acid at position six of the haemoglobin β -chain produces abnormal haemoglobin called HbS.
- Sickle-cell anaemia is an autosomal recessive disorder: its characteristic disease occurs in individuals homozygous for the HbS allele.

Step 1: Connect the substitution to sickling The abnormal HbS molecules can polymerise when oxygen tension is low. This distorts red blood cells from their normal biconcave shape into sickle-shaped cells. The altered cells are less flexible and more fragile than normal red blood cells.

Step 2: Explain the consequences Premature destruction of the affected red blood cells causes anaemia and reduces the blood's oxygen-carrying capacity. Rigid sickled cells can also obstruct small blood vessels, impairing oxygen delivery to tissues and causing painful episodes. Heterozygous individuals generally have the sickle-cell trait rather than the full disease.

Step 3: Conclusion The condition is **sickle-cell anaemia**. At low oxygen tension, red blood cells become sickle-shaped, are destroyed more readily and can obstruct small vessels, causing anaemia and impaired tissue oxygenation.

Quick Tip to Solve: Link the effects in order: abnormal HbS, low-oxygen polymerisation, sickled red cells, anaemia and vessel obstruction.

OR

21(b). DNA is considered a more stable genetic material than RNA. Justify this statement with suitable reasons.

[2 marks]

Solution:

Concept:

- Genetic material must retain biological information reliably. Chemical stability and the capacity to restore damaged information favour long-term storage.
- DNA contains deoxyribose and is usually double-stranded; RNA contains ribose and is usually single-stranded.

Step 1: Compare the sugar groups RNA has a reactive hydroxyl group at the 2' position of each ribose sugar. This 2'-OH group makes its phosphodiester backbone more liable to hydrolysis, especially under alkaline conditions. DNA has hydrogen instead of this hydroxyl group at the corresponding position of deoxyribose. Its backbone is therefore chemically less reactive and more stable.

Step 2: Explain the advantage of two complementary strands DNA's complementary strands are held together by hydrogen bonds and stabilised by base stacking. If the strands separate under suitable conditions, they can reassociate when normal conditions return. Also, an intact complementary strand can provide the information needed to repair damage in the other strand. A usually single-stranded RNA molecule lacks this equivalent complementary backup.

Step 3: Relate thymine to reliable information storage DNA uses thymine instead of uracil. This allows uracil formed by spontaneous deamination of cytosine to be recognised as abnormal in DNA and removed by repair mechanisms. Together with its less reactive sugar and complementary structure, this supports greater fidelity of genetic information.

Step 4: Conclusion DNA is more stable than RNA because it lacks the reactive 2'-OH group and has a complementary double-stranded structure that supports restoration and repair; the use of thymine further aids reliable information storage.

Quick Tip to Solve: Compare DNA and RNA under sugar, strands and bases: emphasise the reactive 2'-OH of RNA and the complementary repair template in DNA.

Section C (21 marks)

22(a). A person inhales dust and pathogens but does not always fall sick. Explain how the body protects against such infections. [1 mark]

Solution:

Concept:

- Innate immunity is the inborn, non-specific defence that acts against many kinds of invading pathogens without requiring prior exposure.
- Respiratory surfaces have barriers that trap inhaled particles and mechanisms that remove or destroy microbes.

Step 1: Explain interception of inhaled particles Mucus coating the respiratory tract traps dust and microorganisms. Cilia move this mucus towards the throat, helping to clear the trapped material before it can establish infection.

Step 2: Explain defence against microbes that enter Phagocytic cells such as macrophages engulf and destroy microbes that get past surface protection. Thus, inhalation of pathogens does not necessarily lead to their successful multiplication or to disease.

Step 3: Conclusion The person is protected by innate immunity, particularly the trapping and clearance of pathogens by respiratory mucus and cilia, supported by phagocytic cells.

Quick Tip to Solve: For an inhaled-pathogen question, link mucus to trapping, cilia to clearance and macrophages to destruction.

22(b). Name and describe any two barriers involved in this protection. [2 marks]

Solution:

Concept:

- Innate immunity provides non-specific protection through physical, physiological, cellular and cytokine barriers.
- Different barriers act at different stages: some prevent entry or trap pathogens, whereas others

destroy pathogens that have entered the body.

Step 1: Describe the physical barrier The mucus coating of the respiratory epithelium is a physical barrier. It traps inhaled dust particles and microorganisms, restricting their contact with underlying tissues. Ciliary movement then carries the mucus and its trapped material towards the throat for removal. Thus, the respiratory lining provides a first line of protection against inhaled pathogens.

Step 2: Describe the cellular barrier Phagocytic cells provide a cellular barrier. Tissue macrophages, including those present in the lungs, and circulating neutrophils can engulf and destroy microorganisms by phagocytosis. They help eliminate pathogens that escape the surface barrier, preventing their multiplication and spread. These cells act as part of innate defence without requiring earlier exposure to that particular pathogen.

Step 3: Conclusion Two barriers are the physical barrier of respiratory mucus, which traps pathogens, and the cellular barrier of phagocytes such as macrophages and neutrophils, which engulf and destroy them.

Quick Tip to Solve: Name the barrier category before its example: respiratory mucus is physical; macrophages and neutrophils are cellular.

23(a). What is a genetic code?

[1 mark]

Solution:

Concept:

- During translation, the nucleotide sequence of mRNA determines the amino acid sequence of a polypeptide.
- A codon is a sequence of three consecutive nucleotides in mRNA, read in the 5' to 3' direction.

Step 1: Identify the information being related Nucleic acids store information as a sequence of bases, whereas proteins are made from a sequence of amino acids. The genetic code gives the correspondence between these two sequences.

Step 2: State how the correspondence is expressed Each mRNA codon specifies a particular amino acid or a termination signal during translation. For example, UUU specifies phenylalanine, while UAA is a stop codon and does not specify an amino acid.

Step 3: Conclusion The genetic code is the set of rules by which triplet codons in mRNA specify amino acids or termination signals during protein synthesis.

Quick Tip to Solve: Define the genetic code as the codon-to-amino-acid correspondence; a single triplet is a codon, not the whole code.

23(b). Why did scientists feel the need to propose a genetic code?

[1 mark]

Solution:

Concept:

- DNA carries hereditary information in its base sequence, and this information is expressed through the synthesis of proteins.
- Nucleic acids use four types of bases, whereas proteins are assembled from twenty standard types of amino acids.

Step 1: Identify the need for a correspondence The sequence of bases in a gene must determine the sequence of amino acids in its protein product. However, bases and amino acids are different chemical units, so their relationship cannot be explained by simply copying one chain into the other.

Step 2: Explain why a code was proposed Scientists therefore needed a coding system to explain how combinations of the four nucleotide bases could specify twenty amino acids. The genetic code provides this relationship through codons in mRNA, allowing the information in a gene to direct a specific polypeptide sequence.

Step 3: Conclusion Scientists proposed a genetic code to explain how the sequence of four kinds of nucleotide bases specifies the sequence of twenty kinds of amino acids in proteins.

Quick Tip to Solve: For why a code is needed, connect the four-base language of nucleic acids with the twenty-amino-acid language of proteins.

23(c). Genetic code is said to be 'Universal'. Why?

[1 mark]

Solution:

Concept:

- Universality concerns the meaning of a codon across organisms: a given triplet generally specifies the same amino acid.
- This property is different from degeneracy, in which more than one codon can specify the same amino acid.

Step 1: Compare codon meanings across organisms The same codon is translated as the same amino acid in almost all organisms, ranging from bacteria to plants and animals. For example, UUU specifies phenylalanine in both bacteria and humans.

Step 2: State the precise scope of universality The code is therefore described as nearly universal. There are a few exceptions, such as certain codon assignments in mitochondrial genetic codes, but these do not change the general commonality of codon meanings across living organisms.

Step 3: Conclusion The genetic code is said to be universal because a particular codon specifies the same amino acid in almost all organisms, with only a few exceptions.

Quick Tip to Solve: Explain universality using one codon with the same meaning in different organisms; do not confuse it with several codons for one amino acid.

24. There are limitations of traditional breeding techniques that led to promotion of micro-propagation ?

[3 marks]

24(a). Mention two advantages of micropropagation.

[2 marks]

Solution:

Concept:

- Totipotency is the capacity of a plant cell to regenerate a complete plant under suitable culture conditions.
- Micropropagation uses tissue culture to multiply a selected plant rapidly; the plants obtained are called somaclones.

Step 1: Explain rapid multiplication A large number of plants can be produced in a short time from a small amount of starting tissue. Repeated multiplication in culture therefore supplies many plantlets without waiting for the repeated breeding cycles needed to build up a large stock by traditional methods.

Step 2: Explain retention of desirable traits The resulting plants are genetically identical to the original selected plant and to one another; they are somaclones. Thus, desirable characteristics of an elite parent are preserved in a uniform population, whereas sexual reproduction can produce variation through segregation and recombination.

Step 3: Conclusion The two advantages are rapid production of many plants and production of genetically identical plants that retain the desirable traits of the selected parent.

Quick Tip to Solve: Give two distinct benefits: speed and number of plants, followed by genetic uniformity of the somaclones.

24(b). Give two examples where it is commercially adopted.

[1 mark]

Solution:

Concept:

- Micropropagation is the commercial production of many plants by tissue culture.
- It is useful for rapidly multiplying selected crop varieties as genetically identical somaclones.

Step 1: Identify a fruit crop Banana is commercially multiplied by micropropagation. Culturing suitable plant tissue produces many plantlets from a selected parent plant.

Step 2: Identify a vegetable crop Tomato is another crop in which micropropagation is commercially adopted. A selected plant can be multiplied rapidly while retaining its desirable genetic characteristics.

Step 3: Conclusion Two examples are banana and tomato.

Quick Tip to Solve: Recall the NCERT commercial examples banana, apple and tomato; write any two of these crops.

25(a). Give the scientific name of the organism used by Morgan to study sex-linked traits. [1 mark]

Solution:

Concept:

- Thomas Hunt Morgan investigated inheritance using the fruit fly.
- In binomial nomenclature, the genus begins with a capital letter, the species with a small letter, and both are italicised.

Step 1: Recall Morgan's experimental organism Morgan studied sex-linked traits, including eye colour, in the fruit fly. The different inheritance patterns in males and females helped relate these traits to the sex chromosomes.

Step 2: Write the binomial name The genus is *Drosophila* and the species is *melanogaster*. Combining these gives the scientific name, with the required capitalisation and italics.

Step 3: Conclusion The organism was *Drosophila melanogaster* (fruit fly).

Quick Tip to Solve: For Morgan, recall the fruit fly; write both words of *Drosophila melanogaster*, not the genus alone.

25(b). Write any four reasons why this organism made it an ideal experimental model. [2 marks]

Solution:

Concept:

- A useful organism for inheritance experiments should be easy to maintain and allow many offspring and generations to be studied.
- Clear identification of males and females helps geneticists set up controlled crosses.

Step 1: State the culture and generation advantages (1) Fruit flies can be grown easily on a simple synthetic medium in the laboratory, making large experimental cultures convenient to maintain. (2) They complete their life cycle in about two weeks, so several successive generations can be studied in a short time.

Step 2: State the offspring and identification advantages (3) A single mating produces a large number of offspring, providing enough individuals to compare observed inheritance ratios reliably. (4) Males and females are easily distinguishable, allowing the investigator to select the appropriate sexes and organise controlled crosses.

Step 3: Conclusion The four reasons are easy laboratory culture, a short life cycle of about two weeks, many offspring per mating, and easily distinguishable males and females.

Quick Tip to Solve: Organise four reasons as culture, generation time, offspring number and sex identification; explain each briefly.

26(a). Compare homologous and analogous organs by giving any one point of difference. [1 mark]

Solution:

Concept:

- Comparative anatomy distinguishes similarity of evolutionary origin from similarity of function.
- The basic structural plan and origin of an organ are the deciding criteria for homology.

Step 1: Characterise homologous organs Homologous organs have the same basic structural plan and evolutionary origin, although they may perform different functions. Their similarity reflects descent from a common ancestral structure.

Step 2: Characterise analogous organs Analogous organs have different basic structural plans and evolutionary origins but perform similar functions. Similarity in function alone therefore does not make two organs homologous.

Step 3: Conclusion Homologous organs share a basic structure and origin; analogous organs have different basic structures and origins despite similar functions.

Quick Tip to Solve: Compare the same criterion on both sides: shared origin for homologous organs versus different origin for analogous organs.

26(b). Mention the type of evolution each represents and give one example of each from plants and animals. [2 marks]

Solution:

Concept:

- Homologous organs represent divergent evolution: a common ancestral structure becomes modified for different functions.
- Analogous organs represent convergent evolution: structures of different origin acquire similar functions under similar selection pressures.

Step 1: Give examples of divergent evolution In plants, the thorn of *Bougainvillea* and the tendril of *Cucurbita* are homologous stem modifications, used for protection and climbing respectively. In animals, the human forelimb and the whale flipper share the basic forelimb skeletal plan but serve manipulation and swimming respectively. Both pairs illustrate divergent evolution.

Step 2: Give examples of convergent evolution In plants, the potato tuber and the sweet-potato storage root are analogous food-storage organs: potato is a stem modification whereas sweet potato is a root modification. In animals, the wings of a butterfly and a bird are analogous organs of flight with different structural origins. Both pairs illustrate convergent evolution.

Step 3: Conclusion Homology represents divergent evolution (*Bougainvillea* thorn/*Cucurbita* tendril; human forelimb/whale flipper). Analogy represents convergent evolution (potato/sweet potato; butterfly wing/bird wing).

Quick Tip to Solve: Give four pairs in total: one plant pair and one animal pair for homology, then one of each for analogy.

27. Draw a neat diagram of enlarged view of one microsporangium of a young anther of an angiosperm. Label the different layers of the wall and write the functions of the outermost and innermost layer.

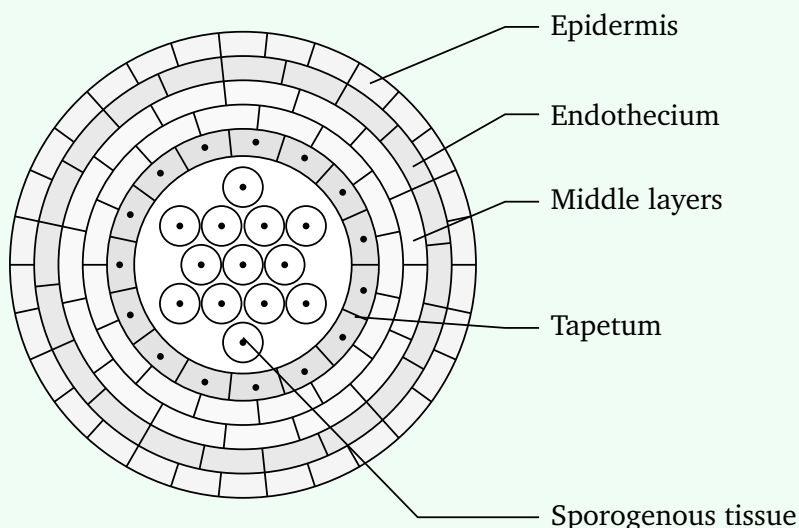
[3 marks]

Solution:

Concept:

- A microsporangium is a pollen sac of the anther. In a young anther, its central region contains compact sporogenous tissue surrounded by a layered wall.
- From outside inward, the wall consists of the epidermis, endothecium, middle layers and tapetum. The position of each layer is related to its protective, supporting or nutritive role.

Step 1: Draw and label the young microsporangium The enlarged transverse view below shows one microsporangium, rather than the whole anther. Label the outermost single layer as epidermis, the next as endothecium, the intervening layers as middle layers, and the innermost layer bordering the sporogenous tissue as tapetum. The centre is shown with sporogenous cells because the anther is young; these cells subsequently differentiate into pollen mother cells.



Enlarged transverse view of one microsporangium of a young anther

Step 2: State the function of the outermost layer The **epidermis** forms the outer protective covering of the microsporangium. It protects the underlying anther tissues and the developing reproductive cells. The other outer wall layers also support the microsporangium; the endothecium later contributes to anther dehiscence, but it is not the outermost layer.

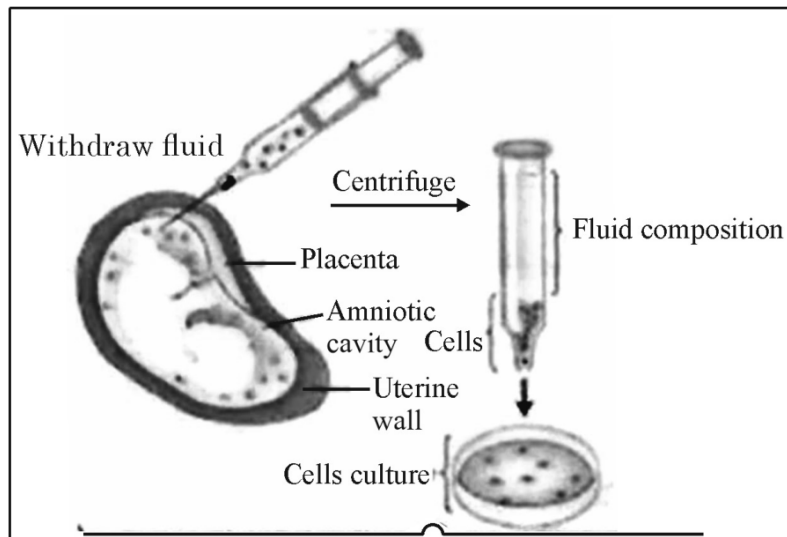
Step 3: State the function of the innermost layer The **tapetum** nourishes the developing microspores and pollen grains. Its cells have dense cytoplasm and commonly more than one nucleus, consistent with their active nutritive role. Its position immediately around the sporogenous tissue allows it to supply the materials needed during pollen development.

Step 4: Conclusion The wall layers are epidermis, endothecium, middle layers and tapetum, from outside inward. The outermost epidermis protects the tissues, while the innermost tapetum nourishes developing pollen grains.

Quick Tip to Solve: Label from outside inward as epidermis, endothecium, middle layers, tapetum; draw sporogenous tissue in the centre of a young microsporangium.

28. Study the diagram given below:

[3 marks]



28(a). Name and explain the procedure shown in the diagram. Mention one of its advantage and one disadvantage. [2 marks]

Solution:

Concept:

- Amniocentesis is a prenatal diagnostic procedure involving a sample of amniotic fluid surrounding the developing foetus.
- Foetal cells in the fluid can be examined to detect certain chromosomal and genetic disorders.

Step 1: Identify and explain the procedure The diagram represents amniocentesis. A small sample of amniotic fluid is withdrawn using a needle. The fluid is centrifuged to separate foetal cells, which may be cultured and analysed, along with relevant components of the fluid, for prenatal diagnosis.

Step 2: State one advantage It enables prenatal detection of certain chromosomal or genetic disorders, such as Down syndrome, by examining foetal cells and their chromosomes. This provides information about foetal health.

Step 3: State one disadvantage The procedure has been misused to determine foetal sex, leading to sex-selective female foeticide. This misuse is the disadvantage relevant to reproductive health; prenatal diagnosis of disease is distinct from sex selection.

Step 4: Conclusion The procedure is amniocentesis: amniotic fluid and foetal cells are analysed for prenatal diagnosis. It can detect chromosomal disorders, but misuse for sex determination can promote female foeticide.

Quick Tip to Solve: Link the syringe and fluid sample to amniocentesis, then give one diagnostic benefit and the misuse for sex selection.

28(b). How is 'Saheli' different from other oral pills in terms of its composition and advantage?

[1 mark]

Solution:

Concept:

- Conventional oral contraceptive pills contain progestogens alone or a progestogen-oestrogen combination.
- Saheli is a non-steroidal oral contraceptive developed in India.

Step 1: Compare the composition Saheli contains the non-steroidal agent centchroman (ormeloxifene). In contrast, conventional oral contraceptive pills contain steroidal hormone preparations, namely progestogens alone or in combination with oestrogens.

Step 2: State its advantage Saheli is described as a once-a-week oral contraceptive with high contraceptive efficacy and very few side effects. Its non-steroidal formulation distinguishes its composition from the usual hormone-containing pills.

Step 3: Conclusion Saheli contains non-steroidal centchroman; it is a once-a-week pill with high contraceptive value and very few side effects.

Quick Tip to Solve: Compare the pills under two headings: steroidal versus non-steroidal composition, then dosing convenience and side effects.

Section D (8 marks)

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

29. Gene manipulation is a fast emerging science. It started with the development of recombinant DNA molecules. This technology which mostly involves cutting and pasting of desired DNA fragments is based on two most important discoveries in bacteria - presence of plasmid and restriction endonucleases. The science of r-DNA technology took birth when Cohen and Boyer (1973) were able to produce a piece of gene containing foreign DNA introduced into plasmid of E.coli.

[4 marks]

29(a). Name one core technique of biotechnology that alters the genetic material.

[1 mark]

Solution:

Concept:

- Biotechnology uses organisms, cells or biological molecules to develop useful products and processes.
- Genetic engineering directly modifies genetic material and can introduce it into a host organism.

Step 1: Identify the relevant core technique The technique is genetic engineering. It includes altering DNA or RNA and introducing the altered material into a host so that the host expresses the desired characteristics.

Step 2: Relate it to the passage In recombinant DNA technology, a desired DNA fragment is joined to a vector and introduced into a host. This deliberate manipulation changes genetic material, unlike the

other core requirement of maintaining sterile conditions during bioprocessing.

Step 3: Conclusion The core technique is genetic engineering, including recombinant DNA technology.

Quick Tip to Solve: Look for deliberate alteration or transfer of DNA: that identifies genetic engineering rather than sterile culture techniques.

29(b). What is a plasmid? Mention its importance in biotechnology.

[2 marks]

Solution:

Concept:

- A plasmid is a usually small, circular, extrachromosomal, double-stranded DNA molecule in a bacterial cell.
- A plasmid has an origin of replication that enables it to replicate independently of the main bacterial chromosome.

Step 1: Define a plasmid A plasmid is an extrachromosomal DNA molecule, typically circular and double-stranded, found in bacteria. It can replicate independently within its host and may carry useful genes such as antibiotic-resistance genes.

Step 2: Explain its importance in biotechnology Plasmids serve as cloning vectors. A desired foreign DNA fragment is inserted into a suitable plasmid to produce recombinant DNA. The recombinant plasmid is introduced into a host bacterium, where replication of the vector also makes copies of the inserted DNA.

Step 3: Connect vector features to their uses The origin of replication permits amplification of inserted DNA. Selectable marker genes help identify cells that have received the vector, and suitable restriction sites allow insertion of foreign DNA into engineered plasmid vectors.

Step 4: Conclusion A plasmid is independently replicating extrachromosomal DNA. In biotechnology, it carries foreign DNA into a host and enables cloning of that DNA.

Quick Tip to Solve: For plasmid importance, connect independent replication with cloning: when the vector replicates, the inserted DNA is copied too.

29(c). Which gene was isolated by Cohen and Boyer and from which bacteria?

[1 mark]

Solution:

Concept:

- A resistance gene enables a bacterium carrying it to survive exposure to the corresponding antibiotic.
- Plasmids are extrachromosomal DNA molecules that can carry such genes and serve as vectors in recombinant DNA technology.

Step 1: Identify the isolated gene Cohen and Boyer isolated an antibiotic-resistance gene. The required answer concerns the function of the isolated DNA, rather than a gene for insulin or a digestive enzyme.

Step 2: Identify its bacterial source The antibiotic-resistance gene was obtained from a plasmid of *Salmonella typhimurium*. Distinguish this source bacterium from *E. coli*, mentioned in the passage in connection with the recombinant plasmid.

Step 3: Conclusion They isolated an antibiotic-resistance gene from *Salmonella typhimurium*.

Quick Tip to Solve: Pair the gene's function, antibiotic resistance, with its source, *Salmonella typhimurium*; do not confuse the source with the recipient.

OR

29(c). How is the action of exonuclease different from that of endonuclease?

[1 mark]

Solution:

Concept:

- Nucleases hydrolyse phosphodiester bonds in nucleic acids and thereby break a DNA chain.
- Exonucleases and endonucleases differ in the position at which they act on the DNA molecule.

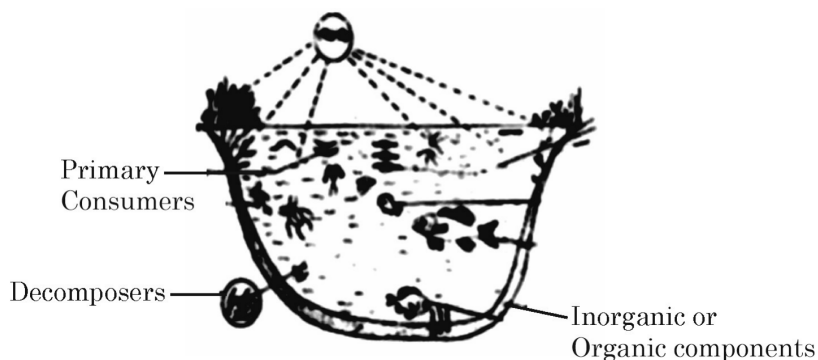
Step 1: Locate exonuclease action An exonuclease removes nucleotides from a free end of DNA. It works inward from the end instead of initiating a cut at an internal position in the chain.

Step 2: Locate endonuclease action An endonuclease cleaves DNA at positions within the chain. Restriction endonucleases are a particular class that recognise specific DNA sequences and cut at defined positions associated with them.

Step 3: Conclusion Exonucleases remove nucleotides from DNA ends, whereas endonucleases make cuts within the DNA molecule.

Quick Tip to Solve: Remember “exo” as acting from an exposed end and “endo” as cutting inside the DNA chain.

30. Below is shown a pond that represents a self-sustaining natural ecosystem with both biotic and abiotic components interacting in a balanced food web. [4 marks]



Based on the diagram, answer the questions:

30(a). Mention two abiotic components of a pond ecosystem. [1 mark]

Solution:

Concept:

- Abiotic components are the non-living physical and chemical components of an ecosystem.
- A pond's living organisms depend on its water, light and dissolved substances for their survival and activities.

Step 1: Identify the physical medium Water is an abiotic component of the pond. It forms the medium in which aquatic organisms live and in which mineral nutrients and gases dissolve.

Step 2: Identify the external energy input Sunlight is another abiotic component. It supplies the energy captured by the pond's photosynthetic producers. Unlike algae, fish or decomposers, sunlight is not a living organism.

Step 3: Conclusion Two abiotic components are water and sunlight.

Quick Tip to Solve: Choose non-living conditions or substances; algae and decomposer bacteria are biotic even when microscopic.

30(b). Differentiate between the roles of producers and decomposers in such an ecosystem. [2 marks]

Solution:

Concept:

- Producers are autotrophs that synthesise organic food from inorganic raw materials using an external energy source.
- Decomposers break down dead organic matter and release inorganic nutrients that can be used again by producers.

Step 1: Explain the role of producers Phytoplankton, algae and aquatic green plants in a pond capture sunlight and use carbon dioxide and water to synthesise organic food by photosynthesis. They form the first trophic level and supply the organic matter and stored chemical energy on which consumers

depend.

Step 2: Explain the role of decomposers Bacteria and fungi act on dead plants, dead animals and organic wastes. Their enzymes break complex organic substances into simpler substances; mineralisation releases inorganic nutrients into the water or sediment. Producers can absorb these nutrients again, so decomposers help maintain nutrient cycling.

Step 3: Conclusion Producers build organic food and introduce usable energy into the food web; decomposers break down organic remains and return inorganic nutrients to the pond.

Quick Tip to Solve: Compare the direction of matter conversion: producers build organic matter, while decomposers break it down and recycle nutrients.

30(c). Draw a simple food chain operating in such an ecosystem and label each trophic level. [1 mark]

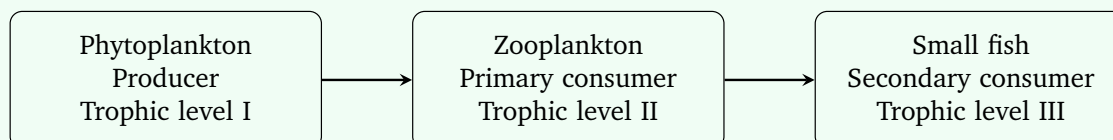
Solution:

Concept:

- A food chain represents the transfer of food and energy through feeding relationships.
- Producers occupy the first trophic level; herbivores and their predators occupy successive consumer levels.

Step 1: Choose organisms in feeding order Phytoplankton manufacture food by photosynthesis. Zooplankton feed on phytoplankton, and small fish feed on zooplankton. This gives a simple grazing food chain of the pond.

Step 2: Label the levels and arrows Label phytoplankton as producers at trophic level I, zooplankton as primary consumers at level II, and small fish as secondary consumers at level III. Each arrow points from the organism eaten to the organism receiving its food energy.



A pond food chain; arrows indicate food and energy transfer.

Step 3: Conclusion The labelled pond food chain is phytoplankton (I) to zooplankton (II) to small fish (III), as shown.

Quick Tip to Solve: Begin with a photosynthetic producer and draw each arrow towards the eater, following energy flow.

30(c). Why is transfer of energy not 100% efficient between trophic levels?

[1 mark]

Solution:

Concept:

- Energy flows through trophic levels and is progressively dissipated as heat rather than being recycled.
- Only energy stored in biomass and made available as food can pass to the next trophic level.

Step 1: Account for metabolic expenditure Organisms use much of the energy they obtain for respiration, maintenance, movement and other life processes. This energy is ultimately dissipated as heat and is unavailable to the next trophic level as food energy.

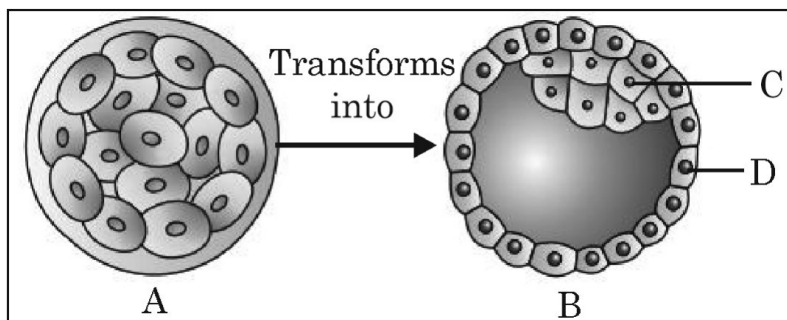
Step 2: Account for untransferred food energy Not all biomass is eaten, and not all ingested material is digested and assimilated. Some energy remains in uneaten material or passes into wastes and the detritus pathway. Only a small fraction becomes consumer biomass available to the next level.

Step 3: Conclusion Transfer is not 100% efficient because energy is lost as heat during metabolism and is retained in uneaten or unassimilated material; typically only about 10% passes to the next trophic level.

Quick Tip to Solve: Separate heat loss through respiration from energy left in uneaten food or wastes; both reduce transfer to the next level.

Section E (15 marks)

31(a). In the given diagram – ‘A’ is an embryonic stage that gets transformed into ‘B’, which in turn gets implanted in the endometrium of human female.



31(a)(i)(1). Identify A, B, C and D.

[2 marks]

Solution:

Concept:

- Cleavage produces a solid ball of blastomeres called the morula, which subsequently develops into a blastocyst.
- A blastocyst has an outer trophoblast layer and an inner cell mass grouped at one pole.

Step 1: Identify the two embryonic stages A is the morula: a solid cluster of blastomeres produced by cleavage. B is the blastocyst: the later hollow stage with a fluid-filled cavity, a peripheral cell layer and a cell cluster at one pole. The blastocyst is the stage involved in implantation.

Step 2: Identify the cells indicated by C and D C indicates the inner cell mass, seen as the cluster projecting into the blastocyst cavity at one pole. D indicates the trophoblast, the outer layer of cells surrounding the blastocyst. The position of each arrow is essential: the clustered inner cells are distinct from the continuous outer layer.

Step 3: Conclusion A: morula; B: blastocyst; C: inner cell mass; D: trophoblast.

Quick Tip to Solve: Identify a solid ball as morula and a hollow ball as blastocyst; then distinguish the inner cluster from the outer trophoblast.

31(a)(i)(2). State the fate of 'C' immediately after implantation.

[1 mark]

Solution:

Concept:

- C represents the inner cell mass of the blastocyst.
- The inner cell mass gives rise to the embryo and differentiates into the primary germ layers.

Step 1: Identify the embryonic tissue The arrow C points to the inner cell mass, not the outer trophoblast. Its fate is therefore development of the embryo proper, rather than formation of the chorionic villi.

Step 2: State the differentiation after implantation After implantation, the inner cell mass differentiates into an outer ectoderm and an inner endoderm. A mesoderm subsequently appears between them. These three germ layers form the various tissues and organs of the embryo.

Step 3: Conclusion C differentiates into ectoderm and endoderm, with mesoderm subsequently forming between them; these germ layers develop into the embryo.

Quick Tip to Solve: Trace C to the inner cell cluster before answering its fate: inner cell mass produces the embryonic germ layers.

31(a)(i)(3). Name the special cells found in 'C' and their function.

[1 mark]

Solution:

Concept:

- The inner cell mass contains embryonic stem cells.
- Stem cells can self-renew and differentiate into specialised cell types.

Step 1: Name the special cells in C C is the inner cell mass of the blastocyst. Its special cells are embryonic stem cells, which are initially undifferentiated and retain the ability to give rise to different cell lineages.

Step 2: State their function These cells differentiate into the diverse specialised tissues and organs of the developing body. Their ability to produce the different body tissues provides the cellular basis for formation of the embryo from the inner cell mass.

Step 3: Conclusion C contains embryonic stem cells, which can differentiate into the various tissues and organs of the body.

Quick Tip to Solve: Associate inner cell mass with embryonic stem cells, and express their function as differentiation into diverse body tissues.

31(a)(ii). What is the role of oxytocin during parturition? Where is it released from?

[1 mark]

Solution:

Concept:

- Parturition is the process of childbirth, driven by strong contractions of the uterine muscles.
- Oxytocin participates in the positive-feedback mechanism that strengthens uterine contractions.

Step 1: State the site of release Oxytocin is released from the posterior pituitary of the mother. It is synthesised in the hypothalamus and stored in the posterior pituitary, so the site of release should be distinguished from its site of synthesis.

Step 2: Explain the role during labour Oxytocin acts on the uterine muscles to produce strong contractions. These contractions stimulate further oxytocin release, strengthening contractions through positive feedback until the baby is expelled from the uterus.

Step 3: Conclusion Oxytocin released from the maternal posterior pituitary stimulates strong uterine contractions during parturition.

Quick Tip to Solve: For oxytocin, pair posterior pituitary release with stronger uterine contractions; distinguish release from hypothalamic synthesis.

OR

31(b). Sexually transmitted infections are a major threat to our society. So it is said that “Prevention is better than cure”.

31(b)(i). Write the three simple principles to be followed to prevent such infections.

[3 marks]

Solution:

Concept:

- Sexually transmitted infections spread mainly through sexual contact, and prevention reduces exposure to infective agents.
- Some infections may remain without obvious symptoms initially; early diagnosis and complete treatment help prevent complications and further transmission.

Step 1: Avoid high-risk sexual exposure Avoid sexual contact with unknown partners or multiple

partners. Restricting exposure lowers the chance of encountering an infected partner; a person can transmit an infection even when symptoms are not apparent.

Step 2: Use a protective barrier Always use condoms during sexual intercourse. A condom provides a physical barrier that reduces direct exposure to potentially infected secretions and thereby helps prevent transmission of sexually transmitted infections.

Step 3: Seek early diagnosis and complete treatment If there is any doubt about infection, consult a qualified doctor for early detection and obtain complete treatment if the disease is diagnosed. Self-medication or stopping treatment prematurely can leave the infection unresolved. Prompt medical attention also helps avoid complications of untreated infections.

Step 4: Conclusion The three principles are: avoid sex with unknown or multiple partners; always use condoms during intercourse; and seek early medical diagnosis with complete treatment when infection is suspected.

Quick Tip to Solve: Remember the prevention sequence as reducing exposure, using a barrier, and obtaining prompt diagnosis with complete treatment.

31(b)(ii). How can sex education programs in schools help in improving reproductive health? (4 points) [2 marks]

Solution:

Concept:

- Reproductive health involves physical, emotional, behavioural and social well-being in all aspects of reproduction.
- Correct, age-appropriate information helps adolescents replace myths with scientific understanding and make responsible decisions.

Step 1: Provide correct biological information Sex education explains reproductive organs, puberty and adolescent changes. It removes myths and misconceptions about sex-related matters, helping students understand normal development without unnecessary fear or shame.

Step 2: Explain prevention of infections It provides scientific information about sexually transmitted infections, including HIV/AIDS, their modes of transmission and prevention. Students learn the importance of safer sexual practices and seeking appropriate medical help.

Step 3: Explain pregnancy and contraception Students learn about reproduction, contraception and the risks of early or unwanted pregnancy. This knowledge helps prevent unwanted pregnancies and encourages responsible decisions about reproduction.

Step 4: Develop healthy attitudes Education promotes reproductive hygiene, respect for others and responsible sexual behaviour. It also builds awareness of sexual abuse and the importance of seeking help from trusted adults, supporting personal safety and reproductive well-being.

Step 5: Conclusion Sex education improves reproductive health through correct biological knowledge, STI awareness, knowledge of contraception and pregnancy, and healthy, responsible attitudes.

Quick Tip to Solve: For four points, organise the answer as puberty, STI prevention, contraception, and responsible behaviour.

32(a). A 30 year old man was admitted to a hospital with recurrent infections, weight loss, prolonged fever. His blood report showed a decline in count of T-Lymphocytes thus affecting immune system.

32(a)(i). Identify the disease and its causative agent.

[2 marks]

Solution:

Concept:

- Helper T-lymphocytes coordinate immune responses; their progressive depletion weakens the body's ability to resist infections.
- AIDS is an acquired immunodeficiency syndrome caused by the human immunodeficiency virus, HIV.

Step 1: Interpret the clinical clues The man has recurrent infections together with weight loss and prolonged fever. The crucial clue is the decline in T-lymphocyte count, indicating damage to the cells that normally support effective immune responses. This combination in the given case points to acquired immunodeficiency.

Step 2: Identify the syndrome and pathogen The disease is AIDS, expanded as Acquired Immuno Deficiency Syndrome. Its causative agent is HIV, the Human Immunodeficiency Virus. HIV is an enveloped retrovirus with an RNA genome; it produces a DNA copy of its genetic material using reverse transcriptase. Infection progressively depletes helper T-lymphocytes, allowing opportunistic infections to develop.

Step 3: Conclusion The disease is AIDS (Acquired Immuno Deficiency Syndrome), caused by HIV (Human Immunodeficiency Virus), a retrovirus.

Quick Tip to Solve: Use the falling helper T-lymphocyte count as the decisive clue linking recurrent infections with AIDS and HIV.

32(a)(ii). How did the pathogen affect the immune system once it entered the body? Explain.

[2 marks]

Solution:

Concept:

- HIV is a retrovirus whose RNA genome is copied into DNA by reverse transcriptase inside an infected host cell.
- Helper T-lymphocytes coordinate immune responses; their loss results in progressive immunodeficiency.

Step 1: Trace viral multiplication After entering the body, HIV enters macrophages. Reverse transcriptase forms viral DNA from viral RNA. Viral DNA becomes incorporated into host-cell DNA and directs production of new virus particles. Macrophages continue producing virus and act as a reservoir, often described as an HIV factory.

Step 2: Explain the loss of immune protection HIV also enters helper T-lymphocytes, multiplies and releases progeny viruses that infect other helper T cells. Repeated infection progressively decreases the number of these lymphocytes. As helper T-cell support for immune responses declines, the body

becomes unable to resist many infections effectively; opportunistic microbes cause the recurrent infections characteristic of AIDS.

Step 3: Conclusion HIV multiplies in macrophages and helper T-lymphocytes and progressively depletes helper T cells, weakening immune defence and permitting opportunistic infections.

Quick Tip to Solve: Write the sequence: viral RNA to DNA, integration, multiplication, helper T-cell depletion, then opportunistic infections.

32(a)(iii). Mention two major modes of its transmission.

[1 mark]

Solution:

Concept:

- HIV transmission requires exposure to infected body fluids through a suitable route of entry.
- Sexual contact and transfusion of infected blood are two major transmission routes.

Step 1: State the sexual route HIV can be transmitted through sexual contact with an infected person, particularly unprotected intercourse, when infected sexual fluids contact susceptible tissues.

Step 2: State the blood route HIV can also be transmitted by transfusion of HIV-contaminated blood or blood products, which introduces the virus directly into the recipient's circulation. Casual contact such as shaking hands does not transmit HIV.

Step 3: Conclusion Two major modes are sexual contact with an infected person and transfusion of HIV-infected blood or blood products.

Quick Tip to Solve: Name two distinct routes: sexual transmission and infected blood transfusion; do not list casual social contact.

OR

32(b)(i). Why are microbes considered effective biocontrol agents in sustainable agriculture?

[1 mark]

Solution:

Concept:

- Biocontrol uses living organisms or their products to control pests and plant pathogens.
- Sustainable agriculture favours control methods that conserve ecological balance and reduce reliance on chemical pesticides.

Step 1: Explain biological pest suppression Selected microbes suppress insect pests or disease-causing organisms through specific biological interactions, such as infection, toxin production or antagonism. They therefore help protect crops from damage.

Step 2: Connect control with sustainability Using suitable microbial agents reduces dependence on chemical pesticides and their polluting residues. Many such agents act on a narrow range of targets, helping conserve beneficial organisms and ecological balance when appropriately selected and used.

Step 3: Conclusion Microbes provide effective biological control of pests and pathogens while reducing chemical pesticide use, pollution and harm to beneficial organisms.

Quick Tip to Solve: Link the two ideas explicitly: biological pest suppression reduces chemical inputs and supports ecological balance.

32(b)(ii). Explain the role of the following as biocontrol agents naming the pests or diseases they help to control:

32(b)(ii)(1). A Bacterium

[1.5 marks]

Solution:

Concept:

- Biological control uses natural enemies or pathogens to suppress pests and plant diseases, reducing dependence on chemical pesticides.
- A useful microbial agent acts against its target pest or pathogen while conserving other organisms in the agricultural ecosystem.

Step 1: Identify the bacterium and its target *Bacillus thuringiensis* (Bt) is a bacterial biocontrol agent used against susceptible butterfly caterpillars and other insect larvae. Dried spores are mixed with water and sprayed on vulnerable plants; feeding larvae ingest the preparation.

Step 2: Explain how it controls the pest In the alkaline gut of a susceptible larva, the Bt protoxin is activated. The active toxin damages the midgut epithelium by forming pores, causing cell swelling and lysis and killing the insect. This protects crops such as brassicas and fruit trees from feeding damage. The action is directed at susceptible target insects, making Bt useful for biological pest management.

Step 3: Conclusion Bt controls susceptible caterpillars through an insecticidal toxin that damages their gut epithelium.

Quick Tip to Solve: Pair Bt with caterpillars, then trace ingestion, activation in the alkaline gut and damage to gut cells.

32(b)(ii)(2). A Fungus

[1 mark]

Solution:

Concept:

- Biological control uses natural enemies or pathogens to suppress pests and plant diseases, reducing dependence on chemical pesticides.
- A useful microbial agent acts against its target pest or pathogen while conserving other organisms in the agricultural ecosystem.

Step 1: Name the fungal agent *Trichoderma* species are free-living fungi commonly found in the root ecosystem. They are used as biological control agents against several soil-borne plant-pathogenic fungi.

Step 2: State the target and action They antagonise susceptible pathogens by competition and mycoparasitism, helping protect plant roots. For example, they suppress fungal pathogens such as *Rhizoctonia*, which can cause damping-off and root rot.

Step 3: Conclusion *Trichoderma* controls soil-borne fungal diseases such as damping-off and root rot.

Quick Tip to Solve: For a fungal biocontrol example, write *Trichoderma* and connect it with root-associated fungal plant diseases.

32(b)(ii)(3). Virus

[1.5 marks]

Solution:

Concept:

- Biological control uses natural enemies or pathogens to suppress pests and plant diseases, reducing dependence on chemical pesticides.
- A useful microbial agent acts against its target pest or pathogen while conserving other organisms in the agricultural ecosystem.

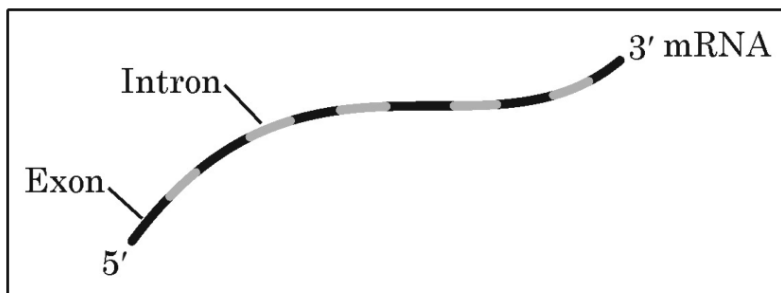
Step 1: Name the virus and target pest Baculoviruses, particularly nucleopolyhedroviruses, are microbial biocontrol agents that infect susceptible insects and other arthropods. For example, a suitable nucleopolyhedrovirus is used against larvae of the cotton bollworm, *Helicoverpa armigera*.

Step 2: Explain biological control The virus infects and multiplies within the susceptible larva, ultimately killing it and reducing crop damage. These agents have narrow-spectrum, species-specific activity and conserve beneficial and non-target organisms. They are therefore valuable in integrated pest management, where natural enemies of pests should remain unharmed.

Step 3: Conclusion A host-specific nucleopolyhedrovirus controls susceptible insect larvae, for example *Helicoverpa armigera*, by infecting and killing them.

Quick Tip to Solve: Link the viral example with its susceptible insect host and emphasise host specificity in pest management.

33(a). Observe the segment of mRNA given below and answers the questions given below:



33(a)(i). Explain and illustrate the steps involved to make fully processed hn RNA.

[3 marks]

Solution:

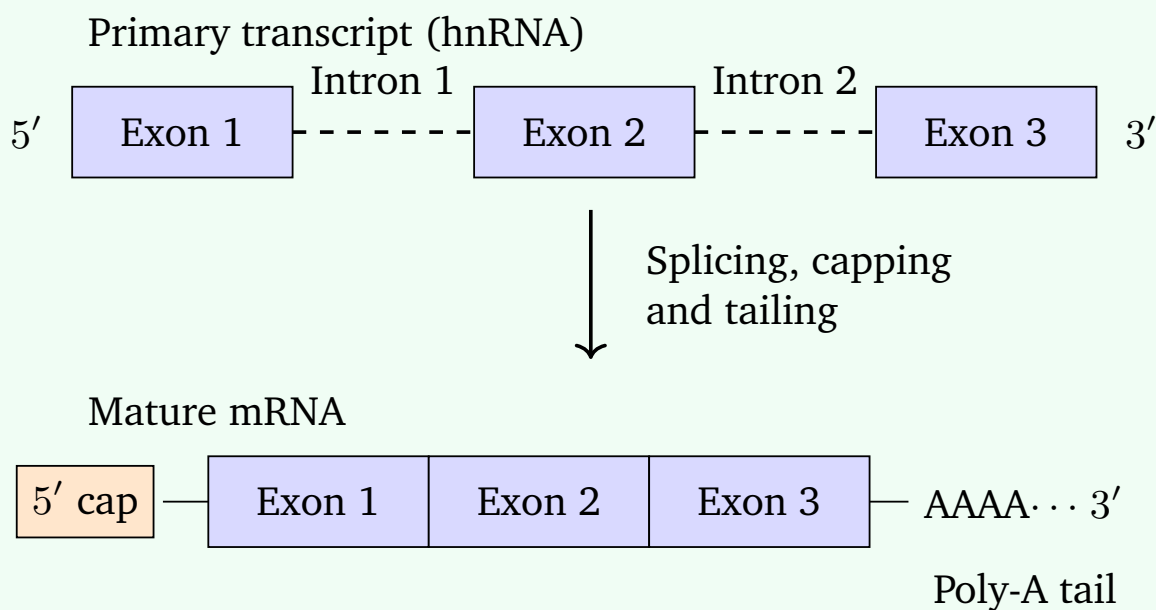
Concept:

- The primary transcript of a eukaryotic protein-coding gene is heterogeneous nuclear RNA (hnRNA), containing both exons and introns.
- RNA processing converts hnRNA into mature mRNA through splicing, capping and tailing. Exons are retained, while introns are removed.

Step 1: Recognise the unprocessed transcript The segment shows alternating exons and introns. It therefore represents the precursor that must be processed before it functions as mature mRNA. The exons are the expressed sequences retained in the final transcript; introns are the intervening sequences removed during processing. The wording asks for the processing of hnRNA: the fully processed product is mature mRNA.

Step 2: Remove introns by splicing During splicing, the introns are excised from the primary transcript and the exons are joined together in their original order. This creates a continuous exon sequence. In the illustration, exon 1, exon 2 and exon 3 remain, while the two intervening introns are removed. Splicing thus removes interruptions from the transcript without reversing the order of its expressed segments.

Step 3: Add the cap and poly-A tail During capping, an unusual nucleotide, methyl guanosine triphosphate, is added to the 5' end of hnRNA. During tailing, about 200–300 adenylate residues are added to its 3' end in a template-independent manner. These changes help protect the transcript and support its subsequent use in translation. The capped, tailed and spliced RNA is mature mRNA, which is transported out of the nucleus for translation. The diagram combines the three processing changes; it does not imply that they occur only in the displayed order.



Processing of hnRNA into mature mRNA (schematic).

Step 4: Conclusion hnRNA becomes mature mRNA by intron removal and exon joining (splicing), addition of a 5' methyl-guanosine cap, and addition of a 3' poly-A tail. The mature transcript is then exported from the nucleus.

Quick Tip to Solve: Show all three changes: delete introns, join exons in order, and label the cap at 5' and the poly-A tail at 3'.

33(a)(ii). Gene encoding RNA polymerase I and RNA polymerase III have been affected by mutation. Explain its impact on the synthesis of polypeptide giving reasons. [2 marks]

Solution:

Concept:

- Eukaryotic RNA polymerases have different transcriptional roles: polymerase I makes most rRNAs, polymerase II makes hnRNA, and polymerase III makes tRNA, 5S rRNA and some small RNAs.
- Translation requires both functional ribosomes and charged tRNAs, as well as an mRNA template.

Step 1: Trace the effect of defective RNA polymerase I A mutation that impairs RNA polymerase I reduces synthesis of the precursor for 28S, 18S and 5.8S rRNAs. These rRNAs are essential structural and functional components of ribosomes. Their shortage prevents normal formation of functional ribosomes, so the cell cannot efficiently translate the mRNA into a polypeptide.

Step 2: Trace the effect of defective RNA polymerase III Impaired RNA polymerase III reduces production of tRNAs and 5S rRNA. tRNAs carry specific amino acids to the ribosome and recognise mRNA codons through their anticodons. Without adequate functional tRNAs, amino acids cannot be supplied and arranged normally during translation. Reduced 5S rRNA also impairs ribosome assembly and function. Thus polypeptide synthesis is severely reduced, or stops if the essential activities are

lost, even though RNA polymerase II may still produce hnRNA that can be processed into mRNA.

Step 3: Conclusion Mutations impairing polymerases I and III inhibit polypeptide synthesis by reducing rRNAs needed for ribosomes and tRNAs needed for amino-acid delivery. The presence of mRNA alone cannot sustain translation.

Quick Tip to Solve: Link I to the major rRNAs and III to tRNA plus 5S rRNA; then explain why both ribosomes and tRNAs are needed to translate mRNA.

OR

33(b). In a particular cattle, the coat colour red and white are controlled by single pair of alleles. A calf that receives allele for red coat from mother and allele for white coat from father shows equal number of red and white hairs on its coat.

33(b)(i). Is this an example of Co-dominance or incomplete dominance. Give a reason for your answer. [1 mark]

Solution:

Concept:

- In co-dominance, both alleles express their effects distinctly in the heterozygote; neither allele masks the other.
- In incomplete dominance, the heterozygote has a phenotype intermediate between those of the two homozygotes.

Step 1: Identify the expression of the parental alleles The calf inherits one allele for red coat colour and one for white coat colour. Its coat contains both red hairs and white hairs in equal numbers, so the effects of both parental alleles can be recognised separately in the same animal.

Step 2: Distinguish the two inheritance patterns The hairs do not all show a single intermediate colour. Red and white remain separately expressed, which is the characteristic feature of co-dominance. An intermediate colour in the heterozygote would instead illustrate incomplete dominance.

Step 3: Conclusion This is co-dominance: both the red and white alleles express themselves in the heterozygous calf, producing a coat with red and white hairs (roan).

Quick Tip to Solve: Look for two distinct parental traits in the heterozygote: separate red and white hairs indicate co-dominance, while a uniform intermediate colour indicates incomplete dominance.

With the help of a genetic cross upto F_2 generation, explain what will be the consequent phenotype of calf when

33(b)(ii)(1). Red is dominant over white,

[2 marks]

Solution:

Concept:

- A monohybrid cross follows one pair of alleles. During gamete formation the two alleles segregate, so each gamete receives only one allele.
- With complete dominance, the heterozygote resembles the dominant homozygote. With incomplete dominance, the heterozygote has an intermediate phenotype.
- Crossing pure-breeding parents produces a uniform heterozygous F_1 . Crossing two F_1 individuals produces an F_2 genotypic ratio of 1 : 2 : 1; the phenotypic ratio depends on allele expression.

Step 1: Cross the parents when red is completely dominant Let R denote the dominant allele for red and r the recessive allele for white. Take pure-breeding red and white cattle as the parental generation:

$$\begin{aligned}P &: RR \text{ (red)} \times rr \text{ (white)}, \\ \text{Gametes} &: R \quad \text{and} \quad r, \\ F_1 &: \text{all } Rr.\end{aligned}$$

Every F_1 calf is red because R masks the effect of r .

Step 2: Obtain the second generation under complete dominance Cross two F_1 cattle: $Rr \times Rr$. Each parent produces R and r gametes in equal proportions. Their combinations are:

	R	r
R	RR	Rr
r	Rr	rr

Thus the F_2 genotypic ratio is 1 RR : 2 Rr : 1 rr . Both RR and Rr are red; only rr is white. Therefore the phenotypic ratio is 3 red : 1 white.

Step 3: Conclusion When red is dominant, all F_1 calves are red. The F_2 genotypic ratio is 1 RR : 2 Rr : 1 rr , while the phenotypic ratio is 3 red : 1 white.

Quick Tip to Solve: For complete dominance, group both RR and Rr as red when converting the 1 : 2 : 1 genotypic ratio to phenotypes.

33(b)(ii)(2). Red is incompletely dominant.

[2 marks]

Solution:

Concept:

- A monohybrid cross follows one pair of alleles. During gamete formation the two alleles segregate, so each gamete receives only one allele.
- With complete dominance, the heterozygote resembles the dominant homozygote. With incomplete dominance, the heterozygote has an intermediate phenotype.

- Crossing pure-breeding parents produces a uniform heterozygous F_1 . Crossing two F_1 individuals produces an F_2 genotypic ratio of 1 : 2 : 1; the phenotypic ratio depends on allele expression.

Step 1: Cross the parents when red is incompletely dominant Now use C^R and C^W for the red and white alleles, respectively. The superscripts distinguish alleles without implying complete dominance. The parental cross is:

$$\begin{aligned} P &: C^R C^R \text{ (red)} \times C^W C^W \text{ (white)}, \\ \text{Gametes} &: C^R \text{ and } C^W, \\ F_1 &: \text{all } C^R C^W. \end{aligned}$$

In this stated hypothetical pattern, every F_1 calf has an intermediate, light-red or pink coat. This is a uniform intermediate phenotype, distinct from a roan coat containing separate red and white hairs.

Step 2: Obtain the second generation under incomplete dominance Cross two heterozygous F_1 cattle: $C^R C^W \times C^R C^W$. Each produces C^R and C^W gametes in equal proportions:

	C^R	C^W
C^R	$C^R C^R$	$C^R C^W$
C^W	$C^R C^W$	$C^W C^W$

The F_2 genotypic ratio is 1 $C^R C^R$: 2 $C^R C^W$: 1 $C^W C^W$. These genotypes produce red, intermediate and white coats, respectively. Thus the phenotypic ratio is also 1 : 2 : 1, because the heterozygote is visibly different from both homozygotes.

Step 3: Conclusion When red is incompletely dominant, all F_1 calves have an intermediate coat colour. The F_2 phenotypic ratio is 1 red : 2 intermediate : 1 white, matching the 1 : 2 : 1 genotypic ratio.

Quick Tip to Solve: For incomplete dominance, keep the heterozygous phenotype separate: its intermediate coat colour makes the phenotypic ratio 1 : 2 : 1.