

CBSE Class 12 Biology Question Paper 2026 with Solution PDF-Set 57-2-1

Question Paper with Solutions

Conducted by the Central Board of Secondary Education (CBSE)



Time Allowed: 3 hours

Maximum Marks: 70

General Instructions

- (i) This question paper contains **33** questions. **All** questions are compulsory.
- (ii) Question paper is divided into **FIVE** sections – Section **A, B, C, D** and **E**.
- (iii) Section **A** – 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. To separate repetitive DNA from bulk genomic DNA, which of the following method is used?

[1 mark]

- (A) Elution
- (B) Southern Blotting
- (C) Polymerase Chain Reaction
- (D) Density Gradient Centrifugation

Correct Answer: (D) Density Gradient Centrifugation

Solution:

Concept:

- Repetitive DNA contains nucleotide sequences repeated many times within the genome.
- DNA fractions with different base compositions may have different buoyant densities and form distinct bands during density gradient centrifugation.

Step 1: Identify the basis of separation In a density gradient, the bulk genomic DNA forms the main band, while repetitive DNA can form separate minor bands called satellite DNA. The separation depends on density differences associated with base composition.

Step 2: Eliminate the other methods Elution recovers DNA from a gel after separation. Southern blotting detects a specific DNA sequence by hybridisation, and polymerase chain reaction amplifies a selected sequence. None of these is the method used to separate satellite repetitive DNA from the bulk genomic DNA on the basis of density.

Step 3: Conclusion Density gradient centrifugation separates repetitive DNA from bulk genomic DNA. Hence, the correct option is (D).

Quick Tip to Solve: Link the term satellite DNA with minor bands produced by density gradient centrifugation.

2. Select the correct option:

[1 mark]

- (A) Tropics between 23.5° N - 23.5° S - Higher biodiversity than temperate areas
- (B) Columbia - 105 bird species
- (C) New York - 1400 bird species
- (D) India - 2000 bird species

Correct Answer: (A) Tropics between 23.5° N - 23.5° S - Higher biodiversity than temperate areas

Solution:

Concept:

- Species diversity generally decreases from the equator towards the poles; this is the latitudinal diversity gradient.
- Tropical regions between 23.5° N and 23.5° S generally support greater biodiversity than temperate regions.

Step 1: Apply the latitudinal pattern Tropical regions have had long evolutionary time, relatively stable climates and greater solar energy availability. These conditions favour productivity, niche specialisation and accumulation of species. Thus the comparison in option (A) follows the recognised biodiversity pattern.

Step 2: Check the numerical alternatives In the NCERT comparison, Colombia has nearly 1,400 bird species, New York has about 105, and India has more than 1,200. Options (B) and (C) interchange the first two figures, while the figure of 2,000 in option (D) does not match this comparison.

Step 3: Conclusion Tropical regions have higher biodiversity than temperate regions. Hence, the correct option is (A).

Quick Tip to Solve: First use the equator-to-pole diversity gradient; then check whether the bird counts have been interchanged.

3. In a dihybrid cross, 2400 individuals are produced in F_2 generation. Approximately how many will be phenotypically similar to parents?

[1 mark]

- (A) 2000
- (B) 1500
- (C) 580
- (D) 450

Correct Answer: (B) 1500

Solution:

Concept:

- A Mendelian dihybrid cross with independent assortment and complete dominance gives an F_2 phenotypic ratio of 9 : 3 : 3 : 1.
- For parental types $AABB$ and $aabb$, the phenotypes matching the original parents are the double-dominant and double-recessive classes.

Step 1: Identify both parental phenotypes The F_1 heterozygotes $AaBb$ produce four gamete types. On selfing, $A_B_$ accounts for 9/16 of the progeny and $aabb$ for 1/16. These two classes resemble the original pure-breeding parents. The two mixed phenotypes, each 3/16, are recombinant combinations.

Step 2: Calculate the number resembling the parents Add both parental classes before multiplying by the total number of individuals:

$$2400 \times \left(\frac{9}{16} + \frac{1}{16} \right) = 2400 \times \frac{10}{16} = 1500.$$

The remaining 900 show recombinant phenotypes. The value 450 counts only one recombinant class, while 2000 and 580 do not represent the combined parental classes.

Step 3: Conclusion Approximately 1500 individuals will resemble the original parents phenotypically. Hence, the correct option is (B).

Quick Tip to Solve: In a standard dihybrid cross, add the 9 and 1 classes to count both original parental phenotypes.

4. 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 between individuals of different species that use a common resource.
- A competitively superior species can exclude another species when their resource requirements overlap strongly.

Step 1: Identify the competing species In the NCERT example, goats introduced on the island were more efficient browsers than the Abingdon tortoise. They competed with tortoises for vegetation, reducing the food available to the tortoise population and contributing to its extinction.

Step 2: Classify the interaction Goats and tortoises belong to different species, so their competition is interspecific. Intraspecific competition would occur among members of the same species. The stated example involves neither a predator feeding on tortoises nor a parasite obtaining nourishment from them, so predation and parasitism do not explain this textbook case.

Step 3: Conclusion Competition with introduced goats was interspecific competition. Hence, the correct option is (D).

Quick Tip to Solve: For the Abingdon tortoise example, recall that introduced goats were more efficient browsers competing for food.

5. 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 their functions differ.
- Divergent evolution modifies an ancestral structure for different uses in different environments.

Step 1: Interpret the shared anatomy Similar basic anatomy in the forelimbs of aquatic and terrestrial animals indicates homology. For example, the same underlying arrangement of bones can be modified for swimming in one lineage and movement on land in another. This similarity provides evidence of common ancestry.

Step 2: Distinguish anatomy from function The animals already occupy different habitats, so option (A) is unsuitable. Shared anatomy does not require identical functions, ruling out option (C). Analogous organs have similar functions but different evolutionary origins and basic structure; this is different from the anatomical similarity described in option (D).

Step 3: Conclusion The animals share common ancestors, as indicated by homologous forelimbs. Hence, the correct option is (B).

Quick Tip to Solve: Identify homology from the underlying structural plan; a similar function alone instead suggests analogy.

6. How many of the following features are related to Nirodh - a popular brand of condoms?

(i) Prevention of sexually transmitted infections.

(ii) Phagocytosis of sperms.

(iii) Male contraceptive device.

(iv) Acts as chemical barrier.

(v) Physiological changes in cervical mucus.

[1 mark]

(A) (i), (ii), (iv)

(B) (i) and (iii)

(C) (i), (ii), (v)

(D) (ii) and (iv)

Correct Answer: (B) (i) and (iii)

Solution:

Concept:

- Condoms are barrier contraceptives that physically prevent semen from entering the female reproductive tract.
- Nirodh is a male condom; appropriate use also helps prevent transmission of sexually transmitted infections.

Step 1: Select the features of a condom A male condom is worn over the penis and retains ejaculated semen. It is therefore a male contraceptive device, making statement (iii) correct. By limiting direct contact and exchange of sexual secretions, it also offers protection against sexually transmitted infections, so statement (i) is correct.

Step 2: Exclude mechanisms of other methods A condom is a physical barrier, not a chemical barrier, so statement (iv) is false. Increased phagocytosis of sperms is associated with intrauterine devices, not condoms; thus (ii) is false. Changes in cervical mucus are associated with hormonal contraceptive methods, not Nirodh, making (v) false. Options (A), (C) and (D) each include at least one of these incorrect features.

Step 3: Conclusion Two features, (i) and (iii), are related to Nirodh. Hence, the correct option is (B).

Quick Tip to Solve: Associate condoms with a physical barrier and STI protection; separate these from IUD and hormonal mechanisms.

7. A bacterium having radioactive thymidine in its DNA is allowed to multiply in a medium having non-radioactive thymidine for two generations. What percentage of bacteria will have radioactive thymidine in its DNA? [1 mark]

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

Correct Answer: (B) 50

Solution:

Concept:

- DNA replication is semiconservative: each daughter DNA molecule contains one parental strand and one newly synthesised strand.
- In a non-radioactive medium, newly synthesised DNA strands are unlabelled, while the original radioactive strands retain their label.

Step 1: Follow the first generation Represent an original labelled strand by L and a new unlabelled strand by U . Starting with LL DNA, replication produces two LU DNA molecules in two daughter bacteria. Both bacteria still contain radioactive thymidine because each has inherited one labelled strand.

Step 2: Follow the second generation Each LU molecule produces one LU and one UU molecule. Therefore, among the four second-generation bacteria, two retain a labelled strand and two contain only unlabelled DNA:

$$\text{Bacteria with radioactive DNA} = \frac{2}{4} \times 100 = 50\%.$$

The value 100% applies after the first generation. The value 25% confuses the fraction of labelled strands after two generations with the fraction of bacteria carrying label. The value 75% does not follow from semiconservative replication.

Step 3: Conclusion After two generations, 50% of the bacteria contain radioactive thymidine in their DNA. Hence, the correct option is (B).

Quick Tip to Solve: Track the two original labelled strands separately, then count bacteria containing at least one of them.

8. What is the role of histamine released by mast cells?

[1 mark]

- (A) Lowers blood pressure
- (B) Causes allergic symptoms
- (C) Stimulates antibody formation
- (D) Destroys pathogens

Correct Answer: (B) Causes allergic symptoms

Solution:

Concept:

- Mast cells release histamine during an allergic response, commonly following exposure to an allergen.
- Histamine promotes vasodilation and increased vascular permeability and contributes to allergic inflammation.

Step 1: Identify the allergic mediator Histamine released by mast cells produces symptoms such as swelling, a runny nose and breathing difficulty. These are characteristic effects of an allergic reaction, which is why antihistamines can relieve many allergic symptoms.

Step 2: Distinguish the other choices Histamine-induced vasodilation can lower blood pressure, particularly in a severe systemic reaction, but the direct textbook role asked for here is the production of allergic symptoms. Histamine does not itself form antibodies; antibodies are secreted by plasma cells. It also does not directly destroy pathogens like a phagocyte or an antimicrobial substance.

Step 3: Conclusion Histamine released by mast cells causes allergic symptoms. Hence, the correct option is (B).

Quick Tip to Solve: Link mast-cell histamine with allergy and antihistamines; do not confuse this mediator with antibody-producing plasma cells.

9. Which of the following is used to visualize DNA bands under UV light after gel electrophoresis?

[1 mark]

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

Correct Answer: (C) Ethidium Bromide

Solution:

Concept:

- Gel electrophoresis separates DNA fragments according to size; the separated DNA must be stained to be seen.
- Ethidium bromide associates with DNA and fluoresces under ultraviolet light, making DNA bands visible.

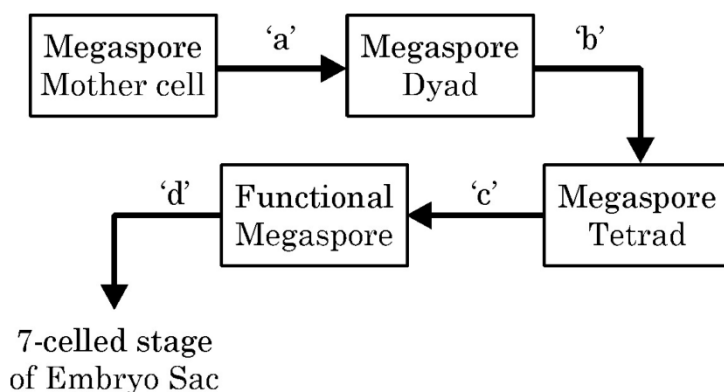
Step 1: Identify the DNA stain After electrophoresis, DNA fragments stained with ethidium bromide appear as bright orange bands when the gel is exposed to UV radiation. The positions of these bands locate the separated DNA fragments for further isolation.

Step 2: Eliminate the other reagents Acetocarmine is used for staining chromosomes in cytological preparations, and safranin is commonly used as a biological stain, including for plant tissues. Neither is the standard fluorescent DNA-band stain in this procedure. Potassium iodide is also not used to reveal electrophoresed DNA bands under UV light.

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: separate DNA in a gel, stain with ethidium bromide, then observe orange bands under UV light.

10. 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 converts one diploid megaspore mother cell into four haploid megaspores through meiosis.
- In the usual monosporic development, one functional megaspore forms the embryo sac through mitotic nuclear divisions.

Step 1: Trace the mother cell to the tetrad At a, the megaspore mother cell undergoes meiosis I to form a dyad. At b, meiosis II produces a tetrad of four haploid megaspores. Thus, these two arrows represent the successive divisions of meiosis, rather than mitosis.

Step 2: Trace the functional megaspore to the embryo sac At c, three megaspores degenerate and one remains functional; no cell division produces this selection. At d, the functional megaspore undergoes three mitotic nuclear divisions, followed by organisation into the usual eight-nucleate, seven-celled embryo sac. Option A wrongly assigns no division to tetrad formation; options C and D wrongly replace the initial meiotic division with mitosis or no division.

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: Read the arrows in order: dyad and tetrad require meiosis; selection requires no division; embryo-sac growth requires mitosis.

11. 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 transfers a region of its tumour-inducing (Ti) plasmid into plant cells, especially dicotyledonous hosts.
- A disarmed Ti plasmid retains its gene-transfer ability and serves as a vector for introducing desired genes into plants.

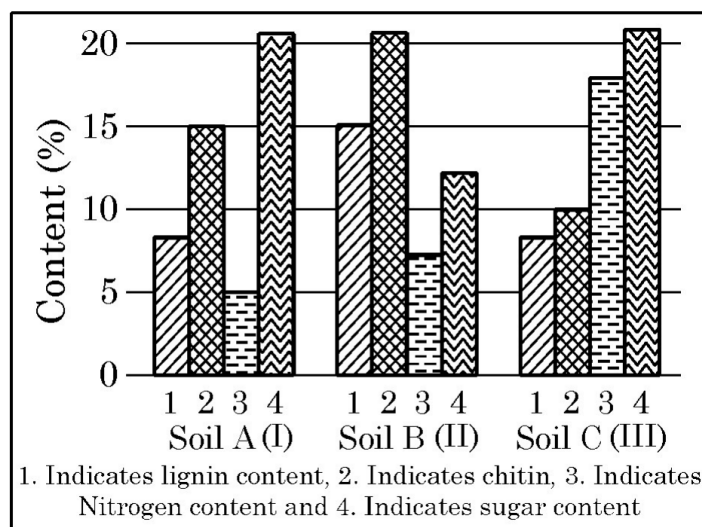
Step 1: Relate the vector to the host Tobacco is a dicotyledonous plant. The ability of *Agrobacterium* to infect dicot plants and transfer Ti-plasmid DNA enables the introduction of nematode-specific gene sequences. In the engineered tobacco, these sequences can initiate RNA interference against the nematode's matching RNA.

Step 2: Check the alternative properties The relevant NCERT description is infection of dicot plants with transfer mediated by the Ti plasmid, not a monocot-specific infection. Infection of both plants and animals is not the vector property used here. The cry genes are associated with *Bacillus thuringiensis*, so a cry gene is not the defining transfer mechanism of this vector.

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

Quick Tip to Solve: Match tobacco with dicot and *Agrobacterium* with Ti plasmid; reserve cry genes for *Bacillus thuringiensis*.

12. 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 faster when detritus is rich in nitrogen and water-soluble substances such as sugars.
- A high proportion of resistant substances such as lignin and chitin slows decomposition; temperature and moisture also influence the rate.

Step 1: Read the four bars for each soil The graph identifies bars 1 and 2 as lignin and chitin, and bars 3 and 4 as nitrogen and sugar. Soil III has much more nitrogen than soils I and II and has a high sugar content. Its lignin content is low, similar to soil I, while its chitin content is lower than in either soil I or soil II.

Step 2: Compare decomposition under equal conditions Since temperature and moisture are identical, the comparison depends on the chemical nature of the material. Soil I has high sugar but little nitrogen and more chitin than soil III. Soil II contains more lignin and chitin and less sugar than soil III, so including soil II with the faster sample is unjustified. Soil III combines abundant readily decomposable material with a smaller resistant fraction.

Step 3: Conclusion Soil sample III will show the fastest decomposition among the samples. Hence, the correct option is (C).

Quick Tip to Solve: Compare nitrogen plus sugar against lignin plus chitin; high sugar alone is insufficient when the other bars differ.

13. 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 produces seeds without fertilisation.
- By avoiding the usual meiotic recombination and fusion of gametes, apomictic reproduction can preserve the maternal genotype.

Step 1: Evaluate the assertion The assertion is true in the standard CBSE account of apomixis. The embryo develops without the usual sexual process, for example from an unreduced egg or a nucellar cell, so the offspring retain the parental genetic constitution.

Step 2: Evaluate the reason The reason is false. Apomixis does not mean fertilisation between genetically similar plants. Its defining feature is seed formation without fertilisation; genetic similarity between two plants does not turn fertilisation into apomixis.

Step 3: Test the explanatory link Genetic identity follows from the asexual origin of the embryo, not from crossing similar plants. Therefore the reason cannot explain the assertion. Options A and B incorrectly treat the reason as true, while option D incorrectly treats the assertion as false.

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

Quick Tip to Solve: In apomixis questions, first check for fertilisation: a statement making fertilisation essential contradicts the definition.

14. 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:

- Microorganisms are used on a commercial scale to obtain useful products, including alcoholic beverages.
- During alcoholic fermentation, yeast converts glucose into ethanol and carbon dioxide under anaerobic conditions.

Step 1: Evaluate the assertion The assertion is true. Yeast, especially *Saccharomyces cerevisiae*, is used to ferment suitable substrates in the commercial production of alcohol and alcoholic beverages.

Step 2: Evaluate the reason The reason is also true. Yeast carries out alcoholic fermentation, in which glucose is broken down to ethanol and carbon dioxide. The production of ethanol is the key biochemical change involved in making these alcoholic products.

Step 3: Test the explanatory link The reason states precisely the microbial activity that makes yeast useful for producing alcohol commercially, so it explains the assertion. Option B wrongly denies this explanatory link, while options C and D wrongly declare one of the true statements false.

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

Quick Tip to Solve: For an assertion about commercial alcohol production, connect it directly to the ethanol formed during yeast fermentation.

15. Assertion (A): IUCN Red List helps in identifying and protecting endangered species worldwide.

Reason (R): The list includes the species facing risk of extinction.

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:

- The IUCN Red List assesses the extinction risk of species and provides information used in conservation planning.
- Identifying threatened species helps direct protective measures towards species that need them.

Step 1: Evaluate the assertion Assertion (A) is true. The IUCN Red List helps identify endangered species worldwide. Its assessments guide conservation priorities and therefore assist the protection of these species.

Step 2: Evaluate the reason Reason (R) is true. The list includes species facing a risk of extinction, along with assessments of their conservation status. It is not restricted only to endangered species, but the reason does not claim that it is.

Step 3: Test the explanatory link Recording species at risk of extinction is precisely what allows the list to identify conservation needs and guide protection. Thus R explains A; option (B) wrongly denies this connection, while (C) and (D) wrongly treat one of the statements as false.

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

Quick Tip to Solve: Link the Red List's extinction-risk information directly to the identification of conservation priorities.

16. 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 suitably aligned DNA fragments.
- Adjacent nucleotides in a DNA strand are linked by phosphodiester bonds; a glycosidic bond joins a sugar to its nitrogenous base.

Step 1: Evaluate the assertion Assertion (A) is true. DNA ligase joins DNA fragments, for example the desired DNA fragment and a vector during the construction of recombinant DNA.

Step 2: Evaluate the reason Reason (R) is false. Ligase catalyses the formation of a phosphodiester bond between a free 3'-hydroxyl group and an adjacent 5'-phosphate group. It does not form a glycosidic bond between nucleotides.

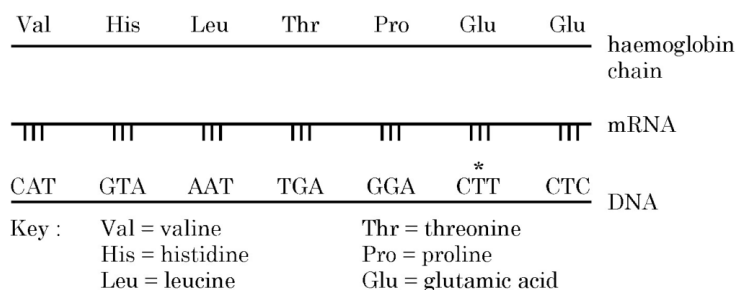
Step 3: Match the truth values Since R names the wrong bond, it cannot explain the true assertion. Options (A) and (B) require R to be true, while (D) requires A to be false; each is therefore excluded.

Step 4: Conclusion A is true and R is false. Hence, the correct option is (C).

Quick Tip to Solve: Associate ligase with the sugar-phosphate backbone: the bond it seals is phosphodiester, not glycosidic.

Section B (10 marks)

17(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 CTT^{*} of DNA strand how would it affect the haemoglobin chain? [1 mark]



Solution:

Concept:

- A base substitution can alter an mRNA codon and replace one amino acid in a polypeptide; this is a missense point mutation.
- mRNA is complementary to template DNA: template C pairs with G, T with A, and A with U in the transcript.

Step 1: Trace the marked base substitution The asterisk identifies the first T in the template-DNA triplet CTT. Replacing this T by A changes the triplet to CAT. Consequently, the corresponding mRNA codon changes from GAA to GUA.

Step 2: Translate the changed codon GAA codes for glutamic acid, whereas GUA codes for valine. The affected triplet corresponds to the sixth amino acid shown in the haemoglobin β -chain. This is a substitution, so the reading frame is retained and the other amino acids are not shifted.

Step 3: Conclusion Glutamic acid at the sixth position of the haemoglobin β -chain is replaced by valine.

Quick Tip to Solve: Use the asterisk to identify which T changes, then transcribe CTT to GAA and CAT to GUA before translating.

17(a)(ii). Name the condition and the effects associated with the above substitution. [1 mark]

Solution:

Concept:

- Replacement of the sixth glutamic acid by valine in the haemoglobin β -chain produces sickle-cell haemoglobin, HbS.
- The altered haemoglobin can polymerise at low oxygen tension, changing the shape and function of red blood cells.

Step 1: Identify the disorder The substitution described in part (i) is associated with sickle-cell anaemia, an autosomal recessive genetic disorder. It changes the structure of haemoglobin rather than shifting the entire reading frame.

Step 2: Explain the effects At low oxygen tension, HbS polymerises and red blood cells become elongated and sickle-shaped instead of retaining their normal biconcave shape. These cells are fragile and may break down prematurely, causing anaemia. Their rigidity can obstruct small blood vessels and impair oxygen delivery to tissues.

Step 3: Conclusion The condition is sickle-cell anaemia; low oxygen promotes sickling of red blood cells, premature cell destruction and impaired oxygen supply.

Quick Tip to Solve: Connect the mutation to HbS, then link low oxygen to sickling and the resulting anaemia and impaired circulation.

OR

17(b). DNA is considered a more stable genetic material than RNA. Justify this statement with suitable reasons. [2 marks]

Solution:

Concept:

- A stable genetic material must preserve hereditary information while allowing accurate replication and repair.
- DNA and RNA differ in their sugar, usual strand organisation and one nitrogenous base; these differences affect stability.

Step 1: Compare the sugars and reactivity RNA contains ribose with a 2'-hydroxyl group. This group makes RNA more reactive and facilitates cleavage of its phosphodiester backbone, especially under alkaline conditions. DNA contains deoxyribose and lacks this 2'-hydroxyl group, making it chemically less reactive and more stable. Some RNA molecules also act as catalysts, consistent with RNA being a more reactive molecule.

Step 2: Explain the advantage of complementary strands DNA is usually double-stranded. The complementary strand can provide a template for repairing damage in the other strand. Complementarity also allows the two strands to reassociate after separation under suitable conditions. RNA is usually single-stranded and lacks this general complementary backup.

Step 3: Relate thymine to preservation of information DNA uses thymine in place of RNA's uracil. If cytosine is accidentally deaminated to uracil in DNA, repair systems can recognise uracil as abnormal and remove it. This helps preserve the original genetic information.

Step 4: Conclusion DNA is more stable because it lacks the reactive 2'-hydroxyl group and has complementary strands that support repair; the use of thymine also improves the preservation of genetic information.

Quick Tip to Solve: For DNA stability, first compare the 2'-OH groups, then explain how a complementary strand supports repair.

18. How do scientists use microinjection and gene gun in biotechnology?

[2 marks]

Solution:

Concept:

- Gene transfer introduces foreign or recombinant DNA into a host cell so that the inserted gene can be maintained or expressed.
- Microinjection and biolistics are direct physical methods of gene transfer and do not require a biological vector to carry DNA through the cell surface.

Step 1: Describe microinjection In microinjection, scientists use a very fine glass micropipette or needle under microscopic control to inject recombinant DNA directly into the nucleus of an animal cell. Direct placement bypasses the plasma membrane as a barrier to DNA entry. This method is used for introducing desired genes into suitable animal cells, including fertilised eggs in the production of transgenic animals.

Step 2: Describe the gene gun In the gene-gun method, also called biolistics, microscopic particles of gold or tungsten are coated with the desired DNA. The particles are accelerated at high velocity and bombarded into target cells, particularly plant cells. They penetrate the cell wall and membrane, delivering DNA into the cells. Successfully transformed cells are then selected and can be used to obtain genetically modified plants.

Step 3: Conclusion Microinjection delivers recombinant DNA directly into an animal-cell nucleus using a fine needle; a gene gun delivers DNA on high-velocity gold or tungsten particles, especially into plant cells.

Quick Tip to Solve: Remember the contrasts: microinjection uses a needle and an animal-cell nucleus; biolistics uses DNA-coated metal particles.

19. After significant reduction of BOD during secondary treatment of sewage, what further processes are carried out? Mention any one important outcome of these processes.

[2 marks]

Solution:

Concept:

- Biochemical oxygen demand (BOD) reflects the oxygen needed by microorganisms to decompose organic matter in water; its reduction indicates removal of biodegradable organic pollution.
- Activated sludge consists of settled microbial flocs, whereas anaerobic sludge digesters break down sludge without free oxygen.

Step 1: Settle the flocs and recycle some sludge After the BOD has fallen significantly in the aeration tank, the effluent is passed into a settling tank. Bacterial flocs sediment and form activated sludge. A small part of this activated sludge is pumped back into the aeration tank as an inoculum, providing microorganisms for treating incoming sewage.

Step 2: Digest the remaining sludge and obtain a useful product The major part of the activated sludge is pumped into large anaerobic sludge digesters. Anaerobic bacteria digest the bacteria and fungi present in the sludge. During digestion, they produce a mixture of gases, including methane,

carbon dioxide and hydrogen sulphide, called biogas. This methane-rich biogas can be used as a source of energy. The treated effluent from the secondary treatment plant is generally released into natural water bodies.

Step 3: Conclusion The subsequent processes are settling, partial recycling of activated sludge and anaerobic digestion of the remaining sludge. One important outcome is the production of biogas, which is useful as fuel.

Quick Tip to Solve: Keep the two streams separate: settled sludge goes to recycling or digestion, while the treated liquid is the effluent.

20(a). In some cases, measuring population density by counting individuals may not be feasible. Mention two other parameters that can be used and justify their use with suitable examples. [2 marks]

Solution:

Concept:

- Population density expresses the abundance of a species per unit area or volume. A count is useful only when individuals can be distinguished and their sizes are reasonably comparable.
- Percent cover and biomass can better represent a population when organisms differ greatly in size or individual counts are difficult.

Step 1: Use percentage cover for spreading vegetation Percentage cover is the percentage of the ground area occupied by the population. It is useful for grasses or other densely spreading plants because distinguishing and counting individual shoots may be impractical. For example, the area covered by a grass population in a quadrat conveys its abundance more clearly than a count of indistinct grass individuals.

Step 2: Use biomass when individual sizes differ greatly Biomass is the mass of living material of the population per unit area or volume. It gives greater weight to large organisms and therefore reflects the amount of living material better than a simple head count. For example, a single large banyan tree may have much more biomass than many small Parthenium plants; counts alone would underestimate the banyan population's contribution to the vegetation.

Step 3: Conclusion Two suitable parameters are percentage cover, for dense or spreading vegetation such as grasses, and biomass, for populations whose individuals differ greatly in size, as illustrated by a banyan tree and small Parthenium plants.

Quick Tip to Solve: Justify each alternative by naming the weakness of counting that it solves: indistinct individuals for cover, unequal sizes for biomass.

20(b). What factors contribute to the Amazonian rain forests in South America being the most biodiverse regions on Earth? [2 marks]

Solution:

Concept:

- The Amazonian rain forests lie in the tropics, where species richness is generally greater than at higher latitudes.
- Long evolutionary time, a relatively stable climate and high solar-energy input favour the accumulation and coexistence of species.

Step 1: Explain evolutionary time and climatic stability Tropical regions have remained relatively undisturbed for millions of years, unlike temperate regions that experienced repeated glaciations. This long evolutionary history has allowed more time for speciation and the accumulation of species. Their comparatively less seasonal, more constant and predictable climate also favours niche specialisation, allowing many species with different ecological requirements to coexist.

Step 2: Relate solar energy to productivity The tropics receive abundant solar energy. Together with the warm, moist conditions of Amazonian rain forests, this supports high primary productivity. High productivity supplies abundant resources to food webs and can support a large variety of organisms. These conditions, combined with long evolutionary time and niche specialisation, help explain the exceptional biodiversity of the Amazon.

Step 3: Conclusion Amazonian rain forests are exceptionally biodiverse because of their long, relatively undisturbed evolutionary history, stable tropical climate favouring niche specialisation, and high solar-energy input supporting high productivity.

Quick Tip to Solve: Recall three explanations for tropical richness: time for speciation, climatic stability and energy supporting productivity.

21(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 developing embryo forms chorionic villi that interact closely with the maternal uterine tissue.
- The placenta is the temporary structural and functional connection between the developing foetus and its mother.

Step 1: Identify the foetal and maternal association Chorionic villi of the embryo become surrounded by uterine tissue and maternal blood. Their intimate association forms a specialised organ at the interface between the developing foetus and the uterine wall.

Step 2: Distinguish the organ from its connecting cord This organ is the placenta. The foetus is connected to the placenta by the umbilical cord, through which foetal blood travels to and from the placenta. Thus, the cord links the foetus to the placenta, while the placenta provides the

foetal-maternal interface in the uterus.

Step 3: Conclusion The organ is the placenta.

Quick Tip to Solve: If asked for the organ linking the foetus with the uterine tissue, name the placenta; the umbilical cord connects the foetus to it.

21(a)(ii). How does it support both nutrition and hormonal regulation?

[1.5 marks]

Solution:

Concept:

- The placenta provides a large exchange surface between maternal blood and foetal blood; these blood supplies normally remain separate.
- The placenta also acts as an endocrine tissue by producing hormones that support pregnancy.

Step 1: Explain the nutritional function Maternal blood supplies nutrients, such as glucose and amino acids, and oxygen to the placenta. These pass across the placental exchange surface into the foetal circulation and are carried to the foetus through the umbilical cord. In the reverse direction, carbon dioxide and other metabolic wastes move from foetal blood into maternal blood for removal. Thus the placenta supports nourishment and respiration without requiring direct mixing of the two blood supplies.

Step 2: Explain the hormonal function The placenta secretes human chorionic gonadotropin (hCG), human placental lactogen (hPL), estrogens and progestogens. Early in pregnancy, hCG helps maintain the corpus luteum and its hormone secretion. Progestogens and estrogens support the uterine environment and maintenance of pregnancy, while hPL helps adapt maternal metabolism and supports mammary development. These endocrine functions accompany the exchange role of the placenta.

Step 3: Conclusion The placenta supplies nutrients and oxygen to the foetus and removes its wastes; it also secretes hCG, hPL, estrogens and progestogens that help regulate and maintain pregnancy.

Quick Tip to Solve: For this two-function question, pair nutrient transfer through the placenta with its named pregnancy-supporting hormones.

OR

21(b)(i). Give reasons for:

All copulations do not lead to pregnancy.

[1 mark]

Solution:

Concept:

- Fertilisation requires a viable sperm and a viable ovum to reach the ampullary region of the fallopian tube at the same time.
- Ovulation releases the secondary oocyte during a limited part of the menstrual cycle; copulation need not coincide with this fertile period.

Step 1: Identify the condition for fertilisation Insemination introduces sperms into the female reproductive tract, but the mere entry of sperms does not ensure fertilisation. An ovum must also be available in the fallopian tube while the sperms remain viable.

Step 2: Relate copulation to ovulation If copulation occurs when no viable ovum and sperm meet in the ampullary region, fertilisation cannot occur. Even after fertilisation, successful implantation of the developing embryo is needed to establish pregnancy.

Step 3: Conclusion All copulations do not lead to pregnancy because copulation does not always result in the simultaneous presence of viable sperm and ovum at the site of fertilisation.

Quick Tip to Solve: Link the reason to the timing of ovulation and the simultaneous availability of both gametes, rather than to insemination alone.

21(b)(ii). Give reasons for:

Meiosis I in spermatogenesis and oogenesis are markedly different.

[1 mark]

Solution:

Concept:

- Meiosis I is a reduction division that separates homologous chromosomes, producing haploid cells from a diploid primary germ cell.
- The distribution of cytoplasm during this division differs in spermatogenesis and oogenesis.

Step 1: Examine meiosis I in spermatogenesis A diploid primary spermatocyte completes meiosis I with equal division of the cytoplasm. It forms two similar-sized haploid secondary spermatocytes, both of which proceed towards sperm formation.

Step 2: Examine meiosis I in oogenesis A diploid primary oocyte divides unequally during meiosis I. Most cytoplasm is retained by one large haploid secondary oocyte, while a small first polar body receives very little cytoplasm. This conserves cytoplasm and its reserves in the cell that can form the ovum.

Step 3: Conclusion Meiosis I produces two equal secondary spermatocytes in spermatogenesis, but one large secondary oocyte and a small first polar body in oogenesis because cytokinesis is unequal.

Quick Tip to Solve: Compare the size and fate of the two products: two secondary spermatocytes versus a secondary oocyte and a polar body.

Section C (21 marks)

22(a). There are limitations of traditional breeding techniques that led to promotion of micro-propagation.

Mention two advantages of micropropagation.

[2 marks]

Solution:

Concept:

- Micropropagation is the production of many plants through tissue culture under controlled, aseptic conditions.
- Plant cells show totipotency: suitable cells or tissues can regenerate a complete plant when supplied with the appropriate nutrients and growth regulators.

Step 1: Explain rapid multiplication A small explant from a selected parent can be cultured and multiplied repeatedly to produce a large number of plants in a short time. This makes the rapid multiplication of a valuable variety possible even when conventional methods produce planting material slowly.

Step 2: Explain the retention of desirable traits Plants produced by micropropagation are genetically identical to the original plant in the usual clonal propagation process and are called somaclones. Hence, desirable characteristics of an elite parent can be maintained uniformly in the propagated stock, without the segregation associated with sexual reproduction.

Step 3: Conclusion Two advantages are rapid production of a large number of plants and production of genetically identical plants that retain the desirable characters of the selected parent.

Quick Tip to Solve: For two advantages, state the quantity benefit first and the uniformity benefit second: many plants quickly, with the parent's desirable traits.

22(b). There are limitations of traditional breeding techniques that led to promotion of micro-propagation.

Give two examples where it is commercially adopted.

[1 mark]

Solution:

Concept:

- Micropropagation uses tissue culture to multiply selected plants on a large scale.
- Commercial use is valuable when many uniform plants carrying the selected parent's desirable traits are required.

Step 1: Identify a fruit crop Banana is a crop in which micropropagation is commercially adopted. Tissue culture enables rapid multiplication of selected banana plants to supply a large number of uniform planting materials.

Step 2: Identify another commercial crop Apple is another example of commercial micropropagation. Selected material is multiplied in culture so that many plants can be raised from a small amount of

initial tissue, while retaining the desirable features of the source plant.

Step 3: Conclusion Two examples of commercial micropropagation are banana and apple.

Quick Tip to Solve: Recall the NCERT examples banana, apple and tomato; any two suitable examples meet this question's demand.

23(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, including sex-linked traits, in the fruit fly.
- A scientific name consists of a capitalised genus followed by a lower-case specific epithet; both words are italicised in print.

Step 1: Identify Morgan's experimental organism Morgan used the fruit fly for genetic experiments. Its easily observable traits, including eye colour, enabled him to follow the transmission of characters through successive generations and relate inheritance to chromosomes.

Step 2: State the binomial name The genus of the fruit fly used is *Drosophila* and its specific epithet is *melanogaster*. Combining the two gives the complete scientific name; the common name alone would not satisfy a request for the scientific name.

Step 3: Conclusion The organism was *Drosophila melanogaster*, the fruit fly.

Quick Tip to Solve: Write both words: capital D in *Drosophila*, lower-case m in *melanogaster*, with the full binomial italicised.

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

Solution:

Concept:

- A suitable organism for inheritance experiments should be easy to maintain and should permit reliable observations over many generations.
- *Drosophila melanogaster* combines simple culture requirements with rapid reproduction, abundant offspring and readily distinguishable sexes.

Step 1: Explain ease of culture First, fruit flies can be grown on a simple synthetic medium in the laboratory. Maintaining experimental populations is therefore convenient and does not require elaborate food or culture arrangements.

Step 2: Explain the short life cycle Second, they complete their life cycle in about two weeks. A geneticist can consequently observe several generations and perform successive crosses in a relatively short period.

Step 3: Explain the advantage of many offspring Third, a single mating produces a large number of progeny. Large samples make it easier to recognise inheritance patterns and compare observed

proportions of traits with expected genetic ratios.

Step 4: Explain easy sex identification Fourth, males and females are easily distinguishable. They can therefore be separated and selected accurately for controlled crosses, which is particularly useful when studying sex-linked inheritance.

Step 5: Conclusion Four reasons are easy culture on simple synthetic medium, a short life cycle of about two weeks, many progeny from one mating, and easily distinguishable male and female flies.

Quick Tip to Solve: Recall four practical features in order: food, time, offspring number and sex identification; briefly link each to conducting crosses.

24. 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.

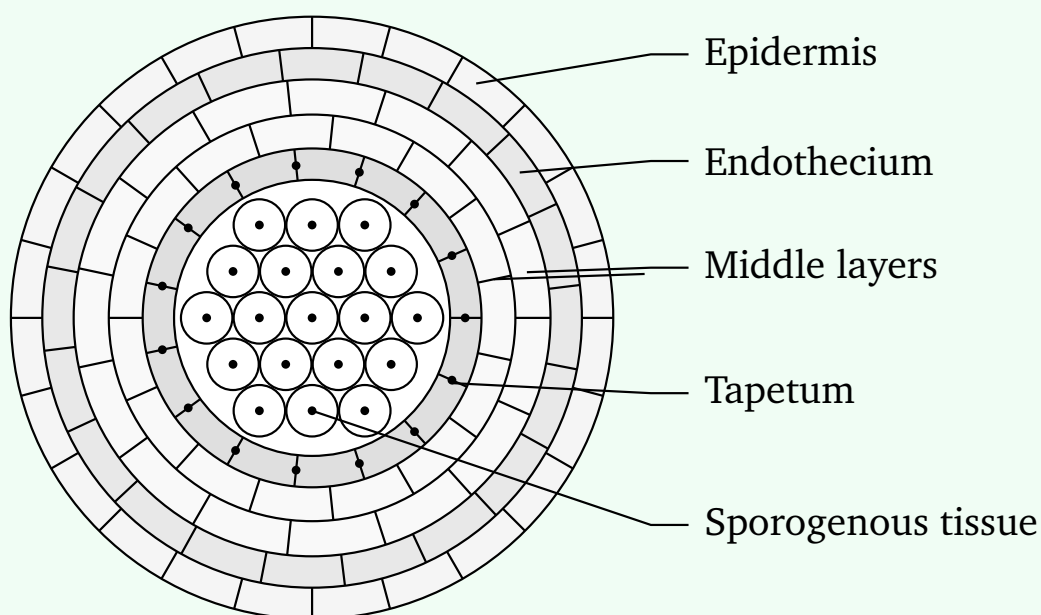
[3 marks]

Solution:

Concept:

- A young microsporangium contains compact sporogenous tissue surrounded by four wall layers: epidermis, endothecium, middle layers and tapetum, in that order from outside to inside.
- The wall protects the developing reproductive cells, while its innermost layer provides nourishment needed for pollen development.

Step 1: Draw and label the young microsporangium The enlarged transverse view below shows one microsporangium, not the entire bilobed anther containing four microsporangia. Label the outermost epidermis, the endothecium immediately beneath it, the intervening middle layers and the innermost tapetum. The centre contains sporogenous tissue; these cells later give rise to pollen mother cells. The tapetum directly borders this developing reproductive tissue.



Enlarged transverse view of one young microsporangium (schematic).

Step 2: State the function of the outermost layer The epidermis is the outermost protective covering. It protects the underlying wall layers and the developing sporogenous tissue from external injury. Distinguish this protective role from the characteristic contribution of the endothecium to anther dehiscence at maturity.

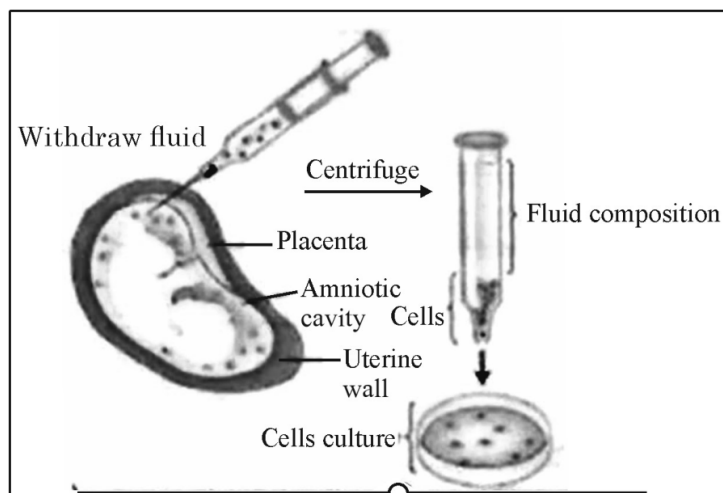
Step 3: State the function of the innermost layer The tapetum is the innermost wall layer. Its cells possess dense cytoplasm and nourish the developing microspores and pollen grains. Its position next to the reproductive tissue enables it to provide the materials required during pollen development.

Step 4: Conclusion From outside to inside the wall has epidermis, endothecium, middle layers and tapetum. The epidermis protects; the tapetum nourishes the developing pollen grains.

Quick Tip to Solve: Label the four wall layers from outside inward, and place sporogenous tissue inside the tapetum rather than labelling it as another wall layer.

25(a). Study the diagram given below:

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 in which amniotic fluid containing foetal cells is collected for analysis.
- Foetal cells in the fluid can be examined to detect chromosomal abnormalities; this diagnostic use must be distinguished from its misuse for sex determination.

Step 1: Identify and explain the procedure The diagram shows amniocentesis. A needle is introduced through the mother's abdominal and uterine walls into the amniotic cavity, and a small sample of amniotic fluid is withdrawn. As shown, the sample is centrifuged to separate the cells from the fluid. The foetal cells can then be cultured and examined, including analysis of their chromosomes; the fluid can also be analysed biochemically.

Step 2: Give an advantage and a disadvantage An advantage is prenatal detection of chromosomal abnormalities, such as Down's syndrome, by analysing the foetal cells. A disadvantage is the possibility of misuse to determine the sex of the foetus, leading to selective female foeticide. This misuse is distinct from the legitimate purpose of diagnosing abnormalities before birth.

Step 3: Conclusion The procedure is amniocentesis: amniotic fluid and foetal cells are sampled and analysed. It helps detect foetal abnormalities but can be misused for sex determination and female foeticide.

Quick Tip to Solve: Recognise amniocentesis by withdrawal of amniotic fluid followed by separation and culture of foetal cells.

25(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 combination of progestogen and estrogen.
- Saheli is a non-steroidal oral contraceptive containing centchroman, also called ormeloxifene.

Step 1: Compare the composition Unlike steroidal hormone-containing pills, Saheli contains a non-steroidal preparation, centchroman. Thus its distinguishing feature is its non-steroidal composition.

Step 2: State the advantage Saheli has high contraceptive effectiveness with very few side effects. Its once-a-week schedule is also convenient compared with the daily schedule of conventional oral contraceptive pills.

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

Quick Tip to Solve: Link Saheli with three NCERT keywords: non-steroidal, once-a-week and very few side effects.

26(a). S.L. Miller conducted an experiment in 1953 to simulate the conditions of early earth in a laboratory setup. Answer the following questions based on the experiment:

What was the aim of his experiment?

[1 mark]

Solution:

Concept:

- The chemical evolution hypothesis proposes that organic molecules arose abiotically from simpler substances under the conditions of early Earth.
- A laboratory simulation can test whether such conditions allow the formation of the organic building blocks of life.

Step 1: Identify the hypothesis being tested Miller sought experimental support for the idea that the first organic compounds could form without living organisms in the primitive atmosphere of Earth.

Step 2: State the experimental aim precisely His aim was to demonstrate the abiotic synthesis of organic molecules, especially amino acids, from simple substances under simulated early-Earth conditions. The experiment tested chemical evolution; it did not aim to produce a complete living organism.

Step 3: Conclusion The aim was to test whether organic molecules such as amino acids could form abiotically under conditions resembling those of early Earth.

Quick Tip to Solve: In Miller's aim, specify the formation of organic building blocks, rather than claiming that he created life.

26(b). S.L. Miller conducted an experiment in 1953 to simulate the conditions of early earth in a laboratory setup. Answer the following questions based on the experiment:

Name the gases used and the source of energy.

[2 marks]

Solution:

Concept:

- Chemical evolution proposes that simple inorganic substances on the early Earth could form organic compounds when supplied with energy.
- Miller's apparatus simulated a reducing atmosphere and a water cycle; an electric discharge represented lightning.

Step 1: Identify the simulated atmosphere The apparatus contained methane (CH_4), ammonia (NH_3), hydrogen (H_2) and water vapour (H_2O). Heating water supplied the water vapour that circulated with the gases. Free oxygen was not added because the experiment was designed to simulate a reducing atmosphere.

Step 2: Identify the energy source Electric sparks were passed through the gas mixture to simulate lightning on the early Earth. The discharge supplied energy for chemical reactions that produced organic molecules. Heating maintained the supply of water vapour, but the energy source asked for in the simulated atmosphere was the electrical discharge.

Step 3: Conclusion The gases were methane, ammonia, hydrogen and water vapour; the energy source was electric sparks simulating lightning.

Quick Tip to Solve: Remember the four components as methane, ammonia, hydrogen and steam, with sparks representing lightning.

27(a). What is a genetic code?

[1 mark]

Solution:

Concept:

- Translation converts the information in an mRNA nucleotide sequence into the amino-acid sequence of a polypeptide.
- A codon is a sequence of three consecutive nucleotides in mRNA read as one unit during translation.

Step 1: Identify the information units The ribosome reads mRNA in triplets called codons. A sense codon specifies an amino acid, while a stop codon signals termination of translation.

Step 2: Relate the two biological sequences The correspondence between codons and their amino acids supplies the rules for interpreting a nucleotide sequence. For example, the mRNA codon AUG specifies methionine and commonly acts as the initiation codon.

Step 3: Conclusion The genetic code is the set of rules by which nucleotide triplets (codons) in mRNA specify amino acids in a polypeptide or signals for termination of translation.

Quick Tip to Solve: Define the code as the codon-to-amino-acid correspondence; a codon itself is only one triplet.

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

[1 mark]

Solution:

Concept:

- DNA stores hereditary information using four kinds of nucleotide bases, whereas proteins are built from twenty kinds of amino acids.
- Protein synthesis therefore requires a correspondence between the nucleotide sequence and the amino-acid sequence.

Step 1: Recognise the difference in molecular languages Scientists knew that hereditary information in nucleic acids controls the synthesis of proteins. However, nucleotides and amino acids are chemically different units, so the sequence of one cannot simply be copied into the other.

Step 2: Explain the need for a coding relationship A genetic code was needed to explain how combinations of four nucleotide bases could specify the twenty amino acids and determine their order in a protein. Triplets provide enough combinations for this correspondence.

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

Quick Tip to Solve: Link the need for a code to the change from the nucleotide language to the amino-acid language.

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

[1 mark]

Solution:

Concept:

- A codon is a triplet of nucleotides in mRNA that specifies an amino acid or a translation stop signal.
- Universality means that the codon-to-amino-acid correspondence is conserved across almost all organisms.

Step 1: Compare the meaning of a codon across organisms A particular codon generally specifies the same amino acid in very different organisms. For example, UUU specifies phenylalanine in bacteria as well as in humans.

Step 2: Interpret universality accurately Thus, the same coding rules operate across the living world rather than each species having its own code. A few exceptions, such as some mitochondrial codons, make the code nearly universal.

Step 3: Conclusion The genetic code is called universal because, with a few exceptions, the same codon specifies the same amino acid in all organisms.

Quick Tip to Solve: Support universality with one codon example: UUU specifies phenylalanine across organisms.

28(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 provides non-specific protection present from birth and acts without prior exposure to a particular pathogen.
- Respiratory surfaces have protective secretions and cellular defences that help prevent infection after inhalation.

Step 1: Trap and remove inhaled particles Mucus coating the respiratory tract traps dust and microbes. Ciliary movement carries this mucus towards the throat, helping remove trapped particles before they establish infection.

Step 2: Destroy microbes that escape surface defences Phagocytic cells, including macrophages, engulf and destroy microbes that reach deeper tissues. These innate defences explain why exposure to pathogens does not necessarily lead to illness.

Step 3: Conclusion Innate immunity protects the person: respiratory mucus and cilia trap and remove inhaled pathogens, while phagocytes destroy microbes that evade these barriers.

Quick Tip to Solve: For inhaled pathogens, connect innate immunity directly to mucus trapping, ciliary clearance and phagocytosis.

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

Solution:

Concept:

- Innate immunity is the body's inborn, non-specific defence against pathogens; it includes physical, physiological, cellular and cytokine barriers.
- Different barriers act at different stages: surface barriers restrict entry, whereas cellular barriers destroy microbes that penetrate the body.

Step 1: Physical barrier of the respiratory tract Mucus coating the respiratory epithelium traps inhaled dust and microorganisms. Cilia move the mucus towards the throat so that the trapped material can be expelled or swallowed. This reduces the number of microbes reaching delicate respiratory surfaces and establishing an infection.

Step 2: Cellular barrier against invading microbes Phagocytic cells such as neutrophils and tissue macrophages engulf and destroy pathogens. In the lungs, macrophages remove microbes and particles that escape the surface clearance mechanisms. This provides a second line of innate protection when some inhaled microorganisms reach the tissues.

Step 3: Conclusion Two barriers are the physical barrier, represented by respiratory mucus with ciliary clearance, and the cellular barrier, represented by phagocytic neutrophils and macrophages.

Quick Tip to Solve: Name each barrier and pair it with its action: mucus traps microbes; phagocytes engulf and destroy them.

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(a). 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*.

Name one core technique of biotechnology that alters the genetic material.

[1 mark]

Solution:

Concept:

- Genetic engineering changes the genetic material of an organism using molecular techniques.
- Recombinant DNA technology joins a desired DNA fragment to a suitable vector for introduction into a host.

Step 1: Identify the operation described The passage describes cutting and joining DNA fragments and inserting foreign DNA into a plasmid. These operations deliberately alter genetic material and can introduce a new trait into a host organism.

Step 2: Name the core technique The core technique is genetic engineering. Restriction endonucleases cut DNA, while DNA ligase joins suitable DNA fragments; these tools allow the preparation of recombinant DNA.

Step 3: Conclusion Genetic engineering is the core biotechnology technique that alters genetic material.

Quick Tip to Solve: Link deliberate cutting and joining of DNA with genetic engineering; sterile culture methods maintain growth conditions.

29(b). 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*.

What is a plasmid? Mention its importance in biotechnology.

[2 marks]

Solution:

Concept:

- A plasmid is a small, usually circular, double-stranded DNA molecule separate from the bacterial chromosome.
- Its origin of replication permits autonomous replication within a suitable host cell.

Step 1: Define a plasmid A plasmid is extrachromosomal DNA present in bacteria. It is generally

circular and double stranded, and can replicate independently of the main bacterial chromosome. Plasmids may carry useful genes, such as genes conferring antibiotic resistance.

Step 2: Explain its role as a vector In biotechnology, a suitable plasmid acts as a cloning vector: the desired DNA fragment is inserted into it to form recombinant DNA, which is introduced into a host bacterium. As the plasmid replicates, the inserted DNA is also copied, producing many copies of the desired gene. Selectable markers in engineered plasmid vectors help identify host cells that have taken up the vector.

Step 3: Conclusion A plasmid is independently replicating extrachromosomal DNA; it is important as a vector that carries and amplifies a desired DNA fragment in a host.

Quick Tip to Solve: Connect plasmid structure to function: an independent origin of replication enables copying of both the vector and its inserted gene.

29(c). 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*.

Which gene was isolated by Cohen and Boyer and from which bacteria?

[1 mark]

Solution:

Concept:

- An antibiotic-resistance gene enables a bacterium carrying it to survive exposure to the corresponding antibiotic.
- Early recombinant DNA work linked an isolated antibiotic-resistance gene to a plasmid, producing a recombinant molecule.

Step 1: Identify the isolated gene Cohen and Boyer isolated an antibiotic-resistance gene. Restriction enzymes allowed DNA to be cut, and DNA ligase allowed the desired fragment to be joined to plasmid DNA.

Step 2: Identify the bacterial source The gene was isolated from a plasmid of *Salmonella typhimurium*. The source of the gene must be distinguished from *E. coli*, which is 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: For this historical example, pair antibiotic resistance with the donor bacterium *Salmonella typhimurium*.

29(c). 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*.

How is the action of exonuclease different from that of endonuclease?

[1 mark]

Solution:

Concept:

- Nucleases cleave phosphodiester bonds in nucleic acids.
- Exonucleases and endonucleases differ in the position at which they attack a DNA strand.

Step 1: Describe exonuclease action An exonuclease removes nucleotides from a free end of DNA. It therefore shortens a DNA strand progressively from an end instead of first cutting at an internal position.

Step 2: Describe endonuclease action An endonuclease cuts DNA at positions within the strand. Restriction endonucleases used in recombinant DNA technology recognise specific DNA sequences and cut at defined positions, producing DNA fragments.

Step 3: Conclusion Exonucleases remove nucleotides from DNA ends, whereas endonucleases cleave DNA at internal sites.

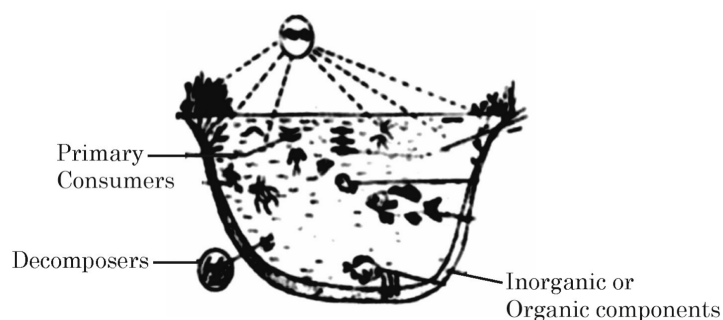
Quick Tip to Solve: Use the prefixes to recall the cutting site: exo means from an end, while endo means within the DNA strand.

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

Based on the diagram, answer the questions:

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 contains water, sunlight, dissolved gases and mineral nutrients along with its living organisms.

Step 1: Identify a physical component Water is an abiotic component of the pond. It forms the medium in which aquatic organisms live and in which many substances needed by them are dissolved.

Step 2: Identify an energy input Sunlight is another abiotic component. It supplies the energy captured by algae and other aquatic producers during photosynthesis. Both water and sunlight are non-living, unlike the consumers and decomposers labelled in the diagram.

Step 3: Conclusion Two abiotic components of a pond ecosystem are water and sunlight.

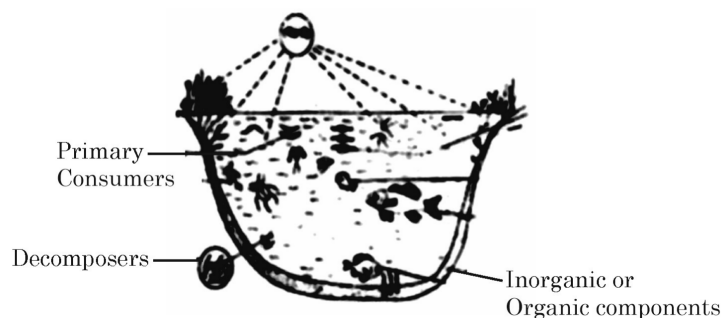
Quick Tip to Solve: Select non-living factors such as water and sunlight; algae, fish and decomposer microbes are biotic components.

30(b). Below is shown a pond that represents a self-sustaining natural ecosystem with both biotic and abiotic components interacting in a balanced food web.

Based on the diagram, answer the questions:

Differentiate between the roles of producers and decomposers in such an ecosystem.

[2 marks]



Solution:

Concept:

- Producers are autotrophs that build organic food from inorganic substances using an external energy source.
- Decomposers break down dead organic matter and release inorganic nutrients, maintaining nutrient cycling.

Step 1: Explain the role of producers In a pond, phytoplankton, algae and aquatic plants capture solar energy through photosynthesis. They use carbon dioxide and water to manufacture organic food. This primary production supplies food and stored chemical energy to consumers and forms the starting point of the grazing food chain.

Step 2: Explain the role of decomposers Bacteria and fungi decompose dead plants, dead animals and organic wastes. Through decomposition and mineralisation, they release inorganic nutrients into the water and sediment, making them available for reuse by producers. Thus, producers build organic matter, while decomposers break it down and recycle nutrients. Energy is not recycled; some is dissipated as heat during these activities.

Step 3: Conclusion Producers synthesise food and introduce solar energy into the food web; decomposers break down dead organic matter and return nutrients for reuse by producers.

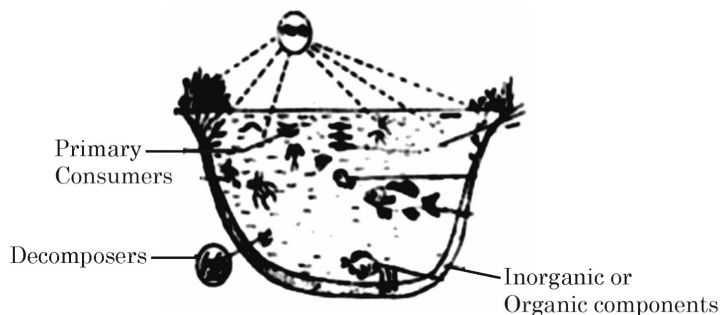
Quick Tip to Solve: Compare their direction of action: producers build organic food, while decomposers break it down and restore inorganic nutrients.

30(c). Below is shown a pond that represents a self-sustaining natural ecosystem with both biotic and abiotic components interacting in a balanced food web.

Based on the diagram, answer the questions:

Draw a simple food chain operating in such an ecosystem and label each trophic level.

[1 mark]



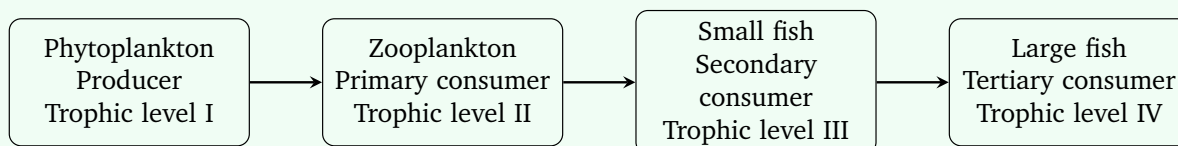
Solution:

Concept:

- A food chain is a sequence of feeding relationships through which food energy passes from a producer to successive consumers.
- Producers occupy the first trophic level; herbivores and their predators occupy successively higher trophic levels.

Step 1: Select organisms from a pond food chain Phytoplankton photosynthesise and form the producer level. Zooplankton feed on phytoplankton, small fish feed on zooplankton, and large carnivorous fish feed on small fish.

Step 2: Label trophic levels and energy flow The labelled chain is shown below. Each arrow points from the organism eaten towards the organism that eats it, showing the direction in which food energy is transferred.



A pond food chain with each trophic level labelled.

Step 3: Conclusion A suitable chain is phytoplankton (level I) to zooplankton (level II) to small fish (level III) to large fish (level IV).

Quick Tip to Solve: Start the pond chain with a photosynthetic producer and point each arrow towards its consumer.

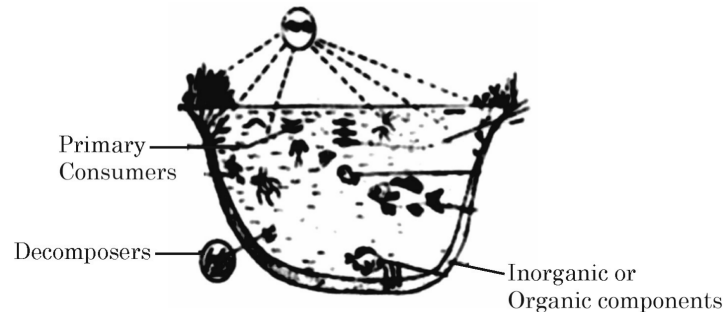
OR

30(c). Below is shown a pond that represents a self-sustaining natural ecosystem with both biotic and abiotic components interacting in a balanced food web.

Based on the diagram, answer the questions:

Why is transfer of energy not 100% efficient between trophic levels?

[1 mark]



Solution:

Concept:

- Energy passes between trophic levels when organisms feed, but only energy stored as new biomass is available for transfer to the next level.
- Organisms use much of their assimilated energy in respiration and other life processes; this energy is ultimately dissipated as heat.

Step 1: Account for energy used by the organism At each trophic level, a large fraction of the energy obtained from food is used for maintenance, movement and metabolism. Respiration releases energy, much of which is lost to the surroundings as heat and cannot be transferred to the next trophic level as food.

Step 2: Account for incomplete consumption and assimilation Not all the biomass of a trophic level is eaten by the next consumer, and some ingested material remains undigested and is egested. Therefore, only a small fraction is incorporated into the consumer's biomass; about 10% is typically passed to the next trophic level.

Step 3: Conclusion Energy transfer is not 100% efficient because energy is dissipated as heat during metabolism, and not all food is consumed or assimilated into transferable biomass.

Quick Tip to Solve: Link inefficient transfer to respiration and heat loss, then distinguish eaten food from energy stored as new biomass.

Section E (15 marks)

31(a)(i). Explain the role of stigma in pollen pistil interaction.

[1 mark]

Solution:

Concept:

- Pollen-pistil interaction is the recognition and subsequent response of the pistil to pollen deposited on the stigma.
- Chemical interaction between the pollen and pistil allows compatible pollen to be accepted and incompatible pollen to be rejected.

Step 1: Identify the receptive surface The stigma receives the pollen grains during pollination and provides the initial site of pollen recognition. Chemical components associated with pollen interact with those of the stigma to establish compatibility.

Step 2: Explain acceptance and rejection For compatible pollen, the stigma supports hydration and germination, allowing a pollen tube to develop and grow into the style. Incompatible pollen is rejected by preventing its germination or subsequent pollen-tube growth, so it does not complete fertilisation.

Step 3: Conclusion The stigma receives and recognises pollen, permits compatible pollen to germinate and initiates the rejection of incompatible pollen.

Quick Tip to Solve: State both recognition and response: compatible pollen germinates, whereas incompatible pollen is rejected.

31(a)(ii). Describe the post pollination events leading to double fertilization in angiosperms starting with 2-celled pollen grain.

[4 marks]

Solution:

Concept:

- A 2-celled pollen grain contains a vegetative cell and a generative cell. Following compatible pollination, it develops a pollen tube that carries the male gametes to the embryo sac.
- Double fertilization comprises syngamy and triple fusion in the same embryo sac. Here n denotes one haploid chromosome complement.

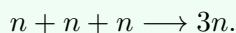
Step 1: Germinate the compatible pollen grain The pistil recognises compatible pollen on the stigma and permits germination. The vegetative cell produces a pollen tube through a germ pore in the pollen wall. This tube grows through the tissues of the stigma and style towards the ovary, carrying the generative cell and vegetative nucleus.

Step 2: Form and deliver the two male gametes During pollen-tube growth, the generative cell divides mitotically to produce two haploid male gametes. The tube reaches an ovule, usually enters through its micropyle and enters one synergid through the region of its filiform apparatus. The filiform apparatus guides pollen-tube entry. The pollen tube releases the two male gametes into the cytoplasm of the synergid.

Step 3: Follow syngamy with the egg One male gamete moves towards the egg cell. Its haploid nucleus fuses with the haploid egg nucleus; this fusion is called syngamy. It produces the diploid zygote, which subsequently develops into the embryo:



Step 4: Follow triple fusion in the central cell The other male gamete enters the central cell and fuses with its two haploid polar nuclei, or their already fused diploid secondary nucleus. Since three haploid nuclear complements unite, this is triple fusion. The resulting triploid primary endosperm nucleus is present in the primary endosperm cell, which develops into the nutritive endosperm:



Step 5: Conclusion Syngamy produces the diploid zygote, while triple fusion produces the triploid primary endosperm nucleus. These two fertilization events in one embryo sac together constitute double fertilization, characteristic of angiosperms.

Quick Tip to Solve: Trace the two male gametes separately: one joins the egg, and the other joins the two polar nuclei. This gives the products $2n$ and $3n$, respectively.

OR

31(b)(i). Explain menstrual phase in the menstrual cycle of human female.

[1 mark]

Solution:

Concept:

- The menstrual phase begins a new menstrual cycle and usually lasts about 3–5 days.
- The uterine endometrium is maintained by ovarian hormones; their decline causes its breakdown.

Step 1: Identify the hormonal cause In the absence of fertilization, the corpus luteum degenerates. Consequently, progesterone and oestrogen levels decline, and the thickened uterine lining loses its hormonal support.

Step 2: Describe the menstrual flow The endometrial lining and its blood vessels break down. Blood, tissue fragments and mucus are discharged through the vagina as menstrual flow; its first day is counted as day 1 of the cycle.

Step 3: Conclusion Menstruation is the shedding of the uterine endometrium with blood for about 3–5 days following a fall in ovarian hormones when fertilization does not occur.

Quick Tip to Solve: Link the events in order: corpus luteum degeneration, hormone decline, then endometrial shedding.

31(b)(ii). Why is follicular phase also called proliferative phase?

[1 mark]

Solution:

Concept:

- The follicular phase describes the growth and maturation of ovarian follicles before ovulation.
- Proliferation means an increase in cells; oestrogen stimulates the rebuilding of the uterine endometrium.

Step 1: Connect follicular growth to oestrogen During this phase, growing ovarian follicles secrete increasing amounts of oestrogen under the influence of pituitary gonadotropins.

Step 2: Explain the corresponding uterine change Oestrogen promotes regeneration of the endometrium after menstruation. Its cells multiply, and the uterine lining thickens with growth of glands and blood vessels. This uterine rebuilding is called proliferation.

Step 3: Conclusion The follicular phase is also called the proliferative phase because follicular oestrogen causes regeneration and proliferation of the uterine endometrium.

Quick Tip to Solve: Use the two names to track two organs: follicles grow in the ovary while the endometrium proliferates in the uterus.

31(b)(iii). Explain the events that occur in Graafian follicle at the time of ovulation and thereafter.

[2 marks]

Solution:

Concept:

- The mid-cycle surge of luteinising hormone (LH) induces ovulation from a mature Graafian follicle.
- The ruptured follicle forms the corpus luteum, a temporary endocrine structure that mainly secretes progesterone.

Step 1: Describe follicular rupture at ovulation The LH surge causes the mature Graafian follicle to rupture, usually around the middle of a typical 28-day cycle. It releases the secondary oocyte, surrounded by the zona pellucida and corona radiata. The oocyte is collected towards the oviduct by the fimbriae; the follicular wall remains in the ovary.

Step 2: Follow the follicle after ovulation The remaining cells of the ruptured follicle undergo luteinisation and form the corpus luteum. It secretes large amounts of progesterone, which maintains the thick, secretory endometrium for implantation and pregnancy. If fertilization and pregnancy do not occur, the corpus luteum degenerates, hormone levels fall and the endometrium breaks down during menstruation. In pregnancy, the corpus luteum is maintained initially by human chorionic gonadotropin (hCG).

Step 3: Conclusion The Graafian follicle ruptures to release the secondary oocyte at ovulation; its remaining cells form the progesterone-secreting corpus luteum thereafter.

Quick Tip to Solve: Keep the fates distinct: the secondary oocyte leaves the ovary, while the ruptured follicle stays and becomes the corpus luteum.

31(b)(iv). Draw a Graafian follicle and label - Antrum and secondary oocyte.

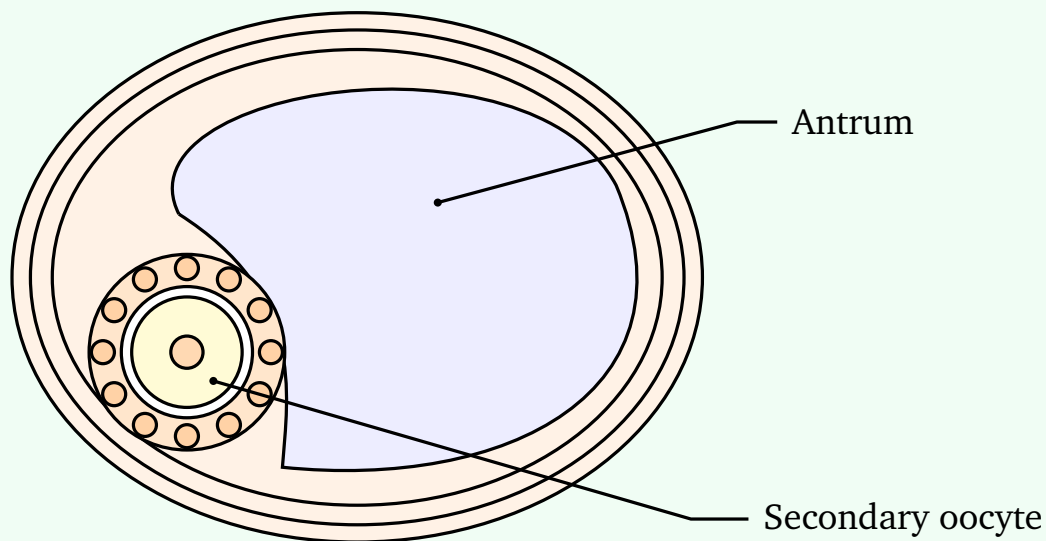
[1 mark]

Solution:

Concept:

- A Graafian follicle is a mature ovarian follicle containing a secondary oocyte surrounded by follicular cells.
- The antrum is the large fluid-filled cavity within the follicle; the secondary oocyte lies eccentrically, supported by follicular cells.

Step 1: Draw the mature follicle Draw the follicular wall enclosing a large cavity. Show the secondary oocyte near one side of the follicle, surrounded by its zona pellucida and follicular cells. It must be distinct from the fluid-filled space.



Graafian follicle with the two requested labels

Step 2: Identify the requested structures The leader labelled Antrum ends inside the large cavity. The leader labelled Secondary oocyte ends within the large cell near the side of the follicle, rather than on its surrounding cell layers.

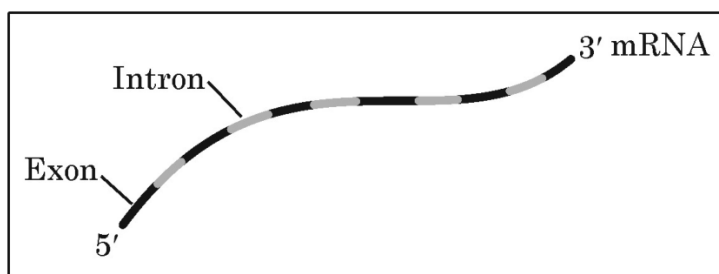
Step 3: Conclusion The diagram shows a Graafian follicle with its antrum and secondary oocyte labelled.

Quick Tip to Solve: Place the oocyte to one side and point the antrum label into the fluid-filled cavity, not into the follicular wall.

32(a)(i). Observe the segment of mRNA given below and answer the questions given below:

Explain and illustrate the steps involved to make fully processed hn RNA.

[3 marks]

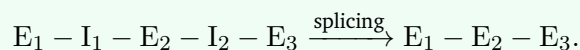


Solution:

Concept:

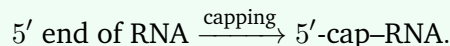
- In eukaryotes, RNA polymerase II transcribes the primary transcript, called heterogeneous nuclear RNA (hnRNA). It contains both exons and introns and must undergo processing.
- Splicing, capping and tailing convert the primary transcript into mature, functional mRNA. Exons are retained, whereas introns are removed.

Step 1: Splice out introns and join exons The transcript shown contains both exons and introns, so it represents the RNA before processing is complete. During splicing, the introns are removed and the exons are joined in their correct order. If E denotes an exon and I denotes an intron, the change is illustrated by

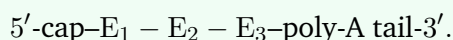


The retained exons form the continuous sequence of the mature RNA.

Step 2: Cap the five-prime end A modified guanosine nucleotide, methyl guanosine triphosphate, is added to the 5' end of hnRNA. This is called capping. The cap protects the RNA and helps its recognition for translation.



Step 3: Add the poly-A tail About 200–300 adenylate residues are added to the 3' end in a template-independent manner. This is called tailing or polyadenylation. The poly-A tail contributes to RNA stability. The completed product can be represented as



These are the three processing changes; their listing here does not imply that capping waits until all splicing has finished. Once fully processed, the RNA is transported from the nucleus to the cytoplasm for translation.

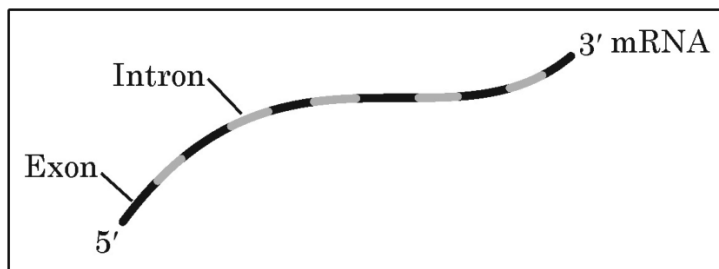
Step 4: Conclusion Removal of introns and joining of exons by splicing, addition of a 5' cap, and addition of a 3' poly-A tail convert hnRNA into mature mRNA.

Quick Tip to Solve: Show exons joined in their original order, then label the cap at the five-prime end and the poly-A tail at the three-prime end.

32(a)(ii). Observe the segment of mRNA given below and answer the questions given below:

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 polymerase I transcribes the precursor for the major ribosomal RNAs: 28S, 18S and 5.8S rRNAs.
- RNA polymerase III transcribes tRNAs, 5S rRNA and some small nuclear RNAs. Ribosomes and tRNAs are essential components of translation.

Step 1: Explain the effect on ribosome formation If the mutations impair RNA polymerase I activity, synthesis of 28S, 18S and 5.8S rRNAs decreases or stops. Impairment of RNA polymerase III also reduces 5S rRNA formation. These rRNAs are needed to assemble functional ribosomal subunits. Consequently, the supply of ribosomes for polypeptide synthesis is reduced; rRNA also performs essential structural and catalytic roles in translation.

Step 2: Explain the effect on amino-acid delivery Defective RNA polymerase III reduces tRNA synthesis. Aminoacyl-tRNAs carry specific amino acids to the ribosome and pair their anticodons with mRNA codons. Without an adequate supply of functional tRNAs, amino acids cannot be supplied normally for chain elongation. RNA polymerase II may still make hnRNA that is processed into mRNA, but this mRNA alone cannot sustain translation without ribosomes and tRNAs. The severity depends on how much the mutations impair the enzymes.

Step 3: Conclusion Polypeptide synthesis is impaired, and may stop if the mutations abolish the required activities, because rRNA deficiency disrupts ribosome formation and tRNA deficiency disrupts amino-acid delivery during translation.

Quick Tip to Solve: Link polymerase I to major rRNAs and polymerase III to tRNA plus 5S rRNA, then explain why mRNA alone is insufficient.

32(b)(i). 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.

Is this an example of Co-dominance or incomplete dominance. Give a reason for your answer.

[1 mark]

Solution:

Concept:

- Co-dominance occurs when both alleles express their effects in a heterozygote, so both parental traits are distinguishable.
- In incomplete dominance, the heterozygote has a phenotype intermediate between those of the two homozygotes.

Step 1: Identify expression of both alleles The calf inherits a red-coat allele from its mother and a white-coat allele from its father. Its coat contains separate red hairs and white hairs in equal numbers. Thus, the effect of each allele remains visibly distinguishable in the same heterozygous animal.

Step 2: Distinguish this from incomplete dominance An intermediate phenotype would show a blended or intermediate hair colour. Here the individual hairs retain the parental red or white colours; neither allele masks the other and the two colours are not blended within each hair.

Step 3: Conclusion This is co-dominance: both the red-coat and white-coat alleles are expressed in the heterozygous calf, producing a coat with red and white hairs.

Quick Tip to Solve: Separate red and white hairs indicate co-dominance; a uniform intermediate hair colour would indicate incomplete dominance.

32(b)(ii). 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.

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

- (1) Red is dominant over white,
- (2) Red is incompletely dominant.

[4 marks]

Solution:

Concept:

- A monohybrid cross follows one pair of alleles. The two alleles segregate during gamete formation, so a heterozygote produces the two gamete types in equal proportions.
- Complete dominance makes the heterozygote resemble the dominant homozygote. In incomplete dominance the heterozygote has an intermediate phenotype, distinct from both homozygotes.
- The red and white hairs described in the stem show codominance. The two requested crosses

instead examine the alternative dominance relationships specified in (1) and (2).

Step 1: Set up the complete-dominance parental cross (1) Let R be the allele for red coat and r the allele for white coat, with R completely dominant over r . Cross a pure red mother with a pure white father:

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

Every calf receives one allele from each parent. Since the red allele masks the white allele in a heterozygote, all these calves have red coats.

Step 2: Intercross the first-generation red offspring Cross $Rr \times Rr$. Each parent produces gametes R and r in equal proportions. Random fertilisation gives the following Punnett square:

	R	r
R	RR	Rr
r	Rr	rr

The F_2 genotypic ratio is 1 RR : 2 Rr : 1 rr . Both RR and Rr are red, whereas rr is white. Thus the phenotypic ratio is 3 red to 1 white.

Step 3: Set up the incomplete-dominance parental cross (2) Use C^R for the red allele and C^W for the white allele. With incomplete dominance, neither allele completely masks the other:

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

Each F_1 calf has an intermediate, light-red (pink) coat. This is an intermediate colour, unlike a codominant coat containing separate red and white hairs.

Step 4: Intercross the intermediate-coloured offspring Cross $C^R C^W \times C^R C^W$. Each parent forms 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 $C^W C^W$. All three genotypes are distinguishable by colour, so the phenotypic ratio is 1 red : 2 intermediate light-red (pink) : 1 white.

Step 5: Conclusion With complete dominance, F_1 is entirely red and F_2 is 3 red : 1 white. With incomplete dominance, F_1 is entirely intermediate-coloured and F_2 is 1 red : 2 intermediate : 1 white. The genotypic ratio remains 1 : 2 : 1 in both cases.

Quick Tip to Solve: First obtain the four genotypes in the Punnett square, then assign phenotypes using the stated dominance rule. Do not carry the stem's codominant red-and-white phenotype into the two hypothetical crosses.

33(a)(i). 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.

Identify the disease and its causative agent.

[2 marks]

Solution:

Concept:

- AIDS stands for Acquired Immunodeficiency Syndrome. It involves progressive damage to the body's immune defences, making the person susceptible to repeated infections.
- Human Immunodeficiency Virus (HIV) is a retrovirus with an RNA genome. Its infection causes a progressive reduction in helper T-lymphocytes, which coordinate immune responses.

Step 1: Relate the findings to the disease Recurrent infections together with weight loss and prolonged fever indicate failure of immune protection. The decisive clue in the question is the decline in T-lymphocyte count. In the given clinical description, these findings identify Acquired Immunodeficiency Syndrome, abbreviated AIDS. The recurrent infections arise because the weakened immune system cannot defend the body effectively against pathogens.

Step 2: Name the causative pathogen The causative agent is Human Immunodeficiency Virus, abbreviated HIV. It belongs to the retrovirus group and attacks cells of the immune system, including helper T-lymphocytes. Distinguish the two names: AIDS names the disease syndrome, whereas HIV names the infectious agent responsible for it.

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

Quick Tip to Solve: Link recurrent infections plus declining helper T-cell numbers to AIDS; when asked for the agent, write HIV separately with its full name.

33(a)(ii). 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.

How did the pathogen affect the immune system once it entered the body? Explain.

[2 marks]

Solution:

Concept:

- HIV is a retrovirus: its reverse transcriptase makes a DNA copy of viral RNA. The viral DNA integrates into the host-cell DNA and directs the production of new viruses.
- Helper T-lymphocytes coordinate immune responses. Their progressive destruction weakens the body's ability to resist infections.

Step 1: Explain multiplication after entry into the body After entering the body, HIV infects macrophages. Its RNA genome is copied into viral DNA by reverse transcriptase. This viral DNA becomes incorporated into the host-cell DNA and directs the infected cell to produce new HIV particles. Macrophages continue to produce virus and act as reservoirs for infection.

Step 2: Connect helper T-cell loss to immunodeficiency HIV also enters helper T-lymphocytes, replicates in them and releases progeny viruses that infect further helper T-cells. Repeated infection and destruction cause a progressive decline in the number of these lymphocytes. Since helper T-cells coordinate both antibody-mediated and cell-mediated immune responses, their loss reduces immune protection. The person becomes susceptible to repeated opportunistic infections, accounting for the recurrent infections described in the question.

Step 3: Conclusion HIV multiplies through reverse transcription and integration in immune cells, then progressively depletes helper T-lymphocytes. This weakens immune responses and produces the immunodeficiency associated with AIDS.

Quick Tip to Solve: Explain HIV action in order: RNA to DNA, integration and virus production, then helper T-cell destruction and susceptibility to opportunistic infections.

33(a)(iii). 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.

Mention two major modes of its transmission.

[1 mark]

Solution:

Concept:

- HIV is transmitted when infected body fluids enter another person's body through a suitable route.
- Sexual contact and exposure to infected blood are major routes; ordinary social contact does not transmit HIV.

Step 1: State the sexual route Sexual contact with an HIV-infected person is a major mode of transmission. Infected sexual fluids can transfer the virus through mucosal surfaces during unprotected sexual intercourse.

Step 2: State the blood route Transfusion of HIV-contaminated blood or blood products is another major mode. Here the virus enters the recipient's bloodstream directly. This is distinct from casual contact such as shaking hands or sharing food.

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

Quick Tip to Solve: Name two distinct routes: sexual contact and contaminated blood transfusion; do not list casual contact as a route.

33(b)(i). Why are microbes considered effective biocontrol agents in sustainable agriculture? [1 mark]

Solution:

Concept:

- Biological control uses living organisms or their products to control agricultural pests and plant pathogens.
- Sustainable agriculture protects crops while conserving useful organisms, biodiversity and environmental quality.

Step 1: Explain natural pest suppression Selected microbes infect insect pests, produce insecticidal substances or antagonise plant pathogens. They therefore reduce crop damage through biological processes; many microbial agents act specifically against their target pests.

Step 2: Link this action to sustainability Their use reduces dependence on chemical pesticides and the associated pollution and harmful residues. Suitable agents preserve beneficial organisms and ecological balance, supporting continued crop protection with less environmental damage.

Step 3: Conclusion Microbes are effective biocontrol agents because they suppress pests or pathogens naturally and reduce chemical-pesticide use, helping conserve biodiversity and environmental quality.

Quick Tip to Solve: Connect the two ideas explicitly: natural pest suppression reduces chemical inputs and protects ecological balance.

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

(1) A Bacterium

(2) A Fungus

(3) Virus

[4 marks]

Solution:

Concept:

- Microbial biocontrol uses selected bacteria, fungi or viruses to suppress agricultural pests and plant pathogens.
- A suitable agent must be matched to its target: an insect pathogen controls insect pests, while an antagonistic fungus suppresses plant-disease organisms.

Step 1: Explain the bacterial agent The bacterium *Bacillus thuringiensis* (Bt) controls insect pests such as butterfly caterpillars. Preparations containing its spores and toxin crystals are sprayed onto vulnerable plants, including brassicas and fruit trees. When caterpillars eat the treated leaves, the alkaline conditions in their gut activate the toxin. The active toxin damages the midgut epithelial cells, causing the larvae to die and preventing further feeding damage. The choice of Bt strain matters because different toxins act against different groups of insects.

Step 2: Explain the fungal agent Species of *Trichoderma* are free-living fungi commonly found in

root ecosystems. They act as antagonists of several soil-borne plant pathogens, for example *Fusarium* species that cause wilt and *Rhizoctonia* species associated with root rot. By competing with and suppressing these disease-causing fungi around the roots, *Trichoderma* helps protect the crop against infection.

Step 3: Explain the viral agent Baculoviruses, particularly nucleopolyhedroviruses (NPVs), are used against insect pests such as the larvae of *Helicoverpa armigera*, a bollworm pest. A suitable host-specific virus infects and multiplies in the susceptible larva, eventually killing it. These viruses have narrow host ranges and are excellent candidates for species-specific insecticidal applications. They do not harm plants, mammals, birds, fish or non-target insects, helping conserve beneficial insects in integrated pest management programmes.

Step 4: Conclusion Examples are *Bacillus thuringiensis* against caterpillars, *Trichoderma* against soil-borne fungal diseases such as wilt and root rot, and a suitable baculovirus/NPV against insect larvae such as bollworms.

Quick Tip to Solve: For each group, write the agent, its target and its action: Bt kills feeding caterpillars, *Trichoderma* suppresses root pathogens, and NPVs infect specific insect larvae.