

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

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

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

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

Solution:

Concept:

- *Agrobacterium tumefaciens* naturally infects many dicot plants and transfers a segment of its tumour-inducing (Ti) plasmid into plant cells.
- A disarmed Ti plasmid can carry a desired foreign gene into a plant without causing tumour formation.

Step 1: Identify the useful host-vector relationship Tobacco is a dicot plant. The natural ability of *Agrobacterium* to infect dicots, together with its Ti plasmid, makes it suitable for transferring nematode-specific sequences into tobacco cells. These sequences can be expressed to trigger RNA interference against the parasite.

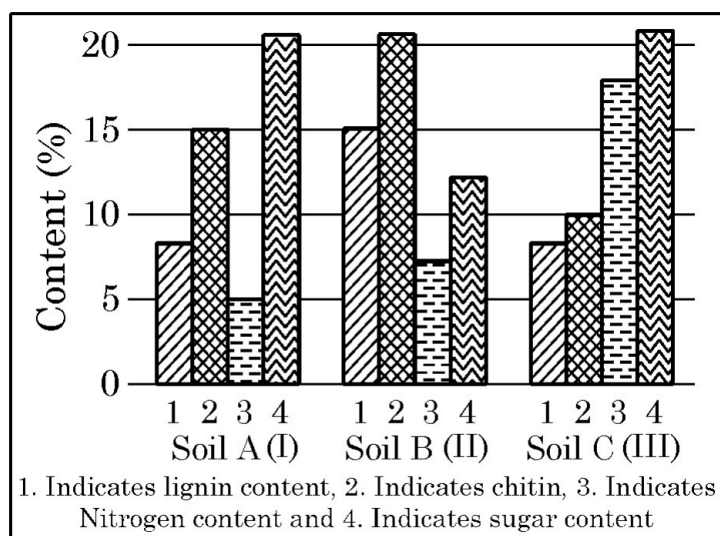
Step 2: Eliminate the incompatible descriptions Option (A) identifies monocots instead of the dicot host relevant here. Option (C) incorrectly describes infection of both plants and animals as the useful property. Option (D) substitutes the cry gene, associated with *Bacillus thuringiensis*, for the Ti-plasmid vector mechanism.

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

Quick Tip to Solve: For gene transfer into tobacco, pair the dicot host with the disarmed Ti plasmid of *Agrobacterium*.

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

[1 mark]



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

Correct Answer: (C) Soil Sample III

Solution:

Concept:

- Decomposition is slower when detritus is rich in resistant compounds such as lignin and chitin.
- Decomposition is faster when detritus is rich in nitrogen and readily usable water-soluble substances such as sugars.

Step 1: Compare the chemical composition In the graph, bars 1 and 2 represent lignin and chitin, whereas bars 3 and 4 represent nitrogen and sugar. Sample III combines low lignin and relatively low chitin with the highest nitrogen content and a high sugar content. These features favour rapid microbial breakdown.

Step 2: Control the other factors and reject alternatives Temperature and moisture are identical, so the comparison depends on substrate composition. Sample I has high sugar but much less nitrogen and more chitin than III. Sample II has much more lignin and chitin and less sugar. Thus neither I nor II has the favourable overall composition of III; the option including II is also unsuitable.

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

Quick Tip to Solve: Read bars 1 and 2 as resistant material and bars 3 and 4 as favourable nutrients; compare all four rather than sugar alone.

3. A woman having genes for haemophilia on one X chromosome and a gene for colour blindness on another X chromosome marries a normal man. The progeny will show [1 mark]

- (A) 50% haemophilic and colour-blind sons, 50% normal sons.
- (B) 50% haemophilic carrier daughter, 50% colour-blind carrier daughters.
- (C) All sons and daughters colour-blind and haemophilic.
- (D) Only haemophilic and colour-blind daughters.

Correct Answer: (B) 50% haemophilic carrier daughter, 50% colour-blind carrier daughters.

Solution:

Concept:

- Haemophilia and red-green colour blindness are X-linked recessive traits. Let H, h denote normal clotting and haemophilia alleles, and C, c denote normal colour vision and colour-blindness alleles.
- The maternal X chromosomes are X^{hC} and X^{Hc} ; the normal father is $X^{HC}Y$. A daughter always receives her father's normal X chromosome.

Step 1: Follow the X chromosomes into daughters For the parental X-chromosome combinations considered in this cross, the mother produces X^{hC} and X^{Hc} eggs in equal proportions. With paternal X^{HC} , these give $X^{HC}X^{hC}$ daughters carrying haemophilia and $X^{HC}X^{Hc}$ daughters carrying colour blindness. Each category constitutes 50% of the daughters; both are phenotypically normal.

Step 2: Check the sons and the other options Sons receive paternal Y, giving $X^{hC}Y$ or $X^{Hc}Y$: respectively haemophilic sons with normal colour vision and colour-blind sons with normal clotting. Option (A) incorrectly places both recessive traits together in half the sons. Options (C) and (D) incorrectly make the daughters affected despite their normal paternal X chromosome.

Step 3: Conclusion Among daughters, 50% are haemophilia carriers and 50% are colour-blindness carriers in the stated cross. Hence, the correct option is (B).

Quick Tip to Solve: Write both loci on each X chromosome first; a normal paternal X prevents either recessive condition from appearing in daughters.

4. Which of the following is an important parameter for assessing the impact of any biotic or abiotic factor on population growth? [1 mark]

- (A) Birth rate
- (B) K - carrying capacity
- (C) Death rate
- (D) r - Intrinsic rate of natural increase

Correct Answer: (D) r - Intrinsic rate of natural increase

Solution:

Concept:

- The intrinsic rate of natural increase, r , expresses the population's capacity for increase under the prevailing conditions.

- For a closed population, $r = b - d$, where b and d are per capita birth and death rates; exponential growth is described by $dN/dt = rN$.

Step 1: Identify the combined growth parameter A biotic or abiotic factor can change reproductive success, survival or both. The parameter r combines their consequences for population increase, so it is an important measure for assessing the effect of such factors on population growth.

Step 2: Distinguish the other quantities Birth rate alone measures additions through reproduction, while death rate alone measures losses. Neither alone expresses the net natural increase. Carrying capacity K describes the population size the habitat can sustain, rather than the intrinsic rate at which the population increases.

Step 3: Conclusion The required parameter is r , the intrinsic rate of natural increase. Hence, the correct option is (D).

Quick Tip to Solve: When the question asks about the effect of environmental factors on population growth, recall the combined rate $r = b - d$.

5. If a sperm nucleus is injected into an oocyte then all of the following events are bypassed except

[1 mark]

- (A) The swimming of sperm to meet the egg in the oviduct.
- (B) The sperm's acquisition of motility in the epididymis.
- (C) A sperm comes in contact with the zona pellucida layer of the ovum.
- (D) The complex process like cell division and cell differentiation.

Correct Answer: (D) The complex process like cell division and cell differentiation.

Solution:

Concept:

- Direct introduction of sperm genetic material into an oocyte bypasses the normal transport and penetration steps required for sperm entry.
- After fertilisation, embryonic development still requires repeated cell divisions and differentiation into specialised cells.

Step 1: Separate delivery from development Injection places the sperm nucleus inside the oocyte. Sperm swimming to the egg, motility required for that journey and normal contact with the zona pellucida are therefore not prerequisites for delivering the nucleus by this method. These are the events described in options (A), (B) and (C).

Step 2: Identify the process that must still occur The resulting fertilised cell cannot develop into an embryo merely because sperm entry has been assisted. Cleavage divisions must increase the number of cells, and subsequent differentiation must produce different cell types and tissues. Injection does not replace these developmental processes.

Step 3: Conclusion Cell division and cell differentiation are not bypassed. Hence, the correct option is (D).

Quick Tip to Solve: For an EXCEPT question on sperm injection, distinguish steps that deliver the sperm nucleus from development that follows fertilisation.

6. If A = species richness and B = Endemism then biodiversity hotspots have

[1 mark]

- (A) low degree of A and low degree of B.
- (B) low degree of A and high degree of B.
- (C) high degree of A and low degree of B.
- (D) high degree of A and high degree of B.

Correct Answer: (D) high degree of A and high degree of B.

Solution:

Concept:

- Species richness is the number of species in a region.
- Endemism is the occurrence of species restricted to a particular geographical region and found naturally nowhere else.

Step 1: Apply both features of a hotspot Biodiversity hotspots are regions with exceptionally high species richness and a high degree of endemism. A large number of species makes them rich in biodiversity, while restricted distributions make loss of their endemic species especially serious.

Step 2: Match the symbols and compare options Here A represents species richness and B represents endemism. The required combination is therefore high A and high B . Option (A) has neither feature, (B) lacks high richness and (C) lacks high endemism. Only the fourth option includes both characteristics.

Step 3: Conclusion Hotspots have a high degree of both A and B . Hence, the correct option is (D).

Quick Tip to Solve: Check both hotspot features together: many species in the region and many species restricted to that region.

7. Two plants whose DNA has been sequenced are

[1 mark]

- (A) Rice and Wheat
- (B) Wheat and Maize
- (C) Maize and Barley
- (D) Rice and Arabidopsis

Correct Answer: (D) Rice and Arabidopsis

Solution:

Concept:

- Genome sequencing determines the order of nucleotide bases in an organism's DNA.
- Rice and *Arabidopsis* are the two plant examples highlighted in the NCERT discussion of organisms whose genomes have been sequenced.

Step 1: Recall the specified textbook examples The Human Genome Project discussion also mentions sequencing of other organisms. Its plant examples are rice, an important food crop, and *Arabidopsis*, a widely used model plant for research. The question tests recall of this particular pair.

Step 2: Compare the complete pairs Option (A) includes rice but replaces *Arabidopsis* with wheat. Options (B) and (C) also fail to give the cited pair. Option (D) contains both rice and *Arabidopsis*. This identifies the textbook examples; it does not imply that other crop genomes cannot be or have not been sequenced.

Step 3: Conclusion The intended textbook pair is rice and *Arabidopsis*. Hence, the correct option is (D).

Quick Tip to Solve: Remember the NCERT plant pair as one major food crop, rice, and one model research plant, *Arabidopsis*.

8. Antivenom injection is an example of

[1 mark]

- (A) Natural Active Immunity
- (B) Artificial Active Immunity
- (C) Natural Passive Immunity
- (D) Artificial Passive Immunity

Correct Answer: (D) Artificial Passive Immunity

Solution:

Concept:

- Passive immunity is produced by receiving preformed antibodies; the recipient does not have to produce these antibodies first.
- Artificial immunity is acquired through deliberate medical administration, whereas natural passive immunity includes maternal antibody transfer.

Step 1: Identify what antivenom supplies Antivenom contains preformed antibodies against venom components. These antibodies can bind and neutralise venom rapidly. Since the injected material supplies antibodies directly, this is passive immunity rather than the active response induced by an antigen or vaccine.

Step 2: Classify the route of acquisition The antibodies are administered by an injection, so their transfer is artificial. Natural active immunity follows infection, artificial active immunity follows vaccination, and natural passive immunity involves maternal antibodies transferred through the placenta or colostrum. None describes an antivenom injection.

Step 3: Conclusion Antivenom injection provides artificial passive immunity. Hence, the correct option is (D).

Quick Tip to Solve: For antivenom, identify both clues: ready-made antibodies mean passive, and injection means artificial.

9. 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 sequences repeated many times; fractions of this DNA can differ in base composition and density from bulk genomic DNA.
- Density-gradient centrifugation separates DNA fractions according to their buoyant densities, producing a major band and separate satellite bands.

Step 1: Identify the required separation The question asks for physical separation of repetitive DNA from the bulk genomic DNA. In a density gradient, the DNA moves to the region matching its buoyant density. Repetitive satellite DNA can therefore appear as small satellite bands distinct from the major band of bulk DNA.

Step 2: Eliminate the other techniques Elution recovers a DNA fragment from a gel after separation. Southern blotting detects a specific DNA sequence using a complementary probe following transfer to a membrane. Polymerase chain reaction amplifies a selected DNA sequence. These operations do not provide the density-based separation asked here.

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

Quick Tip to Solve: Associate satellite DNA and the major genomic DNA band with separation by buoyant density.

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

[1 mark]

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

Correct Answer: (B) Share common ancestors

Solution:

Concept:

- Homologous organs share a basic anatomical plan and evolutionary origin, although they may perform different functions.

- Divergent evolution modifies an inherited structure for different ways of life; homology is evidence of common ancestry.

Step 1: Interpret the anatomical similarity Similar underlying structures in the forelimbs of aquatic and terrestrial animals indicate that the limbs have been inherited from a common ancestral form. Adaptations can modify this basic plan for swimming in one animal and walking in another without removing their homology.

Step 2: Check the alternative conclusions Living in aquatic and terrestrial environments does not imply the same habitat. The forelimbs need not perform the same function, so shared function cannot be inferred. Analogous organs perform similar functions but have different basic origins or structures; that is different from the anatomical similarity described here.

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

Quick Tip to Solve: Use similarity of the basic anatomical plan to identify homology, even when habitat and function differ.

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

[1 mark]

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

Correct Answer: (C) Ethidium Bromide

Solution:

Concept:

- Gel electrophoresis separates DNA fragments, but the separated DNA bands are not visible directly to the unaided eye.
- Ethidium bromide associates with DNA and fluoresces under ultraviolet light, allowing stained DNA bands to be visualised.

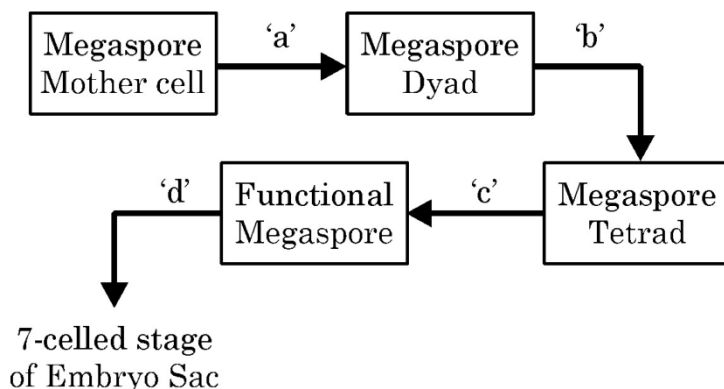
Step 1: Identify the DNA stain After electrophoretic separation, DNA fragments stained with ethidium bromide appear as bright orange bands when exposed to UV radiation. The stain supplies the fluorescence needed to locate the separated DNA fragments in the gel.

Step 2: Compare the other substances Acetocarmine is commonly used to stain chromosomes for microscopic study, while safranin is a general biological stain used for cells and tissues. Potassium iodide is not the DNA-binding fluorescent stain used for this procedure. These options do not match the combination of DNA bands and UV illumination.

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

Quick Tip to Solve: Link the phrase bright orange DNA bands under UV light directly with ethidium bromide staining.

12. 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:

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

Step 1: Follow the two meiotic divisions Arrow a leads from the megaspore mother cell to the dyad, so it represents meiosis I. Arrow b leads from the dyad to the tetrad and therefore represents meiosis II. The two divisions together produce four haploid megaspores.

Step 2: Identify selection and embryo-sac development At c, three megaspores degenerate and the remaining one becomes the functional megaspore; no cell division occurs in this selection. At d, three successive mitotic nuclear divisions give eight nuclei, followed by organisation into seven cells. Thus d represents mitosis, not meiosis. Options A, C and D each assign an incorrect process to at least one of these transitions.

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: Separate megaspore formation by meiosis from embryo-sac formation by mitosis; selecting the surviving megaspore is no division.

13. Assertion (A): Pollen grains have a mucilaginous covering on them in most of the water pollinating plants.

Reason (R): Mucilaginous covering help pollen grains to be submerged in water.

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:

- Hydrophily is pollination through water; pollen must remain protected while being transported to the stigma.
- In most water-pollinated plants, a mucilaginous covering protects pollen grains from wetting.

Step 1: Evaluate the assertion The assertion correctly states that pollen grains in most water-pollinating plants have a mucilaginous covering. This covering is an adaptation associated with pollen transport in an aquatic medium, so Assertion (A) is true.

Step 2: Evaluate the reason The reason assigns the covering the function of helping pollen remain submerged. Its stated protective role is to prevent wetting of the pollen grains, not to cause submergence. Water pollination may occur at the surface or below it, so the claim in Reason (R) is false.

Step 3: Check the explanatory link A false reason cannot explain a true assertion. Options A and B require both statements to be true, while D requires the assertion to be false. Only the code for a true assertion and a false reason fits this pair.

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

Quick Tip to Solve: Remember the precise function of the mucilaginous coat: protection from wetting, rather than helping pollen sink.

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:

- Yeasts such as *Saccharomyces cerevisiae* are used commercially to ferment sugar-rich substrates for alcohol production.
- During alcoholic fermentation, yeast converts glucose into ethanol and carbon dioxide under anaerobic conditions.

Step 1: Evaluate the assertion Microorganisms are used on an industrial scale to produce alcohol and alcoholic beverages. Brewer's yeast ferments suitable substrates such as malted cereals and fruit juices. Therefore, Assertion (A) is true.

Step 2: Evaluate the reason Yeast produces ethanol and carbon dioxide from glucose during fermentation. This biochemical conversion accounts for the accumulation of alcohol in the fermented material, so Reason (R) is also true.

Step 3: Establish the explanatory link The ethanol-producing fermentation described in the reason is the very process exploited for commercial alcohol and beverage production. Thus the reason directly explains the assertion. Option B misses this causal link, and options C and D incorrectly label one of the true statements as false.

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

Quick Tip to Solve: When the reason states the industrial microbe's actual product-forming reaction, check for a direct explanatory link.

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 conservation status and extinction risk of species.
- Identifying threatened species helps set priorities for conservation and protection.

Step 1: Evaluate the assertion Assertion (A) is true. The IUCN Red List supplies information about endangered species worldwide, helping conservationists identify species that need protection and plan conservation measures.

Step 2: Evaluate the reason Reason (R) is true. The list includes species facing a risk of extinction and assesses their degree of threat. It is not restricted to species that are already extinct.

Step 3: Check the explanatory link Recording extinction risk explains how the list helps identify endangered species and direct protective action. Thus R explains A, excluding (B); neither statement is false, excluding (C) and (D).

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

Quick Tip to Solve: Link the Red List's record of extinction risk to its use in choosing 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 joins DNA fragments by sealing breaks in the sugar-phosphate backbone.

- A phosphodiester bond joins adjacent nucleotides; a glycosidic bond joins a nitrogenous base to its sugar.

Step 1: Evaluate the assertion Assertion (A) is true. DNA ligase joins DNA fragments, such as an insert and a vector, during recombinant DNA formation.

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

Step 3: Test the explanation and alternatives Because R names the wrong bond, it cannot explain the true assertion. Options (A) and (B) incorrectly treat R as true, while (D) incorrectly treats A as false.

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

Quick Tip to Solve: Remember: ligase seals the sugar-phosphate backbone, so the bond it forms is phosphodiester.

Section B (10 marks)

17(a). Is it possible for a trait to be inherited by an organism but not expressed in its phenotype? Justify and illustrate your answer with a suitable Mendelian Cross. [2 marks]

Solution:

Concept:

- In complete dominance, a dominant allele expresses itself in a heterozygote and masks the recessive allele.
- The recessive allele is inherited and remains present even when its associated phenotype is not expressed.

Step 1: Choose contrasting Mendelian characters Yes. Consider plant height in garden pea. Let T represent the dominant allele for tallness and t the recessive allele for dwarfness. Cross a true-breeding tall plant with a true-breeding dwarf plant:

$$\begin{array}{l} \text{Parents: } TT \text{ (tall)} \times tt \text{ (dwarf)} \\ \text{Gametes: } T \qquad t \\ F_1 : Tt \text{ (all tall).} \end{array}$$

Each offspring inherits t from the dwarf parent, but the dominant T masks dwarfness.

Step 2: Verify that the recessive allele persists Selfing the F_1 plants gives $Tt \times Tt$. Each parent produces T and t gametes, yielding TT, Tt, Tt, tt in the genotypic ratio 1 : 2 : 1. The tt offspring are dwarf, giving a tall-to-dwarf phenotypic ratio of 3 : 1. Reappearance of dwarfness shows that its allele was inherited, not lost, in the tall F_1 .

Step 3: Conclusion A recessive trait can be inherited without being expressed: the tall Tt pea plant carries the allele for dwarfness, which is masked by T .

Quick Tip to Solve: Use $TT \times tt$ to show masking in F_1 , then $Tt \times Tt$ to show the recessive trait reappearing.

17(b). Explain the two major approaches used while sequencing the total DNA from a cell. [2 marks]

Solution:

Concept:

- Genome analysis can focus on expressed genes or determine the complete DNA sequence, including coding and non-coding regions.
- Expressed sequence tags identify expressed genes; sequence annotation assigns information and functions to sequenced regions.

Step 1: Explain the expressed sequence tag approach The first approach identifies all genes that are expressed as RNA. Messenger RNA represents expressed genes; complementary DNA can be prepared from it and sequenced to obtain expressed sequence tags (ESTs). These sequence tags help identify expressed genes. Because the starting material is expressed RNA, this approach does not cover all non-coding regions of the genome.

Step 2: Explain the sequence annotation approach The second approach sequences the whole set of DNA from a cell, including both coding and non-coding sequences. Functions are subsequently assigned to different regions of this sequence. This interpretation of the complete sequence is called sequence annotation. Thus the DNA is first sequenced without restricting the investigation to genes detected through their expression.

Step 3: Conclusion The two approaches are **expressed sequence tags (ESTs)**, identifying genes expressed as RNA, and **sequence annotation**, sequencing the entire genome and then assigning functions to its regions.

Quick Tip to Solve: Distinguish the starting scope: ESTs follow expressed RNA, whereas whole-genome sequencing includes coding and non-coding DNA.

18. Briefly describe the process of DNA extraction from a fungal cell. Name the chemicals used in the process. [2 marks]

Solution:

Concept:

- DNA isolation requires release of cellular DNA followed by removal of other cellular macromolecules.
- Fungal cell walls contain chitin; chitinase helps break this barrier, while chilled ethanol precipitates purified DNA.

Step 1: Break the fungal cell wall and release DNA Treat fungal cells with **chitinase**, which digests the chitin-containing cell wall. Disrupt the cell and nuclear membranes using a suitable detergent in an extraction buffer so that DNA and other cellular contents are released into the solution.

Step 2: Remove RNA and proteins Treat the extract with **ribonuclease (RNase)** to digest RNA and with a **protease** to digest proteins, including proteins associated with DNA. Remove the resulting

contaminants and cellular debris to obtain a purified DNA-containing solution.

Step 3: Precipitate and collect DNA Add **chilled ethanol** to the purified solution. DNA precipitates as fine threads that can be collected by spooling. Chitinase, RNase, protease and chilled ethanol are the key named reagents in the process; detergent assists membrane disruption.

Step 4: Conclusion Digest the fungal wall with chitinase, release the DNA, remove RNA and proteins using RNase and protease, and precipitate the purified DNA with chilled ethanol.

Quick Tip to Solve: Match each reagent to its target: chitinase–wall, RNase–RNA, protease–protein, chilled ethanol–DNA precipitation.

19(a). Differentiate between opioids and cannabinoids on the basis of their

Receptor site in human body.

[1 mark]

Solution:

Concept:

- Drugs act by binding to specific receptors in the body.
- Opioids and cannabinoids bind to different receptor classes, whose principal locations provide the required distinction.

Step 1: State the receptor sites for opioids Opioids bind to specific **opioid receptors in the central nervous system and the gastrointestinal tract**. Both sites should be included when identifying their receptor distribution.

Step 2: State the receptor sites for cannabinoids Cannabinoids interact with **cannabinoid receptors present principally in the brain**. This identifies their principal receptor site; it should not be confused with the body system on which their effects may be observed.

Step 3: Conclusion **Opioids:** receptors in the central nervous system and gastrointestinal tract. **Cannabinoids:** receptors principally in the brain.

Quick Tip to Solve: Pair opioids with CNS plus gastrointestinal tract, and cannabinoids with receptors principally in the brain.

19(b). Differentiate between opioids and cannabinoids on the basis of their

Mode of action in human body.

[1 mark]

Solution:

Concept:

- Drugs produce their effects by interacting with specific receptors and altering normal physiological activity.
- The characteristic effects of opioids and cannabinoids differ; the question asks for their action rather than their sources.

Step 1: State the action of opioids Opioids, such as heroin, act as depressants. They slow down body functions by depressing central nervous system activity.

Step 2: State the action of cannabinoids Cannabinoids are known for their effects on the cardiovascular system. Thus, their characteristic NCERT description differs from the slowing of body functions caused by opioids.

Step 3: Conclusion Opioids slow down body functions, whereas cannabinoids affect the cardiovascular system.

Quick Tip to Solve: For mode of action, pair opioids with depressant action and cannabinoids with cardiovascular effects.

20(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 establishes an exchange connection with the maternal uterine tissue.
- Chorionic villi of the embryo interdigitate with uterine tissue to form a specialised connection.

Step 1: Identify the maternal and foetal contributions The chorionic villi form the foetal component, while the adjacent uterine tissue provides the maternal component of the exchange organ.

Step 2: Distinguish the connection from the cord The umbilical cord connects the foetus to this exchange organ. It is not itself the organ formed by the association of embryonic and maternal tissues.

Step 3: Conclusion The organ is the placenta.

Quick Tip to Solve: Distinguish the placenta, the maternal–foetal exchange organ, from the umbilical cord connecting the foetus to it.

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

Solution:

Concept:

- The placenta is a specialised maternal–foetal exchange organ formed by chorionic villi and uterine tissue.
- In addition to exchange, the placenta acts as an endocrine tissue that produces hormones supporting pregnancy.

Step 1: Explain the nutritional role The chorionic villi provide a large surface for exchange with maternal blood. Nutrients such as glucose and amino acids, together with oxygen, pass from the maternal circulation to the foetal circulation and are carried to the foetus through the umbilical cord. Carbon dioxide and metabolic wastes pass in the reverse direction for removal by the mother. Maternal and foetal blood do not normally mix directly.

Step 2: Explain hormonal regulation The placenta produces human chorionic gonadotropin (hCG), human placental lactogen (hPL), oestrogens and progestogens. Early in pregnancy, hCG maintains the corpus luteum and its progesterone secretion. Placental progestogens and oestrogens support the uterine conditions required for continued pregnancy, while hPL contributes to maternal metabolic adaptations that support foetal nutrition.

Step 3: Conclusion The placenta supplies nutrients and oxygen to the foetus and acts as an endocrine organ producing hCG, hPL, oestrogens and progestogens to support pregnancy.

Quick Tip to Solve: Answer both roles separately: exchange across chorionic villi, then name the placental hormones and their pregnancy-supporting functions.

OR

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

All copulations do not lead to pregnancy.

[1 mark]

Solution:

Concept:

- Fertilisation requires viable sperm and a viable ovum to reach the ampullary region of the fallopian tube at the same time.
- Ovulation and the limited survival of the gametes restrict the period during which fertilisation can occur.

Step 1: Relate intercourse to ovulation Copulation does not necessarily coincide with the fertile period. Sperm may reach the female reproductive tract when no viable ovum is available, so fertilisation cannot occur.

Step 2: Identify the necessary meeting of gametes Even after semen is deposited, viable sperm must reach the ampullary region while the ovum is present there. Without their simultaneous availability at the fertilisation site, a zygote is not formed.

Step 3: Conclusion All copulations do not lead to pregnancy because viable sperm and an ovum are not always present simultaneously at the site of fertilisation.

Quick Tip to Solve: Link the reason to timing and location: simultaneous availability of viable sperm and ovum in the ampullary region.

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

Meiosis I in spermatogenesis and oogenesis are markedly different.

[1 mark]

Solution:

Concept:

- Meiosis I reduces the chromosome number from diploid to haploid in both spermatogenesis and oogenesis.
- The important difference is the distribution of cytoplasm between the two daughter cells.

Step 1: Describe meiosis I in spermatogenesis A primary spermatocyte undergoes meiosis I with approximately equal cytoplasmic division, forming two similar-sized haploid secondary spermatocytes.

Step 2: Describe meiosis I in oogenesis A primary oocyte undergoes unequal cytoplasmic division during meiosis I, forming one large haploid secondary oocyte and a small first polar body. The secondary oocyte retains most of the cytoplasm and reserves needed for early development.

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

Quick Tip to Solve: Compare the products of meiosis I itself: two secondary spermatocytes versus a secondary oocyte and first polar body.

21(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 need not always be expressed as the number of individuals per unit area or volume.
- Percentage cover and biomass can represent population size more meaningfully when counting individuals is difficult or their sizes differ greatly.

Step 1: Use percentage cover for spreading plants Percentage cover is the fraction of a sampled ground area covered by a species, expressed as a percentage. For a densely growing grass population, individual plants may overlap and be difficult to distinguish. Estimating the area covered by that grass in quadrats gives a practical indication of its abundance without requiring each individual to be counted.

Step 2: Use biomass when individual size matters Biomass expresses the mass of living material of a population per unit area or volume. For example, one large banyan tree may contribute far more living material than hundreds of small *Parthenium* plants. A count of one tree would greatly understate its ecological presence; comparing biomass better represents the large difference in the sizes of the organisms.

Step 3: Conclusion Two useful parameters are percentage cover, for example for dense grasses, and biomass, for example when comparing a large banyan tree with many small *Parthenium* plants.

Quick Tip to Solve: Choose cover when individuals are hard to separate, and biomass when their sizes make simple counts misleading.

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

Solution:

Concept:

- Tropical regions generally have greater species richness than temperate and polar regions.
- Evolutionary time, climatic stability and energy availability explain the exceptionally high biodiversity of tropical rain forests.

Step 1: Relate diversity to evolutionary history and climate Amazonian rain forests have had a long, relatively uninterrupted evolutionary history. Unlike temperate regions repeatedly affected by glaciations, tropical regions have remained relatively undisturbed for millions of years, allowing more time for speciation. Their less seasonal, relatively constant and predictable climate favours niche specialisation, so many species can coexist by using different resources or habitats.

Step 2: Connect solar energy with productivity The tropics receive abundant solar energy. Together with warm, moist conditions, this supports high primary productivity. The large supply of plant biomass and variety of food resources can support numerous consumers and complex ecological interactions, contributing to high species richness.

Step 3: Conclusion Long evolutionary time, a stable tropical climate that promotes niche specialisation, and abundant solar energy supporting high productivity account for the Amazonian rain forests' exceptional biodiversity.

Quick Tip to Solve: Recall the three tropical-diversity explanations: time for speciation, climatic stability and solar energy.

Section C (21 marks)

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

Solution:

Concept:

- Innate immunity is an inborn, non-specific defence that acts against many pathogens.
- Defence barriers prevent entry of microbes or eliminate them before they establish an infection.

Step 1: Identify the first line of protection Inhaled dust and microbes encounter mucus lining the respiratory tract. The mucus traps these particles, and ciliary movements help remove them from the airways. Thus, inhalation does not necessarily allow pathogens to enter tissues and multiply.

Step 2: Explain the internal defence If microbes cross the surface barrier, innate immune cells such as macrophages and neutrophils can engulf and destroy them by phagocytosis. These rapid, non-specific defences help prevent disease after everyday exposure.

Step 3: Conclusion The person is protected by innate immunity: respiratory barriers trap and remove inhaled particles, while phagocytes destroy invading microbes.

Quick Tip to Solve: For inhaled pathogens, link mucus trapping with ciliary removal before mentioning phagocytes.

22(b). Name and describe any two barriers involved in this protection.

[2 marks]

Solution:

Concept:

- Innate immunity includes physical, physiological, cellular and cytokine barriers.
- Physical barriers hinder the entry of pathogens, whereas cellular barriers destroy microbes that have entered the body.

Step 1: Describe the physical barrier The mucus coating of the respiratory epithelium traps inhaled dust and microorganisms. Cilia move this mucus towards the throat for removal, reducing the chance that microbes reach deeper tissues. Mucous membranes therefore act as a physical barrier against infection. The skin is another physical barrier, although respiratory mucus is the relevant example for inhaled pathogens.

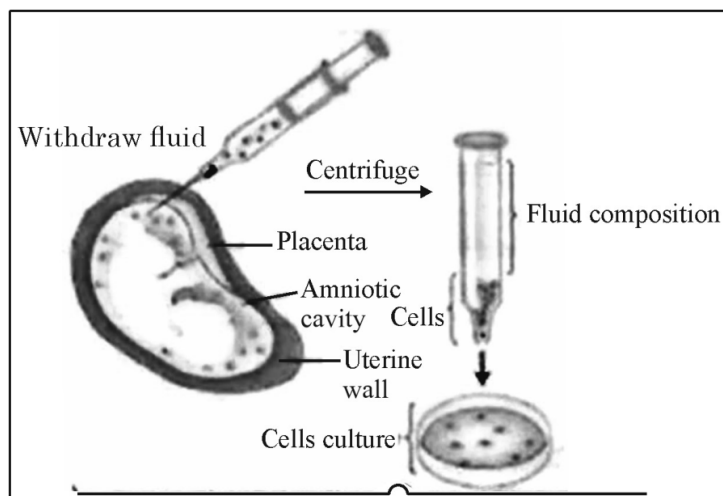
Step 2: Describe the cellular barrier Phagocytic white blood cells, including neutrophils and monocytes in blood and macrophages in tissues, provide a cellular barrier. They engulf microbes into intracellular vesicles and destroy them by digestion. This acts against a broad range of pathogens and does not depend on previous exposure to that particular microbe.

Step 3: Conclusion Two protective barriers are the physical barrier of respiratory mucus, which traps inhaled microbes, and the cellular barrier of phagocytes, which engulf and destroy invading microbes.

Quick Tip to Solve: Name each barrier category, then give a matching example and its action: mucus traps; phagocytes engulf.

23(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 technique using amniotic fluid and the foetal cells present in it.
- Foetal cells can be examined for chromosomal abnormalities, while appropriate analyses can identify certain genetic or metabolic disorders.

Step 1: Identify and explain the procedure The diagram shows amniocentesis. A needle is introduced into the amniotic cavity and a small sample of amniotic fluid is withdrawn. The sample contains cells shed by the foetus. As illustrated, these cells are separated by centrifugation, cultured and examined, for example by analysing their chromosomes; the fluid can also be analysed biochemically.

Step 2: State an advantage and a disadvantage An advantage is prenatal detection of certain foetal disorders, such as the chromosomal abnormality responsible for Down's syndrome. This provides information about the foetus before birth. A major disadvantage is its misuse for prenatal sex determination, which can lead to sex-selective abortion and female foeticide; this is a harmful misuse of a diagnostic technique.

Step 3: Conclusion The procedure is amniocentesis: amniotic fluid containing foetal cells is sampled and analysed. It can detect certain foetal abnormalities, but its misuse for sex determination can promote female foeticide.

Quick Tip to Solve: Identify the sampled material first: fluid from the amniotic cavity containing foetal cells indicates amniocentesis.

23(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 progestogen–estrogen combinations.
- Saheli is a non-steroidal oral contraceptive containing centchroman, also called ormeloxifene.

Step 1: Compare the composition Saheli contains the non-steroidal compound centchroman. It therefore differs from conventional oral pills based on steroidal hormones such as progestogens, alone or in combination with estrogen.

Step 2: State its advantage In the NCERT description, Saheli is a once-a-week pill with high contraceptive value and very few side effects. Its weekly schedule is convenient compared with the daily schedule of conventional oral contraceptive pills.

Step 3: Conclusion Saheli is non-steroidal, containing centchroman, and offers high contraceptive effectiveness with very few side effects and a convenient once-a-week schedule.

Quick Tip to Solve: Pair Saheli with two recall cues: non-steroidal composition and a weekly pill with very few side effects.

24. Chasmogamous flowers remain open and expose their reproductive parts. Explain how this structural feature supports different types of pollination.

[3 marks]

Solution:

Concept:

- Pollination is the transfer of pollen grains from the anther to the stigma. Chasmogamous flowers open, exposing their anthers and stigmas.
- Autogamy, geitonogamy and xenogamy are distinguished by whether the pollen comes from the same flower, another flower on the same plant, or a flower on another plant of the same species.

Step 1: Explain autogamy within one flower In a bisexual chasmogamous flower, pollen from its own anthers can reach its stigma. Autogamy is possible when pollen release and stigma receptivity are synchronised and the anthers and stigma lie close enough for pollen transfer. Opening does not prevent self-pollination, but unlike cleistogamous flowers it does not guarantee autogamy.

Step 2: Explain geitonogamy between flowers of one plant The exposed anthers make pollen available to pollinating agents, while the exposed stigma can receive it. An agent can carry pollen from one open flower to another flower on the same plant. This is geitonogamy: functionally it requires cross-pollination between flowers, but genetically it is similar to autogamy because the pollen comes from the same plant.

Step 3: Explain xenogamy between different plants An exposed stigma can also receive pollen carried by wind or animals from an open flower on a different plant of the same species. This transfer is xenogamy and brings genetically different pollen to the stigma. Thus, access to the reproductive parts

enables exchange of pollen beyond the individual flower and plant.

Step 4: Conclusion Chasmogamy permits autogamy under suitable conditions and allows pollinating agents to bring about geitonogamy and xenogamy by providing access to exposed anthers and stigmas.

Quick Tip to Solve: Classify each transfer by its pollen source: same flower, same plant, or another plant of the same species.

25(a). What is a genetic code?

[1 mark]

Solution:

Concept:

- A protein is a chain of amino acids whose order is specified by the nucleotide sequence of a gene.
- During translation, the message in mRNA is read in successive triplets of nucleotides called codons.

Step 1: Identify the information being read The ribosome reads the sequence of codons in mRNA. A codon is a sequence of three consecutive nucleotides; for example, AUG specifies methionine.

Step 2: State the coding relationship Each codon specifies an amino acid or a termination signal. The set of rules relating these nucleotide triplets to their meanings directs the amino acid sequence during protein synthesis.

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

Quick Tip to Solve: Distinguish a codon, one nucleotide triplet, from the genetic code, the complete codon-to-meaning relationship.

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

[1 mark]

Solution:

Concept:

- Nucleic acids store information using four kinds of nucleotide bases, whereas proteins are assembled from twenty kinds of amino acids.
- Translation must convert the order of nucleotides into the order of amino acids in a polypeptide.

Step 1: Recognise the two different chemical languages Scientists knew that genetic information in DNA determines protein synthesis. However, nucleic acids contain nucleotides and proteins contain amino acids, so their sequences are expressed in different chemical languages.

Step 2: Explain the need for a correspondence A coding relationship was therefore needed to explain how a sequence built from four bases could specify the sequence of twenty amino acids. Proposing the genetic code connected the nucleotide message, carried into mRNA, with the amino acids selected during translation.

Step 3: Conclusion Scientists proposed a genetic code to explain how the sequence of nucleotide

bases determines the amino acid sequence of a protein.

Quick Tip to Solve: For the need for a code, connect the four-base nucleotide language with the twenty-amino-acid protein language.

25(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 stop signal.
- Universality refers to the conservation of the meaning of a codon across organisms.

Step 1: Compare the meaning of a codon In almost all organisms, the same codon specifies the same amino acid. For example, UUU specifies phenylalanine in a bacterium as well as in a human cell.

Step 2: Distinguish a shared code from identical sequences Organisms can have very different genes and proteins while using the same codon meanings to translate their messages. A few exceptions, particularly in mitochondrial codes and some protozoans, mean that the genetic code is more precisely described as nearly universal.

Step 3: Conclusion The genetic code is called universal because a particular codon specifies the same amino acid in almost all organisms.

Quick Tip to Solve: Support universality with one conserved codon meaning, such as UUU for phenylalanine; do not claim all organisms have identical genes.

26(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 using small pieces of plant tissue called explants.
- It uses cellular totipotency: suitable plant cells can regenerate complete plants when supplied with appropriate nutrients and growth regulators under sterile conditions.

Step 1: Explain rapid multiplication A small amount of starting tissue can be cultured and multiplied repeatedly to produce a large number of plants in a short time. Thus a valuable selected plant can supply many plantlets without waiting for repeated cycles of conventional propagation.

Step 2: Explain retention of desirable characteristics Micropropagation can produce genetically identical plants, called somaclones, from a selected parent. The regenerated plants retain the parent's desirable characteristics, giving a uniform crop and allowing a useful plant variety to be multiplied 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 traits of the selected parent.

Quick Tip to Solve: Pair the two advantages with distinct keywords: rapid multiplication for quantity and somaclones for genetic uniformity.

26(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 plant tissue culture to multiply selected plants rapidly under controlled conditions.
- Commercial adoption is useful when large numbers of plants with desirable parental characteristics are required.

Step 1: Identify banana as one example Banana is commercially multiplied by micropropagation. Small explants from selected plants are cultured to generate many plantlets for cultivation.

Step 2: Identify apple as another example Apple is another commercially adopted example of micropropagation. Tissue culture enables selected plant material to be multiplied on a large scale while retaining desirable characteristics of the parent.

Step 3: Conclusion Two examples in which micropropagation is commercially adopted are banana and apple.

Quick Tip to Solve: For two commercial examples of micropropagation, recall the NCERT crop names banana and apple.

27(a). Give the scientific name of the organism used by Morgan to study sex-linked traits.

[1 mark]

Solution:

Concept:

- Morgan used the fruit fly to investigate inheritance, including traits whose genes are located on sex chromosomes.
- A scientific name contains a genus followed by a specific epithet; both words are written in italics.

Step 1: Identify Morgan's experimental organism Thomas Hunt Morgan studied inheritance in fruit flies. His studies of eye colour helped establish the association of certain traits with the X chromosome.

Step 2: State its binomial name The genus is *Drosophila* and the specific epithet is *melanogaster*. Capitalise the genus, keep the specific epithet lowercase and italicise both words.

Step 3: Conclusion Morgan used the fruit fly, *Drosophila melanogaster*.

Quick Tip to Solve: Associate Morgan with fruit flies and write the complete italicised binomial, not only the common name.

27(b). Write any four reasons why this organism made it an ideal experimental model.

[2 marks]

Solution:

Concept:

- An ideal organism for inheritance studies should be easy to maintain and should provide many offspring over several generations.
- Morgan's fruit fly, *Drosophila melanogaster*, combines convenient laboratory culture with rapid reproduction and readily distinguishable sexes.

Step 1: Explain culture and generation time (1) Fruit flies can be grown easily on a simple synthetic medium in the laboratory, so large cultures can be maintained without elaborate conditions.

(2) They complete their life cycle in about two weeks. This short generation time allows inheritance to be followed through several generations within a relatively short experimental period.

Step 2: Explain offspring number and sex identification (3) A single mating produces a large number of offspring, allowing the frequencies of inherited traits and the resulting ratios to be studied reliably. (4) Males and females are easily distinguishable. This makes it convenient to select the sexes required for planned genetic crosses and to compare traits in male and female progeny.

Step 3: Conclusion Four reasons are easy culture on a simple synthetic medium, a short life cycle of about two weeks, many offspring from a single mating, and easily distinguishable males and females.

Quick Tip to Solve: Recall four distinct advantages: culture, short generation time, many progeny and distinguishable sexes.

28(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 simple organic molecules formed from inorganic precursors before the origin of life.
- Such abiotic synthesis requires suitable environmental conditions and a source of energy to drive chemical reactions.

Step 1: Identify the hypothesis being tested Miller recreated conditions thought to resemble those of the primitive Earth, including a reducing gaseous atmosphere and an energy supply. He sought experimental support for the chemical origin of the building blocks of life.

Step 2: Relate the test to organic synthesis The experiment tested whether simple organic compounds, such as amino acids, could be produced abiotically from simple inorganic starting materials under these simulated conditions. It did not aim to create a complete living organism.

Step 3: Conclusion The aim was to demonstrate the abiotic synthesis of organic compounds from inorganic precursors under conditions resembling those of the early Earth.

Quick Tip to Solve: State the aim as abiotic formation of organic molecules; do not confuse forming amino acids with creating life.

28(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:

- Miller's experiment simulated a reducing atmosphere, with simple gases circulating through a closed apparatus.
- An external energy source was needed to drive reactions that could convert these starting materials into simple organic compounds.

Step 1: Name the gaseous mixture The mixture contained methane (CH_4), ammonia (NH_3), hydrogen (H_2) and water vapour (H_2O). Water was heated to supply vapour to the circulating mixture, representing evaporation from the primitive water body. Free molecular oxygen was not included in this reducing atmosphere.

Step 2: Identify the energy source Electric sparks, produced by an electrical discharge between electrodes, provided the reaction energy. These sparks simulated lightning in the primitive atmosphere. Heating supplied water vapour, while the electrical discharge was the energy source used to imitate atmospheric lightning and promote synthesis of organic molecules.

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

Quick Tip to Solve: Recall CH_4 , NH_3 , H_2 and water vapour, then link electric sparks specifically with lightning.

Section D (8 marks)

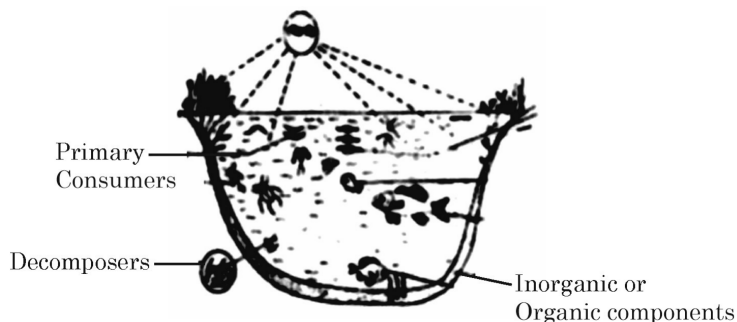
Question Nos. 29 and 30 are case-based questions. Each question has some sub-sections with internal choice in one sub-section.

29(a). 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.
- In a pond, these components supply the medium, energy and materials required by living organisms.

Step 1: Identify a non-living physical component Water is an abiotic component. It forms the medium in which pond organisms live and in which dissolved substances are transported. Water itself is non-living, unlike the plants and animals within it.

Step 2: Identify a non-living chemical component Dissolved mineral nutrients, such as nitrates and phosphates, are another abiotic component. Aquatic producers absorb these inorganic nutrients for growth; the nutrients are distinct from the living producers that use them.

Step 3: Conclusion Two abiotic components are water and dissolved mineral nutrients.

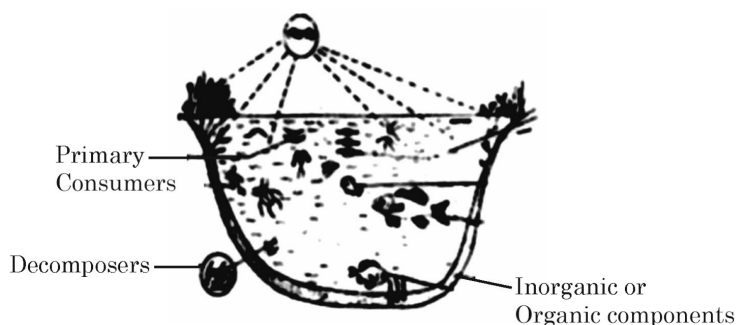
Quick Tip to Solve: Choose non-living factors such as water and mineral nutrients; algae, fish and decomposer microbes are biotic.

29(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 synthesise organic food from inorganic substances using an external energy source, usually sunlight.
- Decomposers are heterotrophic organisms that break down dead organic matter and help return mineral nutrients to the abiotic environment.

Step 1: Explain the role of producers Pond producers include phytoplankton, algae and aquatic plants. They capture solar energy through photosynthesis and use carbon dioxide and water to synthesise organic food. Their biomass supplies food and stored chemical energy to consumers, forming the first trophic level and the base of the pond's food web.

Step 2: Explain the role of decomposers Bacteria and fungi decompose dead plants, dead animals and organic wastes. Their enzymes break complex organic matter into simpler substances; mineralisation releases inorganic nutrients into the water and sediment. Producers can absorb these nutrients again. Thus decomposers recycle nutrients, whereas producers incorporate inorganic materials into new organic biomass. Energy flows through the ecosystem and is dissipated as heat; it is not recycled like nutrients.

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

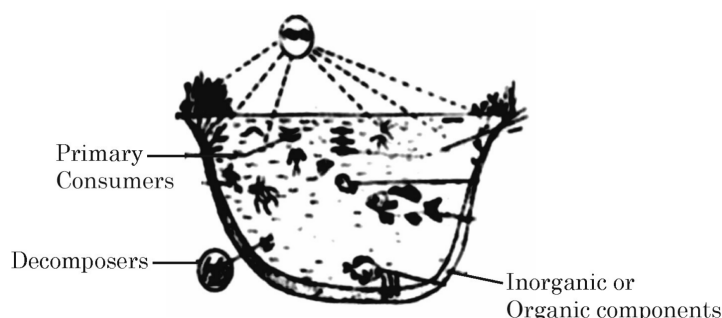
Quick Tip to Solve: Contrast food synthesis by algae and plants with nutrient release by bacteria and fungi; nutrients cycle, but energy does not.

29(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]



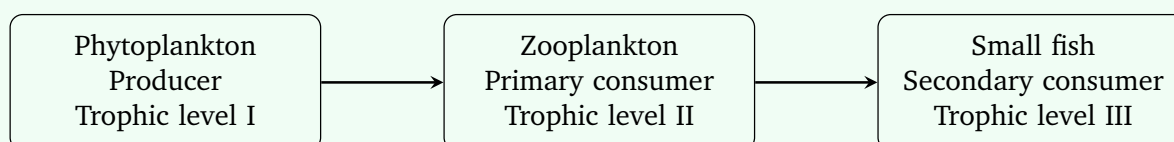
Solution:

Concept:

- A grazing food chain begins with a producer and follows the transfer of food energy to successive consumers.
- Each feeding position is a trophic level; arrows point from the organism eaten towards the organism that eats it.

Step 1: Choose organisms from a pond food chain Phytoplankton are photosynthetic producers. Zooplankton feed on phytoplankton, and small fish feed on zooplankton. These organisms give a simple grazing food chain appropriate to a pond ecosystem.

Step 2: Label the successive trophic levels Place phytoplankton at trophic level I, zooplankton at trophic level II and small fish at trophic level III. Their roles are producer, primary consumer and secondary consumer, respectively. The arrows show the direction in which food and its stored energy pass.



A simple pond food chain with its trophic levels

Step 3: Conclusion The labelled pond food chain is phytoplankton (producer, I) → zooplankton (primary consumer, II) → small fish (secondary consumer, III).

Quick Tip to Solve: Start the pond chain with phytoplankton and point each arrow towards the organism receiving the food energy.

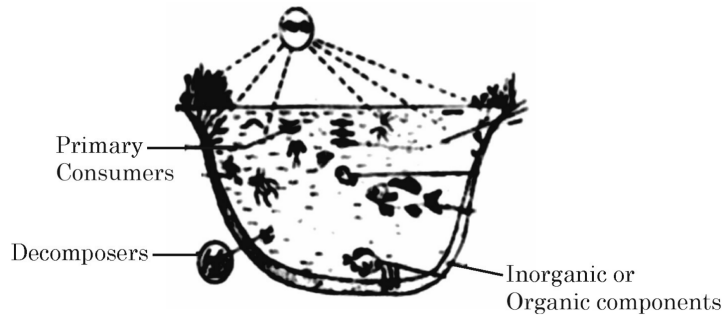
OR

29(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 flows through trophic levels, but organisms use much of the energy they obtain for their own life processes.
- Only energy retained in biomass and consumed by the next trophic level can be transferred to it.

Step 1: Identify the losses within a trophic level Organisms use food energy in respiration, maintenance and other metabolic activities. Much of this energy is dissipated as heat to the surroundings and cannot become food energy for the next trophic level.

Step 2: Identify the losses during feeding Not all biomass is eaten, and part of the food eaten is not digested or assimilated. Consequently, only a small fraction of the energy becomes new consumer biomass. The ten per cent law expresses the approximate transfer of energy to the next trophic level.

Step 3: Conclusion Energy transfer is not 100% efficient because energy is lost as heat during metabolism and through uneaten or unassimilated material; only the energy stored in consumed biomass is passed on.

Quick Tip to Solve: Link the inefficiency to respiratory heat loss and incomplete consumption or assimilation of food.

30(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 involves techniques that alter the chemistry of genetic material and introduce it into a host organism.
- Recombinant DNA technology joins DNA from different sources and is a major means of genetic engineering.

Step 1: Identify the change described The passage describes cutting a desired DNA fragment and joining it to plasmid DNA. This changes the genetic material by making a recombinant DNA molecule rather than merely growing an organism under controlled conditions.

Step 2: Name the core technique Genetic engineering is the core biotechnology technique that makes such alterations possible. The altered genetic material can be introduced into a host, where it is maintained and can change the host's characteristics when the introduced gene is expressed.

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

Quick Tip to Solve: When a question emphasises altering DNA or introducing a desired gene, identify genetic engineering.

30(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 present outside the main bacterial chromosome.
- Plasmids have an origin of replication, allowing them to replicate independently of the bacterial chromosome and act as cloning vectors.

Step 1: Define a plasmid A plasmid is an extrachromosomal, autonomously replicating DNA molecule found in bacteria. It may carry additional genes, such as genes for antibiotic resistance, but it is distinct from the main bacterial chromosome. Its own origin of replication enables the host cell to make copies of it.

Step 2: Explain its role in biotechnology A suitable plasmid acts as a vector that carries a desired foreign DNA fragment into a host cell. The fragment is joined to the plasmid to form recombinant DNA. When the recombinant plasmid replicates inside the host, the inserted DNA is also copied, so many copies of the desired gene can be produced. Selectable markers in a cloning plasmid help identify host cells that have acquired the vector; appropriate expression vectors can also support production of the gene's protein product.

Step 3: Conclusion A plasmid is small, extrachromosomal, independently replicating DNA. In biotechnology it serves as a cloning vector for introducing and amplifying a desired foreign gene in a host.

Quick Tip to Solve: Pair the definition with the vector function: the plasmid's origin of replication enables multiplication of the inserted DNA.

30(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:

- Early recombinant DNA experiments joined an antibiotic-resistance gene to plasmid DNA that could act as a vector.
- The source of the isolated gene must be distinguished from the host bacterium used to multiply the recombinant DNA.

Step 1: Identify the isolated gene Cohen and Boyer isolated a DNA segment carrying an antibiotic-resistance gene. Restriction enzymes made it possible to cut out DNA bearing this trait and join it with plasmid DNA using DNA ligase.

Step 2: State the source bacterium The antibiotic-resistance gene was obtained from *Salmonella typhimurium*. Do not confuse this source with *Escherichia coli*, which was used as the host for introducing and multiplying the recombinant DNA.

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

Quick Tip to Solve: Remember the pairing: antibiotic-resistance gene from *Salmonella typhimurium*; *E. coli* is the cloning host.

30(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 positions at which they act on a DNA molecule.

Step 1: Describe exonuclease action An exonuclease removes nucleotides successively from a free end of DNA. Its action therefore proceeds inward from a terminal position rather than beginning at a site within an intact DNA chain.

Step 2: Describe endonuclease action An endonuclease cuts DNA at internal positions by breaking phosphodiester bonds within the chain. It does not have to start at a free end. Restriction endonucleases are a particular class that recognise specific DNA sequences and cut at defined positions associated with them.

Step 3: Conclusion Exonucleases remove nucleotides from the **ends** of DNA, whereas endonucleases cut DNA at **internal sites**.

Quick Tip to Solve: Associate “exo” with a DNA end and “endo” with an internal cut; the distinction is the site of action.

Section E (15 marks)

31(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:

- Acquired Immuno Deficiency Syndrome (AIDS) is characterised by progressive weakening of acquired immunity and susceptibility to opportunistic infections.
- Human Immunodeficiency Virus (HIV) is the retrovirus that causes AIDS; helper T-lymphocytes are important targets of its infection.

Step 1: Interpret the clinical clues The recurrent infections, prolonged fever and weight loss indicate that the patient's immune defences have become severely weakened. The accompanying decline in T-lymphocyte count is the decisive clue: loss of helper T cells impairs the coordination of immune

responses, so organisms normally controlled by immunity can cause repeated infections.

Step 2: Link the immune deficiency to its pathogen This combination of findings identifies the syndrome as AIDS. Its causative agent is HIV, an RNA-containing retrovirus. It infects immune cells, including helper T-lymphocytes, and progressive depletion of these cells produces the immunodeficiency described in the question. AIDS names the disease syndrome, whereas HIV names the infectious agent.

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

Quick Tip to Solve: Pair recurrent opportunistic infections with a falling helper T-cell count to identify AIDS, then name HIV separately as its cause.

31(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: reverse transcriptase produces a DNA copy from its RNA genome, allowing the viral genetic material to become incorporated into host-cell DNA.
- Helper T-lymphocytes coordinate immune responses, so their progressive depletion reduces the body's ability to resist infections.

Step 1: Explain multiplication in macrophages After entering the body, HIV enters macrophages. Viral RNA forms viral DNA with the help of reverse transcriptase. This viral DNA becomes incorporated into the host-cell DNA and directs the infected cell to produce virus particles. Macrophages continue producing viruses and act as an HIV factory.

Step 2: Trace the loss of immune protection HIV also enters helper T-lymphocytes, replicates in them and produces progeny viruses. These infect further helper T cells; repeated cycles lead to a progressive decrease in their number. As helper T cells are depleted, immune responses become ineffective and the person becomes vulnerable to opportunistic infections, accounting for the recurrent infections in the patient.

Step 3: Conclusion HIV multiplies in macrophages and helper T-lymphocytes, and progressively depletes helper T cells. The resulting loss of immune coordination causes immunodeficiency and recurrent opportunistic infections.

Quick Tip to Solve: Recall the sequence: macrophage infection, reverse transcription, viral multiplication, then progressive helper T-cell depletion.

31(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 transmission requires transfer of infected body fluids through a suitable route of entry.
- Sexual contact and direct exposure to infected blood are major transmission routes; ordinary casual contact does not transmit HIV.

Step 1: Identify sexual transmission Unprotected sexual contact with an HIV-infected person can transmit the virus through infected sexual fluids entering the partner's body.

Step 2: Identify transmission through blood Transfusion of HIV-contaminated blood or blood products can introduce the virus directly into the recipient's circulation.

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

Quick Tip to Solve: Give two distinct routes, such as sexual contact and contaminated blood transfusion; do not list two examples of the same route.

OR

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

Solution:

Concept:

- Biological control uses living organisms to suppress crop pests and disease-causing organisms.
- Suitable microbial biocontrol agents reduce dependence on chemical pesticides while conserving beneficial organisms and ecological balance.

Step 1: Explain effective pest suppression Selected microbes attack target pests or inhibit plant pathogens, thereby reducing crop damage. Their action can be selective, helping preserve beneficial organisms such as pollinators and natural enemies of pests.

Step 2: Relate biocontrol to sustainability By replacing or reducing chemical pesticide use, these agents reduce harmful chemical residues and environmental pollution. Pest suppression with lower disruption of biodiversity supports long-term sustainable agriculture.

Step 3: Conclusion Microbes are effective biocontrol agents because they suppress pests and pathogens in an environmentally friendly way, reducing chemical pesticide use and helping maintain ecological balance.

Quick Tip to Solve: Link microbial pest control to reduced chemical pesticide use and preservation of beneficial organisms when explaining sustainability.

31(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:

- Biocontrol uses living organisms or their products to suppress crop pests and pathogens, reducing dependence on chemical pesticides.
- A microbial agent must be matched to its target: insecticidal bacteria, antagonistic fungi and host-specific viruses perform different protective roles.

Step 1: Explain the bacterial agent *Bacillus thuringiensis* (Bt) controls insect larvae, particularly butterfly caterpillars. Preparations containing its spores and insecticidal protein crystals are sprayed on vulnerable plants, such as brassicas and fruit trees. A caterpillar ingests the preparation while feeding. The alkaline environment of its gut activates the toxin; the active toxin damages midgut epithelial cells, causing the larva to die. Thus the bacterium targets the feeding pest rather than acting as a plant fertiliser.

Step 2: Explain the fungal agent Species of *Trichoderma* are free-living fungi commonly present in root ecosystems. They suppress several soil-borne plant pathogens by competition, antagonistic substances and parasitism of other fungi. For example, they help control damping-off and root-rot pathogens such as *Rhizoctonia* and *Pythium*. Their role is protection against plant disease, unlike Bt's direct action against insect larvae.

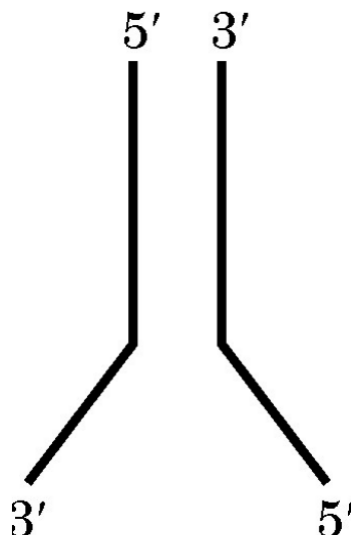
Step 3: Explain the viral agent Baculoviruses, especially members of the genus *Nucleopolyhedrovirus*, are used against insect pests and other arthropods. A host-specific example is the nucleopolyhedrovirus of *Helicoverpa armigera*, used to control its caterpillars, including the cotton bollworm. The virus multiplies in susceptible larvae and kills them. Their narrow host range spares plants, mammals, birds, fish and non-target insects, so they are valuable in integrated pest management where beneficial insects must be conserved.

Step 4: Conclusion Bt controls caterpillar pests; *Trichoderma* suppresses soil-borne plant diseases; and host-specific baculoviruses such as nucleopolyhedroviruses control susceptible insect larvae.

Quick Tip to Solve: Pair each microbe with a target and its action: Bt–caterpillars–gut toxin; *Trichoderma*–root pathogens–antagonism; NPV–specific larvae–viral infection.

32(a)(i). Identify the structure shown above and name the process taking place.

[1 mark]



Solution:

Concept:

- DNA replication copies parental DNA before cell division, using each parental strand as a template.
- Local separation of the two antiparallel parental strands produces a Y-shaped replication fork.

Step 1: Identify the Y-shaped junction The figure shows two strands separating at a fork, with opposite 5' and 3' polarities. This junction is the replication fork, where the parental double helix is opened to expose the templates.

Step 2: Relate the fork to DNA copying Complementary daughter strands are synthesised on the exposed templates during DNA replication. The process is semiconservative: each resulting DNA molecule contains one parental strand and one newly synthesised strand.

Step 3: Conclusion The structure is a replication fork, and the process is DNA replication.

Quick Tip to Solve: Recognise the Y-shaped opening of antiparallel DNA strands as a replication fork, the working region for DNA copying.

32(a)(ii). Write the source of energy for the process and list the enzymes involved.

[1 mark]

Solution:

Concept:

- Deoxyribonucleoside triphosphates (dNTPs) have a dual role in replication: they supply DNA building blocks and energy for polymerisation.
- Replication requires enzymes to open DNA, initiate and extend new strands, and join discontinuously formed segments.

Step 1: State the energy source The incoming dNTPs, namely dATP, dGTP, dCTP and dTTP, supply the

energy for DNA synthesis. Incorporation releases pyrophosphate, whose subsequent hydrolysis helps drive polymerisation; energy is associated with the high-energy phosphate bonds of these substrates.

Step 2: List the replication enzymes Helicase unwinds the parental DNA, primase makes RNA primers, DNA-dependent DNA polymerase extends the new DNA strands, and DNA ligase seals nicks between adjacent DNA fragments. Topoisomerase relieves torsional strain ahead of the fork.

Step 3: Conclusion Energy for DNA polymerisation comes from dNTPs. The enzymes include helicase, primase, DNA-dependent DNA polymerase, DNA ligase and topoisomerase.

Quick Tip to Solve: Remember the dual role of dNTPs: they are both the monomers and the energy source for DNA chain formation.

32(a)(iii). Mention the difference in the process based on polarity. What terms are used for such synthesis? [2 marks]

Solution:

Concept:

- The two parental DNA strands are antiparallel. DNA polymerase adds nucleotides only to a free 3'-OH end, so every new DNA strand grows in the $5' \rightarrow 3'$ direction.
- The relative polarity of a template with respect to fork movement determines whether its daughter strand is made continuously or in fragments.

Step 1: Describe continuous synthesis On the parental template running $3' \rightarrow 5'$ in the direction of fork movement, DNA polymerase can synthesise the complementary daughter strand continuously in the $5' \rightarrow 3'$ direction, following the advancing fork. This is continuous synthesis, and the daughter strand is called the leading strand.

Step 2: Describe discontinuous synthesis The other parental template runs $5' \rightarrow 3'$ in the direction of fork movement. Its daughter strand cannot grow continuously towards the fork because polymerase cannot synthesise DNA in the $3' \rightarrow 5'$ direction. Instead, short Okazaki fragments are made, each in the $5' \rightarrow 3'$ direction away from the fork. DNA ligase joins the fragments after primer removal and gap filling. This is discontinuous synthesis, and the daughter strand is the lagging strand.

Step 3: Conclusion The $3' \rightarrow 5'$ template supports continuous leading-strand synthesis, whereas the oppositely oriented template supports discontinuous lagging-strand synthesis as Okazaki fragments. Both daughter strands are synthesised only $5' \rightarrow 3'$.

Quick Tip to Solve: Assign polarity to the template first: never write that the lagging daughter strand is synthesised $3' \rightarrow 5'$; each of its fragments still grows $5' \rightarrow 3'$.

32(a)(iv). Redraw the structure after completion of the process and label the newly synthesised parts.

[1 mark]

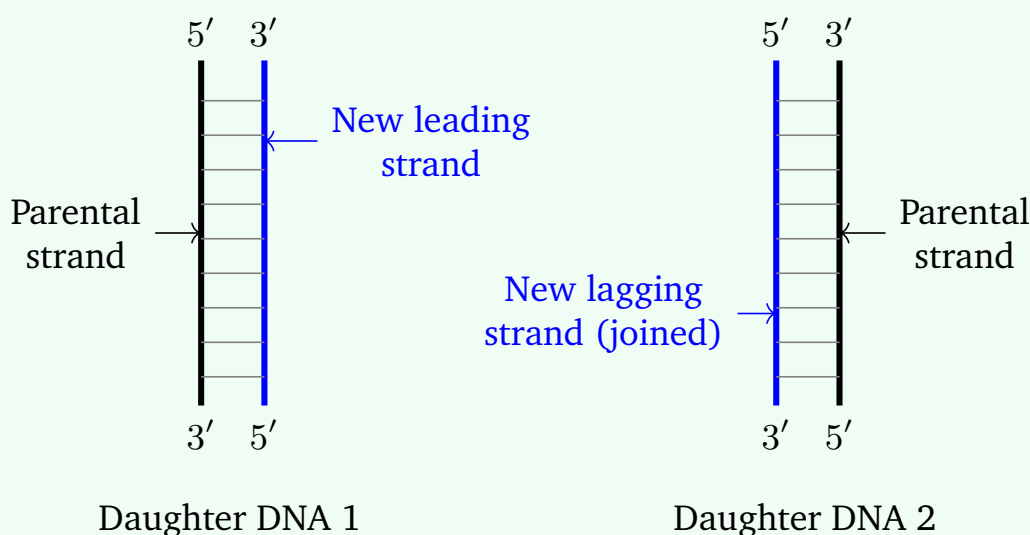
Solution:

Concept:

- DNA replication is semiconservative: each daughter DNA molecule contains one parental strand and one newly synthesised complementary strand.
- The strands in each double-stranded DNA molecule are antiparallel; synthesis always proceeds in the $5' \rightarrow 3'$ direction.

Step 1: Complete the complementary strands Each separated parental strand serves as a template. Draw a new complementary strand alongside each template, keeping their polarities opposite. The result is two daughter DNA molecules, rather than one molecule containing both old strands.

Step 2: Label the newly synthesised parts The blue strands below are newly synthesised DNA. Relative to the upward-moving fork in the question, synthesis on the left-hand template is continuous (leading strand), whereas synthesis on the right-hand template is discontinuous (lagging strand). At completion, DNA ligase has joined the lagging-strand fragments into a continuous strand.



Completed daughter DNA molecules (schematic); blue denotes newly synthesised DNA.

Step 3: Conclusion The two daughter DNA molecules each contain one parental strand and one newly synthesised strand, as labelled in the diagram.

Quick Tip to Solve: In each daughter DNA, pair one old strand with one new strand and put opposite polarity labels at the same end.

32(b)(i). How would you find out whether a given garden pea plant is homozygous or heterozygous? Substantiate your answer with the help of Punnett square. [4 marks]

Solution:

Concept:

- In garden pea, the allele T for tallness is dominant over the allele t for dwarfness. A tall plant may therefore have genotype TT or Tt .
- A test cross crosses an individual showing the dominant phenotype with a homozygous recessive individual. The recessive parent contributes only t , so the offspring reveal the gametes formed by the unknown parent.

Step 1: Cross the tall plant with a dwarf plant For plant height, a dwarf plant is already known to be homozygous recessive, tt . If the given plant is tall, cross it with a dwarf pea plant of known genotype tt , then observe the heights of their offspring. This is a test cross. Crossing it with another tall plant would be less informative because the dominant allele in that other parent could mask a recessive allele carried by the unknown plant.

Step 2: Test the homozygous possibility If the tall parent is TT , it produces only T gametes. The dwarf parent produces only t gametes. The Punnett square for $TT \times tt$ is

Dwarf ↓ Tall →	T	T
t	Tt	Tt
t	Tt	Tt

Every offspring is Tt and therefore tall. The repeated rows and columns show that each parent produces only one allele type in its gametes.

Step 3: Test the heterozygous possibility If the tall parent is Tt , it produces T and t gametes in equal proportions. The Punnett square for $Tt \times tt$ is

Dwarf ↓ Tall →	T	t
t	Tt	tt
t	Tt	tt

Half the expected offspring are tall Tt , and half are dwarf tt . Thus the expected phenotypic and genotypic ratios are both 1 : 1. The occurrence of a dwarf offspring establishes that the tall parent supplied a recessive t allele and is therefore heterozygous.

Step 4: Conclusion Perform a test cross with tt . All-tall progeny are the expected result for TT ; a 1 tall : 1 dwarf ratio indicates Tt . In practice, examine many offspring, since a small family may by chance contain only tall plants even when the parent is Tt .

Quick Tip to Solve: Use a recessive tester: every dwarf offspring exposes a recessive allele in the unknown tall parent.

32(b)(ii). Given below are F_2 phenotypic ratios of two independently carried monohybrid crosses.

(1) 1 : 2 : 1

(2) 3 : 1

Mention what does each ratio suggest.

[1 mark]

Solution:

Concept:

- A monohybrid cross between two heterozygotes gives an F_2 genotypic ratio of 1 : 2 : 1. The phenotypic ratio depends on the relationship between the two alleles.
- Complete dominance makes the heterozygote resemble the dominant homozygote, whereas incomplete dominance gives the heterozygote an intermediate phenotype.

Step 1: Interpret the phenotypic ratio 1 : 2 : 1 This suggests incomplete dominance, as in red, pink and white flowers of snapdragon: both homozygotes and the heterozygote have distinguishable phenotypes. More generally, codominance can also produce this phenotypic ratio because both alleles are expressed in the heterozygote; the ratio alone does not distinguish these two patterns.

Step 2: Interpret the phenotypic ratio 3 : 1 This suggests complete dominance. For example, in $Tt \times Tt$, the genotypes are $1TT : 2Tt : 1tt$, but TT and Tt are both tall. Grouping them gives 3 tall : 1 dwarf.

Step 3: Conclusion (1) 1 : 2 : 1 suggests incomplete dominance (and is also compatible with codominance); (2) 3 : 1 suggests complete dominance.

Quick Tip to Solve: Check whether the ratio is phenotypic: a 1 : 2 : 1 phenotypic ratio means the heterozygote is distinguishable from both homozygotes.

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

[1 mark]

Solution:

Concept:

- The stigma is the receptive surface of the pistil on which pollen grains are deposited during pollination.
- Pollen-pistil interaction includes chemical recognition that determines whether pollen is compatible and can proceed towards fertilisation.

Step 1: Recognise the pollen After pollen lands on the stigma, chemical components of the pollen interact with those of the pistil. This interaction enables the pistil to recognise suitable, compatible pollen and discriminate against incompatible pollen.

Step 2: Promote or prevent further development The receptive stigma supports hydration and germination of compatible pollen, allowing a pollen tube to grow into the style. Incompatible pollen is rejected by inhibiting its germination on the stigma or its subsequent pollen-tube growth in the pistil.

Step 3: Conclusion The stigma receives and recognises pollen, supporting germination and tube growth of compatible pollen while contributing to rejection of incompatible pollen.

Quick Tip to Solve: Link stigma function to both reception and compatibility recognition; pollen deposition alone does not ensure fertilisation.

33(a)(ii). Describe the post pollination events leading to double fertilization in angiosperms starting with 2-celled pollen grain. [4 marks]

Solution:

Concept:

- A two-celled pollen grain contains a vegetative cell and a generative cell. The vegetative cell produces the pollen tube, while the generative cell divides mitotically to form two male gametes.
- Double fertilization in an angiosperm embryo sac comprises syngamy and triple fusion. Here n denotes one haploid chromosome set.

Step 1: Germinate the compatible pollen grain After compatible pollen lands on a receptive stigma, it germinates. A pollen tube emerges through a germ pore and grows through the tissues of the stigma and style towards the ovary. During tube growth, the generative cell of the two-celled pollen grain divides by mitosis to produce two haploid male gametes. The tube carries both male gametes towards the ovule.

Step 2: Deliver both male gametes to the embryo sac The pollen tube reaches the ovule and generally enters through the micropyle. It enters one of the synergids through the filiform apparatus, which helps guide its entry. The pollen tube then releases its two male gametes into the cytoplasm of the synergid, close to the egg cell and the central cell.

Step 3: Carry out syngamy One male gamete moves towards the egg cell and its nucleus fuses with the haploid egg nucleus. This fusion is called syngamy. It produces a diploid zygote, which subsequently develops into the embryo.

$$n \text{ (male gamete)} + n \text{ (egg)} = 2n \text{ (zygote)}.$$

Step 4: Carry out triple fusion The other male gamete moves towards the two polar nuclei in the central cell and fuses with them. Since three haploid nuclei participate, this event is called triple fusion. It forms the triploid primary endosperm nucleus; the resulting primary endosperm cell develops into the endosperm, which nourishes the developing embryo.

$$n \text{ (male gamete)} + n + n \text{ (polar nuclei)} = 3n.$$

Step 5: Conclusion Syngamy and triple fusion occur in the same embryo sac, together constituting double fertilization. They produce the diploid zygote and the triploid primary endosperm nucleus, respectively.

Quick Tip to Solve: Trace the two male gametes separately: one joins the egg, while the other joins the two polar nuclei; then name both fusion events.

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

[1 mark]

Solution:

Concept:

- The menstrual phase begins the menstrual cycle and usually lasts about 3–5 days.
- Maintenance of the uterine endometrium depends on ovarian hormones, especially progesterone.

Step 1: Identify the hormonal trigger When fertilization does not occur, the corpus luteum degenerates. Consequently, progesterone and oestrogen levels fall, so the thickened uterine lining is no longer maintained.

Step 2: Explain the menstrual flow The endometrium and its blood vessels break down. Blood, tissue fragments and secretions are discharged through the vagina as menstrual flow. The first day of this bleeding is counted as the first day of the cycle.

Step 3: Conclusion The menstrual phase is the periodic shedding of the uterine endometrium with bleeding, following the fall in ovarian hormones when pregnancy has not occurred.

Quick Tip to Solve: Link the sequence: corpus luteum degeneration, hormone withdrawal, endometrial breakdown and menstrual flow.

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

[1 mark]

Solution:

Concept:

- The follicular phase describes the development of ovarian follicles before ovulation.
- Oestrogen secreted by growing follicles stimulates regeneration and proliferation of the uterine endometrium.

Step 1: Relate follicular growth to hormone secretion During the follicular phase, ovarian follicles grow and mature under the influence of pituitary gonadotropins, particularly FSH. The developing follicles secrete increasing amounts of oestrogen.

Step 2: Explain the change in the uterine lining Oestrogen causes the endometrium, shed during menstruation, to regenerate through cell proliferation. The lining thickens and its glands and blood vessels develop, preparing the uterus for possible implantation.

Step 3: Conclusion The follicular phase is also called the proliferative phase because the uterine endometrium regenerates and proliferates under the influence of oestrogen from growing follicles.

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

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

[2 marks]

Solution:

Concept:

- Ovulation is the rupture of a mature Graafian follicle and release of its secondary oocyte, triggered by the mid-cycle LH surge.
- After ovulation, the remaining follicular cells form the corpus luteum, a temporary endocrine structure that secretes mainly progesterone.

Step 1: Describe the follicle at ovulation The primary oocyte has completed meiosis I to form a large haploid secondary oocyte and a small first polar body. The secondary oocyte begins meiosis II and is arrested at metaphase II. The rapid rise in luteinising hormone (LH surge), around the middle of the menstrual cycle, causes the mature Graafian follicle to rupture and release the secondary oocyte, surrounded by its zona pellucida and corona radiata.

Step 2: Describe the follicle after ovulation The cells left in the ruptured follicle undergo luteinisation and form the corpus luteum under LH influence. It secretes large amounts of progesterone, which maintains the thickened uterine endometrium for implantation and pregnancy. If pregnancy does not occur, the corpus luteum degenerates, progesterone levels fall and the endometrium breaks down. If pregnancy occurs, embryonic hCG initially maintains the corpus luteum and its hormone secretion.

Step 3: Conclusion At ovulation, the Graafian follicle ruptures and releases the secondary oocyte. Thereafter, its remaining cells form the progesterone-secreting corpus luteum.

Quick Tip to Solve: Keep the two events in order: LH surge causes follicular rupture; luteinisation of the remaining follicle produces the corpus luteum.

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

[1 mark]

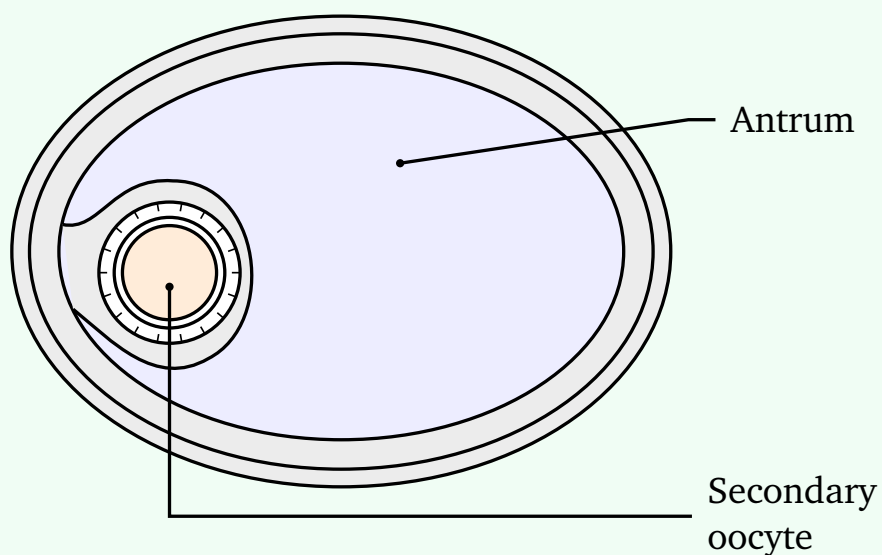
Solution:

Concept:

- A Graafian follicle is the mature ovarian follicle. Its wall encloses a large, fluid-filled cavity called the antrum.
- The secondary oocyte lies eccentrically, surrounded by the zona pellucida and follicular cells, on a mound of granulosa cells attached to the follicular wall.

Step 1: Draw the mature follicle Draw the follicular wall around a large cavity. Show the oocyte near one side, supported by follicular cells, rather than at the centre of the antrum.

Step 2: Label the two structures Direct the antrum label to the fluid-filled cavity and the secondary-oocyte label to the large cell itself. The surrounding rings represent its coverings, not the oocyte.



Graafian follicle with antrum and secondary oocyte

Step 3: Conclusion The labelled Graafian follicle shows the large antrum and the eccentrically placed secondary oocyte.

Quick Tip to Solve: Make the antrum conspicuously large, and end the secondary-oocyte label inside the cell rather than on its outer covering.