

CBSE Class 12 Biology Question Paper 2009 with Solution PDF-Set 57/1

Question Paper with Solutions

Conducted by the Central Board of Secondary Education (CBSE)



Time Allowed: 3 hours

Maximum Marks: 70

General Instructions

- (i) All questions are compulsory.
- (ii) This question paper consists of four Sections **A**, **B**, **C** and **D**. Section **A** contains **8** questions of **one** mark each, Section **B** is of **10** questions of **two** marks each, Section **C** is of **9** questions of **three** marks each and Section **D** is of **3** questions of **five** marks each.
- (iii) There is no overall choice. However, an internal choice has been provided in one question of **2** marks, one question of **3** marks and all the three questions of **5** marks weightage. A student has to attempt only one of the alternatives in such questions.
- (iv) Wherever necessary, the diagrams drawn should be neat and properly labelled.

Section A (8 marks)

1. When and at what end does the 'tailing' of hnRNA take place?

[1 mark]

Solution:

Concept:

- Heterogeneous nuclear RNA (hnRNA) is the primary transcript in a eukaryotic cell; it is processed in the nucleus before becoming mature mRNA.
- Tailing is polyadenylation: addition of a chain of adenylate residues to an RNA end.

Step 1: Identify the stage Tailing occurs during post-transcriptional processing of hnRNA in the nucleus, before the mature mRNA is transported to the cytoplasm for translation.

Step 2: Identify the end A poly-A tail, consisting of about 200–300 adenylate residues, is added at the 3' end. The 5' end instead receives a cap during processing.

Step 3: Conclusion Tailing takes place during post-transcriptional processing of hnRNA, at its 3' end.

Quick Tip to Solve: Remember the two ends as: cap at 5', poly-A tail at 3'.

2. Name the type of flower which favours cross pollination.

[1 mark]

Solution:

Concept:

- Cross-pollination requires pollen to reach a receptive stigma outside the same flower.
- Chasmogamous flowers open at maturity, exposing their anthers and stigma to pollinating agents.

Step 1: Identify the floral condition An open flower gives wind or an animal pollinator access to the anthers and stigma. This allows pollen from another flower to be deposited on its stigma.

Step 2: Distinguish the closed condition Cleistogamous flowers remain closed, so their anthers and stigma stay enclosed together and self-pollination is ensured. In contrast, the exposed organs of a chasmogamous flower favour the opportunity for cross-pollination.

Step 3: Conclusion Chasmogamous flowers favour cross-pollination.

Quick Tip to Solve: Use the opening of the flower as the clue: chasmogamous means open, while cleistogamous means closed.

3. Name the type of cells the AIDS virus enters into after getting in the human body.

[1 mark]

Solution:

Concept:

- Human immunodeficiency virus (HIV), the causative agent of AIDS, infects cells of the immune system.

- Macrophages are early host cells in which HIV can multiply; helper T-lymphocytes are also infected subsequently.

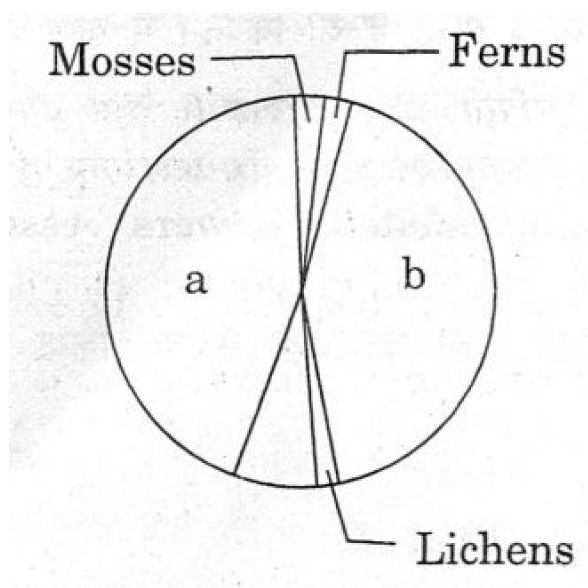
Step 1: Identify the initial host cell After entering the human body, HIV enters macrophages. Within these cells, its RNA genome is reverse-transcribed into viral DNA, which becomes incorporated into the host-cell DNA.

Step 2: Relate entry to infection The infected macrophages produce new virus particles and act as HIV factories. The subsequent infection and depletion of helper T-lymphocytes explains the progressive weakening of immune responses, but the initial cell type sought here is the macrophage.

Step 3: Conclusion HIV enters macrophages after getting into the human body.

Quick Tip to Solve: For the initial entry stage name macrophages; associate progressive immune failure with loss of helper T-lymphocytes.

4. Name the unlabelled areas 'a' and 'b' of the pie chart representing the biodiversity of plants showing their proportionate number of species of major taxa. [1 mark]



Solution:

Concept:

- The sectors of a biodiversity pie chart represent the relative numbers of species in the indicated taxonomic groups.
- The textbook plant-diversity chart includes fungi and angiosperms among its two large sectors, alongside smaller groups such as mosses, ferns and lichens.

Step 1: Identify the left sector The large sector labelled *a*, on the left of the printed chart, represents fungi. Follow the position of the printed letter rather than the neighbouring leader lines for mosses or lichens.

Step 2: Identify the right sector The large sector labelled *b*, on the right of the chart, represents

angiosperms, the flowering plants. The narrow sectors already labelled mosses, ferns and lichens are separate categories.

Step 3: Conclusion *a*: Fungi; *b*: Angiosperms (flowering plants).

Quick Tip to Solve: Anchor each name to the printed letter: the left large sector is fungi and the right large sector is angiosperms.

5. According to Hardy-Weinberg's principle the allele frequency of a population remains constant. How do you interpret the change of frequency of alleles in a population? [1 mark]

Solution:

Concept:

- The Hardy-Weinberg principle describes genetic equilibrium: allele frequencies remain constant from generation to generation in an ideal population.
- A change in allele frequencies over generations is an evolutionary change in the population gene pool.

Step 1: Apply the equilibrium criterion Under Hardy-Weinberg equilibrium, the proportions of the alternative alleles do not change between generations. Constant allele frequencies therefore provide a reference against which evolutionary change can be detected.

Step 2: Interpret the observed change If allele frequencies change, the population has departed from genetic equilibrium. Evolutionary forces such as natural selection, genetic drift, mutation or gene flow may cause this shift; the change itself signals evolution at the population level.

Step 3: Conclusion A change in allele frequency indicates that evolution is occurring in the population, disturbing Hardy-Weinberg equilibrium.

Quick Tip to Solve: Compare allele frequencies across generations: a shift in the gene pool is the key evidence for evolution.

6. A boy of ten years had chicken-pox. He is not expected to have the same disease for the rest of his life. Mention how it is possible. [1 mark]

Solution:

Concept:

- Active acquired immunity develops when the body responds to an infection by producing its own immune response.
- Immunological memory enables a faster and stronger response when the same antigen is encountered again.

Step 1: Explain the first infection During chicken-pox, the viral antigens stimulate a primary immune response. In addition to cells that fight the infection, antigen-specific memory B- and T-lymphocytes are formed and persist after recovery.

Step 2: Explain protection on re-exposure When the same virus is encountered again, these memory cells mount a rapid, strong secondary immune response. It can control the infection before the usual disease develops, explaining the long-lasting protection expected after the first episode.

Step 3: Conclusion He develops long-lasting active acquired immunity through memory cells, which produce a strong secondary response on re-exposure.

Quick Tip to Solve: Link recovery to memory-cell formation, then link the next exposure to the faster secondary immune response.

7. Which one of the following is the baker's yeast used in fermentation? *Saccharum barberi*, *Saccharomyces cerevisiae*, Sonalika.

[1 mark]

Solution:

Concept:

- Yeast is a unicellular fungus used in the fermentation of sugars.
- Baker's yeast releases carbon dioxide during fermentation; this gas causes bread dough to rise.

Step 1: Identify the fermenting organism *Saccharomyces cerevisiae* is the yeast used in baking and fermentation. It converts sugars into ethanol and carbon dioxide under anaerobic conditions; the carbon dioxide becomes trapped in dough.

Step 2: Exclude the other names *Saccharum barberi* is a species of sugarcane, a crop plant rather than a yeast. Sonalika is a wheat variety. Neither is the microorganism called baker's yeast.

Step 3: Conclusion The baker's yeast is *Saccharomyces cerevisiae*.

Quick Tip to Solve: Associate *Saccharomyces* with yeast fermentation; *Saccharum* names sugarcane and Sonalika names wheat.

8. Why is bagging of the emasculated flowers essential during hybridization experiments? [1 mark]

Solution:

Concept:

- Emasculation removes the anthers before pollen is shed, preventing self-pollination in a bisexual flower.
- Bagging isolates the receptive stigma from unwanted pollen carried by wind or pollinating animals.

Step 1: Identify the risk after emasculation Although its own anthers have been removed, the flower still has a functional stigma. Pollen from other, undesired plants can reach this stigma and fertilise its ovules.

Step 2: Ensure controlled pollination Covering the emasculated flower with a suitable bag prevents contamination by unwanted pollen. When the stigma becomes receptive, pollen from the selected male parent is applied and the flower is rebagged.

Step 3: Conclusion Bagging is essential to prevent unwanted cross-pollination and ensure that only pollen from the chosen male parent participates in the intended hybridisation.

Quick Tip to Solve: Link emasculation to preventing self-pollination and bagging to excluding unwanted external pollen.

Section B (20 marks)

9. What are recombinant proteins? How do bioreactors help in their production?

[2 marks]

Solution:

Concept:

- Recombinant DNA technology introduces a gene of interest into a suitable host so that the host expresses the desired protein.
- A bioreactor provides controlled conditions for large-scale culture of cells and formation of a biological product.

Step 1: Define recombinant proteins Proteins produced by expressing introduced recombinant DNA in a host organism are called recombinant proteins. For example, bacteria carrying the appropriate human gene can be used to manufacture human insulin. The introduced gene supplies the information for the desired protein, while the host cell provides the machinery for its synthesis.

Step 2: Explain the role of a bioreactor A bioreactor grows the engineered cells in a large volume of nutrient medium. It maintains suitable temperature, pH, nutrient supply and, when required, oxygen availability. Stirring and aeration keep the culture well mixed and support efficient growth and expression. Thus, the desired recombinant protein can be produced in large quantities under controlled conditions; it is subsequently separated and purified by downstream processing.

Step 3: Conclusion Recombinant proteins are products of genes introduced using recombinant DNA technology. Bioreactors enable their large-scale production by maintaining favourable, controlled culture conditions.

Quick Tip to Solve: Answer both demands: define the protein by its recombinant gene, then name the culture conditions controlled by the bioreactor.

10. (a) Name the lymphoid organ in humans where all the blood cells are produced. (b) Where do the lymphocytes produced by the lymphoid organ mentioned above migrate and how do they affect immunity?

[2 marks]

Solution:

Concept:

- Primary lymphoid organs provide sites for the formation and maturation of lymphocytes; bone marrow also produces the other blood cells.
- Secondary lymphoid organs bring mature lymphocytes into contact with antigens and support

specific immune responses.

Step 1: Identify the blood-cell-producing organ in part (a) The organ is the bone marrow. Its haematopoietic stem cells give rise to all types of blood cells, including lymphocytes. B lymphocytes mature in the bone marrow, whereas T-lymphocyte precursors migrate to the thymus for maturation.

Step 2: Trace migration and immune action in part (b) After maturation, lymphocytes migrate to secondary lymphoid organs, such as the lymph nodes, spleen, tonsils and Peyer's patches. These sites facilitate interaction of lymphocytes with antigens. Antigen stimulation causes the appropriate lymphocytes to proliferate and differentiate. B cells form antibody-secreting plasma cells and provide humoral immunity; T cells mediate cellular immune responses and help regulate immunity. Memory lymphocytes support a faster response on subsequent exposure.

Step 3: Conclusion (a) Bone marrow produces all blood cells. (b) Mature lymphocytes populate secondary lymphoid organs, where antigen recognition initiates specific humoral and cell-mediated immune responses.

Quick Tip to Solve: Separate the sites of production and maturation from secondary lymphoid organs, where lymphocytes encounter antigens and respond.

11. Draw a vertical section of a maize grain and label (i) pericarp, (ii) scutellum, (iii) coleoptile and (iv) radicle. [2 marks]

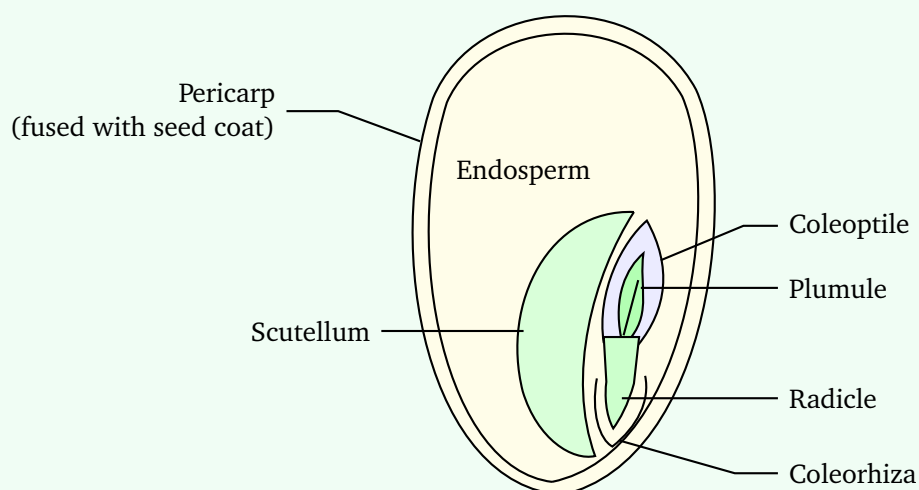
Solution:

Concept:

- A maize grain is a caryopsis: its thin fruit wall, the pericarp, is fused with the seed coat.
- The monocot embryo has a single shield-shaped cotyledon, the scutellum, and an embryonal axis bearing the plumule and radicle.

Step 1: Outline the grain and locate the embryo Draw a vertical section with the endosperm occupying most of the grain and the embryo lying to one side near its base. Indicate the thin outer covering as the pericarp fused with the seed coat. Position the broad scutellum between the endosperm and the embryonal axis; it is the single cotyledon and assists in transfer of stored food to the growing embryo.

Step 2: Label the shoot covering and embryonic root Show the plumule at the upper end of the embryonal axis and surround it with the protective coleoptile. At the lower end, show the radicle, the embryonic root, enclosed by the coleorhiza. The radicle label must point to the root itself, whereas the coleoptile label points to the sheath surrounding the plumule. The labelled vertical section is shown below.



Vertical section of a maize grain (schematic)

Step 3: Conclusion The diagram identifies the pericarp at the outer boundary, scutellum beside the endosperm, coleoptile surrounding the plumule, and radicle at the lower end of the embryo.

Quick Tip to Solve: Remember the protective pairs: plumule–coleoptile and radicle–coleorhiza; label the radicle itself, not its sheath.

OR

11. Where are the Leydig cells present? What is their role in reproduction?

[2 marks]

Solution:

Concept:

- The testes perform both a gamete-producing function and an endocrine function. Different cell types carry out these functions.
- Leydig cells, also called interstitial cells, synthesise and secrete the male sex hormones called androgens, principally testosterone.

Step 1: Locate the Leydig cells Leydig cells occur in the interstitial spaces between the seminiferous tubules of the testes. They lie outside the tubules, in the tissue containing blood vessels; they are not the germ cells or the Sertoli cells present within the tubules.

Step 2: Explain their reproductive role In response to luteinising hormone (LH) from the anterior pituitary, Leydig cells secrete androgens. These hormones support spermatogenesis and the growth and maintenance of male reproductive organs. They also promote the development and maintenance of male secondary sexual characters, such as facial hair and a deep voice, at puberty.

Step 3: Conclusion Leydig cells are present between the seminiferous tubules of the testes and secrete androgens, chiefly testosterone, which support sperm formation and male reproductive development.

Quick Tip to Solve: Link Leydig with the spaces between tubules and testosterone; link Sertoli with nourishment of germ cells inside the tubules.

12. Explain the dual function of AUG codon. Give the sequence of bases it is transcribed from and its anticodon. [2 marks]

Solution:

Concept:

- A codon is a triplet of bases in mRNA read in the $5' \rightarrow 3'$ direction during translation. AUG specifies methionine and also serves as an initiation codon.
- The DNA template and the mRNA are complementary and antiparallel. A tRNA anticodon also pairs with its mRNA codon in an antiparallel manner.

Step 1: State the two functions of AUG AUG codes for the amino acid methionine. In addition, at the translation initiation site it acts as the start codon, specifying where protein synthesis begins and establishing the reading frame. Thus its amino-acid coding function and its initiation function are its two roles.

Step 2: Identify the template triplet and anticodon Apply complementary base pairing, remembering that RNA contains uracil rather than thymine. The DNA template triplet that produces the mRNA codon, and the tRNA anticodon that pairs with it, are aligned as follows:

DNA template: $3'\text{-TAC-}5'$
mRNA codon: $5'\text{-AUG-}3'$
tRNA anticodon: $3'\text{-UAC-}5'$.

The DNA coding strand would be $5'\text{-ATG-}3'$, but it is the complementary template strand that is transcribed. Written in the opposite direction, the same anticodon is $5'\text{-CAU-}3'$.

Step 3: Conclusion AUG codes for methionine and initiates translation. It is transcribed from the template triplet $3'\text{-TAC-}5'$; its complementary anticodon is $3'\text{-UAC-}5'$.

Quick Tip to Solve: Write the mRNA codon with its ends first, then put the DNA template and tRNA anticodon antiparallel to it; this prevents confusing TAC with ATG.

13. Explain the cause of algal bloom in a water body. How does it affect an ecosystem? [2 marks]

Solution:

Concept:

- An algal bloom is the excessive growth of planktonic algae in a water body enriched with nutrients, particularly nitrogen and phosphorus.
- Eutrophication links nutrient enrichment to increased biological production and subsequent deterioration of water quality, including depletion of dissolved oxygen.

Step 1: Explain the cause of the bloom Agricultural runoff containing fertilisers and domestic sewage carry nitrates and phosphates into ponds or lakes. The increased availability of these nutrients permits rapid multiplication of algae, producing a dense algal population or bloom at the water surface.

Step 2: Trace the effects on the ecosystem Dense algal growth reduces light penetration and can

suppress submerged plants. When algae and other aquatic organisms die, aerobic microbes decompose the organic matter and consume dissolved oxygen. The resulting oxygen depletion can kill fish and other oxygen-dependent aquatic animals, changing the species composition of the ecosystem. Blooms also impair water quality, and some bloom-forming organisms release toxins harmful to aquatic life and animals using the water.

Step 3: Conclusion Nutrient enrichment, chiefly by nitrates and phosphates, causes algal blooms. These blooms degrade water quality and can cause oxygen depletion, fish mortality and a loss of aquatic biodiversity.

Quick Tip to Solve: Trace the sequence: extra nutrients, excess algae, decomposition, oxygen depletion and fish death; identify decomposition as the major oxygen-consuming link.

14. List the specific symptoms of typhoid. Name its causative agent.

[2 marks]

Solution:

Concept:

- Typhoid is a bacterial infectious disease caused by *Salmonella typhi*. It usually spreads through food or water contaminated with the pathogen.
- The pathogen enters the small intestine and can spread through the blood to other organs, producing a sustained fever and systemic illness.

Step 1: List the characteristic symptoms The characteristic symptoms are sustained high fever, usually 39–40 °C, weakness, headache, stomach pain, constipation and loss of appetite. The fever is persistent, and the associated abdominal discomfort and weakness are characteristic features of the illness. In severe cases, intestinal perforation may occur and the disease may be fatal.

Step 2: Identify the causative organism The causative agent is the bacterium *Salmonella typhi*. In the scientific name, the genus *Salmonella* begins with a capital letter, while the specific name *typhi* begins with a lower-case letter. Both are written in italics in print.

Step 3: Conclusion Typhoid is caused by *Salmonella typhi*; its characteristic symptoms include sustained high fever, weakness, headache, stomach pain, constipation and loss of appetite.

Quick Tip to Solve: Associate typhoid with sustained high fever and abdominal symptoms, and write both words of the causative bacterium's scientific name.

15. Name the pioneer and the climax species in a water body. Mention the changes observed in the biomass and the biodiversity of the successive seral communities developing in the water body.

[2 marks]

Solution:

Concept:

- Hydrarch succession starts in an aquatic habitat and proceeds through a series of seral communities towards a stable, mesic climax community.

- Each community modifies its environment, making conditions suitable for the community that replaces it.

Step 1: Identify the pioneer and climax communities The pioneer organisms in a water body are phytoplankton, mainly microscopic algae. They are followed by submerged plants, floating plants, reed-swamp plants, marsh-meadow vegetation and, eventually, woody vegetation. The climax community is a forest dominated by trees, as suited to the regional climate.

Step 2: State the trends during succession The biomass of the successive seral communities generally increases as vegetation becomes larger and more complex. Biodiversity, or species diversity, also generally increases as more kinds of organisms and ecological interactions develop. Accumulation of organic matter and sediment gradually changes the aquatic habitat into a mesic terrestrial habitat.

Step 3: Conclusion Phytoplankton are the pioneers and forest trees form the climax community. Both biomass and biodiversity generally increase during the successive seral stages.

Quick Tip to Solve: For hydrarch succession, remember the endpoints: phytoplankton in water to trees on mesic land; biomass and diversity generally rise.

16. How is DNA isolated in purified form from a bacterial cell?

[2 marks]

Solution:

Concept:

- DNA isolation requires breaking open the bacterial cell and separating DNA from RNA, proteins and other cellular components.
- Specific enzymes remove unwanted macromolecules, while chilled ethanol precipitates the purified DNA from solution.

Step 1: Break open the bacterial cell Treat bacterial cells with lysozyme to digest the cell wall. Disruption of the cell membrane releases the cellular contents, including DNA, into solution. This initial extract also contains RNA, proteins and other components, so it is not yet purified DNA.

Step 2: Remove contaminants and precipitate DNA Treat the extract with ribonuclease to remove RNA and with protease to digest proteins associated with DNA. After removing the digested material and other contaminants by suitable separation, add chilled ethanol. DNA precipitates as a collection of fine threads, which can be collected by spooling with a glass rod.

Step 3: Conclusion Lysozyme-assisted cell lysis, removal of RNA by ribonuclease and proteins by protease, followed by chilled-ethanol precipitation, yields purified bacterial DNA.

Quick Tip to Solve: Keep the enzyme targets distinct: lysozyme acts on the bacterial wall, ribonuclease on RNA and protease on proteins; ethanol precipitates DNA.

17. Explain metastasis. Why is it fatal?

[2 marks]

Solution:

Concept:

- Malignant tumour cells divide uncontrollably and can invade surrounding healthy tissues.
- Metastasis is the spread of malignant cells from their original site to distant tissues, where they establish secondary tumours.

Step 1: Explain how metastasis occurs Some cells detach from the primary malignant tumour, enter the blood or lymph and travel to other parts of the body. At a new site they leave the circulation, invade the tissue and proliferate to form secondary tumours. Thus metastasis means spread to new sites, rather than merely enlargement of the original tumour.

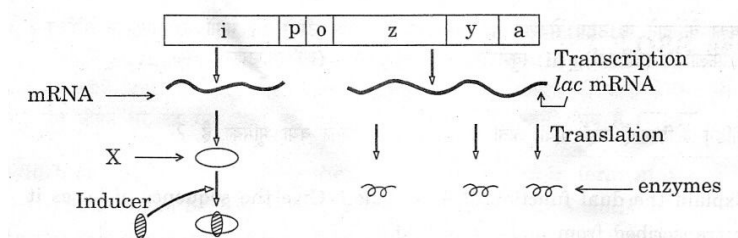
Step 2: Explain its potentially fatal effects Secondary tumours invade and damage normal tissues and compete with healthy cells for nutrients. When they develop in vital organs such as the lungs, liver or brain, they interfere with essential organ functions. Involvement of several distant sites also makes complete removal or control of the cancer difficult; progressive organ failure can cause death.

Step 3: Conclusion Metastasis is the spread of cancer cells to distant sites with formation of secondary tumours. It can be fatal because widespread tumour growth destroys healthy tissue and disrupts vital organ functions.

Quick Tip to Solve: Link the definition and danger in sequence: detached malignant cells, distant secondary tumours, damage to vital organs.

18. (a) Name the molecule 'X' synthesised by 'i' gene. How does this molecule get inactivated? (b) Which one of the structural genes codes for β -galactosidase? (c) When will the transcription of this gene stop?

[2 marks]



Solution:

Concept:

- The lac operon is an inducible gene-regulation system. Its regulatory *i* gene produces a repressor that controls transcription through the operator.
- The structural genes *z*, *y* and *a* code for β -galactosidase, permease and transacetylase, respectively.

Step 1: Identify and inactivate molecule X (a) Molecule X is the repressor protein synthesised from the *i* gene. In the presence of lactose, the inducer binds the repressor and changes its conformation, making it unable to bind the operator. More precisely, the physiological inducer is allolactose, formed from lactose. The operator is therefore available for transcription to proceed.

Step 2: Identify the enzyme-coding gene (b) The z gene, also called $lacZ$, codes for β -galactosidase. This enzyme hydrolyses lactose into glucose and galactose. The neighbouring y gene codes for permease, which increases entry of lactose into the cell.

Step 3: State when transcription stops (c) When lactose is exhausted or absent, the inducer is no longer available to keep the repressor inactive. The active repressor binds the operator and blocks RNA polymerase from transcribing the structural genes, including z . Thus the lactose-utilising enzymes cease to be produced through operon transcription.

Step 4: Conclusion (a) X is the repressor, inactivated by inducer binding. (b) The z gene codes for β -galactosidase. (c) Transcription stops when lactose is absent and the active repressor occupies the operator.

Quick Tip to Solve: Read the figure as an on/off switch: inducer bound to repressor means operator free; active repressor on operator means transcription off.

Section C (27 marks)

19. Fertilization is essential for production of seed, but in some angiosperms seeds develop without fertilization. (i) Give an example of an angiosperm that produces seeds without fertilization. Name the process. (ii) Explain the two ways by which seeds develop without fertilization. [3 marks]

Solution:

Concept:

- Apomixis is seed formation without fertilization. It is an asexual mode of reproduction that mimics sexual reproduction by producing seeds.
- The embryo may arise from an unreduced egg without gamete fusion, or directly from a diploid somatic cell of the ovule.

Step 1: Identify the example and process (i) *Citrus* is an angiosperm in which embryos can develop from nucellar cells without fertilization. The formation of seeds without fertilization is called apomixis. Some members of Asteraceae and some grasses also show this process. Apomixis must be distinguished from parthenocarpy, in which a fruit develops without fertilization and is usually seedless.

Step 2: Explain embryo formation from an unreduced egg (ii) In the first pathway, the diploid egg cell is formed without reduction division, so it retains the maternal chromosome number. This unreduced egg develops into an embryo without fusion with a male gamete. Thus, the usual requirement of fertilization for initiating the embryo is bypassed, while the diploid condition is retained.

Step 3: Explain embryo formation from nucellar cells In the second pathway, diploid nucellar cells surrounding the embryo sac start dividing. They protrude into the embryo sac and develop directly into embryos, without undergoing fertilization. This is adventive embryony, seen in *Citrus* and mango. When several such embryos occur in a single seed, the condition is called polyembryony.

Step 4: Conclusion An example is *Citrus*, and the process is apomixis. The two pathways are development of an unreduced egg without fertilization and direct embryo development from diploid nucellar cells.

Quick Tip to Solve: For the two pathways, identify the embryo's starting cell: an unreduced egg in one and a nucellar cell in the other. Do not confuse seed-producing apomixis with seedless parthenocarpy.

20. Explain any three measures which will control vehicular air pollution in Indian cities. [3 marks]

Solution:

Concept:

- Vehicular exhaust contains harmful pollutants such as carbon monoxide, unburnt hydrocarbons, nitrogen oxides and particulate matter.
- Air pollution can be controlled by using cleaner fuels, treating exhaust gases and ensuring efficient fuel combustion in engines.

Step 1: Replace polluting fuels with a cleaner fuel Convert public transport vehicles from diesel to compressed natural gas (CNG). CNG burns more completely than petrol or diesel and produces much less smoke, soot and other combustion-related pollution. Widespread use of CNG buses therefore reduces the pollutant load released along busy city roads. This measure controls pollution at its source by changing the fuel being burnt.

Step 2: Treat exhaust with catalytic converters Fit vehicles with catalytic converters containing catalysts such as platinum, palladium and rhodium. As exhaust passes through the converter, unburnt hydrocarbons are converted into carbon dioxide and water, carbon monoxide into carbon dioxide, and nitrogen oxides into nitrogen. Use unleaded petrol in these vehicles because lead in petrol inactivates the catalysts and makes the converter ineffective.

Step 3: Maintain engines and check emissions Service vehicles regularly, keep engines properly tuned and conduct periodic pollution-under-control checks. Proper maintenance improves combustion and reduces the release of carbon monoxide and unburnt fuel. Vehicles that exceed emission limits should be repaired, and old, persistently polluting vehicles should be phased out. Such checks ensure that cleaner vehicle technology continues to work during actual use.

Step 4: Conclusion Three effective measures are switching to CNG, using catalytic converters with unleaded petrol, and maintaining vehicles with regular emission checks and removal of persistently polluting vehicles.

Quick Tip to Solve: Organise the three measures as cleaner fuel, exhaust treatment and engine maintenance; explain how each reduces the pollutants released.

21. (a) Why do the symptoms of malaria not appear immediately after the entry of sporozoites into the human body when bitten by female *Anopheles*? Explain. (b) Give the scientific name of the malarial parasite that causes malignant malaria in humans. [3 marks]

Solution:

Concept:

- Female *Anopheles* mosquitoes transmit *Plasmodium* to humans in the sporozoite stage. The parasite first multiplies in liver cells and then infects red blood cells.
- Rupture of infected red blood cells releases the toxic substance haemozoin and is associated with the characteristic chills and fever of malaria.

Step 1: Trace the initial liver stage (a) After an infected female *Anopheles* bites a person, sporozoites

enter the body and reach the liver. They invade liver cells and multiply asexually, producing many daughter parasites. This initial multiplication takes time and precedes the repeated destruction of red blood cells responsible for the characteristic symptoms. Therefore, the entry of sporozoites does not cause an immediate malarial fever.

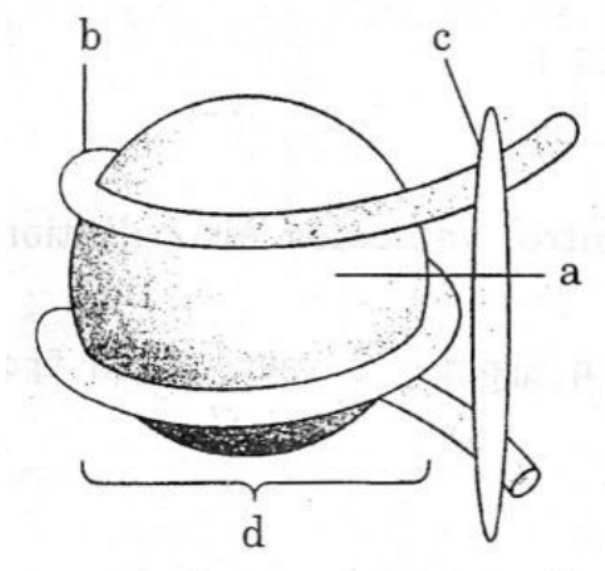
Step 2: Connect the blood stage to delayed symptoms Parasites released from the liver enter red blood cells and multiply within them. The infected red blood cells subsequently rupture, releasing more parasites and haemozoin. Haemozoin release is associated with bouts of chills and high fever. The released parasites infect fresh red blood cells, so further cycles of multiplication and rupture produce recurring attacks. The interval required for liver multiplication and establishment of the blood stage explains the delay between the infective bite and symptoms.

Step 3: Identify the parasite causing malignant malaria (b) The malarial parasite responsible for malignant malaria in humans is *Plasmodium falciparum*. This is the pathogen's scientific name; *Anopheles* is the mosquito vector that transmits it, not the parasite itself.

Step 4: Conclusion Symptoms are delayed because the parasite first multiplies in liver cells and subsequently in red blood cells; rupture of infected red blood cells releases haemozoin and produces the characteristic fever and chills. Malignant malaria is caused by *Plasmodium falciparum*.

Quick Tip to Solve: Remember the sequence: sporozoites enter, liver multiplication occurs, red blood cells become infected and rupture, then haemozoin-associated fever appears.

22. (a) What is this diagram representing? (b) Name the parts a, b and c. (c) In the eukaryotes the DNA molecules are organised within the nucleus. How is the DNA molecule organised in a bacterial cell in absence of a nucleus? [3 marks]



Solution:

Concept:

- A nucleosome is the repeating structural unit of eukaryotic chromatin, formed by DNA wrapped around a histone octamer.
- DNA is negatively charged, whereas histones are rich in positively charged basic amino acids, allowing tight association during DNA packaging.
- Bacteria lack a membrane-bound nucleus, but their DNA is organised in a defined region of the cytoplasm called the nucleoid.

Step 1: Identify the structure in part (a) The diagram represents a **nucleosome**. Its central protein core is surrounded by DNA. Repetition of these units gives chromatin its characteristic beads-on-a-string appearance; subsequent folding helps accommodate the long DNA molecule inside the eukaryotic nucleus.

Step 2: Name the labelled parts in part (b) **a: Histone octamer**, the core containing two molecules each of histones H2A, H2B, H3 and H4. **b: DNA**, which winds around the histone core. **c: Histone H1**, the linker histone associated with DNA near its entry and exit from the nucleosome; it helps stabilise the packaging. H1 is associated with the nucleosome but is not one of the eight histones of its core.

Step 3: Explain bacterial DNA organisation in part (c) In a bacterial cell, the DNA is not scattered randomly throughout the cytoplasm. The usually circular DNA molecule is negatively supercoiled and organised into large loops held by associated proteins, forming the **nucleoid**. Thus protein association and coiling compact the chromosome even though a nuclear envelope is absent; typical eukaryotic nucleosomes are not the bacterial packaging units.

Step 4: Conclusion The figure is a nucleosome: a is the histone octamer, b is DNA and c is histone H1. Bacterial DNA is compacted into protein-associated, supercoiled loops in the nucleoid.

Quick Tip to Solve: Distinguish the central eight-histone core from H1 at the DNA entry and exit region; in bacteria, use the term nucleoid, not nucleus.

23. Ornithologists observed decline in the bird population in an area near a lake after the setting of an industrial unit in the same area. Explain the cause responsible for the decline observed. [3 marks]

Solution:

Concept:

- Biomagnification is the progressive increase in the concentration of a persistent toxic substance at successive trophic levels of a food chain.
- A pollutant that is not readily metabolised or excreted accumulates in organisms and is passed to predators when contaminated prey are eaten.

Step 1: Trace the pollutant from the industrial unit Industrial effluents discharged into the lake can introduce persistent toxic chemicals into its water. These substances enter aquatic producers and small organisms and accumulate in their tissues. A pollutant may therefore have serious biological

effects even when its concentration in the surrounding water is comparatively low.

Step 2: Follow its movement through the food chain A representative route is

Phytoplankton → Zooplankton → Small fish → Large fish → Fish-eating birds.

Each predator consumes many contaminated prey. As the persistent chemical is retained rather than broken down or eliminated effectively, its concentration increases towards the higher trophic levels. Fish-eating birds consequently receive a high toxic load: this is biomagnification.

Step 3: Connect contamination with falling bird numbers Such accumulated pollutants can impair survival and reproduction. In the standard example of DDT contamination, a high concentration in birds disturbs calcium metabolism, causing thinning of eggshells and their premature breakage. Fewer eggs hatch successfully, so fewer young birds enter the population. Continued reproductive failure produces the observed decline. The essential explanation is persistent pollution followed by biomagnification; DDT illustrates the specific eggshell mechanism.

Step 4: Conclusion Toxic effluents can enter the lake food chain and undergo biomagnification in birds, reducing their survival or reproductive success. DDT-induced eggshell thinning and poor hatching illustrate how this leads to a decline in bird population.

Quick Tip to Solve: Link the industrial effluent to the lake food chain, then biomagnification, and finally reproductive failure; simply naming pollution leaves the mechanism incomplete.

24. Recently a girl baby has been reported to suffer from haemophilia. How is it possible? Explain with the help of a cross. [3 marks]

Solution:

Concept:

- Haemophilia is an X-linked recessive disorder. Let X^H carry the normal allele and X^h carry the haemophilia allele.
- A female is normally affected only when both her X chromosomes carry the recessive allele, giving $X^h X^h$; $X^H X^h$ is a phenotypically normal carrier.
- A daughter receives one X chromosome from her father and one from her mother. The father must therefore supply X^h for the daughter to be affected.

Step 1: Identify a parental combination that produces an affected girl A haemophilic father $X^h Y$ and a carrier mother $X^H X^h$ can have a haemophilic daughter. The father produces X^h and Y sperm, while the mother produces X^H and X^h ova. An affected daughter results when an X^h sperm fertilises an X^h ovum.

Step 2: Show the genetic cross

$$\begin{array}{ccc} X^H X^h & \times & X^h Y \\ \text{Carrier mother} & & \text{Haemophilic father} \end{array}$$

Maternal gamete	Paternal X^h	Paternal Y
X^H	$X^H X^h$: carrier daughter	$X^H Y$: normal son
X^h	$X^h X^h$: affected daughter	$X^h Y$: affected son

The four possible genotypes occur in equal proportions. Thus half the daughters are expected to be haemophilic, corresponding to one quarter of all offspring under equal sex and segregation probabilities. These are probabilities for each birth, not a fixed sequence of children.

Step 3: Explain why the disease is possible in a girl The affected girl inherits a recessive haemophilia allele from each parent, so she has no normal allele to mask the disorder. The mother need not herself suffer from haemophilia: a carrier can transmit X^h . An affected mother crossed with an affected father is another possible combination, but the carrier-mother cross already explains the reported case.

Step 4: Conclusion A haemophilic girl $X^h X^h$ can be born to a haemophilic father $X^h Y$ and a carrier mother $X^H X^h$, by receiving X^h from both parents.

Quick Tip to Solve: For an affected daughter in an X-linked recessive cross, first trace her father's X; then check that the mother can supply the same recessive allele.

OR

24. What are satellite DNA in a genome? Explain their role in DNA fingerprinting.

[3 marks]

Solution:

Concept:

- Satellite DNA consists of highly repetitive DNA sequences, generally non-coding, in which short sequences occur as many tandem repeats.
- Variation in the number of tandem repeats produces DNA polymorphism: individuals can carry different lengths of the same repetitive region.

Step 1: Define satellite DNA When genomic DNA is separated by density-gradient centrifugation, most DNA forms a major peak. Some repetitive DNA differs in base composition and therefore buoyant density, producing smaller peaks distinct from the bulk DNA; these fractions are called satellite DNA. On the basis of repeat length and composition, repetitive sequences include microsatellites and minisatellites.

Step 2: Relate repeat variation to individual identification Minisatellite regions called variable number of tandem repeats (VNTRs) are useful in classical DNA fingerprinting. Their repeat numbers vary considerably between individuals, so restriction fragments containing these regions differ in length. These variations are inherited, and comparison of several variable regions gives a highly characteristic pattern for an individual, except in identical twins.

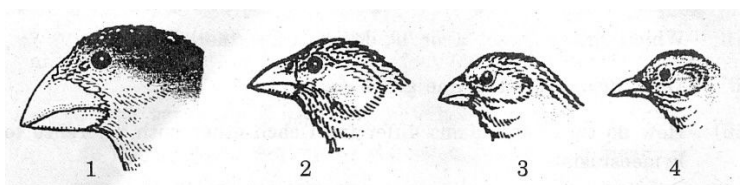
Step 3: Explain how a fingerprint is obtained DNA is isolated and cut with restriction endonucleases. The resulting fragments are separated by gel electrophoresis, transferred to a membrane by Southern blotting, and hybridised with labelled probes specific to the repetitive sequences. Detection, tradition-

ally by autoradiography, reveals the banding pattern. Matching patterns help identify a person, while the inheritance of bands from the parents permits analysis of biological relationships.

Step 4: Conclusion Satellite DNA is repetitive DNA that can form minor density-gradient peaks. Its highly polymorphic tandem-repeat regions provide inherited, individual-specific band patterns used in DNA fingerprinting.

Quick Tip to Solve: Link the definition to the application: tandem repeats vary in number, changing fragment lengths and hence the DNA band pattern.

25. (a) Write your observations on the variations seen in the Darwin's finches shown above. (b) How did Darwin explain the existence of different varieties of finches on Galapagos Islands? [3 marks]



Solution:

Concept:

- Adaptive radiation is the evolution of different forms from a common ancestor within a geographical region as they become adapted to different ecological niches.
- Natural selection favours heritable variations that improve survival and reproduction under the local environmental conditions, including the available food.

Step 1: Compare the beaks shown in part (a) The finches share a similar general body plan but differ conspicuously in the size, depth and shape of their beaks. Finch 1 has a very large, deep, stout beak; finches 2 and 3 have smaller beaks, while finch 4 has a comparatively slender, pointed beak. These differences are related to feeding adaptations. Strong, broad beaks can crack seeds, whereas narrower pointed beaks are suited to picking small food items such as insects.

Step 2: Trace the common ancestry in part (b) Darwin explained the Galapagos finches as descendants of an ancestral seed-eating finch population. Descendants spread to different islands and habitats. Different food resources and environmental conditions favoured different inherited beak variations, so the populations became adapted to distinct ways of feeding.

Step 3: Explain diversification by natural selection Birds with beaks better suited to locally available food survived and reproduced more successfully, passing favourable traits to their offspring. Over many generations, natural selection together with isolation led to distinct varieties and species, including forms adapted to insect feeding and other diets. This diversification from one ancestral stock into different ecological niches is adaptive radiation and illustrates divergent evolution.

Step 4: Conclusion (a) The finches show variation chiefly in beak size and shape associated with different diets. (b) Darwin explained their diversity as adaptive radiation from a common ancestral finch through natural selection in different habitats.

Quick Tip to Solve: Describe the visible beak differences first, then connect common ancestry, different foods and natural selection to adaptive radiation.

26. Name and explain the techniques used in the separation and isolation of DNA fragments to be used in recombinant DNA technology. [3 marks]

Solution:

Concept:

- Agarose gel electrophoresis separates DNA fragments according to size as an electric field drives negatively charged DNA through a gel matrix.
- Elution recovers the required DNA fragment from its gel band so that it can be used in constructing recombinant DNA.

Step 1: Separate the fragments by gel electrophoresis Load the DNA fragments into wells in an agarose gel and apply an electric field. DNA has a negative charge because of its phosphate groups, so the fragments move towards the positive electrode, the anode. The agarose matrix acts as a molecular sieve. Smaller fragments pass through its pores more readily and travel farther than larger fragments during the same time, separating the mixture into bands according to fragment size.

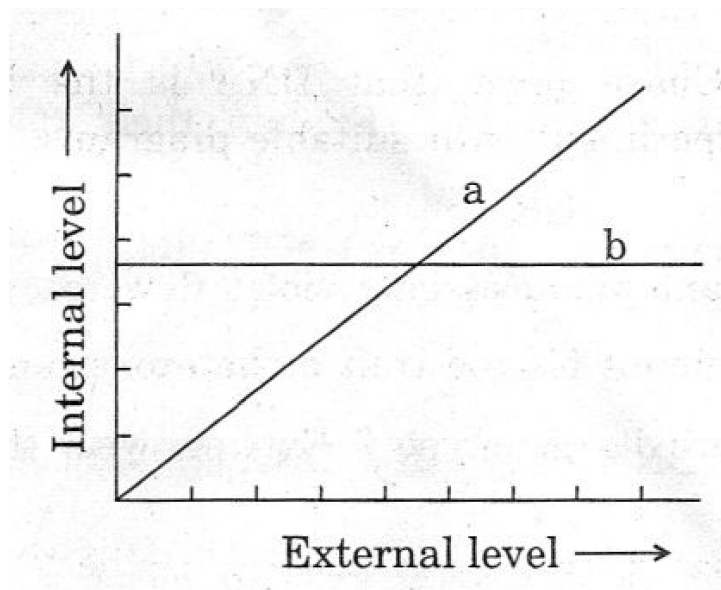
Step 2: Locate the required DNA band DNA bands are not visible in ordinary light. In the standard method, staining with ethidium bromide followed by exposure to ultraviolet radiation makes the DNA appear as bright orange bands. Comparing the position of a band with a DNA size marker helps locate the fragment of the required length; fragments of similar size migrate together in a band.

Step 3: Isolate the fragment by elution Cut out the gel piece containing the desired band and extract the DNA from that piece. This recovery of separated DNA from the gel is called elution. The purified fragment can then be joined by DNA ligase to a suitable vector cut with an appropriate restriction endonuclease, allowing the formation of recombinant DNA.

Step 4: Conclusion The techniques are agarose gel electrophoresis for separation and elution for isolation of the required DNA fragment, with staining and UV observation used to locate its band.

Quick Tip to Solve: Remember the sequence: DNA moves to the anode, smaller fragments move farther, and the selected band is cut out and eluted.

27. The following graph represents the organismic response to certain environmental condition (e.g. temperature): (i) Which one of these, 'a' or 'b', depicts conformers? (ii) What does the other line graph depict? (iii) How do these organisms differ from each other with reference to homeostasis? (iv) Mention the category to which humans belong. [3 marks]



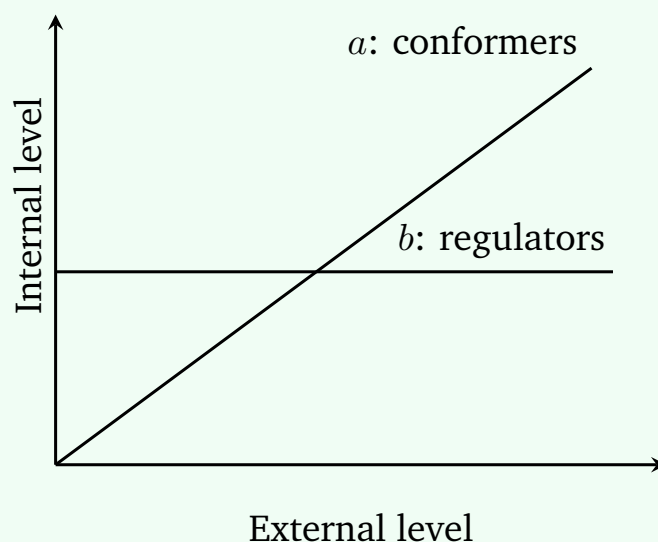
Solution:

Concept:

- Homeostasis is the maintenance of a relatively constant internal environment despite changes in the external environment.
- Conformers allow the internal variable to change with the external condition; regulators use physiological mechanisms to keep that internal variable nearly constant over a range of external conditions.

Step 1: Identify the conformer in part (i) Line *a* represents **conformers**. It slopes upwards: as the external level increases, the internal level also increases. For example, the body temperature of a temperature conformer changes with the surrounding temperature. Thus, the organism does not maintain a constant internal value for the condition shown.

Step 2: Identify the other response in part (ii) Line *b* represents **regulators**. Its horizontal course shows that the internal level remains nearly unchanged while the external level changes. The constant height of this line, rather than its intersection with line *a*, is the evidence for regulation.



The sloping response is conformity; the horizontal response is regulation.

Step 3: Compare homeostasis in part (iii) Regulators maintain homeostasis for the variable shown by physiological adjustments that oppose external changes. For temperature regulation, these adjustments can include altered heat production and heat loss, and require energy. Conformers do not maintain this constant internal state for that variable: their internal condition varies with the surroundings. The graph compares responses over the range shown; it does not imply that regulators withstand every possible environmental extreme.

Step 4: Classify humans in part (iv) Humans are **regulators**. They maintain body temperature at approximately 37°C over a range of ambient temperatures. Sweating increases heat loss in hot conditions, whereas shivering increases heat production in cold conditions. These responses illustrate the homeostasis represented by line *b*.

Step 5: Conclusion (i) *a*: conformers. (ii) *b*: regulators. (iii) Conformers' internal conditions vary with the surroundings, whereas regulators maintain a relatively constant internal environment. (iv) Humans are regulators.

Quick Tip to Solve: Read the slope: a rising internal-versus-external line indicates conforming; a horizontal line indicates regulation.

Section D (15 marks)

28. How did Hershey and Chase prove that DNA is the hereditary material? Explain their experiment with suitable diagrams. [5 marks]

Solution:

Concept:

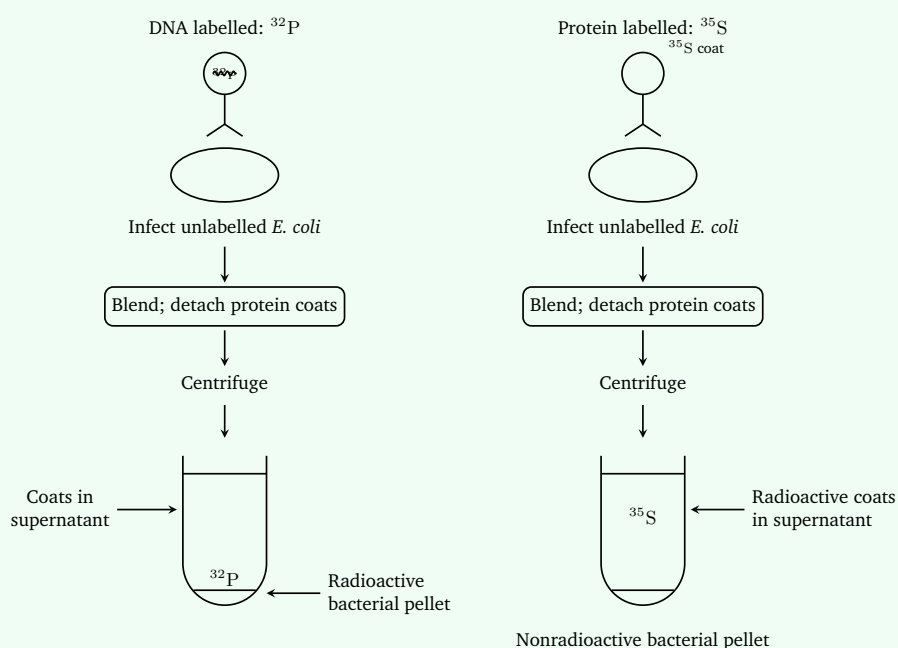
- A bacteriophage contains DNA enclosed in a protein coat. The hereditary material must enter the bacterial host and direct the production of new phages.

- Radioactive phosphorus ^{32}P labels DNA because DNA contains phosphorus in its phosphate backbone. Radioactive sulphur ^{35}S labels the phage protein coat because proteins contain sulphur-bearing amino acids, whereas DNA contains no sulphur.

Step 1: Prepare two separately labelled phage populations Hershey and Chase worked with bacteriophages that infect *Escherichia coli*. They grew one phage population using bacteria in a medium containing ^{32}P , so that the phage DNA became radioactive. A second population was grown using bacteria in a medium containing ^{35}S , so that the phage protein coats became radioactive. These separate tracers allowed them to follow DNA and protein independently during infection.

Step 2: Allow infection and remove the external coats Each labelled phage population was allowed to infect a separate culture of unlabelled *E. coli*. The phages attached to bacterial cells and introduced their infective material. After allowing infection, the mixtures were agitated in a blender. This detached the empty phage protein coats from the outside of the bacterial cells without removing the material that had already entered the cells.

Step 3: Separate the bacteria by centrifugation The blended mixtures were centrifuged. The heavier bacterial cells settled as the **pellet**, while the detached phage coats remained in the liquid **supernatant**. Radioactivity was measured in these two fractions. This separation was essential: radioactivity in the bacterial pellet would identify material that had entered the host, whereas radioactivity in the supernatant would identify material left outside.



Parallel tracer experiments: labelled DNA enters bacteria; labelled protein coats remain outside.

Step 4: Compare the two radioactive tracers With ^{32}P -labelled phages, radioactivity was detected in the bacterial pellet, demonstrating that phage DNA entered the bacteria. With ^{35}S -labelled phages, radioactivity remained mainly in the supernatant with the detached protein coats, while the bacterial pellet was not radioactive. The infected bacteria could produce new phages, showing that the material entering the host directed phage multiplication. Thus, entry of DNA, rather than the external protein coat, was associated with hereditary transmission.

Step 5: Conclusion DNA entered the bacterial cells and directed the formation of progeny phages, whereas the protein coats remained outside. Hershey and Chase therefore established that **DNA is the hereditary material** of the bacteriophage.

Quick Tip to Solve: Remember P for the DNA phosphate backbone and S for protein sulphur: after centrifugation, follow P into the bacterial pellet and S into the supernatant.

OR

28. A particular garden pea plant produces only violet flowers. (a) Is it homozygous dominant for the trait or heterozygous? (b) How would you ensure its genotype? Explain with the help of crosses. [5 marks]

Solution:

Concept:

- In garden pea, violet flower colour is dominant over white. Let V represent the dominant violet allele and v the recessive white allele.
- A violet-flowered plant can be homozygous dominant, VV , or heterozygous, Vv , because one copy of V is sufficient for the dominant phenotype. A white-flowered plant must be vv .
- A test cross crosses an individual showing the dominant phenotype with a homozygous recessive individual. The offspring reveal the kinds of gametes produced by the unknown parent.

Step 1: (a) Identify the possible genotypes The observation that this plant bears only violet flowers describes its phenotype, not whether its two alleles are identical. Both VV and Vv plants bear violet flowers; the recessive allele in Vv is masked by the dominant allele. Therefore flower colour alone cannot distinguish the two possible genotypes. Different flowers on the same plant do not represent separate offspring and cannot provide a segregation ratio.

Step 2: (b) Arrange a test cross Cross the violet-flowered plant of unknown genotype with a white-flowered pea plant, whose genotype is certainly vv . Prevent self-pollination while making the controlled cross and grow the resulting seeds to observe the flower colours of the progeny. The white parent produces only v gametes, so variation in the offspring depends on whether the violet parent contributes only V , or both V and v .

Step 3: Work out the homozygous possibility If the unknown plant is VV , the cross and gametes are

Parents: VV (violet) $\times$ vv (white),
Gametes: V v ,
Progeny: Vv only.

Every fertilisation combines V with v , giving heterozygous violet offspring. Thus the expected progeny are 100% violet, with no white-flowered plants.

Step 4: Work out the heterozygous possibility If the unknown plant is Vv , segregation during gamete

formation produces V and v gametes in equal proportions. The cross is

Parents: Vv (violet) $\times$ vv (white),
Gametes: (V, v) v ,
Progeny: $\frac{1}{2}Vv$ (violet) + $\frac{1}{2}vv$ (white).

The expected genotypic ratio is $Vv : vv = 1 : 1$, and the expected phenotypic ratio is violet:white = $1 : 1$. A white offspring proves that the unknown parent supplied v , establishing heterozygosity. Assess a sufficiently large progeny because small samples need not show the exact expected ratio.

Step 5: Conclusion (a) The violet plant may be VV or Vv ; its appearance alone is insufficient. (b) Test-cross it with a white vv plant: exclusively violet progeny are the expected result for VV , whereas violet and white progeny in an approximately $1 : 1$ ratio identify Vv . A large all-violet progeny supports homozygosity; a small all-violet sample alone is not conclusive.

Quick Tip to Solve: Use the recessive white plant as the tester: it contributes only v , so any white offspring immediately reveals a hidden v allele in the violet parent.

29. How does the pollen mother cell develop into a mature pollen grain? Illustrate the stages with labelled diagrams. [5 marks]

Solution:

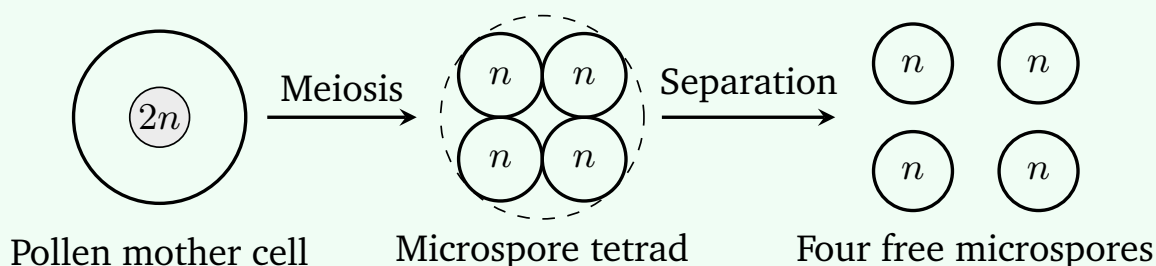
Concept:

- Microsporogenesis is the meiotic formation of haploid microspores from a diploid pollen mother cell (microspore mother cell) in an anther's microsporangium.
- Microgametogenesis is the development of a microspore into the male gametophyte. Mitosis preserves the haploid chromosome number, denoted by n ; the mother cell is $2n$.
- A mature pollen grain has a protective outer exine and an inner intine, and contains a vegetative cell together with a generative cell or its two male-gamete products.

Step 1: Form a tetrad by meiosis In each pollen sac of a young anther, cells of the sporogenous tissue can function as pollen mother cells. Each diploid pollen mother cell enlarges and undergoes meiosis. Meiosis I separates homologous chromosomes, and meiosis II separates sister chromatids. Cytokinesis produces four haploid microspores, initially associated as a microspore tetrad. Thus one mother cell gives four microspores, each with half its chromosome number; these are not yet male gametes.

Pollen mother cell ($2n$) $\xrightarrow{\text{meiosis}}$ 4 microspores (n).

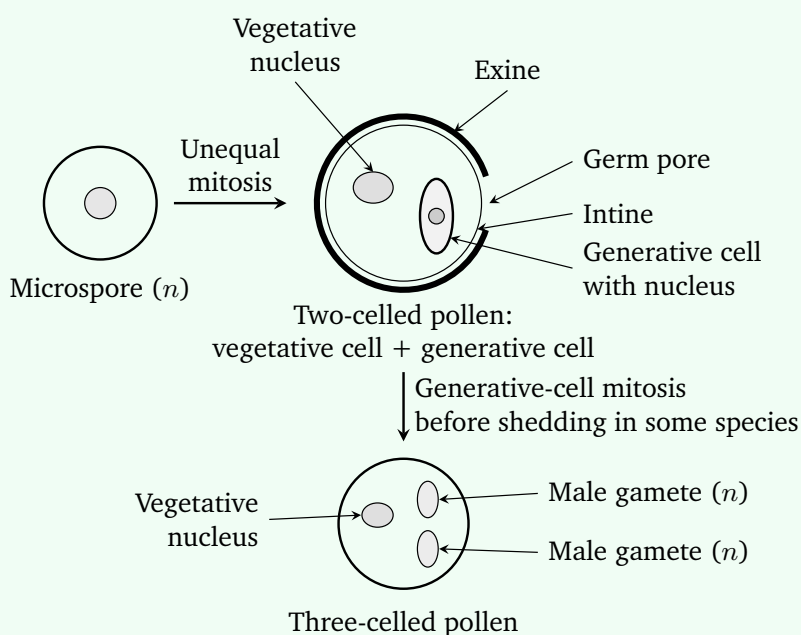
Step 2: Release and enlarge the microspores As the anther matures, the microspores separate from the tetrad and develop into individual pollen grains. Each free microspore initially has a single haploid nucleus. It enlarges and develops its pollen wall. The hard outer exine contains sporopollenin, a highly resistant organic material; exine is absent at apertures called germ pores. The thin inner intine is made of cellulose and pectin. The tapetum provides nourishment to the developing pollen grains.



Microsporogenesis: one diploid mother cell forms four haploid microspores.

Step 3: Differentiate the vegetative and generative cells The microspore nucleus divides mitotically. An unequal division of the cytoplasm produces a large vegetative cell and a small generative cell. The vegetative cell has abundant food reserves and a large, irregularly shaped nucleus. The spindle-shaped generative cell has dense cytoplasm and a nucleus, and floats in the cytoplasm of the vegetative cell. Both nuclei are haploid. The vegetative cell subsequently forms and maintains the pollen tube, whereas the generative cell gives rise to the male gametes.

Step 4: Recognise the two possible stages at pollen shedding In over 60 per cent of angiosperms, pollen grains are shed at this two-celled stage: one vegetative cell and one generative cell. In the remaining species, the generative cell undergoes mitosis before shedding and produces two haploid male gametes, so the pollen is shed at the three-celled stage. In species shedding two-celled pollen, this generative-cell division occurs later in the pollen tube. The labelled sketches show the stages and the organisation of a two-celled mature pollen grain.

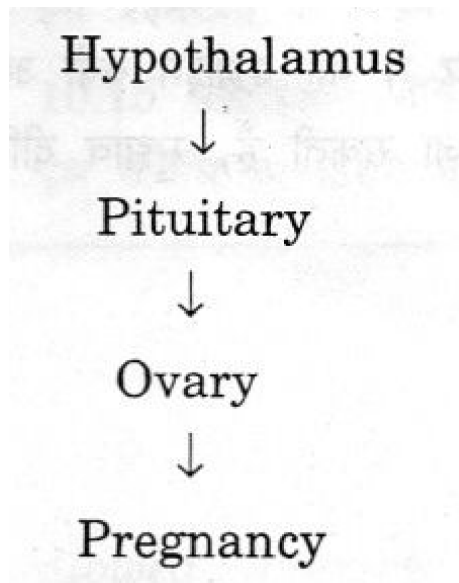


Microgametogenesis and the labelled structure of two-celled mature pollen (schematic).

Step 5: Conclusion A diploid pollen mother cell forms a tetrad of four haploid microspores by meiosis. Each microspore separates, develops its wall and divides mitotically into vegetative and generative cells. Mature pollen is shed with either these two cells or a vegetative cell and two male gametes.

Quick Tip to Solve: Keep the two divisions distinct: meiosis makes four microspores; mitosis within each microspore makes the vegetative and generative cells.

29. Study the flow chart given below. Name the hormones involved at each stage and explain their functions. [5 marks]



Solution:

Concept:

- The hypothalamus controls the anterior pituitary through gonadotropin-releasing hormone (GnRH); pituitary gonadotropins then regulate ovarian activity.
- Follicle-stimulating hormone (FSH) and luteinising hormone (LH) control follicular development, ovulation and corpus luteum formation.
- Ovarian oestrogens and progesterone prepare and maintain the uterine endometrium, making implantation and continuation of pregnancy possible after fertilisation.

Step 1: Identify the hormone from the hypothalamus The hypothalamus secretes **gonadotropin-releasing hormone (GnRH)**. It acts on the anterior pituitary and stimulates the synthesis and release of the two gonadotropins, FSH and LH. Thus, GnRH is the hormonal link from the hypothalamus to the pituitary in the flow chart.

Step 2: Explain the pituitary hormones acting on the ovary The anterior pituitary releases **FSH and LH**. FSH stimulates the growth and maturation of ovarian follicles and promotes oestrogen secretion by the developing follicles. LH supports ovarian hormone secretion; its sharp mid-cycle rise, the **LH surge**, causes rupture of the mature Graafian follicle and release of the secondary oocyte, that is, ovulation. LH also causes the remaining follicular tissue to form the corpus luteum and stimulates its secretion of progesterone.

Step 3: Explain the ovarian hormones preparing the uterus Growing ovarian follicles secrete **oestrogens**. These stimulate proliferation and repair of the uterine endometrium after menstruation. Oestrogens also support the development and maintenance of female secondary sexual characteristics. After ovulation, the corpus luteum secretes mainly **progesterone**, together with oestrogens. Progesterone makes the endometrium thick, glandular and secretory and maintains it for implantation.

These changes allow the uterus to receive and support the developing embryo if fertilisation occurs. The hormones prepare the conditions for pregnancy; ovulation alone does not establish pregnancy.

Step 4: Relate hormonal support to pregnancy Following fertilisation and implantation, **human chorionic gonadotropin (hCG)**, secreted by trophoblastic tissue of the developing placenta, maintains the corpus luteum during early pregnancy. Consequently, progesterone and oestrogen secretion continues and the endometrium is maintained instead of being shed in menstruation. Later, the placenta itself produces substantial progesterone and oestrogens, supporting continued pregnancy. This explains how the ovarian hormonal stage in the chart leads to a uterine environment suitable for implantation and gestation.

Step 5: Conclusion The sequence is hypothalamic **GnRH**, pituitary **FSH and LH**, and ovarian **oestrogens and progesterone**. Together they coordinate follicular growth, ovulation and uterine preparation. After implantation, **hCG** maintains the early corpus luteum, while continued progesterone and oestrogen support maintains pregnancy.

Quick Tip to Solve: Follow each arrow by naming the hormone's source, target and action: GnRH releases gonadotropins, FSH grows follicles, LH triggers ovulation, and progesterone maintains the endometrium.

30. How is a transgenic tobacco plant protected against *Meloidogyne incognita*? Explain the procedure.

[5 marks]

Solution:

Concept:

- RNA interference (RNAi) is a cellular defence mechanism in which a specific messenger RNA (mRNA) is silenced by complementary double-stranded RNA (dsRNA), preventing expression of the corresponding gene.
- The root-knot nematode *Meloidogyne incognita* infects tobacco roots and reduces yield. A transgenic tobacco plant can produce RNA directed against an essential nematode gene.
- Complementary sense and antisense RNA strands pair to form dsRNA. Gene silencing is sequence-specific because the interfering RNA recognises the matching target mRNA.

Step 1: Select the nematode gene sequence Identify and isolate a suitable DNA sequence from a nematode gene whose expression is needed for the parasite's survival. This sequence supplies the information for making RNA complementary to the nematode's target mRNA; it is not introduced to make a toxic protein.

Step 2: Transfer the construct into tobacco cells Use an *Agrobacterium* vector to introduce the selected nematode-specific DNA into tobacco cells. The inserted DNA is arranged so that expression in the host cells produces both sense RNA and antisense RNA corresponding to the selected nematode gene. Select transformed cells and regenerate transgenic tobacco plants carrying this construct.

Step 3: Produce double-stranded RNA In the transformed plant cells, the sense and antisense RNA molecules are complementary and pair with one another, forming dsRNA. Thus the transgenic plant provides the RNA trigger required for interference, including in tissues on which the nematode feeds.

Step 4: Silence the parasite's target mRNA When the nematode feeds on the transgenic root tissue, the interfering RNA reaches the parasite and triggers RNAi against its matching mRNA. The dsRNA is processed into short interfering RNAs, which guide the cellular silencing machinery to the complementary nematode mRNA. The target mRNA is degraded or prevented from being translated, so the essential nematode protein is not produced.

Step 5: Relate gene silencing to protection Loss of the essential gene product disrupts the parasite's normal functioning and survival. It therefore cannot sustain infection of the transgenic tobacco plant. The protection results from sequence-specific silencing of a parasite gene rather than from changing the plant's own target mRNA.

Step 6: Conclusion Transgenic tobacco is protected against the root-knot nematode by RNA interference. An *Agrobacterium*-introduced nematode gene construct produces complementary RNAs; their dsRNA silences the parasite's essential mRNA, preventing protein synthesis and parasite survival.

Quick Tip to Solve: Recall the sequence: nematode DNA into tobacco, sense plus antisense RNA, dsRNA, target mRNA silencing, then protection from the parasite.

OR

30. (a) Name the source of Taq polymerase. Explain the advantage of its use in biotechnology. (b) Expand the name of the enzyme ADA. Why is this enzyme essential in the human body? Suggest a gene therapy for its deficiency. [5 marks]

Solution:

Concept:

- Polymerase chain reaction (PCR) amplifies a selected DNA segment through repeated cycles of DNA denaturation, primer annealing and extension by DNA polymerase.
- A thermostable DNA polymerase retains its activity during the high-temperature steps of PCR and synthesises new DNA strands from the primers.
- Gene therapy supplies a functional copy of a gene to suitable cells so that they can produce a protein missing because of a defective gene.

Step 1: (a) Identify the source of Taq polymerase Taq polymerase is obtained from the thermophilic bacterium *Thermus aquaticus*, which lives in hot springs. Its adaptation to high temperatures makes its DNA polymerase suitable for the temperature cycles used in PCR.

Step 2: (a) Explain the advantage in biotechnology During PCR, the double-stranded DNA is heated to about 94–95 °C to separate its strands. An ordinary DNA polymerase would be denatured by this heating. Taq polymerase withstands these repeated high-temperature treatments and remains functional for primer extension, usually performed near 72 °C. Consequently, fresh enzyme need not be added after every denaturation cycle. Repeated extension cycles rapidly amplify the selected DNA segment, making PCR convenient and efficient.

Step 3: (b) Expand ADA and state its importance ADA stands for **adenosine deaminase**. This enzyme is essential for the normal functioning of the immune system. It participates in purine metabolism

and prevents the accumulation of metabolites that are toxic to lymphocytes. Its deficiency impairs lymphocyte function and causes severe combined immunodeficiency (SCID), leaving the patient highly susceptible to infections.

Step 4: (b) Describe gene therapy for ADA deficiency Lymphocytes are isolated from the patient's blood and grown in a culture outside the body. A functional ADA complementary DNA (cDNA) is introduced into these cultured lymphocytes using a suitable retroviral vector. The genetically modified lymphocytes, now capable of producing functional ADA, are returned to the patient. This restores ADA production in the transferred cells and helps improve immune function.

Step 5: Explain the need for repeated treatment The corrected lymphocytes are not immortal, so the patient requires periodic infusions of genetically engineered lymphocytes. The NCERT gene-therapy approach describes introducing a functional ADA gene into cells at an early embryonic stage as a possible permanent correction, because the functional gene could then be maintained in the developing cell lineages.

Step 6: Conclusion Taq polymerase comes from *Thermus aquaticus*; its thermostability permits repeated DNA amplification by PCR. ADA is adenosine deaminase, essential for normal immune function. ADA deficiency can be treated by returning the patient's cultured lymphocytes after introducing functional ADA cDNA with a retroviral vector; these cell infusions must be repeated periodically.

Quick Tip to Solve: Link Taq to heat-resistant PCR amplification, and remember the ADA sequence: isolate lymphocytes, culture, insert functional ADA cDNA, then reinfuse.