

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

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 – Sections **A, B, C, D** and **E**.
- (iii) **Section A** – questions number **1** to **16** are Multiple Choice Type Questions. Each question carries **1** mark.
- (iv) **Section B** – questions number **17** to **21** are Very Short Answer Type Questions. Each question carries **2** marks.
- (v) **Section C** – questions number **22** to **28** are Short Answer Type Questions. Each question carries **3** marks.
- (vi) **Section D** – questions number **29** and **30** are Case-Based questions. Each question carries **4** marks. Each question has subparts with internal choice in one of the subparts.
- (vii) **Section E** – questions number **31** to **33** are Long Answer Type questions. Each question carries **5** marks.
- (viii) There is no overall choice. However, an internal choice has been provided in Sections B, D and E of the question paper. A candidate has to write answer for only **one** of the alternatives in such questions.
- (ix) Kindly note that there is a separate question paper for Visually Impaired Candidates.
- (x) Wherever necessary, neat and properly labelled diagrams should be drawn.

Section A (16 marks)

Questions no. 1 to 16 are Multiple Choice Type Questions, carrying 1 mark each. Choose the best option.
 $16 \times 1 = 16$

1. Which part of the ovule hardens to form seed coat of a seed?

[1 mark]

- (A) Funicle
- (B) Chalaza
- (C) Nucellus
- (D) Integuments

Correct Answer: (D) Integuments

Solution:

Concept:

- The ovule develops into the seed after fertilisation, and its protective integuments form the seed coat.
- In an ovule with two integuments, the outer integument forms the testa and the inner integument forms the tegmen.

Step 1: Trace the protective coverings The integuments surround and protect the nucellus of the ovule. As the ovule matures into a seed, these coverings become the seed coat; the outer covering commonly becomes hard and protective.

Step 2: Eliminate the other ovular parts The funicle is the stalk attaching the ovule to the placenta, while the chalaza is the basal region opposite the micropyle. The nucellus is nutritive tissue and may persist as perisperm in some seeds. None of these is the source of the seed coat.

Step 3: Conclusion The integuments develop into the seed coat. Hence, the correct option is (D).

Quick Tip to Solve: Link the two coverings directly: ovule integuments become the seed coat; the ovary wall becomes the fruit wall.

2. Some statements regarding drugs and alcohol are given below :

- (i) Adolescents are more vulnerable to peer pressure.
- (ii) Drug addiction leads to increased tolerance level of the receptors present in our body.
- (iii) Alcohol affects the central nervous system.
- (iv) Excessive use of drugs helps to increase energy.
- (v) Anabolic steroids decrease aggressiveness.

Choose the option with correct statement(s).

[1 mark]

- (A) Statements (i), (iv) and (v) are correct
- (B) Statements (i), (ii) and (iii) are correct
- (C) Only statements (i) and (v) are correct
- (D) Only statement (iii) is correct

Correct Answer: (B) Statements (i), (ii) and (iii) are correct

Solution:

Concept:

- Adolescence is a period of increased vulnerability to peer pressure and experimentation with addictive substances.
- Repeated drug use can increase tolerance, so larger doses are needed to obtain the same response; alcohol affects the central nervous system.

Step 1: Evaluate statements (i), (ii) and (iii) Statement (i) is correct because adolescents can be strongly influenced by their peer group. Statement (ii) is correct: repeated exposure increases tolerance of receptors, reducing the response to the same dose. Statement (iii) is also correct because alcohol acts on the central nervous system.

Step 2: Check the remaining statements and combinations Statement (iv) is incorrect: excessive drug use is harmful and cannot be described as a means of increasing energy. Statement (v) is incorrect because anabolic steroid abuse can increase aggressiveness. Options (A) and (C) include false statements, and option (D) leaves out the correct statements (i) and (ii).

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

Quick Tip to Solve: Reject any combination containing (iv) or (v), then retain all three true statements: peer pressure, tolerance and CNS effects.

3. Appearance of antibiotic-resistant bacteria is an example of evolution due to:

[1 mark]

- (A) Adaptive radiation
- (B) Divergent evolution
- (C) Artificial selection
- (D) Anthropogenic action

Correct Answer: (D) Anthropogenic action

Solution:

Concept:

- Natural selection favours heritable variants that survive and reproduce better under a particular environmental pressure.
- Anthropogenic action means human activity that alters the environment, such as the widespread use of antibiotics.

Step 1: Identify the selection pressure In a bacterial population, resistant variants survive antibiotic exposure while susceptible bacteria are killed or inhibited. The resistant bacteria reproduce, increasing the proportion of resistance in subsequent generations. Antibiotic use therefore selects resistant variants; it does not deliberately produce a useful bacterial breed.

Step 2: Distinguish the alternatives Human use of antibiotics creates this selection pressure, making it evolution due to anthropogenic action. Adaptive radiation concerns diversification into different ecological niches, and divergent evolution concerns divergence from common ancestry. Artificial selection usually refers to deliberate breeding for desired traits, which is not what antibiotic treatment does.

Step 3: Conclusion The appearance of antibiotic-resistant bacteria exemplifies evolution due to anthropogenic action. Hence, the correct option is (D).

Quick Tip to Solve: When human use of antibiotics or pesticides selects resistant organisms, identify anthropogenic action as the cause.

4. Consider the following statements and choose the correct option:

Statement I: Using vaccination and immunization programmes, we have been able to eradicate smallpox.

Statement II: Vaccines are available for diphtheria and polio.

[1 mark]

(A) Both Statements I and II are false.

(B) Both Statements I and II are true.

(C) Only Statement I is true.

(D) Only Statement II is true.

Correct Answer: (B) Both Statements I and II are true.

Solution:

Concept:

- Vaccination stimulates specific immunity and immunological memory against a pathogen or its products.
- Population immunisation programmes can interrupt transmission; smallpox eradication is a standard example of their success.

Step 1: Assess Statement I Smallpox was eradicated through an organised programme involving vaccination and control of transmission. Thus Statement I correctly describes the success of vaccination and immunisation programmes.

Step 2: Assess Statement II and choose the combination Vaccines are available against both diphtheria and polio. Diphtheria immunisation uses a toxoid, while polio vaccines protect against poliovirus. Statement II is therefore also true. Option (A) rejects both true statements, and options (C) and (D) each incorrectly reject one of them.

Step 3: Conclusion Both Statements I and II are true. Hence, the correct option is (B).

Quick Tip to Solve: Judge each statement separately: smallpox is the eradication example, and diphtheria and polio both have vaccines.

5. Taylor and colleagues performed an experiment on which of the following organisms to provide proof for semi-conservative replication of DNA in chromosomes?

[1 mark]

(A) Garden pea

(B) *Escherichia coli*

(C) *Vicia faba*

(D) *Drosophila*

Correct Answer: (C) *Vicia faba*

Solution:

Concept:

- In semi-conservative DNA replication, each daughter DNA molecule contains one parental strand and one newly synthesised strand.

- Taylor and colleagues used radioactive thymidine to follow DNA replication in the chromosomes of *Vicia faba*.

Step 1: Recall the chromosome-labelling experiment Taylor and colleagues studied dividing cells of *Vicia faba* using radioactive thymidine, which is incorporated into newly synthesised DNA. The distribution of radioactivity in chromatids over successive replication cycles supported semi-conservative replication in chromosomes.

Step 2: Separate it from other classic experiments *Escherichia coli* is associated with the Meselson–Stahl experiment using nitrogen isotopes, not the Taylor experiment asked here. Garden pea is associated with Mendelian inheritance experiments, and *Drosophila* with classical studies of linkage and inheritance. These alternatives do not identify Taylor’s experimental organism.

Step 3: Conclusion Taylor and colleagues used *Vicia faba*. Hence, the correct option is (C).

Quick Tip to Solve: Pair Taylor with radioactive thymidine and *Vicia faba*; pair Meselson–Stahl with nitrogen isotopes and *E. coli*.

6. Which of the following is not a functional unit of an ecosystem?

[1 mark]

- (A) Energy flow
- (B) Decomposition
- (C) Stratification
- (D) Productivity

Correct Answer: (C) Stratification

Solution:

Concept:

- An ecosystem can be described through its structure and through functional processes such as productivity, decomposition, energy flow and nutrient cycling.
- Stratification is the vertical distribution of different species in layers, so it is a structural feature of a community.

Step 1: Classify the listed processes Productivity concerns the formation of biomass; decomposition breaks down dead organic matter; and energy flow describes energy transfer through trophic levels. Thus options (A), (B) and (D) all describe ecosystem functions.

Step 2: Recognise the structural feature Stratification describes spatial organisation, for example tall trees, shorter shrubs and herbs occupying different vertical layers in a forest. It tells us how organisms are arranged, rather than naming a functional process. The word “not therefore directs us to stratification.

Step 3: Conclusion Stratification is not a functional unit of an ecosystem. Hence, the correct option is (C).

Quick Tip to Solve: Separate arrangement from activity: vertical layers indicate structure; biomass formation, breakdown and energy transfer indicate function.

7. Golden rice is a promising transgenic crop. When released for cultivation, it will help in: [1 mark]

- (A) Producing petrol-like fuel
- (B) Reduction of Vitamin A deficiency in humans
- (C) Pest resistance
- (D) Herbicide tolerance

Correct Answer: (B) Reduction of Vitamin A deficiency in humans

Solution:

Concept:

- Biofortification improves the nutritional quality of a food crop by increasing useful nutrients or their precursors.
- Golden rice is engineered to accumulate beta-carotene, a precursor of vitamin A, in its edible endosperm.

Step 1: Connect the introduced trait to human nutrition Beta-carotene from golden rice can be converted to vitamin A in the human body. Its nutritional purpose is therefore to help reduce vitamin A deficiency among people who consume rice as a staple food.

Step 2: Exclude unrelated crop traits Producing petrol-like fuel is not the purpose of golden rice. Pest resistance and herbicide tolerance are traits introduced into other genetically modified crops, but neither identifies the defining nutritional modification of golden rice. These alternatives therefore do not answer this question.

Step 3: Conclusion Golden rice can help reduce vitamin A deficiency in humans. Hence, the correct option is (B).

Quick Tip to Solve: Associate the golden colour with beta-carotene, then connect this pigment to its role as a vitamin A precursor.

8. Which cells are responsible for producing antibodies in a human body?

[1 mark]

- (A) Macrophages
- (B) Helper T-Lymphocytes
- (C) Cytotoxic T-Cells
- (D) B-Lymphocytes

Correct Answer: (D) B-Lymphocytes

Solution:

Concept:

- Antibodies are immunoglobulins that bind specifically to antigens and participate in humoral immunity.
- Activated B-lymphocytes differentiate into plasma cells, which secrete antibodies; memory B cells support later responses.

Step 1: Identify the antibody-producing cell lineage After recognising an antigen and receiving the necessary activation signals, B-lymphocytes proliferate and form plasma cells. These effector cells

release antibodies into body fluids. Thus, antibody production belongs to the B-cell lineage.

Step 2: Compare the other immune cells Macrophages engulf pathogens and present antigens. Helper T-lymphocytes coordinate immune responses and can help activate B cells, but do not themselves secrete antibodies. Cytotoxic T-cells kill infected or abnormal body cells rather than producing antibodies.

Step 3: Conclusion B-lymphocytes are responsible for antibody production through their plasma-cell derivatives. The correct option is (D).

Quick Tip to Solve: Link B cells with antibodies in body fluids; link cytotoxic T cells with killing infected cells.

9. Which of the following is a secondary consumer?

[1 mark]

- (A) Grasshopper
- (B) Cow
- (C) Fish
- (D) Hawk

Correct Answer: (C) Fish

Solution:

Concept:

- Producers occupy the first trophic level; primary consumers eat producers and occupy the second trophic level.
- Secondary consumers feed on primary consumers and occupy the third trophic level. An organism's trophic level depends on its food in the particular chain.

Step 1: Identify the herbivores Grasshoppers feed on plants and cows feed on grass or other plant material. In the usual grazing food chains they are herbivores and therefore primary consumers, eliminating options (A) and (B).

Step 2: Locate the secondary consumer in the standard chain In the aquatic chain phytoplankton → zooplankton → small fish, zooplankton are primary consumers and the fish eating them are secondary consumers. Hawk is conventionally placed at a higher consumer level in the textbook chain. Although diets can change trophic positions in other chains, fish is the intended secondary consumer among these options.

Step 3: Conclusion Fish, feeding on primary consumers such as zooplankton, is the secondary consumer in the standard example. The correct option is (C).

Quick Tip to Solve: Count producers as trophic level one; the organism that eats a herbivore is a secondary consumer.

10. Match Column I with Column II and select the correct option:

Column I: a. Primers, b. Insertional inactivation, c. Bioreactor, d. Downstream processing

Column II: i. β -galactosidase, ii. To separate and purify products, iii. Chemically synthesized oligonucleotides, iv. Large scale production of specific product of activity of microbes [1 mark]

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

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

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

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

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

Solution:

Concept:

- Primers initiate DNA synthesis, while insertional inactivation identifies recombinants by disrupting a marker gene.
- Bioreactors enable large-scale biological production; downstream processing recovers and purifies the product after production.

Step 1: Match the molecular tools Primers are chemically synthesised short oligonucleotides complementary to template DNA, so a matches iii. In insertional inactivation, insertion into a gene such as the one encoding β -galactosidase disrupts its function, distinguishing recombinant colonies. Thus b matches i.

Step 2: Match the production stages and test the options A bioreactor maintains suitable conditions for large-scale production of a specific microbial product, so c matches iv. Downstream processing separates and purifies the product, so d matches ii. Option (B) reverses these last two roles; (C) exchanges the primer and marker matches; (D) contains several incorrect matches.

Step 3: Conclusion The matching is a-iii, b-i, c-iv and d-ii. The correct option is (A).

Quick Tip to Solve: Match downstream processing to purification first, then bioreactor to large-scale production.

11. Identify the statements that correctly describe Darwin's Theory of Evolution.

- (i) Overproduction of organisms leads to competition.
- (ii) Variation is inherited and causes evolution.
- (iii) Acquired characters are inherited.
- (iv) Survival depends on favourable traits.
- (v) New species arise due to accumulation of favourable variations.

Choose the correct option.

[1 mark]

- (A) (i), (ii), (iv) and (v) are correct
- (B) (ii), (iii) and (iv) are correct
- (C) All are correct
- (D) Only (i) and (iv) are correct

Correct Answer: (A) (i), (ii), (iv) and (v) are correct

Solution:

Concept:

- Darwinian natural selection acts on heritable variations: individuals with favourable traits leave more surviving offspring.
- Overproduction and limited resources produce a struggle for existence; favourable inherited variations accumulate over generations.

Step 1: Identify the Darwinian statements Statement (i) describes competition caused by producing more offspring than resources can support. Statement (ii) refers to inherited variation, the material on which natural selection acts. Statement (iv) describes the survival advantage of favourable traits, and (v) describes the accumulation of such variations leading to new species. These four statements fit Darwin's explanation.

Step 2: Exclude inheritance of acquired characters Statement (iii), inheritance of acquired characters, is associated with Lamarck's theory rather than Darwinian natural selection. Therefore options (B) and (C), which include (iii), are incorrect. Option (D) omits the valid statements (ii) and (v), so it is incomplete.

Step 3: Conclusion Statements (i), (ii), (iv) and (v) correctly describe Darwin's theory. The correct option is (A).

Quick Tip to Solve: Reject any Darwin option containing inheritance of acquired characters; that is the Lamarckian clue.

12. The method of contraception that is hormone-based and prevents ovulation is:

[1 mark]

- (A) Oral Pills
- (B) Copper-T
- (C) Condom
- (D) Lippes loop

Correct Answer: (A) Oral Pills

Solution:

Concept:

- Hormonal oral contraceptive pills contain a progestogen alone or a progestogen–estrogen combination.
- These hormones suppress the hormonal signals required for ovulation; they also alter cervical mucus and the uterine environment.

Step 1: Apply the hormonal mechanism Oral pills provide hormones that inhibit the normal pituitary gonadotropin pattern, including the ovulatory LH surge. Consequently, release of an ovum is prevented, matching both clues in the question: hormone-based action and prevention of ovulation.

Step 2: Distinguish the other contraceptives Copper-T is a copper-releasing intrauterine device whose copper ions reduce sperm motility and fertilising capacity. A condom is a barrier that prevents semen from entering the female reproductive tract. Lippes loop is a non-medicated intrauterine device. None of these three is the hormone-based oral method described.

Step 3: Conclusion Oral pills are the hormone-based contraceptive method that prevents ovulation. The correct option is (A).

Quick Tip to Solve: For hormone-based prevention of ovulation, choose oral pills; Copper-T and Lippes loop are IUDs.

13. Assertion (A): Ecosystems require a constant supply of energy to synthesize the molecules they require.

Reason (R): This is to counteract the universal tendency towards increasing disorderliness as per Second Law of Thermodynamics. [1 mark]

- (A) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of the Assertion (A).
(B) Both Assertion (A) and Reason (R) are true, but Reason (R) is not the correct explanation of the Assertion (A).
(C) Assertion (A) is true, but Reason (R) is false.
(D) Assertion (A) is false, but Reason (R) is true.

Correct Answer: (A) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of the Assertion (A).

Solution:

Concept:

- Ecosystems are open systems that need continuing energy input to support metabolism and the synthesis of organised biological molecules.
- The second law of thermodynamics requires an overall increase in entropy in natural processes; energy transformations dissipate usable energy as heat.

Step 1: Evaluate the assertion Organisms continually synthesise and maintain complex molecules and structures. These activities require usable energy, while energy is dissipated during metabolism and transfers between trophic levels. Therefore an ecosystem needs a constant energy supply, and the assertion is true.

Step 2: Evaluate the reason The tendency towards increasing disorderliness is expressed by the second law of thermodynamics. Maintaining biological organisation requires energy input and is accompanied by greater entropy production in the surroundings. The reason is true; local biological order does not violate this law.

Step 3: Test the explanatory link The continuing energy input allows synthesis and maintenance of ordered biological material despite this tendency towards disorder and the loss of usable energy. Thus the reason directly explains why the constant supply in the assertion is necessary.

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

Quick Tip to Solve: Connect maintained biological order with continuous energy input and heat loss; energy is not recycled.

14. Assertion (A): DNA cannot pass through cell membrane of a bacterial cell.

Reason (R): DNA is a hydrophilic molecule.

[1 mark]

- (A) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of the Assertion (A).
- (B) Both Assertion (A) and Reason (R) are true, but Reason (R) is not the correct explanation of the Assertion (A).
- (C) Assertion (A) is true, but Reason (R) is false.
- (D) Assertion (A) is false, but Reason (R) is true.

Correct Answer: (A) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of the Assertion (A).

Solution:

Concept:

- DNA is a large, hydrophilic molecule whose phosphate backbone carries negative charge.
- The lipid bilayer has a hydrophobic interior that prevents free passage of large charged molecules; bacterial cells must be made competent for efficient uptake of foreign DNA.

Step 1: Evaluate the assertion DNA does not ordinarily pass through the bacterial cell membrane by simple diffusion. Recombinant-DNA methods therefore use treatments that make cells competent to receive DNA. In this normal membrane-permeability context, the assertion is true.

Step 2: Evaluate the reason DNA is hydrophilic because its charged phosphate groups interact with water. It is not a small lipid-soluble molecule that can freely dissolve in the hydrophobic interior of the membrane. The reason is true.

Step 3: Check whether the reason explains the assertion DNA's hydrophilic, charged nature makes passage through the lipid membrane energetically unfavourable and explains its inability to cross freely. Competence treatment, often involving divalent cations followed by heat shock, facilitates uptake without contradicting the statement about ordinary membrane passage.

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

Quick Tip to Solve: Pair hydrophilic DNA with a hydrophobic membrane barrier to recognise why competence treatment is needed.

15. Assertion (A): Activated sludge contains large population of bacteria.

Reason (R): These bacteria help in anaerobic digestion of human waste in biogas plant. [1 mark]

- (A) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of the Assertion (A).
- (B) Both Assertion (A) and Reason (R) are true, but Reason (R) is not the correct explanation of the Assertion (A).
- (C) Assertion (A) is true, but Reason (R) is false.
- (D) Assertion (A) is false, but Reason (R) is true.

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

Solution:

Concept:

- Activated sludge is the sediment of microbial flocs formed during the secondary, biological treatment of sewage.
- Aerobic microbes grow in aeration tanks; anaerobic sludge digestion and biogas production involve a different microbial community, including methanogens.

Step 1: Evaluate the assertion Assertion (A) is true. In the aeration tank, bacteria grow as flocs associated with fungal filaments. After consuming much of the organic matter, these flocs settle in a settling tank and form activated sludge, which therefore contains a large population of bacteria.

Step 2: Evaluate the reason Reason (R) is false in reference to these bacteria. The bacteria that proliferate in the aeration tank are aerobic. Anaerobic digestion in a sludge digester or biogas plant is performed by anaerobic microorganisms, including methane-producing methanogens; it is not the function of the aerobic floc-forming bacteria.

Step 3: Check the explanatory relationship The large bacterial population in activated sludge results from microbial growth during aeration followed by settling. The reason incorrectly assigns anaerobic digestion to this aerobic population. Thus options (A) and (B), which require both statements to be true, are excluded; option (D) also wrongly rejects the assertion.

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

Quick Tip to Solve: Separate aerobic floc formation in the aeration tank from anaerobic digestion and methane production in the sludge digester.

16. Assertion (A): Hardy-Weinberg principle says that allele frequencies in a population are stable.

Reason (R): Hardy-Weinberg principle is applicable only when genetic drift does not occur. [1 mark]

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

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

(C) Assertion (A) is true, but Reason (R) is false.

(D) Assertion (A) is false, but Reason (R) is true.

Correct Answer: (A) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of the Assertion (A).

Solution:

Concept:

- Hardy-Weinberg equilibrium states that allele frequencies remain constant across generations in a population when evolutionary forces are absent.
- Genetic drift is a random change in allele frequencies, especially significant in small populations; it disturbs genetic equilibrium.

Step 1: Evaluate the assertion Assertion (A) is true. Under Hardy-Weinberg equilibrium, the allele frequencies remain stable from one generation to the next. For two alleles with frequencies p and q , $p + q = 1$, and the expected genotype frequencies are p^2 , $2pq$ and q^2 .

Step 2: Evaluate the reason Reason (R) is true. Genetic drift changes allele frequencies by chance. Therefore, the absence of genetic drift is one necessary condition for Hardy-Weinberg equilibrium. The other conditions include random mating and absence of mutation, migration and natural selection.

Step 3: Check whether the reason explains the assertion The absence of drift prevents random fluctuations in allele frequencies and thus explains their stability under the equilibrium conditions. The reason correctly identifies a condition needed for the assertion; it does not claim that this condition alone is sufficient. Options (C) and (D) wrongly call one statement false, while option (B) misses this explanatory connection.

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

Quick Tip to Solve: Ask whether an evolutionary force changes allele frequencies: genetic drift does, so its absence is required for Hardy-Weinberg stability.

Section B (10 marks)

17(a). A patient reports a high fever, chills and sweating. His blood shows the presence of a toxic substance.

(i) Identify the disease and the causative organism.

(ii) Explain why this disease shows recurring pattern of fever.

[2 marks]

Solution:

Concept:

- Malaria is caused by protozoan parasites of the genus *Plasmodium*, which multiply in human liver cells and then in red blood cells.
- The rupture of infected red blood cells releases the toxic substance haemozoin, producing the characteristic recurrent chills and high fever.

Step 1: Identify the disease and pathogen (i) The combination of high fever, chills, sweating and a toxic substance in the blood indicates **malaria**. Its causative organism is *Plasmodium*, for example *P. vivax* or *P. falciparum*. The female *Anopheles* mosquito transmits the parasite but is the vector, not the causative organism.

Step 2: Explain the recurring fever (ii) After the liver phase, the parasites enter red blood cells and multiply. The infected red blood cells rupture, releasing both new parasites and haemozoin into the blood. Haemozoin triggers chills and high fever. The released parasites invade fresh red blood cells, multiply again and cause another cycle of rupture. Repeated, approximately synchronised cycles of red-cell rupture therefore produce recurring attacks of fever, commonly at intervals of three to four days in the NCERT description.

Step 3: Conclusion The disease is malaria, caused by *Plasmodium*. Periodic rupture of infected red blood cells and release of haemozoin cause the recurring fever.

Quick Tip to Solve: Link the clue “toxic substance in blood” to haemozoin, and explain recurrence through repeated red-cell rupture rather than repeated mosquito bites.

OR

17(b). Give the microbial source and mode of action of the following bioactive molecules:

(i) Cyclosporin-A

(ii) Streptokinase

[2 marks]

Solution:

Concept:

- Microorganisms produce bioactive molecules that can be isolated and used as therapeutic agents.
- An immunosuppressant reduces immune responses, whereas a clot-busting agent promotes the breakdown of a blood clot.

Step 1: State the source and action of cyclosporin-A (i) **Cyclosporin-A** is produced by the fungus

Trichoderma polysporum. It acts as an immunosuppressive agent, suppressing the activity of the recipient's immune system. It is used in organ transplantation to reduce immune rejection of the transplanted organ. Thus its action is on the immune response, not on a blood clot.

Step 2: State the source and action of streptokinase (ii) **Streptokinase** is produced by the bacterium *Streptococcus* and is modified by genetic engineering for therapeutic use. It acts as a clot buster: it promotes activation of plasminogen to plasmin, which breaks down the fibrin network of a blood clot. It is used to remove clots from blood vessels in patients who have suffered myocardial infarction, helping restore blood flow to heart muscle.

Step 3: Conclusion Cyclosporin-A from *Trichoderma polysporum* suppresses immune rejection during organ transplantation. Streptokinase from *Streptococcus* helps dissolve intravascular blood clots.

Quick Tip to Solve: Pair cyclosporin-A with the fungus and transplantation; pair streptokinase with the bacterium and clot removal after myocardial infarction.

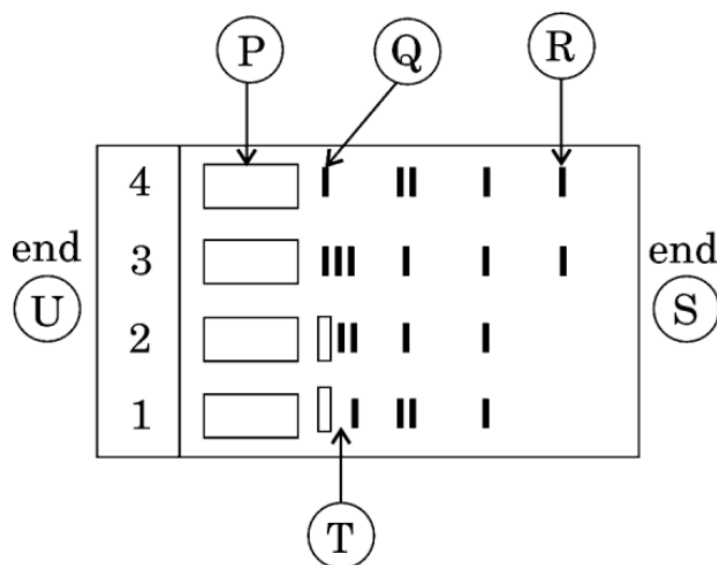
18(a). (i) Given below is the schematic representation of the process of electrophoresis. Identify the alphabets representing the:

(I) Anode end, and

(II) Lightest/Smallest DNA in matrix.

(ii) What is Agarose gel and why is it used in this process?

[2 marks]



Solution:

Concept:

- DNA is negatively charged because of its phosphate backbone and migrates towards the positive electrode, the anode, in an electric field.
- Agarose gel acts as a molecular sieve: smaller DNA fragments move more readily through its pores and travel farther than larger fragments in the same time.

Step 1: Identify the electrode and smallest fragment (i) (I) The anode end is S. The loading wells are at the left, near end U, and the DNA bands have migrated towards the right. Since DNA moves towards the positive electrode, the right-hand end S is the anode. (II) The smallest DNA fragment is represented by R, the band farthest from the loading well in the labelled lane. Q is closer to the well and therefore represents a larger fragment than R; P points to the loading well itself.

Step 2: Explain the role of agarose (ii) Agarose is a natural polymer extracted from seaweeds. When prepared as a gel, it forms a porous supporting matrix. The gel offers size-dependent resistance to migrating DNA molecules, so smaller fragments pass through its pores more easily and move farther. It is therefore used to separate a mixture of DNA fragments according to their size, producing distinct bands that can subsequently be visualised.

Step 3: Conclusion The anode end is S, and the smallest DNA fragment is R. Agarose is a seaweed-derived natural polymer whose porous gel separates DNA fragments by size through a sieving effect.

Quick Tip to Solve: Locate the wells first: DNA moves away from them towards the anode, and the band farthest from its well contains the smallest fragments.

OR

18(b). After performing gel electrophoresis, a student observes that DNA fragments are not visible.

(i) Suggest a reason for this and explain how fragments can be made visible.

(ii) Also explain how a specific DNA fragment can be collected from the gel for further use. [2 marks]

Solution:

Concept:

- DNA is colourless and cannot normally be seen directly in an agarose gel with the naked eye.
- Ethidium bromide associates with DNA and fluoresces under ultraviolet (UV) light; elution recovers a selected fragment from the gel.

Step 1: (i) Make the separated DNA visible A likely reason is that the DNA has not been stained, or the stained gel has not been viewed under UV light. Stain the DNA with ethidium bromide and expose the gel to UV radiation. The separated DNA fragments appear as bright orange bands. Thus, absence of visible bands in ordinary light does not by itself mean that electrophoresis failed.

Step 2: (ii) Recover the required fragment Locate the band corresponding to the required DNA fragment and cut out that portion of the agarose gel. Extract the DNA from the excised gel piece and purify it. This recovery of the DNA fragment from the gel is called **elution**. The purified fragment can then be used, for example, for ligation into a cloning vector.

Step 3: Conclusion Stain with ethidium bromide and observe under UV light to see orange DNA bands; excise the desired band and recover its DNA by elution.

Quick Tip to Solve: Remember the sequence: stain, illuminate with UV, excise the chosen band, then elute its DNA.

19. State any four reasons why Mendel succeeded in his genetic hybridisation experiments on garden peas. [2 marks]

Solution:

Concept:

- A reliable inheritance experiment needs clearly distinguishable traits and controlled parentage.
- Pure parental lines and a large number of offspring help reveal consistent patterns of transmission between generations.

Step 1: Reasons 1 and 2: suitable traits and pure lines **1. Clear contrasting traits:** Mendel chose pea characters with easily distinguished alternatives, such as tall and dwarf plants, so offspring could be classified without confusion.

2. True-breeding parents: He selected stable, true-breeding pea varieties, maintained through self-pollination. This gave a dependable starting point for interpreting the results of crosses.

Step 2: Reasons 3 and 4: controlled crosses and quantitative study **3. Controlled pollination:** Pea flowers normally self-pollinate, but artificial cross-pollination is easy after emasculation and transfer of selected pollen. Mendel could therefore control which parents contributed to a cross.

4. Large samples and statistical analysis: He recorded and counted many offspring over successive generations and analysed the numerical ratios. Large samples reduced the influence of chance and made inheritance patterns evident.

Step 3: Conclusion Clear contrasting traits, true-breeding parental lines, controlled pollination, and quantitative analysis of many offspring were four reasons for Mendel's success.

Quick Tip to Solve: Give four distinct reasons by linking the choice of peas to Mendel's control, recording and analysis of crosses.

20(a). (i) Mention any two characteristics of Neanderthal man that lived near East and Central Asia.

(ii) Identify the following hominids with respect to human evolution:

(I) Brain capacity 900 cc, probably ate meat.

(II) First human-like with brain capacity 650 - 800 cc. [2 marks]

Solution:

Concept:

- Fossil hominids are distinguished using features such as cranial capacity, body structure and evidence of behaviour.
- In the NCERT sequence, *Homo habilis* is the first human-like hominid, followed by *Homo erectus*, which had a larger brain capacity.

Step 1: (i) State two characteristics of Neanderthal man Two characteristics of Neanderthal man are: **(1)** a brain capacity of about 1400 cc, and **(2)** the use of animal hides to protect the body. These identify both an anatomical feature and a behavioural adaptation of the Neanderthal populations referred to in the question.

Step 2: (ii) Identify the two hominids (I) The hominid with a brain capacity of about 900 cc, which probably ate meat, is *Homo erectus*.

(II) The first human-like hominid with a brain capacity of about 650–800 cc is *Homo habilis*. The smaller stated cranial capacity belongs to *Homo habilis*, whereas the 900 cc value belongs to *Homo erectus*; the two names should not be interchanged.

Step 3: Conclusion Neanderthals had a brain capacity of about 1400 cc and used hides for protection. (I) is *Homo erectus*; (II) is *Homo habilis*.

Quick Tip to Solve: Match the capacities in order: habilis, 650–800 cc; erectus, 900 cc; Neanderthal, about 1400 cc.

OR

20(b). The allele for brown eyes (B) is dominant over blue eyes (b). In a population, 36% of individuals have blue eyes. Assuming Hardy-Weinberg equilibrium, calculate:

(i) Frequency of allele B

(ii) Percentage of heterozygous individuals

(iii) Percentage of individuals that are homozygous dominant

(Working to be shown)

[2 marks]

Solution:

Concept:

- Let p be the frequency of allele B and q the frequency of allele b . Then $p + q = 1$.
- At Hardy-Weinberg equilibrium, the genotype frequencies of BB , Bb and bb are p^2 , $2pq$ and q^2 , respectively, and $p^2 + 2pq + q^2 = 1$.

Step 1: (i) Obtain the allele frequencies from the recessive phenotype Blue eyes occur only in the recessive genotype bb , so the given 36% is the genotype frequency q^2 , not the allele frequency q . Therefore,

$$q^2 = 0.36, \quad q = \sqrt{0.36} = 0.60.$$

Since allele frequencies add to one, the frequency of allele B is

$$p = 1 - q = 1 - 0.60 = 0.40.$$

Step 2: (ii) Calculate the heterozygous percentage The frequency of heterozygotes Bb is

$$2pq = 2(0.40)(0.60) = 0.48.$$

Multiplying this frequency by 100 gives 48% heterozygous individuals.

Step 3: (iii) Calculate the homozygous dominant percentage The frequency of BB individuals is

$$p^2 = (0.40)^2 = 0.16,$$

giving 16% homozygous dominant individuals. As a check, the three genotype percentages total $16 + 48 + 36 = 100\%$.

Step 4: Conclusion (i) Frequency of $B = 0.40$; (ii) heterozygous individuals = 48%; (iii) homozygous dominant individuals = 16%.

Quick Tip to Solve: Start with the recessive phenotype as q squared: take its square root before calculating p and $2pq$.

21. A foreign company patented the medicinal use of turmeric already known to Indian households.

(a) Name and define this unethical practice.

(b) What has the Indian Government done to check this?

[2 marks]

Solution:

Concept:

- Communities may possess traditional knowledge about the properties and uses of biological resources, such as the medicinal uses of turmeric.
- Protection of this knowledge requires recognition of its existing use and prevention of its unauthorised appropriation through patents or commercial exploitation.

Step 1: (a) Name and define the practice The practice is **biopiracy**: the use of biological resources or associated traditional knowledge by companies or other organisations without proper authorisation from the countries and people concerned and without compensatory payment. Here, the company claims a patent over a medicinal use of turmeric that was already known to Indian households, appropriating their traditional knowledge.

Step 2: (b) State the Indian Government's measures The Indian Government has strengthened patent protection against such appropriation. As described in NCERT, the Indian Parliament cleared the **second amendment of the Indian Patents Bill**, taking into consideration patent terms, emergency provisions, and research and development initiatives. India has also documented traditional medicinal knowledge through the **Traditional Knowledge Digital Library (TKDL)**, allowing patent examiners to recognise existing knowledge and helping prevent wrongful patents.

Step 3: Conclusion This is biopiracy. Patent-law amendments and documentation of traditional knowledge help India check such unauthorised patent claims.

Quick Tip to Solve: In a turmeric patent example, name biopiracy, define the lack of authorisation or compensation, then state India's protective measures.

Section C (21 marks)

22. (a) Describe the experiment conducted by T.H. Morgan on *Drosophila melanogaster* involving eye colour and body colour.

(b) How did the results deviate from Mendelian inheritance pattern?

(c) Explain the two genetic terms used by Morgan for his observations.

[3 marks]

Solution:

Concept:

- Mendel's law of independent assortment predicts independent transmission of two gene pairs in a dihybrid cross when the genes are unlinked.
- Genes on the same chromosome may show linkage; crossing over can produce new combinations of their alleles.

Step 1: (a) Describe Morgan's cross Morgan crossed yellow-bodied, white-eyed female *Drosophila melanogaster* with brown-bodied, red-eyed males. He then intercrossed the F_1 progeny and examined the combinations of body colour and eye colour in the F_2 offspring. The genes for these characters were located on the same X chromosome. This allowed him to compare the transmission of two genes carried on one chromosome with Mendel's prediction of independent assortment.

Step 2: (b) Compare the offspring with Mendelian expectations The two genes did not segregate independently, and the F_2 phenotypic distribution deviated from the Mendelian dihybrid ratio of 9 : 3 : 3 : 1. Combinations resembling the parental combinations occurred much more frequently than new, non-parental combinations. The body-colour and eye-colour genes were tightly linked, so only a small proportion of recombinant combinations was produced.

Step 3: (c) Explain linkage and recombination **Linkage** is the physical association of genes on the same chromosome and their tendency to be inherited together. It accounts for the excess of parental combinations. **Recombination** is the production of non-parental combinations of alleles. For linked genes, crossing over between homologous chromosomes during meiosis produces such combinations. Closely placed genes recombine less frequently than genes situated farther apart on the same chromosome.

Step 4: Conclusion Morgan's cross showed an excess of parental combinations because the body-colour and eye-colour genes were linked. The fewer new combinations arose through recombination, explaining the departure from independent assortment.

Quick Tip to Solve: Connect each observation to its term: excess parental combinations means linkage; new combinations mean recombination.

23. In vitro fertilization (IVF) is a popular method these days that is helping childless couples to bear a child.

(a) Write the different steps that are carried out in this technique.

(b) Would you consider gamete intra fallopian transfer as a type of IVF? Justify your answer. [3 marks]

Solution:

Concept:

- In vitro fertilisation (IVF) means fertilisation outside the body under laboratory conditions that simulate suitable conditions within the body.
- IVF is followed by embryo transfer (ET). The developmental stage of the embryo determines whether it is transferred to the Fallopian tube or the uterus.

Step 1: (a) Collect gametes and carry out fertilisation Ova are collected from the wife or a donor, and sperms are collected from the husband or a donor. The ova and sperms are brought together under suitable laboratory conditions so that fertilisation occurs outside the woman's body. The resulting zygote is cultured and allowed to undergo early cleavage divisions.

Step 2: (a) Transfer the zygote or embryo The zygote or early embryo with up to eight blastomeres is transferred into the Fallopian tube by zygote intrafallopian transfer (ZIFT). An embryo with more than eight blastomeres is transferred into the uterus by intrauterine transfer (IUT). After successful implantation in the uterine endometrium, development proceeds within the woman's body. Thus, IVF produces the embryo in the laboratory, while embryo transfer enables its further development in the reproductive tract.

Step 3: (b) Distinguish GIFT from IVF Gamete intrafallopian transfer (GIFT) is not a type of IVF, because fertilisation in GIFT occurs inside the woman's body, that is, *in vivo*. In the NCERT description, an ovum from a donor is transferred to the Fallopian tube of a woman who cannot produce ova but can provide a suitable environment for fertilisation and further development. A gamete is transferred before fertilisation in GIFT; in IVF followed by embryo transfer, a zygote or embryo formed after laboratory fertilisation is transferred.

Step 4: Conclusion IVF involves gamete collection, laboratory fertilisation, early embryo culture and embryo transfer by ZIFT or IUT. GIFT is distinct because fertilisation occurs inside the body rather than in the laboratory.

Quick Tip to Solve: First identify the site of fertilisation: laboratory means IVF, whereas fertilisation in the Fallopian tube after gamete transfer means GIFT.

24. Answer the following questions:

(a) Explain the different ways by which apomictic seeds can be developed.

(b) Mention one advantage of apomictic seeds for farmers.

[3 marks]

Solution:

Concept:

- Apomixis is seed formation without fertilisation. It is an asexual mode of reproduction that mimics sexual reproduction by producing seeds.
- An apomictic embryo may develop from an unreduced egg or directly from a diploid somatic cell of the ovule, preserving the maternal genetic constitution.

Step 1: (a) Explain embryo formation from an unreduced egg In some species, a diploid egg cell is formed without reduction division, so it retains the complete maternal chromosome complement. This egg develops directly into an embryo without fusion with a male gamete. Since meiosis is bypassed and fertilisation does not occur, the embryo is formed asexually, yet it becomes enclosed in a seed.

Step 2: (a) Explain embryo formation from nucellar cells In several varieties of *Citrus* and mango, some diploid nucellar cells surrounding the embryo sac start dividing, protrude into the embryo sac and develop into embryos. These embryos arise directly from maternal somatic tissue without fertilisation. More than one such embryo may occur in a seed, producing polyembryony. Thus, apomictic embryos can originate either from an unreduced egg or from diploid cells outside the embryo sac.

Step 3: (b) Relate apomixis to hybrid-seed production If hybrids are made apomictic, their desirable hybrid characters can be maintained in subsequent seed generations because the apomictic embryos do not undergo the segregation of characters associated with sexual reproduction. Farmers can therefore retain and sow seeds from the hybrid crop repeatedly instead of buying fresh hybrid seed each year. This preserves useful hybrid performance and reduces the recurring cost of seed purchase.

Step 4: Conclusion Apomictic seeds develop through an unfertilised diploid egg or through embryos arising from diploid nucellar cells. In apomictic hybrids, farmers can reuse seed while retaining desirable hybrid characters.

Quick Tip to Solve: Name the embryo's starting cell in each route: unreduced egg or diploid nucellar cell. For the farmer's benefit, link absence of segregation to reuse of hybrid seed.

25. Draw a neat diagram of a maize grain showing the internal structure and label any five parts.

[3 marks]

Solution:

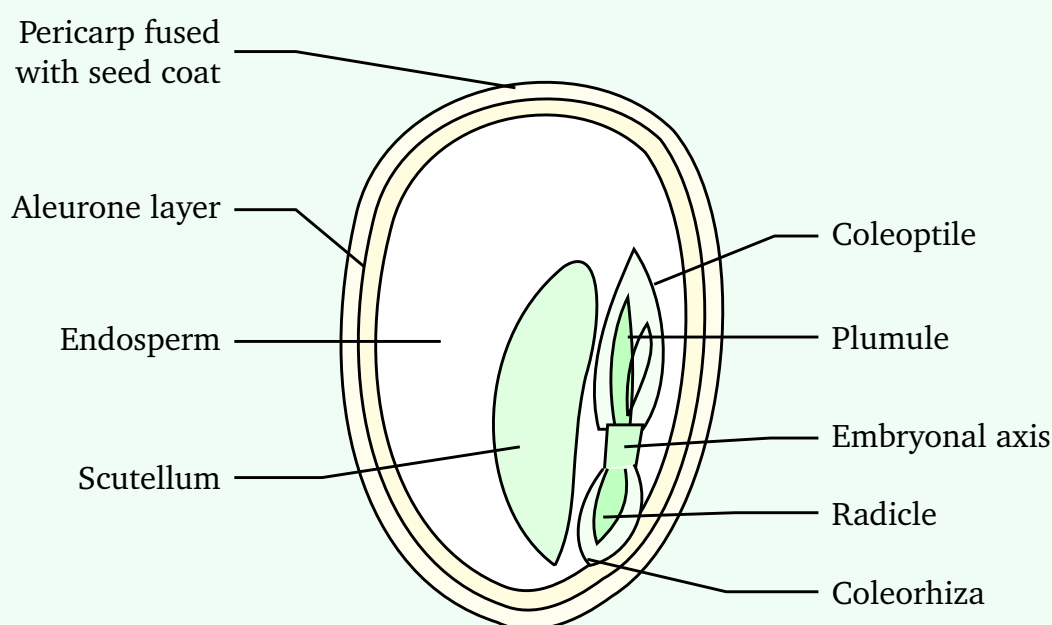
Concept:

- Maize is a monocotyledonous plant. Its grain is a caryopsis, in which the thin seed coat is fused with the fruit wall (pericarp).
- The mature grain retains a large food-storing endosperm. Its outer protein-rich layer is the aleurone layer, while the embryo lies on one side of the endosperm.

- The maize embryo has a single large, shield-shaped cotyledon called the scutellum and an embryonal axis bearing a plumule and a radicle.

Step 1: Draw the longitudinal section Outline the grain and show the fused pericarp and seed coat at its surface. Just inside this covering, indicate the aleurone layer around the starchy endosperm. Make the endosperm occupy most of the grain, since it stores food used during germination. Place the small embryo towards one side of the lower region, rather than in the centre of the endosperm.

Step 2: Identify and label the embryo Show the broad scutellum between the endosperm and the embryonal axis. At the upper end of the axis, draw the plumule enclosed by its protective sheath, the coleoptile. At the lower end, draw the radicle surrounded by the coleorhiza. The leader lines in the figure distinguish the embryonic shoot and root from their respective sheaths. Any five correctly placed labels satisfy the labelling requirement; additional principal parts are shown for clarity.



Longitudinal section of a maize grain (schematic)

Step 3: Conclusion The labelled longitudinal section shows the internal structure of a maize grain: fused pericarp and seed coat, aleurone layer, endosperm, scutellum, plumule, coleoptile, radicle and coleorhiza.

Quick Tip to Solve: Keep the large endosperm and the single shield-shaped scutellum prominent; pair plumule with coleoptile and radicle with coleorhiza.

26. (a) What is meant by translation in protein synthesis?

(b) Explain charging of tRNA (aminoacylation of tRNA) and mention its importance in the process of translation. [3 marks]

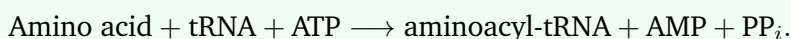
Solution:

Concept:

- Translation is the polymerisation of amino acids into a polypeptide according to the sequence of codons in messenger RNA (mRNA).
- Transfer RNA (tRNA) is an adaptor: its anticodon recognises an mRNA codon, while its amino acid attachment site carries the corresponding amino acid.
- Aminoacyl-tRNA synthetase uses ATP to attach an amino acid to its appropriate tRNA. The product is called charged tRNA or aminoacyl-tRNA.

Step 1: Define translation (a) During translation, ribosomes read the codon sequence of mRNA and join the corresponding amino acids by peptide bonds. Thus, the information in the nucleotide sequence of mRNA is expressed as the amino acid sequence of a polypeptide. The order of amino acids is determined by the order of codons, rather than by the abundance of free amino acids in the cytoplasm.

Step 2: Explain charging of tRNA (b) An amino acid is activated using energy supplied by ATP. A specific aminoacyl-tRNA synthetase recognises the amino acid and its appropriate tRNA and catalyses attachment of the amino acid to the terminal adenosine of the tRNA's 3'-CCA end. This ATP-dependent process is aminoacylation, or charging, of tRNA. Its overall reaction may be represented as



Here PP_i denotes inorganic pyrophosphate. The amino acid is linked to tRNA by an energy-rich ester bond.

Step 3: State why charging is essential Charging supplies the ribosome with activated amino acids attached to their correct adaptor molecules. Codon-anticodon pairing then positions each charged tRNA so that the correct amino acid is added to the growing chain. Energy conserved in the amino acid-tRNA linkage helps drive peptide-bond formation during elongation. Correct charging is therefore essential both for the accuracy of the polypeptide sequence and for the energetics of its synthesis.

Step 4: Conclusion Translation converts the codon sequence of mRNA into a polypeptide. Charging is the ATP-dependent attachment of a specific amino acid to its appropriate tRNA, providing correctly matched, activated amino acids for protein synthesis.

Quick Tip to Solve: Separate the two recognition events: synthetase matches amino acid to tRNA, and the tRNA anticodon matches the mRNA codon at the ribosome.

27. (a) Who discovered Penicillin and how? Explain.

(b) Why is this discovery considered accidental?

(c) In what way did it prove to be a 'milestone' in the field of medicine?

[3 marks]

Solution:

Concept:

- Antibiotics are substances produced by certain microorganisms that can kill other disease-causing microorganisms or inhibit their growth.
- Penicillin is an antibiotic obtained from the fungus *Penicillium*. Its discovery demonstrated the medicinal value of substances produced by microbes.

Step 1: Explain Fleming's observation (a) Alexander Fleming discovered penicillin while working with *Staphylococcus* bacteria. He observed that a culture plate had become contaminated with a mould and that bacteria did not grow around the mould colony. He identified the mould as *Penicillium notatum* and inferred that it produced a substance that inhibited bacterial growth. He named this antibacterial substance penicillin after the mould that produced it.

Step 2: Explain the accidental nature of the discovery (b) The fungal contamination of the bacterial culture was unplanned. Fleming was studying bacteria, rather than deliberately carrying out an experiment designed to obtain penicillin from a mould. The unexpected bacteria-free region around the contaminating fungal colony drew his attention. Thus, the initial event was accidental, while his careful observation and interpretation converted that chance event into a scientific discovery.

Step 3: Explain its importance in medicine (c) Penicillin provided an effective means of treating many bacterial infections that had previously caused serious illness and death. Its discovery opened the antibiotic era and encouraged the search for other antimicrobial substances. Ernst Chain and Howard Florey subsequently established its full potential as an effective antibiotic and helped make therapeutic use possible. Its extensive use during the Second World War saved many lives, making the discovery a major milestone in modern medicine.

Step 4: Conclusion Alexander Fleming discovered penicillin through the accidental contamination of a bacterial culture by *Penicillium notatum*. The resulting antibiotic transformed the treatment of bacterial infections and saved many lives.

Quick Tip to Solve: Remember the observation chain: mould contamination, a bacteria-free zone, an inhibitory substance, and the development of an antibiotic treatment.

28. (a) What is the carrying capacity of a species in a habitat?

(b) Explain the growth curve that takes this capacity into account.

[3 marks]

Solution:

Concept:

- Carrying capacity, denoted by K , is the maximum population size that a habitat can support with its available resources under the prevailing conditions.

- Logistic growth accounts for resource limitation. Its equation is $\frac{dN}{dt} = rN \left(\frac{K - N}{K} \right)$, where N is population size, t is time and r is the intrinsic rate of natural increase.

Step 1: (a) Define the habitat's carrying capacity Food, space, shelter and other resources in a habitat are limited. Therefore, the habitat can sustain only a certain maximum number of individuals of a species over time. This limit is its carrying capacity K ; it depends on the species and the prevailing environmental conditions.

Step 2: (b) Explain the stages of logistic growth A population growing with limited resources initially shows a lag phase, followed by rapid growth when resources are relatively abundant. As population size increases, competition for resources increases and growth decelerates. Eventually the population approaches a stationary phase at the carrying capacity. Plotting population size against time therefore gives a sigmoid or S-shaped curve, also called the Verhulst–Pearl logistic growth curve.

Step 3: Relate the slowing growth to the equation The factor $(K - N)/K$ represents the reduction in growth as the population approaches its resource limit. When N is small compared with K , the factor is close to one. As N approaches K , it approaches zero. At $N = K$, net population growth is zero, so the curve levels off rather than rising indefinitely.

Step 4: Conclusion Carrying capacity K is the maximum population a habitat can sustain. The logistic growth curve includes this limit and is S-shaped, with population size tending towards K .

Quick Tip to Solve: Link limited resources to logistic growth: the factor $(K - N)/K$ becomes zero at $N = K$, explaining the plateau.

Section D (8 marks)

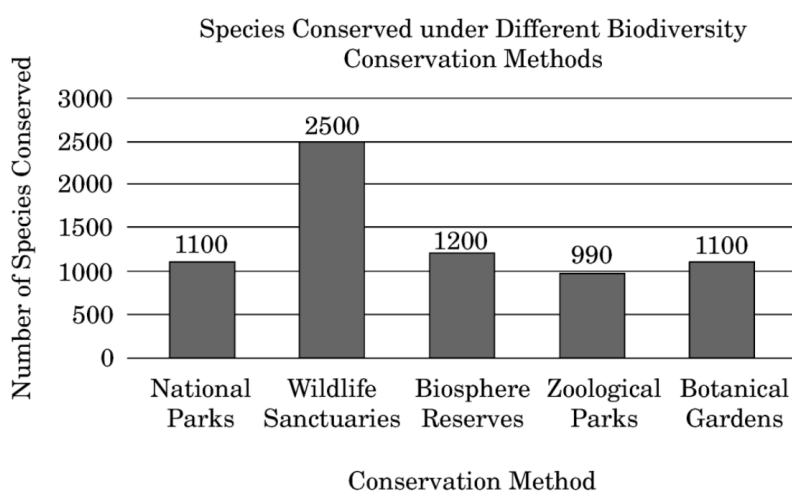
Questions No. 29 and 30 are Case-Based questions. Each question has 3 sub-questions with internal choice in one sub-question.

29. Read the following passage and answer the questions that follow:

India is one of the megadiverse countries housing around 8.1 per cent of global species diversity, although its land area is only 2.4 per cent of the world's land area. Many of the species are highly threatened due to human activities like deforestation, mining and habitat fragmentation. Laws like Wildlife (Protection) Act, 1972 were enacted by the Government of India to preserve our biological wealth. Various conservation measures are being implemented to save the threatened species.

The following bar graph shows the number of species conserved under different biodiversity conservation methods.

[4 marks]



Study the graph and answer the questions.

29(a). Which method conserves the highest number of species? Is it *ex situ* or *in situ* conservation?

[1 mark]

Solution:

Concept:

- The height of each bar represents the number of species conserved by that method; the tallest bar gives the largest number.
- In *in situ* conservation, species are protected within their natural habitats, together with their ecological communities.

Step 1: Compare the bars The wildlife-sanctuary bar reaches 2500 species. This is higher than biosphere reserves (1200), national parks (1100), botanical gardens (1100) and zoological parks (990).

Step 2: Classify the method Wildlife sanctuaries protect organisms in their natural surroundings. They therefore conserve species by the *in situ* approach, while zoological parks and botanical gardens maintain organisms outside their natural habitats.

Step 3: Conclusion Wildlife sanctuaries conserve the highest number shown, 2500 species; this is *in situ* conservation.

Quick Tip to Solve: First find the tallest bar, then classify the location of protection: natural habitat means *in situ*.

29(b). Which other methods shown in the diagram are opposite to the one identified by you in question (a)? How are these two conservation approaches different? [2 marks]

Solution:

Concept:

- *In situ* conservation protects species within their natural habitats and conserves the ecological interactions of the community.
- *Ex situ* conservation maintains organisms outside their natural habitats under human care, allowing targeted protection and propagation.

Step 1: Identify the opposite methods in the graph The method in part (a), wildlife sanctuaries, is *in situ*. The contrasting *ex situ* methods shown are zoological parks and botanical gardens. Zoological parks maintain animals, while botanical gardens maintain living collections of plants.

Step 2: Distinguish the two approaches In *in situ* conservation, organisms remain in the habitat where they naturally occur, so protection includes their surroundings, food webs and interactions. In *ex situ* conservation, selected organisms are maintained away from that habitat in managed conditions, where their care and breeding or propagation can be controlled. National parks and biosphere reserves, like wildlife sanctuaries, belong to the first approach.

Step 3: Conclusion Zoological parks and botanical gardens are the *ex situ* methods. *In situ* protection occurs in natural habitats, whereas *ex situ* protection occurs outside them under managed conditions.

Quick Tip to Solve: Choose the zoo and botanical garden as the contrasting pair; national parks and biosphere reserves also protect natural habitats.

29(c)(i). Write two features of Biodiversity hotspots. [1 mark]

Solution:

Concept:

- Species richness is the number of different species present in a region.
- Endemism means that a species is naturally restricted to a particular geographical region and is not naturally found elsewhere.

Step 1: State the first feature Biodiversity hotspots have exceptionally high species richness: a large variety of species occurs within the region, making it especially valuable for conserving biodiversity.

Step 2: State the second feature They also have a high degree of endemism, with many species confined to that region. Loss of such habitats can therefore threaten species that have no natural

populations elsewhere. Hotspots are prioritised because their rich, distinctive biodiversity faces severe habitat loss.

Step 3: Conclusion Two features are exceptionally high species richness and a high degree of endemism.

Quick Tip to Solve: Keep the two features distinct: richness concerns how many species occur; endemism concerns where else they occur.

OR

29(c)(ii). To which category do sacred groves belong and how do they help in bio-conservation?

[1 mark]

Solution:

Concept:

- *In situ* conservation protects species in their own natural habitats.
- Sacred groves are forest patches protected by local communities because of religious beliefs and cultural traditions.

Step 1: Classify sacred groves As the plants and animals remain within the protected forest patch, sacred groves are examples of *in situ* conservation. They do not involve transferring organisms to zoos or botanical gardens.

Step 2: Explain their conservation value Community traditions restrict tree cutting and disturbance, helping preserve the habitat and its biodiversity. Such patches provide refuges for rare and threatened species, including plants that may have disappeared from the surrounding disturbed landscape.

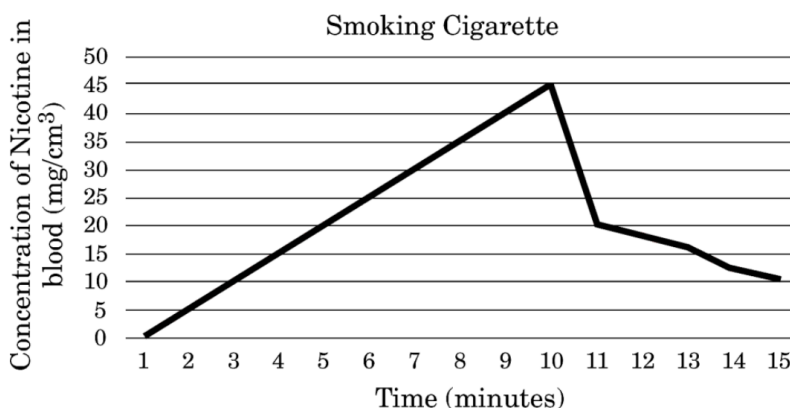
Step 3: Conclusion Sacred groves belong to *in situ* conservation; traditional community protection preserves natural forest habitats and shelters rare and threatened species.

Quick Tip to Solve: Link sacred groves to protected forest patches: organisms stay in their habitat, so the category is *in situ*.

30. Read the following passage and answer the question that follow:

The data below shows the concentration of nicotine smoked by a smoker taking 10 puffs/minute.

[4 marks]



30(a)(i). With reference to the above graph, explain the concentration of nicotine in the blood at 10 minutes.

[1 mark]

Solution:

Concept:

- A concentration–time graph gives the concentration in the blood at any instant from the vertical coordinate corresponding to that time.
- During repeated smoking, nicotine absorbed into the bloodstream accumulates when its input exceeds its removal.

Step 1: Locate the reading at ten minutes Find 10 minutes on the horizontal axis and move vertically to the plotted line. This point is the peak of the curve and aligns with 45 on the concentration axis, whose printed unit is mg/cm³.

Step 2: Explain the rise to the peak Up to ten minutes, the graph rises as repeated puffs supply nicotine, which is absorbed into the blood. Over this interval, entry exceeds removal, producing the highest concentration shown. Beyond ten minutes the graph falls, so the ten-minute reading is the maximum, rather than a value on the declining portion.

Step 3: Conclusion At 10 minutes, the nicotine concentration reaches its maximum shown value, 45 mg/cm³, following its accumulation during smoking.

Quick Tip to Solve: Read directly upwards from ten minutes to the peak, then horizontally to the concentration axis; retain the graph's printed unit.

30(a)(ii). How will this affect the concentration of carbon monoxide and haem-bound oxygen at 10 minutes? [1 mark]

Solution:

Concept:

- Cigarette smoke contains carbon monoxide as well as nicotine; smoking introduces both into the body.
- Carbon monoxide binds strongly to haemoglobin, forming carboxyhaemoglobin and reducing the amount of haemoglobin available to carry oxygen.

Step 1: Relate the ten-minute point to smoking At ten minutes the graph shows the peak nicotine concentration after repeated smoking. Smoke exposure also raises the carbon monoxide level in the blood. The graph measures nicotine, so it does not give a numerical carbon monoxide concentration.

Step 2: Explain the effect on oxygen transport As more carbon monoxide binds haemoglobin, less haemoglobin remains available for oxygen binding. Consequently, haem-bound oxygen decreases and the oxygen-carrying capacity of blood is reduced. This effect is due to carbon monoxide in smoke; nicotine is not converted into carbon monoxide.

Step 3: Conclusion At ten minutes, carbon monoxide in the blood increases, while haem-bound oxygen decreases.

Quick Tip to Solve: For this qualitative comparison, pair increased carbon monoxide with decreased haemoglobin-bound oxygen; do not read their values from the nicotine graph.

30(b). How does cigarette smoking result in high blood pressure and increase in heart rate? [1 mark]

Solution:

Concept:

- Nicotine is an active component of tobacco that stimulates the adrenal glands.
- The adrenal hormones adrenaline and noradrenaline activate physiological responses that increase cardiovascular activity.

Step 1: Identify the hormonal trigger Nicotine absorbed during cigarette smoking stimulates the adrenal glands to release adrenaline and noradrenaline into the blood. These hormones mediate the rapid cardiovascular response to nicotine.

Step 2: Connect the hormones to the observed effects Adrenaline and noradrenaline increase the rate and force of the heartbeat and promote constriction of blood vessels. Increased cardiac activity and vascular resistance raise blood pressure, explaining why smoking can increase both heart rate and blood pressure.

Step 3: Conclusion Nicotine stimulates adrenal release of adrenaline and noradrenaline, which increase heart rate and raise blood pressure.

Quick Tip to Solve: Recall the causal chain: nicotine stimulates adrenal hormones, then the heart beats faster and blood pressure rises.

30(c). To which class of compounds does nicotine belong? Name one other drug from the same class. [2 marks]

Solution:

Concept:

- Alkaloids are naturally occurring nitrogen-containing organic compounds, many of which occur in plants and have marked physiological effects.
- A chemical class groups compounds by chemical characteristics; its members need not have the same effect on the nervous system.

Step 1: Identify the class of nicotine Nicotine is an alkaloid present in the tobacco plant. It contains nitrogen and produces pronounced physiological effects, including stimulation associated with tobacco use. Thus, the requested class of compounds is alkaloids.

Step 2: Name another drug of that class Morphine is another alkaloid. It is obtained from the latex of the opium poppy and acts as an opioid analgesic. Nicotine and morphine belong to the same broad chemical class, even though nicotine has stimulant effects and morphine has very different actions. The question asks for the chemical class, rather than requiring another drug with an identical physiological effect.

Step 3: Conclusion Nicotine belongs to the alkaloids; morphine is another drug of this class.

Quick Tip to Solve: Answer with the chemical class first: alkaloid. Use morphine as the example without claiming that it acts like nicotine.

Section E (15 marks)

31(a). The following questions are based on the classic experiment conducted by Hershey and Chase.

- Why were bacteriophages chosen by the scientists?
- Name the radioactive isotopes used and state the reason for using them.
- Describe the steps of the experiment.
- Why is this experiment considered a major breakthrough in the field of molecular biology?

[5 marks]

Solution:

Concept:

- A genetic material must enter the host cell and direct the formation of new virus particles. A bacteriophage has DNA enclosed in a protein coat, so these two candidate materials can be followed separately.
- Radioactive tracers identify a molecule without relying on its appearance. Phosphorus occurs in the DNA backbone, whereas sulphur occurs in certain protein amino acids but not in DNA.

Step 1: (i) Explain the choice of bacteriophages Hershey and Chase used bacteriophages, viruses that infect bacteria such as *Escherichia coli*. Their simple composition, DNA and a protein coat, allowed a direct test of which component carries hereditary information. During infection the hereditary

material enters the bacterial cell and controls the production of progeny phages; material remaining outside can be separated from the cells.

Step 2: (ii) Choose separate radioactive labels They used radioactive phosphorus, ^{32}P , to label phage DNA because DNA contains phosphorus in its phosphate backbone, whereas the phage protein coat does not. They used radioactive sulphur, ^{35}S , to label the protein coat because proteins contain sulphur in amino acids such as cysteine and methionine, whereas DNA contains no sulphur. The two labels therefore distinguished DNA from protein in separate experiments.

Step 3: (iii) Label the phages and allow infection Two batches of phages were produced by growing them on bacteria in media containing either radioactive phosphorus or radioactive sulphur. One batch thus had labelled DNA and the other labelled protein coats. Each batch was allowed to attach to and infect a fresh culture of non-radioactive *E. coli*. Keeping the experiments separate made the location of each viral component traceable.

Step 4: (iii) Blend, centrifuge and locate radioactivity After infection had begun, the mixtures were agitated in a blender to detach the phage protein coats from the bacterial surfaces. Centrifugation then deposited the heavier bacterial cells in the pellet, while the detached coats remained in the supernatant. With ^{32}P -labelled phages, radioactivity was found associated with the bacterial pellet: phage DNA had entered the cells. With ^{35}S -labelled phages, radioactivity remained mainly in the supernatant: the protein coats had stayed outside. Thus it was the DNA-containing component that entered the bacteria and directed viral multiplication.

Step 5: (iv) State the significance of the evidence The experiment supplied direct experimental evidence that DNA is the genetic material in these bacteriophages. It distinguished the roles of DNA and protein by tracing their physical entry into the host, establishing the molecular basis for transmission of hereditary information.

Step 6: Conclusion Phage DNA labelled with ^{32}P entered the bacteria, whereas protein labelled with ^{35}S remained outside. Hershey and Chase thereby demonstrated that DNA is the genetic material of the bacteriophage.

Quick Tip to Solve: Remember phosphorus for DNA and sulphur for protein; then follow the label into the bacterial pellet or the coat-containing supernatant.

- 31(b).** (i) What are multiple alleles? How do they differ from simple dominant-recessive allele pairs?
 (ii) Explain the concept of multiple alleles with the help of a human trait studied by you.
 (iii) Mention all possible genotypes with their corresponding phenotypes of the human trait as explained by you.
 (iv) Comment on the type of inheritance pattern involved in the example explained by you. [5 marks]

Solution:

Concept:

- Alleles are alternative forms of a gene at the same locus. Multiple allelism means that more than two allelic forms of that gene exist in a population.
- A diploid individual carries only two alleles at a locus, one inherited from each parent, even when the population has several alleles.
- In the human ABO blood-group system, I^A and I^B are codominant; each is dominant over i .

Step 1: (i) Define multiple alleles and distinguish an allele pair Multiple alleles are three or more alternative forms of the same gene found at a particular locus in a population. A simple dominant-recessive system considers only two forms, such as A and a , with the dominant allele expressed in the heterozygote Aa . Multiple allelism concerns the number of alleles available in the population; it does not mean that a normal diploid individual contains three alleles of that gene. Each individual still possesses a pair, which may be identical or different. The relationships among multiple alleles can include dominance as well as codominance.

Step 2: (ii) Explain the human ABO example The human ABO blood group is controlled by the gene I , which has three alleles: I^A , I^B and i . Allele I^A leads to the presence of antigen A on red blood cells, whereas I^B leads to antigen B. Allele i does not produce either of these antigens. An individual receives one allele from the mother and one from the father. The different pairs formed from these three alleles account for the four blood-group phenotypes A, B, AB and O.

Step 3: (iii) List every genotype and its phenotype The six possible genotypes are grouped by their blood-group phenotypes below:

Genotype	Blood group	RBC antigens
$I^A I^A$	A	A
$I^A i$	A	A
$I^B I^B$	B	B
$I^B i$	B	B
$I^A I^B$	AB	A and B
ii	O	Neither A nor B

Thus, blood groups A and B can each have a homozygous or a heterozygous genotype, whereas AB and O each correspond to one genotype.

Step 4: (iv) Identify the inheritance pattern ABO inheritance illustrates multiple allelism because three alleles occur in the population. It also illustrates codominance: both I^A and I^B express themselves in $I^A I^B$, so the AB phenotype has both antigens rather than a blended antigen. Complete

dominance is also present, since I^A and I^B each mask i in $I^A i$ and $I^B i$, respectively. The two alleles of an individual segregate during gamete formation, so each gamete carries only one.

Step 5: Conclusion Multiple alleles are more than two forms of one gene in a population. Human ABO blood groups provide the example: three alleles form six genotypes and four phenotypes, demonstrating both codominance and dominance over the recessive allele i .

Quick Tip to Solve: First list I^A , I^B and i , then form all unordered pairs: three identical pairs and three mixed pairs give all six ABO genotypes.

32(a). Oogenesis is a discontinuous process that begins before birth and is completed after puberty.

(i) Trace the development of a gamete mother cell till its release from the ovary during ovulation.

(ii) Name the two pituitary hormones that play an important role in the process. [5 marks]

Solution:

Concept:

- Oogenesis produces the female gamete from a diploid oogonium. Meiosis reduces the chromosome number from $2n = 46$ to $n = 23$.
- Oogenesis is discontinuous: the primary oocyte arrests in prophase I, and the secondary oocyte arrests in metaphase II. Cytoplasmic division is unequal, retaining most cytoplasm in one cell.
- Follicle-stimulating hormone (FSH) and luteinising hormone (LH) from the anterior pituitary regulate follicular development and ovulation.

Step 1: (i) Begin with the gamete mother cell before birth During foetal development, millions of diploid gamete mother cells, called oogonia, are formed in each ovary by mitotic multiplication. No new oogonia are normally added after birth. Oogonia enter meiosis I and become primary oocytes, which remain arrested in prophase I for a prolonged period. Each primary oocyte becomes surrounded by a layer of granulosa cells to form a primary follicle. Many follicles degenerate between birth and puberty, so only about 60,000–80,000 primary follicles remain in each ovary at puberty.

Step 2: (i) Follow follicular growth after puberty After puberty, gonadotropin stimulation supports follicular development during the ovarian cycles. A primary follicle acquires more layers of granulosa cells and a new theca and becomes a secondary follicle. It then develops into a tertiary follicle with a fluid-filled cavity, the antrum. The theca differentiates into an inner theca interna and an outer theca externa. The primary oocyte within the tertiary follicle grows and completes its first meiotic division.

Step 3: (i) Form the secondary oocyte by unequal division The completion of meiosis I produces two haploid cells: a large secondary oocyte and a small first polar body. Most of the cytoplasm is retained by the secondary oocyte, providing resources needed for early development after fertilisation. Both cells have 23 chromosomes, each still consisting of two chromatids. The tertiary follicle develops into a mature Graafian follicle, and the secondary oocyte is surrounded by a glycoprotein layer called the zona pellucida.

Step 4: (i) Trace development up to ovulation The secondary oocyte begins meiosis II and arrests at metaphase II. The mid-cycle LH surge causes the mature Graafian follicle to rupture and release this secondary oocyte, along with its surrounding zona pellucida and follicular cells, from the ovary: this

is ovulation. Therefore, the cell released is a secondary oocyte, not an oogonium or a fully completed ovum. Meiosis II is completed only if sperm entry occurs, producing the ovum and the second polar body; puberty alone does not complete the second meiotic division.

Step 5: (ii) Name the two pituitary hormones The two anterior pituitary hormones are follicle-stimulating hormone (FSH) and luteinising hormone (LH). FSH promotes the growth and maturation of ovarian follicles. LH supports ovarian activity, and its mid-cycle surge triggers ovulation and subsequent formation of the corpus luteum from the ruptured follicle.

Step 6: Conclusion Oogenesis proceeds from oogonium to primary oocyte, then to secondary oocyte and first polar body. The secondary oocyte arrested in metaphase II is released at ovulation. FSH and LH are the two pituitary hormones involved.

Quick Tip to Solve: Link the two pauses to the two cells: primary oocyte–prophase I; secondary oocyte–metaphase II. At ovulation, write secondary oocyte; completion of meiosis II requires sperm entry.

OR

32(b). (i) Draw a labelled two-celled structure of male gametophyte of an angiosperm.

(ii) Name the three layers that surround the cytoplasm of a male gametophyte starting from innermost to outermost layer.

(iii) Which organic material makes the outermost layer? Mention its advantage.

(iv) Why is the outermost layer of male gametophyte not continuous?

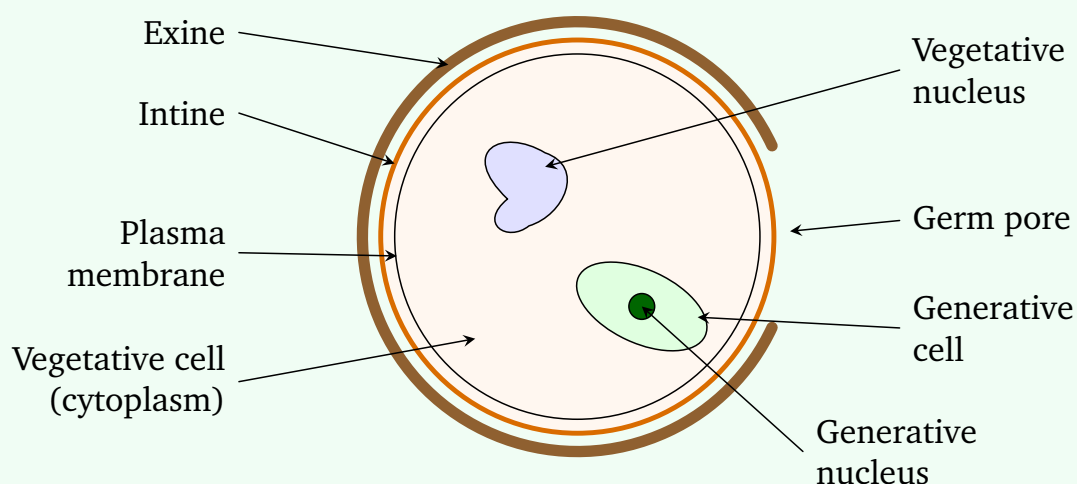
[5 marks]

Solution:

Concept:

- The pollen grain is the male gametophyte of an angiosperm. At its two-celled stage it contains a large vegetative cell and a smaller generative cell.
- The pollen wall has an inner intine and an outer exine. The plasma membrane lies just inside the intine and encloses the cytoplasm.
- Sporopollenin makes the exine highly resistant. Germ pores are regions where sporopollenin is absent and through which the pollen tube can emerge.

Step 1: (i) Draw and identify the two cells The labelled diagram shows a two-celled pollen grain. The large vegetative cell contains abundant food reserve and a large, irregularly shaped vegetative nucleus. The smaller generative cell lies within its cytoplasm; it has its own plasma membrane, dense cytoplasm and a nucleus. The generative cell later divides mitotically to form two male gametes. Thus the two cells at this stage are the vegetative cell and the generative cell, not two male gametes.



Labelled two-celled pollen grain (male gametophyte)

Step 2: (ii) Arrange the surrounding layers from inside to outside Starting immediately outside the cytoplasm, the order is

Plasma membrane → Intine → Exine.

The plasma membrane is the living boundary of the vegetative cell. Outside it is the thin, continuous intine, composed of cellulose and pectin. The thick exine lies outside the intine. Although the question asks for three surrounding layers, the pollen *wall* itself comprises only intine and exine; the plasma membrane is the innermost cellular boundary.

Step 3: (iii) Identify the exine material and its advantage The outermost layer, exine, is made of **sporopollenin**, one of the most resistant organic materials known. It withstands high temperatures and strong acids and alkalis, and no enzyme that degrades it is known. This resistance protects the pollen grain during exposure and dispersal and also allows pollen grains to be preserved as fossils for long periods.

Step 4: (iv) Explain why the exine is discontinuous The exine has apertures called **germ pores**, at which sporopollenin is absent. These interruptions permit the intine to protrude and form a pollen tube when a compatible pollen grain germinates on the stigma. The pollen tube subsequently carries the male gametes towards the embryo sac. Thus the resistant outer wall provides protection while its germ pores allow germination and tube emergence.

Step 5: Conclusion A two-celled male gametophyte has a vegetative cell and a generative cell. Its surrounding layers, from inside out, are plasma membrane, intine and exine. The sporopollenin exine protects the pollen grain and is interrupted at germ pores to permit pollen-tube emergence.

Quick Tip to Solve: Label both cells and both nuclei in a two-celled pollen grain. For the layer order, start at the cytoplasm: membrane, intine, exine; show a gap in the exine at the germ pore.

33(a). (i) Explain any two basic principles/core techniques on which biotechnology is based.

(ii) Describe any three key tools used in Recombinant DNA technology.

[5 marks]

Solution:

Concept:

- Modern biotechnology combines deliberate alteration of genetic material with controlled cultivation of organisms to obtain useful products.
- Recombinant DNA technology requires tools to cut and join DNA, a vector to carry the desired gene, and a suitable host in which the introduced DNA can multiply or be expressed.

Step 1: (i) Explain genetic engineering Genetic engineering comprises techniques that alter the chemistry of genetic material, DNA or RNA, introduce it into a host organism, and thereby change the host's phenotype. For example, a desired gene can be isolated, joined to a vector and transferred into a suitable host. The host then acquires the genetic information required to produce a useful protein. This permits the transfer of selected genes without transferring all the unwanted genes that may accompany conventional breeding.

Step 2: (i) Explain maintenance of sterile conditions The second core technique is maintaining sterile, contamination-free conditions during large-scale cultivation of the desired microbe or eukaryotic cell. Only the selected organism should grow in the culture. Suitable nutrients, temperature, pH and oxygen supply are maintained so that it can produce the required product efficiently. Sterility prevents competing or harmful microbes from multiplying and contaminating products such as antibiotics, vaccines and enzymes.

Step 3: (ii) Describe the enzymes Enzymes are molecular tools for manipulating DNA. Restriction endonucleases recognise specific DNA sequences and cleave DNA at defined sites. Cutting the donor DNA and vector with the same appropriate restriction enzyme can produce compatible ends. DNA ligase joins the insert to the vector by sealing the sugar-phosphate backbone, forming recombinant DNA. DNA polymerases synthesise DNA; for example, a thermostable polymerase is used for amplification by PCR.

Step 4: (ii) Describe cloning vectors A cloning vector, such as a plasmid or bacteriophage, carries the desired DNA into a host. Its origin of replication enables the linked insert to replicate in the host. A selectable marker helps identify cells that received the vector, and suitable cloning sites permit insertion of foreign DNA. Thus a vector both delivers the insert and allows copies of it to be obtained.

Step 5: (ii) Describe a competent host A suitable host, commonly the bacterium *Escherichia coli*, receives recombinant DNA and supplies the cellular machinery for its replication and, when appropriate, expression. Bacterial cells can be made competent by treatment with divalent calcium ions followed by a brief heat shock during transformation. Cells that take up the vector are selected and cultured to obtain many copies of the inserted gene or its product.

Step 6: Conclusion The two core techniques are genetic engineering and maintenance of sterile conditions for large-scale culture. Three key tools of recombinant DNA technology are enzymes, cloning vectors and competent host organisms.

Quick Tip to Solve: Organise the tools by their jobs: enzymes cut and join DNA, vectors carry and replicate it, and hosts multiply or express it.

33(b). “Early and accurate diagnosis of diseases is vital in medical technology.”

(i) Name the conventional methods of diagnosis and their disadvantages.

(ii) Which three diagnostic techniques have been developed through Biotechnology? Explain how each one helps in detecting diseases. [5 marks]

Solution:

Concept:

- Early diagnosis requires detection of a pathogen or a disease-associated molecule even when its concentration is too low to produce obvious symptoms.
- Molecular diagnosis uses specific nucleic-acid sequences or antigen-antibody interactions. Amplification, sequence-specific hybridisation and enzyme-linked detection increase sensitivity and specificity.

Step 1: (i) Identify conventional methods and their limitations Conventional methods include serum analysis and urine analysis. These methods often fail to detect a disease at a very early stage because the concentration of the pathogen or the relevant disease-associated substance is too low for detection. An infection is commonly suspected only after the pathogen has multiplied sufficiently and symptoms appear. Consequently, diagnosis and treatment may be delayed; detecting the disease only after symptoms develop can reduce the benefit of early intervention.

Step 2: (ii) Explain diagnosis using recombinant DNA technology Recombinant DNA technology provides sequence-specific DNA probes for molecular diagnosis. A labelled single-stranded DNA or RNA probe complementary to a target sequence is allowed to hybridise with denatured nucleic acid from the sample. A matching sequence forms a complementary hybrid and can be detected through the label. With a radioactively labelled probe, autoradiography reveals where hybridisation occurred. This can identify a pathogen-specific sequence. In detecting a mutation, a probe complementary to the normal sequence may fail to bind to the altered sequence under suitable conditions, allowing the altered gene to be distinguished from the normal gene.

Step 3: (ii) Explain polymerase chain reaction Polymerase chain reaction (PCR) amplifies a specific DNA sequence through repeated cycles of denaturation, primer annealing and extension by a thermostable DNA polymerase. Even a very small amount of target DNA can therefore yield enough copies for detection. PCR helps detect pathogens at an early stage and mutations associated with genetic disorders or cancers. In the case of an RNA virus such as HIV, its RNA is first converted to complementary DNA by reverse transcriptase, and this DNA is amplified. Thus detection need not wait for a high pathogen load or clear symptoms.

Step 4: (ii) Explain enzyme-linked immunosorbent assay Enzyme-linked immunosorbent assay (ELISA) is based on the specific interaction between an antigen and its antibody. A test may detect an antigen from the pathogen or antibodies produced against that pathogen. An enzyme-linked reagent participates in the assay; addition of its substrate produces a detectable colour signal when the relevant antigen-antibody complex is present. Appropriate controls allow the result to be interpreted. This specific biochemical signal helps identify infection even when it is not evident from symptoms alone.

Step 5: Conclusion Conventional serum and urine analyses can miss early disease when diagnostic substances are present at very low concentrations. Recombinant DNA-based probe diagnosis, PCR and ELISA improve detection through specific sequence recognition, nucleic-acid amplification and antigen-antibody recognition, respectively.

Quick Tip to Solve: Pair each method with its mechanism: probes hybridise, PCR amplifies DNA, and ELISA detects antigen-antibody binding through an enzyme signal.