

CBSE Class 12 Biology Question Paper 2026 with Solution PDF-Set 57-7-2 - Compartment



Question Paper with Solutions

Conducted by the Central Board of Secondary Education (CBSE)

Time Allowed: 3 hours

Maximum Marks: 70

General Instructions

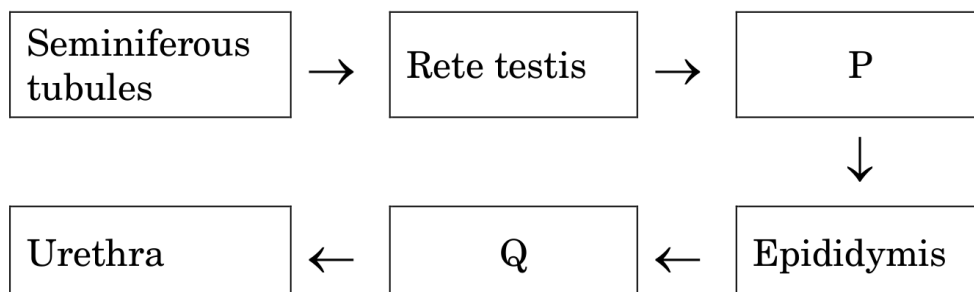
- (i) This question paper contains **33** questions. **All** questions are **compulsory**.
- (ii) Question paper is divided into **five** sections – Sections **A, B, C, D** and **E**.
- (iii) **Section A** – questions number **1** to **16** are Multiple Choice Type Questions. Each question carries **1** 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. The path of the sperm transport is shown below. Identify P and Q and select the correct option.

[1 mark]



- (A) P – Vasa efferentia, Q – Ureter
(B) P – Ejaculatory duct, Q – Vas deferens
(C) P – Vasa efferentia, Q – Vas deferens
(D) P – Vas deferens, Q – Vasa efferentia

Correct Answer: (C) P – Vasa efferentia, Q – Vas deferens

Solution:

Concept:

- Sperm formed in seminiferous tubules pass into the rete testis and then through the vasa efferentia into the epididymis.
- The vas deferens carries sperm from the epididymis towards the ejaculatory duct; the urethra ultimately carries semen outside.

Step 1: Identify the duct at P P lies between the rete testis and epididymis. The vasa efferentia leave the testis and open into the epididymis, so P represents vasa efferentia.

Step 2: Identify Q and check the alternatives Q follows the epididymis, identifying it as the vas deferens. The diagram abbreviates the later pathway: the vas deferens joins the duct from the seminal vesicle to form the ejaculatory duct, which opens into the urethra. Option (A) incorrectly uses the ureter, a urinary duct. Option (B) wrongly places the ejaculatory duct before the epididymis. Option (D) reverses the two identified ducts.

Step 3: Conclusion P is vasa efferentia and Q is vas deferens. Hence, the correct option is (C).

Quick Tip to Solve: Remember the order: rete testis, vasa efferentia, epididymis, vas deferens.

2. Failure of segregation of chromatids during cell division results in gain or loss of chromosomes. Select the correct option. [1 mark]

- (A) Euploidy
- (B) Monoploidy
- (C) Aneuploidy
- (D) Polyploidy

Correct Answer: (C) Aneuploidy

Solution:

Concept:

- Nondisjunction is the failure of chromosomes or sister chromatids to separate properly during cell division.
- Aneuploidy is a gain or loss of individual chromosomes rather than complete chromosome sets.

Step 1: Identify the consequence of failed segregation When chromatids do not segregate normally, one daughter cell may receive an extra chromosome while another receives one fewer. The resulting chromosome number departs from the normal number by individual chromosomes.

Step 2: Distinguish chromosome number changes Such gain or loss is aneuploidy, for example monosomy or trisomy. Euploidy involves complete sets of chromosomes. Monoploidy means possession of one complete set, while polyploidy means possession of more than two complete sets. These alternatives therefore do not describe the stated gain or loss of individual chromosomes.

Step 3: Conclusion The chromosome imbalance described is aneuploidy. Hence, the correct option is (C).

Quick Tip to Solve: A change in individual chromosomes indicates aneuploidy; a change in whole sets indicates euploidy.

3. Polyembryony commonly occurs in which one of the following plants? [1 mark]

- (A) Banana
- (B) Tomato
- (C) Potato
- (D) Citrus

Correct Answer: (D) Citrus

Solution:

Concept:

- Polyembryony is the occurrence of more than one embryo within a single seed.
- In Citrus, some nucellar cells surrounding the embryo sac can divide and develop into additional embryos.

Step 1: Recall the example of polyembryony In Citrus, embryos can arise from nucellar tissue in addition to the embryo developing from the fertilised egg. Consequently, a seed can contain several

embryos, which is the condition called polyembryony.

Step 2: Check the other plants Banana is commonly associated with parthenocarpy, the formation of fruit without fertilisation. Potato is a familiar example of vegetative propagation by stem tubers. Tomato is not the standard example of common nucellar polyembryony among these choices. Citrus is therefore the appropriate selection.

Step 3: Conclusion Polyembryony commonly occurs in Citrus. Hence, the correct option is (D).

Quick Tip to Solve: Link Citrus with several embryos inside one seed, rather than several seeds inside one fruit.

4. Choose the right option that indicates the safe period for medical termination of pregnancy.

[1 mark]

- (A) Second trimester of pregnancy
- (B) 12 weeks of pregnancy
- (C) 5 months of pregnancy
- (D) 21 weeks of pregnancy

Correct Answer: (B) 12 weeks of pregnancy

Solution:

Concept:

- In the textbook account of medical termination of pregnancy, the procedure is considered relatively safe during the first trimester.
- The first trimester covers the first 12 weeks of pregnancy; risk increases in the second trimester.

Step 1: Identify the textbook period The question asks for the relatively safe period described in reproductive health. This is the first trimester, that is, up to 12 weeks of pregnancy. The term relatively safe is comparative and does not imply the absence of procedural risk.

Step 2: Compare the stated choices The second trimester follows the first 12 weeks and is associated with greater risk. Five months and 21 weeks are also later stages of pregnancy, outside the first trimester. Thus only the option specifying 12 weeks corresponds to the period asked for.

Step 3: Conclusion The first 12 weeks of pregnancy are the relatively safe period specified here. Hence, the correct option is (B).

Quick Tip to Solve: For this textbook question, connect the first trimester directly with the first 12 weeks.

5. When an amino acid is coded by more than one codon, the genetic code is said to be : [1 mark]

- (A) Universal
- (B) Punctuated
- (C) Commaless
- (D) Degenerate

Correct Answer: (D) Degenerate

Solution:

Concept:

- A codon is a sequence of three nucleotides in mRNA that specifies an amino acid or a termination signal.
- Degeneracy means that more than one codon can specify the same amino acid.

Step 1: Match the definition The question describes different codons specifying one amino acid. This is the degeneracy of the genetic code. For example, UUU and UUC both specify phenylalanine, although each individual codon retains a definite meaning.

Step 2: Distinguish the other properties Universal means that the same codon generally specifies the same amino acid across organisms. Commaless means that codons are read consecutively without separating punctuation. Punctuated is not the property described and contrasts with the usual commaless reading of the code. None of these terms describes multiple codons for one amino acid.

Step 3: Conclusion The genetic code is degenerate. Hence, the correct option is (D).

Quick Tip to Solve: Several codons for one amino acid means degeneracy; it does not mean that one codon has several meanings.

6. Miller's experiment included some gases in his experiment. Which of the following gas was *not* part of his experiment? [1 mark]

- (A) Methane
- (B) Hydrogen
- (C) Ammonia
- (D) Carbon dioxide

Correct Answer: (D) Carbon dioxide

Solution:

Concept:

- The Miller experiment simulated a proposed reducing atmosphere using methane, ammonia, hydrogen and water vapour.
- Electrical discharges supplied energy, leading to the formation of organic compounds including amino acids.

Step 1: Recall the experimental mixture The classic textbook experiment used methane, hydrogen, ammonia and water vapour in a closed apparatus. Water was heated to supply vapour, and electric sparks simulated lightning in the gaseous mixture.

Step 2: Check each listed gas Methane, hydrogen and ammonia were all components of the experiment, so options (A), (B) and (C) must be rejected. Carbon dioxide was not one of the gases in this classic experimental mixture. The question asks for the gas that was absent, rather than one that was supplied.

Step 3: Conclusion Carbon dioxide was not part of the classic Miller experimental gas mixture. Hence, the correct option is (D).

Quick Tip to Solve: Recall the four components together: methane, ammonia, hydrogen and water vapour.

7. Polio vaccine provides which kind of immunity in children? Select the correct option.

[1 mark]

- (A) Innate immunity
- (B) Passive immunity
- (C) Autoimmunity
- (D) Active immunity

Correct Answer: (D) Active immunity

Solution:

Concept:

- Active immunity develops when exposure to an antigen stimulates the individual to make an immune response and memory cells.
- Passive immunity is provided by transfer of ready-made antibodies rather than by the recipient producing them in response to the antigen.

Step 1: Explain the response to vaccination A polio vaccine presents poliovirus antigens to the child's immune system. The child develops a specific immune response, including antibody production and immunological memory, enabling a quicker response on later exposure.

Step 2: Compare the immunity categories Because the child's own immune system responds, vaccination produces active immunity, specifically artificially acquired active immunity. Innate immunity is present from birth and is non-specific. Passive immunity requires ready-made antibodies, while autoimmunity is an immune response against the body's own components. None describes the response induced by the polio vaccine.

Step 3: Conclusion Polio vaccination induces active immunity. Hence, the correct option is (D).

Quick Tip to Solve: Ask who makes the antibodies: a vaccine stimulates the recipient, so the immunity is active.

8. A person admitted to hospital as he had myocardial infarction. A cardiologist injected him 'streptokinase'. Select the option that indicates the correct reason for using streptokinase. [1 mark]

- (A) It stimulates the heartbeat.
- (B) It reduces hypertension.
- (C) It acts as a clot-buster.
- (D) It reduces the level of blood cholesterol.

Correct Answer: (C) It acts as a clot-buster.

Solution:

Concept:

- Streptokinase is a microbial product used as a thrombolytic, that is, a clot-dissolving agent.
- A coronary blood clot can obstruct the blood supply to heart muscle and cause myocardial infarction.

Step 1: Identify the cause being treated In myocardial infarction, blockage of a coronary blood vessel by a clot can deprive part of the heart muscle of oxygen. The immediate therapeutic aim is to restore blood flow through the affected vessel.

Step 2: Identify the action of streptokinase Streptokinase activates plasminogen to form plasmin, which breaks down fibrin in the clot. It therefore acts as a clot-buster. Stimulating heartbeat, lowering blood pressure and lowering cholesterol are different actions and do not describe its role here.

Step 3: Conclusion Streptokinase is injected to dissolve the obstructing clot. Hence, the correct option is (C).

Quick Tip to Solve: Link streptokinase with thrombolysis: it dissolves a clot in an affected blood vessel.

9. Significance of heat shock method in bacterial transformation is to facilitate which one of the following steps? [1 mark]

- (A) Binding DNA to the cell wall
- (B) Uptake of DNA through membrane transport proteins
- (C) Uptake of DNA through transient pores in the bacterial cell wall
- (D) Expression of antibiotic resistance genes

Correct Answer: (C) Uptake of DNA through transient pores in the bacterial cell wall

Solution:

Concept:

- Bacterial cells are made competent so that they can take up foreign DNA during transformation.
- A brief heat shock after cold treatment facilitates DNA entry by transiently increasing permeability of the bacterial cell envelope.

Step 1: Recall the transformation procedure Competent bacteria are incubated with the desired DNA on ice, exposed briefly to heat shock, and then returned to ice. This temperature treatment facilitates the passage of DNA into the bacterial cell.

Step 2: Compare the proposed steps The intended description is uptake through transient pores in the bacterial cell wall or envelope, as given in (C). Simple binding to the wall does not complete transformation. The procedure is not uptake through specific membrane transport proteins, and antibiotic-resistance gene expression occurs after DNA entry rather than being the direct purpose of heat shock.

Step 3: Conclusion Heat shock facilitates uptake of DNA through transient pores in the bacterial cell envelope. Hence, the correct option is (C).

Quick Tip to Solve: Distinguish DNA entry during heat shock from later expression and selection of transformed cells.

10. Cry proteins coded by the gene Cry IAb controls which one of the following pests?

[1 mark]

- (A) Cotton bollworm
- (B) Corn borer
- (C) Tobacco budworm
- (D) Mosquito

Correct Answer: (B) Corn borer

Solution:

Concept:

- Bt toxin genes from *Bacillus thuringiensis* encode insecticidal Cry proteins with specific target pests.
- The gene cryIAb encodes a toxin used to control corn borer; cryIAc and cryIIAb are associated with cotton bollworm control.

Step 1: Match the named gene to its target The question specifies Cry IAb. The NCERT gene-pest association for this gene is corn borer, which attacks maize. The choice must therefore follow the particular cry gene rather than treating all Bt toxins as identical.

Step 2: Eliminate the other pests Cotton bollworm is associated with cryIAc and cryIIAb. Tobacco budworm is also a lepidopteran pest, but it is not the specified gene-target match here. Mosquito control uses other insecticidal Bt proteins, so it is not the answer for Cry IAb.

Step 3: Conclusion Cry proteins encoded by Cry IAb control corn borer. Hence, the correct option is (B).

Quick Tip to Solve: Remember the specific pair cryIAb–corn borer; distinguish it from the cotton bollworm genes.

11. In spite of interspecific competition in nature, which of the following mechanisms might competing species have evolved to coexist and survive? [1 mark]

- (A) Competitive exclusion
- (B) Competitive release
- (C) Resource partitioning
- (D) Co-evolution

Correct Answer: (C) Resource partitioning

Solution:

Concept:

- Interspecific competition occurs when different species use the same limiting resource.
- Resource partitioning reduces overlap in resource use through differences in food, feeding site or time of activity.

Step 1: Explain coexistence despite competition Competing species may evolve to use different portions of a resource or use it at different times or places. This reduces direct competition sufficiently for the species to coexist and survive in the same habitat.

Step 2: Distinguish the alternatives This mechanism is resource partitioning. Competitive exclusion results in the elimination of an inferior competitor under persistent complete competition. Competitive release is expansion after a competitor is removed. Co-evolution describes reciprocal evolutionary changes between interacting species and is not the specific resource-sharing mechanism asked here.

Step 3: Conclusion The mechanism is resource partitioning. Hence, the correct option is (C).

Quick Tip to Solve: For coexistence of competitors, look for separation in the resource, place or time they use.

12. Which of the following groups of animals has a large number of endemic species in the western ghats? [1 mark]

- (A) Mammals
- (B) Reptiles
- (C) Amphibians
- (D) Birds

Correct Answer: (C) Amphibians

Solution:

Concept:

- Endemic species are naturally restricted to a particular geographical region.
- The Western Ghats have especially high amphibian diversity and endemism, as emphasised in the NCERT comparison of Indian regions.

Step 1: Identify the geographical association The Western Ghats are an important biodiversity-rich region with a large number of endemic amphibians. Many such species occur naturally only within this region, making amphibians the relevant group in this question.

Step 2: Compare the listed groups Mammals, reptiles and birds also occur in the Western Ghats, and some are endemic. However, their occurrence alone does not answer the specific textbook association being tested. Among the four choices, amphibians are the group noted for the large number of endemic species in this region.

Step 3: Conclusion Amphibians have a large number of endemic species in the Western Ghats. Hence, the correct option is (C).

Quick Tip to Solve: Associate Western Ghats endemism with amphibians, and recall that endemic means geographically restricted.

13. Assertion (A): Innate immunity is a non-specific type of defence.

Reason (R): Skin in our body is the main physical barrier which prevents entry of microorganisms.

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

Solution:

Concept:

- Innate immunity is the inborn, non-specific defence that acts broadly against pathogens.
- Physical barriers such as skin form one component of innate immunity; a barrier example must be distinguished from an explanation of non-specificity.

Step 1: Judge Assertion (A) Assertion (A) is true. Innate immunity does not require recognition of one particular antigen or a previous encounter with that pathogen. Its protective mechanisms act broadly against many potential infectious agents.

Step 2: Judge Reason (R) Reason (R) is true. Intact skin is the main physical barrier of the body and prevents the entry of microorganisms. This is a recognised example of an innate defence.

Step 3: Check the explanatory link The reason identifies the protective role of skin, but does not explain why innate immunity is non-specific. Non-specificity concerns the broad nature of the response rather than simply the presence of a physical barrier. Thus both statements are true, while R is not the correct explanation of A.

Step 4: Conclusion Both A and R are true, but R is not the correct explanation of A. Hence, the correct option is (B).

Quick Tip to Solve: In assertion-reason items, test truth first, then ask whether the reason explains the exact property asserted.

14. Assertion (A): Chemically synthesised oligonucleotides are used during annealing in PCR technique.

Reason (R): The primers bind to the double stranded DNA at their complementary regions. [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:

- PCR uses chemically synthesised oligonucleotide primers to initiate DNA synthesis.
- Annealing occurs when primers bind to complementary sequences on separated, single-stranded DNA templates after denaturation.

Step 1: Judge Assertion (A) Assertion (A) is true. Short, chemically synthesised oligonucleotides serve as primers in PCR. During the annealing stage they pair with complementary template sequences and provide starting points for the subsequent extension stage.

Step 2: Judge Reason (R) Reason (R) is false because it states that primers bind to double-stranded DNA. PCR first denatures the DNA duplex into single strands. The primers anneal to these exposed single-stranded templates, not to an intact double-stranded DNA molecule.

Step 3: Select the assertion-reason code The distinction between double-stranded DNA and separated template strands is decisive. Since A is true and R is false, the codes claiming both are true and the code claiming A is false must be rejected.

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

Quick Tip to Solve: Use the PCR order denaturation, annealing, extension: primers bind only after template strands separate.

15. Assertion (A): Vector DNA and foreign DNA are cut by the same restriction enzyme.

Reason (R): Vector DNA and foreign DNA, cut with same enzyme, produces complementary sticky ends. [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:

- Restriction endonucleases recognise specific DNA sequences and cut DNA at defined positions.
- In sticky-end cloning, complementary single-stranded overhangs of vector and insert base-pair; DNA ligase seals the sugar-phosphate backbone.

Step 1: Judge the Assertion The Assertion is true. Cutting the vector DNA and foreign DNA with the same suitable restriction endonuclease is the standard method for obtaining compatible ends for recombinant DNA formation.

Step 2: Judge the Reason The Reason is true in the sticky-end cloning context of this question. The same enzyme produces matching, complementary sticky ends in the two DNA samples, enabling their exposed bases to pair.

Step 3: Relate the Reason to the Assertion The complementary ends explain why the same enzyme is chosen: the foreign DNA can anneal to the cut vector and the joined DNA can then be sealed by DNA ligase. Thus the reason directly explains the assertion. Option (B) wrongly denies this link, while (C) and (D) wrongly treat one of the statements as false.

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

Quick Tip to Solve: For a cloning Assertion-Reason item, connect matching sticky ends to base pairing before considering ligase.

16. Assertion (A): Endosperm in angiosperm is a triploid tissue.

Reason (R): Endosperm is formed after triple fusion i.e. fusion, of a diploid secondary nucleus with a haploid male gamete. [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:

- The two haploid polar nuclei in the central cell together contribute a diploid secondary nucleus, $2n$.
- Triple fusion combines this maternal nuclear contribution with one haploid male gamete, n , giving the primary endosperm nucleus, $3n$.

Step 1: Judge the Assertion The Assertion is true for the usual angiosperm embryo sac described here. Endosperm is triploid because its nuclei contain three haploid chromosome sets.

Step 2: Judge the Reason The Reason is true. One male gamete fuses with the diploid secondary nucleus in the central cell. This is called triple fusion because three haploid nuclear contributions participate: two from the polar nuclei and one from the male gamete.

Step 3: Explain the causal link The ploidy sum is $2n + n = 3n$. The resulting primary endosperm nucleus divides to form endosperm, so triple fusion directly explains its triploid nature. Option (B) incorrectly denies this explanation; options (C) and (D) incorrectly classify one statement as false.

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

Quick Tip to Solve: Add the two maternal sets and one paternal set: triple fusion gives triploid endosperm.

Section B (10 marks)

17(a). (i) Where do the signals for parturition originate from, in humans?

(ii) Why is it important to feed newborn babies on colostrum?

[2 marks]

Solution:

Concept:

- Parturition is childbirth, triggered through a neuroendocrine reflex involving signals from the mature foetus and placenta.
- Colostrum is the first milk secreted by the mother after childbirth and is rich in protective antibodies.

Step 1: (i) Identify the origin of the signals The signals for parturition originate from the fully developed foetus and the placenta. These signals induce mild uterine contractions, called the foetal ejection reflex. The reflex stimulates the maternal pituitary to release oxytocin, which strengthens uterine contractions; stronger contractions in turn promote further oxytocin release until delivery.

Step 2: (ii) Explain the importance of colostrum Newborn babies should be fed colostrum because it contains abundant maternal antibodies, particularly IgA. These provide passive immunity and protect the baby against infections during its early life, when its own immune defence is still developing. This protection is supplied directly by antibodies already produced by the mother, rather than requiring the baby first to generate its own response.

Step 3: Conclusion (i) The fully developed foetus and placenta initiate the signals for parturition. (ii) Antibody-rich colostrum provides passive immunity and protects the newborn from infections.

Quick Tip to Solve: Name both the foetus and placenta for parturition; link colostrum specifically to antibodies and passive immunity.

OR

17(b). How is GIFT different from ZIFT?

[2 marks]

Solution:

Concept:

- GIFT means gamete intrafallopian transfer; the transferred reproductive material consists of unfertilised gametes.
- ZIFT means zygote intrafallopian transfer; fertilisation occurs in vitro before transfer into the fallopian tube.

Step 1: Describe GIFT In GIFT, an ovum collected from a donor is transferred into the fallopian tube of a recipient woman who cannot produce ova but can provide a suitable environment for fertilisation and further development. The transferred material is an unfertilised gamete; fertilisation occurs inside the recipient, that is, in vivo.

Step 2: Describe ZIFT and contrast the stages In ZIFT, an ovum and sperm are brought together outside the body under laboratory conditions (in vitro fertilisation). The resulting zygote or early embryo with up to eight blastomeres is then transferred into the fallopian tube. Thus GIFT transfers gametes before fertilisation, whereas ZIFT transfers the product of fertilisation. Both involve the fallopian tube, so the principal distinction is the developmental stage transferred and where fertilisation takes place.

Step 3: Conclusion GIFT transfers unfertilised gametes into the fallopian tube for in vivo fertilisation; ZIFT transfers an in vitro formed zygote or early embryo (up to eight blastomeres) into the fallopian tube.

Quick Tip to Solve: Read the first letter: GIFT transfers Gametes; ZIFT transfers a Zygote produced by IVF.

18(a). Name the scientist who proposed the central dogma in molecular biology. Give its schematic representation. [2 marks]

Solution:

Concept:

- The central dogma describes the usual direction of genetic information flow from DNA to RNA to protein.
- Transcription copies DNA information into RNA; translation uses the nucleotide sequence of mRNA to specify the amino acid sequence of a protein.

Step 1: Name the scientist Francis Crick proposed the central dogma of molecular biology. It relates the storage of genetic information in DNA to its expression through RNA and protein synthesis.

Step 2: Give the schematic representation The schematic representation is



DNA serves as the template for RNA formation during transcription. During translation, the codon sequence in messenger RNA directs the sequence of amino acids assembled into a protein. DNA also copies itself by replication, represented separately as $\text{DNA} \xrightarrow{\text{replication}} \text{DNA}$. This replication step maintains the information for transmission to daughter cells, while the DNA-to-RNA-to-protein sequence expresses that information.

Step 3: Conclusion Francis Crick proposed the central dogma. Genetic information flows from DNA to RNA by transcription, and from RNA to protein by translation.

Quick Tip to Solve: Write Crick, then label both arrows: transcription makes RNA and translation makes protein.

OR

18(b). Write four criteria to be fulfilled by a molecule to act as a genetic material. [2 marks]

Solution:

Concept:

- A genetic material carries hereditary information and transmits it from one generation to the next.
- It must preserve information reliably while also allowing heritable variation and the expression of characters.

Step 1: State the requirements for inheritance and stability (1) The molecule must be able to generate its replica, that is, undergo replication. This permits copies of the hereditary information to pass to daughter cells and offspring. (2) It must be chemically and structurally stable, so that the stored information is maintained without frequent spontaneous changes.

Step 2: State the requirements for variation and expression (3) It must provide scope for slow changes or mutations that are required for evolution. Such changes produce heritable variation. (4)

It must be able to express itself in the form of Mendelian characters, so that its information can determine observable inherited traits.

Step 3: Conclusion The four criteria are replication, chemical and structural stability, capacity for slow mutation, and expression as Mendelian characters.

Quick Tip to Solve: Recall the four functions in order: copy the information, preserve it, allow variation, and express the inherited character.

19. (a) Define stratification in an ecosystem.

(b) How is stratification represented in a forest ecosystem?

[2 marks]

Solution:

Concept:

- The spatial structure of an ecosystem includes the arrangement of its different species.
- Stratification describes vertical layering: different species occupy different heights or levels within the same ecosystem.

Step 1: Define stratification (a) Stratification is the vertical distribution of different species occupying different levels in an ecosystem. The word vertical is essential: it refers to the arrangement of organisms one above another, rather than their spread across the ground surface.

Step 2: Identify the layers in a forest (b) In a forest, trees occupy the top vertical stratum, shrubs occupy the second stratum, and herbs and grasses occupy the bottom layers. The taller tree crowns form the upper vegetation layer, shorter woody shrubs occur below them, and low-growing herbs and grasses grow near the ground. These differences in plant height produce the characteristic stratification of a forest ecosystem.

Step 3: Conclusion Stratification is vertical species distribution; a forest shows trees at the top, shrubs below them, and herbs and grasses in the bottom layers.

Quick Tip to Solve: Describe forest stratification from top to bottom: trees, then shrubs, then herbs and grasses. Include the word vertical in the definition.

20(a). (i) Name the source plant of heroin drug. How is it obtained from the plant?

(ii) Write the effects of heroin on the human body.

[2 marks]

Solution:

Concept:

- Heroin, commonly called smack, is an opioid drug; chemically, it is diacetylmorphine.
- Opioids bind to specific opioid receptors present in the central nervous system and the gastrointestinal tract.

Step 1: Identify the source and its relationship to heroin (i) The source plant is the opium poppy, *Papaver somniferum*. Morphine is extracted from the latex of this plant, and heroin is obtained by

acetylation of morphine. Thus, heroin is a derivative prepared from the plant-derived morphine; it is not the substance directly extracted unchanged from the poppy latex.

Step 2: Describe the effects on the body (ii) Heroin acts as a depressant and slows down body functions. Through its action on opioid receptors, it depresses central nervous system activity and can slow breathing. It is also highly addictive, and continued use can produce physical and psychological dependence. These effects explain why its use seriously harms normal body functioning.

Step 3: Conclusion Heroin is obtained by acetylating morphine extracted from the latex of *Papaver somniferum*; it is an addictive depressant that slows body functions.

Quick Tip to Solve: Keep the source sequence clear: opium poppy latex supplies morphine, and acetylation of morphine produces heroin.

OR

20(b). What is ‘withdrawal syndrome’? List any two symptoms it is characterised by.

[2 marks]

Solution:

Concept:

- Dependence develops when the body becomes accustomed to the regular presence of a drug or alcohol.
- Abruptly discontinuing regular intake in a dependent individual can produce unpleasant physical and psychological reactions.

Step 1: Define withdrawal syndrome Withdrawal syndrome is the characteristic group of unpleasant symptoms experienced by a dependent person when the regular intake of drugs or alcohol is abruptly discontinued. The body has become adapted to the substance, so its sudden absence causes distress and creates a strong urge to take the substance again.

Step 2: List two characteristic symptoms Two symptoms of withdrawal syndrome are (1) anxiety and (2) shakiness. Anxiety is a feeling of marked uneasiness or nervousness, whereas shakiness refers to trembling. These are symptoms following interruption of intake in a dependent person and should be distinguished from the immediate effects produced while the substance is being taken.

Step 3: Conclusion Withdrawal syndrome consists of unpleasant symptoms following abrupt discontinuation of regular drug or alcohol intake in a dependent person; anxiety and shakiness are two symptoms.

Quick Tip to Solve: Link withdrawal to suddenly stopping regular intake, then name two clear symptoms such as anxiety and shakiness.

21. How can childless couples get help by the following assisted reproductive technologies?

(a) GIFT

(b) ICSI

[2 marks]

Solution:

Concept:

- Assisted reproductive technologies help infertile couples by transferring gametes or by facilitating fertilisation outside the body.
- GIFT transfers an ovum into a fallopian tube, whereas ICSI introduces a sperm directly into an ovum in the laboratory.

Step 1: (a) Gamete intra-fallopian transfer (GIFT) An ovum collected from a donor is transferred into the fallopian tube of a woman who cannot produce ova but can provide a suitable environment for fertilisation and further development. Fertilisation can then occur inside her body, helping the couple achieve a pregnancy.

Step 2: (b) Intra-cytoplasmic sperm injection (ICSI) A single sperm is injected directly into the cytoplasm of an ovum under laboratory conditions to form an embryo. The resulting embryo is subsequently transferred into the female reproductive tract for development. Direct injection helps overcome difficulty in the sperm entering and fertilising the ovum.

Step 3: Conclusion GIFT helps by placing a donor ovum in the recipient's fallopian tube; ICSI helps by directly injecting a sperm into an ovum to produce an embryo for transfer.

Quick Tip to Solve: Remember the transfer target: GIFT places a gamete in the tube; ICSI places a sperm inside the egg cytoplasm.

Section C (21 marks)

22. Name the hormones secreted :

(a) by corpus luteum and placenta (any two), and

(b) during parturition.

Also write their functions.

[3 marks]

Solution:

Concept:

- Pregnancy is maintained by hormones that support the uterine endometrium and maternal changes. The corpus luteum secretes progesterone and oestrogens, and the placenta also secretes these hormones during pregnancy.
- Parturition is childbirth. Strong uterine contractions are promoted by oxytocin through a positive-feedback mechanism.

Step 1: (a) Progesterone and its function Progesterone is secreted by the corpus luteum and later by the placenta. It maintains the thick, vascular, secretory endometrium needed for implantation and continued pregnancy. It also supports pregnancy by reducing uterine contractile activity, so that the

developing embryo remains supported in the uterus.

Step 2: (a) Oestrogens and their function Oestrogens are also secreted by the corpus luteum and placenta. They promote growth of the uterus and development of the mammary glands, especially the mammary ducts, preparing the maternal body for pregnancy and subsequent nursing. Progesterone and oestrogens are the two hormones named for this part.

Step 3: (b) Oxytocin during parturition Oxytocin is released from the mother's posterior pituitary. Signals from the fully developed foetus and placenta initiate mild uterine contractions, called the foetal ejection reflex. This stimulates oxytocin release, which causes stronger uterine contractions. Strong contractions stimulate further oxytocin release; this positive feedback continues until the baby is expelled through the birth canal.

Step 4: Conclusion Progesterone maintains the endometrium and pregnancy, while oestrogens promote uterine and mammary development. During parturition, oxytocin intensifies uterine contractions to bring about childbirth.

Quick Tip to Solve: Link progesterone with maintaining pregnancy, oestrogens with maternal growth, and oxytocin with the positive-feedback contractions of childbirth.

23. (a) Draw a schematic representation of the structure of a transcription unit and show the following in it :

(i) Direction in which transcription occurs

(ii) Polarity of the two strands involved

(iii) Template strand

(iv) Terminator

(b) Mention the function of promoter in transcription.

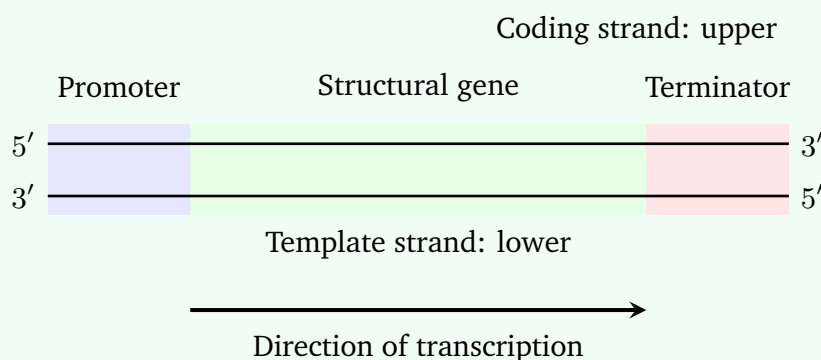
[3 marks]

Solution:

Concept:

- A transcription unit contains a promoter, a structural gene and a terminator. These DNA sequences specify where RNA synthesis begins and ends.
- RNA polymerase reads the template strand in the $3' \rightarrow 5'$ direction and synthesises RNA in the $5' \rightarrow 3'$ direction. The coding strand is antiparallel to the template.

Step 1: (a) Arrange and label the transcription unit The diagram shows transcription proceeding from left to right, from the promoter towards the terminator. The lower DNA strand is the template strand: its polarity is $3'$ at the left end and $5'$ at the right end. The upper coding strand runs $5' \rightarrow 3'$ in the same left-to-right direction. The structural gene lies between the promoter and terminator.



Transcription unit with strand polarity and transcription direction

Step 2: Relate strand polarity to RNA synthesis During transcription, RNA polymerase moves along the template towards its 5' end. Complementary ribonucleotides are added to the growing RNA's 3' end, so RNA synthesis always proceeds $5' \rightarrow 3'$. The coding strand has the same base sequence as the RNA, except that DNA has thymine where RNA has uracil; it is not the strand copied by the polymerase.

Step 3: (b) State the promoter's function The promoter is a DNA sequence that provides the binding site for RNA polymerase and permits initiation of transcription. Its position and orientation determine the template strand and thus the direction in which transcription proceeds. It is situated upstream of the structural gene, towards the 5' end of the coding strand.

Step 4: Conclusion Transcription proceeds from promoter to terminator, reading the template $3' \rightarrow 5'$ and forming RNA $5' \rightarrow 3'$. The promoter binds RNA polymerase and establishes the initiation and direction of transcription.

Quick Tip to Solve: First draw antiparallel DNA strands; then put the promoter at the coding strand's 5-prime side and point transcription towards the terminator.

24. (a) How does the human body respond to an allergen? Which type of antibody is produced during allergic reactions?

(b) Name the types of drugs that help in reducing the symptoms of allergic reactions.

(c) Name the chemicals released in the body during an allergic reaction.

[3 marks]

Solution:

Concept:

- Allergy is an exaggerated immune response to certain environmental antigens called allergens. Common allergens include pollen and dust mites.
- Allergic reactions involve immunoglobulin E (IgE) and the release of inflammatory chemicals from mast cells.

Step 1: (a) Response to an allergen and the antibody produced In an allergic individual, the immune system responds excessively to an allergen that is usually harmless to most people. It produces IgE antibodies against that allergen. IgE binds to mast cells; subsequent contact with the allergen can

trigger these cells to release inflammatory chemicals. This produces symptoms such as sneezing, a runny nose, watery eyes and difficulty in breathing. Thus the antibody associated with allergic reactions is IgE, rather than the other immunoglobulin classes.

Step 2: (b) Drugs that reduce allergic symptoms Antihistamines, adrenaline and steroids help to reduce the symptoms of allergic reactions. Antihistamines oppose the action of histamine, while steroids suppress inflammation. Adrenaline acts rapidly in a severe allergic reaction by helping reverse airway narrowing and circulatory effects. These are the drug types asked for; antibiotics do not address the allergic immune response.

Step 3: (c) Chemicals released during the reaction Mast cells release histamine and serotonin during the allergic reaction. These chemical mediators cause the local inflammatory response and contribute to the characteristic symptoms. Distinguish these released chemicals from IgE: IgE is the antibody involved in initiating the response, whereas histamine and serotonin are mediators released by mast cells.

Step 4: Conclusion (a) The body shows an exaggerated immune response to the allergen and produces IgE antibodies. (b) Antihistamines, adrenaline and steroids reduce symptoms. (c) Histamine and serotonin are released from mast cells.

Quick Tip to Solve: Link allergy to IgE first, then separate mast-cell mediators (histamine and serotonin) from the drugs used to reduce symptoms.

25. Explain the Hardy-Weinberg principle with the help of an algebraic equation.

[3 marks]

Solution:

Concept:

- The Hardy-Weinberg principle states that allele frequencies in a population remain constant from generation to generation in the absence of evolutionary forces. This stable state is genetic equilibrium.
- For a gene with two alleles, let p be the frequency of allele A and q the frequency of allele a . Then $p + q = 1$.

Step 1: State the equilibrium conditions In a large, randomly mating population, allele frequencies remain unchanged across generations if there is no mutation, migration (gene flow), natural selection or genetic drift. Thus the frequency of a particular allele in the gene pool is fixed under these ideal conditions. Random mating brings gametes together according to their allele frequencies without preferential pairing.

Step 2: Derive the algebraic equation Both male and female gametes carry A with probability p and a with probability q . Random fusion gives AA with frequency p^2 , Aa with frequency $pq + qp = 2pq$, and aa with frequency q^2 . Since these are all possible genotypes, their frequencies sum to one:

$$(p + q)^2 = p^2 + 2pq + q^2 = 1.$$

Here p^2 represents homozygous dominant individuals, $2pq$ heterozygous individuals, and q^2 homozy-

gous recessive individuals.

Step 3: Explain the evolutionary significance Under equilibrium, the next generation has the same allele frequencies: the frequency of A is $p^2 + \frac{1}{2}(2pq) = p(p + q) = p$, and that of a is q . A disturbance of this genetic equilibrium indicates evolutionary change. Mutation, gene flow, genetic drift, genetic recombination and natural selection are factors associated with changes in a population's genetic composition.

Step 4: Conclusion The Hardy-Weinberg equilibrium is expressed as $p + q = 1$ and $p^2 + 2pq + q^2 = 1$, with genotype frequencies $AA = p^2$, $Aa = 2pq$ and $aa = q^2$. Allele frequencies remain stable across generations under the stated conditions.

Quick Tip to Solve: Define p and q as allele frequencies before squaring their sum; the middle term $2pq$ counts both ways of forming a heterozygote.

26. (a) Name the type of interaction seen in each of the following examples.

(i) An orchid growing on branch of mango tree

(ii) Wasp pollinating fig inflorescence

(b) Also explain the above interactions shown by (i) and (ii).

[3 marks]

Solution:

Concept:

- In commensalism, one species benefits while the other is neither benefited nor harmed; its interaction sign is $(+, 0)$.
- In mutualism, both interacting species benefit; its interaction sign is $(+, +)$.

Step 1: (a)(i) and (b): Orchid on a mango tree This is commensalism. The orchid is an epiphyte that uses the branch of the mango tree as physical support. Growing above the ground gives it a suitable position for receiving sunlight. The orchid obtains a benefit, whereas the mango tree receives no corresponding benefit and suffers no harm. The orchid does not extract food from the mango tree, so this association must not be classified as parasitism. The interaction therefore has the sign $(+, 0)$.

Step 2: (a)(ii) and (b): Wasp pollinating fig inflorescence This is mutualism. The wasp pollinates the fig inflorescence, enabling fertilisation and seed formation in the fig. The fig inflorescence, in turn, provides a site for the wasp to lay its eggs, and some developing seeds provide food for the wasp larvae. Thus the fig benefits from pollination and the wasp benefits through a place and resources for reproduction. Because each partner gains from the association, its interaction sign is $(+, +)$. The relationship between a fig species and its pollinating wasp species is highly specific and illustrates coevolution.

Step 3: Conclusion (i) Orchid on a mango branch: commensalism, because the orchid gains support while the mango tree is unaffected. (ii) Fig and its pollinating wasp: mutualism, because the fig is pollinated and the wasp obtains a breeding site and food for its larvae.

Quick Tip to Solve: Assign a sign to each partner: orchid gains and mango is unaffected $(+, 0)$; fig and wasp both gain $(+, +)$.

27. 'Indo-Burma' is considered as a hotspot. What is meant by the term 'hotspots' in biodiversity? List two criteria used for determining a 'hotspot'. Name any two hotspots of India. [3 marks]

Solution:

Concept:

- A biodiversity hotspot is a region with exceptionally high species richness and endemism that is also under severe threat of habitat loss.
- Endemic species occur naturally in a particular geographical region and are not naturally found elsewhere; losing their habitat can therefore cause global extinction.

Step 1: Explain the term hotspot Hotspots are priority areas for conservation because a large number of species, including many species restricted to that region, occur in a relatively small area. They combine outstanding biodiversity with a high degree of threat. Thus, a hotspot is not merely an area with many organisms: its unique species and the danger to its natural habitat are crucial.

Step 2: State the two criteria The two principal criteria are **high species richness with a high degree of endemism**, and **a high degree of threat caused by extensive habitat loss**. In the quantitative definition, a region must contain at least 1,500 endemic vascular plant species and must have lost at least 70% of its original natural vegetation. These thresholds identify concentrations of unique biodiversity whose survival is threatened.

Step 3: Name two Indian hotspots Two hotspots that include parts of India are **Indo-Burma** and **Western Ghats and Sri Lanka**. Indo-Burma includes parts of north-eastern India, while the Western Ghats form the Indian portion of the Western Ghats and Sri Lanka hotspot.

Step 4: Conclusion Hotspots are species-rich, highly endemic and threatened regions. Their criteria are exceptional richness/endemism and severe habitat loss; examples are Indo-Burma and Western Ghats and Sri Lanka.

Quick Tip to Solve: Link hotspot identification to both unique species and habitat threat; naming only a species-rich forest is incomplete.

28. Explain any three different approaches used in the treatment of a person suffering from Adenosine Deaminase deficiency. [3 marks]

Solution:

Concept:

- Adenosine deaminase (ADA) is essential for normal immune function. A defective ADA gene can cause severe combined immunodeficiency because toxic metabolites interfere with lymphocyte function.
- Treatment can supply functional immune-cell precursors, replace the missing enzyme, or introduce a functional copy of the gene into the patient's cells.

Step 1: Bone marrow transplantation Bone marrow from a suitable healthy donor is transplanted into the affected person. The donor marrow provides functional haematopoietic stem cells, which can form lymphocytes with a normal ADA gene. These cells produce ADA and can restore immune

function. This approach replaces the defective blood-cell-forming system with one capable of making functional immune cells.

Step 2: Enzyme replacement therapy Functional ADA enzyme is administered to the patient, generally by injection. The supplied enzyme compensates for the absent enzyme and helps reduce the harmful accumulation of metabolites. It does not correct the defective gene; therefore, continued or repeated enzyme administration is needed to maintain its benefit.

Step 3: Gene therapy Lymphocytes are isolated from the patient's blood and grown in culture outside the body. A functional ADA complementary DNA (cDNA) is introduced into these lymphocytes using a retroviral vector. The genetically modified, ADA-producing lymphocytes are then returned to the patient. Since these lymphocytes are not immortal, the patient requires periodic infusions of such modified cells. Introducing the functional gene into appropriate early developmental cells could provide a lasting correction.

Step 4: Conclusion Three approaches are bone marrow transplantation, repeated replacement of functional ADA enzyme, and gene therapy using the patient's lymphocytes carrying a functional ADA gene.

Quick Tip to Solve: Distinguish the three approaches by what is supplied: healthy marrow cells, functional enzyme, or a functional gene.

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(a). Sewage is generated in large quantities in the urban areas. It is treated in sewage treatment-plants (STPs) to make it less polluted before discharging into any natural water body. Observe the flow chart given below and answer the questions that follow :

Name the two products obtained after primary treatment of sewage.

[1 mark]

Primary effluent is passed into large aeration tank



Effluent is passed into settling tank to form the sediment (activated sludge)

Solution:

Concept:

- Primary sewage treatment removes floating and suspended solids by physical processes such as filtration and sedimentation.
- The settled solids and the liquid above them are named separately: primary sludge and primary effluent, respectively.

Step 1: Identify the solid product During primary treatment, suspended solids settle at the bottom of

the sedimentation tank. The collected sediment forms **primary sludge**.

Step 2: Identify the liquid product The supernatant liquid remaining above the settled solids is the **primary effluent**. It still contains organic matter and is passed to aeration tanks for secondary biological treatment. Activated sludge forms later, during secondary treatment, so it is not a product of primary treatment.

Step 3: Conclusion The two products are **primary sludge** and **primary effluent**.

Quick Tip to Solve: Use the word primary for both products; activated sludge belongs to the later biological stage.

29(b). Sewage is generated in large quantities in the urban areas. It is treated in sewage treatment-plants (STPs) to make it less polluted before discharging into any natural water body. Observe the flow chart given below and answer the questions that follow :

What happens to the activated sludge when it is passed into an anaerobic sludge digester? Explain.

[2 marks]

Primary effluent is passed into large aeration tank



Effluent is passed into settling tank to form the sediment (activated sludge)

Solution:

Concept:

- Activated sludge consists largely of microbial flocs that settle after aerobic treatment of sewage. Most of it is sent to an anaerobic sludge digester.
- Anaerobic digestion is the microbial breakdown of organic matter without free oxygen; it stabilises sludge and produces biogas.

Step 1: Describe digestion of the sludge In the anaerobic sludge digester, anaerobic bacteria grow and digest the organic matter of the sludge, including the bacteria and fungi that formed the activated sludge. The absence of oxygen favours these anaerobic microbes. As digestion proceeds, complex organic material is broken down and the amount of biodegradable solids is reduced, leaving a more stable residue.

Step 2: Explain gas production During anaerobic digestion, a mixture of gases is produced, principally methane and carbon dioxide, together with hydrogen sulphide. Methanogenic microbes contribute to methane formation. The gas mixture is called **biogas**; its methane content makes it combustible and useful as a fuel. Thus, the digester both reduces the organic load of sludge and yields an energy-rich gas.

Step 3: Conclusion Anaerobic microbes digest the activated sludge, including its bacteria and fungi, and produce biogas containing methane, carbon dioxide and hydrogen sulphide.

Quick Tip to Solve: Connect the anaerobic digester with microbial digestion and biogas; aeration and floc formation happen earlier.

29(c)(i). Sewage is generated in large quantities in the urban areas. It is treated in sewage treatment-plants (STPs) to make it less polluted before discharging into any natural water body. Observe the flow chart given below and answer the questions that follow :

Name the two groups of microbes present in the primary effluent after it is passed into large aeration tanks. [1 mark]

Primary effluent is passed into large aeration tank



Effluent is passed into settling tank to form the sediment (activated sludge)

Solution:

Concept:

- Aeration provides oxygen for aerobic microbial growth during the secondary treatment of sewage.
- Flocs are masses of bacteria associated with fungal filaments, forming mesh-like structures.

Step 1: Identify the bacterial component In a large aeration tank, the primary effluent is agitated and air is pumped into it. This promotes vigorous growth of useful aerobic bacteria, which consume the organic matter in sewage.

Step 2: Identify the associated microbes Fungal filaments associate with the bacterial masses to form flocs. Thus, the question refers to bacteria and fungi, rather than to the anaerobic methanogens that act later in the sludge digester.

Step 3: Conclusion The two groups are aerobic bacteria and fungi (fungal filaments), which together form flocs.

Quick Tip to Solve: Link the aeration tank with bacterial flocs and fungal filaments; methanogens belong to the anaerobic digester.

OR

29(c)(ii). Sewage is generated in large quantities in the urban areas. It is treated in sewage treatment-plants (STPs) to make it less polluted before discharging into any natural water body. Observe the flow chart given below and answer the questions that follow :

Define BOD. What happens to the BOD when organic matter present in the wastewater increases?

[1 mark]

Primary effluent is passed into large aeration tank



Effluent is passed into settling tank to form the sediment (activated sludge)

Solution:

Concept:

- BOD stands for biochemical oxygen demand and indicates the oxygen requirement for microbial decomposition of organic matter.
- A greater load of biodegradable organic matter produces a greater demand for dissolved oxygen.

Step 1: Define the measurement BOD is the amount of dissolved oxygen required by aerobic microorganisms to oxidise the biodegradable organic matter present in a given sample of water during a specified period under standard conditions.

Step 2: Relate it to the organic load When biodegradable organic matter in wastewater increases, microbial decomposition requires more oxygen. Therefore BOD increases. A high BOD consequently indicates a greater organic pollution load, rather than a larger reserve of dissolved oxygen.

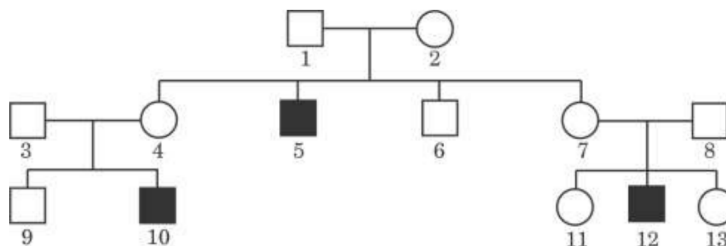
Step 3: Conclusion BOD is biochemical oxygen demand. It increases with an increase in biodegradable organic matter in wastewater.

Quick Tip to Solve: Remember the direction: more biodegradable organic matter means more microbial oxygen demand and hence higher BOD.

30(a). Haemophilia is a sex-linked recessive disease. Study the pedigree analysis given below showing the inheritance of the disease in a family and answer the questions that follow :

Analyse the given pedigree chart to explain why Haemophilia is considered a sex-linked recessive disorder.

[1 mark]



Solution:

Concept:

- Haemophilia is an X-linked recessive disorder: the mutant allele is carried on the X chromosome.
- A male expresses a recessive X-linked allele because he has only one X chromosome; a heterozygous female is an unaffected carrier.

Step 1: Use the affected sons in the pedigree Unaffected parents 1 and 2 have an affected son, 5. Similarly, unaffected mothers 4 and 7 have affected sons 10 and 12, respectively. The disorder can therefore remain unexpressed in carrier mothers and appear in their sons, showing recessive inheritance.

Step 2: Connect the pattern with sex linkage All affected individuals shown (5, 10 and 12) are males. They receive their single X chromosome from their mothers and express the recessive allele on it. This mother-to-son pattern is consistent with X-linked recessive inheritance.

Step 3: Conclusion The appearance of affected sons from unaffected carrier mothers, with affected males in the pedigree, supports X-linked recessive inheritance.

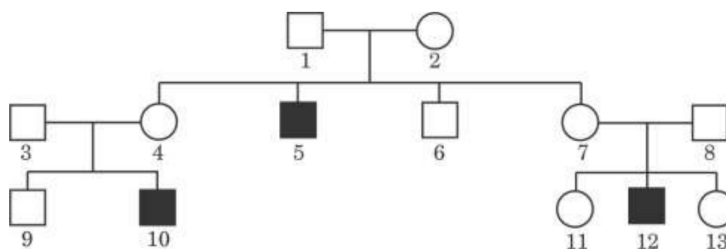
Quick Tip to Solve: Use the specific pairs 2 to 5, 4 to 10 and 7 to 12 to connect carrier mothers with affected sons.

30(b). Haemophilia is a sex-linked recessive disease. Study the pedigree analysis given below showing the inheritance of the disease in a family and answer the questions that follow :

(i) The possibility of a human female becoming a haemophilic is extremely rare. Explain.

(ii) Why do the sons of a haemophilic father never suffer from this disease?

[2 marks]



Solution:

Concept:

- Let X^H carry the normal allele and X^h carry the recessive haemophilia allele.
- A haemophilic female has genotype X^hX^h , whereas a haemophilic male has genotype X^hY .
- A father gives his Y chromosome to a son and his X chromosome to a daughter.

Step 1: (i) Explain why affected females are rare A female must inherit the haemophilia allele on both X chromosomes to express the disease. Her father must therefore be haemophilic and her mother must be at least a carrier (or affected). A female receiving only one mutant allele is generally an unaffected carrier, X^HX^h . The required combination of an affected father and a carrier or affected mother is uncommon, so affected females are extremely rare.

Step 2: (ii) Trace the chromosome passed from father to son A haemophilic father, X^hY , passes his Y chromosome, not his affected X chromosome, to each son. Hence he cannot transmit haemophilia directly to a son. With a non-carrier mother, X^HX^H , all sons are X^HY and unaffected. A son could still be affected if he receives X^h from a carrier or affected mother; that inheritance is maternal.

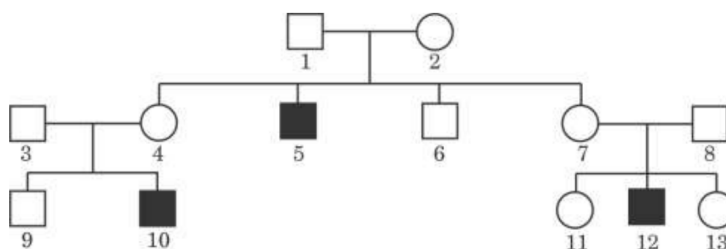
Step 3: Conclusion (i) Two recessive alleles are required in a female, demanding an uncommon parental combination. (ii) Sons do not inherit their father's affected X chromosome; any haemophilia in a son must come through the mother.

Quick Tip to Solve: Trace chromosome origin first: every son receives Y from his father and X from his mother.

30(c)(i). Haemophilia is a sex-linked recessive disease. Study the pedigree analysis given below showing the inheritance of the disease in a family and answer the questions that follow :

Write the possible genotype of the individuals 2 and 5.

[1 mark]



Solution:

Concept:

- Use X^H for the normal allele and X^h for the recessive haemophilia allele.
- An unaffected female with an affected son is an obligate carrier when the disorder follows X-linked recessive inheritance.

Step 1: Determine individual 2 Individual 2 is an unaffected female whose son 5 is affected. A son receives his X chromosome from his mother, so she must carry X^h . Because she is unaffected, her other X carries the normal allele. Her genotype is therefore $X^H X^h$.

Step 2: Determine individual 5 Individual 5 is represented by a filled square, identifying an affected male. A male has one X and one Y chromosome; the X must carry the haemophilia allele. His genotype is $X^h Y$.

Step 3: Conclusion Individual 2: $X^H X^h$ (carrier female); individual 5: $X^h Y$ (haemophilic male).

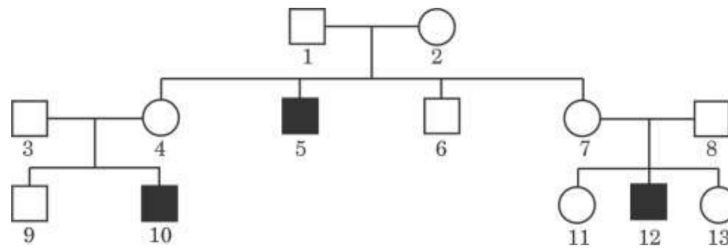
Quick Tip to Solve: An affected son identifies his unaffected mother as a carrier because his X chromosome is maternally inherited.

OR

30(c)(ii). Haemophilia is a sex-linked recessive disease. Study the pedigree analysis given below showing the inheritance of the disease in a family and answer the questions that follow :

Why is haemophilia categorised as a Mendelian disorder?

[1 mark]



Solution:

Concept:

- A Mendelian disorder results from an alteration or mutation in a single gene.
- The alleles of the gene segregate during gamete formation; haemophilia shows X-linked recessive transmission.

Step 1: Identify the genetic basis Haemophilia is caused by a mutation in a single gene affecting a blood-clotting factor. In the form considered in this pedigree, that gene is located on the X chromosome. It is therefore a single-gene disorder rather than a chromosomal-number abnormality.

Step 2: Explain the inheritance category The normal and mutant alleles segregate during gamete formation, and transmission of the mutant allele can be traced through the family. Its recessive expression and its location on the X chromosome produce the characteristic sex-linked pattern, while the single-gene basis makes it Mendelian.

Step 3: Conclusion Haemophilia is categorised as a Mendelian disorder because it results from mutation of a single gene and follows X-linked recessive inheritance.

Quick Tip to Solve: For the category Mendelian disorder, state the single-gene mutation first, then specify the X-linked recessive pattern.

Section E (15 marks)

31(a). Draw a flow chart to show hormonal control of the human male reproductive system. [5 marks]

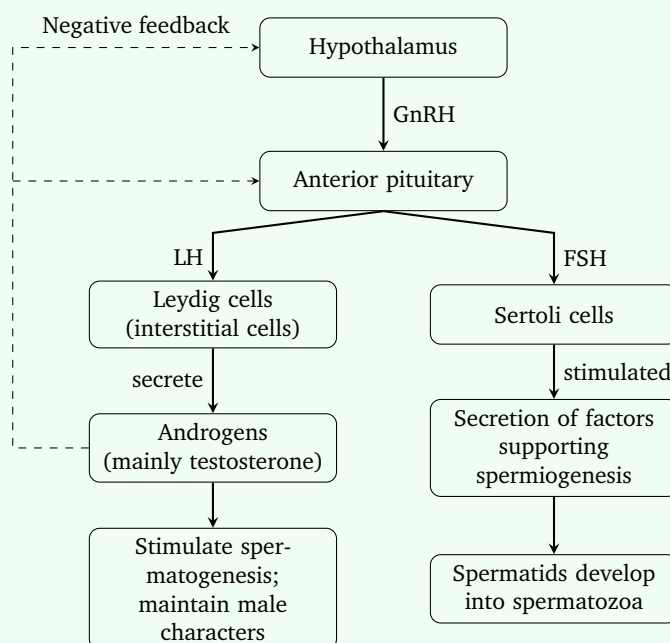
Solution:

Concept:

- Male reproductive activity is regulated by the hypothalamus, anterior pituitary and testes. A marked increase in gonadotropin-releasing hormone (GnRH) secretion at puberty initiates the hormonal sequence.
- GnRH stimulates the anterior pituitary to release two gonadotropins: luteinising hormone (LH) and follicle-stimulating hormone (FSH). Their target cells in the testis are different.

- LH acts on Leydig cells, whereas FSH acts on Sertoli cells. Androgens and Sertoli-cell secretions together support sperm formation and maturation.

Step 1: Trace the hormonal pathways in a flow chart Start with the hypothalamus, connect it to the anterior pituitary by an arrow labelled GnRH, and divide the pituitary output into the LH and FSH pathways. Each branch below identifies the hormone, its target and its effect. Solid arrows show stimulation; the dashed return arrow shows negative feedback by androgens.



Hormonal control of the human male reproductive system

Step 2: Explain the LH pathway LH released by the anterior pituitary acts on the interstitial cells, also called Leydig cells, located between the seminiferous tubules. These cells synthesise and secrete androgens, mainly testosterone. Androgens stimulate spermatogenesis in the seminiferous tubules and maintain the male reproductive organs and secondary sexual characters. Thus, LH supports sperm production through its action on androgen-producing cells.

Step 3: Explain the FSH pathway FSH acts on the Sertoli cells within the seminiferous tubules. It stimulates them to secrete factors that help spermiogenesis, the transformation of spermatids into spermatozoa. Sertoli cells also provide nourishment and support to the developing germ cells. This pathway complements the androgen-dependent stimulation of spermatogenesis; FSH does not act on Leydig cells to produce testosterone.

Step 4: Recognise feedback regulation When the androgen level rises, it exerts negative feedback on the hypothalamus and anterior pituitary, reducing the drive for further androgen secretion. This helps regulate the hormonal output. The two essential forward pathways remain GnRH–LH–Leydig cells–androgens and GnRH–FSH–Sertoli cells–factors supporting spermiogenesis.

Step 5: Conclusion The flow chart shows hypothalamic GnRH stimulating pituitary LH and FSH: LH promotes androgen secretion by Leydig cells, while FSH promotes Sertoli-cell factors that aid spermiogenesis. Together these pathways control male reproductive activity.

Quick Tip to Solve: Pair LH with Leydig cells and FSH with Sertoli cells before drawing the branches; label both the target cells and the final reproductive effects.

31(b). Explain the changes that the primary oocyte undergoes while in different follicular stages before ovulation.

[5 marks]

Solution:

Concept:

- Oogenesis begins in foetal life. Oogonia enter meiosis I and become diploid primary oocytes; these remain arrested in prophase I until follicular maturation after puberty.
- Follicular growth and oocyte maturation are coordinated but distinct: granulosa cells and theca develop around the oocyte, while unequal meiotic division preserves most cytoplasm in the future egg.

Step 1: Primary follicle and meiotic arrest During foetal development, oogonia enlarge and enter the first meiotic division to form primary oocytes. Each primary oocyte becomes surrounded by a layer of granulosa cells, forming a primary follicle. The oocyte remains arrested in prophase I; it has not yet formed an ovum. Many follicles degenerate between birth and puberty.

Step 2: Secondary follicle From puberty onwards, selected follicles grow under gonadotropin stimulation. The primary follicle develops additional layers of granulosa cells and a surrounding theca, becoming a secondary follicle. The enclosed primary oocyte grows, accumulates cytoplasm and receives support from the follicular cells. It is still a primary oocyte at this stage.

Step 3: Tertiary follicle and completion of meiosis I The secondary follicle becomes a tertiary follicle as a fluid-filled cavity called the antrum appears. Its theca differentiates into the inner theca interna and outer theca externa. At this stage the primary oocyte grows and completes meiosis I by an unequal division. This produces a large haploid secondary oocyte and a small first polar body. The secondary oocyte retains the bulk of the nutrient-rich cytoplasm.

Step 4: Mature Graafian follicle before ovulation The tertiary follicle matures into a Graafian follicle. The secondary oocyte is surrounded by a newly formed zona pellucida and follicular cells. It begins meiosis II and is arrested at metaphase II. The LH surge brings about rupture of the mature follicle at ovulation, releasing the secondary oocyte. Completion of meiosis II occurs only after sperm entry, so a fully formed ovum is not released at ovulation.

Step 5: Conclusion Before ovulation, a prophase-I-arrested primary oocyte grows within the developing follicle and completes meiosis I to produce a haploid secondary oocyte and the first polar body. The Graafian follicle releases this secondary oocyte, arrested in metaphase II.

Quick Tip to Solve: Track the follicle and germ cell separately: primary oocyte in the early follicles, secondary oocyte after meiosis I, and ovum only after completion of meiosis II.

32(a)(I)(i). State the role of selectable markers in rDNA technology.

[1 mark]

Solution:

Concept:

- A selectable marker is a vector gene that gives a recognisable selectable property to a host cell carrying the vector.
- Transformation introduces foreign DNA into a host; selection distinguishes cells that received it from cells that did not.

Step 1: Identify transformed cells Selectable markers help identify and select transformants while eliminating non-transformants. For example, a bacterium receiving a vector with an antibiotic-resistance gene can grow on medium containing that antibiotic.

Step 2: Apply selection correctly A cell lacking the vector cannot grow under the same selective condition. Thus the marker provides a practical way to recover cells that have taken up the vector. A marker does not itself cut DNA or join the insert to the vector.

Step 3: Conclusion Selectable markers permit identification and selection of transformants and elimination of non-transformants.

Quick Tip to Solve: Link the marker to survival on selective medium: vector uptake gives the trait needed for growth.

32(a)(I)(ii). Name two such selectable markers which are considered to be useful for *E. coli* cloning vector.

[1 mark]

Solution:

Concept:

- Antibiotic-resistance genes are useful selectable markers because they confer a survival advantage on transformed bacteria under defined culture conditions.
- The selectable marker is the resistance gene carried by the vector, whereas the antibiotic is added to the culture medium.

Step 1: Name the first marker An ampicillin-resistance gene, commonly written as ampR, is a useful selectable marker. Cells that receive a vector carrying this functional gene can be selected on medium containing ampicillin.

Step 2: Name the second marker A tetracycline-resistance gene, commonly written as tetR, is another useful marker. Cells with the functional resistance gene survive on tetracycline-containing medium. These two resistance markers are used in the *E. coli* cloning vector pBR322.

Step 3: Conclusion Two useful selectable markers are the ampicillin-resistance gene and the tetracycline-resistance gene.

Quick Tip to Solve: Name the resistance genes, rather than only the antibiotic chemicals, when asked for selectable markers.

32(a)(I)(iii). State two significances of 'Ori' in *E. coli* cloning vector.

[1 mark]

Solution:

Concept:

- The origin of replication, or ori, is the DNA sequence from which replication begins in a vector.
- DNA linked to a functional ori can be replicated in the host as part of the same DNA molecule.

Step 1: Initiation and propagation Ori provides the site at which vector DNA replication starts in the host. Therefore a foreign DNA segment linked to it can also be replicated, enabling the inserted DNA to be maintained and multiplied in *E. coli*.

Step 2: Control of copy number Ori also controls the copy number of linked DNA in the host. Consequently the choice of origin influences how many copies of the vector and its inserted DNA are produced per host cell. Ori is distinct from a selectable marker and does not confer antibiotic resistance.

Step 3: Conclusion Ori initiates replication of the vector and linked foreign DNA, and controls their copy number in the host.

Quick Tip to Solve: Recall the two ori functions together: starting replication and determining the number of vector copies.

32(a)(II). How have biotechnologists effectively used *Agrobacterium tumefaciens* in plants and retroviruses in animals? Explain.

[2 marks]

Solution:

Concept:

- A vector carries a desired gene into a host cell. A naturally gene-transferring pathogen can be converted into a vector by removing its disease-causing ability while retaining gene delivery.
- *Agrobacterium tumefaciens* transfers T-DNA to plant cells; retroviruses can deliver genetic material into animal cells.

Step 1: Use of *Agrobacterium* in plants In nature, *Agrobacterium tumefaciens* transfers a segment of DNA, called T-DNA, from its tumour-inducing (Ti) plasmid into plant cells and causes tumours. Biotechnologists disarm the Ti plasmid by removing or disabling the tumour-inducing genes and introduce the desired gene into the transfer region. The modified plasmid delivers the gene of interest into plant cells without causing disease, allowing the production of genetically modified plants.

Step 2: Use of retroviruses in animals Retroviruses naturally infect animal cells and can integrate a DNA copy of their genetic material into the host genome. They are modified so that disease-causing functions are removed and the desired gene is carried instead. Such disarmed retroviral vectors introduce useful foreign genes into animal cells without producing the disease caused by the original virus.

Step 3: Conclusion Biotechnologists use disarmed Ti plasmids of *A. tumefaciens* as plant gene-transfer vectors and disarmed retroviruses as animal gene-transfer vectors, retaining delivery of the desired gene while removing pathogenicity.

Quick Tip to Solve: Link each vector to its host, then state the common modification: remove disease-causing genes but retain the ability to deliver the desired gene.

32(b). Name and describe the technique that helps in separation and isolation of DNA fragments after cutting of DNA by restriction endonucleases. [5 marks]

Solution:

Concept:

- Agarose gel electrophoresis separates DNA fragments according to their size. DNA has a negatively charged phosphate backbone and therefore moves towards the positive electrode (anode) in an electric field.
- Agarose, a natural polymer obtained from seaweeds, forms a porous matrix that acts as a molecular sieve. Smaller DNA fragments pass through its pores more easily than larger fragments.

Step 1: Prepare the gel and load the restriction digest The technique is **agarose gel electrophoresis**. Prepare an agarose gel containing wells and place it in a suitable buffer. Load the mixture of DNA fragments produced by restriction endonucleases into the wells near the negative electrode. A DNA size marker may be loaded in a separate well to compare fragment sizes.

Step 2: Separate DNA fragments using an electric field Apply an electric field across the gel. Since DNA is negatively charged, the fragments migrate through the agarose towards the anode. The gel offers greater resistance to larger fragments, whereas smaller fragments move more easily and travel farther in the same time. Thus, the mixture separates into distinct bands according to fragment size; fragments of similar size occur together in a band.

Step 3: Visualise the separated bands DNA is not visible directly in the gel. Stain it with ethidium bromide and expose the gel to ultraviolet radiation. Ethidium bromide associated with DNA fluoresces, making the separated fragments visible as bright orange-coloured bands. The band containing the required DNA fragment is identified by its position, with a size marker helping when the desired fragment size is known.

Step 4: Isolate the required DNA fragment Cut out the portion of agarose containing the desired DNA band and extract the DNA from that gel piece. This recovery of separated DNA is called **elution**. The purified DNA fragment can then be joined to a suitable cloning vector using DNA ligase for the construction of recombinant DNA. Separation produces the bands; excision and elution recover the selected fragment for further use.

Step 5: Conclusion Agarose gel electrophoresis separates restriction-generated DNA fragments by size. Ethidium bromide staining and ultraviolet illumination reveal the bands, and excision followed by elution isolates the desired DNA fragment.

Quick Tip to Solve: Remember the complete sequence: load, migrate towards the anode, visualise the bands, cut out the desired band and elute its DNA. Smaller fragments travel farther.

- 33(a).** (i) How and why is charging of tRNA essential in the process of translation?
(ii) State the function of ribosome as a catalyst in translation in bacteria.
(iii) Explain the process of binding of ribosomal units to mRNA during protein synthesis.
(iv) Where are untranslated regions located in mRNA? Mention their role.

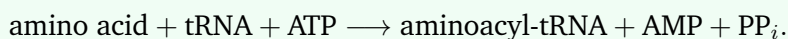
[5 marks]

Solution:

Concept:

- Translation decodes the codons of mRNA into an amino-acid sequence. A tRNA is an adaptor: its anticodon recognises a codon, while its amino-acid acceptor end carries the corresponding amino acid.
- Aminoacyl-tRNA synthetases use ATP to attach each amino acid to its specific tRNA. The ribosome positions mRNA and tRNAs and catalyses peptide-bond formation.
- Initiation assembles the small and large ribosomal subunits at the start codon. Untranslated regions (UTRs) flank the coding region and support efficient translation.

Step 1: (i) How tRNA is charged In the presence of ATP and a specific aminoacyl-tRNA synthetase, an amino acid is first activated and then linked to the acceptor end of its corresponding tRNA. The amino acid attaches to the terminal adenosine of the 3'-CCA end, forming aminoacyl-tRNA, also called charged tRNA. The overall reaction is



Specific recognition by the enzyme ensures that the appropriate amino acid is attached to the tRNA that will recognise its codon.

Step 2: (i) Why charging is essential Charging supplies the amino acid in an activated form for protein synthesis. When two charged tRNAs are brought close together on the ribosome, a peptide bond can form between their amino acids. Energy stored in the aminoacyl linkage helps drive peptide-bond formation. Thus, charging both delivers the correct amino acid to the codon and provides the activated substrate needed to build the polypeptide.

Step 3: (ii) Catalytic role of the bacterial ribosome In bacteria, the 23S rRNA of the large 50S ribosomal subunit acts as a ribozyme. Its peptidyl-transferase activity catalyses peptide-bond formation between adjacent amino acids during elongation. The catalytic component is therefore ribosomal RNA.

Step 4: (iii) Binding of ribosomal subunits to mRNA Before translation begins, the ribosome exists as separate small and large subunits. The small subunit first binds to mRNA and positions it so that the start codon, usually AUG, can be recognised by the initiator tRNA. In bacteria the initiator tRNA carries formylmethionine. Its anticodon pairs with the start codon. The large subunit then joins to form the complete initiation complex, with the initiator tRNA at the P site. The ribosome is now ready to receive the next charged tRNA and begin elongation.

Step 5: (iv) Location and role of untranslated regions The 5'-UTR lies before the start codon, between the 5' end of mRNA and the coding region. The 3'-UTR lies after the stop codon, between the coding region and the 3' end of mRNA. These regions are present in the mRNA but are not translated into amino acids. They are required for efficient translation; their sequences help regulate how effectively the mRNA is used for protein synthesis.

Step 6: Conclusion ATP-dependent charging attaches the correct activated amino acid to tRNA; bacterial 23S rRNA catalyses peptide-bond formation. Translation begins by assembly of the small subunit, mRNA, initiator tRNA and large subunit, while the flanking 5'- and 3'-UTRs promote efficient translation.

Quick Tip to Solve: Keep the four roles distinct: synthetase charges tRNA, 23S rRNA catalyses peptide bonds, the small subunit starts mRNA binding, and UTRs flank the coding region.

OR

33(b). (i) State the arrangement of different genes, that in bacteria is referred to as 'operon'.

(ii) Draw a schematic labelled illustration of *lac* operon in a switched on state.

(iii) Describe the role of lactose in *lac* operon.

[5 marks]

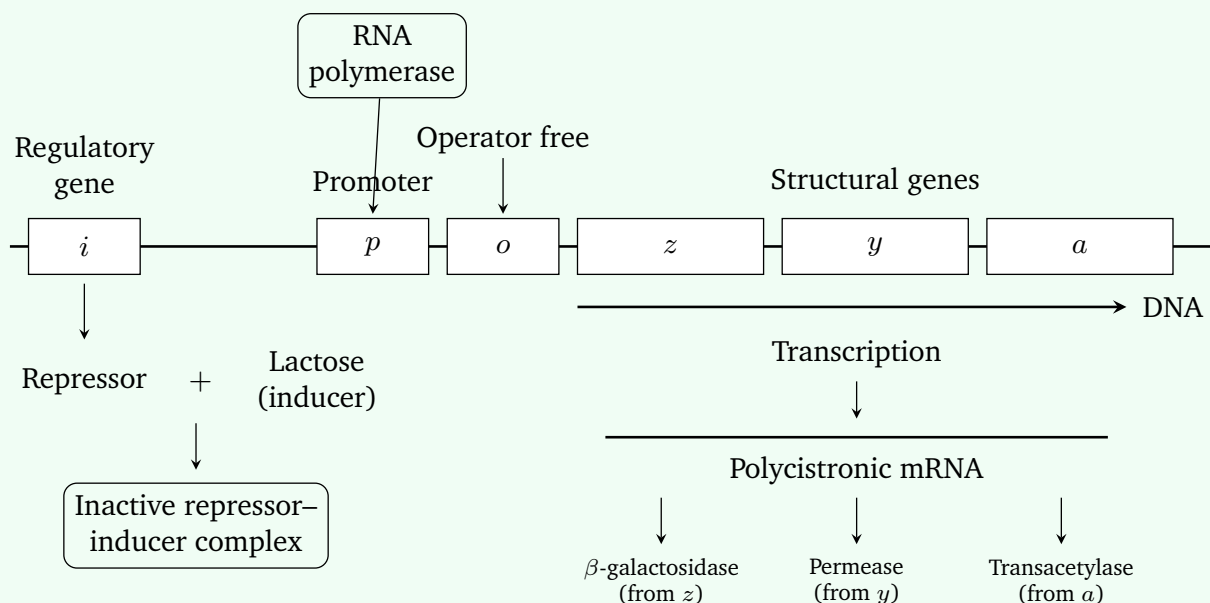
Solution:

Concept:

- An operon is a group of structural genes regulated together by a common promoter and operator. The structural genes are transcribed as a single polycistronic mRNA.
- The *lac* operon is an inducible system: the regulatory gene *i* produces a repressor, while lactose acts as the inducer that allows expression of the structural genes *z*, *y* and *a*.

Step 1: (i) Arrangement of genes in an operon In bacteria, several structural genes with related functions are arranged in a linear sequence under the control of a common promoter and operator. Together, these constitute an operon. RNA polymerase binds to the promoter; binding of a repressor to the operator controls transcription of the structural genes. Since the structural genes share this control region, they can be switched on or off together and transcribed into one polycistronic mRNA. In the *lac* system the structural genes are *z*, *y* and *a*; the regulatory gene *i* supplies the repressor protein.

Step 2: (ii) The switched-on lac operon The labelled schematic shows the condition when lactose is available. Inducer binding inactivates the repressor, leaving the operator unblocked. RNA polymerase can then transcribe the structural genes *z*, *y* and *a*. Translation of this polycistronic mRNA produces β -galactosidase, permease and transacetylase, respectively. The *z* product hydrolyses lactose into glucose and galactose; permease increases entry of lactose into the cell. Thus the cell makes the proteins required for using the available substrate.



The lac operon in the switched-on state; the inactive repressor cannot occupy the operator.

Step 3: (iii) Role of lactose as an inducer Without lactose, the active repressor binds to the operator and prevents transcription of the structural genes. When lactose is present, it acts as an inducer: the inducing form derived from lactose, allolactose, binds to the repressor and changes its conformation. The repressor becomes unable to bind to the operator. RNA polymerase therefore gains access to transcribe the structural genes, and the operon is switched on. Lactose is both the substrate to be metabolised and the signal inducing production of the enzymes needed for its utilisation. When the inducer is depleted, the repressor can again bind the operator and turn transcription off.

Step 4: Conclusion An operon contains structural genes under common promoter-operator control. In the switched-on *lac* operon, lactose-induced inactivation of the repressor permits transcription of *z*, *y* and *a*, followed by synthesis of the proteins involved in lactose utilisation.

Quick Tip to Solve: Draw the DNA in the order promoter-operator-*z*-*y*-*a*, keep the operator free in the ON state, and show lactose bound to the inactive repressor.