

CBSE Class 12 Biology Question Paper 2025 with Solution PDF-Set 57-S-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 enzyme 'Taq Polymerase' used in PCR, has been isolated from bacterium :

[1 mark]

(A) *Agrobacterium tumefaciens*

(B) *Thermus aquaticus*

(C) *Streptomyces albus*

(D) *Escherichia coli*

Correct Answer: (B) *Thermus aquaticus*

Solution:

Concept:

- PCR amplifies DNA through repeated denaturation, primer annealing and extension.
- Taq DNA polymerase is a heat-stable enzyme isolated from the thermophilic bacterium *Thermus aquaticus*.

Step 1: Connect the enzyme to its source The name Taq is derived from *Thermus aquaticus*. This bacterium lives in hot environments, and its DNA polymerase remains functional through the high-temperature denaturation steps of PCR. It extends the primers by adding deoxyribonucleotides.

Step 2: Eliminate the other organisms *Agrobacterium tumefaciens* is used as a vector in plant genetic engineering, not as the source of Taq polymerase. Neither *Streptomyces albus* nor *Escherichia coli* is the organism from which Taq was isolated. Thus, options (A), (C) and (D) do not match the named enzyme.

Step 3: Conclusion Taq polymerase is isolated from *Thermus aquaticus*. Hence, the correct option is (B).

Quick Tip to Solve: Expand Taq as *Thermus aquaticus*, and connect its heat stability with repeated PCR denaturation.

2. A man with a certain disease marries a normal woman. They have four children (three daughters and one son). All the daughters suffer from their father's disease but the son is not affected. Which of the following mode of inheritance do you suggest for this disease ? [1 mark]

- (A) Autosome Linked Recessive
- (B) Sex-linked Dominant
- (C) Autosome Linked Dominant
- (D) Sex-linked Recessive

Correct Answer: (B) Sex-linked Dominant

Solution:

Concept:

- A father passes his X chromosome to every daughter and his Y chromosome to every son.
- A dominant disease allele on the X chromosome is expressed even when a normal allele is also present.

Step 1: Trace the paternal chromosome Let X^D carry the dominant disease allele and X^d the normal allele. The affected father is $X^D Y$, and the unaffected mother is $X^d X^d$. Their daughters receive the paternal X^D and are $X^D X^d$, so they are affected. Their sons receive the paternal Y and maternal X^d , so they are unaffected $X^d Y$.

Step 2: Compare the inheritance patterns The transmission to daughters but not sons is characteristic of X-linked dominant inheritance. An X-linked recessive allele from an affected father would normally produce carrier, unaffected daughters with a non-carrier mother. Autosomal inheritance does not predict this specific father-to-all-daughters pattern because an autosome is inherited by either sex. Thus, (A), (C) and (D) are not the suggested mode.

Step 3: Conclusion The suggested mode is sex-linked dominant (X-linked dominant) inheritance. Hence, the correct option is (B).

Quick Tip to Solve: For an affected father, follow his X to daughters and his Y to sons before deciding dominance.

3. What would happen if in a gene encoding a polypeptide of 51 amino acids, codon present at 32 position (UAU) is mutated to UGA ? Select the option that indicates the polypeptide with correct number of amino acids formed after mutation. [1 mark]

- (A) A polypeptide of 50 amino acids will be formed.
- (B) A polypeptide of 32 amino acids will be formed.
- (C) Two polypeptides of 20 and 31 amino acids will be formed.
- (D) A polypeptide of 31 amino acids will be formed.

Correct Answer: (D) A polypeptide of 31 amino acids will be formed.

Solution:

Concept:

- A codon is a sequence of three RNA bases; UAU codes for tyrosine, whereas UGA is a stop codon.
- A stop codon terminates translation without adding an amino acid. Conversion of an amino-acid codon to a stop codon is a nonsense mutation.

Step 1: Locate the premature stop The first 31 codons are unchanged and can each contribute their amino acid. At codon 32, the ribosome encounters UGA in place of UAU. A release factor recognises this stop signal, and the growing polypeptide is released before an amino acid can be added at this position.

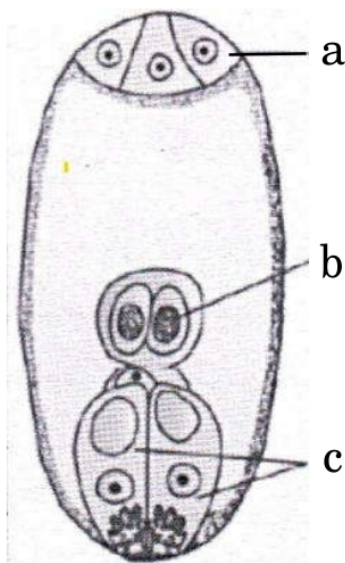
Step 2: Count only the translated codons The number of incorporated amino acids is $32 - 1 = 31$. A chain of 32 amino acids would incorrectly count the stop codon as coding for an amino acid. A chain of 50 would imply that only one residue is skipped, although translation actually terminates. The remaining codons do not automatically form a second polypeptide, so the proposal of two chains is also incorrect.

Step 3: Conclusion A single polypeptide of 31 amino acids will be formed. Hence, the correct option is (D).

Quick Tip to Solve: When codon number n becomes a stop codon, count $n - 1$ amino acids; do not count the stop itself.

4. Identify a, b and c in the given figure of an embryo sac.

[1 mark]



- (A) a – Antipodals, b – Polar nuclei, c – Synergids
(B) a – Antipodals, b – Central cells, c – Egg cells
(C) a – Synergids, b – Polar nuclei, c – Egg cells
(D) a – Synergids, b – Egg cells, c – Filiform apparatus

Correct Answer: (A) a – Antipodals, b – Polar nuclei, c – Synergids

Solution:

Concept:

- A typical mature angiosperm embryo sac is seven-celled and eight-nucleate, with an egg apparatus at the micropylar end and three antipodals at the chalazal end.
- The large central cell contains two polar nuclei; the egg apparatus consists of one egg cell and two synergids.

Step 1: Identify the upper and central labels Label a points to the group of three cells at the chalazal end, so these are antipodals. Label b points to the two nuclei within the large central cell, so these are the polar nuclei, rather than two separate central cells.

Step 2: Identify the paired micropylar cells Label c points to the two cells beside the egg at the micropylar end. These are the synergids, whose filiform apparatus helps guide the pollen tube. They are not two egg cells, because the egg apparatus has only one egg. Options (C) and (D) wrongly identify a as synergids; option (B) also misidentifies b and c.

Step 3: Conclusion a represents antipodals, b represents polar nuclei and c represents synergids. Hence, the correct option is (A).

Quick Tip to Solve: Orient the embryo sac using the three antipodals at one end and the egg with two synergids at the other.

5. Which of the following statements are true in respect of chorionic villi in humans ?

- (i) It appears after implantation of human embryo in the uterus.
- (ii) It becomes interdigitated with cervical tissue of female reproductive tract.
- (iii) It increases the surface area for exchange of materials.
- (iv) It develops from the inner cell mass of blastocyst.

[1 mark]

- (A) (i) and (ii)
- (B) (ii) and (iii)
- (C) (i) and (iv)
- (D) (i) and (iii)

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

Solution:

Concept:

- After implantation, finger-like projections called chorionic villi appear on the trophoblast of the embryo.
- Chorionic villi interdigitate with uterine tissue and contribute to the placenta, increasing the surface available for exchange between mother and embryo.

Step 1: Check the correct statements Statement (i) is correct because chorionic villi appear after the embryo has implanted in the uterine lining. Statement (iii) is also correct: their numerous projections enlarge the exchange surface for oxygen, nutrients and waste materials between maternal and foetal tissues.

Step 2: Correct the false statements Statement (ii) is false because the villi interdigitate with uterine endometrial tissue, not cervical tissue. Statement (iv) is false because villi arise from the trophoblast-associated outer tissues; the inner cell mass develops into the embryo proper. Options (A) and (B) include the false statement (ii), while (C) includes the false statement (iv).

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

Quick Tip to Solve: Link chorionic villi with trophoblast, uterine lining and a larger exchange surface; reject cervix and inner cell mass.

6. Given below are four contraceptive methods and their modes of action. Select the correct match.

Contraceptive methods	Modes of Action
a. Condoms	i. Ovum not able to reach fallopian tube
b. Vasectomy	ii. Prevents ovulation
c. Pill	iii. Prevents sperm reaching the cervix
d. Tubectomy	iv. Semen contains no sperms

[1 mark]

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

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

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

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

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

Solution:

Concept:

- Barrier methods prevent sperm from entering the female reproductive tract, whereas hormonal pills can suppress ovulation.
- Surgical contraception blocks gamete transport: vasectomy interrupts the vasa deferentia, and tubectomy interrupts the fallopian tubes.

Step 1: Match condoms and vasectomy Condoms act as a physical barrier and prevent sperm from reaching the cervix, giving a–iii. Vasectomy involves cutting and tying the vasa deferentia so sperm cannot enter the semen, giving b–iv. Sperm production may continue in the testes despite this blocked transport.

Step 2: Match pills and tubectomy Hormonal contraceptive pills inhibit ovulation, giving c–ii. Tubectomy blocks the fallopian tubes and prevents normal ovum transport and the meeting of sperm and ovum; this corresponds to the listed mode i, giving d–i. The four associations must hold together. Option (A) mismatches condoms with ovum transport, (B) mismatches condoms with ovulation, and (D) mismatches condoms with sperm-free semen.

Step 3: Conclusion The correct matching is a–iii, b–iv, c–ii and d–i. Hence, the correct option is (C).

Quick Tip to Solve: Match condoms to a barrier, vasectomy to sperm transport, pills to ovulation and tubectomy to the oviduct.

7. Which of the following animals exhibit male heterogamety ?

[1 mark]

(i) Fruit fly (ii) Fowl (iii) Human (iv) Honey bee

- (A) (i) and (iii)
- (B) (ii) and (iv)
- (C) (ii) and (iii)
- (D) (i) and (iv)

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

Solution:

Concept:

- Male heterogamety means that the male produces two kinds of gametes differing in their sex-chromosome content.
- In an XX–XY system, males produce X-bearing and Y-bearing sperm, whereas females produce eggs carrying an X chromosome.

Step 1: Identify the XX–XY examples Male fruit flies and human males have the XY constitution. Each produces two types of sperm, one bearing X and the other bearing Y. Therefore, both fruit fly (i) and human (iii) exhibit male heterogamety.

Step 2: Distinguish the other mechanisms In fowl, the male is ZZ and the female is ZW. The female produces Z-bearing and W-bearing eggs, so this is female heterogamety. Honey bees show haplodiploid sex determination: males are haploid and develop from unfertilised eggs, whereas females are diploid and develop from fertilised eggs. Hence, (ii) and (iv) do not belong to the male-heterogamety pair; this excludes (B), (C) and (D).

Step 3: Conclusion Fruit fly and human, listed as (i) and (iii), exhibit male heterogamety. Hence, the correct option is (A).

Quick Tip to Solve: Use XY males for fruit fly and human, ZW females for fowl, and haplodiploidy for honey bee.

8. *Monascus purpureus* is a yeast used commercially in the production of which of the following ?

[1 mark]

- (A) Ethanol
- (B) Streptokinase for removing clots from blood vessels
- (C) Citric acid
- (D) Blood-cholesterol lowering statins

Correct Answer: (D) Blood-cholesterol lowering statins

Solution:

Concept:

- Microorganisms produce useful industrial metabolites, including organic acids, enzymes and medicines.

- Statins lower blood cholesterol by competitively inhibiting the enzyme involved in cholesterol synthesis.

Step 1: Identify the microbial product *Monascus purpureus* is commercially used to produce statins. Their inhibition of cholesterol synthesis explains their use as blood-cholesterol lowering agents.

Step 2: Eliminate the other products Ethanol is commercially produced by yeast such as *Saccharomyces cerevisiae*; streptokinase is obtained from *Streptococcus*; and citric acid is produced using *Aspergillus niger*. Thus options (A), (B) and (C) describe other organism–product associations.

Step 3: Conclusion The product is blood-cholesterol lowering statins. Hence, the correct option is (D).

Quick Tip to Solve: Link *Monascus* with statins, then use inhibition of cholesterol synthesis to identify their function.

9. The chronological order of evolution of modern man from man-like primates is given below. Choose the option that indicates the evolution of man in correct order from early to recent times : [1 mark]

- (A) Australopithecines → Ramapithecus → Homo habilis → Homo erectus → Homo sapiens
 (B) Ramapithecus → Australopithecines → Homo habilis → Homo erectus → Homo sapiens
 (C) Ramapithecus → Homo habilis → Australopithecines → Homo erectus → Homo sapiens
 (D) Australopithecines → Homo habilis → Homo sapiens → Ramapithecus → Homo erectus

Correct Answer: (B) Ramapithecus → Australopithecines → Homo habilis → Homo erectus → Homo sapiens

Solution:

Concept:

- The NCERT account places man-like primates before australopithecines and the later members of the genus *Homo*.
- The sequence among the listed *Homo* forms is *Homo habilis*, then *Homo erectus*, and finally *Homo sapiens*.

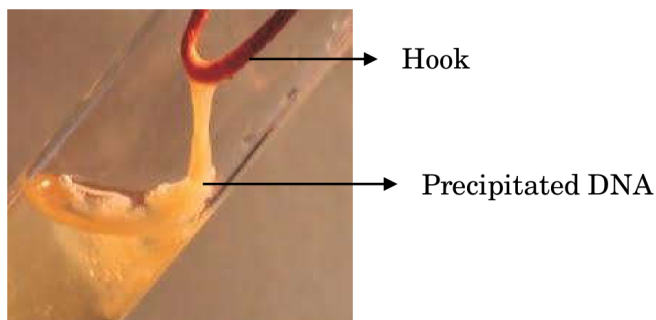
Step 1: Place the earliest forms In the chronology used in this question, *Ramapithecus* precedes the australopithecines. The australopithecines in turn precede *Homo habilis*. This is a chronological ordering of the listed forms.

Step 2: Check every proposed sequence Option (B) preserves both the early sequence and the order of the three *Homo* forms. Option (A) reverses *Ramapithecus* and australopithecines; option (C) places *Homo habilis* before australopithecines; option (D) puts *Homo sapiens* before much earlier forms.

Step 3: Conclusion The order is *Ramapithecus*, australopithecines, *Homo habilis*, *Homo erectus*, *Homo sapiens*. Hence, the correct option is (B).

Quick Tip to Solve: Check the first two forms first, then remember the *Homo* sequence: *habilis*, *erectus*, *sapiens*.

10. Identify the material that helps in the precipitation of purified DNA during the process of isolation of DNA as shown in the given diagram. [1 mark]



- (A) Protease
- (B) Lysozyme
- (C) Cellulase
- (D) Chilled ethanol

Correct Answer: (D) Chilled ethanol

Solution:

Concept:

- DNA isolation involves breaking cells, removing associated proteins and other contaminants, and precipitating purified DNA.
- Chilled ethanol precipitates DNA from the aqueous solution; the visible threads can be collected by spooling.

Step 1: Interpret the pictured material The diagram labels precipitated DNA being collected with a hook. This represents the precipitation and collection stage, after the DNA has been released and purified. Adding chilled ethanol makes the DNA appear as fine threads.

Step 2: Distinguish precipitation from enzyme treatment Protease removes proteins by digestion. Lysozyme breaks bacterial cell walls, whereas cellulase breaks plant cell walls. These enzymes assist earlier isolation steps; none is the reagent used to precipitate the purified DNA in the diagram.

Step 3: Conclusion The material added for precipitation is chilled ethanol. Hence, the correct option is (D).

Quick Tip to Solve: When a diagram shows DNA threads on a hook, identify the spooling stage and choose chilled ethanol.

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

- (A) Producing a petrol-like fuel from rice
- (B) Enrichment of Vitamin A
- (C) Pest resistance
- (D) Herbicide tolerance

Correct Answer: (B) Enrichment of Vitamin A

Solution:

Concept:

- Biofortification improves the nutritional quality of a food crop by increasing a useful nutrient or its precursor.
- Golden rice accumulates β -carotene, a precursor that the human body can convert into vitamin A, in its edible endosperm.

Step 1: Identify the introduced nutritional trait The characteristic golden colour is associated with carotenoid accumulation. The relevant nutritional benefit is the supply of provitamin A, which helps address dietary vitamin A deficiency.

Step 2: Compare the offered applications Option (B), enrichment of vitamin A, describes this nutritional purpose. Production of a petrol-like fuel is a biofuel application, while pest resistance and herbicide tolerance are crop-protection traits. These are not the characteristic purpose of golden rice.

Step 3: Conclusion Golden rice helps improve vitamin A nutrition through its provitamin A content. Hence, the correct option is (B).

Quick Tip to Solve: Connect the golden colour with β -carotene, then recall that it is a precursor of vitamin A.

12. In *Antirrhinum*, RR is a phenotypically red flower, rr is white and Rr is pink. Select the correct phenotypic ratio in F_1 generation, when a cross is performed between $RR \times Rr$: [1 mark]

- (A) 1 Red : 2 Pink : 1 White
- (B) 2 Pink : 2 White
- (C) 2 Red : 2 Pink
- (D) 2 Red : 1 Pink : 1 White

Correct Answer: (C) 2 Red : 2 Pink

Solution:

Concept:

- Flower colour in *Antirrhinum* shows incomplete dominance: RR is red, Rr is pink and rr is white.
- A homozygous RR parent produces only R gametes; a heterozygous Rr parent produces R and r gametes in equal proportions.

Step 1: Combine the parental gametes For the given cross $RR \times Rr$, the R gamete of the red parent

combines equally often with either gamete of the pink parent:

$$R \times R \longrightarrow RR, \quad R \times r \longrightarrow Rr.$$

The offspring therefore occur in the genotypic ratio $1 RR : 1 Rr$.

Step 2: Translate genotypes into flower colours Half the offspring are red and half are pink. No rr offspring can form because the RR parent never contributes r . Hence all options containing white flowers are excluded. The familiar $1 : 2 : 1$ phenotypic ratio applies to $Rr \times Rr$, not to the present cross.

Step 3: Conclusion The phenotypic ratio is 1 red : 1 pink, equivalent to 2 red : 2 pink. Hence, the correct option is (C).

Quick Tip to Solve: List each parent's gametes before using a memorised ratio: an RR parent rules out white offspring.

13. Assertion (A) : All the events starting from pollen landing on stigma till pollen tube entering the ovule are included in pollen-pistil interaction.

Reason (R) : Pollen-pistil interaction ensures that only suitable pollens germinate on the stigma.

[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:

- Pollen–pistil interaction includes recognition of pollen, pollen germination and subsequent pollen-tube growth towards and into the ovule.
- The pistil recognises compatible pollen and promotes its germination and growth; incompatible pollen is rejected.

Step 1: Evaluate the assertion The assertion is true. Pollen–pistil interaction is the collective term for the events from deposition of pollen on the stigma until the pollen tube enters the ovule.

Step 2: Evaluate the reason The reason is also true. Recognition between pollen and pistil permits suitable, compatible pollen to germinate and continue growth, while unsuitable pollen is rejected.

Step 3: Test the explanatory connection The reason describes a selective function of the interaction. It does not explain why the term includes the entire sequence extending from pollen landing to tube

entry into the ovule. Thus the statements are individually correct, but the reason does not explain the assertion's definition and scope.

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

Quick Tip to Solve: In an assertion–reason item, separate a definition covering a sequence of events from one function of that sequence.

14. Assertion (A) : DNA chemically is less reactive and structurally more stable when compared to RNA.

Reason (R) : DNA has 2'– OH group present at every nucleotide, which makes it more stable than RNA. [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:

- DNA contains deoxyribose, whereas RNA contains ribose; their sugars differ at the 2' carbon.
- RNA has a reactive 2'-OH group; DNA has hydrogen at this position and is chemically more stable.

Step 1: Evaluate the assertion The assertion is true. Compared with RNA, DNA is chemically less reactive and structurally more stable, making it better suited for long-term storage of genetic information.

Step 2: Evaluate the reason The reason is false because it assigns the 2'-OH group to DNA. This group is present in RNA, not DNA. Its presence increases RNA's reactivity and facilitates cleavage of its backbone, rather than providing the claimed extra stability.

Step 3: Check the proposed explanation DNA's absence of the 2'-OH group contributes to its greater chemical stability. The printed reason reverses both the sugar identification and the stability effect, so it cannot explain the true assertion. Options requiring a true reason are therefore excluded.

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

Quick Tip to Solve: Remember that deoxyribose lacks the oxygen of the 2'-OH group: that group belongs to RNA.

15. Assertion (A) : Verhulst-Pearl logistic growth curve is sigmoid in nature.

Reason (R) : A population growing in a habitat with limited resources shows initially a lag phase, followed by phases of acceleration and deceleration and finally an asymptote. [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:

- Logistic growth occurs when environmental resources are limited; population size approaches the carrying capacity, K .
- A sigmoid curve is S-shaped, with an initially slow rise, a faster middle phase and a final levelling off.

Step 1: Evaluate the assertion The Verhulst-Pearl logistic model describes an S-shaped population growth curve. As population density increases, resource limitation checks further growth. Thus Assertion (A) is true.

Step 2: Evaluate the reason With limited resources, the population initially shows a lag phase, then accelerates, subsequently decelerates, and approaches an asymptote at the carrying capacity. These are the phases of logistic growth, so Reason (R) is true.

Step 3: Connect the phases to the shape The succession of slow, fast and slowing growth produces the sigmoid shape stated in the assertion. The reason therefore explains the assertion, excluding (B); neither statement is false, excluding (C) and (D).

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

Quick Tip to Solve: Identify the final asymptote at carrying capacity: limited resources and levelling off signal logistic, S-shaped growth.

16. Assertion (A) : In bioreactors, raw materials are biologically converted into desired products.

Reason (R) : In bioreactors, optimum growth conditions for microbes such as temperature, pH, substrate, salts, etc. are available. [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:

- A bioreactor is a large vessel in which living cells or their enzymes convert raw materials into desired biological products.
- Product formation requires controlled conditions such as suitable temperature, pH, substrate, salts and oxygen availability.

Step 1: Evaluate the assertion Microorganisms use the supplied raw materials in their metabolic processes, producing useful substances such as enzymes and other biological products. A bioreactor enables this biological conversion on a large scale. Assertion (A) is true.

Step 2: Evaluate the reason Bioreactors provide optimum conditions for microbial growth and activity. Temperature, pH and nutrient supply are regulated, while mixing and aeration can maintain suitable conditions throughout the culture. Thus Reason (R) is true.

Step 3: Establish the explanatory link The controlled conditions allow the microorganisms and their enzymes to function efficiently and convert the raw materials into the desired product. Thus the reason explains the stated function of the bioreactor. Option (B) misses this link, while (C) and (D) incorrectly treat a true statement as false.

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

Quick Tip to Solve: Link optimum culture conditions to active microbial metabolism: this is what enables raw materials to become biological products.

Section B (10 marks)

17(a). How many meiotic divisions will a wheat plant undergo in order to produce 100 zygotes /100 grains ? Calculate and give explanation. [2 marks]

Solution:

Concept:

- One pollen mother cell undergoes meiosis to form four haploid microspores, each developing into a pollen grain.
- One megaspore mother cell undergoes meiosis to form four megaspores, but normally only one is functional and develops into an embryo sac containing one egg.

Step 1: Count meioses on the female side Each grain develops from one ovule, and each zygote needs one egg. Therefore, 100 zygotes require 100 embryo sacs. Since a megaspore mother cell produces only one functional megaspore and hence one embryo sac, the female side requires 100 meiotic events.

Step 2: Count meioses on the male side One pollen grain supplies the two male gametes involved in double fertilisation of one embryo sac. One gamete fuses with the egg to form the zygote, and the other participates in triple fusion. Thus 100 pollen grains suffice for 100 zygotes. As one pollen mother cell produces four pollen grains, the number of male meiotic events is

$$\frac{100}{4} = 25.$$

Formation of the two male gametes from the generative cell is mitotic, so it adds no meiosis to this count.

Step 3: Combine the two requirements Both microsporogenesis and megasporogenesis must be counted. Adding the required meioses gives

$$N = 100 + 25 = 125.$$

Here each complete meiosis of a mother cell is counted as one meiotic event, as in the usual reproductive-cell calculation.

Step 4: Conclusion The wheat plant requires 125 meiotic events: 100 in megaspore mother cells and 25 in pollen mother cells.

Quick Tip to Solve: For n grains, count n female meioses and $n/4$ male meioses; do not double the pollen requirement for double fertilisation.

17(b). How many pollen grains and ovules are likely to be formed in the anther and the ovary of an angiosperm bearing 35 microspore mother cells and 35 megaspore mother cells respectively ?

[2 marks]

Solution:

Concept:

- Microsporogenesis produces four haploid microspores from each diploid microspore mother cell; each microspore can develop into a pollen grain.
- In the usual angiosperm condition, each ovule contains one megaspore mother cell, and only one of its four meiotic products forms the functional embryo sac.

Step 1: Calculate the pollen grains Each of the 35 microspore mother cells in the anther undergoes meiosis to give a tetrad of four microspores. With normal development of these microspores, the pollen-grain yield is

$$35 \times 4 = 140.$$

All four products can contribute to pollen formation, so the multiplier is four on the male side.

Step 2: Relate megaspore mother cells to ovules The 35 megaspore mother cells correspond to 35 ovules, with one mother cell in each ovule in the usual condition. Although each mother cell forms four megaspores by meiosis, three generally degenerate. The remaining functional megaspore develops into one embryo sac within that same ovule. Thus the number of ovules represented is 35, not 35×4 . Ovules themselves are not the four products of megaspore mother-cell meiosis.

Step 3: Conclusion The expected numbers are 140 pollen grains and 35 ovules.

Quick Tip to Solve: Multiply microspore mother cells by four for pollen grains, but count one ovule per megaspore mother cell in the usual angiosperm condition.

18(a). A couple believed that hospital authorities have exchanged babies and they have been given another baby by them. The wife is blood group 'A', her husband is blood group 'B' and the child is blood group 'O'.

[2 marks]

18(a)(i). Could the baby be theirs ?

Solution:

Concept:

- In ABO inheritance, I^A and I^B are each dominant over the recessive allele i .
- Blood group O has genotype ii , so an O child receives one i allele from each parent.

Step 1: Identify the possible parental genotypes The mother's group A phenotype can correspond to $I^A I^A$ or $I^A i$. The father's group B phenotype can correspond to $I^B I^B$ or $I^B i$. Thus neither phenotype excludes carriage of i .

Step 2: Check whether an O child is possible If the mother is $I^A i$ and the father is $I^B i$, each can

contribute i . Their child can consequently have genotype ii and blood group O. These blood-group observations alone therefore do not establish that the hospital exchanged the baby.

Step 3: Conclusion Yes, the baby could be theirs, provided both parents are heterozygous: $I^A i$ and $I^B i$.

Quick Tip to Solve: For an O child, trace one recessive i allele to each parent before deciding whether the parental blood groups exclude parentage.

18(a)(ii). Justify your answer with the help of a cross.

Solution:

Concept:

- Heterozygous blood-group-A and blood-group-B parents have genotypes $I^A i$ and $I^B i$, respectively.
- Segregation places one allele from each parent in an offspring; the recessive combination ii expresses blood group O.

Step 1: Write the parents and their gametes Take the compatible parental cross

$$\underbrace{I^A i}_{\text{mother, A}} \times \underbrace{I^B i}_{\text{father, B}}.$$

The mother produces gametes I^A and i , and the father produces gametes I^B and i , in equal proportions.

Step 2: Combine the gametes in a Punnett square The possible offspring are

	I^B	i
I^A	$I^A I^B$ (AB)	$I^A i$ (A)
i	$I^B i$ (B)	ii (O)

The four blood groups AB, A, B and O occur in an expected 1 : 1 : 1 : 1 ratio. The ii combination forms when both gametes carry i .

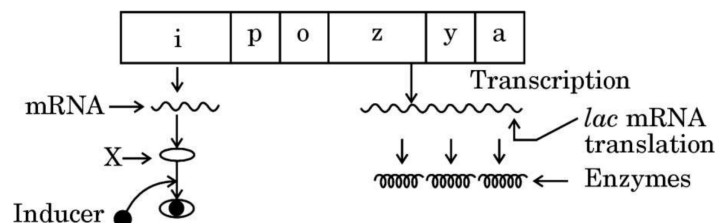
Step 3: Conclusion The cross $I^A i \times I^B i$ gives a 25% probability of a blood-group-O child, so the baby could be theirs.

Quick Tip to Solve: Place the mother's two gametes along one edge and the father's along the other; the i -by- i cell establishes the possibility of an O child.

18(b)(i). Observe the diagram given below and answer the following questions.

Name the molecule 'X' synthesized by 'i' gene.

[0.5 marks]



Solution:

Concept:

- The regulatory *i* gene of the lac operon codes for a repressor protein.
- The active repressor can bind the operator and prevent transcription of the structural genes; an inducer binds to and inactivates the repressor.

Step 1: Trace the product of the regulatory gene In the diagram, the *i* gene is transcribed to mRNA, and this mRNA is translated to form molecule X. Since *i* is the regulatory gene, its translated product is the lac repressor protein.

Step 2: Check its interaction with the inducer The diagram shows the inducer associating with X. This is characteristic of the repressor: inducer binding prevents it from binding effectively to the operator, allowing the structural genes to be transcribed. X is therefore a regulatory protein, rather than one of the enzymes encoded by *z*, *y* or *a*.

Step 3: Conclusion Molecule X is the **repressor protein** encoded by the *i* gene.

Quick Tip to Solve: Follow the *i*-gene arrow to its protein product: *i* makes the repressor, whereas *z*, *y* and *a* encode the structural-gene enzymes.

18(b)(ii). Which one of the structural genes codes for β -galactosidase ?

[0.5 marks]

Solution:

Concept:

- The lac operon contains the structural genes *z*, *y* and *a*, which encode enzymes involved in lactose utilisation.
- A structural gene specifies the amino-acid sequence of its protein through transcription and translation.

Step 1: Identify the enzyme requested β -galactosidase hydrolyses lactose into its constituent monosaccharides, glucose and galactose. It is the lactose-breaking enzyme encoded by the lac operon.

Step 2: Match each structural gene to its product The *z* gene encodes β -galactosidase. In contrast, *y* encodes permease, which increases cell permeability to lactose, and *a* encodes transacetylase. Thus the requested enzyme belongs to *z*, not *y* or *a*.

Step 3: Conclusion The structural gene z (lacZ) codes for β -galactosidase.

Quick Tip to Solve: Recall the z-y-a sequence as beta-galactosidase, permease and transacetylase, respectively.

18(b)(iii). When will the transcription of this gene stop ?

[1 mark]

Solution:

Concept:

- The lac operon is an inducible system: the inducer inactivates the repressor and permits transcription.
- An active repressor binds the operator and prevents RNA polymerase from transcribing the structural genes.

Step 1: Identify when induction ends When lactose is absent or is used up, sufficient inducer is no longer available to keep the repressor inactive. Therefore the repressor produced by the regulatory i gene remains or becomes active.

Step 2: Relate the repressor to transcription The active repressor binds the operator of the lac operon. This obstructs RNA polymerase action on the structural genes, so transcription of z, and of the other structural genes in the operon, is switched off.

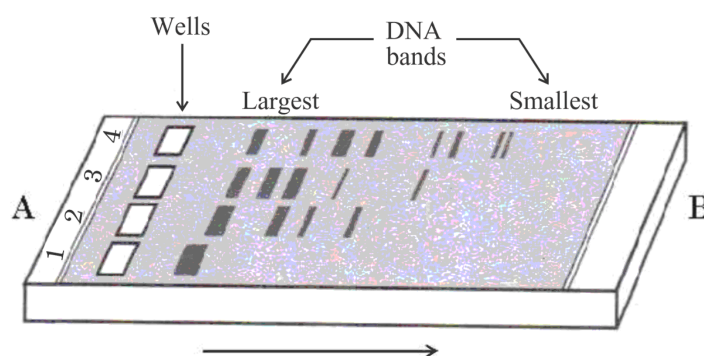
Step 3: Conclusion Transcription stops when lactose is absent or depleted, allowing the active repressor to bind the operator.

Quick Tip to Solve: For lac operon switching, trace lactose availability to repressor activity and then to operator binding.

19(a). Given below is the diagram representing the observation made for separating DNA fragments by gel electrophoresis. Observe the illustration and answer the questions that follow :

DNA fragments move in the direction A→B. Explain.

[1 mark]



Solution:

Concept:

- DNA has an overall negative charge because of the phosphate groups in its sugar-phosphate backbone.
- In an electric field, negatively charged DNA migrates towards the positive electrode, the anode.

Step 1: Locate the loading end The diagram shows the wells at end A. DNA samples are loaded into these wells near the negative electrode, so that they can migrate through the gel when an electric field is applied.

Step 2: Explain the direction of migration DNA fragments are repelled by the negative electrode and attracted towards the positive electrode at B. Hence their movement is from A to B. The gel restricts their movement according to size, but their negative charge determines the direction.

Step 3: Conclusion DNA moves A→B because its negatively charged phosphate backbone is attracted towards the positive electrode at B.

Quick Tip to Solve: Use charge to determine direction: DNA is negative, so the end towards which it travels is the anode.

19(b). Name the matrix used and its role in gel electrophoresis.

[0.5 marks]

Solution:

Concept:

- Agarose, a natural polymer obtained from seaweeds, forms the commonly used matrix for separating DNA fragments.
- A gel acts as a molecular sieve: its pores retard DNA fragments differently according to their size.

Step 1: Name the gel matrix The matrix is agarose gel. It provides a porous medium through which the charged DNA fragments migrate under an applied electric field.

Step 2: Explain how the matrix separates fragments Smaller DNA fragments move more easily through the gel pores and therefore travel farther from the wells in a given time. Larger fragments encounter more resistance and remain nearer the wells, giving the size-dependent pattern shown.

Step 3: Conclusion Agarose gel is the matrix; it acts as a molecular sieve to separate DNA fragments according to size.

Quick Tip to Solve: In an agarose gel, the band farthest from the wells contains the smallest DNA fragments.

19(c). Mention how the separated fragments can be visualized for further technical use.

[0.5 marks]

Solution:

Concept:

- Separated DNA fragments are not visible to the unaided eye without staining.

- Ethidium bromide stains DNA and allows its bands to be detected by fluorescence under ultraviolet light.

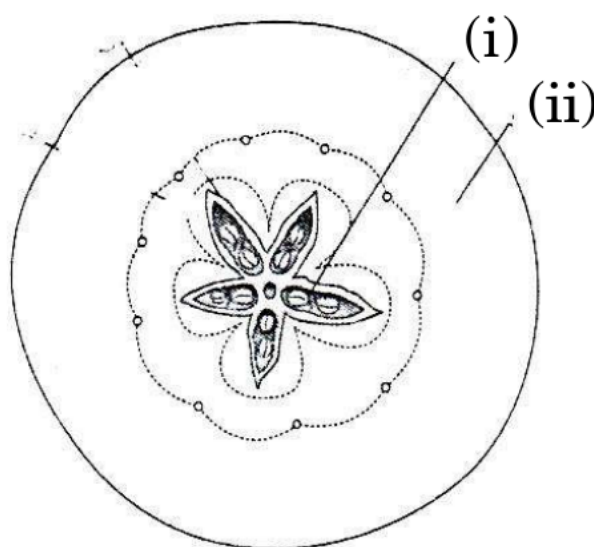
Step 1: Stain the separated DNA Treat the DNA in the gel with ethidium bromide. The dye associates with DNA, allowing the positions of the separated fragments to be detected after electrophoresis.

Step 2: View and recover the required band Expose the stained gel to ultraviolet radiation. The DNA fragments appear as bright orange bands. For further technical use, the required band may be cut from the gel and its DNA extracted by elution.

Step 3: Conclusion Stain with ethidium bromide and view under ultraviolet light to observe bright orange DNA bands.

Quick Tip to Solve: Remember the detection pair: ethidium bromide is the stain and ultraviolet light reveals the orange bands.

20. Given below is a transverse sectional view of an apple. Label the following parts (i) and (ii) and write down their functions. [2 marks]



Solution:

Concept:

- After fertilisation, the ovary develops into the fruit and its wall becomes the pericarp, while ovules form seeds.
- Apple is a false fruit because the thalamus also enlarges and contributes substantially to the fleshy fruit.

Step 1: Identify part (i) and its function The label (i) points to the pericarp, the ovary-derived wall surrounding the seed-bearing chambers in the central portion of the apple. Its main function is to enclose and protect the developing seeds against injury and other external influences.

Step 2: Identify part (ii) and its function The label (ii) points to the enlarged, fleshy thalamus forming

the outer edible region. It accumulates and stores food, making the fruit fleshy and attractive to animals. Feeding by animals can aid seed dispersal. This participation of a floral part other than the ovary is why apple is called a false fruit.

Step 3: Conclusion (i) Pericarp: encloses and protects the seeds. (ii) Fleshy thalamus: stores food and forms the edible part, helping attract animals for seed dispersal.

Quick Tip to Solve: In an apple section, distinguish the central ovary-derived pericarp from the broad fleshy thalamus outside it.

21(a)(i). Draw a pyramid of numbers where a large number of insects are feeding on the leaves of a tree. What is the shape of this pyramid ? [1 mark]

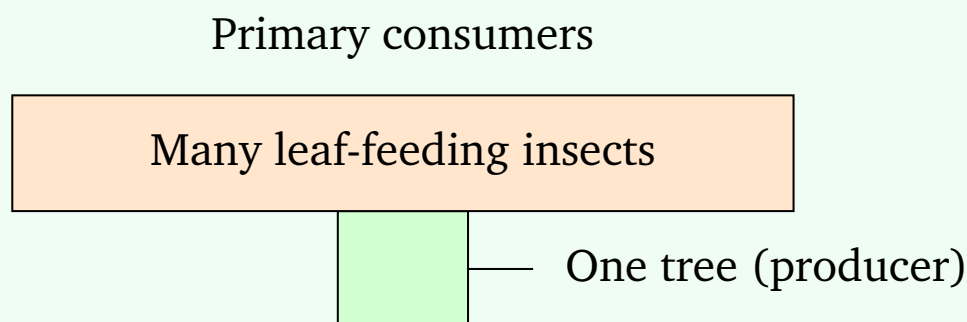
Solution:

Concept:

- A pyramid of numbers represents the number of individual organisms at each trophic level; the width of each bar indicates their relative abundance.
- A tree is a producer, while insects feeding on its leaves are herbivores and occupy the primary-consumer level.

Step 1: Count the producer individuals The entire tree counts as one producer, even though it has many leaves and a large biomass. Therefore, represent the producer level by a narrow bar at the base.

Step 2: Represent the herbivores Numerous insects feed on this single tree, so draw the primary-consumer bar much wider than the producer bar. The diagram compares numbers of organisms, not their sizes or masses.



Inverted pyramid of numbers for a tree and its leaf-feeding insects

Step 3: Conclusion The pyramid of numbers for one tree supporting many leaf-feeding insects is inverted.

Quick Tip to Solve: Count the tree as one organism; do not count its leaves as separate producers.

21(a)(ii). Will the pyramid of energy also be of the same shape in this situation ? Give reason for your response. [1 mark]

Solution:

Concept:

- A pyramid of energy represents the energy available at successive trophic levels per unit area per unit time.
- Energy transfer between trophic levels is inefficient: much of the energy is used in metabolism and dissipated as heat.

Step 1: Distinguish energy from organism number A single tree can support many insects, giving an inverted pyramid of numbers. However, being more numerous does not mean that the insects collectively receive more energy than the tree makes available.

Step 2: Trace the energy transfer Only a fraction of the producer's energy passes to the insects; approximately 10 percent is transferred to the next trophic level. Energy decreases at successive transfers because of respiratory and other losses, so the producer level remains the widest in an energy pyramid.

Step 3: Conclusion No. The pyramid of energy is always upright, since energy decreases at every successive trophic level.

Quick Tip to Solve: Keep numbers and energy separate: many insects may feed on one tree, but energy still decreases upward.

OR

21(b)(i). What could be the reason for the fast rate of decomposition in the tropics ? [1 mark]

Solution:

Concept:

- Decomposition is the breakdown of dead organic matter by detritivores and decomposers, including bacteria and fungi.
- Climatic conditions, especially temperature and soil moisture, strongly influence decomposer activity and the rate of decomposition.

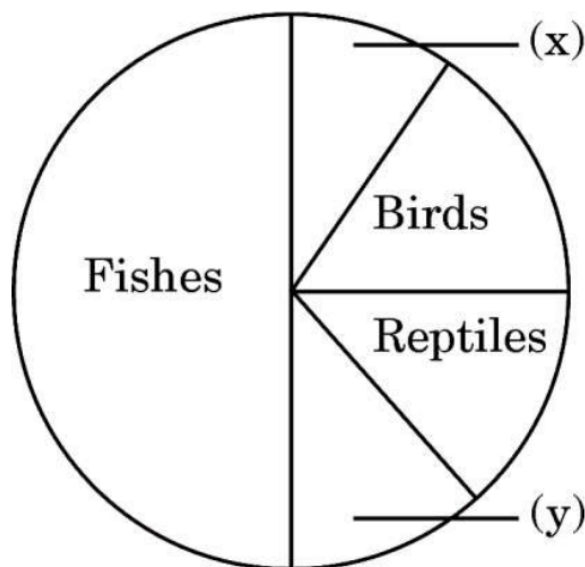
Step 1: Identify the favourable tropical conditions Tropical regions generally have a warm and moist climate. Adequate warmth and moisture provide favourable conditions for the growth and activity of decomposer microorganisms.

Step 2: Relate climate to breakdown of detritus Under these favourable conditions, decomposers and their extracellular enzymes rapidly break down organic remains. Consequently, detritus decomposes faster than under cold or dry conditions, which inhibit microbial activity.

Step 3: Conclusion The warm, moist tropical climate favours decomposer activity and therefore promotes rapid decomposition.

Quick Tip to Solve: For rapid tropical decomposition, connect both warmth and moisture to increased microbial activity.

21(b)(ii). Identify 'x' and 'y' in the figure given below representing proportionate number of major vertebrate taxa. [1 mark]



Solution:

Concept:

- The major vertebrate taxa shown in the biodiversity chart are fishes, amphibians, reptiles, birds and mammals.
- Each sector represents the relative number of species in a taxon, rather than the number of individual animals or their biomass.

Step 1: Read the upper unlabelled sector Follow the pointer marked x to the small sector between the upper vertical radius and the sector labelled Birds. In the standard chart of major vertebrate taxa, this upper sector represents mammals.

Step 2: Read the lower unlabelled sector The pointer marked y enters the sector below Reptiles and to the right of the lower vertical radius. This remaining vertebrate taxon is amphibians; fishes already occupy the large left-hand sector.

Step 3: Conclusion x : Mammals; y : Amphibians.

Quick Tip to Solve: Follow each pointer into its sector: the upper small sector is mammals and the lower one is amphibians.

Section C (21 marks)

22(a). Why do sportspersons often fall victim to cocaine addiction ? Name the plant from which this drug is derived. Also write down the mode of action of this drug. [3 marks total]

Solution:

Concept:

- Cocaine is a powerful central nervous system stimulant obtained from the coca plant, *Erythroxylum coca*.
- Dopamine is a neurotransmitter involved in reward signalling. Blocking its reuptake prolongs its action at a synapse and contributes to cocaine's euphoric effects.

Step 1: Explain why sportspersons may misuse cocaine Some sportspersons misuse cocaine because its stimulant effects produce a temporary feeling of increased energy, alertness and confidence, with reduced fatigue. The desire for these feelings, together with cocaine-induced euphoria, can encourage repeated use and lead to dependence and addiction.

Step 2: Identify the source and mode of action Cocaine is obtained from the coca plant, *Erythroxylum coca*, native to South America. It interferes with the transport of dopamine by blocking dopamine reuptake into the presynaptic neuron. Dopamine therefore remains in the synaptic cleft for longer, prolonging stimulation of the postsynaptic neuron. This produces the characteristic sense of euphoria and increased energy.

Step 3: Conclusion Sportspersons may become addicted while seeking cocaine's temporary stimulant and euphoric effects. Cocaine comes from *Erythroxylum coca* and acts by inhibiting dopamine reuptake.

Quick Tip to Solve: Link the three requested facts: increased energy and euphoria, coca plant, and inhibition of dopamine reuptake.

22(b). Name one drug and its harmful effect obtained from latex of Poppy plant.

Solution:

Concept:

- The latex of the opium poppy, *Papaver somniferum*, contains morphine, an opioid drug.
- Opioids bind to specific opioid receptors in the central nervous system and gastrointestinal tract. Their depressant effects can be harmful when the drugs are misused.

Step 1: Identify the drug from poppy latex Morphine is extracted from the latex of the opium poppy, *Papaver somniferum*. It is an effective analgesic, meaning that it relieves pain, and is used medically for severe pain under supervision.

Step 2: State a harmful effect Misuse of morphine can cause respiratory depression: breathing becomes dangerously slow and inadequate. This results from its depressant action on the central nervous system. In severe overdose, breathing may stop and the effect can be fatal. Repeated misuse can also cause dependence.

Step 3: Conclusion One drug obtained from poppy latex is **morphine**. A harmful effect of its misuse is **respiratory depression**.

Quick Tip to Solve: Pair the named poppy drug morphine with a clear harmful effect, such as dangerously depressed breathing.

23. Biotechnology has helped farmers to get pest-resistant cotton crops. Explain the technique adopted along with its mode of action. [3 marks]

Solution:

Concept:

- Bt cotton is a transgenic crop carrying insecticidal *cry* genes from the bacterium *Bacillus thuringiensis* (Bt).
- The Bt protein is produced as an inactive protoxin; it becomes toxic in the alkaline gut of a susceptible insect.

Step 1: Produce pest-resistant cotton by genetic engineering Isolate the required Bt toxin genes from *Bacillus thuringiensis* and introduce them into cotton cells using recombinant DNA technology. Select transformed cells and regenerate plants that express these genes. The genes *cryIAc* and *cryIIAb* encode proteins that control cotton bollworms. These plants are called Bt cotton; the resistance comes from the insecticidal protein produced within their tissues.

Step 2: Activate the toxin inside the feeding insect When a susceptible bollworm feeds on Bt cotton, it ingests the Bt protein. In Bt, this protein occurs in crystalline inclusions as an inactive protoxin, so it does not kill the bacterium that produces it. The alkaline pH of the insect gut solubilises the crystals, and gut processing converts the protoxin into its active form.

Step 3: Damage the insect midgut The activated toxin binds to receptors on the surface of midgut epithelial cells and creates pores in their membranes. This causes the cells to swell and lyse, damaging the gut and ultimately killing the insect. The action is specific to susceptible insects, so the appropriate *cry* gene is selected for the target pest.

Step 4: Conclusion Bt cotton is obtained by introducing Bt *cry* genes into cotton. The expressed protoxin is activated in the bollworm's alkaline gut and destroys midgut cells by pore formation, providing pest resistance.

Quick Tip to Solve: Link the three key events in order: transfer the Bt gene, activate the protoxin in the alkaline gut, then form pores in midgut cells.

24(a). After a brief medical examination, a couple came to know that both of them are unable to produce children and should look for Assisted Reproductive Technologies (ART). Name the ART and the procedure involved that you can suggest to them to help them bear a child. [2 marks]

Solution:

Concept:

- In vitro fertilisation followed by embryo transfer (IVF-ET), commonly called the test-tube baby programme, assists conception by fertilising an ovum outside the body.
- Gametes may be obtained from the couple or from suitable donors, depending on the cause of infertility.

Step 1: Fertilise the gametes in the laboratory Suggest IVF-ET. Collect ova from the wife or a donor and sperms from the husband or a donor, and allow fertilisation under simulated physiological conditions in the laboratory. If both partners cannot produce functional gametes, donor ova and donor sperms can be used. Infertility alone does not establish that both partners lack gametes, so donor use depends on their medical findings.

Step 2: Transfer the embryo for development Culture the resulting embryo and transfer an embryo with more than eight blastomeres into the woman's uterus by intrauterine transfer (IUT), where it can implant and continue development. Alternatively, a zygote or an early embryo with up to eight blastomeres can be transferred into a suitable fallopian tube by zygote intrafallopian transfer (ZIFT). Thus, fertilisation occurs outside the body but subsequent development occurs inside the woman.

Step 3: Conclusion IVF followed by embryo transfer can help the couple bear a child: laboratory fertilisation is followed by transfer of the embryo to the appropriate site in the female reproductive tract, using donor gametes if required.

Quick Tip to Solve: For IVF-ET, state both laboratory fertilisation and embryo transfer; up to eight blastomeres go to the tube, while later embryos go to the uterus.

24(b). Justify the statutory ban on Amniocentesis. [1 mark]

Solution:

Concept:

- Amniocentesis examines foetal cells present in amniotic fluid and can help detect certain genetic or chromosomal abnormalities.
- Its misuse for prenatal sex determination can promote sex-selective abortion.

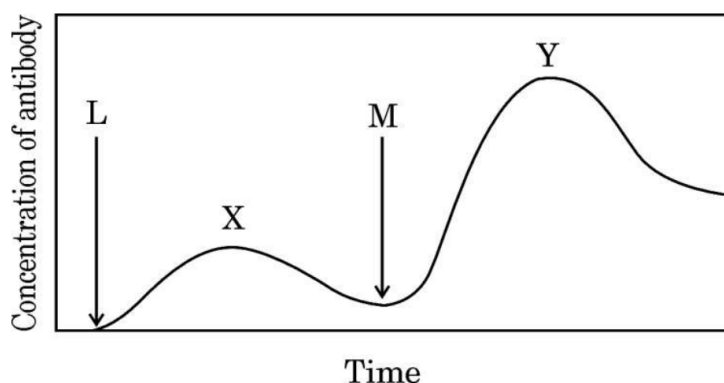
Step 1: Identify the misuse Foetal cells can reveal the chromosomal sex of the foetus. This information has been misused to identify female foetuses and terminate such pregnancies, leading to female foeticide.

Step 2: Explain the purpose of the ban The statutory restriction on using amniocentesis for sex determination helps prevent female foeticide, protects the girl child and checks distortion of the sex ratio. The reason is prevention of discriminatory misuse; it does not mean that medically indicated prenatal diagnosis of genetic disorders has no legitimate role.

Step 3: Conclusion The ban on the misuse of amniocentesis for prenatal sex determination is justified because it helps prevent female foeticide and the resulting imbalance in the sex ratio.

Quick Tip to Solve: Connect the ban specifically to sex determination and female foeticide; distinguish misuse from diagnosis of genetic disorders.

25. The graph given below indicates the administration of the first (L) and second dose (M) of a vaccine. The corresponding response of the body is indicated by X and Y. Interpret the graph and explain the reason for such a response shown by the body. [3 marks]



Solution:

Concept:

- Vaccination induces acquired active immunity by exposing the immune system to antigens without causing the corresponding disease.
- Acquired immunity is antigen-specific and has memory: subsequent exposure to the same antigen elicits a faster and stronger response.

Step 1: Interpret the response after the first dose at L L marks the first administration of the vaccine. The low, relatively slow antibody peak X is the primary immune response. The immune system encounters these antigens for the first time, so antigen recognition, activation and multiplication of specific lymphocytes take time. Activated B lymphocytes form plasma cells that secrete specific antibodies. Consequently, the antibody concentration rises gradually to a modest level and later declines.

Step 2: Interpret the response after the second dose at M M marks the second dose of the same vaccine, called a booster dose. Y is the secondary or anamnestic response. Compared with X, its antibody level rises more rapidly, reaches a much higher peak and remains elevated for longer. Thus, the second exposure produces a quicker and more intense immune response than the first exposure.

Step 3: Explain the role of immune memory The first exposure also generates antigen-specific memory B and T lymphocytes that persist after the primary response subsides. On re-exposure to the same antigen, memory cells recognise it and respond rapidly. In particular, memory B cells proliferate and differentiate into antibody-secreting plasma cells, producing a large amount of specific antibody. This immunological memory explains the shape of Y and the value of a booster dose.

Step 4: Conclusion X is the slow, weaker primary response after dose L, whereas Y is the rapid, stronger and longer-lasting secondary response after booster M. Memory lymphocytes formed during the first exposure account for this enhanced response.

Quick Tip to Solve: Read the graph by comparing the delay, peak height and persistence of antibody levels; then explain all three differences using immune memory.

26. (a) How does the Mediterranean orchid 'Ophrys' ensure its pollination by bees without offering any floral rewards ?

(b) Name the type of interaction seen in each of the following examples :

(i) *Ascaris* worms living in the intestine of humans.

(ii) Clown fish living amongst the tentacles of sea anemone.

[3 marks]

Solution:

Concept:

- Sexual deceit is a pollination mechanism in which a flower attracts a male insect by resembling its female mate, without providing nectar or another floral reward.
- In parasitism one organism benefits while its host is harmed (+, -); in commensalism one benefits and the other is neither benefited nor harmed (+, 0).

Step 1: Explain how the orchid attracts the bee (a) One petal of the Mediterranean orchid *Ophrys* closely resembles the female bee in size, colour and markings. A male bee is attracted to this resemblance and attempts to mate with the flower. This behaviour is called pseudocopulation and is an example of sexual deceit.

Step 2: Trace the transfer of pollen During the attempted mating, pollen from the flower attaches to the male bee's body. When the same bee visits another *Ophrys* flower and attempts pseudocopulation again, it transfers the pollen to that flower's stigma. Thus the orchid achieves pollination by exploiting the bee's mating behaviour, without offering nectar or other floral rewards.

Step 3: Identify the worm-human interaction (b)(i) *Ascaris* living in the human intestine shows **parasitism**, specifically endoparasitism. The worm obtains food and shelter from the host, whereas the human suffers harm from the infection. The partners therefore have a (+, -) relationship.

Step 4: Identify the fish-anemone interaction (b)(ii) The clown fish-sea anemone association is **commensalism**. The fish gains protection from predators among the anemone's stinging tentacles. In this NCERT example, the anemone receives no apparent benefit and is not harmed, so the relationship is (+, 0).

Step 5: Conclusion (a) *Ophrys* uses sexual deceit and pseudocopulation to transfer pollen through male bees. (b)(i) *Ascaris*-human: parasitism; (ii) clown fish-sea anemone: commensalism.

Quick Tip to Solve: Track the effect on both partners: host harm indicates parasitism; protection for the fish with no apparent effect on the anemone indicates commensalism.

27(a). State whether each of these statements given below is true or false. Justify your answer.
Plasmids with a single recognition site are preferred over those with multiple sites for the same restriction enzyme during cloning process. [1.5 marks]

Solution:

Concept:

- A restriction endonuclease recognises a specific DNA sequence and cuts DNA at that recognition site.
- A suitable plasmid vector has a unique recognition site for the restriction enzyme chosen for inserting the foreign DNA.

Step 1: Consider a single recognition site Cutting a circular plasmid once opens it into one linear DNA molecule. The foreign DNA, prepared with compatible ends, can be joined to these ends by DNA ligase to form a recombinant plasmid. The vector backbone remains together and can carry the inserted DNA into the host cell.

Step 2: Compare multiple sites for the same enzyme If the same restriction enzyme recognises several sites in the plasmid, digestion cuts the vector into several fragments. This complicates insertion and reassembly and may separate essential vector sequences. A unique site therefore makes construction of the desired recombinant plasmid simpler and more reliable.

Step 3: Conclusion The statement is true. A single recognition site opens the plasmid at one defined position, whereas multiple sites for the same enzyme fragment the vector and complicate cloning.

Quick Tip to Solve: Count sites for the same enzyme: one cut opens a circular plasmid; several cuts produce several fragments.

27(b). State whether each of these statements given below is true or false. Justify your answer.
The tumor inducing (Ti) plasmid can be extracted from *Agrobacterium tumefaciens* cells and can be used for cloning of foreign gene without any modifications. [1.5 marks]

Solution:

Concept:

- *Agrobacterium tumefaciens* naturally transfers a segment of its tumour-inducing (Ti) plasmid, called T-DNA, into susceptible plant cells.
- A useful cloning vector must deliver the desired foreign gene without producing the disease caused by the natural plasmid.

Step 1: Examine the natural Ti plasmid The unmodified Ti plasmid carries genes in its T-DNA that cause tumour formation in infected plant tissues. Its natural DNA-transfer ability is useful for genetic engineering, but the tumour-causing activity makes the unchanged plasmid unsuitable as the intended plant cloning vector.

Step 2: Explain the necessary modification The Ti plasmid is disarmed by removing or inactivating its tumour-inducing genes. The foreign gene is introduced into the modified T-DNA region while retaining the sequences and transfer functions required to deliver DNA into plant cells. Such a modified vector

can introduce a gene of interest without causing tumours.

Step 3: Conclusion The statement is false. The Ti plasmid must first be disarmed by removing or inactivating tumour-inducing genes before it is used as a vector to introduce a foreign gene into plant cells.

Quick Tip to Solve: For a Ti-vector question, distinguish the useful DNA-transfer ability from the tumour-causing genes that must be disarmed.

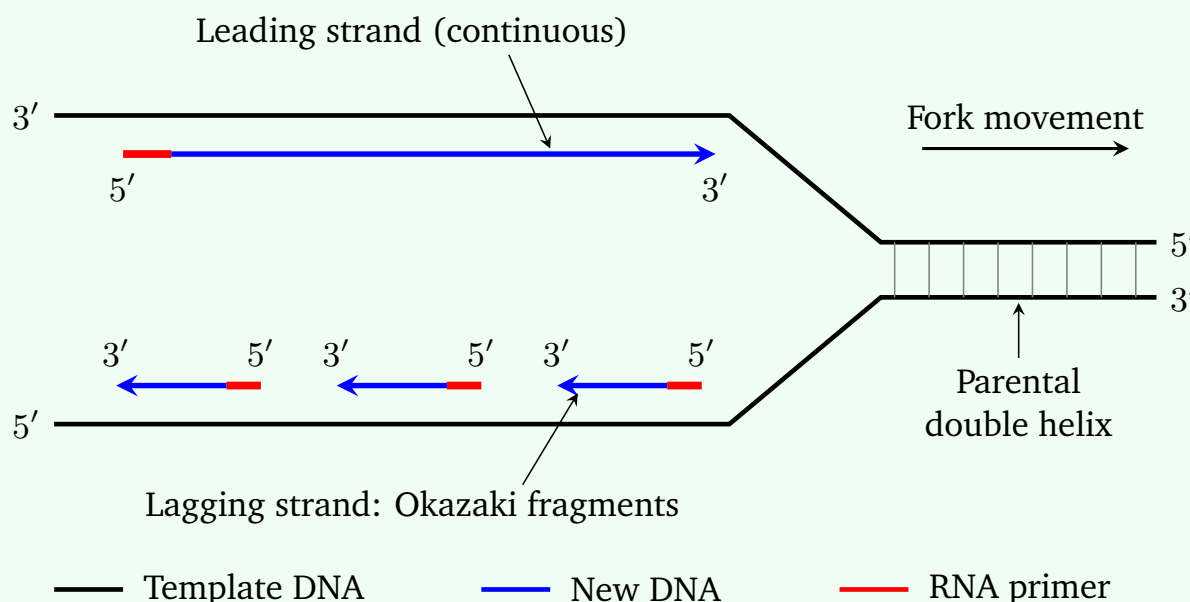
28. Draw a labelled schematic sketch of replication fork of DNA. Explain the role of any two enzymes involved in DNA replication. [3 marks]

Solution:

Concept:

- DNA replication is semiconservative: each daughter DNA molecule contains one parental strand and one newly synthesised strand.
- DNA-dependent DNA polymerase adds nucleotides to a free 3'-OH end, so every new strand grows only in the 5' → 3' direction. The two parental templates are antiparallel.

Step 1: Draw and interpret the replication fork The parental double helix opens over a small region to form a Y-shaped replication fork. The sketch shows the fork moving to the right. On the upper template, oriented 3' → 5' towards the fork, the leading strand is synthesised continuously towards the fork. On the lower template, the lagging strand is synthesised discontinuously as short Okazaki fragments away from the fork. Each new fragment begins from a primer; its arrow indicates 5' → 3' synthesis. Thus, opposite directions of overall growth do not change the common direction of nucleotide addition.



Replication fork moving right; arrows on new DNA show the direction of synthesis.

Step 2: Explain the role of DNA polymerase DNA-dependent DNA polymerase uses each parental strand as a template and joins complementary deoxyribonucleotides to the growing daughter strand. It extends an existing primer by adding nucleotides to its free 3'-OH end and forms phosphodiester bonds. Base pairing ensures that A pairs with T and G with C, preserving the sequence information in the replicated DNA.

Step 3: Explain the role of DNA ligase After RNA primers have been removed and the gaps filled with DNA, DNA ligase seals the remaining nicks between adjacent Okazaki fragments. It forms phosphodiester bonds in the sugar-phosphate backbone, converting the discontinuously formed fragments into a continuous daughter strand.

Step 4: Conclusion The labelled fork shows continuous leading-strand and discontinuous lagging-strand synthesis, both in the 5' → 3' direction. DNA polymerase synthesises the daughter DNA, while DNA ligase seals the nicks between its Okazaki fragments.

Quick Tip to Solve: Mark the parental strands antiparallel first, then place every synthesis arrow from 5' to 3': leading towards the fork and lagging away from it.

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.

The chromosome number is fixed for all normal organisms leading to species specification, whereas any abnormality in the chromosome number of an organism results into abnormal individuals. Sometimes an error may occur during meiosis of cell cycle, where the sister chromatids fail to segregate, called non-disjunction, leading to the production of abnormal gametes with altered chromosome number. On fertilization, such gametes develop into abnormal individuals. [4 marks]

29(a). State what is aneuploidy. [1 mark]

Solution:

Concept:

- A normal diploid cell has two homologous sets of chromosomes, represented by $2n$.
- Non-disjunction can change the number of individual chromosomes without changing the number of whole chromosome sets.

Step 1: Identify the numerical change Failure of chromosome segregation produces gametes with an extra or a missing chromosome. Fertilization involving such a gamete can therefore produce an individual whose chromosome number differs from the normal diploid number.

Step 2: Distinguish individual chromosomes from sets The change concerns one or more individual chromosomes, for example $2n + 1$ or $2n - 1$. It is different from polyploidy, in which one or more complete chromosome sets are added.

Step 3: Conclusion Aneuploidy is the gain or loss of one or more individual chromosomes from the normal chromosome complement.

Quick Tip to Solve: Use $2n + 1$ and $2n - 1$ to remember aneuploidy; addition of a complete set is polyploidy.

29(b). A normal human sperm ($22 + Y$) fertilizes an ovum with karyotype ($22 + XX$). Name the disorder of the offspring thus produced and write any two symptoms of the disorder. [2 marks]

Solution:

Concept:

- Fertilization combines the autosomes and sex chromosomes contributed by the two gametes.
- Klinefelter's syndrome results from an additional X chromosome in a male, giving the chromosome constitution $44 + XXY$, or $47, XXY$.

Step 1: Combine the chromosome complements The normal sperm contributes 22 autosomes and one Y chromosome. The ovum contributes 22 autosomes and two X chromosomes because the sex chromosomes failed to segregate normally. Thus the zygote receives 44 autosomes and three sex chromosomes:

$$(22 + Y) + (22 + XX) = 44 + XXY.$$

Its total chromosome number is therefore $44 + 3 = 47$, one more than the normal human diploid number.

Step 2: Identify the disorder and its features The presence of a Y chromosome gives male sex, while the extra X chromosome produces Klinefelter's syndrome. Two characteristic features are sterility due to impaired testicular function and development of breasts, called gynaecomastia. This is different from Turner's syndrome, whose chromosome constitution is $44 + XO$ and which affects females.

Step 3: Conclusion The offspring has **Klinefelter's syndrome** ($47, XXY$). Two symptoms are **sterility** and **gynaecomastia** (development of breasts in a male).

Quick Tip to Solve: Add autosomes and sex chromosomes separately: an XX ovum plus a Y-bearing sperm gives an XXY male.

29(c)(i). What is meant by trisomy? Mention the chromosome number that shows trisomy in Down's syndrome. [1 mark]

Solution:

Concept:

- A normal diploid cell contains two copies of each autosome, one inherited from each parent.
- Trisomy is an aneuploid condition represented by $2n + 1$, where $2n$ is the normal diploid number.

Step 1: Explain the extra chromosome In trisomy, a particular chromosome is present in three copies instead of the usual two. The extra copy increases the total chromosome number by one; it does not add an entire chromosome set.

Step 2: Apply the definition to Down's syndrome Down's syndrome is caused by an additional copy of chromosome 21. Thus chromosome 21 occurs in triplicate, and the usual total is $46 + 1 = 47$ chromosomes. Here 21 identifies the affected chromosome, whereas 47 is the total chromosome count.

Step 3: Conclusion Trisomy means the presence of three copies of a particular chromosome instead

of two. **Chromosome 21** shows trisomy in Down's syndrome.

Quick Tip to Solve: Distinguish the affected chromosome number, 21, from the total chromosome count, 47, in Down's syndrome.

OR

29(c)(ii). Write any two symptoms of Down's syndrome.

[1 mark]

Solution:

Concept:

- Down's syndrome is a chromosomal disorder associated with an extra copy of chromosome 21.
- The altered chromosome dosage affects physical growth and development, producing characteristic features.

Step 1: Identify a growth feature One characteristic physical feature is short stature. The individual has reduced height compared with typical growth for the same age.

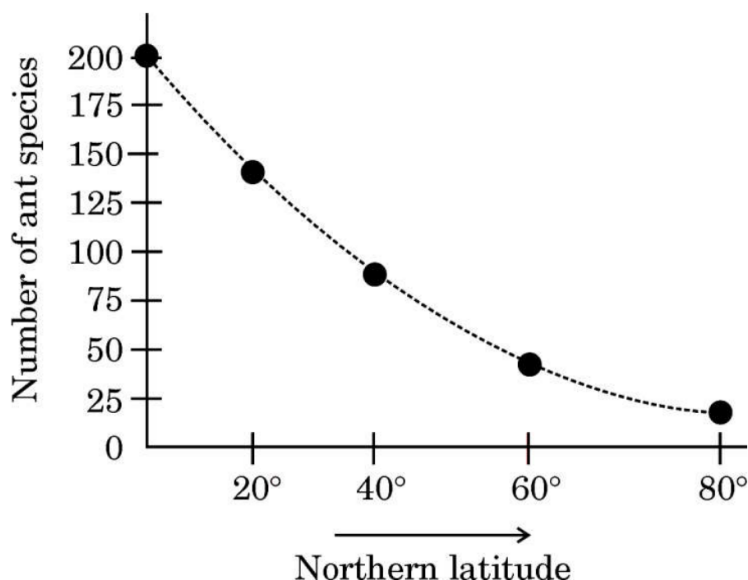
Step 2: Identify a characteristic hand feature Another feature is a broad palm with a characteristic single transverse palmar crease. This crease extends across the palm and is a standard textbook feature associated with Down's syndrome.

Step 3: Conclusion Two symptoms of Down's syndrome are **short stature** and **a broad palm with a characteristic single transverse palmar crease**.

Quick Tip to Solve: For two symptoms, name two distinct observable features; the extra chromosome explains the cause, not a symptom.

30. Biodiversity shows latitudinal and altitudinal gradients. There is little biodiversity at poles. It increases in temperate areas but reaches the maximum in tropics (latitudinal range of 23.5° N to 23.5° S). It is because the tropical rainforests have favourable environmental conditions not only for speciation, but also for supporting both variety and number of organisms. Harsh conditions exist in temperate areas during the cold season only. Number of vascular species is 118 – 236/0.1 ha in tropical forests and 21 – 48 species/0.1 ha in temperate forests. Their number would be 0.0 – 10.0 species/0.1 ha in arctic regions. Such a correlation occurs also in case of other taxonomic groups like ants, butterflies, birds, etc.

[4 marks]



Based on the above information and graph, answer the following questions :

30(a). What does the graph depict ?

[1 mark]

Solution:

Concept:

- Species richness is the number of different species present in a region, rather than the number of individuals of one species.
- A latitudinal diversity gradient describes the change in species richness with increasing distance from the equator.

Step 1: Identify the two plotted quantities The horizontal axis gives northern latitude and the vertical axis gives the number of ant species. Thus the graph compares ant species richness at different latitudes.

Step 2: Read the direction of the trend The plotted number is highest near the equator, about 200 species, and falls towards higher northern latitudes, reaching about 20 species near 80° N. The graph therefore illustrates the general decrease in biodiversity from tropical towards polar regions.

Step 3: Conclusion The graph depicts the latitudinal diversity gradient: ant species richness decreases as northern latitude increases away from the equator.

Quick Tip to Solve: Read both axes before naming the trend: latitude versus species number identifies a latitudinal diversity gradient.

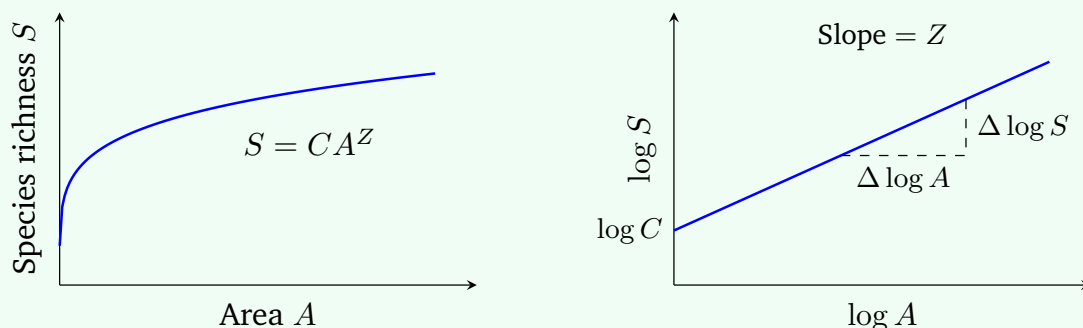
30(b). With the help of graph, show the species-area relationship for a wide variety of taxa in a forest. Write an equation that shows this relationship on a logarithm scale. [2 marks]

Solution:

Concept:

- Within a region, species richness increases with the area explored, but the rate of addition of species gradually decreases.
- The species-area relationship is $S = CA^Z$, where S is species richness, A is area, C is a constant and Z is the regression coefficient (slope on logarithmic axes).

Step 1: Show the species-area curve Alexander von Humboldt observed that, within a region, increasing the area explored increases species richness up to a limit. For a wide variety of taxa, the relationship on ordinary arithmetic axes is a rising, progressively flattening curve, described in NCERT as a rectangular hyperbola. The horizontal axis represents area and the vertical axis represents species richness. This is a species-area graph; the supplied ant graph instead illustrates the separate latitudinal gradient.



Species-area relationship on arithmetic and logarithmic scales (schematic).

Step 2: Express the relationship on logarithmic axes Taking logarithms of $S = CA^Z$ gives

$$\begin{aligned}\log S &= \log(CA^Z) \\ &= \log C + Z \log A.\end{aligned}$$

Thus a plot of $\log S$ against $\log A$ is a straight line, with slope Z and vertical intercept $\log C$. For smaller areas within a region, the observed value of Z generally lies between 0.1 and 0.2 for many taxonomic groups.

Step 3: Conclusion Species richness increases with area as $S = CA^Z$; its logarithmic form is $\log S = \log C + Z \log A$, which gives a straight line.

Quick Tip to Solve: Label the axes first: ordinary axes give a curved species-area plot, whereas logarithmic axes give a straight line of slope Z .

30(c)(i). Explain the correlation between latitudinal gradient and number of plant species. [1 mark]

Solution:

Concept:

- Plant species richness generally decreases with increasing absolute latitude, moving from the equator towards either pole.
- Equal sampling areas must be compared to distinguish a latitudinal diversity pattern from a species-area effect.

Step 1: Compare species counts at equal area The passage gives about 118–236 vascular plant species per 0.1 ha in tropical forests, compared with 21–48 in temperate forests and only 0–10 in arctic regions for the same area.

Step 2: Relate the change to latitude Moving from tropical to temperate and then polar regions increases the distance from the equator and decreases plant species richness. Favourable tropical conditions support a wider variety of plants, whereas increasingly harsh conditions towards the poles restrict it.

Step 3: Conclusion Plant species richness is negatively correlated with absolute latitude: it is greatest in the tropics and generally falls towards the poles.

Quick Tip to Solve: Keep the sampled area fixed, then compare tropics, temperate regions and poles to state the direction of the latitude-richness relationship.

OR

30(c)(ii). Tropics are considered to be more stable where species continue to flourish and evolve undisturbed for millions of years. Give any two reasons. [1 mark]

Solution:

Concept:

- Long periods without major environmental disturbance allow species to persist and evolutionary diversification to accumulate.
- Less seasonal, relatively constant and predictable environments favour niche specialisation and the coexistence of many species.

Step 1: State the historical reason Tropical latitudes have remained relatively undisturbed for millions of years, unlike temperate regions that experienced frequent glaciations. This long evolutionary time has allowed tropical species to survive and diversify through speciation.

Step 2: State the climatic reason Tropical environments are less seasonal and relatively more constant and predictable than temperate environments. These conditions favour niche specialisation and allow organisms with different ecological requirements to flourish over long periods.

Step 3: Conclusion The two reasons are a long history relatively free from glaciation and a less seasonal, more constant and predictable tropical climate.

Quick Tip to Solve: Give one historical reason (long undisturbed evolutionary time) and one climatic reason (low seasonality and predictability).

Section E (15 marks)

31(a). (i) Draw a diagram of an enlarged view of transverse section (T.S.) of one microsporangium of an angiosperm and label the following parts :

(I) Tapetum

(II) Middle layers

(III) Endothecium

(IV) Microspore mother cell

(ii) Write the function of Tapetum.

(iii) Explain the following giving reasons :

(I) Pollen grains are well-preserved as fossils.

(II) Pollen tablets are in use by people these days.

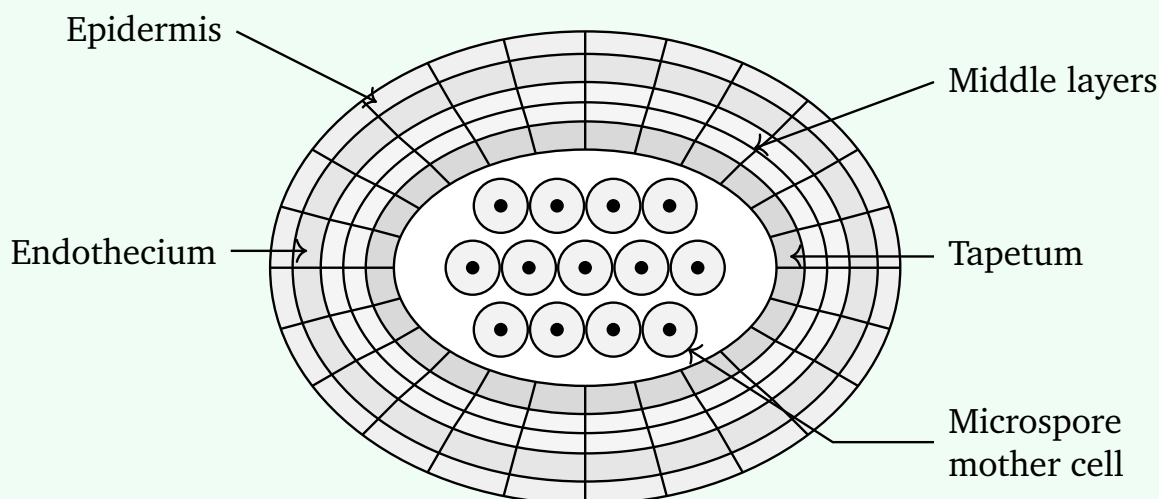
[5 marks]

Solution:

Concept:

- A microsporangium has a central sporogenous tissue surrounded by four wall layers: epidermis, endothecium, middle layers and tapetum, from outside to inside.
- Diploid microspore mother cells undergo meiosis to form haploid microspores; the tapetum supports their development into pollen grains.
- The pollen exine contains sporopollenin, an exceptionally resistant organic material. Pollen grains also contain nutrients.

Step 1: (i) **Draw and identify the layers of one microsporangium** The enlarged transverse section below shows one microsporangium at the microspore mother-cell stage. Locate the microspore mother cells in its central region. Moving outwards from them, identify the innermost tapetum, the middle layers, the endothecium and the outer epidermis. The tapetum directly borders the developing sporogenous tissue, while the endothecium lies just inside the epidermis. The central cells are mother cells at this stage, not mature pollen grains.



Enlarged T.S. of one microsporangium at the microspore mother-cell stage

Step 2: (ii) State the function of tapetum The tapetum nourishes the developing pollen grains. Its cells have dense cytoplasm and commonly more than one nucleus. Its position as the innermost wall layer allows it to supply nutrients to the developing microspores. Thus, it provides nutritional support during pollen development, whereas the outer wall layers primarily provide protection and help in anther dehiscence.

Step 3: (iii)(I) Explain preservation of pollen as fossils The outer wall of a pollen grain, called the exine, is made of sporopollenin. This material withstands high temperatures and strong acids and alkalis; no enzyme that degrades sporopollenin is known. Consequently, the exine resists decay and can remain preserved for very long periods in sediments. This resistance of the pollen wall explains why pollen grains are well-preserved as fossils.

Step 4: (iii)(II) Explain the use of pollen tablets Pollen grains are rich in nutrients and are therefore used in pollen tablets and syrups as food supplements. Their nutrient content, rather than the resistant nature of their exine, is the reason for this use. They are sold with claims of improving the performance of athletes and racehorses; the key biological reason asked here is their nutritional value.

Step 5: Conclusion The labelled T.S. identifies the tapetum, middle layers, endothecium and microspore mother cells. Tapetum nourishes developing pollen; sporopollenin preserves the pollen exine as fossils, while nutrient richness explains the use of pollen tablets as food supplements.

Quick Tip to Solve: Label the wall from outside in as epidermis, endothecium, middle layers and tapetum; link fossils to sporopollenin and tablets to nutrients.

OR

31(b)(i). Where does spermatogenesis occur in human testes ? Describe the process of spermatogenesis up to the formation of spermatozoa.

[3 marks]

Solution:

Concept:

- Spermatogenesis is the production of male gametes from diploid spermatogonia in the seminiferous tubules of the testes; it begins at puberty.
- Meiosis reduces the chromosome number from diploid $2n = 46$ to haploid $n = 23$. Spermiogenesis changes the shape of spermatids to form spermatozoa without further cell division.

Step 1: Identify the site and multiplication phase Spermatogenesis occurs in the seminiferous tubules of human testes. Spermatogonia, present along the inner wall of these tubules, multiply by mitotic divisions. Each spermatogonium is diploid and has 46 chromosomes. Some spermatogonia grow and become primary spermatocytes, which are also diploid.

Step 2: Describe the two meiotic divisions Each primary spermatocyte completes meiosis I, the reduction division, producing two haploid secondary spermatocytes. Each secondary spermatocyte has 23 chromosomes. The two secondary spermatocytes then undergo meiosis II to produce four

haploid spermatids in total. The chromosome number of each spermatid remains 23.

$$\begin{aligned} &1 \text{ primary spermatocyte } (2n) \xrightarrow{\text{meiosis I}} 2 \text{ secondary spermatocytes } (n), \\ &2 \text{ secondary spermatocytes } (n) \xrightarrow{\text{meiosis II}} 4 \text{ spermatids } (n). \end{aligned}$$

Step 3: Describe differentiation into spermatozoa The spermatids transform into spermatozoa by spermiogenesis. During this differentiation, the nucleus condenses, the acrosome and tail develop, and mitochondria become arranged in the middle piece. Sertoli cells nourish the developing germ cells. The sperm heads remain embedded in the Sertoli cells until the spermatozoa are released into the lumen of the seminiferous tubule by spermiation. Spermiogenesis is thus the formation of spermatozoa from spermatids; spermiation is their subsequent release.

Step 4: Conclusion Spermatogenesis occurs in the seminiferous tubules. The sequence is spermatogonia, primary spermatocytes, secondary spermatocytes, spermatids and finally spermatozoa. Each primary spermatocyte gives rise to four haploid spermatozoa through meiosis followed by spermiogenesis.

Quick Tip to Solve: Track one primary spermatocyte as $1 \rightarrow 2 \rightarrow 4$: the chromosome number halves in meiosis I; spermiogenesis changes form, while spermiation means release.

31(b)(ii). Trace the path of movement of spermatozoa from the testes upto the ejaculatory duct.

[2 marks]

Solution:

Concept:

- Spermatozoa are formed in the seminiferous tubules of the testes and are transported through a continuous system of male accessory ducts.
- The rete testis and vasa efferentia carry sperm out of the testis; the epididymis leads into the vas deferens, which joins the duct of the seminal vesicle.

Step 1: Trace the route out of the testis Spermatozoa released into the lumen of the seminiferous tubules pass into the rete testis. From this network they enter the vasa efferentia, which leave the testis and open into the epididymis along its posterior surface.

Step 2: Follow the ducts to the ejaculatory duct The epididymis continues as the vas deferens. The vas deferens ascends into the abdomen and loops over the urinary bladder. It receives the duct of the seminal vesicle, forming the ejaculatory duct. Thus, the seminal vesicle contributes its secretion through a joining duct; sperm do not pass through the seminal vesicle itself.

Step 3: Conclusion The route is: seminiferous tubules $\rightarrow$ rete testis $\rightarrow$ vasa efferentia $\rightarrow$ epididymis $\rightarrow$ vas deferens $\rightarrow$ ejaculatory duct.

Quick Tip to Solve: Keep rete testis before vasa efferentia, and epididymis before vas deferens; the seminal-vesicle duct joins the sperm pathway near its end.

32(a). (i) Identify the disease in which the body cells of the patient lose the property of contact inhibition. State its possible causes (any three). Also name any two methods to detect and to diagnose this disease.

(ii) Your classmate complains of headache and cough. The doctor confirms that he is suffering from pneumonia and not common cold, on the basis of certain symptoms. List these symptoms and write any two precautions to be followed to prevent the spread of this disease. [5 marks]

Solution:

Concept:

- Normal cells show contact inhibition: contact with neighbouring cells inhibits further uncontrolled growth. Cancer cells lose this property and proliferate without normal control.
- Carcinogens are physical, chemical or biological agents that can transform normal cells into cancerous cells.
- Pneumonia infects the alveoli of the lungs, which may fill with fluid and impair breathing. Common cold mainly affects the nose and respiratory passage, but not the lungs.

Step 1: (i) Identify the disease and give three causes The disease is **cancer**. When cells lose contact inhibition, continued cell division can produce an abnormal mass of cells called a tumour. Three possible causes are: (1) physical carcinogens, such as ionising X-rays or gamma rays, and non-ionising ultraviolet radiation, which can damage DNA; (2) chemical carcinogens, such as those present in tobacco smoke, which are associated with lung cancer; and (3) oncogenic viruses carrying viral oncogenes, which can cause cancerous transformation.

Step 2: (i) Name two methods of detection and diagnosis **Biopsy followed by histopathological examination** is one method: a small piece of suspected tissue is removed, stained and examined microscopically for cancerous cells. A second method is **computed tomography (CT)**: X-rays produce a three-dimensional image of internal organs that helps detect and locate abnormal tissue masses.

Step 3: (ii) List the symptoms suggesting pneumonia In addition to headache and cough, pneumonia produces **fever and chills**, with **difficulty in breathing** because fluid accumulates in the alveoli. In severe cases, the **lips and fingernails may turn grey to bluish**. These lung-related symptoms help distinguish pneumonia from a common cold, which typically causes nasal congestion and discharge, sore throat and hoarseness without alveolar infection.

Step 4: (ii) State two precautions against spread (1) Prevent exposure to respiratory droplets: the infected person should cover the mouth and nose while coughing or sneezing, and others should avoid close contact with these droplets. (2) Do not share the infected person's drinking glasses or eating utensils; wash them properly before reuse.

Step 5: Conclusion The disease in part (i) is cancer, detected by biopsy with histopathology and by CT. In part (ii), fever, chills, breathing difficulty and severe-case bluish lips or nails indicate pneumonia; droplet precautions and avoiding shared utensils limit its spread.

Quick Tip to Solve: Organise part (i) as disease, three causes and two diagnostic methods; for part (ii), connect pneumonia to fluid-filled alveoli and distinguish its symptoms from a blocked or runny nose.

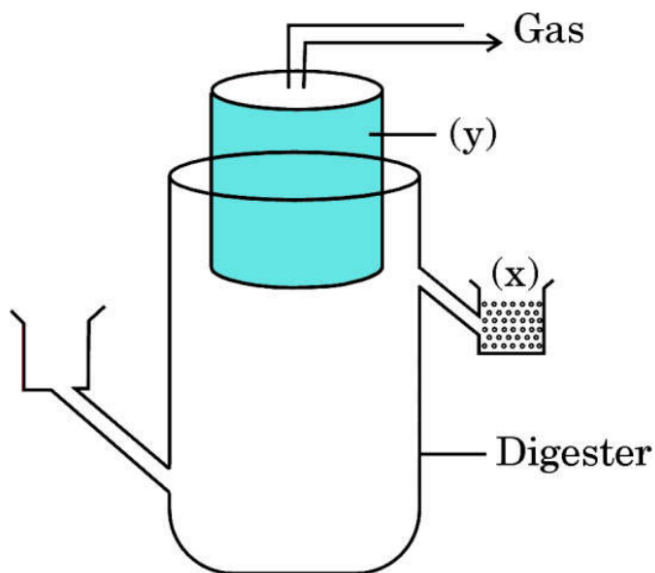
32(b). Study the diagram of a typical biogas plant and answer the following questions :

(i) Identify 'x' and 'y'.

(ii) Write three components of biogas. Name one microorganism which is involved in biogas production.

(iii) Name two institutes which developed the technology of biogas production in India.

[5 marks]



Solution:

Concept:

- A biogas plant uses anaerobic digestion: microorganisms decompose organic matter in the absence of oxygen and produce a combustible gas mixture.
- Methanogens, such as *Methanobacterium*, produce methane during the breakdown of organic material under anaerobic conditions.
- A floating gas holder collects the gas above the slurry, while the spent slurry passes out through an outlet and can be used as manure.

Step 1: (i) Identify the outlet and gas holder The label x indicates the **outlet for spent slurry** (the outlet tank containing digested sludge). After digestion, the residual slurry leaves the digester here; it is nutrient-rich and is used as manure. The label y indicates the **floating gas holder or floating cover**. Gas produced inside the digester collects under this cover. As gas accumulates, the cover rises, and the gas is supplied through the pipe shown at the top. Thus x is on the slurry-discharge side, whereas y belongs to the gas-collection arrangement.

Step 2: (ii) State the gas components and microorganism Three components of biogas are **methane** (CH_4), **carbon dioxide** (CO_2) and **hydrogen** (H_2). Methane is the major combustible component responsible for its usefulness as a fuel. One microorganism involved is *Methanobacterium*, a methanogen. These organisms occur in anaerobic sludge and also in the rumen of cattle. Cattle dung therefore supplies both organic material and methanogenic microorganisms to the plant; decomposition in the oxygen-free digester generates biogas.

Step 3: (iii) Name the Indian institutions The technology of biogas production in India was developed mainly through the efforts of the **Indian Agricultural Research Institute (IARI)** and the **Khadi and Village Industries Commission (KVIC)**. Their full names identify the agricultural research institution and the village-industries organisation associated with the development of this technology.

Step 4: Conclusion x : spent-slurry outlet; y : floating gas holder. Biogas contains CH_4 , CO_2 and H_2 ; a producer is *Methanobacterium*. The two institutions are IARI and KVIC.

Quick Tip to Solve: Follow the pipes: the upper gas pipe identifies the floating holder, while the side channel carrying residual material identifies the spent-slurry outlet.

33. (a) The figure given below represents Miller's apparatus used for his experiment :

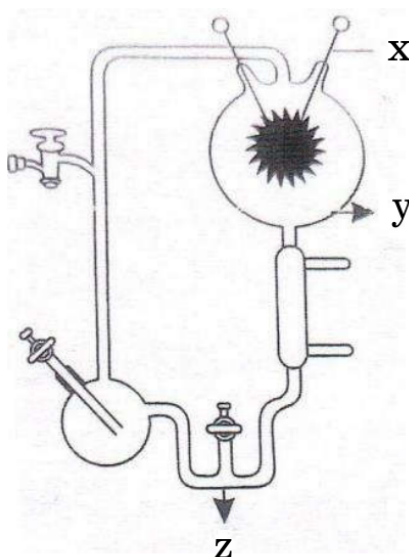
(i) Write the purpose of 'x' in his set-up.

(ii) Name the chemical found in the sample drawn from 'z'.

(iii) Write the conclusion the scientist arrived at.

(b) What is adaptive radiation ? When can adaptive radiation be referred to as convergent evolution ? Give an example.

[5 marks]



Solution:

Concept:

- Chemical evolution proposes the abiotic formation of organic molecules from inorganic precursors under conditions resembling those of the primitive Earth.
- Adaptive radiation is diversification from an ancestral stock within a geographical area into forms occupying different ecological niches.
- Convergent evolution produces similar adaptations independently in different evolutionary lineages exposed to similar selection pressures.

Step 1: (a) (i) Explain the purpose of the electrodes The part labelled x represents the **electrodes**

that produce electric sparks. The discharge supplies energy to drive reactions in the gas mixture and simulates **lightning in the primitive atmosphere**. Miller used a reducing mixture containing methane, ammonia, hydrogen and water vapour, rather than an oxygen-rich modern atmosphere. The sparks allowed these simple starting substances to react and form more complex organic compounds.

Step 2: (a)(ii) Identify the collected chemical The sample drawn from the collection trap z contained **amino acids**, for example **glycine** and alanine. Water vapour and reaction products passed through the condenser; the cooled liquid accumulated in the trap, where the newly formed organic products could be sampled. Amino acids are the building blocks of proteins.

Step 3: (a)(iii) State the experimental conclusion Miller concluded that **organic molecules such as amino acids can be formed abiotically from simple inorganic precursors under conditions simulating the early Earth**. The experiment therefore provided experimental support for the chemical-evolution hypothesis of the origin of life. It demonstrated a possible early step in that process: the synthesis of life's molecular building blocks. It did not produce a living organism or establish that a complete cell arose in the apparatus.

Step 4: (b) Define adaptive radiation and explain convergence **Adaptive radiation** is the evolution of different species from a common ancestral stock in a given geographical area, with the descendants spreading into different habitats or ecological niches. Darwin's finches, whose beaks became adapted to different food sources, illustrate diversification within one ancestral lineage.

When more than one adaptive radiation occurs in an isolated geographical area and members of different ancestral groups independently evolve similar adaptations for similar habitats, the corresponding forms show **convergent evolution**. Australian marsupials and placental mammals provide the standard example: the **Tasmanian wolf (a marsupial)** and the **placental wolf** independently evolved a similar body form and predatory mode of life. Diversification within each group is adaptive radiation; the resemblance between the corresponding forms of the two groups is convergence.

Step 5: Conclusion x supplies sparks simulating lightning; z yields amino acids. Miller demonstrated abiotic organic synthesis. Adaptive radiation produces diverse niche-adapted descendants, while independent radiations can show convergence, as in the marsupial and placental wolves.

Quick Tip to Solve: For Miller's apparatus, link the electrodes to energy and the trap to amino acids; for radiation, distinguish diversification within a lineage from similarity between separate lineages.

33. (a) (i) The average length of a DNA double helix in a typical mammalian cell is approximately 2.2 metres and the dimension of nucleus is 10^{-6} m. How is it possible that such long DNA polymers are packed within a very small nucleus ? Explain.

(ii) Differentiate between Euchromatin and Heterochromatin.

[5 marks]

Solution:

Concept:

- Eukaryotic DNA is packaged with histone proteins into nucleosomes, the repeating structural units of chromatin.
- Negatively charged DNA associates with positively charged histones, which are rich in the basic amino acids lysine and arginine.
- Chromatin compaction determines DNA accessibility: loosely packed euchromatin is transcriptionally active, whereas densely packed heterochromatin is generally inactive.

Step 1: (i) Form nucleosomes by wrapping DNA around histone octamers DNA is organised into successively more compact structures. Eight histone molecules form a histone octamer, containing two copies each of H2A, H2B, H3 and H4. The negatively charged DNA double helix wraps around this positively charged core to form a nucleosome. About 146 base pairs wrap around the core; including the associated linker DNA, a typical nucleosome repeat contains approximately 200 base pairs. Linker DNA connects adjacent nucleosomes, and histone H1 associates with linker DNA and helps stabilise the packaging.

Step 2: (i) Fold nucleosomes into higher-order chromatin A chain of nucleosomes appears as a beads-on-string structure under an electron microscope. These nucleosomes are further packed into chromatin fibres. The fibres form loops associated with a protein scaffold and undergo additional coiling and condensation. Non-histone chromosomal proteins help organise this higher-level packaging. During cell division, the fibres become highly condensed to form visible chromosomes. This hierarchical compaction accommodates DNA within the nucleus while allowing access for transcription and replication.

Step 3: (ii) Compare euchromatin and heterochromatin **Degree of packing:** Euchromatin is loosely packed chromatin, whereas heterochromatin is densely packed chromatin.

Staining: Euchromatin stains relatively lightly, whereas heterochromatin stains darkly because of its greater compaction.

Transcription: Euchromatin is transcriptionally active, with DNA more accessible to transcription machinery. Heterochromatin is generally transcriptionally inactive because its densely packed DNA is less accessible.

Step 4: Conclusion (i) Nucleosomes and higher-order chromatin folding compact DNA into the nucleus. (ii) Euchromatin is loose, lightly staining and active; heterochromatin is dense, darkly staining and generally inactive.

Quick Tip to Solve: Explain packaging in order: DNA wraps around histone octamers, nucleosomes form fibres, and fibres condense further. Compare the two chromatin types using packing, staining and transcription.