

CBSE Class 12 Biology Question Paper 2025 with Solution PDF-Set 57-S-3 - 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.

1. The wings of a bird and the wings of an insect are :

[1 mark]

- (A) Homologous structures and represent convergent evolution
- (B) Homologous structures and represent divergent evolution
- (C) Analogous structures and represent convergent evolution
- (D) Phylogenetic structures and represent divergent evolution

Correct Answer: (C) Analogous structures and represent convergent evolution

Solution:

Concept:

- Analogous organs perform similar functions but have different basic structural plans and evolutionary origins.
- Convergent evolution produces similar adaptations independently in different evolutionary lineages; divergent evolution produces homologous organs.

Step 1: Compare function and origin Both bird wings and insect wings enable flight. A bird wing is a modified vertebrate forelimb with an internal skeleton, whereas an insect wing is an outgrowth of the body wall without the same skeletal origin. Their common function therefore does not make them homologous.

Step 2: Test the evolutionary description Independent adaptations for flight in these unrelated groups illustrate convergence. Options (A) and (B) incorrectly call these wings homologous. Option (D) does not identify their analogous relationship and incorrectly invokes divergence.

Step 3: Conclusion The wings are analogous structures and represent convergent evolution. Hence, the correct option is (C).

Quick Tip to Solve: For bird and insect wings, compare their structural origins before using their shared function of flight.

2. What would be the genotype of parents if the F_1 offspring have the phenotypes in 1 : 1 proportion ?

[1 mark]

- (A) $Aa \times Aa$
- (B) $AA \times AA$
- (C) $Aa \times AA$
- (D) $Aa \times aa$

Correct Answer: (D) $Aa \times aa$

Solution:

Concept:

- With complete dominance, AA and Aa show the dominant phenotype, whereas aa shows the recessive phenotype.
- A test cross between a heterozygote and a homozygous recessive individual yields equal dominant and recessive offspring.

Step 1: Perform the test cross In $Aa \times aa$, the heterozygous parent produces A and a gametes in equal proportions, while the recessive parent produces only a gametes. Thus, the progeny are $\frac{1}{2}Aa$ and $\frac{1}{2}aa$, giving a phenotypic ratio of 1 : 1.

Step 2: Check the other crosses Option (A), $Aa \times Aa$, gives a dominant-to-recessive phenotypic ratio of 3 : 1. Option (B), $AA \times AA$, gives only AA . Option (C), $Aa \times AA$, gives AA and Aa , but both have the dominant phenotype. A 1 : 1 genotypic ratio in (C) is therefore not a 1 : 1 phenotypic ratio.

Step 3: Conclusion The parental genotypes are $Aa \times aa$. Hence, the correct option is (D).

Quick Tip to Solve: Distinguish genotype from phenotype: AA and Aa count together when A is completely dominant.

3. With respect to insulin, choose the correct option :

- (i) C-peptide is not present in mature insulin.
- (ii) The insulin produced by rDNA technology has C-peptide.
- (iii) The pro-insulin has C-peptide.
- (iv) A-peptide and B-peptide of insulin are interconnected by disulphide bridges.

[1 mark]

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

Correct Answer: (D) (i), (iii) and (iv) only

Solution:

Concept:

- Pro-insulin is the precursor containing the A and B regions linked by an additional connecting segment, the C-peptide.

- Mature functional insulin contains the A and B polypeptide chains joined by disulphide bridges; the C-peptide is removed during processing.

Step 1: Assess the precursor and mature forms Statement (i) is true because mature insulin lacks C-peptide. Statement (iii) is also true because pro-insulin contains C-peptide before maturation. Statement (iv) is true: disulphide bridges connect the A and B chains of mature insulin.

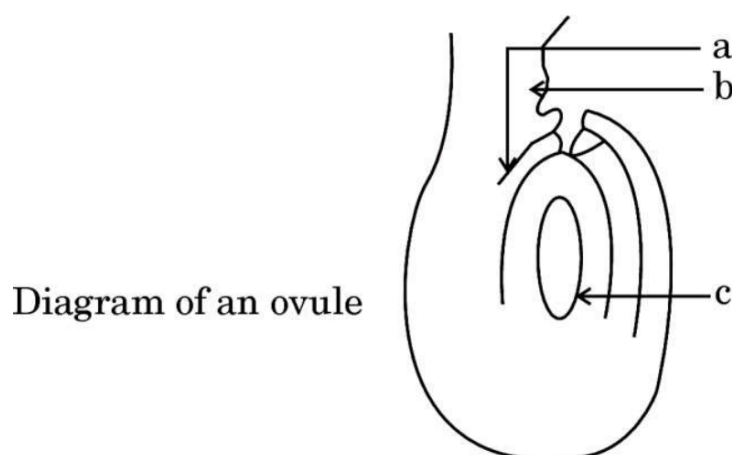
Step 2: Assess recombinant insulin and the options Statement (ii) is false. The final insulin produced by recombinant DNA technology is mature functional insulin and does not retain C-peptide. In the standard recombinant production method, A and B chains are made separately and then joined. Options (B) and (C) include false statement (ii); option (A) wrongly omits true statement (iii).

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

Quick Tip to Solve: Separate pro-insulin from mature insulin: C-peptide belongs to the precursor, while A and B chains remain in the hormone.

4. Identify the various parts, 'a', 'b' and 'c', in the given diagram of ovule :

[1 mark]



- (A) a – Embryo sac, b – Inner integuments, c – Outer integuments
 (B) a – Inner integuments, b – Nucellus, c – Chalazal end
 (C) a – Hilum, b – Funicle, c – Embryo sac
 (D) a – Mycropyllar end, b – Hilum, c – Inner integuments

Correct Answer: (C) a – Hilum, b – Funicle, c – Embryo sac

Solution:

Concept:

- The funicle is the stalk attaching an ovule to the placenta, and the hilum is the junction of the ovule body with the funicle.
- The embryo sac is the female gametophyte located inside the nucellus and surrounded externally by the integuments.

Step 1: Trace the attachment labels The pointer labelled a indicates the junction where the ovule

body joins its stalk: this is the hilum. The pointer labelled b indicates the stalk itself: this is the funicle. These are identified by their position, rather than by the upper or lower direction of the page.

Step 2: Identify the central structure and reject alternatives The pointer labelled c terminates at the small oval inside the ovule, representing the embryo sac. It does not point to an outer covering or to the chalazal end. Options (A), (B) and (D) assign a different identity to at least one of these clearly indicated structures.

Step 3: Conclusion a – Hilum; b – Funicle; c – Embryo sac. Hence, the correct option is (C).

Quick Tip to Solve: Follow each pointer to its tip: the stalk is the funicle, its junction is the hilum, and the inner oval is the embryo sac.

5. Which of the following animals exhibit male heterogamety ?

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

[1 mark]

- (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 types of gametes with respect to sex chromosomes.
- Fruit flies and humans have XY males and XX females; birds have ZZ males and ZW females.

Step 1: Identify the heterogametic males In fruit flies and humans, males produce X-bearing and Y-bearing sperm, while females produce only X-bearing eggs. Thus, animals (i) and (iii) exhibit male heterogamety.

Step 2: Distinguish the other mechanisms In fowl, the female is heterogametic (ZW), whereas the male is homogametic (ZZ). Honey bees show haplodiploid sex determination: males develop from unfertilised haploid eggs and females from fertilised diploid eggs. This is not the male heterogamety asked here. Every other option contains fowl or honey bee and omits a correct example.

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

Quick Tip to Solve: Ask which sex makes two sex-chromosome types of gametes; do not confuse honey-bee haplodiploidy with XY male heterogamety.

6. Given below is Column A with a list of certain Assisted Reproductive Technologies (ART), and Column B, with the procedures followed during ART :

Column A (ART)	Column B (Procedures)
a. GIFT	i. Transfer of ovum from a donor into the fallopian tube of another female
b. ICSI	ii. Transfer of semen from the donor into the vagina of female
c. ZIFT	iii. Injecting sperms directly into the ovum
d. IUI	iv. Transfer of early embryos into the fallopian tube

Select the correct match :

[1 mark]

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

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

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

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

Correct Answer: No fully correct option as printed; intended option (D).

Solution:

Concept:

- GIFT transfers a donor ovum into the fallopian tube; ICSI introduces a sperm directly into an ovum.
- ZIFT transfers a zygote or early embryo with up to eight blastomeres into the fallopian tube. IUI introduces semen into the uterus.

Step 1: Match the three accurate procedures GIFT matches i because the donor ovum is placed in a fallopian tube. ICSI matches iii because a sperm is directly injected into the ovum. ZIFT matches iv because early embryos are transferred into the fallopian tube. These three matches select a-i, b-iii and c-iv.

Step 2: Check the remaining printed match Only option (D) contains those three matches, so it is the intended matching answer. However, its remaining match d-ii is inaccurate as printed: procedure ii says that donor semen is transferred into the vagina, whereas IUI means intrauterine insemination, with semen introduced into the uterus. Vaginal deposition is a form of artificial insemination but is not IUI. Options (A), (B) and (C) also mismatch the first three technologies.

Step 3: Conclusion No option is completely correct as printed. Option (D), a-i, b-iii, c-iv, d-ii, is the intended answer, but procedure ii must specify the uterus for IUI.

Quick Tip to Solve: Use the procedure site to distinguish IUI (uterus) from vaginal insemination; match GIFT, ICSI and ZIFT independently.

7. Match the terms in Column-I with their description in Column-II and choose the correct option :

Column-I	Column-II
a. Dominance	i. Many genes govern a single character.
b. Codominance	ii. In heterozygous organism, only one allele expresses itself.
c. Pleiotropy	iii. In heterozygous organism, both alleles express fully.
d. Polygenic inheritance	iv. A single gene influences many characters.

[1 mark]

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

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

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

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

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

Solution:

Concept:

- Dominance and codominance describe allele expression in a heterozygote: one allele determines the phenotype in dominance, while both express fully in codominance.
- Pleiotropy means one gene influences several characters; polygenic inheritance means several genes govern one character.

Step 1: Match the allele-expression terms Dominance matches ii because only one of the alternative alleles expresses itself in the heterozygous organism. Codominance matches iii because both alleles express fully. Thus a-ii and b-iii must occur together in the correct option.

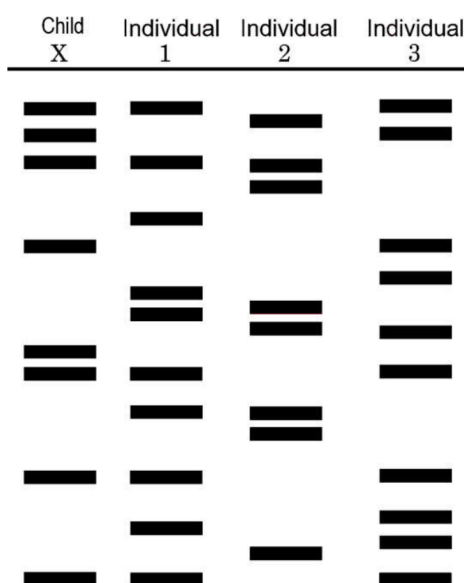
Step 2: Match gene-to-character relationships and compare options Pleiotropy matches iv: a single gene influences many characters. Polygenic inheritance matches i: many genes govern a single character. Hence c-iv and d-i complete the matching. Option (A) contains all four associations. Options (B) and (C) misidentify dominance; option (D) incorrectly exchanges the descriptions for codominance and polygenic inheritance.

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

Quick Tip to Solve: For pleiotropy read one gene to many characters; for polygenic inheritance reverse this to many genes to one character.

8. DNA profiles of the child and three individuals 1, 2 and 3 who claim to be the parents of the child are given below. Select the option that shows the correct profile of the actual parent/parents of a child.

[1 mark]



- (A) Individuals 1 and 3
- (B) Individuals 1 and 2
- (C) Individuals 2 and 3
- (D) Individual 1 is the only parent of the child amongst 1, 2 and 3

Correct Answer: (A) Individuals 1 and 3

Solution:

Concept:

- Children inherit DNA from both biological parents; a DNA profile is compared by aligning band positions horizontally.
- Parentage is inferred from the combination of matching bands, rather than the number of bands in one individual.

Step 1: Compare the informative bands The child has an upper band corresponding to the second upper band of individual 3 and a middle band corresponding to another band of individual 3. These distinguish individual 3 from individual 2.

Step 2: Compare the remaining profile Individual 1 shares several other bands with the child, including the third upper band and lower bands. Together individuals 1 and 3 provide the matching parental profiles. Individual 2 has a substantially different pattern, so combinations involving 2 are excluded; option (D) incorrectly excludes individual 3.

Step 3: Conclusion The parental profiles are those of individuals 1 and 3. Hence, the correct option is (A).

Quick Tip to Solve: Align the bands horizontally and compare the child with both proposed parents together.

9. Diseases like pneumonia and common cold are caused by pathogens. Choose the option that correctly indicates the difference between Pneumonia and Common cold : [1 mark]

- (A) Pneumonia is a communicable disease, whereas Common cold is a non-communicable disease.
- (B) Pneumonia is caused by a virus, while the Common cold is caused by bacteria.
- (C) Pneumonia pathogen infects alveoli of the lungs, whereas Common cold affects nose and respiratory passage but not the lungs.
- (D) Pneumonia cannot be prevented by vaccine, whereas Common cold can be prevented by vaccine.

Correct Answer: (C) Pneumonia pathogen infects alveoli of the lungs, whereas Common cold affects nose and respiratory passage but not the lungs.

Solution:

Concept:

- Pneumonia involves infection of the alveoli, the air sacs where gaseous exchange occurs.
- Common cold, usually caused by rhinoviruses, affects the nose and respiratory passages but not the lungs.

Step 1: Identify the affected regions In pneumonia, alveoli can fill with fluid and breathing becomes difficult. In common cold, the typical features are nasal congestion, nasal discharge, sore throat and cough; the characteristic infection does not involve the alveoli.

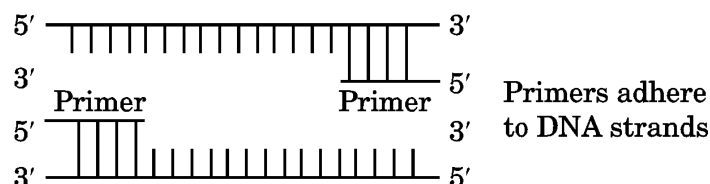
Step 2: Check the alternatives Option (A) is incorrect because both diseases are communicable. Option (B) reverses the usual NCERT examples: bacterial pneumonia is caused by organisms such as *Streptococcus pneumoniae*, whereas common cold is viral. Option (D) is incorrect because vaccines can prevent some causes of pneumonia; the stated vaccine contrast is wrong.

Step 3: Conclusion Pneumonia affects alveoli, while common cold affects the nose and respiratory passages but not the lungs. Hence, the correct option is (C).

Quick Tip to Solve: Use the site of infection: alveoli indicate pneumonia; nasal passages indicate common cold.

10. What is the process of binding a primer to the denatured strand called ?

[1 mark]



- (A) Denaturation
- (B) Annealing
- (C) Renaturation
- (D) Polymerisation

Correct Answer: (B) Annealing

Solution:

Concept:

- PCR involves denaturation, annealing of primers and extension of new DNA strands.
- A primer is a short DNA sequence complementary to part of a template strand and provides a free end for DNA synthesis.

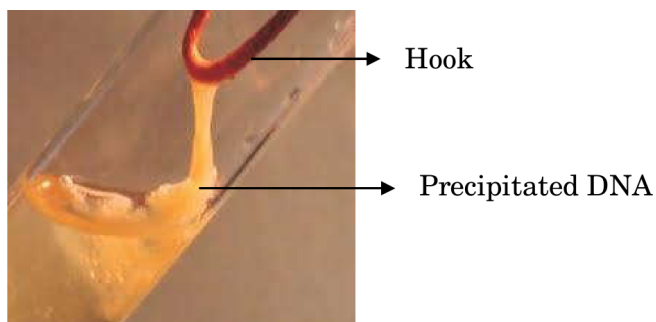
Step 1: Identify the event in the diagram The two original DNA strands have already separated. Short primers bind to their complementary sequences through hydrogen bonding when the temperature is lowered. This primer-binding stage is called annealing.

Step 2: Distinguish the other stages Denaturation is the earlier separation of the double-stranded DNA. Renaturation generally describes reassociation of complementary DNA strands; the specific PCR term for primer binding is annealing. Polymerisation is the subsequent addition of nucleotides by DNA polymerase, extending the bound primer.

Step 3: Conclusion Binding a primer to the denatured DNA template is annealing. Hence, the correct option is (B).

Quick Tip to Solve: Read the action shown: separation is denaturation, primer binding is annealing, and extension is polymerisation.

11. 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:

- After cells are lysed, proteins and other impurities are removed to obtain purified DNA.
- Adding chilled ethanol precipitates DNA, which can then be collected as visible threads by spooling.

Step 1: Identify the precipitation reagent Purified DNA in an aqueous extract is treated with chilled ethanol. DNA becomes insoluble under these conditions and separates as a fibrous precipitate. The threads caught on the hook in the figure are the precipitated DNA.

Step 2: Separate precipitation from cell lysis Protease removes proteins, including proteins associated with DNA. Lysozyme breaks bacterial cell walls, while cellulase helps digest plant cell walls. These enzymes help release or purify DNA earlier in the procedure; they are not the reagent used to precipitate the purified DNA.

Step 3: Conclusion Chilled ethanol precipitates purified DNA. Hence, the correct option is (D).

Quick Tip to Solve: A hook collecting visible DNA threads points to ethanol precipitation, after enzymatic cell lysis and purification.

12. Foetal ejection reflex in human female is induced by :

[1 mark]

- (A) differentiation of mammary gland
- (B) pressure exerted by amniotic fluid
- (C) release of oxytocin from pituitary gland
- (D) fully developed foetus and placenta

Correct Answer: (D) fully developed foetus and placenta

Solution:

Concept:

- Parturition is childbirth and is initiated by a neuroendocrine mechanism.
- Signals from the fully developed foetus and placenta induce mild uterine contractions called the foetal ejection reflex.

Step 1: Identify the initiating signals At the end of gestation, signals from the fully developed foetus and placenta initiate the foetal ejection reflex. The question asks for this initiating stimulus, rather than a hormone that acts later.

Step 2: Place oxytocin in the sequence The reflex triggers release of oxytocin from the maternal pituitary. Oxytocin strengthens uterine contractions; stronger contractions stimulate further oxytocin release through positive feedback. Thus option (C) describes a later response. Mammary-gland differentiation and pressure from amniotic fluid are not the stated initiating signals, excluding (A) and (B).

Step 3: Conclusion The fully developed foetus and placenta induce the foetal ejection reflex. Hence, the correct option is (D).

Quick Tip to Solve: Keep the sequence clear: foetus and placenta signal, the reflex begins, and oxytocin strengthens contractions.

13. Assertion (A) : Western Ghats are included among the hot spots of biodiversity.

Reason (R) : Western Ghats have greater amphibian diversity than Eastern Ghats.

[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:

- A biodiversity hotspot has exceptionally high species richness and endemism and faces severe habitat loss.
- Endemism means that a species is confined to a particular geographical region.

Step 1: Judge the assertion The Western Ghats form part of a recognised biodiversity hotspot. Their rich diversity includes many endemic species, and their natural habitats face substantial threats. The assertion is therefore true.

Step 2: Judge the reason The Western Ghats have greater amphibian diversity than the Eastern Ghats. This is a correct example of geographical variation in species richness, so the reason is true.

Step 3: Test the explanatory link Greater amphibian diversity than another mountain range does not by itself establish hotspot status. Hotspot identification also depends on high endemism and severe habitat loss. The reason therefore does not adequately explain why the Western Ghats are included among biodiversity hotspots.

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

Quick Tip to Solve: For hotspot questions, check endemism and habitat loss; a comparison of amphibian numbers alone is insufficient.

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.
- RNA has a hydroxyl group at the sugar's second carbon; DNA has hydrogen at that position. The hydroxyl group increases RNA reactivity.

Step 1: Judge the assertion DNA is chemically less reactive and more stable than RNA. The absence of the reactive hydroxyl group at the second carbon of deoxyribose contributes to this stability, making DNA suitable for long-term storage of genetic information. The assertion is true.

Step 2: Judge the reason The reason assigns a hydroxyl group at the second carbon to DNA. This is incorrect: that group occurs in RNA, whereas DNA has hydrogen in its place. The group makes RNA more reactive and more susceptible to cleavage, rather than making DNA more stable. The reason is false.

Step 3: Select the appropriate code Since the assertion is true and the reason is false, codes (A) and (B), which require both statements to be true, are excluded. Code (D) reverses the truth values and is also excluded.

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

Quick Tip to Solve: Remember the deoxy in deoxyribose: DNA lacks the second-carbon hydroxyl group that increases RNA reactivity.

15. 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:

- Bioreactors are vessels in which biological agents convert raw materials into useful products on a large scale.
- Controlled temperature, pH, aeration and nutrient supply favour microbial growth and product formation.

Step 1: Evaluate the assertion The assertion is true. Microbes, cells or their enzymes carry out biological reactions in a bioreactor, converting supplied raw materials into desired products.

Step 2: Evaluate the reason The reason is true. A bioreactor provides optimum conditions such as temperature, pH, substrate and salts; suitable mixing and oxygen supply are also maintained as required.

Step 3: Check the explanatory link These favourable conditions allow the biological agents to grow and function efficiently, enabling conversion of the raw materials into the desired products. Thus R explains A. Option (B) wrongly denies this link, while (C) and (D) wrongly treat a true statement as false.

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

Quick Tip to Solve: Link the controlled conditions in a bioreactor to microbial activity and efficient product formation.

16. 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 events from the landing of pollen on the stigma to entry of the pollen tube into the ovule.
- The pistil recognises compatible pollen through chemical interactions and accepts or rejects it.

Step 1: Evaluate the assertion A is true. Pollen reception, recognition, germination and the subsequent growth of the pollen tube towards and into the ovule belong to pollen-pistil interaction.

Step 2: Evaluate the reason R is true. Compatibility recognition allows suitable pollen to germinate and continue pollen-tube growth, whereas incompatible pollen is rejected.

Step 3: Check whether the reason explains the assertion R describes the selective function of the interaction. It does not explain the full range of events or the starting and ending points stated in A. Thus both statements are true, but R does not explain A. Option (A) incorrectly treats a function as an explanation of the definition; (C) and (D) incorrectly reject a true statement.

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

Quick Tip to Solve: Distinguish the scope of pollen-pistil interaction from its function of selecting compatible pollen.

Section B (10 marks)

17. Differentiate between Follicular phase and Luteal phase of the menstrual cycle in human females on the basis of following criteria :

(a) Days of their occurrence in the cycle

(b) Hormones influencing the phases

[2 marks]

Solution:

Concept:

- The ovarian cycle has a pre-ovulatory follicular phase and a post-ovulatory luteal phase, separated by ovulation.
- FSH and LH are pituitary gonadotropins; growing follicles secrete oestrogens, while the corpus luteum predominantly secretes progesterone.

Step 1: Compare the days of occurrence In a typical 28-day cycle, the follicular or proliferative phase follows menstruation and extends approximately from day 5 to day 13, with ovulation around day 14. The luteal or secretory phase occurs approximately from day 15 to day 28. In the broader ovarian classification, the follicular phase begins on day 1 and includes the menstrual days; the pre-ovulatory proliferative interval is usually quoted as days 5–13.

Step 2: Compare the hormonal influences During the follicular phase, rising FSH and LH stimulate follicular growth, and the growing follicles secrete increasing oestrogens that regenerate the endometrium. During the luteal phase, LH supports the corpus luteum, which secretes predominantly progesterone, along with some oestrogen. Progesterone maintains a thick, secretory endometrium suitable for implantation.

Step 3: Conclusion The follicular phase is pre-ovulatory and is associated with FSH/LH-driven follicular growth and oestrogen secretion; the luteal phase is post-ovulatory, approximately days 15–28, and is dominated by corpus-luteum progesterone under LH support.

Quick Tip to Solve: Use ovulation near day 14 as the dividing point: growing follicle and oestrogen before it, corpus luteum and progesterone after it.

18(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]

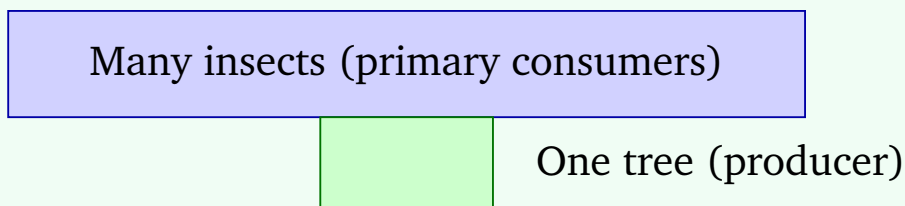
Solution:

Concept:

- A pyramid of numbers represents the number of individual organisms at successive trophic levels.
- Its bar widths represent numbers of organisms, rather than their size, biomass or energy.

Step 1: Identify the trophic levels The tree is the producer at the first trophic level. The insects feeding directly on its leaves are herbivores and constitute the primary consumers at the next trophic level.

Step 2: Compare the numbers and draw There is only one large tree but a large number of insects. Therefore the producer bar is narrow and the primary-consumer bar is broad, as shown. The comparison concerns the two trophic levels specified in the question; no additional consumers need to be assumed.



Inverted pyramid of numbers for a tree and its herbivorous insects

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

Quick Tip to Solve: For a numbers pyramid count individuals: a single large tree still counts as only one producer.

18(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:

- An energy pyramid shows energy available at successive trophic levels per unit area per unit time.
- Energy transfer between trophic levels is inefficient: much energy is used in metabolism and lost as heat.

Step 1: Compare energy at the two levels The tree fixes solar energy through photosynthesis. Only a fraction of this energy is passed to the insects feeding on its leaves; all the energy fixed by the tree is not available to them.

Step 2: Determine the resulting shape Energy is dissipated as heat during respiration and other life processes at each trophic level. Thus energy available to the primary consumers is less than that at the producer level. Many small insects can outnumber a tree, but they cannot collectively receive more energy than the producer supplies.

Step 3: Conclusion No. The pyramid of energy is always upright because available energy decreases at every successive trophic level owing to energy loss as heat.

Quick Tip to Solve: Keep number and energy separate: many insects can exceed one tree in number, while energy still decreases upwards.

18(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 decomposers, especially bacteria and fungi.
- Temperature and moisture strongly control decomposer activity and the rate of decomposition.

Step 1: Identify the tropical conditions Tropical regions generally have warm temperatures and abundant moisture. These conditions favour the growth and activity of decomposer microorganisms in detritus and soil.

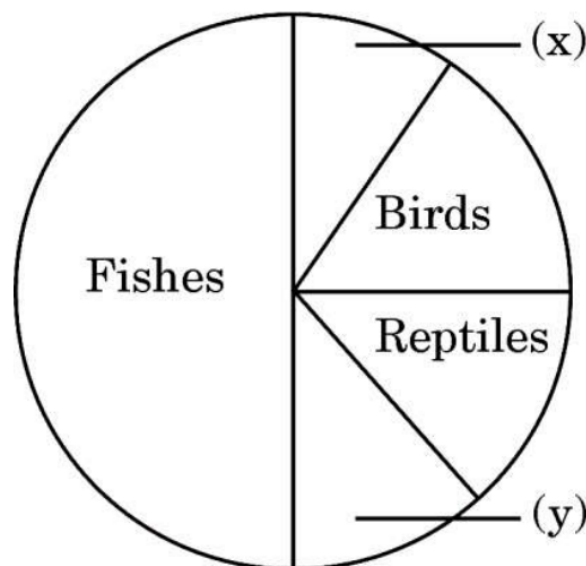
Step 2: Relate the conditions to breakdown Warmth promotes enzyme-mediated reactions, and adequate moisture supports microbial metabolism. Consequently, fragmentation and microbial breakdown of organic matter proceed rapidly. In contrast, low temperature or dry conditions inhibit decomposer activity and slow decomposition.

Step 3: Conclusion The warm and moist conditions of the tropics favour decomposers and their enzyme activity, causing rapid decomposition.

Quick Tip to Solve: Connect rapid tropical decomposition to warmth plus moisture, which together favour bacterial and fungal activity.

18(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 NCERT species-diversity chart are fishes, amphibians, reptiles, birds and mammals.
- The size of each sector represents its proportion of described vertebrate species, rather than the number of individual animals.

Step 1: Identify the upper unlabelled sector The label x points to the small sector between the upward radius and the sector labelled Birds. In the standard proportionate representation of vertebrate taxa, this sector represents mammals.

Step 2: Identify the lower unlabelled sector The label y points to the lower sector between Reptiles and the downward radius. This sector represents amphibians. Fishes already occupy the large left half, and Birds and Reptiles are explicitly labelled, leaving mammals and amphibians for the two unlabelled sectors.

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

Quick Tip to Solve: Locate the leader lines: the upper unlabelled sector is mammals and the lower one adjoining reptiles is amphibians.

19(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, which develop into four pollen grains.
- One megaspore mother cell undergoes meiosis to form four megaspores; normally only one survives and develops into an embryo sac containing one egg.

Step 1: Count meioses needed on the female side Each zygote requires one egg, so 100 zygotes require 100 embryo sacs, one in each of 100 ovules. Since one meiotic division of a megaspore mother cell supplies only one functional megaspore, the number of female meiotic divisions is

$$100 \times 1 = 100.$$

Step 2: Count meioses needed on the male side Each pollen grain produces two male gametes by mitosis. One fuses with the egg to form the zygote; the other participates in triple fusion. Thus one pollen grain is needed for each zygote, so 100 pollen grains are required. Each pollen mother cell gives four pollen grains by meiosis:

$$\text{Male meiotic divisions} = \frac{100}{4} = 25.$$

Step 3: Add the two requirements The total includes both microsporogenesis and megasporogenesis:

$$\text{Total meiotic divisions} = 100 + 25 = 125.$$

Fertilisation itself is fusion of gametes and does not add a meiotic division. Subsequent development of the grain also does not change this required count.

Step 4: Conclusion The wheat plant requires 125 meiotic divisions: 100 in megaspore mother cells and 25 in pollen mother cells, to produce 100 zygotes/100 grains.

Quick Tip to Solve: For 100 angiosperm seeds, count one female meiosis per seed and one male meiosis per four pollen grains; do not count the two male gametes as two pollen grains.

OR

19(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:

- During microsporogenesis, each diploid microspore mother cell undergoes meiosis and produces a tetrad of four haploid microspores.
- During megasporogenesis, each megaspore mother cell produces four megaspores, but normally only one is functional. Each megaspore mother cell is associated with one ovule.

Step 1: Calculate pollen-grain production All four microspores produced by one microspore mother cell normally develop into pollen grains. Therefore, for 35 microspore mother cells,

$$\text{Pollen grains} = 35 \times 4 = 140.$$

The later division of the generative cell produces male gametes within the pollen lineage and does not double the number of pollen grains.

Step 2: Determine the number of ovules An ovule normally contains one megaspore mother cell in its nucellus. Thus 35 megaspore mother cells correspond to 35 ovules. Each mother cell produces four megaspores, of which three usually degenerate; the surviving megaspore forms the female gametophyte. The four megaspores are not four separate ovules, so multiplying 35 by four would be incorrect for the ovule count.

Step 3: Conclusion 140 pollen grains and 35 ovules are likely to be present.

Quick Tip to Solve: Multiply microspore mother cells by four for pollen grains; use one ovule per megaspore mother cell, rather than counting all four megaspores as ovules.

20(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'.

(i) Could the baby be theirs ?

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

[2 marks]

Solution:

Concept:

- ABO blood groups are controlled by three alleles: I^A , I^B and i . The first two are codominant and each is dominant over i .
- A group-A individual may be $I^A I^A$ or $I^A i$; a group-B individual may be $I^B I^B$ or $I^B i$. Group O has genotype ii .

Step 1: Choose parental genotypes that can produce group O (i) Yes, the baby could be theirs. A group-O child must receive an i allele from each parent. This is possible if the wife is heterozygous $I^A i$ and the husband is heterozygous $I^B i$. Their stated blood-group phenotypes do not exclude these genotypes.

Step 2: Show the genetic cross (ii) The cross and gametes are

Wife $I^A i \times I^B i$ Husband,

Wife gametes: I^A, i ; Husband gametes: I^B, i .

The possible offspring are

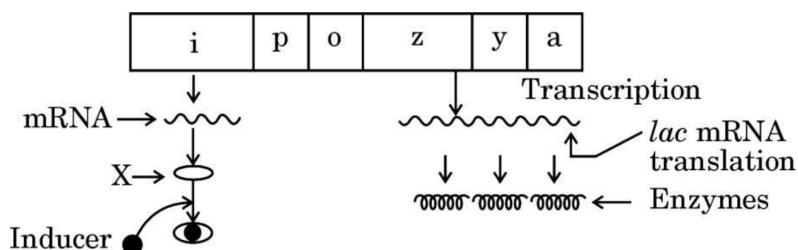
	I^B	i
I^A	$I^A I^B$ (AB)	$I^A i$ (A)
i	$I^B i$ (B)	ii (O)

Each genotype has probability $1/4$, giving the phenotypic ratio A:B:AB:O of $1 : 1 : 1 : 1$.

Step 3: Conclusion Yes. The cross $I^A i \times I^B i$ can produce an ii , group-O child with probability $1/4$. Therefore these blood groups do not establish that the hospital exchanged the baby.

Quick Tip to Solve: A group-O child needs an i allele from each parent: first test the heterozygous cross $I^A i \times I^B i$.

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



20(b)(i). Name the molecule 'X' synthesized by 'i' gene.

[0.5 marks]

Solution:

Concept:

- The lac operon contains a regulatory *i* gene whose product controls access to the operator.
- A regulatory protein can prevent transcription by binding to the operator; an inducer changes its binding ability.

Step 1: Trace the product of the regulatory gene In the diagram, the *i* gene is first transcribed into its mRNA. Translation of this mRNA forms molecule X, which is therefore a protein rather than the mRNA itself.

Step 2: Identify its regulatory role X combines with the inducer in the diagram. This identifies X as the lac repressor: without inducer it binds the operator, whereas binding of inducer inactivates it and allows structural-gene transcription.

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

Quick Tip to Solve: Remember that the regulatory *i* gene makes the repressor, while *z*, *y* and *a* encode the operon's enzymes.

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

[0.5 marks]

Solution:

Concept:

- The lac operon has three structural genes, *z*, *y* and *a*, which encode proteins involved in lactose metabolism.
- β -galactosidase hydrolyses lactose into glucose and galactose.

Step 1: Match the enzyme to its structural gene The structural gene *z*, also called *lacZ*, encodes β -galactosidase. It is the first of the three structural genes shown after the operator in the printed diagram.

Step 2: Distinguish the other genes The *y* gene encodes permease, which increases entry of lactose into the cell, and the *a* gene encodes transacetylase. The regulatory *i* gene encodes the repressor, so none of these is the required enzyme-coding gene.

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

Quick Tip to Solve: Pair *z* with beta-galactosidase, *y* with permease and *a* with transacetylase to avoid mixing up the three structural genes.

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

[1 mark]

Solution:

Concept:

- The lac operon is an inducible system: the inducer binds to the repressor and prevents it from binding the operator.
- An active repressor bound to the operator prevents transcription of the structural genes by RNA polymerase.

Step 1: Identify the condition that maintains transcription In the diagram, the inducer has bound to molecule X, the repressor made by the regulatory gene *i*. This inactivates the repressor, leaving the operator accessible for transcription of the structural genes.

Step 2: Explain how the operon switches off When lactose, the inducer, is absent or has been used up, the repressor is no longer inactivated. The active repressor binds the operator and blocks RNA polymerase, switching off transcription of the lac structural genes, including *z*.

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

Quick Tip to Solve: Trace inducer removal to repressor activation, then operator binding and transcription stopping.

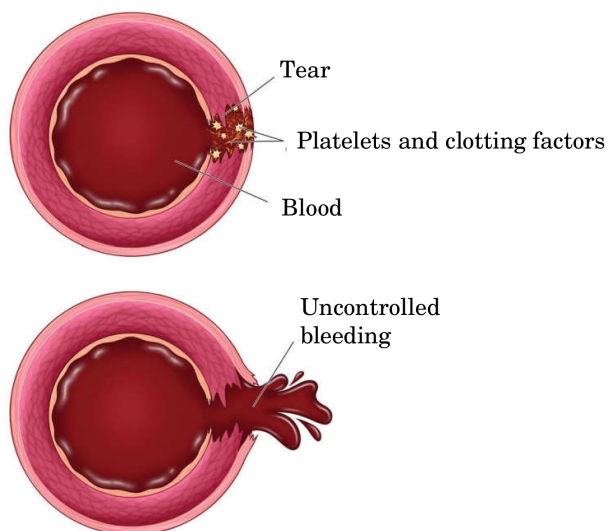
21. (a) Name the sex-linked genetic disorder shown in the diagram given below :

(b) Is it a recessive or a dominant disorder ?

(c) Why do only human males generally suffer from this disease ?

[2 marks]

Normal Blood vessel



Solution:

Concept:

- Haemophilia is a sex-linked recessive disorder in which defective blood clotting causes prolonged bleeding after injury.
- Males have one X chromosome and one Y chromosome; females have two X chromosomes. A recessive allele on the single X chromosome is expressed in a male.

Step 1: (a) Identify the disorder The diagram contrasts normal clot formation at a tear in a blood vessel with uncontrolled bleeding. The sex-linked disorder indicated is haemophilia, caused by deficiency of a functional blood-clotting factor.

Step 2: (b) State its inheritance Haemophilia is an X-linked recessive disorder. Let X^H represent the normal allele and X^h the haemophilia allele.

Step 3: (c) Explain the predominance in males A male with genotype X^hY is affected because his Y chromosome has no corresponding normal allele to mask the recessive allele on his only X chromosome. A female with $X^H X^h$ is generally an unaffected carrier because the normal allele masks the recessive allele. A female usually needs $X^h X^h$ to be affected, a much rarer combination. Thus males generally suffer, although females can also be affected.

Step 4: Conclusion (a) Haemophilia. (b) X-linked recessive. (c) A single affected X causes the disease in a male, whereas a female generally requires the recessive allele on both X chromosomes.

Quick Tip to Solve: For X-linked recessive traits, compare an affected male's single X with a carrier female's two X chromosomes.

Section C (21 marks)

22. A group of youth were having a 'party' in an isolated area and were raided by police. Packets of 'smack' and syringes with needles were found littered around.

- (a) Why is taking 'smack' considered an abuse ?
- (b) Write the chemical name of 'smack' and the name of its source plant.
- (c) Syringes and needles used by the youth for taking the drug could prove to be very fatal. Why ?

[3 marks]

Solution:

Concept:

- Drug abuse means taking a drug for a non-medical purpose or in a manner or amount that harms physical or mental health.
- Heroin is an opioid obtained by acetylation of morphine; it is a depressant that slows body functions.
- Sharing injection equipment can transfer infected blood and transmit blood-borne pathogens.

Step 1: (a) Explain why taking smack is abuse The youth are taking smack for its intoxicating effects, without a therapeutic purpose or medical supervision. Heroin is highly addictive and produces

dependence; as a depressant, it slows body functions and can impair judgement and health. Repeated use can lead to tolerance and compulsive drug seeking. Such non-medical, harmful consumption is drug abuse.

Step 2: (b) Give the chemical identity and source plant Smack is heroin, chemically diacetylmorphine. It is prepared by acetylating morphine extracted from the latex of the poppy plant, *Papaver somniferum*. Thus poppy is the source plant, while morphine is the substance from which heroin is chemically prepared.

Step 3: (c) Explain why the injection equipment can be fatal Shared or contaminated syringes and needles may carry infected blood from one person directly into another person's bloodstream. They can transmit HIV, which can lead to AIDS, and hepatitis B virus, which can cause serious liver disease. These infections may be life-threatening. The danger is therefore especially high when injecting drug users share needles or reuse them without sterilisation.

Step 4: Conclusion Smack use here is harmful, addictive non-medical drug consumption. Smack is diacetylmorphine (heroin), derived from morphine obtained from *Papaver somniferum*. Contaminated shared needles can transmit HIV and hepatitis B, causing potentially fatal disease.

Quick Tip to Solve: Link smack to diacetylmorphine and poppy; link shared injection equipment to HIV and hepatitis B transmission.

23. A vector is genetically engineered with three features which facilitate gene-cloning within the host cell. List the three features and explain each one of them. [3 marks]

Solution:

Concept:

- A cloning vector carries a foreign DNA fragment into a host cell and allows that fragment to be maintained and multiplied.
- An effective cloning vector needs an origin of replication, a selectable marker and suitable cloning sites.

Step 1: Origin of replication (ori) The ori is the DNA sequence from which replication begins. A DNA fragment linked to this sequence can replicate within the host along with the vector. The origin also influences the copy number of the linked DNA, so an appropriate ori allows the desired number of copies of the foreign DNA to be produced. Without a functional origin recognised in the host, the vector would not be maintained through replication.

Step 2: Selectable marker A selectable marker helps identify and select transformants, the host cells that have taken up the vector, and eliminate non-transformants. For example, an antibiotic-resistance gene allows transformed bacteria to grow on a medium containing that antibiotic, while susceptible non-transformants do not grow. In suitable vector designs, disruption of a marker by the inserted DNA can also help distinguish recombinant vectors from non-recombinant vectors.

Step 3: Cloning or recognition sites The vector must contain a suitable restriction-enzyme recognition site at which foreign DNA can be inserted. Preferably, the selected enzyme has a single recognition site in the vector, so digestion opens it at one defined position rather than fragmenting it at several

positions. The foreign DNA is joined at this cloning site by DNA ligase, forming the recombinant vector for introduction into the host.

Step 4: Conclusion The three features are an origin of replication for replication and copy-number control, a selectable marker for selecting transformed cells, and suitable unique cloning sites for inserting the foreign DNA.

Quick Tip to Solve: Remember the vector's three jobs: replicate the insert, select the transformed host, and provide a site for insertion.

24. A woman has certain queries as listed below, before starting with contraceptive pills. Answer them.

(a) What do contraceptive pills contain ? Why are they considered as contraceptives ?

(b) What schedule should be followed for taking these pills ?

[3 marks]

Solution:

Concept:

- Oral contraceptive pills contain small doses of progestogens alone, or a combination of progestogen and estrogen.
- These hormonal preparations prevent pregnancy by inhibiting ovulation and implantation and by altering cervical mucus to prevent or retard sperm entry.

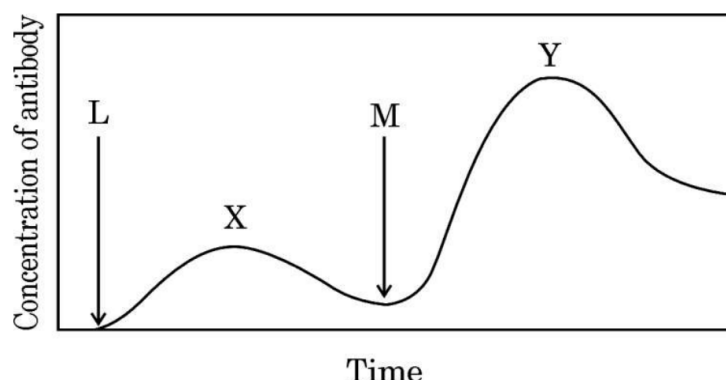
Step 1: (a) Contents and contraceptive action Conventional oral pills contain a progestogen, either alone or combined with estrogen. Their hormonal action inhibits ovulation, so an ovum is not released for fertilisation. They also make the endometrium unsuitable for implantation and change the quality of cervical mucus, making sperm entry difficult. These actions prevent conception and establishment of pregnancy; therefore, the pills act as contraceptives.

Step 2: (b) Schedule of administration Take one pill orally each day for 21 days, starting preferably within the first five days of the menstrual cycle. After the 21-day course, leave a gap of seven days, during which menstruation usually occurs. Then begin the next 21-day course and repeat the same cycle for as long as contraception is required. Regular daily intake is essential to maintain the contraceptive effect.

Step 3: Conclusion (a) Pills contain progestogens alone or with estrogen and prevent pregnancy through hormonal effects on ovulation, implantation and cervical mucus. (b) Take a pill daily for 21 days from within the first five days of the cycle, followed by a seven-day gap; repeat this schedule.

Quick Tip to Solve: Remember the standard oral-pill schedule as 21 days of daily pills followed by a seven-day gap.

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 exposes the immune system to antigenic material and establishes acquired immunity without requiring the person to suffer the disease.
- The primary immune response follows the first exposure; memory lymphocytes enable a faster and stronger secondary response to the same antigen.

Step 1: Interpret L and X L represents the first dose of vaccine and hence the first exposure to its antigen. X is the primary immune response: after an initial lag, the antibody concentration rises slowly to a relatively low peak and then declines. The lag reflects the time needed for antigen recognition, activation and multiplication of specific lymphocytes, and differentiation of B cells into antibody-secreting plasma cells.

Step 2: Interpret M and Y M represents the second dose, or booster dose, of the same vaccine. Y is the secondary, or anamnestic, immune response. The antibody level rises much more rapidly and reaches a considerably higher peak than X. Antibodies also persist at an elevated level for longer, showing that the booster evokes a more effective response.

Step 3: Explain the difference The first exposure produces antigen-specific memory B and T lymphocytes in addition to effector cells. These memory cells remain in the body after the primary response subsides. At the second exposure, they recognise the same antigen rapidly and undergo extensive proliferation and differentiation, producing a larger population of antibody-secreting cells. This immunological memory accounts for the quicker, stronger response Y.

Step 4: Conclusion X is the slow, relatively weak primary response to the first vaccine dose L. Y is the faster, stronger and longer-lasting secondary response to booster M, caused by antigen-specific memory lymphocytes formed after L.

Quick Tip to Solve: Compare the lag, height and persistence of X and Y, then connect all three differences to memory cells.

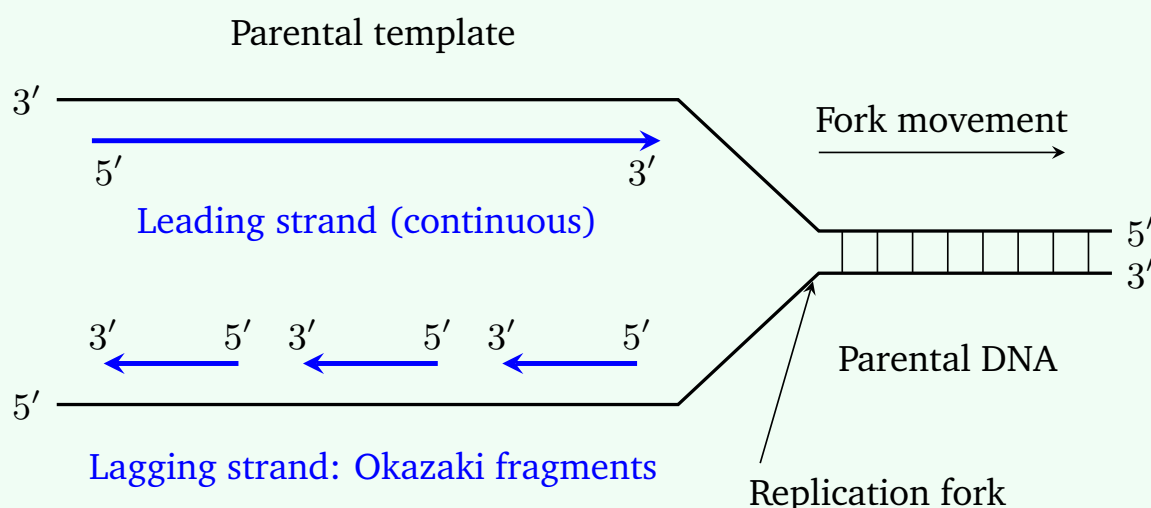
26. Draw a labelled schematic sketch of replication fork of DNA. Explain the role of any two enzymes involved in DNA replication. [3 marks]

Solution:

Concept:

- DNA replication is semiconservative: each daughter DNA molecule contains one parental strand and one newly synthesised strand.
- DNA strands are antiparallel. DNA-dependent DNA polymerase extends a new strand only in the direction $5' \rightarrow 3'$, by adding deoxyribonucleotides to its free $3'$ -OH end.

Step 1: Label the replication fork The schematic below shows parental strands separating at a fork that advances to the right. The daughter leading strand is synthesised continuously towards the fork. The daughter lagging strand is synthesised discontinuously as Okazaki fragments, each growing away from the fork. Both modes of synthesis proceed only in the $5' \rightarrow 3'$ direction. The arrows on the daughter strands show the direction of synthesis.



Replication fork: arrows on new strands indicate synthesis direction.

Step 2: Role of DNA-dependent DNA polymerase DNA-dependent DNA polymerase uses each parental DNA strand as a template and catalyses the joining of complementary deoxyribonucleotides to form the daughter strand. Adenine pairs with thymine and guanine with cytosine. It extends an existing primer at the free $3'$ -OH end, so synthesis is always $5' \rightarrow 3'$. This directionality, together with the antiparallel templates, produces continuous and discontinuous synthesis.

Step 3: Role of DNA ligase DNA ligase joins adjacent DNA fragments on the lagging strand after primer replacement. It seals the nicks in the sugar-phosphate backbone by forming phosphodiester bonds between the neighbouring $3'$ -OH and $5'$ -phosphate ends. In this way, separate Okazaki fragments become a continuous daughter DNA strand.

Step 4: Conclusion The fork has antiparallel parental templates, a continuous leading daughter strand and a discontinuous lagging daughter strand. DNA polymerase synthesises complementary DNA; DNA ligase seals the nicks between adjacent fragments.

Quick Tip to Solve: Label both ends of each template first; draw every daughter-strand synthesis arrow from its $5'$ -prime end towards its $3'$ -prime end.

27. (a) Why do Lepidopterans die when they feed on Bt cotton plant ? Explain how does it happen.

(b) Write two important applications of tissue culture in Agriculture.

[3 marks]

Solution:

Concept:

- Bt cotton carries a gene from *Bacillus thuringiensis* and produces an insecticidal Cry protein as an inactive protoxin.
- Plant tissue culture uses totipotency: a plant cell or explant can regenerate an entire plant under suitable sterile culture conditions.

Step 1: Explain how the ingested toxin kills the larva (a) When a lepidopteran larva feeds on Bt cotton, it ingests the Cry protoxin present in the plant tissues. The alkaline conditions in the insect gut solubilise the protein crystals, and processing activates the protoxin. The activated toxin binds to specific receptors on the surface of midgut epithelial cells. It creates pores in their membranes, causing swelling and lysis of the cells. The damaged gut can no longer function normally, and the larva dies. The receptor specificity explains why a susceptible insect is killed; the inactive form does not kill the bacterium that produces it.

Step 2: State two agricultural applications of tissue culture (b) First, micropropagation produces a large number of plants rapidly from a selected explant. Plants obtained from the same parent are genetically identical somaclones, so desirable agricultural characters can be multiplied uniformly. Second, meristem culture helps produce virus-free plants from an infected parent. The apical or axillary meristem, which is generally free of viruses, is isolated and cultured to regenerate healthy plants; this is useful in crops such as banana and potato.

Step 3: Conclusion Lepidopteran larvae die because activated Bt toxin forms pores in their midgut cells. Tissue culture is used for rapid clonal multiplication and production of virus-free plants by meristem culture.

Quick Tip to Solve: For Bt action, write the sequence: ingestion, alkaline activation, receptor binding, pore formation and gut-cell lysis; give two distinct tissue-culture uses.

28. (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:

- Pollination by sexual deceit occurs when a flower mimics a female insect and attracts a male without supplying nectar or another floral reward.
- In parasitism one species benefits and its host is harmed (+, -); in commensalism one benefits while the other is neither helped nor harmed (+, 0).

Step 1: Explain pollination in the orchid (a) One petal of the Mediterranean orchid *Ophrys* resembles the female bee in size, colour and markings. A male bee is attracted by this resemblance and attempts to mate with the flower, an act called pseudocopulation. During this contact, pollen adheres to the male bee. When it attempts pseudocopulation with another flower, it transfers the pollen to that flower's stigma. Thus the flower uses sexual deceit to achieve pollination, while offering no floral reward.

Step 2: Identify the two interactions (b)(i) *Ascaris* in the human intestine shows parasitism. The worm obtains nutrition and shelter from the host, while the human is harmed by the infection and loss of nutrients.

(ii) The clown fish and sea anemone show commensalism in the standard NCERT account. The fish gains protection from predators by living among the anemone's stinging tentacles, while the sea anemone is neither benefited nor harmed.

Step 3: Conclusion *Ophrys* is pollinated through sexual deceit and pseudocopulation by male bees. The interactions are (i) parasitism and (ii) commensalism.

Quick Tip to Solve: Identify which partner benefits and whether the other is harmed or unaffected: this separates *Ascaris* parasitism from clown fish commensalism.

Section D (8 marks)

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

29(a). 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.

State what is aneuploidy.

[1 mark]

Solution:

Concept:

- The normal diploid chromosome complement contains two copies of each chromosome.
- Failure of chromosome segregation can cause the gain or loss of individual chromosomes.

Step 1: Identify the kind of chromosome change Aneuploidy is an abnormal chromosome number caused by the loss or gain of one or more individual chromosomes from the normal complement.

Step 2: Distinguish it from a complete-set change The change involves particular chromosomes rather than an entire chromosome set. For example, a diploid complement $2n$ may become $2n - 1$ (monosomy) or $2n + 1$ (trisomy), commonly following non-disjunction.

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 individual chromosomes in the definition; a change in entire sets is polyploidy, not aneuploidy.

29(b). 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.

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:

- A normal human gamete has 22 autosomes and one sex chromosome; the stated ovum has an extra X chromosome.
- Klinefelter syndrome results from an additional X chromosome in a male, commonly giving 47, XXY.

Step 1: Combine the chromosomes at fertilisation The sperm contributes 22 autosomes and Y, while the ovum contributes 22 autosomes and XX. Therefore the offspring has

$$(22 + Y) + (22 + XX) = 44 + XXY = 47 \text{ chromosomes.}$$

The Y chromosome determines male development, while the additional X produces the sex-chromosomal aneuploidy called Klinefelter syndrome.

Step 2: Give two characteristic symptoms Two symptoms are: (i) development of enlarged breasts, called gynaecomastia, and (ii) poorly developed testes with impaired sperm formation, causing sterility. These features reflect abnormal sexual development in an individual with the XXY chromosome complement. The extra X does not make this Turner syndrome, which is associated with a missing sex chromosome.

Step 3: Conclusion The offspring has Klinefelter syndrome (47, XXY). Two symptoms are gynaecomastia and underdeveloped testes leading to sterility.

Quick Tip to Solve: Add the sex chromosomes first: Y from the sperm plus XX from the ovum gives XXY, which identifies Klinefelter syndrome.

29(c)(i). 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.

What is meant by trisomy ? Mention the chromosome number that shows trisomy in Down's syndrome.

[1 mark]

Solution:

Concept:

- Trisomy is an aneuploid condition with three copies of one particular chromosome instead of the usual two.
- A single extra chromosome changes a normal diploid complement from $2n$ to $2n + 1$.

Step 1: Define trisomy In trisomy, an additional copy of one chromosome is present, so a particular homologous chromosome pair is represented by three chromosomes. It is a gain of one chromosome, not an extra complete chromosome set.

Step 2: Identify the chromosome in Down syndrome Down syndrome is caused by trisomy of chromosome 21: chromosome 21 is present in three copies. In the usual free-trisomy form, the affected individual therefore has 47 chromosomes rather than the normal 46.

Step 3: Conclusion Trisomy means three copies of a particular chromosome; chromosome 21 shows trisomy in Down syndrome.

Quick Tip to Solve: Keep the two numbers distinct: 21 identifies the chromosome involved, whereas 47 is the total in usual trisomy 21.

OR

29(c)(ii). 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.

Write any two symptoms of Down's syndrome.

[1 mark]

Solution:

Concept:

- Down's syndrome is a chromosomal disorder caused by an additional copy of chromosome 21 (trisomy 21).
- It produces characteristic physical and developmental features; any two recognised symptoms

answer the question.

Step 1: State a characteristic of growth An affected individual commonly has short stature. This refers to reduced overall height and is one of the characteristic physical features described for this disorder.

Step 2: State a characteristic of the hands The palm is broad and characteristically shows a single transverse palmar crease. This provides a second, distinct physical feature in addition to short stature.

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

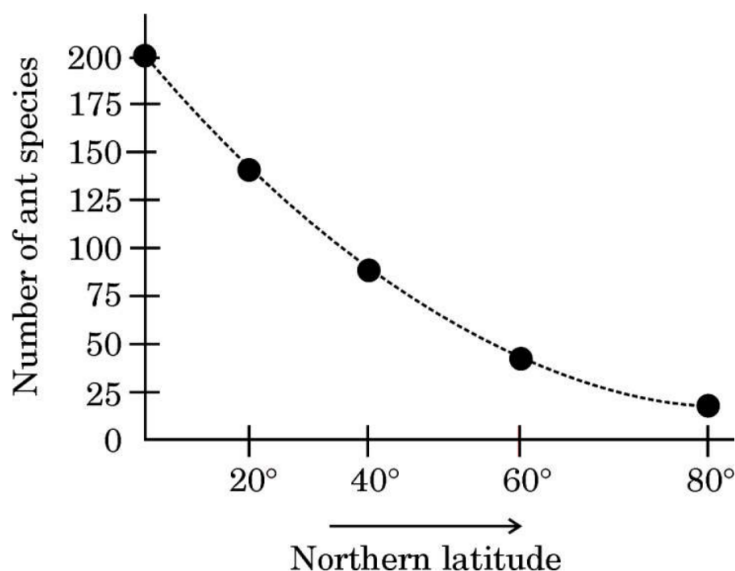
Quick Tip to Solve: Recall two distinct NCERT physical features: short stature and the characteristic broad palm with a single crease.

30(a). 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.

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

What does the graph depict ?

[1 mark]



Solution:

Concept:

- A latitudinal gradient describes a systematic change in species richness with latitude, measured as distance north or south of the equator.

- Species richness means the number of species present; the vertical axis here specifically counts ant species.

Step 1: Read the two axes The horizontal axis represents northern latitude, while the vertical axis represents the number of ant species. Thus, the figure compares ant species richness at different latitudes, rather than the number of individual ants.

Step 2: Identify the trend The plotted number of ant species is highest near the equator and decreases towards higher northern latitudes. The descending curve therefore illustrates the general decrease in biodiversity from tropical towards polar regions.

Step 3: Conclusion The graph depicts the latitudinal gradient in ant species richness: the number of ant species decreases as northern latitude increases.

Quick Tip to Solve: Read both axis labels first: northern latitude versus number of ant species identifies a latitudinal gradient, not a species-area curve.

30(b). 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.

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

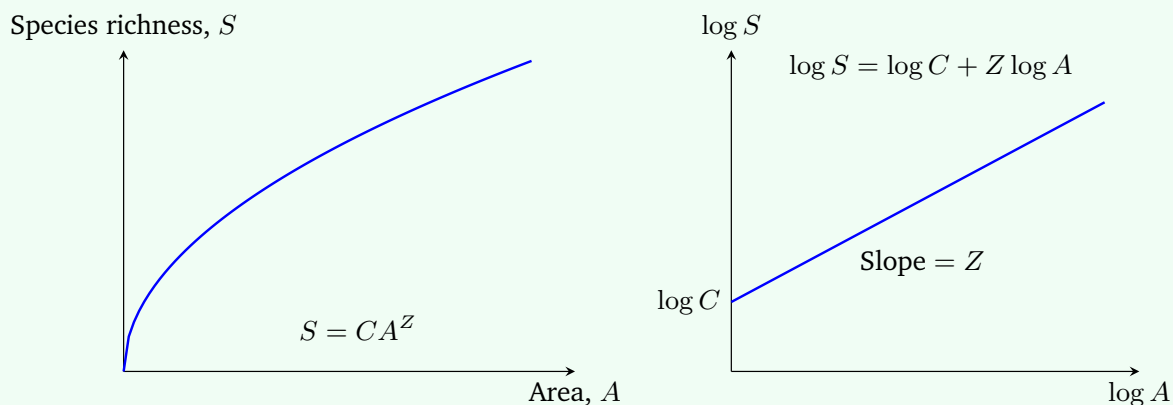
With the help of graph, show the species-area relationship for a wide variety of taxa in a forest. Write an equation that shows this relationship on a logarithm scale. [2 marks]

Solution:

Concept:

- For a wide variety of taxa in a forest, species richness increases with the area explored, within a region, according to $S = CA^Z$.
- Here S is species richness, A is the area explored, C is a constant and Z is the regression coefficient; the relationship is a rectangular-hyperbola-type rising curve on ordinary axes.

Step 1: Show richness against explored area Plot species richness S on the vertical axis and explored area A on the horizontal axis. As sampling covers a larger area, more habitats and species are encountered, so richness increases. The rate of increase gradually decreases; the ordinary-scale curve rises and flattens rather than forming a straight line.



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

Step 2: Transform the equation to logarithmic form Take logarithms of both sides of the power relationship. Using $\log(xy) = \log x + \log y$ and $\log(A^Z) = Z \log A$, obtain

$$S = CA^Z,$$

$$\log S = \log C + Z \log A.$$

A plot of $\log S$ against $\log A$ is therefore a straight line, with slope Z and vertical intercept $\log C$. For small areas within a region, Z is generally between 0.1 and 0.2, irrespective of the taxonomic group considered.

Step 3: Conclusion The species-area relationship is $S = CA^Z$; on logarithmic axes it is the straight line $\log S = \log C + Z \log A$.

Quick Tip to Solve: Match the graph to its axes: ordinary axes give a rising curve, while log-log axes give a straight line of slope Z .

30(c)(i). 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.

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

Explain the correlation between latitudinal gradient and number of plant species.

[1 mark]

Solution:

Concept:

- Plant species richness follows a latitudinal gradient: it generally decreases with increasing absolute latitude, away from the equator.
- The passage compares the number of vascular plant species in equal areas of tropical, temperate and arctic vegetation.

Step 1: Compare tropical and temperate regions Tropical forests, at low latitudes, contain about 118–236 vascular plant species per 0.1 ha. Temperate forests contain only about 21–48 species in the same area. Thus, richness decreases as one moves from tropical to temperate latitudes.

Step 2: Extend the comparison towards the poles Arctic regions, at high latitudes, have only about 0.0–10.0 vascular plant species per 0.1 ha. Comparing the same area avoids confusing a change in latitude with a change in the size of the sampled habitat.

Step 3: Conclusion The number of plant species is highest in the tropics, lower in temperate regions and lowest near the poles; it is negatively correlated with increasing absolute latitude.

Quick Tip to Solve: Compare species counts for the same 0.1 ha: tropical greater than temperate greater than arctic shows the latitude trend directly.

30(c)(ii). 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.

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

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, undisturbed evolutionary time permits the accumulation of species through speciation.
- A relatively constant, less seasonal environment promotes niche specialisation and supports the persistence of tropical species.

Step 1: Identify the long evolutionary history Tropical latitudes have remained relatively undisturbed for millions of years. Unlike temperate regions repeatedly subjected to glaciations in the past, tropical regions allowed species to persist and evolve over a long, relatively uninterrupted period.

Step 2: Identify the stable climate Tropical environments are less seasonal, relatively constant and more predictable. Such conditions favour niche specialisation and allow different species to continue occupying their habitats, contributing to sustained high species diversity.

Step 3: Conclusion Two reasons are the long evolutionary history without repeated major glaciations and the relatively constant, predictable and less seasonal tropical climate.

Quick Tip to Solve: For tropical stability, pair evolutionary time with climate: fewer historical disruptions and less seasonal environmental variation.

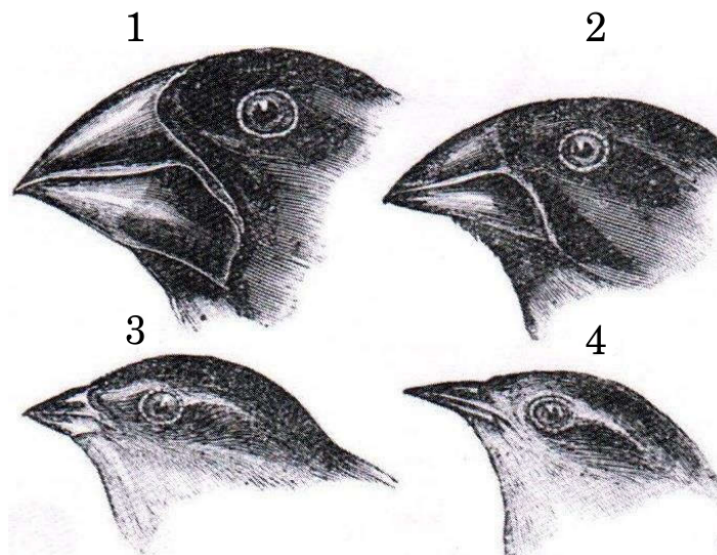
Section E (15 marks)

31(a). Study the diagram given below showing the variety of beaks of finches in Galapagos Islands and answer the questions that follow.

(i) Explain the interpretation of Charles Darwin when he observed a variety of small black birds on Galapagos Islands.

(ii) State Hardy-Weinberg principle of equilibrium. Explain any two factors affecting the equilibrium.

[5 marks]



Solution:

Concept:

- Adaptive radiation is the evolution of several species from a common ancestor within a geographical region, with each species becoming adapted to a different ecological niche.
- The Hardy-Weinberg principle states that allele frequencies in a population remain constant from generation to generation in the absence of evolutionary influences. For two alleles, $p + q = 1$ and $p^2 + 2pq + q^2 = 1$.
- Natural selection and gene migration can change allele frequencies and disturb genetic equilibrium.

Step 1: (i) Interpret Darwin's observation of finches Darwin observed different small black birds on the Galapagos Islands, now called Darwin's finches. He inferred that these different forms had evolved on the islands from an ancestral seed-eating finch. Descendants spread into different habitats and occupied different feeding niches. Heritable variations in beak shape were favoured according to the available food, so different populations evolved different beaks. Some became adapted for eating insects and others for different plant foods. Thus, the variety of beaks represents adaptive radiation: diversification from a common ancestor into several forms adapted to different ways of life in the same geographical region.

Step 2: (ii) State the Hardy-Weinberg principle In an ideal population, allele frequencies remain constant through successive generations; the gene pool is in genetic equilibrium. For a gene with alleles having frequencies p and q , the expected genotype frequencies are p^2 , $2pq$ and q^2 for the two

homozygotes and the heterozygote, respectively:

$$p + q = 1, \quad p^2 + 2pq + q^2 = 1.$$

This equilibrium requires random mating in a sufficiently large population without mutation, migration, natural selection or genetic drift. A change in allele frequencies indicates evolutionary change.

Step 3: Explain natural selection as one disturbing factor Natural selection produces differences in survival and reproductive success among individuals with different heritable traits. Individuals carrying an advantageous allele leave more offspring in a particular environment. Consequently, that allele tends to become more frequent over generations, while less favourable alleles may become less frequent. Because the gene pool changes, the original Hardy-Weinberg equilibrium is disturbed.

Step 4: Explain gene migration as the second disturbing factor When individuals enter or leave a population, their alleles enter or leave its gene pool. Immigration can introduce new alleles or change the frequencies of existing ones, while emigration can remove alleles. Repeated movement and interbreeding produces gene flow between populations. These changes in allele frequencies disturb the original genetic equilibrium of the population.

Step 5: Conclusion Darwin's finches illustrate adaptive radiation from a common ancestral finch. Hardy-Weinberg equilibrium means constancy of allele frequencies, and it can be disturbed by natural selection and gene migration.

Quick Tip to Solve: Link each finch beak to a feeding niche, and explain each equilibrium-disturbing factor through its effect on allele frequencies.

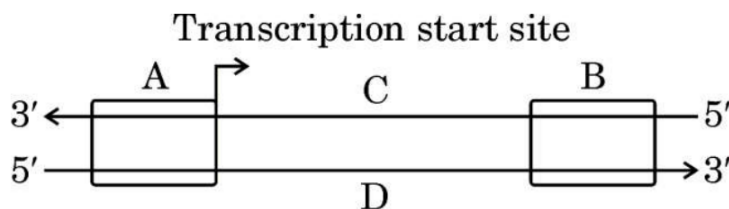
31(b). Study the schematic structure of a transcription unit given below and answer the questions that follow.

(i) Identify strand 'C' and 'D' in the diagram of transcription unit given above and write the basis on which you identify them.

(ii) Why can both the strands of DNA not be copied during transcription ? Explain.

(iii) Write the function of RNA polymerase in Eukaryotes.

[5 marks]



Solution:

Concept:

- RNA polymerase synthesises RNA only in the $5' \rightarrow 3'$ direction by reading the DNA template in the $3' \rightarrow 5'$ direction.
- The coding DNA strand has the same base sequence as the RNA transcript when both are read $5' \rightarrow 3'$, except that DNA contains thymine in place of uracil.
- Eukaryotes have specialised nuclear RNA polymerases I, II and III that transcribe different classes of RNA.

Step 1: (i) Identify strands C and D from their polarity In the given diagram, transcription proceeds from the start site towards the right. Strand C, the upper strand, runs from $3'$ at the left to $5'$ at the right. It is therefore the template strand: RNA polymerase reads it $3' \rightarrow 5'$ while making RNA $5' \rightarrow 3'$. Strand D, the lower strand, runs $5' \rightarrow 3'$ in the same left-to-right direction and is the coding or non-template strand. The RNA sequence is complementary to C and matches D, with uracil replacing thymine. The promoter's orientation determines which strand serves as the template for this transcription unit.

Step 2: (ii) Explain why both strands cannot be copied for the same unit The two DNA strands are complementary and have different base sequences. If both were transcribed for the same transcription unit, two RNA molecules with different sequences would be formed. If both acted as messenger RNAs, they would generally specify different amino acid sequences and hence different proteins. One DNA segment would then carry conflicting messages for protein synthesis. Further, the two RNA molecules would be complementary to one another and could pair to form double-stranded RNA. Such pairing would prevent the normal translation of these RNAs into proteins. Therefore, only one DNA strand acts as the template for a particular transcription unit. Different genes can use different DNA strands as templates; the restriction applies to a given transcription unit.

Step 3: (iii) State the functions of eukaryotic RNA polymerases RNA polymerases catalyse DNA-dependent RNA synthesis, joining ribonucleotides complementary to a DNA template. In the eukaryotic nucleus, their functions are specialised:

- RNA polymerase I transcribes the precursor that gives rise to 28S, 18S and 5.8S ribosomal RNAs.
- RNA polymerase II transcribes heterogeneous nuclear RNA (hnRNA), the precursor of messenger RNA. Processing by capping, splicing and tailing produces mature mRNA.
- RNA polymerase III transcribes transfer RNAs, 5S ribosomal RNA and certain small nuclear RNAs (snRNAs).

Thus, the enzymes collectively produce the RNA molecules needed for gene expression and protein synthesis, while polymerase II specifically produces the primary transcript of protein-coding genes.

Step 4: Conclusion C is the template strand and D is the coding strand. Copying both strands of the same unit would produce conflicting, complementary RNA messages. Eukaryotic RNA polymerases I, II and III synthesise specialised classes of RNA.

Quick Tip to Solve: Follow the transcription arrow first: the strand read 3' to 5' is the template, and remember that 5S rRNA belongs to polymerase III.

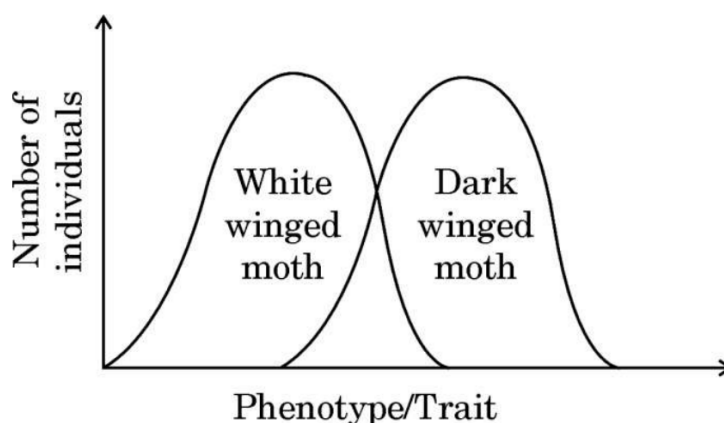
32(a). (i) Natural selection operates in different ways in nature.

(I) In England after industrialisation, the population of dark winged moths were more favoured than white winged moths. Explain.

(II) Identify the type of natural selection depicted in the graph above.

(ii) State Hugo de Vries' theory of mutation. How is it different from Darwin's theory of natural selection ?

[5 marks]



Solution:

Concept:

- Natural selection increases the frequency of heritable variants that survive and reproduce more successfully in a particular environment. Selection acts on existing variation in a population.
- Industrial melanism illustrates how a change in the environment can reverse the selective advantage of light and dark body colours.
- Hugo de Vries proposed that mutations, sudden heritable changes, bring about evolution. His mutation theory emphasised discontinuous change rather than Darwin's gradual accumulation of small variations.

Step 1: (i)(I) Explain the environmental change after industrialisation Before industrialisation, tree trunks in England were relatively light and covered with lichens. White-winged moths were camouflaged against this background, whereas dark-winged moths were conspicuous to insectivorous birds. Industrial pollution deposited soot on tree trunks and reduced the lichens, making the background darker.

Step 2: (i)(I) Explain why dark-winged moths became more abundant On the darkened trunks, dark-winged moths were better camouflaged and were eaten less frequently by birds. White-winged moths now stood out and suffered greater predation. Consequently, more dark moths survived to reproduce and transmit their heritable colour to their offspring, increasing the proportion of dark-winged moths over successive generations. Pollution did not directly turn individual white moths dark; it changed which existing variant had a selective advantage.

Step 3: (i)(II) Identify the selection shown in the graph The graph shows the population distribution shifting from the white-winged phenotype towards the dark-winged phenotype. This is **directional selection**: one end of the range of phenotypic variation is favoured, so the population mean shifts in that direction. It is not stabilising selection, which favours the intermediate phenotype, or disruptive selection, which favours both extremes over the intermediate phenotype.

Step 4: (ii) State de Vries' mutation theory and distinguish it from Darwin's theory From his studies on the evening primrose, *Oenothera lamarckiana*, Hugo de Vries proposed that evolution occurs through sudden, heritable mutations. Mutations are random and directionless; in his theory, a large mutation could give rise to a new species in a single step, called **saltation**.

In contrast, Darwin explained evolution through natural selection acting over many generations on small, heritable variations. Individuals possessing favourable variations leave more offspring, and the gradual accumulation of such variations produces evolutionary change. Thus, de Vries emphasised sudden, discontinuous changes and single-step speciation, whereas Darwin emphasised gradual change through selection. In the textbook comparison, de Vries' mutations are random and directionless, while the variations favoured by Darwinian selection accumulate in a particular adaptive direction; this does not imply that organisms deliberately produce useful variations.

Step 5: Conclusion Dark-winged moths increased after industrialisation because camouflage on soot-darkened trunks reduced their predation and improved reproductive success. The graph represents directional selection. De Vries proposed sudden mutation-driven evolution and saltation, whereas Darwin proposed gradual evolution through natural selection of small heritable variations.

Quick Tip to Solve: For industrial melanism, connect background colour to camouflage, bird predation and differential reproduction; a shift of the population towards one phenotype identifies directional selection.

32(b). (i) (I) Why did Hershey and Chase use ^{35}S and ^{32}P in their experiments ? Explain.

(II) Write the conclusion they reached at the end of the experiment.

(ii) Draw a clover leaf-like structure of tRNA showing the following :

(I) Tyrosine attached to the amino acid site.

(II) Anticodon for this amino acid in its correct site (codon for tyrosine is UAC).

[5 marks]

Solution:

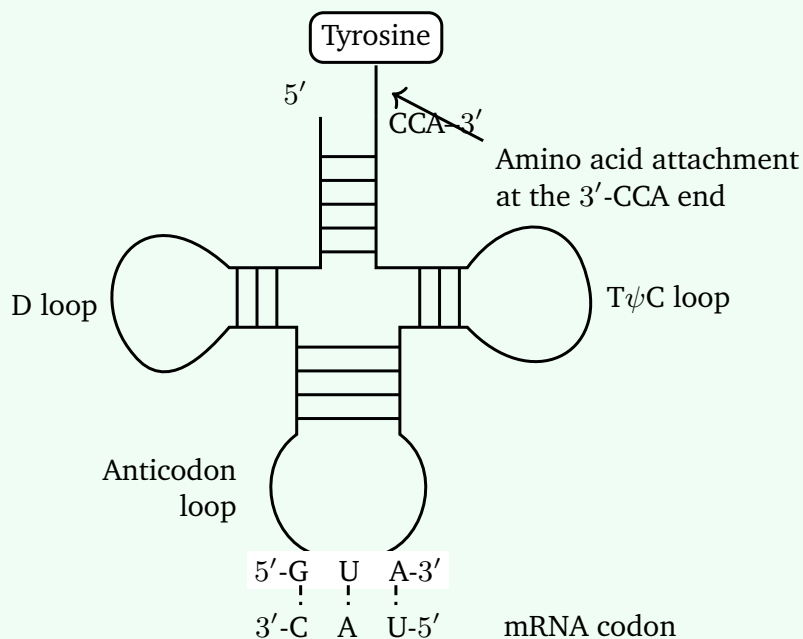
Concept:

- A selective radioactive label distinguishes the two major components of a bacteriophage: protein contains sulphur in certain amino acids, whereas DNA contains phosphorus in its phosphate backbone.
- The genetic material must enter the bacterial host and direct the formation of new phages. Tracking labelled phage components therefore identifies the inherited material.
- A tRNA carries its amino acid at the terminal adenosine of its 3'-CCA end. Its anticodon pairs with the mRNA codon by complementary, antiparallel base pairing.

Step 1: (i)(I) Selectively label protein and DNA Hershey and Chase grew bacteriophages in two separate radioactive media. In the medium containing ^{35}S , the radioactive sulphur was incorporated into sulphur-containing amino acids of the phage protein coat. DNA contains no sulphur, so this treatment labelled protein without labelling DNA. In the medium containing ^{32}P , radioactive phosphorus was incorporated into the phosphate backbone of phage DNA. The phage protein coat did not acquire this DNA-specific label. Thus, the two isotopes allowed them to follow protein and DNA independently during infection of *E. coli*.

Step 2: (i)(II) Relate the experimental observations to inheritance After the labelled phages infected bacteria, blending detached the phage coats from the bacterial surfaces. Centrifugation collected bacteria in the pellet, while detached coats remained in the supernatant. Most ^{35}S radioactivity remained in the supernatant, showing that the protein coat stayed outside the bacteria. In contrast, ^{32}P radioactivity was associated with the bacterial pellet: phage DNA had entered the cells. The infected cells subsequently produced new phages. These observations established that DNA, rather than the protein coat, carries the genetic information in these bacteriophages.

Step 3: (ii) Place tyrosine and its anticodon on tRNA The cloverleaf below shows tyrosine attached to the amino acid attachment site at the 3'-CCA end of tRNA. The anticodon lies in the anticodon loop, opposite the acceptor arm. Because the tyrosine codon is 5'-UAC-3', its complementary anticodon must be written antiparallel as 3'-AUG-5'. If written in the 5'-to-3' direction, the same anticodon is GUA. Keeping the terminal directions visible avoids confusing the anticodon with the codon.



Cloverleaf structure of tyrosine tRNA with complementary codon alignment.

Step 4: Conclusion ^{35}S traced the protein coat and ^{32}P traced DNA, establishing DNA as the genetic material of the bacteriophage. Tyrosine attaches to the 3'-CCA end of tRNA, whose anticodon 3'-AUG-5' pairs with 5'-UAC-3'.

Quick Tip to Solve: Use sulphur for the protein coat and phosphorus for DNA; then write codon and anticodon on opposite strands with their terminal directions shown.

33(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]

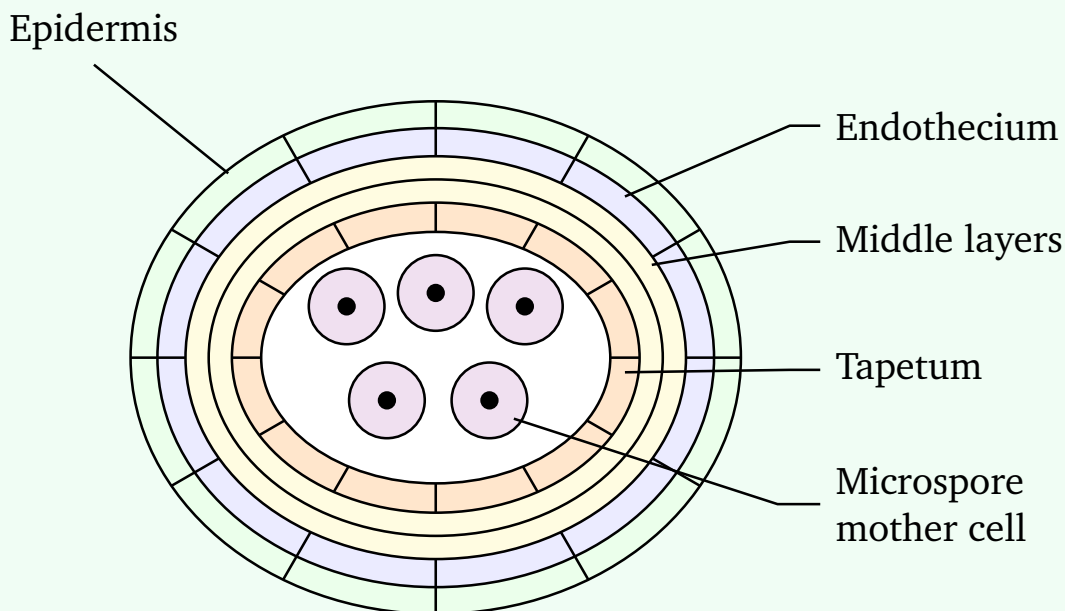
Solution:

Concept:

- A young microsporangium has four wall layers: epidermis, endothecium, middle layers and tapetum, arranged from outside towards the centre. The central sporogenous tissue gives rise to diploid microspore mother cells.

- Tapetum is the innermost nutritive wall layer. A pollen grain has an outer exine made of sporopollenin and an inner intine; the resistant exine explains fossil preservation.

Step 1: (i) Draw and label one microsporangium The enlarged transverse section below represents one young microsporangium, not the entire anther. The endothecium lies beneath the epidermis, the middle layers lie between endothecium and tapetum, and microspore mother cells occupy the central region. The four required labels identify the corresponding wall layers and a central mother cell.



Enlarged T.S. of one young microsporangium (schematic).

Step 2: (ii) State the function of tapetum Tapetum nourishes the developing microspores and pollen grains. Its cells have dense cytoplasm and supply nutrients to the developing male gametophytes. It also contributes materials needed for pollen-wall formation; its position immediately around the sporogenous tissue facilitates this support during pollen development.

Step 3: (iii)(I) Explain preservation of pollen fossils The exine of pollen grains contains sporopollenin, an exceptionally resistant organic substance. It withstands high temperatures and strong acids and alkalis, and no enzyme is known to degrade it. Therefore the exine resists decomposition and can persist in sediments for long periods, allowing pollen grains to be preserved as fossils. It is the resistant wall, rather than continued survival of the living pollen contents, that explains this preservation.

Step 4: (iii)(II) Explain the use of pollen tablets Pollen grains are rich in nutrients. Hence pollen products, including tablets and syrups, are used as food supplements. They are marketed with claims of improved performance by athletes and race horses. Their use in this context follows their nutritional value; it is distinct from the protective role of sporopollenin in the pollen wall.

Step 5: Conclusion The labelled T.S. shows tapetum, middle layers, endothecium and microspore mother cells. Tapetum nourishes developing pollen; sporopollenin accounts for fossil preservation, while the nutrient-rich contents explain the use of pollen tablets as food supplements.

Quick Tip to Solve: Label wall layers from outside inward, and link fossil preservation to exine but pollen tablets to nutrients.

33(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 formation of haploid spermatozoa from diploid spermatogonia in the seminiferous tubules of the testes. It begins at puberty.
- Mitosis maintains the germ-cell population, meiosis halves the chromosome number, and spermiogenesis differentiates spermatids into spermatozoa. Sertoli cells support and nourish developing germ cells.

Step 1: Identify the site and the initial germ cells Spermatogenesis occurs in the seminiferous tubules of the human testes. Diploid spermatogonia situated on the inner wall of these tubules multiply by mitotic divisions. Each spermatogonium has 46 chromosomes, or $2n$. Some spermatogonia grow and become primary spermatocytes while others maintain the population of germ cells.

Step 2: Follow the two meiotic divisions Each diploid primary spermatocyte undergoes meiosis I, the reduction division, and produces two haploid secondary spermatocytes, each containing 23 chromosomes. Each secondary spermatocyte undergoes meiosis II to produce two haploid spermatids. Thus, one primary spermatocyte produces four spermatids, each with $n = 23$ chromosomes. The chromosome number is reduced in the first meiotic division and remains haploid after the second division.

Step 3: Describe formation of spermatozoa The spermatids transform into spermatozoa by spermiogenesis. During this differentiation, each develops the specialised head with an acrosome, a middle piece containing mitochondria, and a flagellar tail; excess cytoplasm is removed. The resulting sperm heads remain embedded in Sertoli cells. Finally, spermatozoa are released from these cells into the lumen of the seminiferous tubule by spermiation. Spermiogenesis is a change in cell form and does not involve another meiotic division.

Step 4: Conclusion In the seminiferous tubules, spermatogonia form primary spermatocytes, which yield secondary spermatocytes and then spermatids through meiosis. Spermiogenesis converts the four haploid spermatids derived from each primary spermatocyte into four spermatozoa.

Quick Tip to Solve: Track the sequence as one primary spermatocyte, two secondary spermatocytes, four spermatids, then four spermatozoa.

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

[2 marks]

Solution:

Concept:

- Spermatozoa are produced in the seminiferous tubules of the testes and are transported through the male accessory ducts.
- The ordered duct system connects the seminiferous tubules to the ejaculatory duct; the vas deferens joins the duct of a seminal vesicle to form the ejaculatory duct.

Step 1: Trace the route out of the testis Spermatozoa released into the lumen of the seminiferous tubules pass into the rete testis. From the rete testis, they travel through the vasa efferentia, which leave the testis and open into the epididymis situated along its posterior surface. Thus, the first part of the route is seminiferous tubules, rete testis, vasa efferentia and epididymis, in that order.

Step 2: Follow the route 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 joins the duct from the seminal vesicle to form the ejaculatory duct. Spermatozoa therefore enter the ejaculatory duct through the vas deferens; they do not pass through the seminal vesicle itself.

Step 3: Conclusion The path is: seminiferous tubules of the testis → rete testis → vasa efferentia → epididymis → vas deferens → ejaculatory duct.

Quick Tip to Solve: Memorise the duct order as rete testis, vasa efferentia, epididymis and vas deferens. The duct of the seminal vesicle joins this route at its end; sperm do not travel through the seminal vesicle.