

CBSE Class 12 Biology Question Paper 2026 with Solution PDF-Set 57-5-2

Question Paper with Solutions

Conducted by the Central Board of Secondary Education (CBSE)



Time Allowed: 3 hours

Maximum Marks: 70

General Instructions

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

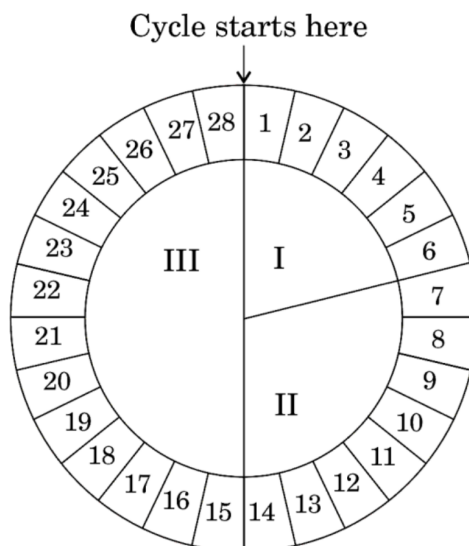
Section A (16 marks)

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

1. In a human female, menstrual cycle of 28 days is represented by the diagram given below.

Select the correct statement related with this diagram.

[1 mark]



- (A) Primary follicle of ovary matures into Graafian follicle in phase II.
- (B) The hormone secreted in large amounts in phase III is also responsible for maintaining pregnancy in human females.
- (C) Corpus luteum secretes progesterone in phase I, however it degenerates completely in phase III.
- (D) Both (A) and (B).

Correct Answer: (D) Both (A) and (B).

Solution:

Concept:

- Follicles grow during the follicular phase before ovulation; after ovulation the ruptured follicle forms the corpus luteum.
- The corpus luteum secretes progesterone, which maintains the endometrium and supports pregnancy.

Step 1: Identify the phases in the diagram Phase I covers the beginning of the cycle, including menstruation. Phase II is the pre-ovulatory interval in which the ovarian follicle grows and matures into a Graafian follicle. Therefore statement (A) is correct.

Step 2: Check the progesterone statements Phase III follows ovulation and corresponds to the luteal phase. The corpus luteum secretes large amounts of progesterone during this phase; this hormone also helps maintain pregnancy. Thus (B) is correct. Statement (C) assigns corpus-luteum secretion to phase I instead of the luteal phase and is incorrect. In the absence of fertilisation, the corpus luteum degenerates towards the end of the luteal phase.

Step 3: Conclusion Both the follicular-maturation statement and the pregnancy-maintaining hormone statement are correct. Hence, the correct option is (D).

Quick Tip to Solve: Locate day 14 first: follicle maturation precedes ovulation, whereas high progesterone follows it.

2. The cells of endosperm have 24 chromosomes. What will be the number of chromosomes in the gametes? [1 mark]

- (A) 8
- (B) 16
- (C) 23
- (D) 32

Correct Answer: (A) 8

Solution:

Concept:

- In a typical angiosperm, a male gamete with n chromosomes fuses with two polar nuclei, each with n chromosomes, during triple fusion.
- The resulting primary endosperm nucleus and the endosperm are triploid, $3n$; the gametes are haploid, n .

Step 1: Relate endosperm chromosomes to the haploid number The question gives 24 chromosomes in an endosperm cell. Since the endosperm contains three haploid sets,

$$3n = 24 \Rightarrow n = \frac{24}{3} = 8.$$

Step 2: Distinguish the other chromosome counts A gamete contains one set, not two or three. The count 16 would be $2n$, the diploid number of this plant, so option (B) is unsuitable. The counts 23 and 32 likewise do not equal the haploid number calculated from the triploid endosperm.

Step 3: Conclusion Each gamete has 8 chromosomes. Hence, the correct option is (A).

Quick Tip to Solve: For an angiosperm endosperm count, divide by three to obtain the chromosome number of a gamete.

3. During different phases of menstrual cycle, hormones are secreted. Choose the option showing the correct sequence of hormones. [1 mark]

- (A) FSH, Progesterone, Estrogen
- (B) Estrogen, FSH, Progesterone
- (C) FSH, Estrogen, Progesterone
- (D) Estrogen, Progesterone, FSH

Correct Answer: (C) FSH, Estrogen, Progesterone

Solution:

Concept:

- Follicle-stimulating hormone (FSH) from the anterior pituitary stimulates the growth of ovarian follicles.
- Growing follicles secrete estrogen; after ovulation, the corpus luteum secretes large amounts of progesterone.

Step 1: Follow follicular development At the beginning of the cycle, FSH promotes follicular growth. As follicles develop, their estrogen secretion increases. Thus the sequence of the dominant events starts with FSH followed by estrogen.

Step 2: Follow the post-ovulatory phase After ovulation, the ruptured Graafian follicle becomes the corpus luteum, which produces progesterone. Therefore progesterone follows the follicular estrogen rise. Option (A) reverses estrogen and progesterone, while (B) and (D) place estrogen before the FSH-driven follicular development. These are not the requested sequence. Hormone secretion overlaps in time; this sequence describes the principal successive events.

Step 3: Conclusion The sequence is FSH → Estrogen → Progesterone. Hence, the correct option is (C).

Quick Tip to Solve: Associate FSH with follicle growth, estrogen with the growing follicle and progesterone with the corpus luteum.

4. A DNA molecule is 160 base pairs long. It has 30% Guanine. How many Adenine bases are present in this DNA molecule? [1 mark]

- (A) 48
- (B) 64
- (C) 96
- (D) 192

Correct Answer: (B) 64

Solution:

Concept:

- In double-stranded DNA, adenine pairs with thymine and guanine pairs with cytosine, so $A = T$ and $G = C$.

- Each base pair contains two nucleotide bases; therefore 160 base pairs contain 320 bases in total.

Step 1: Find the adenine percentage Guanine is 30%, so cytosine is also 30%. The remaining 40% is adenine plus thymine. Since their amounts are equal,

$$A = \frac{100 - 30 - 30}{2}\% = 20\%.$$

Step 2: Apply this percentage to all bases The molecule contains $2 \times 160 = 320$ bases. Hence

$$N_A = \frac{20}{100} \times 320 = 64.$$

The answer must count bases on both strands. The value 48 comes from taking 30 percent of 160, whereas 96 is the number of guanine bases in the complete molecule. Neither these values nor 192 represents its adenine count.

Step 3: Conclusion The DNA molecule contains 64 adenine bases. Hence, the correct option is (B).

Quick Tip to Solve: Convert base pairs into total bases before multiplying by a base percentage: 160 base pairs means 320 bases.

5. Arrange the following in the correct sequence of their evolution and select the correct option:

(i) Seaweed

(ii) Invertebrates

(iii) Jawless fish

[1 mark]

(A) (i), (ii), (iii)

(B) (i), (iii), (ii)

(C) (ii), (iii), (i)

(D) (ii), (i), (iii)

Correct Answer: (C) (ii), (iii), (i)

Solution:

Concept:

- The sequence in this question follows the evolutionary timeline given in NCERT for the listed life forms.
- In that timeline, invertebrates appear before jawless fish, followed by the stated occurrence of seaweeds and a few plants.

Step 1: Place the three entries on the textbook timeline NCERT describes invertebrates as formed and active by about 500 million years ago, jawless fish as having evolved around 350 million years ago, and seaweeds and a few plants as existing around 320 million years ago.

Step 2: Arrange from earlier to later A larger number of millions of years ago indicates an earlier time. Thus the order is invertebrates, then jawless fish, then seaweed: (ii), (iii), (i). Options (A) and (B) put seaweed first, while (D) puts it between invertebrates and jawless fish; none follows the stated

textbook chronology.

Step 3: Conclusion The required sequence is (ii) $\rightarrow$ (iii) $\rightarrow$ (i). Hence, the correct option is (C).

Quick Tip to Solve: Use the NCERT timeline: 500, 350 and 320 million years ago run from earlier to later, respectively.

6. S is the stimulant of central nervous system and interferes with the transport of T, a neurotransmitter. Identify S and T and choose the correct option.

[1 mark]

- (A) S - Cocaine, T - Dopamine
- (B) S - Heroin, T - Acetylcholine
- (C) S - Heroin, T - Dopamine
- (D) S - Cocaine, T - Acetylcholine

Correct Answer: (A) S - Cocaine, T - Dopamine

Solution:

Concept:

- Cocaine is a central nervous system stimulant obtained from the coca plant, *Erythroxylum coca*.
- It interferes with dopamine transport, including its reuptake, and thereby enhances dopamine action at synapses.

Step 1: Identify the stimulant S The described stimulant is cocaine. It produces a sense of euphoria and increased energy. Heroin, in contrast, is an opioid commonly described as a depressant that slows body functions; therefore the heroin-containing options (B) and (C) do not fit S.

Step 2: Identify the neurotransmitter T The neurotransmitter associated with cocaine in this description is dopamine. Interference with its reuptake prolongs its presence and action in the synaptic region. Acetylcholine is not the neurotransmitter specified by this cocaine effect, so option (D) is also excluded. Only the cocaine-dopamine combination satisfies both clues.

Step 3: Conclusion S is cocaine and T is dopamine. Hence, the correct option is (A).

Quick Tip to Solve: Match both clues together: cocaine is the stimulant and dopamine is the neurotransmitter whose transport it interferes with.

7. Select the odd option in the context of convergent evolution.

[1 mark]

- (A) Eyes of Octopus and Mammals
- (B) Flippers of Penguins and Dolphins
- (C) Flying Squirrel and Flying Phalanger
- (D) Thorns of Bougainvillea and Tendrils of Cucurbita

Correct Answer: (D) Thorns of Bougainvillea and Tendrils of Cucurbita

Solution:

Concept:

- Convergent evolution produces similar functional adaptations independently in different lineages; analogous structures illustrate it.
- Divergent evolution modifies structures with a common origin for different functions; these structures are homologous.

Step 1: Check the examples of convergence Eyes of octopus and mammals show independently evolved visual similarity. Penguin and dolphin flippers provide similar swimming adaptations, while flying squirrel and flying phalanger independently show adaptations for gliding. Thus options (A), (B) and (C) fit the context of convergent evolution.

Step 2: Identify the pair with a shared structural origin The thorns of *Bougainvillea* and tendrils of *Cucurbita* are both modifications of the stem or axillary shoot. Their common origin makes them homologous, although thorns function in protection and tendrils help in climbing. They therefore illustrate divergent evolution and are the odd pair in this list.

Step 3: Conclusion Thorns of *Bougainvillea* and tendrils of *Cucurbita* are the odd pair. Hence, the correct option is (D).

Quick Tip to Solve: For the plant pair, ask about origin before function: both are stem modifications, so their relationship is homologous.

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

[1 mark]

- (A) Ethanol
- (B) Streptokinase
- (C) Citric acid
- (D) Statins

Correct Answer: (D) Statins

Solution:

Concept:

- Commercially useful microbes produce specific metabolites; the organism must be matched with its characteristic industrial product.
- Statins lower blood cholesterol by competitively inhibiting the enzyme responsible for cholesterol synthesis.

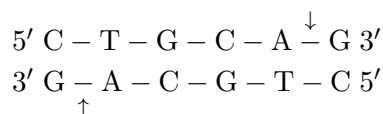
Step 1: Identify the producer *Monascus purpureus* is used commercially to produce statins. These microbial products inhibit HMG-CoA reductase, an important enzyme in cholesterol biosynthesis.

Step 2: Check the other products Ethanol is produced by brewer's yeast, *Saccharomyces cerevisiae*; streptokinase is obtained from *Streptococcus*; and citric acid is produced by *Aspergillus niger*. Thus none of the first three organism-product associations fits the organism named here.

Step 3: Conclusion *Monascus purpureus* produces statins. Hence, the correct option is (D).

Quick Tip to Solve: Recall the pair Monascus–statins; distinguish it from Saccharomyces–ethanol.

9. Given below is the restriction site of a restriction endonuclease Pst I and the cleavage sites on a DNA molecule.



Choose the option that gives the correct resultant fragments.

[1 mark]

- (A) $\begin{array}{ccc} 5' C - T - G & & C - A - G 3' \\ 3' G - A - C - G - T & & C 5' \end{array}$
- (B) $\begin{array}{ccc} 5' C - T & & G - C - A - G 3' \\ 3' G - A - C - G & & T - C 5' \end{array}$
- (C) $\begin{array}{ccc} 5' C - T - G - C & & A - G 3' \\ 3' G - A - C - G & & T - C 5' \end{array}$
- (D) $\begin{array}{ccc} 5' C - T - G - C - A & & G 3' \\ 3' G & & A - C - G - T - C 5' \end{array}$

Correct Answer: (D) $\begin{array}{ccc} 5' C - T - G - C - A & & G 3' \\ 3' G & & A - C - G - T - C 5' \end{array}$

Solution:

Concept:

- A restriction endonuclease cuts the phosphodiester backbone at definite positions within its recognition sequence.
- The two DNA strands run antiparallel; staggered cuts can leave complementary single-stranded sticky ends.

Step 1: Read each marked cleavage site On the upper strand, the indicated cut is between A and G: 5'-CTGCA|G-3'. On the lower strand, it is between G and A: 3'-G|ACGTC-5'. The positions must be read independently on the two strands.

Step 2: Compare the fragments with the choices The left fragment therefore retains CTGCA on its upper strand and G on its lower strand; the right fragment retains G on its upper strand and ACGTC on its lower strand. These are the staggered fragments shown in (D), leaving four-base 3' overhangs. Options (A), (B) and (C) move one or both cuts away from the arrows printed in the question.

Step 3: Conclusion The resultant fragments are those in option (D).

Quick Tip to Solve: Mark the cut separately on each strand before matching the two resulting fragments.

10. Which of the following ecosystem is most productive in terms of net primary productivity?

[1 mark]

- (A) Desert
- (B) Tropical rainforests
- (C) Oceans
- (D) Estuaries

Correct Answer: (B) Tropical rainforests

Solution:

Concept:

- Net primary productivity is the organic matter retained by producers after respiratory losses:
$$NPP = GPP - R.$$
- Comparing the productivity of ecosystems uses the rate of biomass production per unit area per unit time.

Step 1: Compare conditions supporting plant growth Tropical rainforests have warm temperatures, abundant rainfall and a long growing season. Their dense vegetation maintains high photosynthetic production throughout the year, giving a very high net primary productivity.

Step 2: Eliminate the alternatives Deserts have low productivity because water limits plant growth. Open oceans have relatively low productivity per unit area despite their enormous total area. Estuaries are nutrient-rich and highly productive, but the standard ecosystem comparison places tropical rainforests above estuaries. Thus the rainforest is the most productive ecosystem among these choices.

Step 3: Conclusion Tropical rainforests have the highest net primary productivity among the listed ecosystems. Hence, the correct option is (B).

Quick Tip to Solve: For ecosystem productivity comparisons, compare output per unit area, not total geographical area.

11. Bt-toxin genes have been expressed in plants in order to provide resistance against:

- (i) lepidopterans and fungi
- (ii) animals and bacteria
- (iii) coleopterans and dipterans
- (iv) lepidopterans

Options:

[1 mark]

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

Correct Answer: (C) (iii) and (iv)

Solution:

Concept:

- *Bacillus thuringiensis* produces insecticidal proteins encoded by cry genes; selected genes can be expressed in crop plants.
- Different Bt toxins act against particular insect groups, including lepidopterans, coleopterans and dipterans.

Step 1: Evaluate the four listed groups Lepidopterans include caterpillars of moths and butterflies, coleopterans include beetles, and dipterans include flies and mosquitoes. Bt toxin genes can provide resistance to susceptible insects in these groups, so statements (iii) and (iv) are correct.

Step 2: Reject the mixed groups Statement (i) incorrectly includes fungi, while statement (ii) incorrectly groups animals generally with bacteria. Bt toxins are not general agents against all animals, bacteria or fungal pathogens. Consequently, every option containing (i) or (ii) must be rejected: (A), (B) and (D) fail this check.

Step 3: Conclusion The correct combination is (iii) and (iv). Hence, the correct option is (C).

Quick Tip to Solve: Associate Bt with susceptible insects; reject a combination that adds fungi or bacteria.

12. According to IUCN, some of the extinctions include:

- (i) Dodo
- (ii) Indian gazelle
- (iii) Thylacine
- (iv) Steller's Sea Cow

Options:

[1 mark]

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

Correct Answer: (C) (i), (iii) and (iv)

Solution:

Concept:

- Extinction means that no living individual of a species remains anywhere in the world.
- Dodo, thylacine and Steller's sea cow are well-known examples of extinct animals.

Step 1: Identify the extinct species The dodo of Mauritius, the thylacine of Australia and Steller's sea cow of Russia are the extinction examples in the list. They correspond to statements (i), (iii) and (iv).

Step 2: Separate extinction from a surviving species The Indian gazelle, also called the chinkara, is an extant species and must not be included. Options (A) and (B) incorrectly include statement (ii). Option (D) lists two extinct species but omits the dodo; only option (C) contains the complete correct set.

Step 3: Conclusion The extinct animals are (i), (iii) and (iv). Hence, the correct option is (C).

Quick Tip to Solve: Check both inclusion and completeness: an option must exclude the gazelle and retain the dodo.

13. Assertion (A): Genetically modified microbes help in crop protection.

Reason (R): *Bacillus thuringiensis* (Bt) bacteria control insects by producing prototoxins. [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:

- Microbial genes for insecticidal products can be used in biotechnology to protect crop plants from insect pests.
- Bt toxin is produced as an inactive protoxin and becomes active in the alkaline gut of a susceptible insect.

Step 1: Judge the assertion The assertion is true. Genetically modified microbes can help crop protection by producing useful pest-control products; microbial insecticidal genes also supply important tools for engineering insect-resistant crops.

Step 2: Judge the reason The reason is true. *Bacillus thuringiensis* produces insecticidal proteins in an inactive protoxin form. After ingestion, the alkaline insect gut activates the toxin, which binds to midgut epithelial cells and forms pores, damaging these cells and killing the susceptible insect.

Step 3: Test the explanatory link The production of insecticidal protoxins provides the biological basis for using microbial biotechnology in crop protection. Thus the reason explains how microbial toxin production can protect crops, rather than merely stating an unrelated feature of the organism.

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

Quick Tip to Solve: Connect crop protection to toxin action: inactive protoxin becomes active inside the insect gut.

14. Assertion (A): *Trichoderma* species are free living fungi that are very common in the root ecosystems.

Reason (R): They are effective bio-control agents of several plant pathogens.

[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:

- *Trichoderma* species are free-living fungi commonly found in root ecosystems.
- A biological control agent suppresses pests or pathogens through the action of a living organism.

Step 1: Judge the assertion The assertion is true: *Trichoderma* species are free-living fungi and are very common in the root ecosystems of plants. This statement describes their mode of life and usual habitat.

Step 2: Judge the reason The reason is also true: *Trichoderma* species are effective biological control agents against several plant pathogens. Their antagonistic interactions with pathogens are useful for protecting plants.

Step 3: Test whether the reason explains the assertion Being useful as a biocontrol agent does not explain why these fungi are free-living or why they commonly occur in root ecosystems. The reason describes a useful biological role, whereas the assertion describes habitat and lifestyle. Therefore both statements are correct, but the required explanatory relationship is absent.

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: For assertion-reason items, distinguish an organism's useful role from the cause of its habitat.

15. Assertion (A): The endometrium undergoes cyclic changes during the menstrual cycle.

Reason (R): Perimetrium contracts strongly during delivery of the baby.

[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:

- The uterine wall has an outer perimetrium, a middle muscular myometrium and an inner glandular endometrium.
- Ovarian hormones regulate cyclical changes in the endometrium; the myometrium supplies the strong contractions of childbirth.

Step 1: Evaluate the assertion The assertion is true. The endometrium proliferates, becomes thick and secretory in preparation for implantation, and is shed during menstruation if pregnancy does not occur. These changes recur during the menstrual cycle.

Step 2: Evaluate the reason The reason is false. It is the smooth muscle of the myometrium that contracts strongly during delivery. The perimetrium is the thin external covering of the uterus, not its contractile muscular layer.

Step 3: Check the explanatory link A false reason cannot explain the true assertion. Options (A) and (B) incorrectly regard the reason as true, while option (D) incorrectly regards the assertion as false.

Step 4: Conclusion Assertion is true, but Reason is false. Hence, the correct option is (C).

Quick Tip to Solve: Link endometrium with the menstrual cycle and myometrium with muscular contractions during childbirth.

16. Assertion (A): Repetitive sequences make up a very large portion of human genome.

Reason (R): Repetitive sequences do not have direct coding functions in the genome. [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:

- Repetitive DNA consists of stretches of DNA whose sequences occur many times in the genome.
- The abundance of a DNA sequence and its protein-coding function are distinct properties of the genome.

Step 1: Evaluate the assertion The assertion is true. Repetitive sequences constitute a very large portion of the human genome. Their repeated occurrence, sometimes in hundreds or thousands of copies, distinguishes them from single-copy sequences.

Step 2: Evaluate the reason The reason is true in the NCERT description: repetitive sequences do not have direct coding functions. This does not mean that they are biologically irrelevant; they can shed light on chromosome structure, dynamics and evolution.

Step 3: Test whether the reason explains the assertion The absence of a direct coding function does not explain why these sequences occupy a large portion of the genome. The reason states a property, not a cause of their abundance. Thus option (A) makes an unsupported explanatory connection, while (C) and (D) incorrectly treat one of the true statements as false.

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

Quick Tip to Solve: After checking both statements, test the causal link separately: a true property need not explain another true property.

Section B (10 marks)

17. Draw a labelled diagram of the embryonic stage that gets implanted in the human uterus. State the functions of two labelled parts. [2 marks]

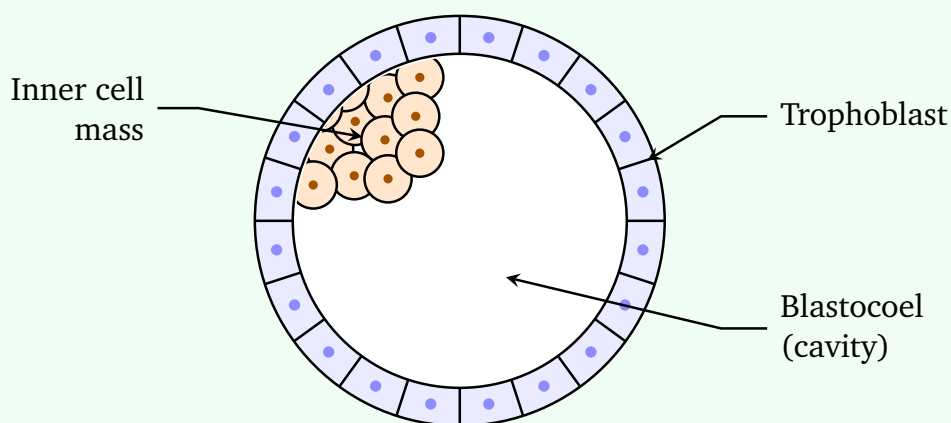
Solution:

Concept:

- Cleavage converts the zygote into a morula, which develops into a blastocyst as it reaches the uterus.

- A blastocyst has an outer trophoblast, an inner cell mass at one pole and a fluid-filled cavity called the blastocoel.

Step 1: Identify and draw the implantation stage The embryonic stage that gets implanted is the **blastocyst**. Its trophoblast forms the outer layer, while the inner cell mass is attached internally at one pole. The central cavity is labelled to distinguish this hollow stage from the solid morula. The schematic section below shows these structures.



Labelled schematic section of a human blastocyst

Step 2: State the functions of the labelled parts **Trophoblast:** This outer cell layer attaches to the uterine endometrium and helps establish implantation. Subsequently, trophoblast-derived chorionic villi participate in forming the fetal component of the placenta.

Inner cell mass: These cells differentiate to form the embryo proper. They give rise to the embryonic tissues from which the body of the developing baby is formed.

Step 3: Conclusion The blastocyst is implanted in the uterus. Its trophoblast supports attachment and implantation, and its inner cell mass develops into the embryo proper.

Quick Tip to Solve: Draw a hollow blastocyst with an outer cell layer and a cell cluster at one pole; label trophoblast and inner cell mass before stating their functions.

18(a). Mention the functions of each of the following:

(i) Tassels of Corn Cob

(ii) Scutellum

[2 marks]

Solution:

Concept:

- Wind-pollinated flowers have exposed receptive structures that efficiently intercept airborne pollen grains.
- The scutellum is the single, shield-shaped cotyledon of a grass embryo, such as maize; it helps nourish the embryo during germination.

Step 1: Explain the function of tassels on the corn cob The silky tassels projecting from the corn

cob represent the elongated styles and stigmas of its female flowers. Their function is to **trap pollen grains carried by wind**. Their exposed surfaces increase the chance of receiving pollen. A compatible pollen grain germinates on the stigma, and its pollen tube grows through the style towards the ovule, enabling fertilisation.

Step 2: Explain the function of the scutellum The **scutellum absorbs nutrients from the endosperm and transfers them to the developing embryo** during seed germination. It lies between the embryo axis and the food-storing endosperm, allowing the young seedling to use stored reserves before it can make sufficient food by photosynthesis. It is a cotyledon, rather than the endosperm itself.

Step 3: Conclusion (i) Tassels of the corn cob catch wind-borne pollen. (ii) The scutellum absorbs endosperm nutrients and supplies them to the growing embryo.

Quick Tip to Solve: Associate the exposed corn-cob silks with pollen capture and the scutellum inside the seed with nutrient absorption.

OR

18(b). Farmers prefer apomictic seeds over hybrid seeds. Give any two reasons.

[2 marks]

Solution:

Concept:

- Apomixis is seed formation without fertilisation. It can preserve the maternal plant's genetic constitution in the offspring.
- In ordinary sexually produced hybrid seeds, segregation in later generations can break up the desirable combination of parental characters.

Step 1: Retention of desirable hybrid characters If a hybrid is made apomictic, its seeds develop without the normal meiotic segregation and fertilisation involved in sexual reproduction. The hybrid characters are therefore maintained in the offspring, allowing farmers to retain the desirable traits and hybrid vigour over successive generations.

Step 2: Reduced recurring cost of seeds Seeds collected from an ordinary hybrid crop do not reliably reproduce the same hybrid performance, so farmers usually need to buy fresh hybrid seeds for each crop. Apomictic seed can be collected from the crop and sown again while maintaining the desirable parental characters. This reduces the recurring expense of purchasing costly hybrid seeds.

Step 3: Conclusion Farmers prefer apomictic seeds because they preserve desirable hybrid characters across generations and allow seed reuse, reducing the cost of buying fresh hybrid seed each season.

Quick Tip to Solve: Link apomixis to two benefits: no segregation of hybrid traits, and no repeated purchase of hybrid seed.

19(a). Suggest how a virus-free healthy plant can be obtained from a diseased sugarcane plant.

[2 marks]

Solution:

Concept:

- Meristem culture is tissue culture using a small piece of actively dividing meristematic tissue as the explant.
- The apical and axillary meristems can remain free of viruses even when the rest of a plant is infected; their cells can regenerate a complete plant under suitable culture conditions.

Step 1: Select and excise a healthy meristem Select the shoot apical meristem or an axillary meristem from the diseased sugarcane plant. Excise a small meristem tip aseptically, avoiding the surrounding infected mature tissue. This region is used because the meristem is generally free of the virus present elsewhere in the plant.

Step 2: Regenerate a complete plant in culture Place the excised meristem on a sterile nutrient medium containing the required minerals, sugar and growth regulators. Under controlled conditions, allow it to develop shoots and roots to form a complete plantlet. Acclimatise the regenerated plantlet and transfer it to soil to establish a healthy sugarcane plant.

Step 3: Conclusion A virus-free sugarcane plant can be obtained by culturing an excised, virus-free apical or axillary meristem from the diseased plant and regenerating it into a complete plant.

Quick Tip to Solve: Name meristem culture and specify the apical or axillary meristem; an arbitrary infected tissue explant is unsuitable.

OR

19(b). In order to force bacteria to take up the recombinant DNA, they must be made competent. Explain how it can be achieved.

[2 marks]

Solution:

Concept:

- Competent bacterial cells are cells prepared to take up foreign DNA from their surroundings during transformation.
- DNA is hydrophilic and does not readily pass through the bacterial cell membrane; chemical treatment followed by heat shock promotes its uptake.

Step 1: Treat the bacteria with calcium ions Treat bacterial cells with a suitable concentration of a divalent cation such as calcium, usually supplied as calcium chloride. This treatment makes the cells competent by increasing the efficiency with which DNA enters through pores in the cell wall. The treated cells can then be mixed with the recombinant DNA.

Step 2: Use an ice–heat shock–ice sequence Incubate the competent bacterial cells with recombinant DNA on ice. Expose them briefly to a temperature of 42 °C, a treatment called heat shock, and then place them back on ice. This temperature sequence enables the bacteria to take up the recombinant

DNA; cells that have taken it up are transformed cells.

Step 3: Conclusion Bacteria are made competent by calcium-ion treatment, then incubated with recombinant DNA on ice, briefly heat-shocked at 42 °C, and returned to ice to facilitate DNA uptake.

Quick Tip to Solve: Recall the ordered sequence: calcium treatment, DNA on ice, heat shock at 42 °C, then ice again.

20(a). Differentiate between grazing food chain and detritus food chain.

[2 marks]

Solution:

Concept:

- A food chain represents the transfer of food and its energy through successive organisms in an ecosystem.
- Grazing and detritus food chains differ in their starting material and in the organisms that first obtain energy from that material.

Step 1: Compare the starting point A grazing food chain begins with living green plants, which capture solar energy by photosynthesis and produce organic food. A detritus food chain begins with dead organic matter, such as fallen leaves, animal remains and organic wastes. Its initial energy source is therefore the chemical energy already stored in this detritus.

Step 2: Compare the first consumers In a grazing food chain, herbivores consume the living plants and are subsequently eaten by carnivores; for example, grass → grasshopper → frog. In a detritus food chain, decomposers such as bacteria and fungi obtain nutrients from dead organic matter. They secrete enzymes, digest the material externally and absorb the products; detritivores also feed on and fragment detritus.

Step 3: Conclusion The grazing food chain starts with living producers and passes first to herbivores, whereas the detritus food chain starts with dead organic matter and is associated with decomposers and detritivores.

Quick Tip to Solve: Compare both chains on the same two bases: their starting material and the organisms that first feed on it.

OR

20(b). Ecological pyramids are widely accepted but they still have some limitations. Write any two limitations.

[2 marks]

Solution:

Concept:

- An ecological pyramid represents the number, biomass or energy of organisms at successive trophic levels, beginning with producers at its base.
- A trophic level describes an organism's feeding position. Actual ecosystems contain interconnected

feeding relationships that are more complex than a single chain.

Step 1: Identify the restriction to a simple food chain Ecological pyramids assume a simple food chain and do not accommodate a food web. In nature, a consumer can feed on several species, and different food chains become interconnected. A single pyramid therefore cannot represent all these feeding links and alternative pathways of energy transfer.

Step 2: Identify the missing decomposer component Saprophytes or decomposers are not given a place in ecological pyramids, although they perform an essential role in ecosystems. They break down dead organic matter and wastes originating from organisms at different trophic levels and release inorganic nutrients for reuse by producers. Their activity cannot be placed neatly at one successive level of a grazing-chain pyramid.

Step 3: Conclusion Two limitations are that ecological pyramids do not accommodate food webs and do not assign a place to saprophytes (decomposers).

Quick Tip to Solve: For two distinct limitations, recall the feeding links omitted (food webs) and the organisms omitted (decomposers).

21. One of the salient features of the genetic code is that it is nearly universal from bacteria to humans. Mention two exceptions to this rule. Why are some codes said to be degenerates? [2 marks]

Solution:

Concept:

- The genetic code is nearly universal: a given codon usually specifies the same amino acid in organisms ranging from bacteria to humans.
- Degeneracy means that more than one codon can specify the same amino acid. It does not mean that a single codon normally specifies several different amino acids.

Step 1: State the exceptions to universality The two exceptions are the genetic code used in **mitochondria** and that used in **some protozoans**. In these systems, certain codons have meanings different from those in the standard genetic code. Thus, universality is described as nearly universal rather than absolutely universal; the exceptions concern codon assignment, not the use of triplet codons.

Step 2: Explain degeneracy with an example Some amino acids are encoded by two or more different codons, so the genetic code is described as degenerate. For example, the mRNA codons UUU and UUC both specify phenylalanine. Each of these codons still specifies only phenylalanine in the standard code, so degeneracy is compatible with the code being unambiguous.

Step 3: Conclusion Mitochondria and some protozoans show exceptions to universality. Degeneracy refers to the specification of one amino acid by more than one codon.

Quick Tip to Solve: Remember the direction: several codons can give one amino acid; this is degeneracy, not ambiguity.

Section C (21 marks)

22. (a) Draw a sectional view of seminiferous tubule of a human. Label the following cells in the seminiferous tubule:

(i) Cells that divide by mitosis to increase their number

(ii) Cells that undergo meiosis I

(iii) Cells that undergo meiosis II

(iv) Cells that help in the process of spermiogenesis

(b) Mention the role of Leydig cells.

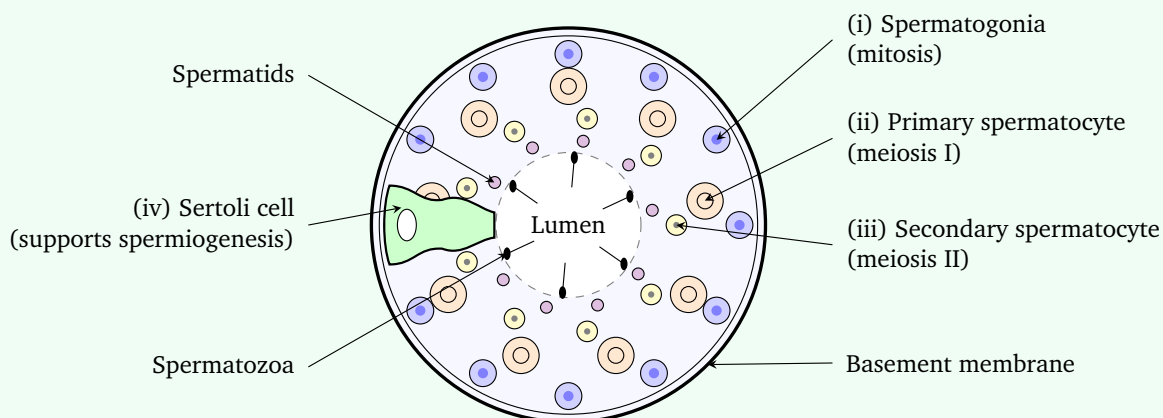
[3 marks]

Solution:

Concept:

- Spermatogenesis takes place in the seminiferous tubules. Germ cells develop from the outer germinal epithelium towards the lumen, with Sertoli cells providing support and nourishment.
- Diploid spermatogonia multiply by mitosis. Primary spermatocytes undergo meiosis I, and the resulting secondary spermatocytes undergo meiosis II to form spermatids.
- Spermiogenesis is the transformation of spermatids into spermatozoa; it involves differentiation rather than another cell division.

Step 1: Draw and identify the cells in part (a) The sectional view shows the basement membrane around the tubule and its central lumen. The germ cells are arranged in their developmental sequence from the periphery towards the lumen. The required labels are: (i) spermatogonia, (ii) primary spermatocytes, (iii) secondary spermatocytes and (iv) Sertoli cells. Sertoli cells extend through the germinal epithelium and support the developing germ cells.



Sectional view of a seminiferous tubule (schematic); the four requested cell types are numbered (i)–(iv).

Step 2: Relate the labels to their functions Spermatogonia near the basement membrane divide by mitosis to increase their number. Some enlarge into primary spermatocytes. Each primary spermatocyte undergoes meiosis I to form two haploid secondary spermatocytes; each secondary spermatocyte then undergoes meiosis II to produce two haploid spermatids. Sertoli cells nourish and support the germ cells and help spermatids differentiate into spermatozoa during spermiogenesis. Spermiogenesis must not be confused with spermiation, the release of spermatozoa into the lumen.

Step 3: State the role of Leydig cells in part (b) Leydig cells, also called interstitial cells, occur in the spaces outside and between seminiferous tubules. They synthesise and secrete testicular androgens, chiefly testosterone. These hormones stimulate spermatogenesis and support the development and maintenance of male reproductive organs and secondary sexual characters.

Step 4: Conclusion Labels (i)–(iv) are spermatogonia, primary spermatocytes, secondary spermatocytes and Sertoli cells, respectively. Leydig cells secrete androgens, principally testosterone.

Quick Tip to Solve: Trace cells from the basement membrane towards the lumen: spermatogonia, primary spermatocytes, secondary spermatocytes, spermatids and spermatozoa.

23. Explain the polygenic inheritance pattern with the help of a suitable example.

[3 marks]

Solution:

Concept:

- Polygenic inheritance occurs when a single character is controlled by several genes whose effects are additive.
- The phenotype depends on the total contribution of the contributing alleles, producing quantitative variation; environmental conditions may also influence its expression.

Step 1: Explain the additive inheritance pattern In polygenic inheritance, each contributing allele adds a small amount to the expression of the same trait. No single gene alone determines the complete phenotype. Individuals carrying different numbers of contributing alleles therefore show a range of phenotypes, with intermediates more common than the extremes.

Step 2: Apply the pattern to human skin colour In the simplified three-gene model, human skin colour is controlled by three pairs of genes, A/a , B/b and C/c . Each capital-letter allele contributes an equal amount of melanin pigment, while its corresponding small-letter allele contributes no additional pigment in this model. Thus, $AABBCC$, with six contributing alleles, has the darkest skin colour, whereas $aabbcc$, with none, has the lightest.

Step 3: Trace the cross and the intermediate phenotypes Crossing the two extremes gives

$$AABBCC \times aabbcc \longrightarrow AaBbCc.$$

All F_1 individuals have three contributing alleles and an intermediate skin colour. On intercrossing the F_1 , independent assortment produces offspring with zero to six contributing alleles. The seven pigment classes occur in the idealised F_2 ratio 1 : 6 : 15 : 20 : 15 : 6 : 1, from one extreme to the other; the middle class is most frequent.

Step 4: Conclusion Human skin colour illustrates polygenic inheritance: the combined additive effects of several genes determine the amount of pigment, yielding many intermediate phenotypes between the two parental extremes.

Quick Tip to Solve: Count the capital-letter alleles across all three gene pairs; genotypes with the same total have the same pigment contribution in this model.

24. Mention a product of human welfare obtained with the help of each one of the following:

- (a) *Saccharomyces cerevisiae*
- (b) *Propionibacterium shermanii*
- (c) *Aspergillus niger*
- (d) *Trichoderma polysporum*
- (e) *Acetobacter aceti*
- (f) *Streptococcus*

[3 marks]

Solution:

Concept:

- Microbes produce useful food products, organic acids, enzymes and medicines during controlled growth or fermentation.
- The desired product depends on the particular microorganism; each name must therefore be matched to its specific industrial or medicinal product.

Step 1: Identify the fermentation and food products in parts (a) and (b) (a) *Saccharomyces cerevisiae*: **ethanol**, obtained by fermentation of sugars. This yeast is used in brewing and in the production of alcoholic beverages.

(b) *Propionibacterium shermanii*: **Swiss cheese**. Its activity contributes to cheese production, and the large holes characteristic of Swiss cheese result from the carbon dioxide it produces.

Step 2: Identify the acid and medicinal product in parts (c) and (d) (c) *Aspergillus niger*: **citric acid**, an organic acid produced commercially using this fungus.

(d) *Trichoderma polysporum*: **cyclosporin A**, an immunosuppressive agent used in organ-transplant patients to help prevent rejection of the transplanted organ.

Step 3: Identify the products in parts (e) and (f) (e) *Acetobacter aceti*: **acetic acid**, the acid present in vinegar. This bacterium converts alcohol into acetic acid under aerobic conditions.

(f) *Streptococcus*: **streptokinase**, a microbial enzyme used as a clot buster to help remove blood clots in blood vessels of patients who have suffered myocardial infarction.

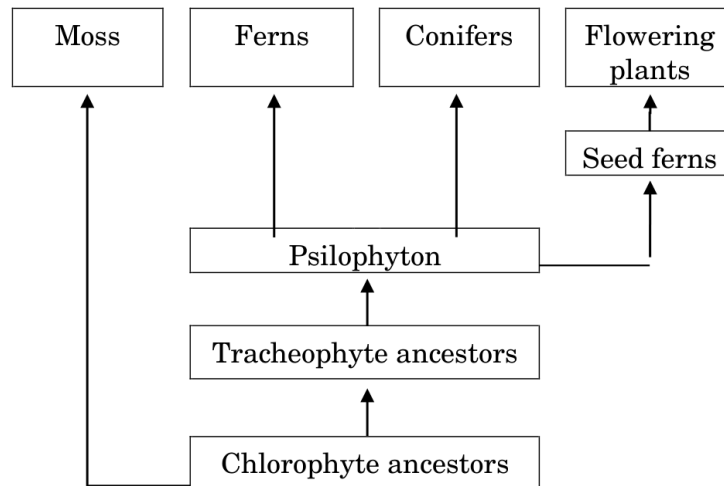
Step 4: Conclusion The products, in order (a)–(f), are ethanol, Swiss cheese, citric acid, cyclosporin A, acetic acid and streptokinase.

Quick Tip to Solve: Pair *Streptococcus* with streptokinase and *Trichoderma* with cyclosporin A; the former removes clots, while the latter suppresses immune responses.

25. Study the given chart showing evolution of plants. Answer the following questions:

- (a) Identify the plant which acts as an immediate ancestor of both ferns and conifers.
- (b) Name the nearest ancestors of flowering plants.
- (c) Name the most primitive group of plants.
- (d) *Psilophyton* provides common ancestry to which classes?
- (e) Name the common ancestor of *psilophyton* and seed ferns.
- (f) Name the common ancestor of mosses and tracheophytes.

[3 marks]



Solution:

Concept:

- In an evolutionary chart, follow arrows from an ancestral group towards its descendants. A direct connecting arrow identifies the immediate ancestor shown.
- To identify common ancestry, trace the relevant branches backwards to their shared ancestral stock; the lowest ancestral group in this chart represents its most primitive group.

Step 1: Trace the immediate ancestors in parts (a) and (b) (a) ***Psilophyton*** acts as the immediate ancestor of both ferns and conifers. Separate upward arrows from its box lead directly to these two groups.

(b) **Seed ferns** are the nearest ancestors of flowering plants. The arrow immediately below the flowering-plants box comes from the seed-ferns box.

Step 2: Identify the basal group and descendant classes in parts (c) and (d) (c) **Chlorophyte ancestors**, or green-algal ancestors, form the most primitive group shown. They occupy the base of the chart, before the moss and tracheophyte lineages diverge.

(d) *Psilophyton* provides common ancestry to **ferns (pteridophytes) and gymnosperms**, represented by conifers and the seed-fern lineage. The chart shows direct branches towards ferns and conifers and a branch towards seed ferns; flowering plants arise subsequently through seed ferns.

Step 3: Trace the common ancestral stocks in parts (e) and (f) (e) **Tracheophyte ancestors** are the ancestral stock common to *Psilophyton* and seed ferns. The chart runs from tracheophyte ancestors to *Psilophyton*, and then towards seed ferns.

(f) **Chlorophyte ancestors** are the common ancestors of mosses and tracheophytes. From this basal

box, one branch leads to moss and the other to tracheophyte ancestors.

Step 4: Conclusion (a) *Psilophyton*; (b) seed ferns; (c) chlorophyte ancestors; (d) ferns and gymnosperms (conifers and the seed-fern lineage); (e) tracheophyte ancestors; (f) chlorophyte ancestors.

Quick Tip to Solve: For a nearest ancestor, follow just one arrow backwards; for a common ancestral stock, trace both lineages backwards to their shared origin.

26. (a) Write the scientific name of the nematode that infects tobacco plants. Also name the part of the plant that it infects.

(b) How is *Agrobacterium* used to protect tobacco plants from attack by this pest?

[3 marks]

Solution:

Concept:

- RNA interference (RNAi) is a cellular defence mechanism in which double-stranded RNA silences a complementary messenger RNA, preventing its translation.
- A disarmed *Agrobacterium* vector can introduce selected DNA sequences into plant cells to produce a transgenic plant.

Step 1: Identify the pest and its site of infection (a) The nematode is *Meloidogyne incognita*. It infects the roots of tobacco plants and reduces their yield. The roots, rather than the leaves, are the site of infection asked for here.

Step 2: Introduce nematode-specific sequences into tobacco (b) Using *Agrobacterium* as the vector, nematode-specific gene sequences are introduced into the host tobacco plant. The inserted DNA is designed so that the plant produces both sense RNA and antisense RNA corresponding to the target nematode gene. These two RNA strands are complementary and pair to form double-stranded RNA.

Step 3: Explain how RNA interference protects the plant The double-stranded RNA initiates RNA interference, which silences the specific complementary nematode mRNA and prevents its translation. Consequently, the nematode cannot produce the essential protein encoded by that mRNA. The parasite cannot survive in the transgenic host expressing this interfering RNA, so the tobacco plant is protected. *Agrobacterium* supplies the gene-delivery system; the protection itself results from sequence-specific RNA silencing.

Step 4: Conclusion *Meloidogyne incognita* infects tobacco roots. *Agrobacterium*-mediated introduction of nematode-specific sequences produces complementary RNAs that trigger RNAi and prevent the parasite's survival.

Quick Tip to Solve: Write the protective sequence in order: sense and antisense RNA, double-stranded RNA, specific mRNA silencing, and failure of nematode survival.

27. Explain the level of biodiversity at genetic, species and ecological levels with the help of one example each. [3 marks]

Solution:

Concept:

- Biodiversity includes variation within a species, diversity among species, and diversity of ecosystems in a region.
- Genetic, species and ecological diversity describe different levels of biological organisation; an example must match the level being explained.

Step 1: Explain diversity within a species Genetic diversity is the variation in genes within a species, including differences among its populations across its distributional range. For example, populations of *Rauwolfia vomitoria* growing in different Himalayan ranges vary genetically in the potency and concentration of the active chemical reserpine that they produce. These are genetic differences within the same species, rather than differences between separate species.

Step 2: Explain diversity among species Species diversity refers to the variety of species present in a region. For example, the Western Ghats have greater amphibian species diversity than the Eastern Ghats. This comparison concerns the variety of amphibian species in the two regions, rather than genetic differences among individuals of one amphibian species.

Step 3: Explain diversity of ecosystems Ecological diversity refers to the variety of ecosystems, habitats and associated ecological processes in a geographical region. For example, India has deserts, rain forests, mangroves, coral reefs, wetlands, estuaries and alpine meadows, and therefore has greater ecosystem diversity than a Scandinavian country such as Norway. These different ecosystems support different communities under different environmental conditions.

Step 4: Conclusion Genetic diversity is variation within a species, species diversity is the variety of species, and ecological diversity is the variety of ecosystems; the examples above illustrate each distinct level.

Quick Tip to Solve: Match each example to its scale: variation in one species, variety of species in a region, or variety of ecosystems in a country.

28. Explain Gause's 'Competitive Exclusion Principle' with the help of a suitable example. [3 marks]

Solution:

Concept:

- Interspecific competition occurs when different species use the same limited resources, adversely affecting their growth, survival or reproduction.
- Gause's competitive exclusion principle predicts that complete competitors cannot coexist indefinitely when they depend on the same limiting resources under unchanged conditions.

Step 1: State the competitive exclusion principle Gause's principle states that two closely related species competing for the same resources cannot coexist indefinitely, and the competitively inferior species will eventually be eliminated locally. The principle applies when resources are limiting and

the two species have essentially the same requirements. Merely occupying the same geographical area does not establish competitive exclusion if the species use different resources.

Step 2: Illustrate exclusion with competing barnacles In Connell's field experiments on rocky sea coasts of Scotland, the larger and competitively superior barnacle *Balanus* excluded the smaller barnacle *Chthamalus* from the lower intertidal region. Both could use space in this region, but *Balanus* was the more effective competitor for the available space, restricting *Chthamalus* to the upper region.

Step 3: Connect the observation to the principle When *Balanus* was removed experimentally, *Chthamalus* could occupy the lower region. This showed that competition, rather than an inability to live there, explained its exclusion from that region. The inferior competitor was excluded locally; the principle does not imply extinction of that species everywhere. Species may coexist when they reduce competition by partitioning their resources.

Step 4: Conclusion Complete competitors sharing limiting resources cannot coexist indefinitely. The exclusion of *Chthamalus* from the lower intertidal zone by *Balanus* illustrates Gause's competitive exclusion principle.

Quick Tip to Solve: Include the limiting resource and identify both competitors: in the barnacle example, competition for space excludes the smaller barnacle from the lower zone.

Section D (8 marks)

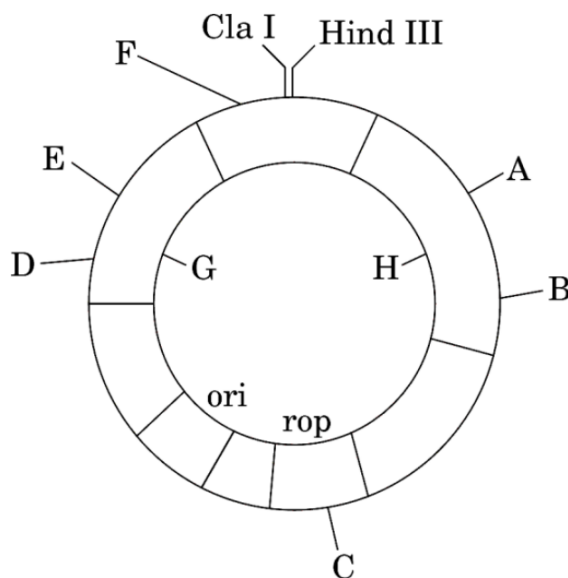
Questions No. 29 and 30 are Case-Based questions. Each question has 3 sub-questions with internal choice in one sub-question.

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

We know that plasmids and bacteriophages are the most commonly used vectors in biotechnology experiments. If we can link an alien piece of DNA to the plasmid DNA, the alien DNA can be multiplied equal to the copy number of the plasmid. Engineered vectors are used these days. Study the diagram of the *E. coli* cloning vector pBR322 and answer the questions that follow:

Why are plasmids and bacteriophages used as cloning vectors?

[1 mark]



Solution:

Concept:

- A cloning vector carries an inserted DNA fragment into a host and enables the fragment to be copied there.
- Plasmids and bacteriophages possess the ability to replicate within bacterial cells.

Step 1: Identify the useful property of these vectors Plasmids and bacteriophages can replicate within bacterial cells. Plasmids replicate independently of the bacterial chromosomal DNA, while bacteriophages multiply their genomes in suitable bacterial hosts.

Step 2: Relate replication to cloning the inserted DNA When an alien DNA fragment is linked to the vector DNA, it is copied along with the vector. Thus, many copies of the desired DNA can be obtained; the number of copies depends on the replication and copy number of the vector. Their ability to carry and amplify foreign DNA makes them useful cloning vectors.

Step 3: Conclusion Plasmids and bacteriophages are used as cloning vectors because they replicate in bacterial hosts and thereby multiply the foreign DNA inserted into them.

Quick Tip to Solve: For a question asking why a vector is used, connect its replication in the host directly to multiplication of the inserted foreign DNA.

29(b)(i). Read the following passage and answer the questions that follow:

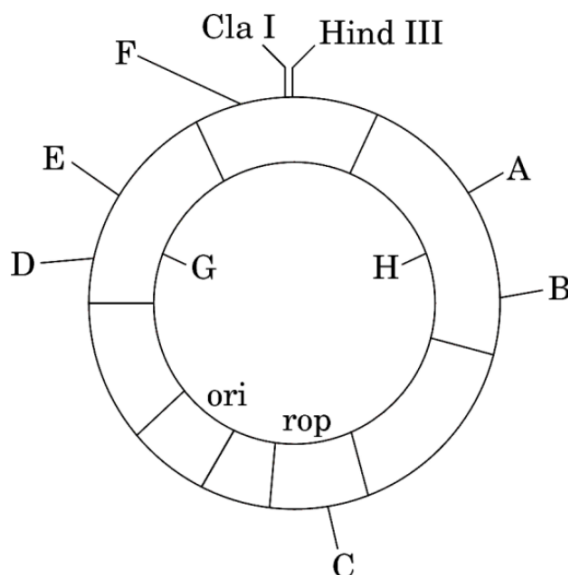
We know that plasmids and bacteriophages are the most commonly used vectors in biotechnology experiments. If we can link an alien piece of DNA to the plasmid DNA, the alien DNA can be multiplied equal to the copy number of the plasmid. Engineered vectors are used these days. Study the diagram of the *E. coli* cloning vector pBR322 and answer the questions that follow:

Identify:

(I) The gene in the cloning vector that controls the copy number of the vector.

(II) The restriction site - C in the 'rop' gene.

[1 mark]



Solution:

Concept:

- A plasmid replicates in its bacterial host; its copy number is regulated by sequences and proteins associated with replication.
- The *rop* gene encodes a protein involved in replication control, whereas *ori* is the origin sequence at which replication begins.

Step 1: Identify the replication-control gene For part (I), identify *rop*. Its product regulates plasmid replication and hence helps control copy number. The question asks for a gene, so distinguish *rop* from *ori*, which is a DNA sequence rather than a protein-coding gene.

Step 2: Locate the restriction site in the map For part (II), C marks the site in the lower part of the pBR322 map, in the *rop* region. This is the recognition site for PvuII; it should not be confused with the PvuI site in the ampicillin-resistance region.

Step 3: Conclusion (I) *rop* gene; (II) C is the PvuII restriction site.

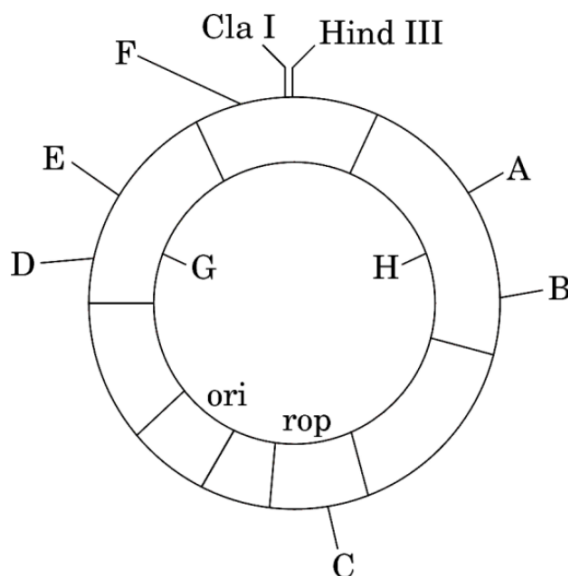
Quick Tip to Solve: Separate the replication origin *ori* from the regulatory gene *rop*; C at the bottom of this map is PvuII.

29(b)(ii). Read the following passage and answer the questions that follow:

We know that plasmids and bacteriophages are the most commonly used vectors in biotechnology experiments. If we can link an alien piece of DNA to the plasmid DNA, the alien DNA can be multiplied equal to the copy number of the plasmid. Engineered vectors are used these days. Study the diagram of the E. coli cloning vector pBR322 and answer the questions that follow:

Identify and name two selectable markers shown in the diagram.

[1 mark]



Solution:

Concept:

- A selectable marker lets cells carrying a cloning vector be distinguished from cells that have not acquired it.
- The pBR322 plasmid carries genes conferring resistance to ampicillin and tetracycline; these antibiotic-resistance genes serve as selectable markers.

Step 1: Identify the left-hand marker G is the ampicillin-resistance gene, written amp^R . A host bacterium with a functional copy of this marker can grow on an ampicillin-containing medium, whereas an ampicillin-sensitive non-transformant cannot.

Step 2: Identify the right-hand marker H is the tetracycline-resistance gene, written tet^R . This marker permits selection on tetracycline-containing medium. The *ori* and *rop* regions regulate replication and do not serve as these antibiotic-resistance markers.

Step 3: Conclusion G: amp^R , ampicillin resistance; H: tet^R , tetracycline resistance.

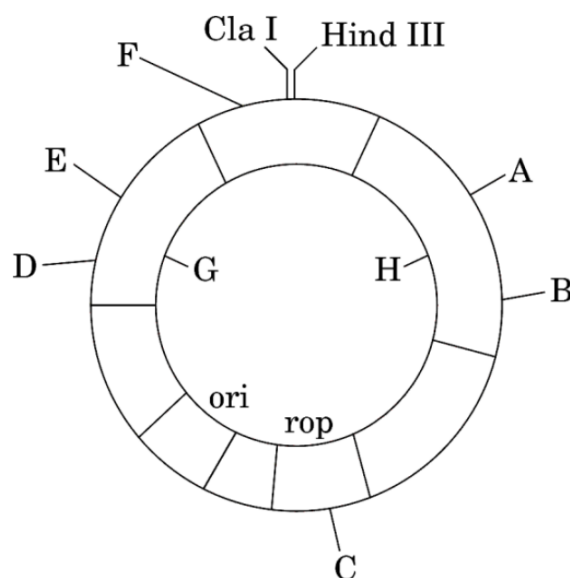
Quick Tip to Solve: On this pBR322 map, G is the left-hand ampicillin marker and H the right-hand tetracycline marker.

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

We know that plasmids and bacteriophages are the most commonly used vectors in biotechnology experiments. If we can link an alien piece of DNA to the plasmid DNA, the alien DNA can be multiplied equal to the copy number of the plasmid. Engineered vectors are used these days. Study the diagram of the *E. coli* cloning vector pBR322 and answer the questions that follow:

Name the two restriction sites each in the two genes you have identified as selectable markers.

[2 marks]



Solution:

Concept:

- The selectable markers of pBR322 are amp^R and tet^R , conferring resistance to ampicillin and tetracycline respectively.
- Restriction sites are specific DNA sequences recognised by restriction endonucleases. A site lying within a marker gene can be used for insertional inactivation of that gene.

Step 1: Read the sites in the ampicillin-resistance region G represents amp^R , the marker on the left of the circular map. Its two indicated restriction sites are PstI (E) and PvuI (D). These are the sites to associate with ampicillin resistance; the PvuII site C lies in the *rop* region and is not one of this pair.

Step 2: Read the sites in the tetracycline-resistance region H represents tet^R , the marker on the right of the map. The two sites indicated within this region are BamHI (A) and SalI (B). Inserting foreign DNA at a suitable site within a resistance gene can disrupt its function, allowing recombinants to be distinguished by loss of that resistance while the other marker remains functional.

Step 3: Conclusion amp^R (G): PstI and PvuI. tet^R (H): BamHI and SalI.

Quick Tip to Solve: Group the sites by the marker region: D/E belong to amp^R , A/B to tet^R ; do not include C (PvuII).

30(a). Read the following passage and answer the questions that follow:

The process of copying genetic information from template strand of DNA into RNA is called transcription. It is mediated by RNA polymerase. Transcription takes place in the nucleus of eukaryotic cells. In transcription, only a segment of DNA and only one of the strands is copied into RNA.

Why is the strand of DNA with $3' \rightarrow 5'$ polarity transcribed and not the other strand of $5' \rightarrow 3'$ polarity? [1 mark]

Solution:

Concept:

- RNA polymerase synthesises an RNA chain only in the $5' \rightarrow 3'$ direction, adding nucleotides to its free $3'$ end.
- Complementary DNA and RNA strands align antiparallel, so their polarities run in opposite directions.

Step 1: Apply the direction of RNA synthesis During elongation, RNA polymerase adds each incoming ribonucleotide to the $3'$ -OH end of the growing RNA. Therefore, the new transcript grows $5' \rightarrow 3'$; it cannot grow in the reverse direction.

Step 2: Match the template polarity To form an antiparallel complementary RNA, the enzyme must read the template DNA in the $3' \rightarrow 5'$ direction. The other DNA strand runs $5' \rightarrow 3'$ in this transcription unit and is the coding strand, rather than the template for this transcript.

Step 3: Conclusion The $3' \rightarrow 5'$ DNA strand is transcribed because RNA polymerase synthesises its complementary RNA only $5' \rightarrow 3'$.

Quick Tip to Solve: Write RNA as $5' \rightarrow 3'$, then reverse the arrow to obtain the template-reading direction.

30(b)(i). Read the following passage and answer the questions that follow:

The process of copying genetic information from template strand of DNA into RNA is called transcription. It is mediated by RNA polymerase. Transcription takes place in the nucleus of eukaryotic cells. In transcription, only a segment of DNA and only one of the strands is copied into RNA.

Why is hnRNA required to undergo splicing? [1 mark]

Solution:

Concept:

- In eukaryotes, the primary transcript called heterogeneous nuclear RNA (hnRNA) contains both exons and introns.
- Splicing removes the intervening introns and joins the exons in the correct order to form a continuous mature transcript.

Step 1: Identify the unwanted sequences The primary transcript copies intron sequences as well as exon sequences from DNA. Introns must be removed from this transcript; leaving them in the RNA would interrupt the sequence used to produce the correct polypeptide.

Step 2: Join the retained sequences During splicing, introns are excised and the exons are joined.

This makes the retained information continuous in the processed mRNA. Together with the other RNA-processing events, splicing prepares the transcript for normal translation.

Step 3: Conclusion hnRNA undergoes splicing to remove introns and join exons, producing the properly processed sequence needed for functional mRNA.

Quick Tip to Solve: Use the paired actions in your answer: introns are removed, and exons are joined in their original order.

OR

30(b)(ii). Read the following passage and answer the questions that follow:

The process of copying genetic information from template strand of DNA into RNA is called transcription. It is mediated by RNA polymerase. Transcription takes place in the nucleus of eukaryotic cells. In transcription, only a segment of DNA and only one of the strands is copied into RNA.

Mention the two additional processes which hnRNA needs to undergo after splicing to become functional.

[1 mark]

Solution:

Concept:

- Eukaryotic primary transcripts require end modifications as well as splicing to form mature, functional mRNA.
- Capping modifies the 5' end, whereas polyadenylation, also called tailing, modifies the 3' end of the transcript.

Step 1: Describe capping at the first end During capping, a modified guanine nucleotide, methyl guanosine triphosphate, is added to the 5' end of hnRNA. This cap helps protect the transcript and assists its recognition during translation.

Step 2: Describe tailing at the other end During tailing, about 200–300 adenylate residues are added to the 3' end in a template-independent manner, forming the poly-A tail. This modification helps stabilise the mRNA; together with capping and splicing it contributes to producing a functional transcript.

Step 3: Conclusion The two additional processes are **capping** at the 5' end and **tailing (polyadenylation)** at the 3' end.

Quick Tip to Solve: Remember the ends as a pair: a methyl-guanosine cap at 5', and an adenylate tail at 3'.

30(c). Read the following passage and answer the questions that follow:

The process of copying genetic information from template strand of DNA into RNA is called transcription. It is mediated by RNA polymerase. Transcription takes place in the nucleus of eukaryotic cells. In transcription, only a segment of DNA and only one of the strands is copied into RNA.

Why is only one strand of the DNA transcribed? Give two reasons.

[2 marks]

Solution:

Concept:

- For a given transcription unit, one DNA strand serves as the template and produces RNA complementary to its base sequence.
- The two DNA strands are complementary rather than identical; complementary RNA molecules can also pair with one another.

Step 1: Consider the information in the two possible transcripts If both DNA strands of the same transcription unit acted as templates, the two RNA molecules would have different base sequences. Their codons would therefore specify different amino-acid sequences and could produce two different polypeptides from the same DNA segment. This would complicate the transfer of genetic information instead of providing the specified message for that gene.

Step 2: Consider pairing between the two RNA molecules Because the DNA strands are complementary, RNA transcribed from one strand would be complementary to RNA transcribed from the other. The two RNAs could pair to form double-stranded RNA. Such pairing would prevent the RNA from functioning as the single-stranded messenger needed for translation by ribosomes.

Step 3: Conclusion Only one strand is transcribed for a given transcription unit to avoid producing two different genetic messages and to prevent complementary transcripts from forming double-stranded RNA that cannot serve normally in translation.

Quick Tip to Solve: Give two distinct consequences of transcribing both strands: different coding messages and complementary RNAs pairing together.

Section E (15 marks)

31(a). Work out separate monohybrid crosses up to F_2 generation between two pea plants and two Antirrhinum plants, both having contrasting traits with respect to the colour of the flower. Comment on the patterns of inheritance in the crosses carried out in such two cases.

[5 marks]

Solution:

Concept:

- A monohybrid cross follows one pair of contrasting traits. The two alleles segregate during gamete formation, so each gamete receives only one allele.
- In complete dominance, a heterozygote resembles the dominant parent. In incomplete dominance, the heterozygote has a phenotype intermediate between those of the two homozygotes.

Step 1: Cross true-breeding pea plants to obtain the first generation Let P represent the allele for

violet (purple) flowers and p the allele for white flowers in pea. Violet is completely dominant over white. Cross a homozygous violet-flowered plant with a homozygous white-flowered plant:

$$\begin{aligned}\text{Parents: } & PP \text{ (violet)} \times pp \text{ (white)} \\ \text{Gametes: } & P \qquad p \\ F_1 : & Pp \text{ (all violet)}.\end{aligned}$$

The white-flower allele is present in the hybrid but its expression is masked by the dominant allele.

Step 2: Self the pea hybrids to obtain the second generation Self-pollinate the F_1 hybrids: $Pp \times Pp$. Each parent produces P and p gametes in equal proportions. Their random union gives:

	P	p
P	PP	Pp
p	Pp	pp

Thus the F_2 genotypic ratio is $1 PP : 2 Pp : 1 pp$. Since both PP and Pp are violet, the phenotypic ratio is 3 violet : 1 white. Reappearance of white flowers shows that the recessive allele was retained in F_1 and segregated during gamete formation.

Step 3: Cross true-breeding Antirrhinum plants In *Antirrhinum* (snapdragon), let R denote the red-flower allele and r the white-flower allele. Here R is not completely dominant over r . Cross homozygous red and white plants:

$$\begin{aligned}\text{Parents: } & RR \text{ (red)} \times rr \text{ (white)} \\ \text{Gametes: } & R \qquad r \\ F_1 : & Rr \text{ (all pink)}.\end{aligned}$$

The heterozygous flowers are intermediate in colour; they resemble neither homozygous parent exactly.

Step 4: Self the pink hybrids and compare inheritance Self-pollinate the pink F_1 plants: $Rr \times Rr$. Each parent produces equal proportions of R and r gametes:

	R	r
R	RR	Rr
r	Rr	rr

The F_2 genotypic ratio is $1 RR : 2 Rr : 1 rr$, and the phenotypic ratio is 1 red : 2 pink : 1 white. The heterozygote is phenotypically distinct, so these two ratios coincide. The parental red and white phenotypes reappear, showing that the alleles remain discrete and do not permanently blend. Both crosses obey the law of segregation; their difference lies in the expression of the alleles in the heterozygote.

Step 5: Conclusion Pea flower colour shows complete dominance, with violet F_1 flowers and a 3 : 1 F_2 phenotypic ratio. *Antirrhinum* shows incomplete dominance, with pink F_1 flowers and a 1 : 2 : 1 F_2 phenotypic ratio. Both crosses have the same 1 : 2 : 1 F_2 genotypic ratio.

Quick Tip to Solve: Form the same heterozygote-by-heterozygote Punnett square in both crosses, then assign colours: the heterozygote is violet in pea but pink in snapdragon.

31(b)(i). Answer the following questions:

How does a chromosomal disorder differ from a Mendelian disorder? Write one example for each.

[2 marks]

Solution:**Concept:**

- A chromosomal disorder results from an alteration in the number or structure of chromosomes, which can affect many genes together.
- A Mendelian disorder results from an alteration or mutation in a single gene and is transmitted according to a Mendelian pattern of inheritance.

Step 1: Identify the basis of a chromosomal disorder A chromosomal disorder involves the gain, loss or structural rearrangement of chromosomes, rather than a mutation confined to one gene. For example, Down's syndrome is caused by the presence of an additional copy of chromosome 21 (trisomy 21). The affected individual usually has 47 chromosomes instead of 46.

Step 2: Identify the basis of a Mendelian disorder A Mendelian disorder is caused by a mutation in a single gene; the chromosome number need not change. For example, sickle-cell anaemia is an autosomal recessive disorder caused by a mutation in the gene encoding the beta-globin chain of haemoglobin. Its inheritance can be traced through the segregation of the normal and mutant alleles in a family.

Step 3: Conclusion Chromosomal disorders involve changes in chromosome number or structure, as in Down's syndrome. Mendelian disorders involve mutation of a single gene, as in sickle-cell anaemia.

Quick Tip to Solve: Contrast the level of change first: a chromosome change in Down's syndrome versus a single-gene mutation in sickle-cell anaemia.

31(b)(ii). Answer the following questions:

Name the phenomenon that leads to situations like 'XO' abnormality in humans. Also name this genetic disorder. How are individuals with an XO chromosomal abnormality affected? Write its symptoms as well as karyotype.

[3 marks]

Solution:**Concept:**

- Nondisjunction is the failure of homologous chromosomes or sister chromatids to separate normally during cell division. It can produce gametes with an abnormal chromosome number.
- Aneuploidy is the gain or loss of one or more individual chromosomes. Absence of one sex chromosome produces monosomy X, written as 45, X.

Step 1: Identify the phenomenon and the disorder Meiotic nondisjunction can produce a gamete lacking a sex chromosome. When this gamete fuses with a normal gamete carrying an X chromosome, the zygote has only one X chromosome. Thus, the phenomenon is nondisjunction, producing

aneuploidy, and the resulting disorder is Turner's syndrome. The symbol O in XO denotes the absence of a second sex chromosome; it is not a chromosome.

Step 2: State the effects and characteristic symptoms The affected individual is phenotypically female. Her ovaries are rudimentary or poorly developed, so she is usually sterile and secondary sexual characters are poorly developed. Typical features include short stature, a webbed neck and a broad chest. Ovarian underdevelopment also commonly leads to absence of menstruation. These effects arise from the missing X chromosome rather than from a mutation in a single gene.

Step 3: Write the karyotype There are 44 autosomes and only one X chromosome, giving a total of 45 chromosomes. The karyotype is 45, X, equivalently $44 + XO$. This is one chromosome fewer than the normal female complement of 46, XX.

Step 4: Conclusion Nondisjunction causes aneuploidy resulting in Turner's syndrome: a female with karyotype 45, X ($44 + XO$), rudimentary ovaries, sterility and poorly developed secondary sexual characters, often with short stature and a webbed neck.

Quick Tip to Solve: Read XO as one X and one missing sex chromosome: 44 autosomes plus X gives 45, not 46.

32(a)(i). Draw the structure of an antibody molecule and label any four of its parts.

[2 marks]

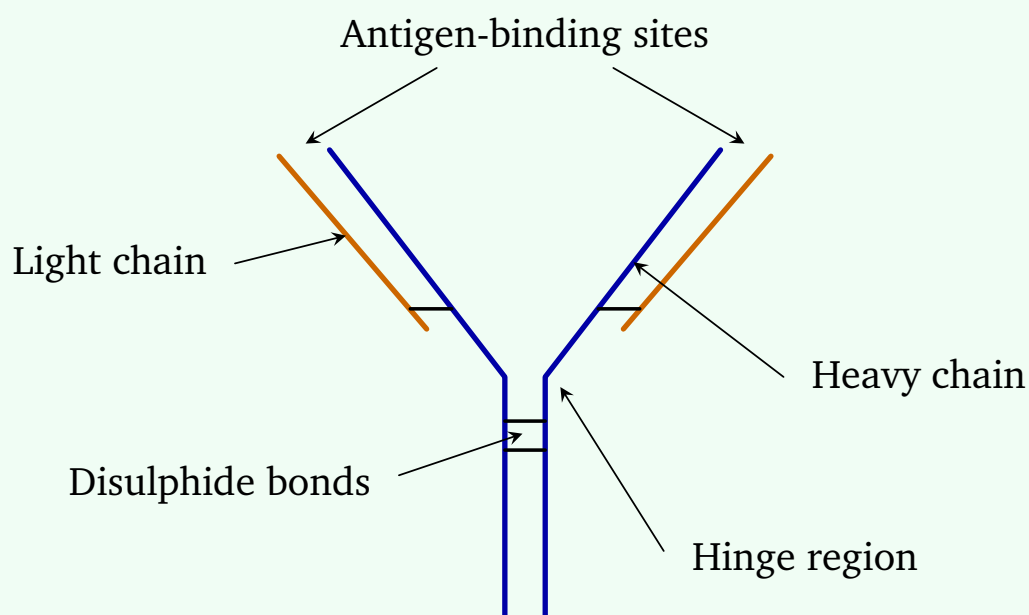
Solution:

Concept:

- An antibody is an immunoglobulin with two identical heavy polypeptide chains and two identical light polypeptide chains, represented as H_2L_2 .
- Disulphide bonds join the chains. The two tips of the Y contain antigen-binding sites formed by the variable regions of a heavy chain and a light chain.

Step 1: Arrange the four polypeptide chains Draw two long heavy chains forming the inner arms and stem of the Y. Place one shorter light chain along the outer side of each arm. Join the two heavy chains near the hinge and connect each light chain to its adjacent heavy chain by disulphide bonds.

Step 2: Label the structure In the diagram, the heavy chain, light chain, disulphide bonds and antigen-binding sites are labelled. The hinge region gives flexibility to the arms. Each binding site lies at an arm tip, where the variable ends of one heavy and one light chain together recognise an antigen.



Structure of an antibody molecule (schematic).

Step 3: Conclusion The labelled antibody is a Y-shaped H_2L_2 molecule with two antigen-binding sites and disulphide bonds connecting its chains.

Quick Tip to Solve: Draw the two heavy chains through the Y stem; the shorter light chains belong only on the outer arms.

32(a)(ii). Differentiate between active and passive immunity. Write any three differences. [3 marks]

Solution:

Concept:

- Active immunity develops when exposure to an antigen stimulates the individual's own immune system to produce a specific response.
- Passive immunity results from transfer of ready-made antibodies from another source. The recipient does not have to produce these antibodies to obtain immediate protection.

Step 1: Difference 1: source of antibodies In active immunity, the person's own B lymphocytes respond to an antigen and form antibody-secreting plasma cells. This occurs following a natural infection or vaccination. In passive immunity, preformed antibodies are supplied from outside the person's body, for example maternal antibodies received by the baby or injected antiserum. Thus, the key distinction is production by the recipient versus transfer from a donor or preparation.

Step 2: Difference 2: speed of protection Active immunity develops slowly during the primary response because antigen recognition, lymphocyte multiplication and antibody production take time. Passive immunity acts immediately or very rapidly after antibodies become available, because they are already formed and can bind the relevant antigen without waiting for the recipient's primary immune response.

Step 3: Difference 3: duration and immunological memory Active immunity is generally long-lasting because it produces memory cells; a subsequent encounter with the same antigen produces a faster and stronger secondary response. Passive immunity is temporary because the transferred antibodies are gradually degraded and the transfer itself does not generate specific memory cells in the recipient. Protection therefore declines when those antibodies disappear.

Step 4: Conclusion Active immunity involves the body's own antibody production, has a delayed onset and generally persists with immunological memory. Passive immunity uses ready-made antibodies, acts rapidly and provides temporary protection without generating memory through the antibody transfer.

Quick Tip to Solve: Compare the same three features on both sides: who makes the antibodies, how fast protection begins, and how long it lasts.

OR

32(b)(i). (I) Write the scientific names of the two species of filarial worms causing filariasis.

(II) How do they affect the body of infected persons?

(III) How does the disease spread?

[3 marks]

Solution:

Concept:

- Filariasis, also called elephantiasis, is a helminth disease in which filarial worms affect the lymphatic vessels.
- An infected female mosquito acts as the vector: it transfers infective larvae between human hosts during blood feeding.

Step 1: Name the two filarial worms (I) The two species are *Wuchereria bancrofti* and *Wuchereria malayi* (also known as *Brugia malayi*). They are parasitic roundworms, rather than the mosquitoes that transmit the infection.

Step 2: Explain the effects on the infected person (II) The worms reside for many years in lymphatic vessels, particularly those of the lower limbs. Their presence causes chronic inflammation and interferes with the normal drainage of lymph. Accumulation of lymph produces extensive swelling of the affected region, especially the legs, which gives the disease the name elephantiasis. The genital organs may also be affected and become grossly deformed.

Step 3: Describe transmission by the vector (III) A female mosquito takes up the parasite while sucking blood from an infected person. The parasite develops into the infective larval stage inside the mosquito. When this infected mosquito bites a healthy person, the larvae enter the person's body through the bite site and subsequently reach the lymphatic system. Thus the disease spreads through the bite of an infected female mosquito, not by ordinary physical contact with the patient.

Step 4: Conclusion The causative worms are *W. bancrofti* and *W. malayi*. They cause chronic lymphatic inflammation and severe swelling or deformity, and are transmitted by infected female mosquitoes.

Quick Tip to Solve: Link the three requested points as worm, lymph vessel and female mosquito: these identify the pathogen, its damage and its route of spread respectively.

32(b)(ii). Mention the source and the role of the following in providing defence against infection in the human body:

(I) Histamine

(II) Interferons

[2 marks]

Solution:

Concept:

- Innate defence includes local inflammatory responses and cytokine barriers that act against infection.
- Histamine promotes inflammation at the affected site, whereas interferons provide protection against viral infection.

Step 1: State the source and role of histamine (I) Histamine is released by mast cells in tissues; basophils can also release it. It causes dilation of small blood vessels and increases capillary permeability at the affected site. This promotes the movement of fluid and defence components into the tissue, helping the local inflammatory response bring phagocytes and protective substances to the site of infection.

Step 2: State the source and role of interferons (II) Interferons are proteins secreted by virus-infected cells. They act on nearby, uninfected cells and induce an antiviral state that inhibits viral replication if those cells encounter the virus. In this way, they protect neighbouring cells and restrict the spread of viral infection; they form a cytokine barrier of innate immunity.

Step 3: Conclusion Histamine from mast cells supports local inflammatory defence. Interferons from virus-infected cells protect neighbouring cells against viral infection by inhibiting viral multiplication.

Quick Tip to Solve: Pair each mediator with its source and action: mast cell–histamine–inflammation; virus-infected cell–interferon–antiviral protection.

33(a). Briefly explain the events of fertilisation and implantation in an adult human female. [5 marks]

Solution:

Concept:

- Fertilisation is the fusion of the male and female gametes to form a diploid zygote. In humans it normally occurs at the ampullary-isthmic junction of the fallopian tube.
- Cleavage consists of successive mitotic divisions of the zygote. Implantation is the attachment and embedding of the blastocyst in the uterine endometrium.

Step 1: Bring the gametes together During insemination, semen is released into the vagina. Motile sperm pass through the cervix and uterus to the ampullary-isthmic junction of the fallopian tube. The secondary oocyte released at ovulation is collected by the fimbriae and transported towards this site. Fertilisation can occur only if sperm and the oocyte reach this region at the same time.

Step 2: Permit entry of one sperm A sperm contacts the zona pellucida surrounding the secondary oocyte. Enzymes released from its acrosome help it penetrate the egg coverings, and its membrane

fuses with the oocyte membrane. Sperm entry induces changes in the zona pellucida that prevent additional sperm from entering, ensuring that only one sperm fertilises the oocyte.

Step 3: Complete meiosis and form the zygote Entry of the sperm induces completion of meiosis II in the secondary oocyte. This unequal division produces a mature haploid ovum and a second polar body. The haploid male and female nuclei then fuse, restoring the diploid chromosome number and producing the zygote with 46 chromosomes.

Step 4: Develop a blastocyst by cleavage As the zygote moves through the oviduct towards the uterus, it undergoes successive mitotic divisions, producing 2, 4, 8 and 16 blastomeres. The embryo with 8–16 blastomeres is called a morula. It continues dividing and develops into a blastocyst as it enters the uterus. The blastocyst has an outer trophoblast and an inner cell mass; the inner cell mass subsequently forms the embryo.

Step 5: Implant the blastocyst The trophoblast attaches to the uterine endometrium. The endometrial cells divide rapidly and cover the blastocyst, so that it becomes embedded in the uterine lining. This process is called implantation and leads to the establishment of pregnancy.

Step 6: Conclusion Fertilisation at the ampullary-isthmic junction forms a diploid zygote. Cleavage produces a morula and then a blastocyst, whose trophoblast attaches to the endometrium and enables implantation in the uterus.

Quick Tip to Solve: Keep the sequence clear: gamete fusion, zygote, cleavage, morula, blastocyst, then implantation; fertilisation occurs in the oviduct and implantation in the uterus.

OR

33(b)(i). Arrange the following hormones in sequence of their secretion in a pregnant woman:

hCG; LH; FSH; Relaxin.

[1 mark]

Solution:

Concept:

- FSH promotes ovarian follicular growth before ovulation, while the mid-cycle LH surge triggers ovulation.
- hCG appears during early pregnancy, whereas relaxin is secreted by the ovary in the later phase of pregnancy.

Step 1: Order the hormones preceding conception FSH acts first to stimulate growth and maturation of ovarian follicles. The subsequent LH surge induces ovulation, releasing the secondary oocyte that can be fertilised. Thus FSH precedes LH in the reproductive sequence leading to pregnancy.

Step 2: Place the pregnancy hormones After fertilisation and implantation, hCG is secreted during early pregnancy and supports the corpus luteum. Relaxin is associated with the later phase of pregnancy, so it follows hCG. The requested order includes the preparatory ovarian cycle as well as pregnancy.

Step 3: Conclusion The sequence is $\boxed{\text{FSH} \rightarrow \text{LH} \rightarrow \text{hCG} \rightarrow \text{Relaxin}}$.

Quick Tip to Solve: Link the order to events: follicular growth, ovulation, early pregnancy support, and later pregnancy changes.

Solution:**Concept:**

- The hormones named in part (i) are human chorionic gonadotropin (hCG), luteinising hormone (LH), follicle-stimulating hormone (FSH) and relaxin. Their sources and functions differ.
- Pituitary gonadotropins regulate follicular development and ovulation; pregnancy hormones help maintain pregnancy and prepare the mother for childbirth.

Step 1: Identify the source and action of hCG **Source:** Human chorionic gonadotropin (hCG) is secreted by the trophoblast of the developing embryo and subsequently by the placenta. **Function:** It maintains the corpus luteum during early pregnancy, allowing continued secretion of progesterone and oestrogens. Progesterone maintains the uterine endometrium, which supports implantation and the developing embryo. Thus, hCG supports early pregnancy through its action on the corpus luteum.

Step 2: Identify the source and action of LH **Source:** Luteinising hormone (LH) is secreted by the anterior pituitary. **Function:** The mid-cycle LH surge induces ovulation, releasing the ovum from the mature Graafian follicle. LH also promotes conversion of the ruptured follicle into the corpus luteum and stimulates its secretion of progesterone. These actions prepare the reproductive system for pregnancy.

Step 3: Identify the source and action of FSH **Source:** Follicle-stimulating hormone (FSH) is secreted by the anterior pituitary. **Function:** It stimulates the growth and development of ovarian follicles and promotes oestrogen secretion by the growing follicles. Follicular maturation precedes ovulation. During an established pregnancy, high levels of ovarian and placental hormones suppress FSH and LH secretion by negative feedback, preventing another ovarian cycle.

Step 4: Identify the source and action of relaxin **Source:** Relaxin is secreted by the ovary, particularly the corpus luteum, during pregnancy; NCERT identifies ovarian secretion in the later phase of pregnancy. **Function:** It helps relax the pelvic ligaments and facilitates softening and dilation of the cervix, preparing the birth passage for childbirth. This action eases the passage of the baby during delivery.

Step 5: Conclusion hCG is a placental hormone that maintains the corpus luteum in early pregnancy; LH and FSH are anterior-pituitary hormones involved in ovulation and follicular growth, respectively; ovarian relaxin helps prepare the birth passage for delivery.

Quick Tip to Solve: Link each hormone to a key action: FSH grows follicles, LH releases the ovum, hCG maintains the corpus luteum, and relaxin prepares the birth passage.