

CBSE Class 12 Biology Question Paper 2026 with Solution PDF-Set 57-1-2

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 – Section **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, internal choices have been provided in some questions. 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)

Question Nos. 1 to 16 are Multiple Choice Type Questions, carrying 1 mark each. Choose the best option.

1. Match Column-I with Column-II and choose the correct option:

Column-I	Column-II
a. Biolistic gun	i. Bacterial cell
b. Chitinase	ii. Tumour inducing
c. Ti	iii. Animal cell
d. Ca^{++}	iv. Fungal cell
	v. Plant cell

[1 mark]

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

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

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

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

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

Solution:

Concept:

- Gene transfer methods depend on the structure of the recipient cell; plant cells can receive DNA by particle bombardment.
- Enzymes used to release DNA must act on the cell wall material, whereas calcium ions help make bacterial cells competent.

Step 1: Match the delivery method and enzyme A biolistic gun bombards plant cells with DNA-coated gold or tungsten particles, so a matches v. Fungal cell walls contain chitin; chitinase digests this wall during DNA isolation, so b matches iv.

Step 2: Match the plasmid term and ion Ti means tumour inducing, referring to the Ti plasmid of *Agrobacterium tumefaciens*; thus c matches ii. Treatment with divalent calcium ions increases the efficiency with which bacterial cells take up DNA, so d matches i. Option (D) incorrectly pairs chitinase with bacteria, and (A) and (B) already give the wrong association for the biolistic gun.

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

Quick Tip to Solve: Use chitinase → fungal wall and Ti → tumour inducing as quick anchors, then check the remaining two pairs.

2. Microbes commonly used in kitchen are

[1 mark]

- (A) Lactobacillus and Yeast
- (B) Penicillium and Yeast
- (C) Microspora and E.coli
- (D) Rhizopus and Lactobacillus

Correct Answer: (A) Lactobacillus and Yeast

Solution:

Concept:

- Useful microbes ferment food materials to produce household foods such as curd and bread.
- *Lactobacillus* produces lactic acid, while yeast releases carbon dioxide during fermentation.

Step 1: Identify the everyday food applications *Lactobacillus* and other lactic acid bacteria convert milk into curd by producing acid that coagulates milk proteins. Baker's yeast ferments sugars in dough; the carbon dioxide released makes the dough rise.

Step 2: Check the competing pairs *Penicillium* is associated with particular industrial products and cheeses, rather than being the usual kitchen partner of yeast in this NCERT context. *Microspora* and *E. coli* are not the standard pair used for household fermentation. *Rhizopus*, commonly seen as bread mould, does not replace yeast as the usual organism for raising bread dough.

Step 3: Conclusion The commonly used kitchen microbes are *Lactobacillus* and yeast. Hence, the correct option is (A).

Quick Tip to Solve: Recall the two kitchen products: curd points to lactic acid bacteria, and raised bread dough points to yeast.

3. The features of some structures of human male reproductive system are given below. Choose the correct option that matches the features with the structures.

- (i) It opens into the Vasa efferentia through rete testis.
- (ii) It carries semen as well as urine.
- (iii) It maintains temperature (2 - 2.5°C) lower than body temperature for sperm formation.
- (iv) It leads to vas deferens that ascends to the abdomen.

[1 mark]

- (A) (i) Seminal vesicle, (ii) Urethra, (iii) Scrotum, (iv) Seminiferous tubule
- (B) (i) Prostate, (ii) Scrotum, (iii) Testes, (iv) Vas Deferens
- (C) (i) Seminiferous tubule, (ii) Urethra, (iii) Scrotum, (iv) Epididymis
- (D) (i) Seminiferous tubule, (ii) Vas Deferens, (iii) Urethra, (iv) Sertoli cells

Correct Answer: (C) (i) Seminiferous tubule, (ii) Urethra, (iii) Scrotum, (iv) Epididymis

Solution:

Concept:

- Sperm travel from seminiferous tubules through the rete testis and vasa efferentia to the epididymis, and then into the vas deferens.

- The scrotum provides a lower temperature for sperm formation; the male urethra is a common passage for urine and semen at different times.

Step 1: Trace the sperm transport pathway Seminiferous tubules open into the vasa efferentia through the rete testis, giving (i) seminiferous tubule. The epididymis continues as the vas deferens, which ascends into the abdomen, giving (iv) epididymis. Neither the seminal vesicle nor the prostate is the structure described in (i).

Step 2: Match the common passage and temperature regulator The urethra carries urine and semen at different times, so (ii) is urethra; the vas deferens transports sperm and does not carry urine. The scrotum keeps the testes about 2–2.5 °C below body temperature, so (iii) is scrotum. This eliminates the incorrect combinations in (A), (B) and (D).

Step 3: Conclusion The sequence is seminiferous tubule, urethra, scrotum and epididymis. Hence, the correct option is (C).

Quick Tip to Solve: First match the unique clues: urine and semen means urethra, while lower temperature means scrotum; then verify the sperm pathway.

4. Exploration of molecular, genetic and species level diversity for gaining products of economic importance is called [1 mark]

- (A) Exploitation
- (B) Bio-prospecting
- (C) Bio-patenting
- (D) Bio-piracy

Correct Answer: (B) Bio-prospecting

Solution:

Concept:

- Biodiversity provides molecules, genes and species that may yield useful commercial products.
- Bioprospecting is the exploration of biodiversity for products of economic importance.

Step 1: Identify the activity described The question describes exploring diversity at molecular, genetic and species levels to discover useful products. Examples include investigating organisms for biologically active compounds or useful genes. The key feature is a search for economically valuable biological resources.

Step 2: Distinguish the other terms Exploitation is a broad term for using resources and does not specifically name this exploration. Bio-patenting concerns obtaining patent rights for eligible biological inventions. Bio-piracy concerns unauthorised use of biological resources or traditional knowledge without proper authorisation or benefit sharing. Neither of these legal or ethical terms names the exploration itself.

Step 3: Conclusion The activity is bio-prospecting. Hence, the correct option is (B).

Quick Tip to Solve: Link prospecting with searching: exploration for useful molecules or genes indicates bioprospecting; patenting refers to rights.

5. Which connective tissue connects ovary to pelvic wall and uterus?

[1 mark]

- (A) Tendons
- (B) Ligaments
- (C) Cartilage
- (D) Bone

Correct Answer: (B) Ligaments

Solution:

Concept:

- The ovaries are supported in the pelvic cavity by ligaments that attach them to neighbouring structures.
- Connective tissues differ in function: ligaments support attachments, tendons transmit muscle pull, and cartilage and bone provide skeletal support.

Step 1: Identify the ovarian supporting tissue Each ovary is connected to the pelvic wall and uterus by ligaments. These connective tissue attachments support the ovary in its position while permitting the normal relationships of the female reproductive organs.

Step 2: Eliminate the other connective tissues Tendons characteristically join muscles to bones and transmit the force of muscle contraction. Cartilage is a firm but flexible supporting tissue, while bone is a hard, mineralised skeletal tissue. None of these is the named tissue attaching the ovary to the pelvic wall and uterus in the female reproductive system.

Step 3: Conclusion Ligaments connect the ovary to the pelvic wall and uterus. Hence, the correct option is (B).

Quick Tip to Solve: For ovarian support, recall ligaments; reserve tendons for the attachment of muscle to bone.

6. Which of the following is not a component of detritus food chain?

[1 mark]

- (A) Dead Leaves
- (B) Bacteria
- (C) Fungi
- (D) Zooplankton

Correct Answer: (D) Zooplankton

Solution:

Concept:

- A detritus food chain begins with dead organic matter, called detritus, rather than with living producers.
- Bacteria and fungi are major decomposers that obtain nutrients by breaking down dead organic material.

Step 1: Identify the detrital material and decomposers Dead leaves are detritus and therefore form a

starting resource for the detritus food chain. Bacteria and fungi release enzymes onto dead organic matter and absorb the products of decomposition. Thus the first three choices belong to the standard description of this chain.

Step 2: Identify the grazing-chain consumer Zooplankton commonly feed on living phytoplankton in aquatic ecosystems and are primary consumers in the grazing food chain. In the standard comparison intended here, zooplankton contrast with dead leaves and the decomposer microbes. Although feeding links can connect food chains in real ecosystems, this question asks for the characteristic classification of the listed components.

Step 3: Conclusion Zooplankton is the choice not included in the standard detritus food chain here. Hence, the correct option is (D).

Quick Tip to Solve: Sort the options into dead matter, decomposers and consumers of living producers; the last category identifies the exception.

7. Identify the plant in which emasculation is not required for artificial hybridization.

[1 mark]

- (A) Rice
- (B) Wheat
- (C) Pea
- (D) Papaya

Correct Answer: (D) Papaya

Solution:

Concept:

- Emasculation is removal of anthers from a bisexual flower before they dehisce, to prevent contamination by its own pollen.
- A unisexual female flower has no anthers, so emasculation is unnecessary before controlled pollination.

Step 1: Identify the flower used as the female parent Papaya is dioecious: male and female flowers occur on separate plants. The female flower selected for artificial hybridisation has no anthers to remove. It can be protected by bagging and pollinated with pollen from the chosen male parent at the appropriate time.

Step 2: Compare the other plants Rice, wheat and pea normally have bisexual flowers containing both stamens and pistil. When such a flower is used as the female parent in the standard artificial hybridisation procedure, its anthers are removed before dehiscence to prevent self-pollination. Papaya differs because the selected female flower is already free of anthers.

Step 3: Conclusion Emasculation is not required in the female flowers of papaya. Hence, the correct option is (D).

Quick Tip to Solve: Ask whether the selected female flower has anthers: unisexual female flowers need protection and controlled pollen, but no emasculation.

8. Pomato was produced by fusing protoplasts of

[1 mark]

- (A) Tomato and Potato
- (B) Pomegranate and Tomato
- (C) Pomegranate and Potato
- (D) Pomegranate, Potato and Tomato

Correct Answer: (A) Tomato and Potato

Solution:

Concept:

- Somatic hybridisation combines isolated protoplasts of different plant varieties or species to produce a somatic hybrid.
- A protoplast is a plant cell with its cell wall removed; fusion brings together the genetic material of the two parents.

Step 1: Identify the parental plants Pomato is the somatic hybrid obtained by fusing the protoplast of a potato cell with that of a tomato cell. The fused cell can be cultured and regenerated into a hybrid plant; this is not fusion of gametes through ordinary sexual reproduction.

Step 2: Eliminate the other combinations Each of the remaining alternatives includes pomegranate. Pomegranate is not a parent in pomato, so the combinations in (B), (C) and (D) do not describe this example of protoplast fusion.

Step 3: Conclusion Pomato was produced by fusing tomato and potato protoplasts. Hence, the correct option is (A).

Quick Tip to Solve: Read pomato as a reminder of potato plus tomato, and associate the example with protoplast fusion.

9. Which of the following sacred groves is found in Meghalaya?

[1 mark]

- (A) Jaintia hills
- (B) Bastar
- (C) Chanda
- (D) Sarguja

Correct Answer: (A) Jaintia hills

Solution:

Concept:

- Sacred groves are forest patches protected by local communities because of religious or cultural traditions.
- Such protection conserves organisms in their natural habitats and is an example of in situ conservation.

Step 1: Recall the Meghalaya example The Khasi and Jaintia Hills of Meghalaya contain sacred groves. These protected forest patches provide refuges for rare and threatened plants and other

organisms; the named Meghalaya locality in the choices is Jaintia hills.

Step 2: Compare the other localities Bastar, Chanda and Sarguja are examples associated with central Indian sacred groves, rather than Meghalaya. Their appearance in the list does not make them north-eastern hill localities; match the place to its region before selecting.

Step 3: Conclusion Jaintia hills is the sacred-grove locality in Meghalaya. Hence, the correct option is (A).

Quick Tip to Solve: Pair Meghalaya with Khasi and Jaintia Hills; group Bastar, Chanda and Sarguja with central Indian examples.

10. Messelson and Stahl's experiment carried out centrifugation in CsCl_2 density gradient to separate:

[1 mark]

- (A) DNA from RNA
- (B) DNA from protein
- (C) RNA from protein
- (D) Normal DNA from heavy DNA

Correct Answer: (D) Normal DNA from heavy DNA

Solution:

Concept:

- Density-gradient centrifugation separates DNA molecules according to their buoyant densities.
- DNA containing the heavy nitrogen isotope ^{15}N has a higher density than DNA containing ordinary ^{14}N .

Step 1: Identify what was labelled The experiment first grew bacteria in a medium containing ^{15}N , which became incorporated into their DNA. After transfer to ^{14}N medium, DNA samples were isolated at successive generations. Their nitrogen isotope content determined the positions of the bands in the density gradient.

Step 2: Identify the separation being used Heavy DNA bands at a greater density than normal light DNA, while hybrid DNA forms an intermediate band. The comparison was therefore between DNA molecules of different densities, not between DNA and RNA, DNA and protein, or RNA and protein. Those alternatives do not describe the purpose of this experiment.

Step 3: Conclusion Centrifugation separated normal DNA from heavy DNA. Hence, the correct option is (D).

Quick Tip to Solve: When an experiment labels DNA with ^{15}N , look for density differences between DNA molecules, not separation of different biomolecules.

11. Which one of the following is not a component required for Polymerase Chain Reaction (PCR)?

[1 mark]

- (A) Template DNA
- (B) Primers
- (C) DNA Ligase
- (D) DNA Polymerase

Correct Answer: (C) DNA Ligase

Solution:

Concept:

- PCR amplifies a selected DNA segment through repeated denaturation, primer annealing and extension.
- Extension requires a template, two primers, deoxyribonucleotides and a thermostable DNA polymerase in suitable reaction conditions.

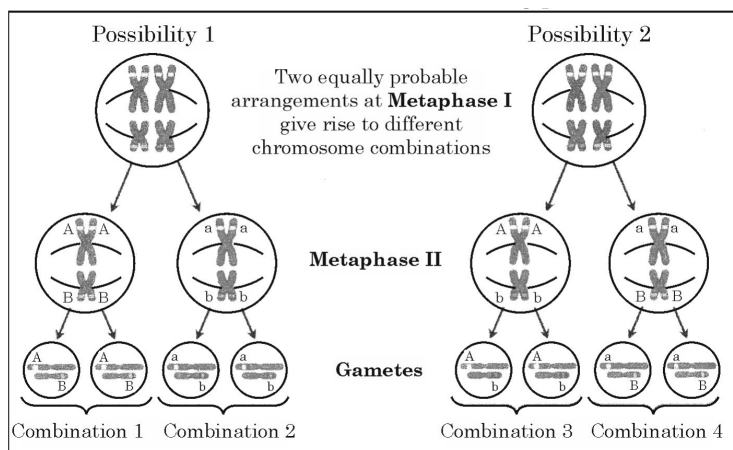
Step 1: Check the required components Template DNA contains the sequence to be amplified. Primers anneal on opposite strands and provide free ends for extension. A thermostable DNA polymerase, such as Taq polymerase, adds nucleotides to synthesise the new DNA strands. Thus the components in (A), (B) and (D) have essential roles in PCR.

Step 2: Distinguish joining from amplification DNA ligase joins DNA fragments by sealing breaks in the sugar-phosphate backbone. PCR amplification proceeds by polymerase-mediated extension from primers, so it does not require ligase to join separate DNA fragments during its standard cycle.

Step 3: Conclusion DNA ligase is not a component required for standard PCR. Hence, the correct option is (C).

Quick Tip to Solve: For PCR, connect primers with polymerase extension; reserve ligase for joining DNA fragments in cloning.

12. In the following figure, two ways of pairing of two homologous pairs of chromosomes are shown. Which of the following phenomena is expressed? [1 mark]



- (A) Linkage of genes
- (B) Independent assortment of genes
- (C) Multiple alleles
- (D) Incomplete dominance

Correct Answer: (B) Independent assortment of genes

Solution:

Concept:

- During metaphase I, the orientation of one homologous chromosome pair is independent of the orientation of another pair.
- Independent assortment generates different combinations of maternal and paternal chromosomes in gametes.

Step 1: Read the chromosome combinations The diagram shows two equally probable arrangements of two homologous pairs at metaphase I. In one arrangement, the gametes contain the combinations AB and ab ; in the other, they contain Ab and aB . The orientation of the pair carrying A/a does not determine that of the pair carrying B/b .

Step 2: Distinguish the alternatives This random orientation and subsequent segregation is the chromosomal basis of independent assortment. Linkage instead concerns genes on the same chromosome tending to be inherited together. Multiple alleles means more than two allelic forms in a population, while incomplete dominance describes an intermediate heterozygous phenotype; neither explains the arrangements shown.

Step 3: Conclusion The figure expresses independent assortment of genes. Hence, the correct option is (B).

Quick Tip to Solve: When two chromosome pairs can orient in two ways and produce AB , ab , Ab , aB , identify independent assortment.

13. Assertion (A): When we see stars, we are apparently peeping into the past.

Reason (R): What we see today is an object whose emitted light started its journey millions of years back reaching our eyes now. [1 mark]

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

Solution:

Concept:

- Light travels at a finite speed, so light from a distant astronomical object takes time to reach Earth.
- The travel time is $t = d/c$, where d is the distance travelled and c is the speed of light.

Step 1: Evaluate the assertion The assertion is true. We see a star as it was when the light reaching our eyes was emitted. Thus observing starlight gives information about an earlier state of the source, rather than its state at the instant of observation.

Step 2: Evaluate the reason The reason is true in the distant-object context of the statement: light from very distant objects can have begun its journey millions of years ago and reach us only now. The precise delay depends on distance; the central point is that emitted light requires a travel time.

Step 3: Check the explanatory link The delay described in the reason is exactly why viewing a distant source amounts to looking into its past. Therefore the two statements are not merely independently true; the reason explains the assertion. The alternatives that deny either statement, or deny this link, do not apply.

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

Quick Tip to Solve: Use the travel-time idea: the greater the distance to the light source, the earlier the event you are seeing.

14. Assertion (A): Flocs are masses of bacteria associated with fungal filaments in secondary treatment of sewage.

Reason (R): Flocs help in digestion of solid waste by anaerobic respiration.

[1 mark]

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

- Flocs are mesh-like aggregates of bacteria associated with fungal filaments that develop during secondary sewage treatment.
- Aeration supports aerobic microbes that consume organic matter and reduce the biochemical oxygen demand of sewage.

Step 1: Evaluate the assertion The assertion is true: bacterial masses associated with fungal filaments form flocs in the aeration tank. Continuous agitation and air supply promote their growth during biological, or secondary, treatment.

Step 2: Evaluate the reason The reason is false because flocs act under aerobic conditions. Their microbes consume much of the organic matter in the effluent using oxygen. Anaerobic digestion is associated with the sludge digester, where a portion of the activated sludge is treated by anaerobic microorganisms.

Step 3: Check the explanatory link The reason attributes an anaerobic mode of respiration to the aerobic floc stage and therefore cannot explain the assertion. The later anaerobic sludge-treatment stage must not be confused with organic-matter removal by flocs in an aerated tank.

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

Quick Tip to Solve: Separate the stages: aeration tank means aerobic flocs; sludge digester means anaerobic digestion and biogas.

15. Assertion (A): In terrestrial ecosystem much larger fraction of energy flows through grazing food chain.

Reason (R): Grazing food chain may be connected to Detritus food chain at some levels. [1 mark]

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

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

Solution:

Concept:

- The grazing food chain begins with living green plants, whereas the detritus food chain begins with dead organic matter.
- In terrestrial ecosystems, a much larger fraction of energy flows through the detritus food chain.

Step 1: Judge Assertion (A) Assertion (A) is false. In terrestrial ecosystems, much of the plant biomass enters the detritus food chain as dead leaves, other plant remains and organic wastes. The assertion incorrectly assigns the larger energy fraction to the grazing food chain.

Step 2: Judge Reason (R) Reason (R) is true. The grazing and detritus food chains can be connected at several levels. For example, an animal in a grazing food chain may also feed on organisms that consume detritus, linking the two pathways.

Step 3: Check the explanation and the codes A true statement about connections between food chains cannot make the false assertion true. Codes (A) and (B) both require a true assertion, and code (C) requires a false reason; none matches the judgments above.

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

Quick Tip to Solve: For this assertion, associate terrestrial energy flow with detritus; assess the connection between the chains separately.

16. Assertion (A): The milk produced by transgenic cow 'Rosie' was nutritionally more balanced product for human babies than natural cow milk.

Reason (R): It was human protein enriched milk containing human alpha lactaglobulin. [1 mark]

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

- Transgenic animals contain and express introduced genetic material, which can enable production of a useful human protein.
- Rosie produced milk enriched with human alpha-lactalbumin; this protein name must be distinguished from lactoglobulin.

Step 1: Judge Assertion (A) Assertion (A) is true. The transgenic cow Rosie produced human-protein-enriched milk that was nutritionally more balanced for human babies than normal cow milk.

Step 2: Judge Reason (R) Reason (R) is false as printed. The human protein present in Rosie's milk was alpha-lactalbumin, not the stated alpha lactaglobulin. The correct identity of the protein is essential; merely describing the milk as protein enriched does not make the entire reason true.

Step 3: Check the explanation and the codes Since the reason contains an incorrect protein name, it cannot be accepted as a correct explanation. Codes (A) and (B) require both statements to be true, whereas code (D) requires the assertion to be false.

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

Quick Tip to Solve: In questions on Rosie, check the protein name first: human alpha-lactalbumin is the NCERT term.

Section B (10 marks)

17(a). What is the role of LAB (Lactic Acid Bacteria) in preparation of curd?

[1 mark]

Solution:

Concept:

- Lactic acid bacteria (LAB), including Lactobacillus, grow in milk and convert milk sugar into lactic acid.
- The acid produced causes coagulation of milk proteins, changing milk into curd.

Step 1: Identify the microbial action A small amount of curd added to warm milk acts as an inoculum containing LAB. These bacteria multiply and ferment the milk sugar, lactose, producing lactic acid.

Step 2: Connect acid formation to curd formation The lactic acid lowers the pH of milk and causes its proteins, especially casein, to coagulate. This produces the characteristic semisolid curd; bacterial acid production is therefore the key role of LAB in the process.

Step 3: Conclusion LAB convert lactose into lactic acid, which coagulates milk proteins and converts milk into curd.

Quick Tip to Solve: Link the answer in order: LAB ferment lactose, lactic acid forms, and milk proteins coagulate.

17(b). Mention two health benefits of consuming curd.

[1 mark]

Solution:

Concept:

- LAB improve the nutritional quality of curd by increasing its vitamin B12 content.
- LAB present in curd help check disease-causing microbes in the stomach.

Step 1: State the nutritional benefit Curd has improved nutritional quality because lactic acid bacteria increase its vitamin B12 content during curd formation. This identifies a specific nutrient benefit, rather than merely describing curd as healthy.

Step 2: State the protective benefit The lactic acid bacteria in curd help check the growth of disease-causing microbes in the stomach. This beneficial microbial action is distinct from the increase in vitamin content and supplies the second requested health benefit.

Step 3: Conclusion The two benefits are increased vitamin B12 content and suppression of disease-causing microbes in the stomach.

Quick Tip to Solve: Give two distinct NCERT points: vitamin B12 enrichment and checking disease-causing stomach microbes.

18(a). Name the muscular and glandular layers of female uterus. Mention one function of each.

[2 marks]

Solution:

Concept:

- The uterine wall has an outer perimetrium, a middle muscular myometrium and an inner glandular endometrium.
- The muscle layer provides contractile force, while the glandular lining undergoes cyclic changes and supports pregnancy.

Step 1: Name the muscular layer and its function The muscular layer is the myometrium. It consists of smooth muscle and produces strong contractions during childbirth. These uterine contractions help expel the baby through the birth canal at parturition. Thus its thick muscular nature is directly related to its mechanical function.

Step 2: Name the glandular layer and its function The glandular layer is the endometrium, which lines the uterine cavity. Its thickened, vascular and glandular surface provides the site for implantation of the blastocyst. This lining undergoes cyclic changes during the menstrual cycle; preparation of the endometrium makes the uterus suitable for implantation and establishment of pregnancy.

Step 3: Conclusion Muscular layer: myometrium, which contracts during childbirth. Glandular layer: endometrium, which provides the site for blastocyst implantation.

Quick Tip to Solve: Use the layer names to recall their roles: myometrium is muscle for contractions; endometrium is the inner implantation lining.

OR

18(b)(i). Why are STI (Sexually Transmitted Infections) not detected in time? (2 pts.)

[1 mark]

Solution:

Concept:

- Early STI symptoms may be absent or minor; females with STIs can often be asymptomatic.
- Social stigma can delay medical consultation, so an infection may progress before it is diagnosed.

Step 1: Explain the lack of early warning An infected person may have no noticeable symptoms, especially in females, or only minor early symptoms such as itching, fluid discharge or slight pain. These signs may be ignored or not recognised as an STI, delaying detection.

Step 2: Explain the delay in seeking help The social stigma associated with STIs can deter people from discussing symptoms or obtaining medical consultation. Consequently, even a person who notices symptoms may not seek timely diagnosis and treatment.

Step 3: Conclusion STIs may go undetected because early symptoms are absent or minor, and social stigma discourages timely medical consultation.

Quick Tip to Solve: For the two points, separate the biological reason (few symptoms) from the social reason (stigma and delayed consultation).

18(b)(ii). Write two complications caused in later stages.

[1 mark]

Solution:

Concept:

- Untreated STIs can progress beyond the initial infection and damage reproductive organs.
- Pelvic inflammatory disease and infertility are recognised later complications of untreated STIs.

Step 1: Identify pelvic inflammatory disease One later complication is pelvic inflammatory disease (PID), in which infection causes inflammation of organs in the female reproductive tract. This is a complication of an advancing infection, rather than simply an early symptom such as itching.

Step 2: Identify infertility A second complication is infertility. Infection and resulting damage or

scarring in reproductive structures can impair their normal function and reduce the ability to conceive. Thus delayed treatment can have long-term effects on reproductive capacity.

Step 3: Conclusion Two later complications are pelvic inflammatory disease (PID) and infertility.

Quick Tip to Solve: Name established complications, such as PID and infertility; avoid substituting early symptoms like itching or discharge.

19(a). Write the importance of following in biotechnology:

Ori (Origin of Replication)

[1 mark]

Solution:

Concept:

- The origin of replication (ori) is a specific DNA sequence at which replication begins.
- A cloning vector carries ori so that the vector and the foreign DNA attached to it can be replicated inside the host.

Step 1: Identify the initiation site The host replication machinery recognises the vector's ori and initiates DNA replication there. The inserted DNA is copied along with the vector, allowing the desired DNA fragment to multiply in the host cell.

Step 2: Relate ori to copy number The ori also controls the number of copies of the linked DNA maintained within the host. A suitable ori is therefore chosen when a large number of copies of the desired gene is required.

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

Quick Tip to Solve: Link ori with two ideas: the starting point of replication and the copy number of the inserted DNA.

19(b). Write the importance of following in biotechnology:

Enzyme Polymerase used in Polymerase Chain Reaction

[1 mark]

Solution:

Concept:

- Polymerase chain reaction (PCR) amplifies a selected DNA segment through repeated denaturation, primer annealing and extension.
- A thermostable DNA polymerase, commonly Taq polymerase from *Thermus aquaticus*, remains functional after the high-temperature denaturation step.

Step 1: Explain the extension reaction DNA polymerase extends the annealed primers by adding deoxyribonucleotides complementary to the template strand. It synthesises new DNA in the 5' → 3' direction, producing copies of the selected DNA segment.

Step 2: Explain why thermostability matters The enzyme tolerates the repeated heating used to

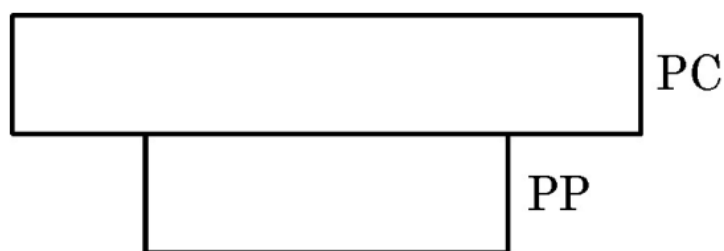
separate the DNA strands, so a fresh enzyme need not be supplied after every cycle. Repeated synthesis in successive cycles greatly amplifies the target DNA.

Step 3: Conclusion The thermostable polymerase synthesises new DNA strands by extending primers, enabling repeated amplification of the target DNA during PCR.

Quick Tip to Solve: For PCR polymerase, state both its DNA-synthesis role and its ability to withstand repeated heating.

20(a)(i). Given below is a pyramid found in an ecosystem, where each bar represents the standing crop available in the trophic level.

Identify the kind of pyramid and with the help of an example explain the conditions where this kind of pyramid is possible in nature. [1 mark]



Solution:

Concept:

- A pyramid of biomass compares the standing biomass at successive trophic levels at a particular time.
- Standing biomass is the material present at an instant; it differs from the amount produced over a period of time.

Step 1: Read the relative bar widths PP denotes primary producers and PC denotes primary consumers. The producer bar is smaller than the consumer bar, so the figure represents an inverted pyramid of biomass: the consumers have more standing biomass than the producers.

Step 2: Explain an aquatic example In a pond or sea, a small standing biomass of phytoplankton can support a larger biomass of zooplankton. Phytoplankton reproduce rapidly and are consumed rapidly, continually renewing the food supply. Their high turnover permits this inverted relationship at any given instant.

Step 3: Conclusion It is an inverted pyramid of biomass, possible in aquatic ecosystems where rapidly replenished phytoplankton support a greater standing biomass of consumers.

Quick Tip to Solve: A small producer stock can feed a larger consumer stock when producers replace themselves rapidly; compare stock with turnover.

20(a)(ii). Write any two limitations of ecological pyramids.

[1 mark]

Solution:

Concept:

- Ecological pyramids summarise trophic structure using numbers, biomass or energy at different trophic levels.
- This simplified representation cannot capture every organism or feeding relationship in a natural ecosystem.

Step 1: State the single-trophic-level limitation A pyramid does not take account of the same species occupying two or more trophic levels. For example, an omnivore may act as a primary consumer when eating plants and as a secondary consumer when eating herbivores; placing it in only one bar loses this distinction.

Step 2: State the food-web limitation A pyramid assumes a simple food chain and does not accommodate a food web. In nature, each consumer may have several food sources, and different chains are interconnected, so the pyramid does not display these multiple feeding pathways.

Step 3: Conclusion Two limitations are failure to represent a species at more than one trophic level and failure to accommodate the complexity of food webs.

Quick Tip to Solve: Recall one limitation about placement of a species and one about the network of feeding links.

OR

20(b)(i). In an ecosystem there was loss of biodiversity due to some project in that area.

How will biodiversity be affected? (2 points)

[1 mark]

Solution:

Concept:

- Biodiversity includes the variety of species and their ecological roles within an ecosystem.
- Loss of species affects both the productivity of the community and its ability to withstand environmental disturbances.

Step 1: Explain the effect on production Loss of biodiversity generally causes a decline in plant production. The disappearance of species reduces the diversity of ecological functions and resource use within the community, weakening ecosystem functioning.

Step 2: Explain the effect on resistance The community shows lowered resistance to environmental perturbations such as drought. With fewer species and fewer differing responses to stress, ecosystem functioning is more vulnerable when conditions change.

Step 3: Conclusion Two consequences are a decline in plant production and lowered resistance to environmental disturbances such as drought.

Quick Tip to Solve: For effects of biodiversity loss, remember reduced production and reduced resistance; keep these distinct from its causes.

20(b)(ii). In an ecosystem there was loss of biodiversity due to some project in that area.

List two major causes of loss of biodiversity.

[1 mark]

Solution:

Concept:

- Human activities can reduce biodiversity by destroying the places where species live or by removing organisms faster than populations can replace them.
- Habitat loss and fragmentation and over-exploitation are two major causes of biodiversity loss.

Step 1: State habitat loss and fragmentation Conversion of forests or wetlands into settlements, agricultural land or project sites destroys habitats. Breaking a large habitat into small, isolated patches also restricts movement and threatens species that require extensive territories.

Step 2: State over-exploitation Excessive hunting, fishing or harvesting removes organisms beyond the capacity of their populations to recover. Continued overuse reduces population size and can ultimately cause extinction.

Step 3: Conclusion Two major causes are habitat loss and fragmentation, and over-exploitation of biological resources.

Quick Tip to Solve: Name habitat loss and fragmentation as one cause, then give a distinct cause such as over-exploitation.

21(a). Analyse the following two cases of sex determination in different organisms:

Case I: Males have (XO) sex chromosomes and females have two copies of same sex chromosome (XX).

Case II: Females have two different sex chromosomes (ZW) and males have two copies of same sex chromosome (ZZ).

Identify the type of heterogamety in each case, giving one example of each.

[2 marks]

Solution:

Concept:

- Heterogamety is the production of two kinds of gametes that differ in their sex-chromosome complement.
- The sex producing these two types is heterogametic; the other sex produces one sex-chromosome type of gamete and is homogametic.

Step 1: Analyse Case I An XO male produces two types of sperm: one carrying an X chromosome and one carrying no sex chromosome. Here O means absence of a sex chromosome, not a different chromosome. An XX female produces eggs carrying an X chromosome. Fertilisation gives XX females or XO males according to the sperm involved. This is **male heterogamety**, as seen in the grasshopper.

Step 2: Analyse Case II A ZW female produces two types of eggs, carrying either Z or W. A ZZ male produces sperm that all carry Z. Fertilisation gives ZZ males or ZW females according to the egg involved. This is **female heterogamety**, as seen in birds such as the domestic fowl.

Step 3: Conclusion Case I: male heterogamety, for example grasshopper. Case II: female heterogamety, for example domestic fowl.

Quick Tip to Solve: Identify which sex makes two sex-chromosome types of gametes: *XO* males or *ZW* females.

OR

21(b)(i). Differentiate between a DNA and RNA nucleotide.

[1 mark]

Solution:

Concept:

- A nucleotide consists of a nitrogenous base, a pentose sugar and a phosphate group.
- DNA and RNA nucleotides differ chiefly in the pentose sugar; their characteristic pyrimidine bases also differ.

Step 1: Compare their sugars A DNA nucleotide contains 2-deoxyribose, with a hydrogen atom at the 2' carbon. An RNA nucleotide contains ribose, with a hydroxyl group at the corresponding 2' carbon.

Step 2: Compare their bases DNA nucleotides contain adenine, guanine, cytosine or thymine. RNA nucleotides contain adenine, guanine, cytosine or uracil. Thus uracil replaces thymine in RNA, while adenine, guanine and cytosine are common to both.

Step 3: Conclusion DNA nucleotide: deoxyribose sugar and one of A, G, C or T. RNA nucleotide: ribose sugar and one of A, G, C or U.

Quick Tip to Solve: Compare the sugar first: deoxyribose in DNA, ribose in RNA; then distinguish thymine from uracil.

21(b)(ii). Name the two types of bonds present within a single nucleotide.

[1 mark]

Solution:

Concept:

- A nucleotide is formed from a nitrogenous base, pentose sugar and phosphate group.
- The bonds within one nucleotide must be distinguished from the phosphodiester linkage joining successive nucleotides.

Step 1: Identify the base-sugar bond The nitrogenous base is attached to the 1' carbon of the pentose sugar through an N-glycosidic linkage. Joining just the base and sugar produces a nucleoside.

Step 2: Identify the sugar-phosphate bond The phosphate group is attached to a hydroxyl group of the sugar, usually at its 5' carbon, through a phosphoester linkage. Addition of this phosphate converts the nucleoside into a nucleotide.

Step 3: Conclusion The two bonds are an N-glycosidic bond and a phosphoester bond.

Quick Tip to Solve: For a single nucleotide, name glycosidic and phosphoester bonds; reserve phosphodiester for the linkage between nucleotides.

Section C (21 marks)

22(a). A farmer grew two varieties of corn crop in field A and B. He grew normal corn crops in field A and GM corn crops in field B.

He observed that corn borers attacked only in field A. To control it, spores of Bt were sprayed on field A.

Name the gene in the spores responsible for control of pest.

[0.5 marks]

Solution:

Concept:

- Bt is the bacterium *Bacillus thuringiensis*, which produces insecticidal crystalline proteins encoded by *cry* genes.
- Different *cry* genes encode proteins effective against particular insect pests; the gene is identified from the pest named in the question.

Step 1: Identify the target pest The insect attacking field A is the corn borer. Therefore, identify the Bt toxin gene associated specifically with resistance against corn borers.

Step 2: Match the pest to its Bt gene The Bt protein effective against corn borers is encoded by *cryIAb*. This distinguishes it from *cryIAc* and *cryIIAb*, which are associated with control of cotton bollworms.

Step 3: Conclusion The gene is *cryIAb*, a Bt toxin gene whose product controls corn borers.

Quick Tip to Solve: Match corn borer with *cryIAb*; associate *cryIAc* and *cryIIAb* with cotton bollworms.

22(b). A farmer grew two varieties of corn crop in field A and B. He grew normal corn crops in field A and GM corn crops in field B.

He observed that corn borers attacked only in field A. To control it, spores of Bt were sprayed on field A.

What effect will the spores of Bt have on insect pest?

[1.5 marks]

Solution:

Concept:

- *Bacillus thuringiensis* produces crystalline insecticidal protein during sporulation. This protein initially occurs as an inactive protoxin.
- The protoxin becomes active in the alkaline insect gut, and the active toxin damages the epithelial lining of the midgut.

Step 1: Activate the toxin after ingestion The corn borer ingests the sprayed Bt spore preparation while feeding on the corn plant. The preparation contains protein crystals. The alkaline conditions in the insect gut solubilise these crystals, and the inactive protoxin is converted into the active toxin. Thus, the insecticidal effect follows ingestion rather than simply contact of a spore with the insect's outer surface.

Step 2: Trace the damage to the insect gut The activated toxin binds to the surface of midgut

epithelial cells and creates pores in their membranes. These pores cause the cells to swell and lyse, disrupting the midgut lining. This cellular damage kills the corn borer and therefore controls the pest in field A.

Step 3: Conclusion Ingestion of the Bt preparation activates its toxin in the alkaline gut; the toxin forms pores in midgut epithelial cells, causing swelling, lysis and death of the insect pest.

Quick Tip to Solve: Recall the order: ingestion, alkaline activation, binding to midgut cells, pore formation, cell lysis and insect death.

22(c). A farmer grew two varieties of corn crop in field A and B. He grew normal corn crops in field A and GM corn crops in field B.

He observed that corn borers attacked only in field A. To control it, spores of Bt were sprayed on field A.

How has corn plants of field B developed resistance against this pest? Explain.

[1 mark]

Solution:

Concept:

- Bt corn contains an introduced insecticidal protein gene from the bacterium *Bacillus thuringiensis*.
- The Bt gene *cryIAb* encodes a toxin effective against corn borers; expression of the transgene gives the crop resistance.

Step 1: Introduce and express the Bt gene The *cryIAb* gene from *Bacillus thuringiensis* was introduced into the corn plants by genetic engineering. The resulting GM plants in field B express this gene and produce the Bt insecticidal protein in their tissues.

Step 2: Explain protection against the borer When corn-borer larvae feed on these tissues, they ingest the Bt protein. The alkaline insect gut activates the toxin, which damages the midgut epithelial cells and kills the larvae. This prevents successful borer feeding and protects the crop.

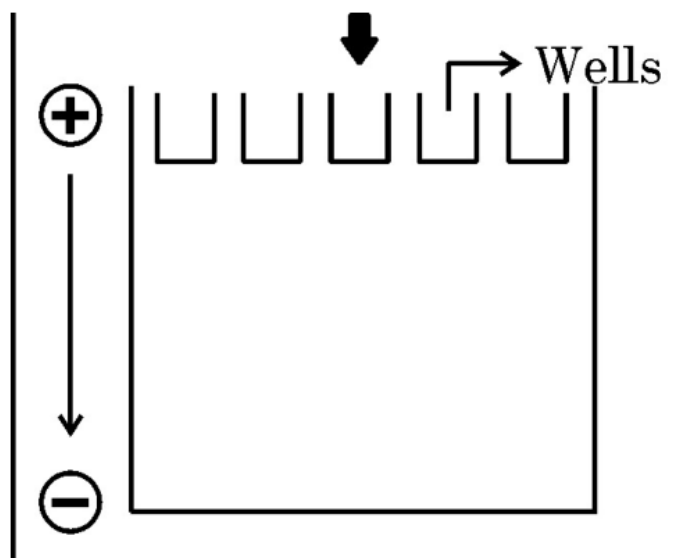
Step 3: Conclusion Field B corn is resistant because it carries and expresses the Bt *cryIAb* gene, producing a protein toxic to corn borers.

Quick Tip to Solve: For corn borer resistance, connect the specific gene *cryIAb* with toxin production inside the GM plant.

23(a). Observe the given picture carefully. A mixture of DNA with fragments ranging from 100 base pairs to 1800 base pairs were separated by electrophoresis on agarose gel with the following arrangement:

What result will be obtained in staining with ethidium bromide? Explain with reasons.

[1 mark]



Solution:

Concept:

- DNA has a net negative charge because of its phosphate backbone and therefore moves towards the positive electrode during electrophoresis.
- Ethidium bromide-stained DNA fluoresces orange under ultraviolet light; visible separated bands require DNA to migrate through the gel.

Step 1: Check the electrodes against the wells In the given arrangement, the positive electrode is at the well end and the negative electrode is at the opposite end of the gel. This is the reverse of the arrangement needed to drive DNA from the wells through the length of the gel.

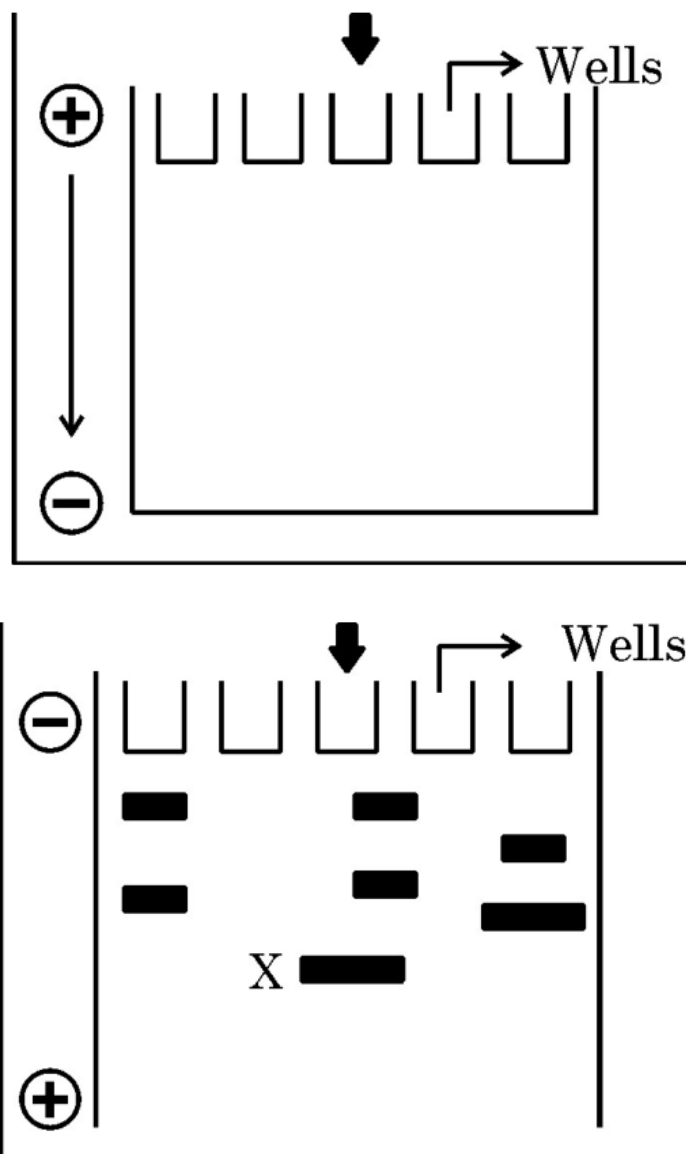
Step 2: Predict migration and the staining result The negatively charged DNA moves towards the positive electrode near the wells, away from the main gel, and may escape into the buffer. Consequently, the DNA fragments will not form the expected separated orange fluorescent bands in the gel on staining with ethidium bromide and viewing under UV light.

Step 3: Conclusion No properly separated DNA bands will be observed in the gel: the reversed polarity drives DNA towards the positive electrode at the well end, out of the gel.

Quick Tip to Solve: Always check that DNA-loading wells are at the negative end before predicting the positions of fluorescent bands.

23(b). Observe the given picture carefully. A mixture of DNA with fragments ranging from 100 base pairs to 1800 base pairs were separated by electrophoresis on agarose gel with the following arrangement:

The above setup was modified as shown below and a band with 100 base pairs was obtained at X. What changes were made to the previous design to get a band at 'X'. Why did the band appear at 'X'? [2 marks]



Solution:

Concept:

- DNA has a net negative charge because of its phosphate backbone and migrates towards the positive electrode (anode) in an electric field.
- Agarose acts as a molecular sieve: smaller DNA fragments move through its pores more readily and travel farther than larger fragments in the same time.

Step 1: **Correct the polarity of the electrodes** Reverse the electrode connections shown in the first

arrangement. Place the negative electrode (cathode) at the wells and the positive electrode (anode) at the opposite, lower end of the gel. The negatively charged DNA now moves away from the wells into the gel towards the positive electrode, instead of towards the upper end outside the intended separation path.

Step 2: Explain the position of the band at X The fragments range from 100 to 1800 base pairs. The 100-base-pair fragments are the smallest in this mixture, so the agarose matrix offers them the least resistance to migration. In the same running time, they travel the farthest from the wells. The band at X is the most distant band in the illustrated separation and therefore contains these 100-base-pair fragments.

Step 3: Conclusion Reverse the polarity so that the wells are beside the negative electrode. The smallest DNA fragments, of 100 base pairs, migrate farthest towards the positive electrode and form the band at X.

Quick Tip to Solve: First check that DNA is loaded near the negative electrode; then identify the farthest band as the smallest DNA fragment.

24(a). Mention the scientific name of the source plant and the part from which opioids are extracted.

[1 mark]

Solution:

Concept:

- Natural opioids such as morphine are obtained from the opium poppy.
- The milky latex of its unripe capsules is the plant material used to obtain opium and its alkaloids.

Step 1: Identify the source plant The source is the opium poppy, whose scientific name is *Papaver somniferum*. The scientific name specifies the plant from which the natural opioid morphine is extracted.

Step 2: Identify the part yielding the extract Opioids are extracted from the latex of this plant, obtained from its unripe fruit capsules. The required source material is the latex, rather than the seeds or dried leaves.

Step 3: Conclusion The plant is *Papaver somniferum*; opioids are extracted from the latex of its unripe capsules.

Quick Tip to Solve: Link opium poppy with latex from unripe capsules, and write the full binomial *Papaver somniferum*.

24(b). How are morphine and heroin related? Mention the effect each one of them has on human body. [2 marks]

Solution:

Concept:

- Morphine is a natural opioid obtained from the latex of *Papaver somniferum*; heroin is a chemically modified derivative of morphine.
- Opioids bind to specific opioid receptors in the central nervous system and gastrointestinal tract, altering nervous activity and bodily functions.

Step 1: State the chemical relationship Heroin is chemically diacetylmorphine. It is obtained by acetylation of morphine, so morphine is the parent substance from which heroin is derived. They are related opioids, but they are not two names for the same unchanged compound.

Step 2: Explain the effect of morphine Morphine acts as an effective sedative and painkiller (analgesic). It relieves severe pain and is used medically, particularly to manage pain in patients who have undergone surgery. Its analgesic effect reduces the perception of pain.

Step 3: Explain the effect of heroin Heroin is a depressant. It slows down body functions by depressing nervous activity. It is highly addictive and can produce dependence; its depressant action can also slow breathing. The characteristic effect asked for here is the slowing of body functions.

Step 4: Conclusion Heroin (diacetylmorphine) is formed by acetylation of morphine. Morphine is a sedative and strong painkiller; heroin is a depressant that slows body functions.

Quick Tip to Solve: Pair morphine with pain relief and heroin with depressed body functions; connect the two by the term diacetylmorphine.

25. Give the schematic representation of oogenesis in human female. Indicate chromosome number also. [3 marks]

Solution:

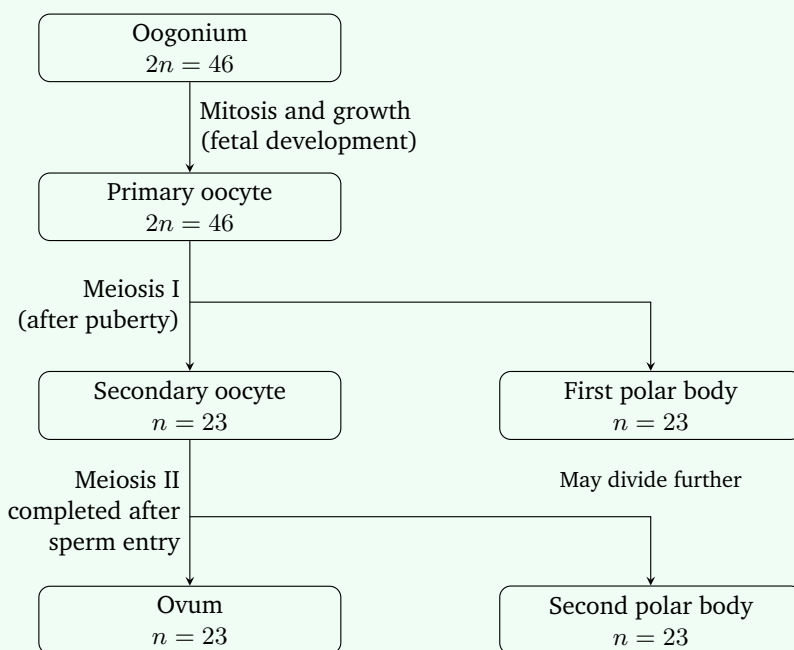
Concept:

- Oogenesis forms a functional female gamete from a diploid oogonium by growth and two meiotic divisions. In humans, $2n = 46$ and $n = 23$, where n is the haploid chromosome number.
- Unequal cytokinesis retains most of the cytoplasm in one large cell; the other products are small polar bodies. Meiosis I reduces chromosome number, whereas meiosis II separates sister chromatids.

Step 1: Show the diploid stages and first meiotic division Oogonia multiply by mitosis during fetal development and form primary oocytes, each with 46 chromosomes. Primary oocytes enter meiosis I and remain arrested in prophase I. After puberty, a selected primary oocyte completes meiosis I, producing a large secondary oocyte and a small first polar body. Each product has 23 chromosomes, with each chromosome still consisting of two chromatids.

Step 2: Complete the schematic through meiosis II The secondary oocyte begins meiosis II and is released at ovulation while arrested in metaphase II. Sperm entry triggers completion of this division, forming the ovum and the second polar body, each with 23 chromosomes. The first polar body may

also divide. The diagram tracks chromosome number rather than DNA content; DNA replication does not double the chromosome count.



Oogenesis in humans; chromosome numbers are shown in every cell.

Step 3: Conclusion Oogonium (46) → primary oocyte (46) → secondary oocyte (23) → ovum (23). Polar bodies are haploid (23); only one large functional ovum is produced from each primary oocyte.

Quick Tip to Solve: Reduce 46 to 23 at meiosis I; keep 23 after meiosis II, and label both polar bodies as haploid.

26(a). Do all pollen grains remain viable for the same length of time? Support your answer with two suitable examples. [2.5 marks]

Solution:

Concept:

- Pollen viability is the period during which a pollen grain retains its ability to germinate on a compatible stigma and bring about fertilisation.
- The duration of viability varies among plant species and also depends on environmental conditions, particularly temperature and humidity.

Step 1: Compare the duration of viability Pollen grains do not all remain viable for the same length of time. Their longevity is species-dependent; therefore, the time available for successful pollination after pollen release differs greatly between plants. A pollen grain that has lost viability cannot produce a functional pollen tube for fertilisation even if it reaches a suitable stigma.

Step 2: Give an example of short viability In rice, pollen grains generally lose viability within about 30 minutes of their release. Wheat also illustrates this short-lived type. Successful pollination in such cereals must therefore occur soon after the pollen is shed.

Step 3: Give an example of prolonged viability In some members of the family Rosaceae, pollen grains can remain viable for months. Similar prolonged viability is found in some members of Leguminosae and Solanaceae. These examples contrast with the brief viability of rice pollen and show that one fixed duration cannot be assigned to all pollen grains.

Step 4: Conclusion No. Rice pollen usually loses viability within about 30 minutes of release, whereas pollen of some Rosaceae members can remain viable for months.

Quick Tip to Solve: Pair a cereal with a long-lived family example: rice, about 30 minutes; some Rosaceae members, months.

26(b). How are pollen grains stored in pollen banks?

[0.5 marks]

Solution:

Concept:

- Pollen viability is the ability of a pollen grain to germinate and bring about fertilisation.
- Cryopreservation maintains biological material at a very low temperature for long-term storage.

Step 1: Name the preservation method Pollen banks preserve pollen grains by cryopreservation. This allows viable pollen to be retained for later use in crop breeding instead of being used immediately after its collection.

Step 2: Specify the storage condition The pollen grains are stored in liquid nitrogen at -196°C . At this very low temperature, biological activity is greatly suppressed, enabling pollen grains of many species to remain viable for years.

Step 3: Conclusion Pollen grains are cryopreserved in liquid nitrogen at -196°C .

Quick Tip to Solve: For pollen-bank storage, state both liquid nitrogen and its temperature, -196°C .

27(a). What is pedigree analysis? Mention its importance in human genetics. (2 pts.)

[2 marks]

Solution:

Concept:

- A pedigree is a family chart showing the occurrence of a particular trait in successive generations.
- Inheritance patterns are inferred by comparing affected and unaffected relatives and the transmission of the trait.

Step 1: Define pedigree analysis Pedigree analysis is the study of the inheritance of a particular trait in several generations of a family with the help of a family-tree diagram. Standard symbols record males, females, parental relationships, offspring and individuals expressing the trait.

Step 2: Explain its importance in humans First, it helps trace the inheritance of a genetic trait or disorder and determine whether its pattern is dominant, recessive or sex-linked. Second, it helps infer possible carrier status and assess the chance of the trait appearing in offspring, supporting genetic counselling. This is especially useful in humans because controlled experimental crosses cannot be

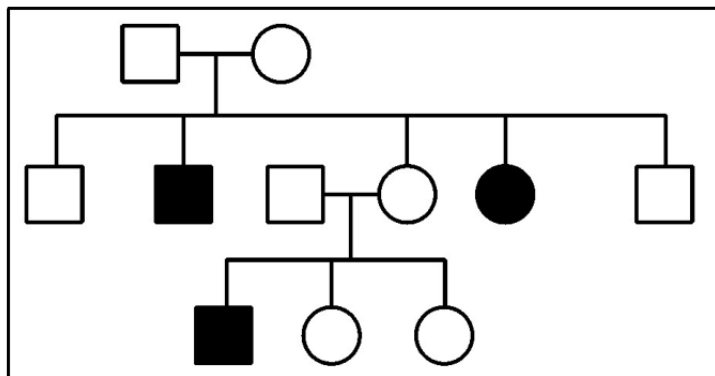
performed as they can in experimental organisms.

Step 3: Conclusion Pedigree analysis traces a trait through family generations; it helps identify its inheritance pattern and estimate carrier status or the risk to offspring.

Quick Tip to Solve: When asked for two points of importance, distinguish identifying the inheritance pattern from predicting carriers or affected offspring.

27(b)(i). Analyse the following pedigree and write the Pattern of inheritance.

[0.5 marks]



Solution:

Concept:

- A recessive trait can appear in a child of two phenotypically unaffected carrier parents.
- An autosomal trait can affect males and females; an affected daughter with an unaffected father excludes ordinary X-linked recessive inheritance.

Step 1: Inspect the unaffected parents The unaffected parents in the first generation have affected offspring. This is consistent with a recessive trait: both parents can be heterozygous carriers, Aa , while affected offspring have genotype aa .

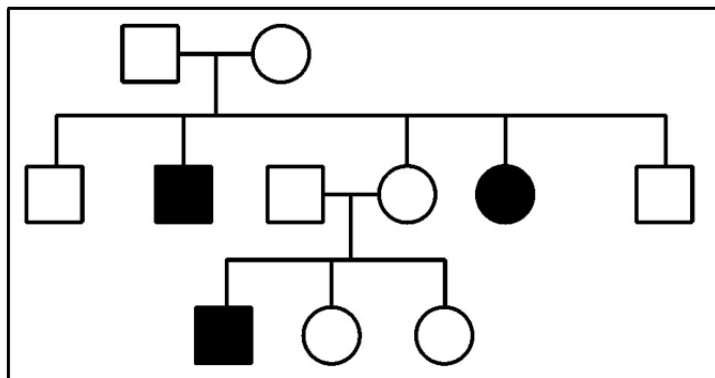
Step 2: Use the affected daughter to identify the chromosome Both a son and a daughter are affected. In X-linked recessive inheritance an affected daughter must receive a recessive allele from her father and would therefore have an affected father. The father here is unaffected, so the depicted pattern is autosomal recessive.

Step 3: Conclusion The pedigree shows autosomal recessive inheritance.

Quick Tip to Solve: Start with unaffected parents producing affected children; then check the affected daughter and her unaffected father to identify autosomal recessive inheritance.

27(b)(ii). Give one example of disease showing such an inheritance pattern.

[0.5 marks]



Solution:

Concept:

- The pedigree represents an autosomal recessive trait, expressed in homozygous recessive individuals.
- Phenylketonuria is an autosomal recessive inherited metabolic disorder.

Step 1: Recall the inheritance pattern The affected individuals include both males and females, and affected children occur among the offspring of unaffected parents. These observations fit autosomal recessive inheritance, in which the parents can be carriers without expressing the disorder.

Step 2: Match a disease to the pattern Phenylketonuria follows this pattern. It results from deficiency of the enzyme required to convert phenylalanine into tyrosine. An individual with two recessive disease alleles is affected, whereas a heterozygote is a carrier; two carrier parents can therefore have an affected child.

Step 3: Conclusion One example is phenylketonuria.

Quick Tip to Solve: Choose an autosomal recessive example such as phenylketonuria; haemophilia is X-linked recessive and does not match this pedigree.

28(a). How is Hardy-Weinberg expression ($p^2 + 2pq + q^2 = 1$) derived?

[2 marks]

Solution:

Concept:

- For two alleles A and a at one locus, let their frequencies be p and q , respectively; then $p + q = 1$.
- In a large, randomly mating population without disturbing evolutionary forces, gamete unions give the Hardy-Weinberg genotype frequencies.

Step 1: Assign frequencies to the gametes An allele occupies either of the two possible states, A or a , so their frequencies exhaust all possibilities: $p + q = 1$. Under random mating, male and female gamete pools have these same allele frequencies, and the probabilities of their independent unions are multiplied.

Step 2: Find each genotype frequency An A gamete joining another A gamete produces AA with

frequency $p \times p = p^2$. An a gamete joining another a gamete produces aa with frequency $q \times q = q^2$. A heterozygote Aa can arise in two ways: paternal A with maternal a , or paternal a with maternal A . Its frequency is therefore $pq + qp = 2pq$.

Step 3: Add the genotype frequencies The three genotypes cover every possible zygote. Hence their frequencies sum to one:

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

Here p^2 , $2pq$ and q^2 are the frequencies of AA , Aa and aa , respectively.

Step 4: Conclusion The Hardy-Weinberg expression is $p^2 + 2pq + q^2 = 1$, obtained by expanding $(p + q)^2$ for random union of gametes.

Quick Tip to Solve: Remember the factor 2 in $2pq$: the dominant allele can come from either parent, giving two ways to form a heterozygote.

28(b). List any two factors that disturb the genetic equilibrium.

[1 mark]

Solution:

Concept:

- Genetic equilibrium means that allele frequencies remain constant from generation to generation.
- Evolutionary forces can change allele frequencies and therefore disturb Hardy-Weinberg equilibrium.

Step 1: Identify gene migration Gene migration, or gene flow, introduces alleles into a population or removes them when individuals enter or leave and reproduce. If migrants differ in allele frequencies, the composition of the receiving population changes.

Step 2: Identify genetic drift Genetic drift is a random change in allele frequencies due to chance sampling, especially in small populations. Some alleles may become more frequent, disappear or become fixed even without a survival advantage.

Step 3: Conclusion Two factors are gene migration (gene flow) and genetic drift.

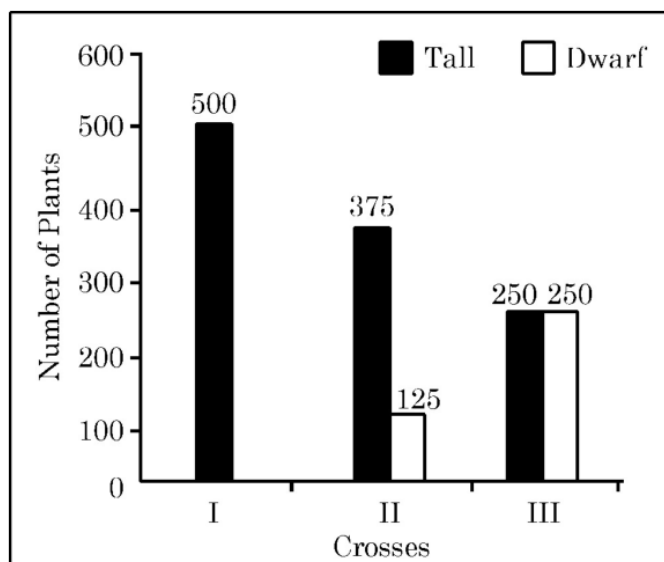
Quick Tip to Solve: For this question, list gene flow and genetic drift; remember that gene flow involves migration, while drift involves chance.

Section D (8 marks)

Question Nos. 29 and 30 are case-based questions. Each question has sub-sections with internal choice in one sub-section.

29. A student performed some crosses in plants and represented the result in the form of bar graphs as shown below. Each graph displays the phenotypic proportion of the progeny. Study the graphs and answer the questions:

[4 marks]



29(a). What can you infer about the genotype of parents in crosses I and II?

[1 mark]

Solution:

Concept:

- Let T denote the dominant allele for tallness and t the recessive allele for dwarfness.
- In the standard Mendelian monohybrid experiment, pure parents produce a uniform F_1 ; crossing the F_1 hybrids gives segregation in F_2 .

Step 1: Interpret cross I Cross I has 500 tall plants and no dwarf plant. In the parental cross illustrated by the Mendelian experiment, the parents are homozygous tall and homozygous dwarf: $TT \times tt$. Every offspring receives T from one parent and t from the other, so all are tall Tt .

Step 2: Interpret cross II Cross II gives $375 : 125 = 3 : 1$ tall to dwarf offspring. This is produced by two heterozygous tall parents, $Tt \times Tt$, giving $1TT : 2Tt : 1tt$. The all-tall result of cross I alone need not uniquely establish both genotypes; the pure-parent interpretation follows the standard sequence shown.

Step 3: Conclusion In the standard monohybrid sequence: cross I is $TT \times tt$, and cross II is $Tt \times Tt$.

Quick Tip to Solve: Reduce the plant counts to a ratio: 375 tall and 125 dwarf give the diagnostic $3 : 1$ heterozygote-cross ratio.

29(a). Which genetic cross is represented by these crosses?

[1 mark]

Solution:

Concept:

- A monohybrid cross studies the inheritance of one character represented by a pair of contrasting traits.
- Here the character is plant height, with tall and dwarf as the contrasting traits; T is dominant to t .

Step 1: Count the characters studied All three bar graphs classify progeny only by height: tall or dwarf. No second character, such as seed colour, is recorded. Hence the graphs belong to a monohybrid inheritance experiment.

Step 2: Relate the crosses to the monohybrid pattern Cross I shows all tall progeny, as in $TT \times tt$. Cross II gives $375 : 125 = 3 : 1$, as in $Tt \times Tt$. Cross III gives $250 : 250 = 1 : 1$, the test cross $Tt \times tt$. These are different crosses involving the same single character.

Step 3: Conclusion The graphs represent monohybrid crosses for plant height; cross III is specifically a monohybrid test cross.

Quick Tip to Solve: Count characters, not bars: tall and dwarf are two forms of one character, so this is monohybrid inheritance.

29(b). Looking at bar graph of cross III, identify the type of cross performed and its importance in genetics.

[2 marks]

Solution:

Concept:

- A test cross mates an individual showing the dominant phenotype with a homozygous recessive individual to determine the dominant individual's genotype.
- For plant height, T denotes tallness and t dwarfness; the recessive tester has genotype tt .

Step 1: Read the progeny ratio Cross III produces 250 tall and 250 dwarf plants, so the phenotypic ratio is $1 : 1$. The dwarf offspring must have received a recessive allele from each parent. Thus the tall parent carries t as well as T , and is heterozygous.

Step 2: Write the test cross The cross is $Tt \times tt$. The tall parent forms equal proportions of T and t gametes, while the dwarf parent forms only t gametes. Fertilisation therefore produces $\frac{1}{2}Tt$ tall and $\frac{1}{2}tt$ dwarf offspring, matching the graph.

Step 3: Explain its genetic importance A dominant phenotype alone cannot distinguish TT from Tt . A test cross reveals this hidden genotype: a TT parent crossed with tt gives all tall Tt offspring, whereas a Tt parent gives the observed equal tall and dwarf classes. It is therefore useful for testing the genetic purity of a dominant individual.

Step 4: Conclusion Cross III is a test cross, $Tt \times tt$; its $1 : 1$ progeny ratio establishes that the tall parent is heterozygous.

Quick Tip to Solve: Use a homozygous recessive tester: each offspring phenotype then reveals which allele came from the dominant parent.

29(c). What conclusion can you draw from the results of bar graphs of crosses I and II? Name the genetic principle illustrated. [1 mark]

Solution:

Concept:

- The law of dominance states that only the dominant allele is expressed in a heterozygote; the recessive allele remains present.
- The law of segregation states that the two alleles of a gene separate during gamete formation, so each gamete carries one allele.

Step 1: Explain the uniform tall progeny Cross I shows all tall plants. In $TT \times tt$, all progeny are Tt , but they express tallness. Thus tallness is dominant and dwarfness is recessive; the dwarf allele is masked rather than lost.

Step 2: Explain the reappearance of dwarfness Cross II gives $375 : 125 = 3 : 1$ tall to dwarf plants. The Tt parents each form T and t gametes, yielding $1TT : 2Tt : 1tt$. Dwarfness reappears in tt offspring because the alleles segregate without blending.

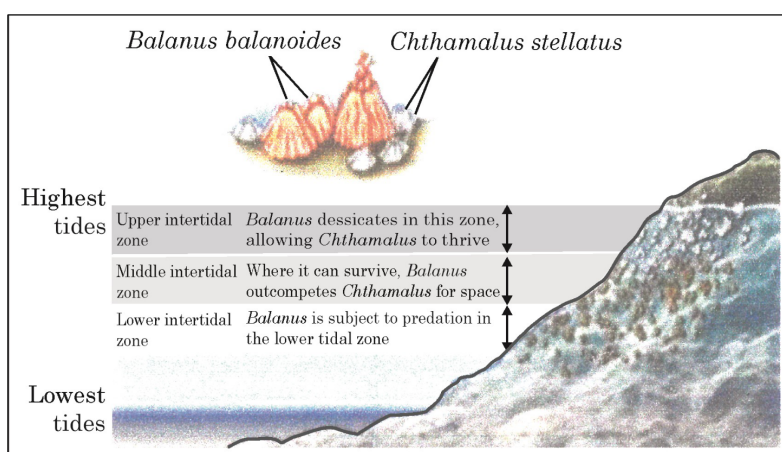
Step 3: Conclusion Cross I illustrates the law of dominance; the reappearance of dwarf plants in cross II illustrates the law of segregation (purity of gametes).

Quick Tip to Solve: Link all-tall hybrids to dominance, and the reappearance of dwarf offspring in a 3 : 1 ratio to segregation.

30. The diagram below shows the distribution of two barnacle species, *Chthamalus* and *Balanus* on a rocky sea shore.

When *Balanus* is experimentally removed, *Chthamalus* expands its range in lower intertidal zone.

[4 marks]



30(a). Identify and define the ecological phenomenon demonstrated by this observation. [1 mark]

Solution:

Concept:

- Interspecific competition can restrict a species to a smaller distribution than the habitat it could otherwise occupy.
- Competitive release is the expansion of a species' range or resource use when a competing species is removed.

Step 1: Identify what changes in the experiment With *Balanus* present, *Chthamalus* is restricted largely to the upper intertidal region. After *Balanus* is removed, *Chthamalus* expands into the lower intertidal region.

Step 2: Relate the expansion to competition The expanding species was capable of living in the additional region, but competition from *Balanus* limited its occupation of that habitat. Removal of this competitor releases the restriction, allowing *Chthamalus* to occupy a wider range.

Step 3: Conclusion The phenomenon is competitive release: a species expands its distribution or resource use after removal of a competing species.

Quick Tip to Solve: Look for the experimental trigger: expansion after a competitor is removed identifies competitive release.

OR

30(a). State the principle that explains the elimination of one species. [1 mark]

Solution:

Concept:

- Interspecific competition occurs when different species require the same limited resource, such as attachment space on a rocky shore.
- Gause's competitive exclusion principle describes the outcome when two species compete for the same limiting resources in the same niche.

Step 1: Identify the competing species *Balanus* and *Chthamalus* compete for space on the shore. In the region where *Balanus* survives well, it is the superior competitor and restricts *Chthamalus*.

Step 2: State the principle and its scope Two species competing for the same limiting resources cannot coexist indefinitely in the same ecological niche; the competitively inferior species is eventually excluded. Here exclusion is from the shared part of the habitat, not necessarily extinction of the species from every habitat.

Step 3: Conclusion The principle is Gause's competitive exclusion principle: complete competitors for the same limiting resources cannot coexist indefinitely, and the inferior competitor is excluded.

Quick Tip to Solve: Distinguish exclusion from release: elimination by a superior competitor is exclusion; expansion after its removal is release.

30(b). Two different species can compete for the same resource. Give another example of it. [1 mark]

Solution:

Concept:

- Interspecific competition occurs when individuals of two different species use the same limited resource.
- The competitors need not be closely related; sharing a food resource can bring very different animals into competition.

Step 1: Identify two competing species In shallow South American lakes, visiting flamingoes and resident fishes compete with one another for food.

Step 2: Identify their common resource Both feed on zooplankton in the lake. Consumption of this shared food by one competitor reduces its availability to the other, illustrating interspecific competition.

Step 3: Conclusion Flamingoes and resident fishes in shallow South American lakes compete for zooplankton.

Quick Tip to Solve: For an example of competition, name both competitors and the particular resource they share.

30(c). How do species avoid competition in nature? Explain with an example. [2 marks]

Solution:

Concept:

- Resource partitioning reduces interspecific competition by allowing species to use a resource in different ways.
- Species may differ in their feeding locations, feeding times or foraging behaviour, reducing overlap of their ecological niches.

Step 1: Explain how competition is reduced Species that might otherwise compete can divide the available resources. By feeding in different places or at different times, or by using different foraging patterns, they reduce direct competition and can coexist in the same habitat.

Step 2: Apply the warbler example MacArthur observed five closely related species of warblers living on the same tree. They could coexist because they used different foraging patterns and searched for food in different regions of the tree. Their use of distinct feeding areas reduced competition for insects.

Step 3: Conclusion Species avoid or reduce competition through resource partitioning; five warbler species coexist on one tree by adopting different foraging patterns.

Quick Tip to Solve: Link the warbler example to different feeding regions of one tree, showing how food-resource overlap is reduced.

Section E (15 marks)

31(a)(i). In angiosperms, the female gametophyte develops from a single cell of megasporangium. Name that cell of megasporangium and describe the sequential changes it undergoes to form a mature female gametophyte. [3 marks]

Solution:

Concept:

- The megaspore mother cell (MMC) is a diploid $2n$ cell differentiated in the nucellus of the ovule, the megasporangium.
- Megasporogenesis produces haploid n megaspores by meiosis; megagametogenesis develops the functional megaspore into the embryo sac.
- The usual angiosperm embryo sac is monosporic because it develops from one functional megaspore.

Step 1: Identify the initial cell and its meiotic division The initial cell is the **megaspore mother cell (MMC)**. It is generally a large cell with dense cytoplasm and a prominent nucleus in the micropylar region of the nucellus. The diploid MMC undergoes meiosis to produce four haploid megaspores.

Step 2: Select the functional megaspore Usually three megaspores degenerate and only one remains functional. This single surviving megaspore develops into the female gametophyte or embryo sac; this is monosporic development.

Step 3: Describe the free-nuclear mitoses The nucleus of the functional megaspore divides mitotically three times, giving successively 2, 4 and 8 nuclei. These divisions are initially free-nuclear: cell walls are not laid down immediately. Four nuclei are positioned at each pole.

Step 4: Organise the mature embryo sac One nucleus from each pole moves towards the centre; these are the two polar nuclei in the large central cell. Of the three nuclei remaining at the micropylar pole, one forms the egg cell and two form synergids. The synergids possess a filiform apparatus. The three nuclei at the chalazal pole form three antipodal cells. Cellular organisation thus produces seven cells containing eight nuclei.

Step 5: Conclusion The megaspore mother cell undergoes meiosis; one functional megaspore then undergoes three mitoses and cellular organisation to form a seven-celled, eight-nucleate embryo sac.

Quick Tip to Solve: Keep the sequence distinct: MMC, meiosis, four megaspores, one functional megaspore, three mitoses, then seven cells with eight nuclei.

31(a)(ii). In angiosperms, the female gametophyte develops from a single cell of megasporangium. Draw a well labelled diagram of mature female gametophyte. Label any four parts. [2 marks]

Solution:

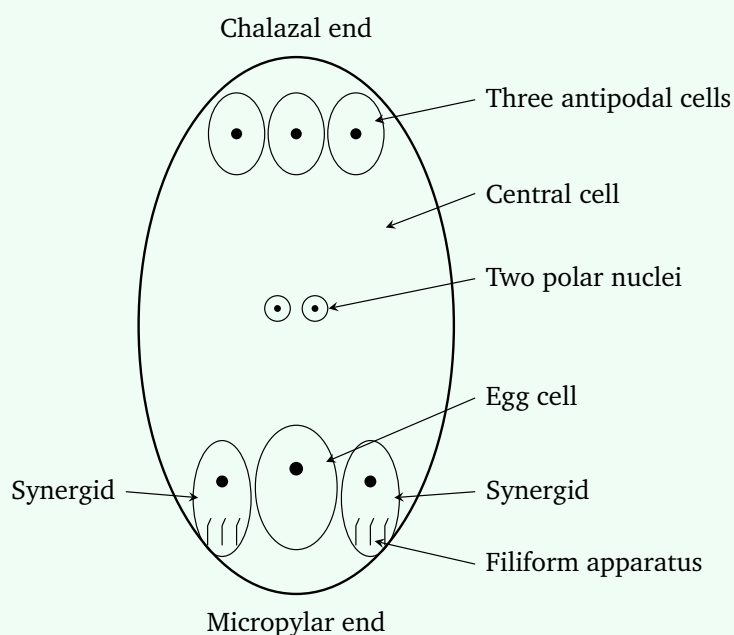
Concept:

- A typical mature angiosperm female gametophyte is the embryo sac, with seven cells and eight nuclei.

- Its egg apparatus lies at the micropylar end, the antipodal cells lie at the chalazal end, and the large central cell contains two polar nuclei.

Step 1: Place the cells at the two poles Draw an elongated embryo sac. At the micropylar end show an egg cell flanked by two synergids, together forming the egg apparatus. Show the filiform apparatus as finger-like thickenings near the micropylar tips of the synergids. At the opposite, chalazal end draw three separate antipodal cells.

Step 2: Label the centre and check the count Place two polar nuclei in the large central cell. Label the egg cell, synergids, antipodal cells and polar nuclei; the central cell and filiform apparatus are also labelled in the diagram. The three egg-apparatus cells, three antipodal cells and one central cell total seven cells. The two nuclei of the central cell give a total of eight nuclei.



Mature angiosperm embryo sac with its principal parts labelled

Step 3: Conclusion The labelled diagram shows the mature seven-celled, eight-nucleate embryo sac, including the egg cell, synergids, antipodals and polar nuclei.

Quick Tip to Solve: Orient the egg apparatus towards the micropyle and count the central cell once even though it contains two polar nuclei.

31(b). Given below are certain situations related to birth control. Analyse each situation carefully and suggest appropriate contraceptive method that could be used. Also explain its mode of action.

Situation 1 - To prevent entry of sperm into cervix.

Situation 2 - Devices that are inserted by doctors or expert nurses in the vagina.

Situation 3 - Effective emergency contraceptive.

Situation 4 - Permanent method for male partner.

Situation 5 - Surgical method in female to prevent pregnancy.

[5 marks]

Solution:

Concept:

- Contraceptive methods prevent conception by blocking sperm transport, preventing fertilisation or modifying reproductive physiology. The appropriate method depends on whether protection must be temporary, emergency or permanent.
- Barrier methods cover the cervix, intrauterine devices act within the uterus, and sterilisation interrupts the transport of gametes without removing the gonads.

Step 1: Situation 1: block sperm entry into the cervix A diaphragm, cervical cap or vault is suitable. This rubber barrier is inserted into the vagina to cover the cervix during intercourse, preventing sperm from entering the uterus and meeting the ovum. These barriers are reusable; spermicidal creams, jellies or foams may be used with them to increase contraceptive efficiency.

Step 2: Situation 2: identify the professionally inserted device Intrauterine devices (IUDs), such as Copper-T, are inserted by a doctor or expert nurse. The device passes through the vagina and cervix, but its final position is inside the uterus, not in the vaginal cavity. IUDs increase phagocytosis of sperm within the uterus. In a copper-releasing IUD, copper ions also suppress sperm motility and their fertilising capacity. Hormone-releasing IUDs additionally make the cervix hostile to sperm and the uterus unsuitable for implantation.

Step 3: Situation 3: use emergency contraception Emergency contraceptive pills containing a progestogen, or a progestogen–oestrogen combination, may be used within 72 hours of unprotected intercourse in the standard NCERT account. Their action includes delaying or inhibiting ovulation, thereby preventing an ovum from becoming available for fertilisation. A copper-releasing IUD is another effective emergency contraceptive option: its copper-mediated effects on sperm help prevent fertilisation. Emergency contraception prevents pregnancy; it does not terminate an established pregnancy.

Step 4: Situation 4: select permanent male contraception Vasectomy is the appropriate surgical method. A small portion of each vas deferens is removed or tied through a small incision in the scrotum. Sperm can no longer pass from the testes into the semen, so insemination does not deliver sperm for fertilisation after clearance of residual sperm. The testes remain present and continue producing male sex hormones.

Step 5: Situation 5: select surgical female contraception Tubectomy is appropriate. A small portion of each fallopian tube is removed or tied through a small incision in the abdomen or through the vagina. This blocks gamete transport through the oviducts, so sperm and ovum cannot meet for fertilisation.

The ovaries are retained, so the operation does not remove the source of ovarian hormones.

Step 6: Conclusion The suitable methods are: (1) diaphragm/cervical cap/vault; (2) an IUD such as Copper-T, placed within the uterus through the vaginal route; (3) emergency contraceptive pills or a copper IUD; (4) vasectomy; and (5) tubectomy.

Quick Tip to Solve: Match the target to the method: cervix barrier, uterus IUD, emergency pills, male vas deferens vasectomy, and female fallopian tubes tubectomy.

32(a)(i). Name the protozoan species that is responsible for causing the most serious and even fatal malarial disease. [0.5 marks]

Solution:

Concept:

- Malaria is caused by protozoan parasites belonging to the genus *Plasmodium*.
- Different species cause different forms of malaria, so the full species name identifies the parasite requested.

Step 1: Identify the causative genus The organism asked for is a protozoan parasite of humans. Malaria is caused by species of *Plasmodium*; the female *Anopheles* mosquito is its vector, rather than the protozoan responsible for the disease.

Step 2: Identify the species associated with severe malaria Among the malarial parasites, *Plasmodium falciparum* causes the most serious form, commonly called malignant malaria. This infection can become fatal. The species name *falciparum* is essential because writing only *Plasmodium* does not distinguish it from other malarial species.

Step 3: Conclusion *Plasmodium falciparum* causes the most serious and potentially fatal form of malaria.

Quick Tip to Solve: Link the words “most serious” or “malignant malaria” with the species *Plasmodium falciparum*.

32(a)(ii). Name the host in which the parasite completes its sexual stages and explain the changes taking place. [2 marks]

Solution:

Concept:

- The malarial parasite, *Plasmodium*, needs two hosts to complete its life cycle: humans and the female *Anopheles* mosquito.
- The definitive host is the host in which sexual reproduction takes place. For *Plasmodium*, this is the female *Anopheles* mosquito; humans support its asexual multiplication.

Step 1: Identify the host and entry of the parasite The female *Anopheles* mosquito is the host in which the parasite completes its sexual stages. When it bites an infected person and takes a blood meal, it

ingests male and female gametocytes present in the person's blood.

Step 2: Explain fertilisation and subsequent development In the mosquito's gut, gametocytes produce male and female gametes. These fuse to form a zygote, which develops into a motile ookinete. The ookinete penetrates the gut wall and develops into an oocyst. Further development and multiplication within the oocyst produce numerous sporozoites. After release, these reach the mosquito's salivary glands. During a later bite, the mosquito injects sporozoites into a human host along with its saliva, initiating a new infection.

Step 3: Conclusion Sexual reproduction occurs in the female *Anopheles* mosquito. Gametocytes give rise to gametes, fertilisation produces a zygote, and subsequent development through the ookinete and oocyst stages produces infective sporozoites that reach the salivary glands.

Quick Tip to Solve: Remember the distinction: the mosquito ingests gametocytes from a human but injects sporozoites into the next human.

32(a)(iii). How does the parasite damage the human body after entering the blood stream? [1.5 marks]

Solution:

Concept:

- The malaria parasite, *Plasmodium*, multiplies asexually in human liver cells and then in red blood cells (RBCs).
- Repeated rupture of infected RBCs releases parasites and the toxic substance haemozoin, producing the characteristic attacks of malaria.

Step 1: Trace multiplication after infection An infected female *Anopheles* mosquito introduces sporozoites into the human blood. They reach liver cells and multiply there. The resulting parasites enter the bloodstream and invade RBCs, where further multiplication takes place.

Step 2: Explain the damage and symptoms Infected RBCs burst and release new parasites, which invade other RBCs and repeat the cycle. Their rupture releases haemozoin, responsible for chills and recurring high fever. Continued destruction of RBCs reduces the blood's oxygen-carrying capacity and causes anaemia and weakness.

Step 3: Conclusion The parasite damages the body by multiplying in liver cells and RBCs, destroying RBCs and releasing haemozoin; this causes recurrent fever with chills and anaemia.

Quick Tip to Solve: Link the symptoms to their causes: RBC rupture releases haemozoin for fever, while RBC loss causes anaemia.

32(a)(iv). Suggest two effective preventive measures to control the spread of this disease in endemic regions. [1 mark]

Solution:

Concept:

- Malaria spreads through the bite of an infected female *Anopheles* mosquito.
- Prevention interrupts transmission by reducing mosquito breeding and preventing mosquito bites.

Step 1: Eliminate breeding sites Drain stagnant water near houses and regularly empty or cover water containers. Mosquitoes breed in water, so removing these breeding sites reduces the number of vectors in the locality.

Step 2: Prevent mosquito bites Use insecticide-treated mosquito nets while sleeping. The net forms a barrier between people and mosquitoes, and the insecticide helps kill mosquitoes contacting it, reducing transmission of the parasite.

Step 3: Conclusion Two effective measures are eliminating stagnant-water breeding sites and using insecticide-treated mosquito nets.

Quick Tip to Solve: Give one measure against mosquito breeding and one against bites to cover two points of transmission control.

OR

32(b)(i). What are bio-fertilizers? [1 mark]

Solution:

Concept:

- Bio-fertilizers are living organisms that enrich the nutrient quality of soil.
- Useful soil microorganisms improve nutrient availability through processes such as nitrogen fixation and enhanced mineral uptake.

Step 1: State the definition Bio-fertilizers are organisms used to enrich soil nutrients and promote plant growth. The main groups include bacteria, cyanobacteria and fungi; their biological activity improves the supply of nutrients to plants.

Step 2: Illustrate their action For example, *Rhizobium* in the root nodules of leguminous plants fixes atmospheric nitrogen into forms usable by plants. Thus, the useful organism acts as the bio-fertilizer through its activity in association with the plant.

Step 3: Conclusion Bio-fertilizers are organisms that enrich the nutrient quality of soil, such as the nitrogen-fixing bacterium *Rhizobium*.

Quick Tip to Solve: Begin the definition with organisms that enrich soil nutrients, then give a familiar example such as *Rhizobium*.

32(b)(ii). Name the different types of microorganisms used as bio-fertilizers in organic farming and explain how each contributes to soil fertility. [3 marks]

Solution:

Concept:

- Bacteria, cyanobacteria and fungi are important microorganisms used as bio-fertilizers in organic farming.
- Nitrogen-fixing organisms increase the supply of usable nitrogen, whereas mycorrhizal fungi improve the uptake of phosphorus and other resources by plant roots.

Step 1: Explain the contribution of bacteria *Rhizobium* lives symbiotically in the root nodules of leguminous plants and fixes atmospheric nitrogen into nitrogenous compounds usable by plants. Free-living bacteria such as *Azotobacter* and *Azospirillum* also fix atmospheric nitrogen in the soil, enriching its nitrogen content. These organisms reduce dependence on externally supplied nitrogen fertilizers.

Step 2: Explain the contribution of cyanobacteria Cyanobacteria such as *Anabaena* and *Nostoc* fix atmospheric nitrogen. They are important bio-fertilizers in paddy fields, where they enrich the soil with nitrogen. Their biomass also adds organic matter to the soil and improves its fertility.

Step 3: Explain the contribution of fungi Fungi such as *Glomus* form mycorrhizal associations with plant roots. The fungal partner absorbs phosphorus from the soil and passes it to the plant. Its extensive hyphae improve the plant's access to soil resources. Mycorrhizal plants also show better tolerance to drought and salinity and resistance to root-borne pathogens, supporting healthier plant growth.

Step 4: Conclusion Bacteria and cyanobacteria improve soil nitrogen through nitrogen fixation, while mycorrhizal fungi improve nutrient availability to plants, especially phosphorus uptake.

Quick Tip to Solve: Organize the answer into three groups: bacteria and cyanobacteria for nitrogen fixation, and mycorrhizal fungi for phosphorus uptake.

32(b)(iii). Write two advantages of using bio-fertilizers over chemical fertilizers. [1 mark]

Solution:

Concept:

- Bio-fertilizers improve nutrient availability through the activity of beneficial organisms.
- Their use can reduce reliance on chemical fertilizers and support sustainable soil fertility.

Step 1: Explain the environmental advantage Bio-fertilizers are eco-friendly: by reducing the requirement for chemical fertilizers, they reduce the risk of soil and water pollution caused by excess fertilizer use and nutrient runoff.

Step 2: Explain the advantage for soil fertility Beneficial microbes maintain soil fertility by fixing nitrogen or improving mineral uptake. They support biological activity in the soil and provide a sustainable way of improving plant nutrition without repeated heavy application of chemical fertilizers.

Step 3: Conclusion Two advantages are reduced environmental pollution and maintenance of soil fertility through beneficial microbial activity.

Quick Tip to Solve: State two distinct advantages: one concerning reduced pollution and one concerning sustained soil fertility.

33(a)(i). Watson and Crick's discovery of double helical structure was based on which two findings. Also mention the name of the scientists associated with these findings. [2 marks]

Solution:

Concept:

- DNA is a polymer of deoxyribonucleotides. Structural evidence and the proportions of its nitrogenous bases helped explain its double-helical organisation.
- In double-stranded DNA, adenine pairs with thymine and guanine pairs with cytosine; therefore $A = T$ and $G = C$.

Step 1: Identify the structural evidence Maurice Wilkins and Rosalind Franklin obtained X-ray diffraction data of DNA. These data indicated a helical structure with regularly repeating dimensions. Watson and Crick used this physical evidence when constructing their double-helical model.

Step 2: Identify the base-composition evidence Erwin Chargaff found that, in double-stranded DNA, the amount of adenine equals that of thymine and the amount of guanine equals that of cytosine:

$$A = T, \quad G = C.$$

Hence the total purines equal the total pyrimidines. These relationships supported specific complementary pairing, with A opposite T and G opposite C, in the model.

Step 3: Conclusion The two findings were the X-ray diffraction evidence of Maurice Wilkins and Rosalind Franklin, and the base-equivalence relationships of Erwin Chargaff.

Quick Tip to Solve: Associate the helical shape with Franklin and Wilkins, and the equal base quantities with Chargaff.

33(a)(ii). Write down the salient features of double helix structure of DNA (any three points). [3 marks]

Solution:

Concept:

- The Watson–Crick model describes DNA as two complementary polynucleotide chains wound around a common axis.
- A nucleotide contains deoxyribose sugar, phosphate and a nitrogenous base. Phosphodiester bonds join successive nucleotides within a chain, whereas hydrogen bonds join paired bases between chains.

Step 1: Describe the arrangement of the chains The two polynucleotide chains form a right-handed double helix. Each chain has a sugar–phosphate backbone on the outside, while its nitrogenous bases project inwards. The chains are antiparallel: one runs in the $5' \rightarrow 3'$ direction and the other in the $3' \rightarrow 5'$ direction. Thus the adjacent strands have opposite chemical polarities.

Step 2: Describe complementary base pairing Adenine pairs specifically with thymine through two hydrogen bonds; guanine pairs with cytosine through three hydrogen bonds. Each pair contains one purine and one pyrimidine, maintaining a nearly uniform separation of the backbones. The sequence of either strand therefore determines the complementary sequence of the other.

Step 3: State the dimensions of the helix The pitch, or distance covered in one complete turn, is 3.4 nm. There are approximately ten base pairs per turn, so consecutive base pairs are separated by 0.34 nm. The helix has an approximately uniform diameter of 2 nm. Base pairs lie stacked approximately perpendicular to the helical axis; this stacking also contributes to stability.

Step 4: Conclusion Three salient features are antiparallel chains in a right-handed helix, specific complementary A–T and G–C pairing, and about ten base pairs per turn with a pitch of 3.4 nm.

Quick Tip to Solve: Organise three features as chain arrangement, base pairing and dimensions; distinguish hydrogen bonds between strands from phosphodiester bonds within a strand.

OR

33(b)(i). Given below is a stretch of DNA showing the coding strand of structural gene of transcription unit.

5'- ATG ACC GTA TTT TCT GTA GTG CCC GTA CTT CAG GCA TTA 3'

Write the corresponding template strand and m-RNA strand that will be transcribed along with its polarity. [2 marks]

Solution:

Concept:

- RNA polymerase reads the DNA template in the $3' \rightarrow 5'$ direction and synthesises RNA in the $5' \rightarrow 3'$ direction.
- The template is complementary and antiparallel to the coding strand. The RNA sequence matches the coding strand when both are read in the same direction, except that RNA contains U instead of T.

Step 1: Construct the template strand Pair each coding-strand base with its DNA complement: A with T and G with C. Keep the groups in their printed left-to-right order and reverse the polarity labels, giving

$3'$ -TAC TGG CAT AAA AGA CAT CAC
GGG CAT GAA GTC CGT AAT- $5'$.

The second displayed line continues the first; together they form a single template strand.

Step 2: Transcribe the RNA strand Use the template as the guide, pairing its A with U, T with A, G

with C and C with G. Equivalently, replace every T in the given coding sequence with U:

5'-AUG ACC GUA UUU UCU GUA GUG

CCC GUA CUU CAG GCA UUA-3'.

Again, the second line is a continuation. Both strands contain 39 nucleotides, and each RNA nucleotide is complementary to the corresponding template nucleotide.

Step 3: Conclusion The template runs from 3' to 5' as written above; the corresponding mRNA runs from 5' to 3', with U replacing the coding strand's T.

Quick Tip to Solve: First copy the coding strand and replace T by U to obtain mRNA; complement the coding bases and reverse the end labels to obtain template DNA.

33(b)(ii). Given below is a stretch of DNA showing the coding strand of structural gene of transcription unit.

5'- ATG ACC GTA TTT TCT GTA GTG CCC GTA CTT CAG GCA TTA 3'

If GUA of transcribed mRNA is an intron, then depict the sequence involved in formation of mRNA / mature / processed hnRNA strand:

(1) In a bacterium

(2) In humans

[2 marks]

Solution:

Concept:

- In the standard bacterial transcription unit, mRNA does not require the intron-removal processing characteristic of eukaryotic hnRNA; transcription and translation can be coupled.
- Human primary RNA transcripts undergo splicing to remove introns and join exons. Capping at the 5' end and polyadenylation at the 3' end also form part of processing.

Step 1: Write the bacterial mRNA Replace T in the given coding DNA with U. In the bacterial case, the transcript retains the sequence as transcribed, including the GUA groups:

5'-AUG ACC GUA UUU UCU GUA GUG

CCC GUA CUU CAG GCA UUA-3'.

The two lines show one continuous strand. No eukaryotic hnRNA splicing is applied to this bacterial answer.

Step 2: Process the human hnRNA The primary hnRNA has the same sequence shown above. As the question specifies GUA as the intron sequence, remove all three GUA groups, at positions 3, 6 and 9 in the displayed grouping. Join the remaining exon sequences in their original order. The retained sequence is

5'-AUG ACC UUU UCU GUG

CCC CUU CAG GCA UUA-3'.

The mature human mRNA also receives a methylguanosine cap at its 5-prime end and a poly-A tail at its 3-prime end. These additions are separate from the retained coding sequence.

Primary transcript (5' to 3'):

AUG ACC GUA UUU UCU GUA GUG CCC GUA CUU CAG GCA UUA



Bacterium: no hnRNA splicing; sequence retained

5'-AUG ACC GUA UUU UCU GUA GUG CCC GUA CUU CAG GCA UUA-3'

Humans: remove the three GUA introns, join exons, add cap and tail

5' cap-AUG ACC UUU UCU GUG CCC CUU CAG GCA UUA-poly-A-3'

Sequence processing in a bacterium and in humans; each row is read from left to right.

Step 3: Conclusion Bacterial mRNA retains the transcribed sequence. In humans, splicing removes the three specified GUA introns, giving the retained sequence AUG ACC UUU UCU GUG CCC CUU CAG GCA UUA, with a 5-prime cap and 3-prime poly-A tail.

Quick Tip to Solve: Underline every GUA in the primary transcript before deleting it; retain the order of all other groups and add cap and tail only to the human processed RNA.

33(b)(iii). Given below is a stretch of DNA showing the coding strand of structural gene of transcription unit.

5'- ATG ACC GTA TTT TCT GTA GTG CCC GTA CTT CAG GCA TTA 3'

How many amino acids the resulting polypeptide will have after the process of translation in humans?

[1 mark]

Solution:

Concept:

- Each sense codon is a triplet of nucleotides that specifies one amino acid during translation.
- In humans, introns are removed from the primary transcript by splicing; only the retained coding sequence of mature mRNA is translated.

Step 1: Count the codons retained after processing The given coding strand contains 13 triplets. In the preceding part, GUA in the transcribed RNA is specified as an intron. GUA occurs three times, corresponding to the three GTA triplets of the coding DNA. Removal of these intron triplets during human RNA processing leaves $13 - 3 = 10$ codons in the given stretch.

Step 2: Check which retained codons specify amino acids The retained mRNA sequence, written in

the 5' to 3' direction, is

AUG ACC UUU UCU GUG CCC CUU CAG GCA UUA.

AUG initiates translation and also specifies methionine, so it is counted. Every retained triplet is a sense codon; none is UAA, UAG or UGA, the three stop codons. Thus every one of these ten codons contributes an amino acid to the polypeptide encoded by the given stretch.

Step 3: Conclusion The resulting polypeptide has 10 amino acids from the given stretch after human RNA processing and translation.

Quick Tip to Solve: Remove the three GUA intron triplets before counting; include AUG because the start codon also codes for methionine.