

CBSE Class 12 Biology Question Paper 2026 with Solution PDF-Set 57-4-3

Question Paper with Solutions

Conducted by the Central Board of Secondary Education (CBSE)



Time Allowed: 3 hours

Maximum Marks: 70

General Instructions

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

Section A (16 marks)

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

1. A female undergoing IVF treatment has blocked fallopian tube. The technique by which the embryo with more than 8 blastomeres will be transferred into the female for further development is: [1 mark]

- (A) ZIFT
- (B) GIFT
- (C) IUT
- (D) AI

Correct Answer: (C) IUT

Solution:

Concept:

- In vitro fertilisation (IVF) produces a zygote outside the body; embryo transfer places it in the appropriate part of the female reproductive tract.
- Zygotes or embryos up to eight blastomeres are transferred into the fallopian tube by ZIFT; embryos with more than eight blastomeres are transferred into the uterus by IUT.

Step 1: Identify the stage and transfer site The embryo already has more than eight blastomeres. At this developmental stage it is transferred into the uterus for further development. Intrauterine transfer also bypasses the blocked fallopian tube.

Step 2: Distinguish the other techniques ZIFT means zygote intrafallopian transfer and uses the fallopian tube for a zygote or early embryo up to eight blastomeres. GIFT transfers gametes into the fallopian tube, not an embryo. Artificial insemination (AI) introduces semen into the female reproductive tract; it does not transfer an embryo.

Step 3: Conclusion The required technique is intrauterine transfer (IUT). Hence, the correct option is (C).

Quick Tip to Solve: Use the blastomere count to choose the site: up to eight, fallopian tube; more than eight, uterus.

2. Which one of the following statements is correct?

[1 mark]

- (A) Homozygous sex chromosomes (ZZ) determine female sex in birds.
- (B) XO type of sex chromosomes determine male sex in grasshoppers.
- (C) XXY condition in humans is found in Turner's syndrome.
- (D) Homozygous sex chromosomes (XX) produce males in *Drosophila*.

Correct Answer: (B) XO type of sex chromosomes determine male sex in grasshoppers.

Solution:

Concept:

- Sex determination differs among organisms: grasshoppers use the XX-XO system, whereas birds use the ZZ-ZW system.
- In the XO notation, O means the absence of a second sex chromosome; it is not a separate chromosome.

Step 1: Check the grasshopper statement Male grasshoppers possess only one X chromosome and are designated XO. Females possess two X chromosomes and are XX. Therefore, the statement linking XO with male sex in grasshoppers is correct.

Step 2: Check the other three statements In birds, ZZ individuals are males and ZW individuals are females, so (A) reverses the sexes. In humans, XXY is associated with Klinefelter's syndrome, whereas Turner's syndrome involves a single X chromosome, so (C) is incorrect. In *Drosophila*, XX individuals are females, not males, so (D) is incorrect.

Step 3: Conclusion XO sex chromosomes determine male sex in grasshoppers. Hence, the correct option is (B).

Quick Tip to Solve: Remember the heterogametic sex: male in the grasshopper XX-XO system, female in the bird ZZ-ZW system.

3. Choose the option that gives the correct number of pollen grains that will be formed after 325 microspore mother cells undergo microsporogenesis.

[1 mark]

- (A) 325
- (B) 650
- (C) 1300
- (D) 975

Correct Answer: (C) 1300

Solution:

Concept:

- Microsporogenesis is the formation of haploid microspores by meiosis of a diploid microspore mother cell.
- One mother cell produces a tetrad of four microspores; each microspore can develop into one pollen grain.

Step 1: Relate mother cells to pollen grains One complete meiotic division of a microspore mother cell produces four haploid daughter cells, not two. These are the four microspores of a tetrad. Each is counted as the precursor of a separate pollen grain.

Step 2: Multiply by the tetrad size For 325 microspore mother cells, the number of pollen grains is

$$N = 325 \times 4 = 1300.$$

The alternatives 325, 650 and 975 would correspond to one, two and three pollen grains per mother cell respectively. None follows the four-product outcome of meiosis.

Step 3: Conclusion The 325 microspore mother cells form 1300 pollen grains. Hence, the correct option is (C).

Quick Tip to Solve: For microsporogenesis, multiply the number of mother cells by four; do not confuse microspores with the nuclei inside a pollen grain.

4. The first movements of the foetus and appearance of hair on its head are usually observed during which month of pregnancy? [1 mark]

- (A) Fourth month
- (B) Fifth month
- (C) Sixth month
- (D) Third month

Correct Answer: (B) Fifth month

Solution:

Concept:

- Foetal development follows characteristic milestones that help identify the stage of pregnancy.
- The first movements of the foetus and the appearance of hair on its head are usually observed during the fifth month.

Step 1: Match both observations to a milestone The question gives two linked developmental observations: the first foetal movements and the appearance of head hair. In the standard pregnancy timeline, this combination corresponds to the fifth month.

Step 2: Distinguish neighbouring stages By the end of the first trimester, most major organ systems have formed. By the end of the second trimester, around 24 weeks, the body is covered with fine hair, the eyelids separate and eyelashes form. Thus, the third and sixth months refer to different stages, while the fourth month does not match the stated pair of milestones.

Step 3: Conclusion The observations are usually made during the fifth month of pregnancy. Hence, the correct option is (B).

Quick Tip to Solve: Associate the fifth month with two clues together: first foetal movements and hair appearing on the head.

5. Thorns of *Bougainvillea* and tendrils of *Cucurbita* are examples of:

[1 mark]

- (A) Analogous organs
- (B) Convergent evolution
- (C) Homologous organs
- (D) Vestigial organs

Correct Answer: (C) Homologous organs

Solution:

Concept:

- Homologous organs share a common origin and basic structural plan, although they may perform different functions.
- Divergent evolution modifies structures of common ancestry for different uses; analogous organs instead perform similar functions despite different origins.

Step 1: Compare the origin of the structures Thorns of *Bougainvillea* and tendrils of *Cucurbita* are both modifications of the stem or axillary bud. Their common developmental origin establishes the structural relationship.

Step 2: Compare their functions and reject alternatives Thorns provide protection, whereas tendrils help the plant climb by supporting it. Different functions arising from the same basic organ indicate homology and divergent evolution. Analogous organs and convergent evolution involve similar functions with different origins. These functional structures are not vestigial remnants.

Step 3: Conclusion The thorns and tendrils are homologous organs. Hence, the correct option is (C).

Quick Tip to Solve: Compare origin before function: a common stem origin with different uses indicates homology, even when the structures look different.

6. Internal bleeding, muscular pain, blockage of the intestinal passage and anaemia are some of the symptoms caused due to infection by:

[1 mark]

- (A) *Ascaris*
- (B) *Wuchereria*
- (C) *Plasmodium*
- (D) *Trichophyton*

Correct Answer: (A) *Ascaris*

Solution:

Concept:

- Ascariasis is an intestinal infection caused by the roundworm *Ascaris*.
- Typical symptoms include internal bleeding, muscular pain, fever, anaemia and blockage of the intestinal passage.

Step 1: Match the symptom cluster The question combines intestinal blockage with internal bleeding, muscular pain and anaemia. This is the characteristic symptom group of ascariasis. The intestinal

location of *Ascaris* explains why obstruction of the intestinal passage is an especially useful identifying clue.

Step 2: Distinguish the other pathogens *Wuchereria* causes filariasis, associated with chronic inflammation of lymphatic vessels and swelling. *Plasmodium* causes malaria with recurring fever and chills. *Trichophyton* is a fungus that causes ringworm, producing dry, scaly lesions. None matches the complete intestinal symptom cluster given.

Step 3: Conclusion The infection is caused by *Ascaris*. Hence, the correct option is (A).

Quick Tip to Solve: Use intestinal obstruction as the decisive clue for *Ascaris*; lymphatic swelling, periodic fever and scaly skin lesions indicate the other options.

7. Choose the correct statements:

(i) Polycistronic mRNA is generally found in eukaryotes.

(ii) The RNA polymerase II transcribes precursor of mRNA, the hnRNA.

(iii) The process of translation of mRNA begins when the mRNA encounters the large subunit of ribosomes.

(iv) Stop codons do not have any tRNAs.

[1 mark]

(A) (i) and (ii)

(B) (ii) and (iii)

(C) (ii) and (iv)

(D) (i), (ii) and (iv)

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

Solution:

Concept:

- Eukaryotic nuclear mRNA is generally monocistronic, while polycistronic mRNA is generally found in prokaryotes.
- RNA polymerase II transcribes hnRNA, the precursor of mature mRNA; stop codons are recognised by release factors rather than tRNAs.

Step 1: Evaluate the transcription statements Statement (i) is false: polycistronic mRNA is generally a prokaryotic feature, whereas eukaryotic mRNA is generally monocistronic. Statement (ii) is true: RNA polymerase II produces hnRNA, which undergoes processing to form mature mRNA.

Step 2: Evaluate the translation statements Statement (iii) is false because translation initiation involves the mRNA associating with the small ribosomal subunit, followed by assembly of the complete initiation complex. Statement (iv) is true because stop codons have no corresponding tRNAs; release factors recognise them and bring about termination. Options (A) and (D) include false statement (i), and option (B) includes false statement (iii).

Step 3: Conclusion Only statements (ii) and (iv) are correct. Hence, the correct option is (C).

Quick Tip to Solve: Check the key contrasts: prokaryotes for polycistronic mRNA, small subunit for initiation, and release factors for stop codons.

8. Name the extinct ancestor of humans who ate only fruits and hunted with stone weapons. [1 mark]

- (A) Ramapithecus
- (B) Australopithecus
- (C) Dryopithecus
- (D) Homo erectus

Correct Answer: (B) Australopithecus

Solution:

Concept:

- Human evolution is traced using fossil evidence and the characteristic diet, locomotion and tools associated with each stage.
- NCERT describes australopithecines of the East African grasslands as using stone weapons and essentially eating fruits.

Step 1: Match the two clues The question combines fruit eating with hunting using stone weapons. This combination corresponds to *Australopithecus*, which lived in the East African grasslands about two million years ago. Identify the ancestor by both clues together, rather than by its diet alone.

Step 2: Check the alternatives *Ramapithecus* and *Dryopithecus* were earlier primates, described as more man-like and more ape-like, respectively; the stated stone-weapon association is not their distinguishing NCERT description. *Homo erectus* probably ate meat, so the fruit-only clue rules it out.

Step 3: Conclusion The extinct ancestor is *Australopithecus*. Hence, the correct option is (B).

Quick Tip to Solve: Link the paired clues stone weapons and fruit eating to australopithecines; meat eating points instead towards a later human ancestor.

9. *Bacillus thuringiensis* is used to control which one of the following pathogens/pests? [1 mark]

- (A) Bacterial pathogen
- (B) Fungal pathogen
- (C) Nematodes
- (D) Insect pests

Correct Answer: (D) Insect pests

Solution:

Concept:

- Biocontrol uses organisms or their products to suppress pests and disease-causing organisms.
- *Bacillus thuringiensis* (Bt) produces insecticidal proteins that act against susceptible insect larvae.

Step 1: Identify the action of Bt Bt preparations are used as biological insecticides. When a susceptible insect larva ingests the bacterial toxin, the alkaline conditions in its gut activate the toxin. It damages the gut epithelial cells, causing the larva to die.

Step 2: Distinguish the target from the agent The fact that Bt is a bacterium does not mean its target

is a bacterial pathogen. Its standard biocontrol use here is against insect pests, such as caterpillars. Fungal pathogens and nematodes are not the target group identified by this Bt bioinsecticide example.

Step 3: Conclusion *Bacillus thuringiensis* is used to control insect pests. Hence, the correct option is (D).

Quick Tip to Solve: For Bt questions, separate the agent (a bacterium) from its target (susceptible insects); the toxin acts in the insect gut.

10. In pBR322, tetracycline, resistance gene (tet^R) has recognition site for which of the following restriction endonuclease? [1 mark]

- (A) Hind III
- (B) BamHI
- (C) EcoRI
- (D) PstI

Correct Answer: (B) BamHI

Solution:

Concept:

- The cloning vector pBR322 contains antibiotic-resistance genes that serve as selectable markers.
- Inserting foreign DNA into a restriction site within a resistance gene can disrupt that gene; this is insertional inactivation.

Step 1: Locate the site within the resistance gene The BamHI recognition site lies within the tetracycline-resistance gene, tet^R , of pBR322. Inserting a DNA fragment at this site can therefore make a recombinant bacterium tetracycline-sensitive while its ampicillin resistance remains available for selection.

Step 2: Compare the other sites PstI is associated with the ampicillin-resistance gene, not the tetracycline-resistance coding region. EcoRI lies outside the two resistance coding regions. HindIII is associated with the upstream tetracycline promoter region; BamHI is the site within the gene used in the standard insertional-inactivation example.

Step 3: Conclusion The required restriction endonuclease is BamHI. Hence, the correct option is (B).

Quick Tip to Solve: Remember the selectable-marker pair: BamHI insertion disrupts tetracycline resistance, whereas PstI insertion can disrupt ampicillin resistance.

11. In RNAi, genes are silenced using which of the following biomolecules?

[1 mark]

- (A) ssDNA
- (B) dsDNA
- (C) dsRNA
- (D) ssRNA

Correct Answer: (C) dsRNA

Solution:

Concept:

- RNA interference (RNAi) is sequence-specific, post-transcriptional silencing of gene expression.
- Double-stranded RNA triggers a pathway that targets complementary messenger RNA, preventing production of its protein.

Step 1: Identify the silencing trigger In RNAi, double-stranded RNA (dsRNA) is processed into short RNA molecules. A guide strand directs the silencing machinery to the complementary mRNA, leading to its degradation or preventing its translation. Thus gene expression is blocked at the RNA stage.

Step 2: Compare the molecular alternatives Single-stranded DNA and double-stranded DNA are not the RNA trigger required by this pathway. Single-stranded RNA may participate later as a guide, but the molecule that initiates the RNAi mechanism described in NCERT is double-stranded RNA. The terms ds and ss mean double-stranded and single-stranded, respectively.

Step 3: Conclusion Genes are silenced using dsRNA in RNA interference. Hence, the correct option is (C).

Quick Tip to Solve: Connect RNAi with a complementary RNA pair: dsRNA starts the pathway, and the matching mRNA is the target that is silenced.

12. The biomass available in plants for consumption by herbivores and decomposers, is called:

[1 mark]

- (A) Gross primary productivity
- (B) Net primary productivity
- (C) Standing crop
- (D) Secondary productivity

Correct Answer: (B) Net primary productivity

Solution:

Concept:

- Gross primary productivity (GPP) is the total rate of organic matter production by photosynthesis.
- Net primary productivity is $NPP = GPP - R$, where R is the respiratory loss of the producers.

Step 1: Subtract the producers' own respiratory use Plants use some of their photosynthetic production for respiration. The remaining organic matter represents net primary productivity and is available as food to herbivores or, through dead organic matter, to decomposers. The wording of the question

identifies this available production.

Step 2: Distinguish the other ecological measures Gross primary productivity includes the fraction consumed in plant respiration, so all of it is not available to consumers. Standing crop is the amount of living material present at a particular time, rather than net production. Secondary productivity is the formation of new organic matter by consumers, not by plants.

Step 3: Conclusion The available plant production is net primary productivity. Hence, the correct option is (B).

Quick Tip to Solve: When a question asks what producers make available to consumers, first subtract plant respiration: $NPP = GPP - R$.

13. Assertion (A): Nucleopolyhedrovirus are useful as they are good biocontrol agents.

Reason (R): They are species-specific, narrow spectrum bioinsecticides.

[1 mark]

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

Correct Answer: (A) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of the Assertion (A).

Solution:

Concept:

- Baculoviruses used for biological pest control commonly belong to the genus *Nucleopolyhedrovirus*.
- A species-specific, narrow-spectrum agent targets particular pests while sparing many non-target organisms.

Step 1: Evaluate the assertion The assertion is true. Nucleopolyhedroviruses are useful biological control agents because they infect susceptible insect pests and help reduce pest populations in agricultural systems.

Step 2: Evaluate the reason The reason is also true. These viruses are species-specific and have a narrow spectrum of insect targets. They do not broadly harm plants, mammals, birds, fish or non-target insects in the way a non-selective insecticide might.

Step 3: Check the explanatory link The narrow host range makes these viruses valuable in integrated pest management: they suppress the target pest while conserving beneficial insects and other non-target organisms. Therefore the stated specificity directly explains their usefulness as biocontrol agents; it is not merely an unrelated true fact.

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

Quick Tip to Solve: For a biocontrol assertion, connect narrow host specificity with protection of beneficial organisms; this establishes the explanation, not just truth.

14. Assertion (A): The interaction between a whale and the small barnacles on its back is considered as commensalism.

Reason (R): In the above association, neither of the species is benefitted.

[1 mark]

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

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

Solution:

Concept:

- Commensalism is an interaction in which one species benefits and the other is neither benefitted nor harmed: (+, 0).
- The relationship must be classified by the effect on each partner, rather than simply by their physical association.

Step 1: Evaluate the assertion The assertion is true. Barnacles attached to a whale obtain a surface on which to live and are transported through water, gaining access to food-bearing currents. The whale is regarded as neither benefitted nor harmed in this NCERT example, so the association is commensalism.

Step 2: Evaluate the reason The reason is false because it claims that neither species benefits. Barnacles do benefit, even though the whale is unaffected. If both partners were unaffected, the sign pattern would be (0, 0), which is not the definition of commensalism.

Step 3: Check the explanatory link A false statement that ignores the barnacles' benefit cannot explain this commensal relationship. The correct basis for the assertion is benefit to the barnacles coupled with no appreciable effect on the whale.

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

Quick Tip to Solve: Assign signs to the named partners: barnacle +, whale 0. This immediately rules out a statement that neither partner benefits.

15. Assertion (A): The pyramid of biomass in a pond aquatic ecosystem is always inverted.

Reason (R): The biomass of consumers like fishes far exceeds that of the producers like phytoplanktons.

[1 mark]

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

Correct Answer: (A) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of the Assertion (A).

Solution:

Concept:

- A pyramid of biomass represents the standing biomass present at successive trophic levels at a given time.
- In the standard aquatic food chain, a small standing crop of rapidly reproducing phytoplankton can support a larger standing biomass of consumers.

Step 1: Evaluate the assertion Assertion (A) is true for the pond aquatic food chain described. Phytoplankton form the producer level, but their standing biomass is smaller than the consumer biomass they support. The producer bar is therefore narrower than the consumer bar, giving an inverted biomass pyramid.

Step 2: Evaluate the reason Reason (R) is true. Consumers such as fishes can have a much greater standing biomass than phytoplankton. The phytoplankton reproduce and replace the biomass consumed rapidly; a small standing stock does not mean that little organic matter is produced over time.

Step 3: Connect the reason to the assertion The relative biomass of the consumers and producers directly determines the shape of this pyramid. Thus R explains the inversion stated in A. Option (B) incorrectly denies this explanatory connection, while (C) and (D) incorrectly reject one of the statements. Do not confuse the biomass pyramid with the energy pyramid, which is always upright.

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

Quick Tip to Solve: Compare standing biomass at one time, not productivity over an entire season, when deciding whether a biomass pyramid is inverted.

16. Assertion (A): Cleistogamous flowers have assured seed set.

Reason (R): Cleistogamous flowers are invariably autogamous and do not depend on any pollinating agents. [1 mark]

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

Correct Answer: (A) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of the Assertion (A).

Solution:

Concept:

- Cleistogamous flowers remain closed, so their anthers and stigma are not exposed to external pollinating agents.
- Autogamy is transfer of pollen from the anther to the stigma of the same flower.

Step 1: Evaluate the assertion Assertion (A) is true. Cleistogamous flowers have assured seed set even when pollinators are absent, because the pollen can reach the stigma within the closed flower itself.

Step 2: Evaluate the reason Reason (R) is also true. The anthers and stigma lie close to one another in these unopened flowers. When the anthers dehisce, pollen comes into contact with the stigma of the same flower. Hence these flowers are invariably autogamous and require no pollinating agent.

Step 3: Check the explanatory connection The absence of dependence on external pollen carriers removes uncertainty in pollination and explains assured seed set. Therefore R correctly explains A. Option (B) misses this causal relationship; options (C) and (D) incorrectly classify one of the two true statements as false.

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

Quick Tip to Solve: Link a closed cleistogamous flower to compulsory self-pollination, and hence to seed set without any external pollinator.

Section B (10 marks)

17. Mention the sites of action of the hormones 'GnRH' and 'FSH' during spermatogenesis. Write one function of each of these hormones. [2 marks]

Solution:

Concept:

- Spermatogenesis begins at puberty under the control of the hypothalamus, anterior pituitary and testes.
- Gonadotropin-releasing hormone (GnRH) regulates the pituitary, whereas follicle-stimulating hormone (FSH) acts on supporting cells within the testes.

Step 1: State the site and function of GnRH GnRH is released from the hypothalamus and acts on the **anterior pituitary**. Its function is to stimulate the secretion of the gonadotropins, luteinising hormone (LH) and FSH. Thus it initiates the pituitary hormonal signals that regulate sperm formation; it does not act directly on the developing sperm cells.

Step 2: State the site and function of FSH FSH is released from the anterior pituitary and acts on the **Sertoli cells of the seminiferous tubules** in the testes. It stimulates these cells to secrete factors that help in **spermiogenesis**, the transformation of spermatids into spermatozoa. The Sertoli cells provide the supporting environment for the developing germ cells.

Step 3: Conclusion GnRH acts on the anterior pituitary to stimulate LH and FSH release. FSH acts on Sertoli cells to stimulate secretion of factors that support spermiogenesis.

Quick Tip to Solve: Remember the sequence hypothalamus–GnRH–anterior pituitary–FSH–Sertoli cells; LH, in contrast, targets Leydig cells.

18. A laboratory assistant collected three water samples, namely river water, untreated sewage water and secondary effluent discharged from a sewage treatment plant. But the laboratory attendant did not note which was which. The samples were labelled A, B and C and subjected to a BOD test. The BOD values of the three samples A, B and C were recorded as 30 mg/L, 8 mg/L and 400 mg/L respectively.

(a) Which sample of the water is most polluted?

(b) Can you assign the correct label to each, assuming the river water is relatively clean? [2 marks]

Solution:

Concept:

- Biochemical oxygen demand (BOD) measures the oxygen required by aerobic microorganisms to oxidise biodegradable organic matter in a water sample under specified conditions.
- A higher BOD indicates a greater biodegradable organic load and, for these samples, greater pollution. Biological sewage treatment reduces this organic load and hence lowers BOD.

Step 1: Identify the most polluted sample For part (a), compare the recorded values: A has 30 mg/L, B has 8 mg/L, and C has 400 mg/L. Sample C has the highest BOD, so microorganisms would require

the most oxygen to decompose its organic matter. It is therefore the most polluted of the three samples.

Step 2: Assign the sources to the labels For part (b), untreated sewage contains the largest biodegradable organic load, so it corresponds to **C**. The relatively clean river water has the smallest oxygen demand, so it corresponds to **B**. The secondary effluent has undergone microbial treatment, which has reduced its BOD substantially below that of untreated sewage; its remaining intermediate BOD identifies it as **A**.

Step 3: Conclusion (a) Sample C is most polluted. (b) A: secondary effluent (30 mg/L); B: relatively clean river water (8 mg/L); C: untreated sewage (400 mg/L).

Quick Tip to Solve: Rank BOD from highest to lowest as untreated sewage, treated secondary effluent, then the relatively clean river sample.

19. How do 'implants' act as an effective method of contraception in human females? Mention one advantage of implants over contraceptive pills. [2 marks]

Solution:

Concept:

- Contraceptive implants placed under the skin release progestogens, either alone or in combination with oestrogens, in a controlled manner.
- These hormones prevent conception through actions similar to those of oral contraceptive pills, but their delivery provides protection for a much longer period.

Step 1: Explain the contraceptive action The hormones released by the implant inhibit ovulation, so an ovum is not available for fertilisation. They also alter the quality of cervical mucus, making sperm entry into the female reproductive tract difficult, and render the uterine endometrium unsuitable for implantation. Together these hormonal effects make implants an effective method of contraception.

Step 2: State the advantage over pills An implant releases its hormones gradually and remains effective for a prolonged period. Unlike oral contraceptive pills, it does not require the woman to remember a daily dose. This long duration of action provides convenience and avoids failure arising from missed daily tablets.

Step 3: Conclusion Implants release hormones that inhibit ovulation and implantation and impede sperm entry by altering cervical mucus. Their advantage over pills is long-lasting protection without daily administration.

Quick Tip to Solve: For implants, state the same hormonal targets as pills, then distinguish them by sustained release and freedom from daily dosing.

20. Why and how can bacteria be made 'competent'?

[2 marks]

Solution:

Concept:

- A competent bacterial cell can take up foreign DNA, such as a recombinant plasmid, from its surroundings.
- DNA is hydrophilic and cannot readily pass through the cell membrane; the host must therefore be treated to enable DNA uptake.

Step 1: Explain why competence is needed In recombinant DNA technology, the engineered DNA must enter a bacterial host so that it can be maintained and multiplied. Simply mixing untreated bacteria with DNA does not ensure its entry because the membrane presents a barrier to the hydrophilic DNA molecule. Bacteria are therefore made competent before transformation.

Step 2: Describe the treatment and heat shock Treat the bacteria with a suitable concentration of divalent cations, such as Ca^{2+} . This increases the efficiency with which DNA enters the bacteria through pores in the cell wall. Incubate the competent cells with recombinant DNA on ice, expose them briefly to 42°C (heat shock), and then place them back on ice. This treatment enables the bacterial cells to take up the recombinant DNA.

Step 3: Conclusion Bacteria are made competent to introduce foreign DNA into them. Calcium-ion treatment followed by incubation with DNA on ice, a brief heat shock at 42°C , and cooling on ice facilitates transformation.

Quick Tip to Solve: Remember the order: divalent cations, DNA on ice, brief heat shock at 42°C , then ice again.

21(a). Biodiversity must be conserved as it plays an important role in many ecosystem services that nature provides. Explain any two ecosystem services.

[2 marks]

Solution:

Concept:

- Ecosystem services are benefits that humans obtain from the natural functioning of ecosystems and their living organisms.
- Conserving biodiversity protects the organisms and interactions that sustain services such as pollination and oxygen production.

Step 1: Explain pollination as an ecosystem service Bees, butterflies, birds and bats transfer pollen between flowers while visiting them. Pollination enables fertilisation and the subsequent formation of seeds and fruits in many flowering plants, including crop plants. Protecting these pollinators and their habitats therefore supports plant reproduction and agricultural food production. The service depends on the continued survival of these animal species and their interactions with plants.

Step 2: Explain oxygen production as an ecosystem service Green plants and other photosynthetic organisms release oxygen during photosynthesis. This contributes to the atmospheric oxygen supply used in aerobic respiration by humans and other organisms. Conserving forests and other ecosystems

maintains the photosynthetic producers responsible for this essential life-supporting service.

Step 3: Conclusion Two ecosystem services supported by biodiversity are pollination, which helps produce seeds and fruits, and oxygen production by photosynthetic organisms, which supports aerobic life.

Quick Tip to Solve: For each service, name the organisms, describe what they do, and state the resulting benefit to humans or other life.

OR

21(b). (i) State, what does 'standing crop' of a trophic level represent.

(ii) List any two ways of measuring the standing crop of a trophic level.

[2 marks]

Solution:

Concept:

- Each trophic level contains a certain quantity of living material at a particular time; this is its standing crop.
- Standing crop is a stock measured at a given instant, whereas productivity is the rate at which biomass is produced over time.

Step 1: State what standing crop represents (i) The standing crop of a trophic level represents the amount of living material present in the organisms belonging to that trophic level at a given time. For example, the living plant material present in a grassland at the time of observation forms the standing crop of its producer level. It is not the total production accumulated over an entire year.

Step 2: Give two methods of measurement (ii) Standing crop can be measured as the number of organisms, such as the number of individuals per unit area, or as their biomass, such as the mass of living material per unit area. Biomass may be recorded as fresh weight or dry weight; dry weight is more accurate for comparison because it excludes variation caused by water content. Number and biomass are the two requested ways of expressing the same standing stock.

Step 3: Conclusion Standing crop is the living material present at a trophic level at a particular time. It is measured as the number of organisms or as their biomass.

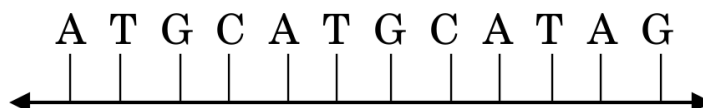
Quick Tip to Solve: Pair standing crop with "at a given time" and give number and biomass as the two measures; do not confuse it with productivity.

Section C (21 marks)

22. (a) Construct a complete transcription unit with promoter and terminator on the basis of the hypothetical coding strand given below:

(b) Write the RNA strand transcribed from the above transcription unit along with its polarity.

[3 marks]



Solution:

Concept:

- A transcription unit contains a promoter, a structural gene and a terminator. The promoter is upstream, towards the 5' end of the coding strand, and the terminator is downstream, towards its 3' end.
- The template and coding DNA strands are complementary and antiparallel. RNA polymerase reads the template in the 3' → 5' direction and synthesises RNA in the 5' → 3' direction.
- RNA has the same base sequence as the coding strand when both are written 5' → 3', except that uracil replaces thymine.

Step 1: Construct the two DNA strands for part (a) Write the given coding sequence in the conventional 5' → 3' direction from left to right. Pair A with T and G with C to obtain the template strand. Include the promoter before the structural gene and the terminator after it:

	Promoter	Structural gene	Terminator
Coding DNA:	5'—	ATGCATGCATAG	—3'
Template DNA:	3'—	TACGTACGTATC	—5'

Transcription proceeds from left to right. The promoter provides the binding site for RNA polymerase and fixes the direction of transcription; the terminator signals its end. Their exact nucleotide sequences are not supplied, so their positions are labelled rather than assigning invented bases.

Step 2: Derive the RNA sequence for part (b) Read the template from its 3' end towards its 5' end and add complementary RNA bases: template A pairs with RNA U, T with A, G with C, and C with G. Thus the twelve bases yield



As a check, compare this sequence with the coding strand: the order of the bases is unchanged and every T has become U. Copying the complementary template sequence directly would instead give the wrong RNA.

Step 3: Conclusion (a) The transcription unit has the promoter on the left, the displayed antiparallel coding and template strands, and the terminator on the right. (b) The RNA transcribed is 5'—AUGCAUGCAUAG—3'.

Quick Tip to Solve: Start from the coding strand written 5' → 3': replace T by U to obtain RNA, then use the complementary strand to check polarity.

23. (a) Draw a diagram of human ovum prior to fertilization. Label any four parts.

(b) Explain how polyspermy is avoided during fertilization.

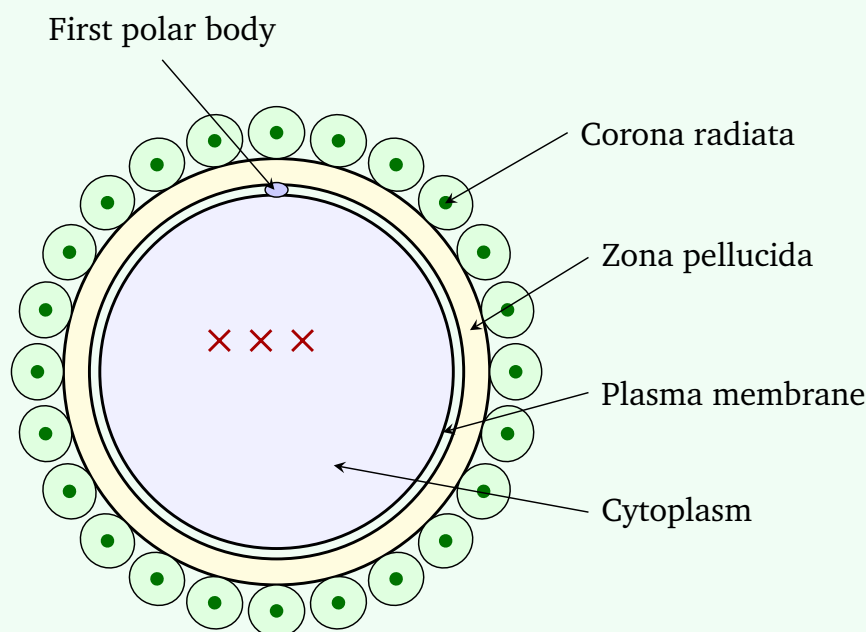
[3 marks]

Solution:

Concept:

- The human egg is surrounded by the zona pellucida, a non-cellular glycoprotein layer, and an outer layer of follicular cells called the corona radiata.
- Fertilisation normally involves fusion of one sperm with the egg. Entry of additional sperms, called polyspermy, would produce an abnormal chromosome number.

Step 1: (a) Draw and label the unfertilised egg Draw the egg as a large cell with its cytoplasm bounded by the plasma membrane. Outside it, show the thick zona pellucida and then the corona radiata as a ring of distinct follicular cells. The labelled drawing below shows these four parts and the first polar body in the space beneath the zona pellucida. Strictly, the cell released at ovulation is a secondary oocyte arrested in metaphase II; sperm entry stimulates completion of the second meiotic division.



Human egg before fertilisation (secondary oocyte); schematic sectional view.

Step 2: (b) Explain the block to polyspermy When a sperm contacts and penetrates the zona pellucida and fuses with the egg membrane, it induces changes that prevent additional sperms from entering. Cortical granules beneath the egg's plasma membrane release their contents, modifying the zona pellucida so that it no longer permits further sperm binding and penetration. Thus, only one sperm normally fertilises the ovum. This ensures that one haploid paternal chromosome set combines with one haploid maternal set, restoring the normal diploid chromosome number rather than producing a polyspermic embryo.

Step 3: Conclusion The labelled egg shows the corona radiata, zona pellucida, plasma membrane and cytoplasm. Sperm-induced changes in the zona pellucida prevent the entry of additional sperms and thereby avoid polyspermy.

Quick Tip to Solve: Label the egg coverings from outside inward: corona radiata, zona pellucida, then plasma membrane; link the polyspermy block specifically to changes in the zona pellucida.

24. (a) Draw a figure of *E. coli* vector pBR322 and label the following:

(i) Origin of replication

(ii) Ampicillin resistance site

(iii) Tetracycline resistance site

(iv) 'rop'

(b) Mention the significance of origin of replication.

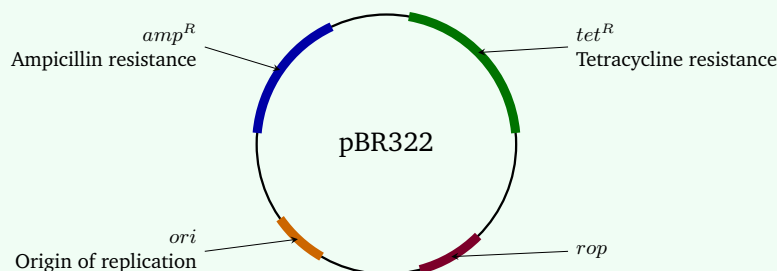
[3 marks]

Solution:

Concept:

- pBR322 is a circular plasmid cloning vector used in *Escherichia coli*. A vector carries foreign DNA and allows it to be maintained and multiplied in the host cell.
- The origin of replication (*ori*) initiates replication, whereas antibiotic-resistance genes act as selectable markers. The *rop* gene encodes a protein involved in plasmid replication control.

Step 1: (a) Draw the labelled pBR322 vector Represent pBR322 by a circular DNA map. Mark *ori*, the origin of replication, and the two selectable-marker genes: *amp^R* for ampicillin resistance and *tet^R* for tetracycline resistance. Also mark *rop*, which encodes a protein involved in regulating plasmid replication. The antibiotic-resistance markers allow bacteria carrying the plasmid to be selected by growth on a suitable antibiotic-containing medium. These are distinct labelled regions of the same plasmid, as shown below.



Schematic map of the *E. coli* cloning vector pBR322.

Step 2: (b) Explain the significance of the origin The origin of replication is the specific DNA sequence from which replication of the plasmid begins. Any foreign DNA linked to this sequence as part of the recombinant plasmid can be replicated within the host cell along with the vector. The origin also controls the copy number of the linked DNA in the host. Therefore, choosing a vector with a suitable origin permits the desired gene to be amplified and maintained in the transformed bacterial cells. It is a replication-control sequence, whereas the antibiotic-resistance genes provide selection.

Step 3: Conclusion The pBR322 map labels *ori*, *amp^R*, *tet^R* and *rop*. The origin initiates replication of the vector and its linked foreign DNA and controls their copy number in the host cell.

Quick Tip to Solve: Remember the four requested pBR322 labels as two resistance markers plus two replication features: *amp^R*, *tet^R*, *ori* and *rop*.

25. Define adaptive radiation. How did Darwin explain adaptive radiation?

[3 marks]

Solution:

Concept:

- Adaptive radiation is the evolution of different species from a common ancestral stock within a geographical area, with the descendants becoming adapted to different ecological habitats or niches.
- Natural selection favours inherited variations that improve survival and reproduction in a particular environment; different environments can favour different adaptations.

Step 1: Define the evolutionary pattern In adaptive radiation, evolution begins from a common ancestral form in a geographical area and radiates into several forms that occupy different habitats or use different resources. Thus, the descendants share an origin but develop different adaptive features. It is an example of divergent evolution.

Step 2: Explain Darwin's example of finches Darwin observed many kinds of finches on the Galapagos Islands. Although these birds were related, their beaks differed in size and shape. He reasoned that the different finches had evolved from an ancestral seed-eating finch that reached the islands. Descendant populations spread into different habitats and encountered different kinds of food.

Step 3: Link food habits with natural selection Variations in beak form made some birds better suited to particular foods. Natural selection favoured these useful variations in the respective habitats. Over generations, populations diverged into species with beaks adapted to feeding on seeds, insects or other plant material. The formation of these diverse finches from one ancestral stock illustrates adaptive radiation.

Step 4: Conclusion Adaptive radiation produces several species adapted to different niches from a common ancestor in a geographical area. Darwin explained it through the diversification of Galapagos finches, especially their beaks and food habits, from ancestral seed-eating finches.

Quick Tip to Solve: Link the definition to Darwin's finches in this order: common ancestor, different food sources, different beaks, and divergent species.

26. (a) How do some viruses cause cancer in humans?

(b) How do benign tumours turn malignant? How do malignant tumours harm the human body?

[3 marks]

Solution:

Concept:

- Cancer involves the loss of normal regulation of cell growth and division. Normal cells show contact inhibition, whereas cancer cells continue to divide despite contact with neighbouring cells.
- A benign tumour remains localised and does not invade surrounding tissues. A malignant tumour contains invasive cells capable of spreading to distant sites by metastasis.

Step 1: (a) Explain the action of cancer-causing viruses Cancer-causing viruses are called oncogenic viruses. They possess cancer-causing genes called viral oncogenes. When these genes are expressed

in infected human cells, their products can disrupt the normal control of cell growth and division, transforming normal cells into cancerous cells. The resulting uncontrolled proliferation can produce a tumour.

Step 2: (b) Explain malignant transformation A benign tumour consists of a localised mass of cells and does not invade neighbouring tissues. If its cells undergo further genetic changes that disrupt growth control and acquire the ability to invade surrounding tissue, it can become malignant. Such transformed cells lose normal contact inhibition and proliferate uncontrollably. Not every benign tumour necessarily becomes malignant; the acquisition of invasive behaviour distinguishes malignant transformation.

Step 3: (b) Describe the harm caused by malignant tumours Malignant cells grow rapidly, invade nearby tissues and damage normal cells and organs. The proliferating tumour also competes with normal cells for vital nutrients, depriving them of nutrition and impairing their function. Some cancer cells detach from the original tumour, enter the blood or lymph and reach distant organs. There they establish new tumours. This spread, called metastasis, extends tissue damage to other parts of the body.

Step 4: Conclusion Oncogenic viruses can cause cancer through viral oncogenes that disturb cell-growth control. A tumour becomes malignant when transformed cells acquire invasive properties; uncontrolled growth, nutrient deprivation, tissue destruction and metastasis harm the body.

Quick Tip to Solve: Separate the two mechanisms: viral oncogenes initiate transformation, while invasion and metastasis explain the danger of malignancy.

27. There are many animals, which have become extinct in the wild, but continue to be maintained in zoological parks. Answer the questions that follow:

- (a) What type of bio-diversity conservation is observed in this case?
- (b) Explain any other two ways which help in this type of conservation.
- (c) Besides zoological parks, mention one place that serves this purpose.

[3 marks]

Solution:

Concept:

- Ex situ conservation protects threatened organisms or their reproductive material outside their natural habitats under controlled care.
- Living collections and preserved germplasm can maintain species and their genetic resources, supporting propagation, captive breeding and possible future reintroduction.

Step 1: (a) Identify the conservation method Maintaining animals in zoological parks after they have become extinct in the wild is ex situ conservation. The animals are protected outside the natural habitats in which their wild populations originally lived. Human care provides food, shelter and conditions for survival and captive breeding.

Step 2: (b) Explain cryopreservation Gametes of threatened species can be preserved in a viable and fertile condition for long periods by cryopreservation. Storage at very low temperatures, commonly in liquid nitrogen at -196°C , greatly reduces biological activity and helps preserve the material.

Preserved gametes can subsequently be used in assisted breeding, helping conserve the species' genetic resources outside the natural habitat.

Step 3: (b) Explain seed-bank conservation Seeds of suitable plant species can be stored for long periods in seed banks under controlled conditions of temperature and moisture. Storage maintains seed viability while protecting plant genetic diversity. When needed, the seeds can be germinated to raise plants and multiply threatened species. Thus, the living reproductive material is conserved outside its original ecosystem.

Step 4: (c) Name another place for ex situ conservation A botanical garden is another place that serves this purpose. It maintains living collections of plants outside their natural habitats, including rare and threatened species, and provides care and facilities for their propagation.

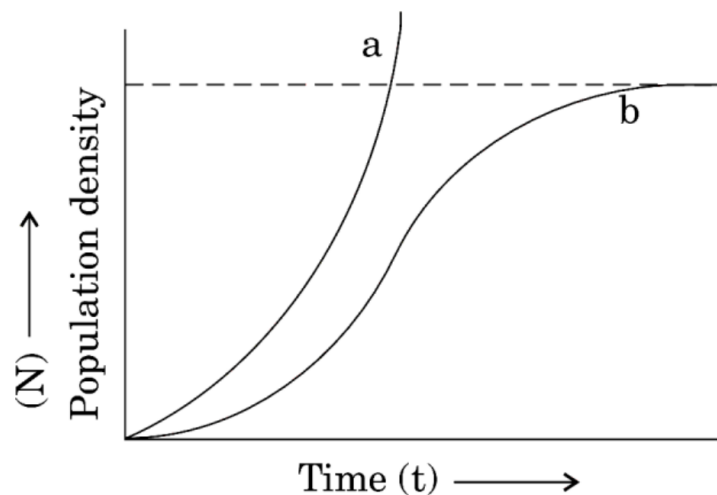
Step 5: Conclusion (a) Ex situ conservation is involved. (b) Cryopreservation of gametes and storage of viable seeds in seed banks are two other methods. (c) Botanical gardens also serve the purpose of ex situ conservation.

Quick Tip to Solve: Use the location test: protection outside the natural habitat is ex situ. Give two explained methods for (b) and a named place for (c).

28(a). Study the graph given below and answer the questions that follow:

- (i) Write the status of food and space in the curves a and b.
- (ii) In the absence of predators, which one of the two curves would appropriately depict the prey population?
- (iii) 'Time' has been shown on x-axis and there is a parallel dotted line above it. Give the significance of this dotted line.

[3 marks]



Solution:

Concept:

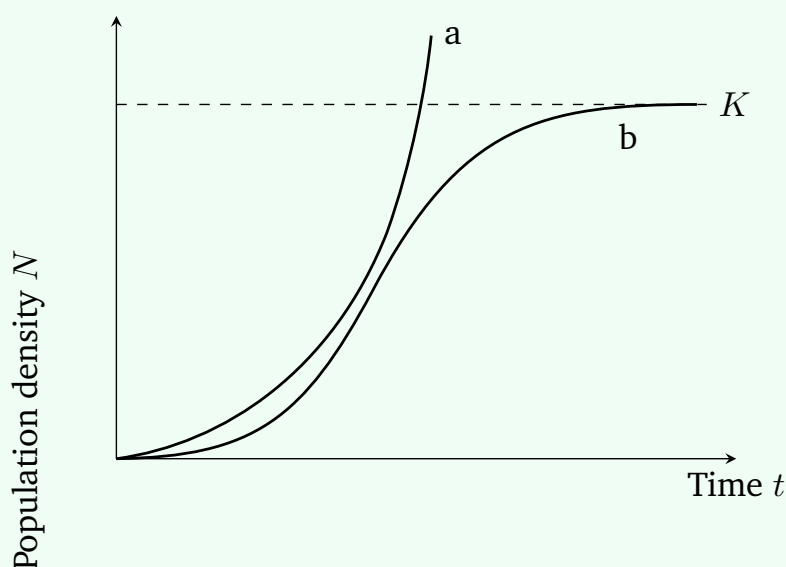
- Population growth depends on resources and environmental resistance. Exponential growth gives a J-shaped curve when food and space are unlimited.

- Logistic growth gives an S-shaped curve when resources are limited. Carrying capacity, K , is the maximum population size the habitat can sustain with its available resources.

Step 1: (i) Compare resources in the two curves Curve a is J-shaped and represents exponential growth. Food and space are effectively unlimited, allowing the population to increase rapidly. Curve b is S-shaped and represents logistic growth. Food and space are limited; competition and other limiting effects increase as population density rises, so growth slows near the habitat's carrying capacity.

Step 2: (ii) Identify growth without predators Curve a appropriately represents the prey population when predators are absent in the comparison shown. Removal of predation reduces mortality and permits a rapid increase in prey numbers. This depicts the idealised phase of unchecked growth; absence of predators does not remove resource limits indefinitely in a real habitat.

Step 3: (iii) Interpret the horizontal dotted line The dotted line represents the carrying capacity K of the environment. It is a population-density level, not a time interval. Curve b approaches this level because the habitat's limited food, space and other resources cannot support continued unrestricted growth. Near K , net population growth tends to zero.



Exponential growth (a), logistic growth (b), and carrying capacity K .

Step 4: Conclusion (i) Curve a: unlimited food and space; curve b: limited food and space. (ii) Curve a depicts the unchecked prey increase in the absence of predators. (iii) The dotted line indicates carrying capacity, K .

Quick Tip to Solve: Read the curve shape first: J means exponential growth; S means logistic growth. A horizontal limit on the population axis indicates K .

28(b). Answer the following questions:

(i) Define 'predation'.

(ii) Why is predation required in a community of different organisms? Give any two points.

(iii) Why are predators 'prudent' in nature?

[3 marks]

Solution:

Concept:

- Predation is an interspecific interaction in which the predator benefits and the prey is harmed; it is represented as a (+, -) interaction.
- Predators regulate prey abundance and can help maintain species diversity by reducing competition among competing prey species.

Step 1: (i) Define predation Predation is an interaction in which one organism, the predator, captures, kills and feeds on another organism, the prey. The predator obtains food and energy, while the prey is harmed. For example, a tiger feeding on a deer is a predator-prey interaction.

Step 2: (ii) Explain two roles in the community First, predators keep prey populations under control. Without this check, prey may increase excessively and overexploit the resources on which they depend. Second, predators help maintain species diversity by reducing the intensity of competition among competing prey species. By checking a competitively dominant prey species, a predator can prevent it from excluding other species from the community.

Step 3: (iii) Explain why predators are prudent Predators depend on prey for their food. If a predator overexploits its prey and eliminates it, the predator loses its own food supply and may itself become extinct. Predators are therefore described as prudent: predator-prey interactions generally allow prey populations to persist. The term describes the ecological outcome, not conscious planning by the predator.

Step 4: Conclusion Predation is feeding by a predator on its prey. It controls prey numbers and helps maintain species diversity. Predators are prudent because destroying their prey would destroy their own food resource and threaten their survival.

Quick Tip to Solve: For the two community roles, state population control and maintenance of diversity separately; link prudence directly to the predator's dependence on prey.

Section D (8 marks)

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

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

Gene expresses itself in a cell system as a protein/enzyme. How an expression of gene occurs in a cell system, when it needs to occur and how the gene expression is regulated in prokaryotic cell system was studied by the combined efforts of Francois Jacob, a geneticist and Jacques Monod, a biochemist. For their work on lactose metabolism in *E. coli* and introducing the concept of 'lac operon', they were awarded the Nobel Prize in 1965. [4 marks]

29(a). It is said that 'lac operon' has to be operational at a very low level in the bacterial cell all the time. Justify. [1 mark]

Solution:

Concept:

- The lac operon is an inducible system, but a small basal level of expression produces traces of its enzymes even before full induction.
- The lac *y* gene encodes permease, which increases the permeability of the bacterial cell to lactose.

Step 1: Identify the need for basal permease A very low level of lac operon activity ensures that some permease is already present in the bacterial membrane. This allows lactose from the surrounding medium to enter the cell when it becomes available.

Step 2: Connect entry with induction After entering the cell, lactose can bring about induction by inactivating the repressor, allowing much greater transcription of the structural genes. If permease were completely absent, lactose entry needed to initiate this response would be severely restricted.

Step 3: Conclusion Basal operation of the lac operon maintains a small amount of permease so that lactose can enter the cell and induce the operon when available.

Quick Tip to Solve: Link basal expression to permease first, then link lactose entry to induction; lactose outside the cell alone cannot initiate the intracellular response.

29(b)(i). How are the structural genes activated in the lac operon in *E. coli*? [1 mark]

Solution:

Concept:

- The lac repressor normally binds the operator and prevents transcription of the structural genes.
- An inducer inactivates the repressor, allowing RNA polymerase to transcribe lac *z*, *y* and *a*.

Step 1: Inactivate the repressor In the presence of lactose, the inducer binds to the repressor and changes its conformation. The repressor becomes inactive and cannot bind to the operator region. Allolactose, formed from lactose inside the cell, is the effective inducer.

Step 2: Allow transcription of the structural genes With the operator no longer blocked, RNA

polymerase can transcribe the structural genes *lac z*, *y* and *a*. Their mRNA is translated to produce β -galactosidase, permease and transacetylase, respectively.

Step 3: Conclusion Lactose-dependent inactivation of the repressor frees the operator and permits RNA polymerase to transcribe the *lac* structural genes.

Quick Tip to Solve: Remember the sequence: inducer binds repressor, operator becomes free, and structural-gene transcription proceeds.

OR

29(b)(ii). Why is the regulation of operon called negative regulation?

[1 mark]

Solution:

Concept:

- Negative regulation means that a regulatory protein inhibits the expression of structural genes.
- In the *lac* operon, the regulator gene produces a repressor that can bind to the operator.

Step 1: Identify the inhibitory action In the absence of the inducer, the active repressor binds to the operator. This prevents RNA polymerase from transcribing the structural genes of the *lac* operon.

Step 2: Relate inhibition to regulation The regulatory protein thus switches expression off by blocking transcription. The inducer permits expression by inactivating this repressor and removing the block; it does not make the repressor an activator.

Step 3: Conclusion *Lac* operon regulation is called negative regulation because the repressor negatively controls transcription by binding to the operator and blocking expression of the structural genes.

Quick Tip to Solve: Link the word negative to the repressor's blocking action at the operator, not to the absence of lactose alone.

29(c). Why is *lac* operon said to be a transcriptionally regulated system?

[2 marks]

Solution:

Concept:

- Transcription produces RNA from a DNA template. In bacteria, regulation of gene expression commonly controls whether RNA polymerase can transcribe the genes.
- The *lac* operon's operator and repressor control transcription of its structural genes, *z*, *y* and *a*, into a common messenger RNA.

Step 1: Examine the condition without inducer In the absence of lactose, the repressor is active and binds to the operator. This blocks RNA polymerase from transcribing the structural genes. As their messenger RNA is not efficiently produced, the enzymes for lactose utilisation are not synthesised at an appreciable rate.

Step 2: Examine the condition with inducer When lactose is available, its inducer form binds to the repressor and inactivates it. The repressor can no longer bind to the operator, so RNA polymerase can transcribe the structural genes. The resulting messenger RNA is then translated to form the lactose-metabolising proteins. Thus the regulatory switch determines formation of messenger RNA, before translation occurs.

Step 3: Conclusion The lac operon is a transcriptionally regulated system because the repressor-operator interaction controls whether the structural genes are transcribed into messenger RNA.

Quick Tip to Solve: Locate the control point: blocking RNA polymerase and messenger RNA formation means regulation at transcription.

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

Immunity in our body is of two types (i) Innate immunity, and (ii) Acquired immunity. Innate immunity is a non-specific defence mechanism, whereas Acquired immunity is pathogen specific. Acquired immunity is characterised by memory. Antibodies are specific to antigens and there are four types of antibodies produced in our body — IgA, IgE, IgG and IgM. It shows primary response where it encounters the pathogen for the first time and secondary response during the subsequent encounters with the same antigen/pathogen. These immune responses are carried out with the help of two special types of lymphocytes present in the blood.

[4 marks]

30(a). Name the two types of specialised cells which carry out the primary and secondary responses.

[1 mark]

Solution:

Concept:

- Acquired immunity is antigen-specific and has memory, producing primary and secondary responses.
- Its two specialised lymphocyte populations are B-lymphocytes and T-lymphocytes.

Step 1: Identify the antibody-producing lineage B-lymphocytes respond to specific antigens and differentiate into plasma cells that secrete antibodies. They provide the humoral component of acquired immunity.

Step 2: Identify the cellular component T-lymphocytes mediate cellular immune responses, and helper T-cells assist B-cell responses. Activation of these lymphocyte populations also generates memory cells, allowing a faster and stronger response on subsequent encounters with the same antigen.

Step 3: Conclusion The two specialised cell types are **B-lymphocytes and T-lymphocytes**.

Quick Tip to Solve: For acquired immune responses name B-cells and T-cells; phagocytes alone do not explain antigen-specific memory.

30(b)(i). Name any two barriers present in our body that provide innate immunity.

[1 mark]

Solution:

Concept:

- Innate immunity is present from birth and provides non-specific defence against pathogens.
- Its barriers act before an antigen-specific response is required; physical and physiological barriers are two categories.

Step 1: Identify a physical barrier The skin forms a physical barrier that prevents the entry of many microorganisms. Mucus on the epithelial lining of the respiratory and other tracts also traps microbes and restricts their entry.

Step 2: Identify a physiological barrier Acid in the stomach is a physiological barrier: its low pH inhibits or destroys many swallowed microorganisms. Such protection does not depend on previous exposure to a particular pathogen.

Step 3: Conclusion Two barriers are **physical barriers**, such as skin, and **physiological barriers**, such as stomach acid.

Quick Tip to Solve: Name each barrier category with one clear example: physical–skin; physiological–stomach acid.

OR

30(b)(ii). The organ transplants (grafts) are often rejected if not taken from suitable compatible persons. Mention the characteristic of our immune system that is responsible for the rejection.

[1 mark]

Solution:

Concept:

- The immune system can distinguish self components from non-self or foreign components.
- An incompatible graft bears donor antigens that can be recognised as foreign by the recipient's immune system.

Step 1: Identify the recognition property Cells of an incompatible transplanted organ carry surface antigens that differ from those of the recipient. The recipient's immune system therefore recognises the graft as non-self rather than as its own tissue.

Step 2: Connect recognition with rejection Recognition of these foreign antigens triggers an immune attack on the graft. T-lymphocyte-mediated cellular immunity plays an important role in this response, which can damage and reject the transplanted tissue.

Step 3: Conclusion The responsible characteristic is the immune system's **ability to distinguish self from non-self**; the incompatible graft is recognised as non-self and attacked.

Quick Tip to Solve: For graft rejection, state self–non-self discrimination first; T-cell action describes how rejection occurs.

30(c). How is active immunity different from passive immunity? Write any two differences. [2 marks]

Solution:

Concept:

- Acquired immunity may be active, when the person's own immune system responds to an antigen, or passive, when protective antibodies are received from another source.
- Compare the source of antibodies and the time taken to develop protection to distinguish these two forms.

Step 1: Compare how antibodies are obtained In **active immunity**, exposure to an antigen stimulates the individual's own immune system to produce antibodies, as after vaccination or natural infection. In **passive immunity**, ready-made antibodies are transferred to the individual, as when maternal antibodies reach a baby or preformed antibodies are administered by injection. The recipient need not first produce these protective antibodies.

Step 2: Compare the onset of protection Active immunity develops comparatively slowly because antigen recognition, lymphocyte activation and antibody production require time. Passive immunity gives immediate protection because functional antibodies are already available at transfer. It is therefore useful when protection is needed without waiting for the recipient to mount a new response.

Step 3: Conclusion Two differences are: active immunity uses antibodies produced by the person's own immune system and develops slowly; passive immunity uses transferred, ready-made antibodies and provides immediate protection.

Quick Tip to Solve: Contrast the same feature in both columns: self-produced versus transferred antibodies, then slow versus immediate onset.

Section E (15 marks)

31(a). Write the types and locations of the genes causing thalassemia in humans. State the cause and symptoms of the disease. How is sickle-cell anemia different from this disease? [5 marks]

Solution:

Concept:

- Thalassemia is an autosomal recessive blood disorder in which synthesis of an α - or β -globin chain of haemoglobin is reduced or absent.
- Normal adult haemoglobin contains two α and two β polypeptide chains, represented as $\alpha_2\beta_2$. Balanced production of both chain types is necessary for functional haemoglobin.
- Thalassemia is a quantitative defect in globin production, whereas sickle-cell anaemia is a qualitative defect in the structure of the β -globin chain.

Step 1: Identify the genes and their chromosome locations In α -thalassemia, synthesis of the α -globin chain is affected. It is controlled by the two closely linked genes *HBA1* and *HBA2* on chromosome 16. Since each homologous chromosome carries both genes, a diploid individual has four α -globin gene copies. Deletion or mutation of these copies reduces α -chain production; severity generally

increases with the number of affected copies.

In β -thalassemia, synthesis of the β -globin chain is affected. The *HBB* gene lies on chromosome 11. There is one copy on each homologue, hence two copies in a diploid individual. Mutant alleles can reduce or abolish β -chain production. These are autosomal genes, so the disease is not sex-linked.

Step 2: Explain the cause of thalassemia Inherited mutations or deletions in the globin genes impair the synthesis of one type of globin chain. Consequently, production of normal haemoglobin falls and the balance between α and β chains is disturbed. Excess unpaired chains damage developing red blood cells, and many cells are destroyed prematurely. Ineffective red blood cell formation and shortened red blood cell survival together cause anaemia. The disorder is inherited through recessive alleles; clinically severe forms result when the relevant gene copies are extensively affected.

Step 3: State the symptoms of the disease Reduced haemoglobin lowers the oxygen-carrying capacity of blood, producing pallor, weakness, easy fatigue and breathlessness. More severe disease can cause jaundice from increased red blood cell destruction, enlargement of the spleen and delayed growth in children. The severity varies with the type and extent of the globin-gene defect; a mildly affected carrier need not show the severe symptoms.

Step 4: Distinguish sickle-cell anaemia from thalassemia In sickle-cell anaemia, a point mutation in *HBB* replaces glutamic acid by valine at the sixth position of the β -globin chain. The corresponding coding DNA triplet changes from *GAG* to *GTG*. Thus abnormal haemoglobin, *HbS*, is produced: the primary defect concerns the amino-acid sequence, rather than a reduced rate of globin-chain synthesis.

Under low oxygen tension, *HbS* polymerises, making red blood cells rigid and sickle-shaped. These cells can obstruct small blood vessels and are destroyed more readily. In contrast, thalassemia chiefly involves deficient synthesis of structurally normal α or β chains; sickling is not its characteristic defect. Both disorders are inherited and can cause anaemia, but their molecular causes differ.

Step 5: Conclusion α -thalassemia involves *HBA1/HBA2* on chromosome 16, while β -thalassemia involves *HBB* on chromosome 11. Reduced globin synthesis produces anaemia and its associated symptoms. Sickle-cell anaemia instead involves a glutamic-acid-to-valine substitution in β -globin, producing *HbS* and sickling at low oxygen tension.

Quick Tip to Solve: Link alpha-thalassemia to two linked genes on chromosome 16 and beta-thalassemia to one gene on chromosome 11; compare reduced chain quantity with the altered chain quality in sickle-cell anaemia.

OR

31(b)(i). Enlist any four prime goals of the Human Genome Project (HGP).

[5 marks total]

Solution:

Concept:

- The Human Genome Project aimed to identify human genes and determine the complete nucleotide sequence of human DNA.

- Genome information must also be stored and analysed systematically to become useful for biological research.

Step 1: State the gene and sequence goals Two prime goals were: (1) identify all the genes present in human DNA, thereby preparing a catalogue of human genes; and (2) determine the sequence of approximately 3 billion chemical base pairs that constitute human DNA. Gene identification establishes the gene inventory, while sequencing establishes the order of the DNA bases.

Step 2: State the information-management goals Two further prime goals were: (3) store the information obtained in databases, so that the large amount of sequence and gene information could be organised and retrieved; and (4) improve tools for data analysis, so that researchers could compare sequences and interpret the genomic information. These are separate goals concerning storage and analysis of the data generated.

Step 3: Conclusion Four prime HGP goals were identification of all human genes, determination of the complete DNA sequence, storage of information in databases, and improvement of tools for data analysis.

Quick Tip to Solve: Recall four distinct actions for HGP goals: identify genes, sequence DNA, store information and improve analysis tools.

31(b)(ii). List the two methodologies which were involved in the human genome project. Mention how they were used.

Solution:

Concept:

- One HGP methodology focused on genes expressed as RNA, whereas the other examined the whole genome.
- Coding and non-coding regions are both part of genomic DNA, so complete genome sequencing is broader than studying expressed genes alone.

Step 1: Explain expressed sequence tags The first methodology was **expressed sequence tags (ESTs)**. It focused on identifying all genes expressed as RNA. RNA transcripts are represented by complementary DNA (cDNA), and short sequences from these cDNAs serve as tags for identifying expressed genes. Thus, the starting information is obtained from gene expression rather than from sequencing every region of genomic DNA.

Step 2: Explain sequence annotation The second methodology was **sequence annotation**. This involved sequencing the entire genome, including both coding and non-coding regions, and then assigning functions to the different regions of the sequence. Sequencing establishes the order of bases, while annotation interprets the regions within that sequence. Unlike the EST approach, the initial study is not restricted to genes represented by RNA transcripts.

Step 3: Conclusion ESTs were used to identify genes expressed as RNA; sequence annotation involved sequencing the whole genome and subsequently assigning functions to its regions.

Quick Tip to Solve: Pair each name with its use: ESTs identify expressed genes; sequence annotation interprets regions after whole-genome sequencing.

31(b)(iii). Expand 'YAC' and mention what it was used for.

Solution:

Concept:

- A cloning vector carries a DNA fragment into a suitable host so that copies of the inserted DNA can be produced.
- Studying the very large human genome required dividing genomic DNA into manageable fragments and multiplying those fragments for analysis.

Step 1: Expand the abbreviation YAC stands for **Yeast Artificial Chromosome**. It is an artificially constructed chromosome-based vector maintained in yeast cells. Its chromosome-like organisation allows it to carry relatively large fragments of foreign DNA and be propagated in the yeast host.

Step 2: Explain its use in the HGP YAC was used as a **cloning vector for large fragments of human genomic DNA**. A human DNA fragment was inserted into the vector and introduced into yeast cells, where it could be multiplied along with the vector. This supplied copies of the DNA for subsequent genome analysis and sequencing. Cloning separated genomic fragments made the enormous human genome more manageable for study; YAC itself was the carrier, not an enzyme that read the DNA sequence.

Step 3: Conclusion YAC means Yeast Artificial Chromosome; it was used to clone and multiply large human genomic DNA fragments in yeast for genome analysis and sequencing.

Quick Tip to Solve: Expand all three letters, then state both the role and host: a cloning vector for large DNA fragments in yeast.

32(a). (i) EcoR I has played a very important role in rDNA technology.

(I) Explain the convention for naming EcoR I.

(II) Write the recognition site of this endonuclease restriction enzyme.

(ii) Name the overhanging stretches of DNA produced by these restriction enzymes. Describe their role in the formation of rDNA.

[5 marks]

Solution:

Concept:

- Restriction endonucleases recognise specific palindromic sequences in double-stranded DNA and cut the sugar-phosphate backbones at defined positions.
- A restriction enzyme's name identifies its source bacterium and strain, followed by a Roman numeral giving its order of isolation from that strain.
- Complementary single-stranded sticky ends pair through hydrogen bonds; DNA ligase then joins the DNA backbones by forming phosphodiester bonds.

Step 1: (i)(I) Decode the name EcoR I EcoR I was isolated from the bacterium *Escherichia coli*, strain RY13. The first letter, E, comes from the genus *Escherichia*; the next two letters, co, come from the species *coli*. The letter R identifies the bacterial strain, RY13. The Roman numeral I indicates that it was the first restriction endonuclease isolated from this strain. Thus the letters identify the biological

source, while the numeral records the order of isolation.

Step 2: (i)(II) Write the recognition sequence EcoR I recognises the following six-base-pair palindromic DNA sequence:



Reading either strand in its own 5' to 3' direction gives GAATTC. EcoR I cuts between G and A in each strand when read in that direction. The cuts are staggered rather than directly opposite each other, leaving short single-stranded overhangs.

Step 3: (ii) Identify the ends and explain their pairing These overhanging stretches are called **sticky ends** or cohesive ends. EcoR I produces 5'-AATT overhangs. Cutting both the desired DNA fragment and a suitable vector with EcoR I produces compatible ends. When the cut vector and insert are mixed, the complementary bases in their overhangs pair by hydrogen bonding, with A pairing with T. This annealing brings the two DNA fragments together in the correct alignment for joining.

Step 4: (ii) Explain how the joined molecule becomes stable Base pairing alone does not seal the breaks in the sugar-phosphate backbones. DNA ligase forms phosphodiester bonds between the adjacent 3'-hydroxyl and 5'-phosphate ends, sealing the nicks. The inserted DNA and vector are thereby joined covalently into a recombinant DNA molecule. The restriction enzyme generates compatible ends; the ligase completes their stable joining.

Step 5: Conclusion EcoR I is the first restriction endonuclease isolated from *Escherichia coli* strain RY13. It recognises the palindromic sequence 5'-GAATTC-3', produces sticky ends, and enables complementary vector and insert ends to anneal before DNA ligase seals them to form recombinant DNA.

Quick Tip to Solve: Decode EcoR I as E + co + R + I. Write both antiparallel strands of GAATTC, and distinguish hydrogen bonding of sticky ends from phosphodiester-bond formation by ligase.

OR

- 32(b).** (i) Insertional inactivation is a method to detect the recombinant DNA. Explain this method.
(ii) Name the commonly used vector for transferring genes in plants from bacteria.
(iii) How is this able to transform a normal plant cell into a tumour? [5 marks]

Solution:

Concept:

- Insertional inactivation identifies recombinant vectors by the loss of activity of a marker gene into which foreign DNA has been inserted.
- The marker encoding β -galactosidase permits colour-based screening: an active enzyme produces a blue colour with a suitable chromogenic substrate, whereas its inactivation prevents that colour.
- The tumour-inducing (Ti) plasmid of *Agrobacterium tumefaciens* transfers a segment called T-DNA into plant cells. A disarmed Ti plasmid is used as a plant cloning vector.

Step 1: (i) Insert foreign DNA into a marker gene A cloning vector is cut at a suitable restriction site within a marker gene, and the desired foreign DNA is ligated into that site. The inserted DNA interrupts the normal sequence and function of the marker. This loss of marker function is called insertional inactivation. A vector that has closed without an insert retains the intact marker gene, allowing recombinant and non-recombinant vectors to be distinguished after introduction into host cells.

Step 2: (i) Identify recombinants using the colour test For example, insertion into the coding sequence associated with β -galactosidase prevents production of functional enzyme. Grow transformed bacterial cells on medium containing a suitable chromogenic substrate. Cells carrying non-recombinant plasmids have an active marker: the enzyme acts on the substrate and their colonies turn blue. Cells carrying recombinant plasmids have an inactivated marker, so their colonies remain white or colourless. Thus the white colonies are picked as candidate recombinants, while blue colonies are non-recombinants. An antibiotic-resistance marker on the vector first selects transformed cells; the colour test then distinguishes recombinant from non-recombinant transformants.

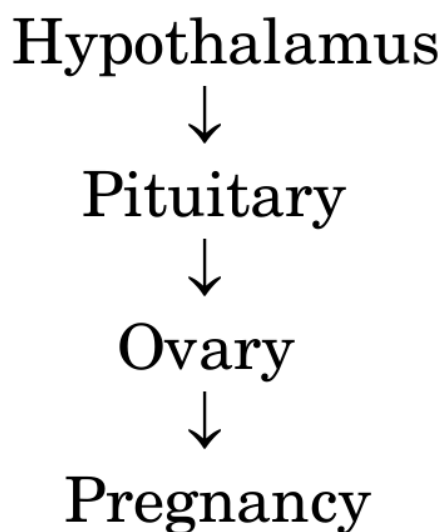
Step 3: (ii) Name the plant gene-transfer vector The commonly used vector is the Ti (tumour-inducing) plasmid of *Agrobacterium tumefaciens*, a bacterium that infects several dicot plants. For genetic engineering, this plasmid is disarmed by removing its tumour-inducing genes and inserting the desired gene, while retaining the ability to transfer DNA into plant cells.

Step 4: (iii) Explain transformation into a tumour In natural infection, *A. tumefaciens* transfers the T-DNA region of its Ti plasmid into a normal plant cell, where it integrates into the plant genome. Expression of tumour-inducing genes in this transferred DNA stimulates uncontrolled cell division, producing a crown-gall tumour. The transformed cells also produce substances used by the bacterium. It is the natural, tumour-inducing Ti plasmid that causes this change; the disarmed vector used in biotechnology retains gene-transfer ability without inducing a tumour.

Step 5: Conclusion Insertional inactivation detects recombinants through loss of marker activity, exemplified by white recombinant colonies in the β -galactosidase colour test. The plant vector is the Ti plasmid of *Agrobacterium tumefaciens*; naturally, its transferred T-DNA carries genes that convert plant cells into tumour cells.

Quick Tip to Solve: Link insertion to inactivation: an intact colour marker gives blue colonies, while an interrupted marker gives white colonies. Distinguish natural tumour-inducing Ti plasmids from the disarmed vectors used for gene transfer.

33(a). Study the flow chart given below. Name the hormones involved at each stage and explain their functions. [5 marks]



Solution:

Concept:

- The hypothalamus controls the anterior pituitary, whose gonadotropins regulate ovarian activity. Ovarian hormones prepare the uterus for implantation and support pregnancy.
- Follicle-stimulating hormone (FSH) and luteinising hormone (LH) act on the ovary. The developing follicles secrete oestrogens, and the corpus luteum secretes mainly progesterone.

Step 1: Identify the hypothalamic hormone The hypothalamus releases gonadotropin-releasing hormone (GnRH). GnRH stimulates the anterior pituitary to synthesise and release the two gonadotropins, FSH and LH. Thus the first link in the chart is a hormonal signal from the hypothalamus to the pituitary, rather than a direct action of the hypothalamus on the uterus.

Step 2: Explain the pituitary hormones acting on the ovary FSH stimulates the growth and maturation of ovarian follicles and promotes the secretion of oestrogens by the developing follicles. LH supports ovarian hormone secretion; its sharp mid-cycle rise, called the LH surge, induces rupture of the mature Graafian follicle and ovulation. LH also promotes transformation of the ruptured follicle into the corpus luteum. Ovulation releases the secondary oocyte, making fertilisation possible.

Step 3: Explain the ovarian hormones preparing for pregnancy Oestrogens from the growing follicles stimulate regeneration and proliferation of the uterine endometrium following menstruation. After ovulation, the corpus luteum secretes a large amount of progesterone. Progesterone maintains the thick, vascular, secretory endometrium needed for implantation and subsequent support of the developing embryo. Hence ovarian hormones create and maintain the uterine conditions necessary for pregnancy; fertilisation and implantation must also occur.

Step 4: Relate the hormonal sequence to maintenance of pregnancy Following implantation, human chorionic gonadotropin (hCG), secreted by the developing placental tissue, maintains the corpus luteum during early pregnancy. Continued progesterone secretion prevents breakdown of the endometrium. As pregnancy progresses, the placenta itself secretes progesterone and oestrogens, helping

maintain pregnancy. Thus the progesterone-supported endometrium is retained instead of being shed in menstruation.

Step 5: Conclusion The sequence is hypothalamic GnRH, pituitary FSH and LH, and ovarian oestrogens and progesterone. Together they coordinate follicular development, ovulation and preparation and maintenance of the endometrium; hCG sustains the corpus luteum in early pregnancy.

Quick Tip to Solve: Follow each arrow by naming the hormone and its target: GnRH to pituitary, FSH/LH to ovary, and ovarian hormones to the uterine endometrium.

OR

33(b). (i) Draw a diagram of L.S. of maize grain and label its any six parts.

(ii) Differentiate between perisperm and endosperm giving one example of each.

[5 marks]

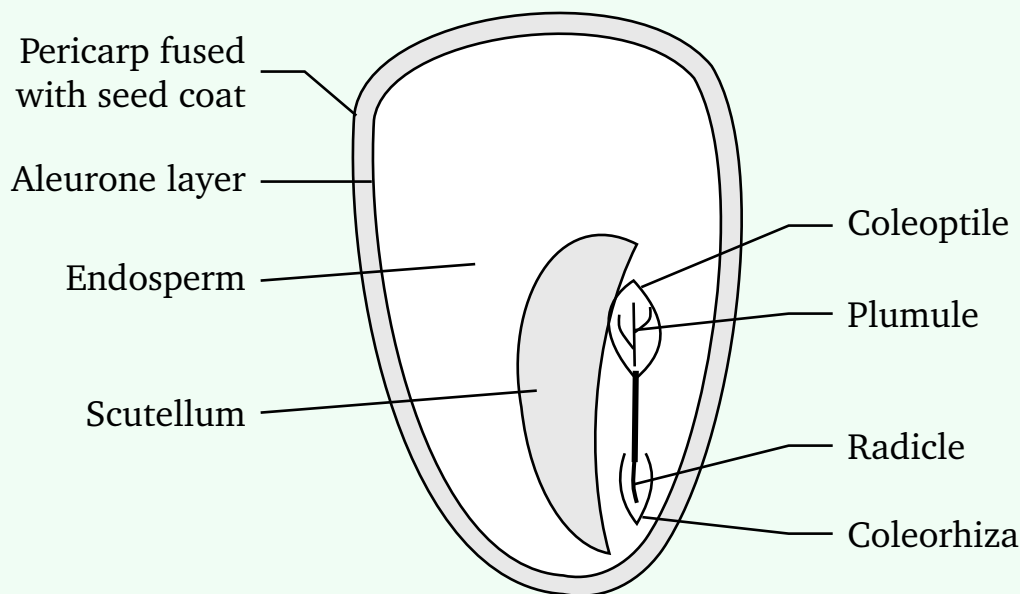
Solution:

Concept:

- A maize grain is a caryopsis: its thin fruit wall (pericarp) is fused with the seed coat. It is an endospermic seed containing a single cotyledon, the scutellum.
- Perisperm is persistent nucellus, a diploid maternal tissue. Endosperm develops from the primary endosperm nucleus formed by triple fusion and is usually triploid.

Step 1: (i) Draw and label the longitudinal section Draw the large endosperm occupying most of the grain and the small embryo lying to one side near its base. The outer covering consists of the fused pericarp and seed coat. Immediately inside it, the protein-rich aleurone layer forms the outer layer of the endosperm. The shield-shaped scutellum lies between the embryo axis and the stored food in the endosperm.

Label the plumule at the upper end of the embryonal axis, enclosed by the coleoptile, and the radicle at its lower end, enclosed by the coleorhiza. The labelled drawing below includes more than the required six parts; the protective sheaths must be distinguished from the structures they enclose.



Longitudinal section of a maize grain (schematic)

Step 2: (ii) Compare the origin and chromosome number **Perisperm:** It is the residual nucellus that persists in the mature seed. Since the nucellus belongs to the maternal sporophyte, perisperm is diploid, $2n$. It is not produced by triple fusion.

Endosperm: It develops after fertilisation from the primary endosperm nucleus. In the usual embryo sac, one male gamete fuses with the two polar nuclei (or their diploid secondary nucleus), so the resulting tissue is usually triploid:

$$n + n + n = 3n.$$

Thus, the two tissues differ both in developmental origin and in their usual chromosome number, although either can serve as a food-storage tissue in a seed.

Step 3: Give one example of each tissue **Perisperm example: black pepper.** Its mature seed retains a portion of the nucellus as perisperm.

Endosperm example: maize. Much of the endosperm persists in the mature maize grain and stores reserves that support the developing seedling. The scutellum is the cotyledon of the embryo, not the endosperm; it absorbs nutrients from the endosperm during germination.

Step 4: Conclusion The L.S. of maize grain shows the covering, aleurone layer, endosperm and lateral embryo with its scutellum and protected plumule and radicle. Perisperm is persistent diploid nucellus, as in black pepper; endosperm is usually triploid tissue formed following triple fusion, as in maize.

Quick Tip to Solve: In the maize sketch, put the scutellum between endosperm and embryo axis, and label each sheath separately: coleoptile around plumule, coleorhiza around radicle. Remember perisperm as persistent nucellus.