

CBSE Class 12 Biology Question Paper 2024 with Solution PDF-Set 57-S-1 - Compartment



Question Paper with Solutions

Conducted by the Central Board of Secondary Education (CBSE)

Time Allowed: 3 hours

Maximum Marks: 70

General Instructions

- (i) This question paper contains **33** questions. All questions are **compulsory**.
- (ii) Question paper is divided into **five** sections – Sections **A, B, C, D** and **E**.
- (iii) **Section A** – questions number **1** to **16** are multiple choice type questions. Each question carries **1** mark.
- (iv) **Section B** – questions number **17** to **21** are very short answer type questions. Each question carries **2** marks.
- (v) **Section C** – questions number **22** to **28** are short answer type questions. Each question carries **3** marks.
- (vi) **Section D** – questions number **29** and **30** are case-based questions. Each question carries **4** marks. Each question has subparts with internal choice in one of the subparts.
- (vii) **Section E** – questions number **31** to **33** are long answer type questions. Each question carries **5** marks.
- (viii) There is no overall choice. However, an internal choice has been provided in Sections B, C and D 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. $16 \times 1 = 16$

1. Long ribbon-like pollen grains are seen in some :

[1 mark]

- (A) Aquatic plants
- (B) Wind-pollinated grasses
- (C) Gymnosperms
- (D) Bird-pollinated flowers

Correct Answer: (A) Aquatic plants

Solution:

Concept:

- In hydrophily, pollen is transported by water; pollen shape and surface adaptations help it reach the stigma.
- In some submerged aquatic plants, such as *Zostera*, pollen grains are long and ribbon-like.

Step 1: Identify the adaptation Long ribbon-like pollen grains are characteristic of some submerged aquatic plants. In *Zostera*, pollen is carried below the water surface; its elongated form helps it travel in water and contact the stigma.

Step 2: Compare the alternatives Wind-pollinated grasses typically produce abundant, light pollen that can be carried by air. Gymnosperms do not as a group possess the ribbon-like pollen adaptation, while bird-pollinated flowers use birds as pollen carriers. Thus these alternatives do not identify the stated hydrophilous adaptation.

Step 3: Conclusion Some aquatic plants have long ribbon-like pollen grains. Hence, the correct option is (A).

Quick Tip to Solve: Associate ribbon-like pollen with *Zostera* and underwater pollination.

2. Estrogen is secreted by :

[1 mark]

- (A) Corpus luteum
- (B) Membrane granulosa of Graafian follicle
- (C) Pituitary gland
- (D) Germinal epithelium

Correct Answer: (B) Membrane granulosa of Graafian follicle

Solution:

Concept:

- The growing ovarian follicle contains granulosa cells, which participate in estrogen secretion.
- After ovulation, the ruptured follicle becomes the corpus luteum, whose characteristic major secretion is progesterone.

Step 1: Identify the follicular tissue The membrane granulosa of the Graafian follicle is the follicular cell layer associated with estrogen secretion. Estrogen supports the proliferative growth of the uterine endometrium during the follicular phase.

Step 2: Distinguish the other tissues The corpus luteum primarily secretes progesterone, although it can also produce estrogen; the expected follicular source among these options is the membrane granulosa. The pituitary releases gonadotropins such as FSH and LH, while the germinal epithelium is not the specified estrogen-secreting follicular tissue.

Step 3: Conclusion Estrogen is secreted by the membrane granulosa of the Graafian follicle. Hence, the correct option is (B).

Quick Tip to Solve: Link the growing Graafian follicle with estrogen and the corpus luteum chiefly with progesterone.

3. Amniocentesis is a technique that is used to :

[1 mark]

- (A) determine any disease of the heart
- (B) determine any genetic disorder of the foetus
- (C) determine any disorder of the brain
- (D) detect any abnormality in the bone formation

Correct Answer: (B) determine any genetic disorder of the foetus

Solution:

Concept:

- Amniocentesis samples amniotic fluid surrounding the developing foetus.
- Foetal cells in the fluid can be examined for chromosomal abnormalities and other genetic disorders.

Step 1: Identify the diagnostic sample Amniotic fluid contains cells shed by the foetus. These cells can be collected and analysed, for example by examining their chromosomes, to identify certain inherited or chromosomal disorders before birth.

Step 2: Match the purpose to the options Detection of a genetic disorder of the foetus is the general prenatal diagnostic use described here. A general examination of diseases of the heart, disorders of the brain or abnormalities of bone formation is not the defining purpose of this technique; these alternatives do not describe its genetic basis.

Step 3: Conclusion Amniocentesis is used to determine genetic disorders of the foetus. Hence, the correct option is (B).

Quick Tip to Solve: For amniocentesis, recall amniotic fluid, foetal cells and genetic or chromosomal testing.

4. In humans, non-disjunction of the 21st pair of chromosomes leads to :

[1 mark]

- (A) Acquired Immune Deficiency Syndrome
- (B) Klinefelter's Syndrome
- (C) Turner's Syndrome
- (D) Down's Syndrome

Correct Answer: (D) Down's Syndrome

Solution:

Concept:

- Non-disjunction is failure of a chromosome pair or sister chromatids to separate normally during cell division.
- An extra copy of chromosome 21 produces trisomy 21, the chromosomal basis of Down's syndrome.

Step 1: Trace the chromosome imbalance Non-disjunction involving chromosome 21 can produce a gamete with two copies of this chromosome. When it fuses with a normal gamete carrying one copy, the resulting zygote has three copies of chromosome 21 and a total of 47 chromosomes.

Step 2: Identify the associated syndrome Trisomy 21 causes Down's syndrome. Klinefelter's syndrome and Turner's syndrome involve sex-chromosome abnormalities rather than chromosome 21. Acquired Immune Deficiency Syndrome is caused by HIV infection and is not a chromosome-21 non-disjunction disorder.

Step 3: Conclusion Non-disjunction of chromosome 21 leading to trisomy 21 causes Down's syndrome. Hence, the correct option is (D).

Quick Tip to Solve: Remember the association: chromosome 21 in three copies means Down's syndrome.

5. Which one of the following codons has dual function ?

[1 mark]

- (A) AUG
- (B) AUC
- (C) ACU
- (D) ACA

Correct Answer: (A) AUG

Solution:

Concept:

- A codon is a sequence of three nucleotides in mRNA specifying an amino acid or a translation signal.
- AUG acts as an initiation codon and also codes for the amino acid methionine.

Step 1: Identify the two functions AUG has a dual role: it signals the start of translation in the appropriate initiation context and specifies methionine. When AUG occurs within a coding sequence, it also codes for methionine.

Step 2: Test the remaining codons AUC codes for isoleucine, whereas ACU and ACA code for threonine.

These codons specify amino acids but are not the standard initiation codon in the CBSE genetic-code description. Therefore they do not exhibit the dual function asked about.

Step 3: Conclusion AUG functions both as the start codon and as the codon for methionine. Hence, the correct option is (A).

Quick Tip to Solve: Recall AUG as both the translation start signal and the methionine codon.

6. Which one of the following options gives the correct temperature condition and the mixture of the gaseous components that were used by S.L. Miller in 1953 to prove abiogenesis of life ? [1 mark]

- (A) CH_4 , H_2 , NO_2 and water vapour at 1800°C
- (B) CH_4 , H_2 , NH_3 and water vapour at 1800°C
- (C) CO_2 , H_2 , NH_3 and water vapour at 800°C
- (D) CH_4 , H_2 , NH_3 and water vapour at 800°C

Correct Answer: (D) CH_4 , H_2 , NH_3 and water vapour at 800°C

Solution:

Concept:

- Miller's experiment simulated a reducing primitive atmosphere containing methane, ammonia, hydrogen and water vapour.
- Electrical discharges supplied energy for formation of organic compounds such as amino acids from inorganic precursors.

Step 1: Recall the experimental conditions In the NCERT description of Miller's 1953 experiment, a closed apparatus contained methane, hydrogen, ammonia and water vapour at a temperature of 800°C . Electric discharge was passed through the mixture to simulate lightning in the primitive atmosphere.

Step 2: Check each proposed mixture Option (A) incorrectly includes nitrogen dioxide and gives the wrong temperature. Option (B) has the correct gases but gives 1800°C . Option (C) substitutes carbon dioxide for methane. Only option (D) combines methane, hydrogen, ammonia and water vapour with the stated 800°C condition. The experiment demonstrated abiotic synthesis of organic molecules, rather than production of living organisms.

Step 3: Conclusion The mixture was CH_4 , H_2 , NH_3 and water vapour at 800°C . Hence, the correct option is (D).

Quick Tip to Solve: Check both parts of each option: the reducing gas mixture and the temperature of 800 degrees Celsius.

7. The mosquito-borne disease in humans causing chronic inflammation of the lymphatic vessels is : [1 mark]

- (A) Elephantiasis
- (B) Ascariasis
- (C) Ringworm
- (D) Amoebiasis

Correct Answer: (A) Elephantiasis

Solution:

Concept:

- Wuchereria worms cause lymphatic filariasis, commonly called elephantiasis.
- The infection is transmitted by mosquitoes, and prolonged infection can inflame and obstruct lymphatic vessels.

Step 1: Identify the affected system and vector Chronic inflammation of lymphatic vessels, together with mosquito-borne transmission, points to lymphatic filariasis. The filarial worms *Wuchereria bancrofti* and *Wuchereria malayi* are associated with this disease; persistent lymphatic damage can cause marked swelling.

Step 2: Exclude the other diseases Ascariasis is caused by an intestinal roundworm and is acquired by ingesting infective eggs. Ringworm is a fungal skin infection. Amoebiasis is caused by *Entamoeba histolytica* and spreads through contaminated food or water. None matches the mosquito-transmitted chronic lymphatic infection described.

Step 3: Conclusion The disease is elephantiasis (lymphatic filariasis). Hence, the correct option is (A).

Quick Tip to Solve: Use the combination of mosquito transmission and lymphatic swelling to identify elephantiasis.

8. In plants, which one of the following helps in the absorption of phosphorus from soil ? [1 mark]

- (A) *Glomus*
- (B) *Rhizobium*
- (C) *Frankia*
- (D) *Anabaena*

Correct Answer: (A) *Glomus*

Solution:

Concept:

- Mycorrhiza is a symbiotic association between a fungus and plant roots.
- The fungal partner absorbs phosphorus from the soil and transfers it to the plant.

Step 1: Identify the mycorrhizal fungus Many members of the genus *Glomus* form mycorrhizae. Their fungal hyphae explore the soil and improve phosphorus uptake by the associated plant roots.

Step 2: Eliminate the nitrogen fixers *Rhizobium* fixes nitrogen in legume root nodules, while *Frankia* forms nitrogen-fixing nodules in some non-leguminous plants. *Anabaena* is a nitrogen-fixing cyanobacterium. These options concern nitrogen enrichment rather than the characteristic mycorrhizal role in phosphorus absorption.

Step 3: Conclusion *Glomus* helps plants absorb phosphorus from soil. Hence, the correct option is (A).

Quick Tip to Solve: Link phosphorus uptake with mycorrhiza and *Glomus*; link the other three organisms here with nitrogen fixation.

9. The most primitive ancestor of humans is :

[1 mark]

- (A) *Homo habilis*
- (B) *Australopithecus*
- (C) *Ramapithecus*
- (D) *Homo neanderthalensis*

Correct Answer: (C) *Ramapithecus*

Solution:

Concept:

- Human-evolution questions compare the relative ages of the named ancestral forms.
- In the NCERT account, *Ramapithecus* is an early, more man-like primate described before australopithecines and species of *Homo*.

Step 1: Compare the earliest forms *Ramapithecus* lived about 15 million years ago in the textbook account. The australopithecines are described much later, around 2 million years ago. Thus *Ramapithecus* is the most primitive form among the choices.

Step 2: Compare the later humans *Homo habilis* is described as an early human-like hominid with a larger brain than the earlier forms. Neanderthal humans lived much later, about 100,000 to 40,000 years ago. Neither is earlier than *Ramapithecus*, and *Australopithecus* is also a later stage in this comparison.

Step 3: Conclusion Among the given forms, *Ramapithecus* is the most primitive ancestor in the textbook sequence. Hence, the correct option is (C).

Quick Tip to Solve: Arrange the choices by the textbook timeline: *Ramapithecus* precedes australopithecines and the named *Homo* forms.

10. The sequence that controls the copy number of linked DNA in the vector is termed : [1 mark]

- (A) Selectable marker
- (B) Ori site
- (C) Palindromic sequence
- (D) Recognition site

Correct Answer: (B) Ori site

Solution:

Concept:

- The origin of replication, or ori, is the DNA sequence from which replication begins.
- The ori also controls the copy number of DNA linked to it in a cloning vector.

Step 1: Identify the copy-number control sequence A foreign DNA fragment linked to a functional ori can replicate inside a suitable host. The properties of this origin determine the number of copies of the linked DNA maintained in the host cell.

Step 2: Separate replication from other vector functions A selectable marker helps identify transformants, for example through antibiotic resistance. A recognition site is the sequence recognised by a restriction enzyme; many such sequences are palindromic. These sites help cut and insert DNA, but they are not the origin that controls replication and copy number.

Step 3: Conclusion The sequence is the ori site. Hence, the correct option is (B).

Quick Tip to Solve: When a vector question mentions initiation of replication or copy number, identify ori; selection and cutting involve different sequences.

11. Crystals of Bt toxin produced by some bacteria, do not kill the bacteria producing them because : [1 mark]

- (A) bacteria are resistant to the toxin
- (B) toxin is immature
- (C) toxin is inactive
- (D) bacteria encloses 'toxin' in a special capsule

Correct Answer: (C) toxin is inactive

Solution:

Concept:

- *Bacillus thuringiensis* produces insecticidal proteins as inactive protoxins.
- The alkaline conditions in a susceptible insect gut solubilise the crystals and allow activation of the toxin.

Step 1: Identify the state inside the bacterium The Bt protein is present in the producing bacterium as an inactive protoxin. It therefore does not exert its toxic action on that bacterium while stored in this form.

Step 2: Explain activation and reject the alternatives After ingestion by a susceptible insect, the

protoxin is converted into active toxin. The active toxin binds to midgut epithelial cells and forms pores, causing cell swelling and lysis. General bacterial resistance or enclosure in a special capsule is not the stated mechanism. The precise biological term is inactive protoxin, rather than merely an immature toxin.

Step 3: Conclusion The toxin does not kill the producing bacterium because it is inactive. Hence, the correct option is (C).

Quick Tip to Solve: Remember the sequence for Bt action: inactive protoxin in the bacterium, activation in the insect gut, then damage to gut epithelial cells.

12. The population interaction where one species is harmed and the other is unaffected is : [1 mark]

- (A) Amensalism
- (B) Commensalism
- (C) Parasitism
- (D) Predation

Correct Answer: (A) Amensalism

Solution:

Concept:

- Population interactions can be represented by their effects on the two partners: benefit (+), harm (−), or no effect (0).
- Amensalism has the effect pair (−, 0): one species is harmed and the other is unaffected.

Step 1: Match the stated effects The question gives harm to one species and no effect on the other. This is the defining combination for amensalism; there is no benefit assigned to either partner.

Step 2: Distinguish the other interactions Commensalism has the combination (+, 0), because one species benefits while the other is unaffected. Parasitism and predation both have (+, −): the parasite or predator benefits while the host or prey is harmed. They therefore cannot describe the stated unaffected partner.

Step 3: Conclusion The interaction is amensalism. Hence, the correct option is (A).

Quick Tip to Solve: Write the two effects first: harm plus no effect gives (−, 0), the signature of amensalism.

13. Assertion (A) : Periodic abstinence is a method in which couples avoid coitus from day 10 to 17 of menstrual cycle.

Reason (R) : Periodic abstinence has limited effectiveness because menstrual cycles are not always regular. [1 mark]

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

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

Solution:

Concept:

- Periodic abstinence avoids intercourse during the expected fertile period of the menstrual cycle.
- Assertion–Reason questions require separate truth checks and a further check of whether the reason explains the assertion.

Step 1: Evaluate the assertion The assertion is true. In the usual textbook description, couples avoid coitus from day 10 to day 17 because ovulation and the fertile period are expected around the middle of the cycle.

Step 2: Evaluate the reason The reason is also true. Menstrual cycles are not always regular, so predicting the fertile interval from calendar days alone can be unreliable. This limits the effectiveness of periodic abstinence.

Step 3: Test the explanatory link The reason explains a limitation of the method. It does not explain why days 10 to 17 are selected; that interval is chosen because of the expected timing of ovulation and the fertile period. Thus both statements are true, but the reason does not correctly explain the assertion.

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

Quick Tip to Solve: For this pair, distinguish why the fertile days are avoided from why calendar-based avoidance can fail.

14. Assertion (A) : *Streptococcus pneumoniae* and *Haemophilus influenzae* are responsible for causing infectious diseases in human beings.

Reason (R) : A healthy person acquires the infection by inhaling the droplets/aerosols released by an infected person. [1 mark]

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

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

Solution:

Concept:

- *Streptococcus pneumoniae* and *Haemophilus influenzae* are bacterial pathogens that can cause pneumonia.
- Droplet or aerosol inhalation describes transmission of an infection; it must be distinguished from identifying its causative organisms.

Step 1: Evaluate the assertion The assertion is true. Both named bacteria can cause pneumonia, an infectious disease in which the alveoli may fill with fluid and respiratory function is affected.

Step 2: Evaluate the reason The reason is true. A healthy person can acquire the infection by inhaling droplets or aerosols released by an infected person. This is a recognised route by which these respiratory pathogens spread.

Step 3: Test whether the reason explains the assertion The assertion identifies bacteria responsible for causing disease. The reason describes how the infection reaches another person; it does not explain the disease-causing role of those bacteria. Therefore the statements are both true, but the reason is not the correct explanation of the assertion.

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

Quick Tip to Solve: Separate the causative agent from its route of transmission when judging the explanatory link in this pneumonia pair.

15. Assertion (A) : Biotechnology produces transgenic micro-organisms that act as microfactories for proteins.

Reason (R) : To produce proteins for human use like insulin, transgenic microorganisms can be developed. [1 mark]

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

Solution:

Concept:

- A transgenic microorganism carries an introduced gene and can express it to manufacture the protein encoded by that gene.
- Recombinant DNA technology allows useful human proteins, including insulin, to be produced in suitable microbial hosts on a large scale.

Step 1: Judge the assertion Assertion (A) is true. A microorganism into which a desired protein-coding gene has been introduced can use its cellular machinery to synthesise that protein. Such engineered cells act as microfactories when grown under suitable conditions.

Step 2: Judge the reason Reason (R) is true. Transgenic microorganisms can be developed for producing proteins used by humans; recombinant human insulin is a standard example. The inserted genetic information directs the production of the required protein.

Step 3: Check the explanatory connection The reason explains the assertion because production of useful proteins such as insulin is precisely the activity for which the engineered microorganism functions as a microfactory. Thus the explanation is directly linked to the asserted role. Option (B) incorrectly denies this link, while (C) and (D) incorrectly declare one statement false.

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 an assertion about microbial protein factories, connect the inserted gene with its expressed protein, such as human insulin.

16. Assertion (A) : Gross primary productivity is always less than net primary productivity.

Reason (R) : Rate of synthesis of organic matter by consumers is known as secondary productivity.

[1 mark]

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

- Gross primary productivity (GPP) is the total rate of organic matter production by photosynthesis. Producers consume part of this production in respiration, denoted by R .
- Net primary productivity (NPP) is the production remaining after respiratory losses: $NPP = GPP - R$. Secondary productivity is the rate of formation of new organic matter by consumers.

Step 1: Judge the assertion using the productivity relation Assertion (A) is false. Since a portion of the gross production is used in respiration, subtracting this loss gives net production. Consequently, GPP is greater than NPP when respiratory loss is positive, rather than less than NPP as asserted.

Step 2: Judge the reason independently Reason (R) is true. Consumers are heterotrophs; their synthesis of new organic matter, using the food they consume, is termed secondary productivity. It differs from the primary productivity of photosynthetic producers.

Step 3: Match the truth values to the printed options The reason is a correct definition of secondary productivity, but it does not make the incorrect GPP–NPP comparison true. Options (A) and (B) require both statements to be true; option (C) reverses their actual truth values.

Step 4: Conclusion A is false and R is true. Hence the correct option is (D).

Quick Tip to Solve: Write $NPP = GPP$ minus respiration before comparing the two; the subtraction immediately fixes the direction of the inequality.

Section B (10 marks)

17. State the cellular nature and functions of myometrium and endometrium.

[2 marks]

Solution:

Concept:

- The uterine wall has an outer perimetrium, a middle myometrium and an inner endometrium. Their different cellular structures suit different reproductive functions.
- Smooth muscle produces involuntary contractions, whereas a glandular epithelial lining provides a receptive and secretory surface for implantation and early development.

Step 1: State the nature and function of the myometrium The myometrium is a thick layer made of smooth muscle cells. These cells undergo strong, coordinated contractions during childbirth, helping to expel the fully developed foetus from the uterus. Its muscular nature therefore provides the force required for parturition.

Step 2: State the nature and function of the endometrium The endometrium is the inner glandular lining of the uterus, containing epithelium and underlying vascular tissue. It undergoes cyclical changes during the menstrual cycle and becomes suitable for implantation of the blastocyst. Its glands and blood supply support the implanted embryo; if pregnancy does not occur, its superficial functional layer is shed during menstruation.

Step 3: Conclusion Myometrium: smooth muscle, responsible for uterine contractions during childbirth. Endometrium: inner glandular lining, which undergoes menstrual changes and supports implantation and early embryonic development.

Quick Tip to Solve: Associate the middle muscular layer with contraction and the inner glandular layer with implantation and menstrual changes.

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

Solution:

Concept:

- Hormonal implants contain progestogens alone or progestogen–estrogen combinations and are placed beneath the skin of a female.
- Slow, sustained release of hormones alters reproductive processes so that ovulation, fertilisation and implantation are prevented or made less likely.

Step 1: Explain the contraceptive action Implants steadily release contraceptive hormones into the body. Their action is similar to that of hormonal contraceptive pills: they inhibit ovulation, make the endometrium unsuitable for implantation, and alter cervical mucus so that sperm entry is impeded. By preventing release of the ovum and creating barriers to sperm passage and implantation, they provide effective contraception.

Step 2: Give one advantage over pills An implant provides protection for a much longer period after insertion and does not require the woman to remember a pill every day. Sustained hormone release therefore avoids the loss of protection that can result from missed daily doses of oral contraceptive pills. The implant must be inserted by a trained healthcare provider.

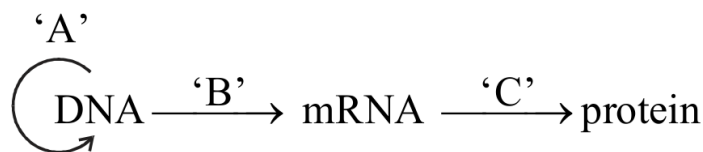
Step 3: Conclusion Hormonal implants prevent pregnancy by inhibiting ovulation, reducing endometrial receptivity and impeding sperm entry through altered cervical mucus. Their advantage over pills is prolonged protection without daily dosing.

Quick Tip to Solve: Explain implants using the hormonal pill mechanism, then distinguish their long duration and freedom from daily pill-taking.

19. (a) Given below is a representation of the “Central dogma” :

Identify ‘A’, ‘B’ and ‘C’ in the above representation.

(b) What does the Central dogma state in molecular biology ? Write an example where it is not applicable. [2 marks]



Solution:

Concept:

- The central dogma represents the usual flow of genetic information from DNA to RNA and from RNA to protein.
- DNA replication copies DNA, transcription produces RNA from a DNA template, and translation uses the sequence of mRNA to specify the amino acid sequence of a protein.

Step 1: (a) Identify the labelled processes A is replication: the loop begins and ends at DNA, indicating copying of DNA to form DNA. B is transcription: the arrow leads from DNA to mRNA. C is translation: the arrow leads from mRNA to protein, whose amino acid sequence is specified by the mRNA codons.

Step 2: (b) State the usual information flow In the conventional school-level representation, the central dogma states that genetic information flows from DNA to RNA to protein:



DNA also replicates to transmit its information to daughter cells.

Step 3: Give the exception to this usual representation In retroviruses such as HIV, RNA serves as a template for synthesis of DNA by the enzyme reverse transcriptase. Thus the information initially flows from RNA to DNA, called reverse transcription, rather than following only the DNA-to-RNA direction shown in the diagram. This is the standard exception to the simple school-level representation.

Step 4: Conclusion A: replication; B: transcription; C: translation. The usual flow is DNA to RNA to protein; retroviruses such as HIV show RNA-to-DNA reverse transcription.

Quick Tip to Solve: Read each arrow from its starting molecule to its product: DNA to DNA is replication, DNA to RNA transcription, and RNA to protein translation.

20. Why is making host cells ‘competent’ essential for rDNA technology ? Mention any two ways by which this can be achieved. [2 marks]

Solution:

Concept:

- DNA is a large, hydrophilic molecule and cannot normally cross the lipid-rich plasma membrane of a host cell.

- A competent host cell can take up foreign DNA, allowing recombinant DNA to enter and subsequently multiply in the host.

Step 1: Explain why competence is essential In recombinant DNA technology, a recombinant vector must be introduced into a suitable host. Merely mixing DNA with untreated cells does not ensure entry because DNA cannot readily pass through their membrane. Making the host competent increases its ability to take up the recombinant DNA; this permits transformation and cloning of the introduced DNA.

Step 2: Method 1: chemical treatment and heat shock Treat bacterial cells with a suitable concentration of a divalent cation, such as calcium ions, which increases the efficiency of DNA entry. Incubate the competent cells with recombinant DNA on ice, give a brief heat shock at 42 °C, and return them to ice. This treatment facilitates uptake of recombinant DNA.

Step 3: Method 2: electroporation Expose cells mixed with recombinant DNA to a brief, controlled electrical pulse. The pulse produces temporary pores in the cell membrane through which DNA can enter. The membrane then reseals, and surviving transformed cells can be selected and grown.

Step 4: Conclusion Competence is essential for uptake of recombinant DNA. Two ways are calcium-ion treatment followed by heat shock, and electroporation.

Quick Tip to Solve: Link competence to DNA entry first; then name each method and state how it enables uptake.

21(a). Comment on the interaction between a fig tree and wasp. Mention the phenomenon that operates in their relationship.

[2 marks]

Solution:

Concept:

- Mutualism is an interaction in which both interacting species benefit.
- Coevolution is reciprocal evolutionary change in interacting species, with adaptations in one favouring complementary adaptations in the other.

Step 1: Explain the benefits to the fig tree and the wasp The female fig wasp uses the fig inflorescence as a site for laying her eggs. Developing seeds provide nourishment for the larvae. While searching for suitable egg-laying sites inside the inflorescence, the wasp pollinates the fig flowers, enabling the plant to produce seeds. Thus the fig provides a breeding site and food, whereas the wasp provides pollination; both partners benefit.

Step 2: Name the evolutionary phenomenon This specialised mutualistic association illustrates coevolution. The fig and its pollinating wasp have evolved closely matching adaptations, so the wasp can reproduce in the fig and the fig can be pollinated by its associated wasp. In many figs the partnership is highly species-specific: a particular fig species is associated with its particular pollinator wasp species.

Step 3: Conclusion The fig tree and fig wasp show mutualism: pollination benefits the fig, and an egg-laying site and larval food benefit the wasp. Their specialised relationship demonstrates

coevolution.

Quick Tip to Solve: Give one benefit to each partner, then name coevolution as the phenomenon shaping their matching adaptations.

OR

21(b). Explain “brood parasitism” with the help of an example.

[2 marks]

Solution:

Concept:

- Brood parasitism is an interaction in which a bird lays its eggs in the nest of another bird and relies on that host to incubate the eggs and rear its young.
- The parasite benefits through reduced parental care, while the host spends time and resources raising another species' offspring.

Step 1: Describe how brood parasitism operates Instead of building a nest and providing all parental care itself, the brood parasite deposits its eggs in a host bird's nest. The host incubates the eggs along with its own and feeds the resulting young. This transfers the costs of incubation and chick-rearing to the host, while increasing the parasite's opportunity to reproduce.

Step 2: Explain using the cuckoo and crow The cuckoo (koel) lays its eggs in the nest of a crow. The crow incubates these eggs and subsequently feeds the cuckoo's chicks. During evolution, the parasite's eggs have come to resemble those of the host in size and colour. Such resemblance reduces the chance that the host will recognise and eject the foreign eggs, helping the parasite exploit the host's parental care.

Step 3: Conclusion Brood parasitism is the use of another bird's nest and parental care for raising young; for example, the cuckoo lays eggs in a crow's nest and the crow rears its chicks.

Quick Tip to Solve: Remember the sequence: foreign egg in host nest, host incubation, then host feeding of the parasite's chick.

Section C (21 marks)

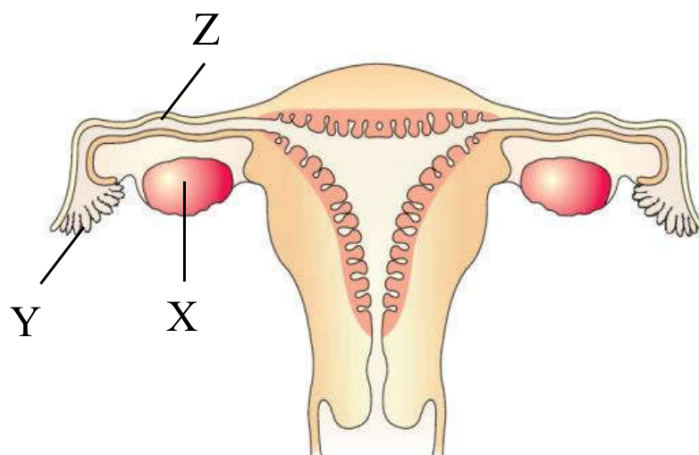
22. Given below is the diagram showing a part of the reproductive system of a human female.

(a) Identify 'Y' and write its function.

(b) Identify 'Z' and write the events that may occur here.

(c) Mention the stage at which the process of oogenesis temporarily gets arrested and name the cells thus formed in the 'X' of a baby girl at the time of her birth.

[3 marks]



Solution:

Concept:

- The ovary produces oocytes; the fimbriae at the ovarian end of the oviduct help collect the ovulated secondary oocyte.
- The fallopian tube transports the oocyte or early embryo. Fertilisation normally occurs at its ampullary-isthmic junction.
- Oogenesis begins before birth, and primary oocytes remain arrested in prophase I of meiosis until their later development.

Step 1: (a) Identify Y and state its function Y indicates the fimbriae, the finger-like projections at the margin of the infundibulum of the fallopian tube. They help collect the secondary oocyte released from the ovary during ovulation and guide it into the oviduct.

Step 2: (b) Identify Z and describe the events there Z indicates the fallopian tube (oviduct). A secondary oocyte can be fertilised by a sperm at the ampullary-isthmic junction. The resulting zygote undergoes successive mitotic cleavage divisions while moving through the oviduct towards the uterus, producing early blastomeres and then a morula.

Step 3: (c) State the arrested stage and name the cells in X X is the ovary. During fetal development, oogonia enter meiosis I and become primary oocytes. Meiosis then temporarily stops in prophase I, specifically the diplotene stage. Thus, at birth, the baby girl's ovaries contain primary oocytes arrested in prophase I.

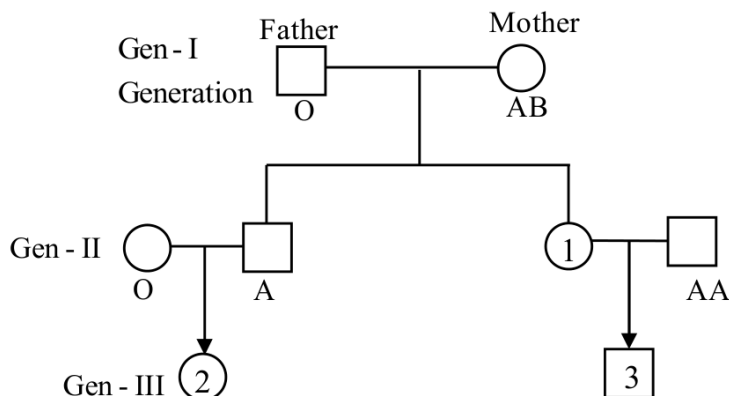
Step 4: Conclusion Y: fimbriae, which collect the ovulated oocyte. Z: fallopian tube, where fertilisation and early cleavage can occur. X: ovary, containing primary oocytes arrested in prophase I (diplotene) at birth.

Quick Tip to Solve: At birth remember primary oocyte plus prophase I; secondary oocytes arrest later in metaphase II.

23. Given below is the pedigree chart up to 3 generations (Generation I, Generation II, Generation III) of a family with respect to their blood groups.

- (a) Mention the blood group along with the genotype of the offspring numbered '1' in Generation II.
 (b) Write the possible blood groups along with their genotypes of the offsprings numbered '2' and '3' in Generation III.

[3 marks]



Solution:

Concept:

- The ABO system has three alleles: I^A , I^B and i . Alleles I^A and I^B are codominant, and each is dominant over i .
- Group O has genotype ii , group AB has $I^A I^B$, and group A can be $I^A I^A$ or $I^A i$. Each offspring receives one allele from each parent.

Step 1: Determine the possible genotype of individual 1 The Generation I father is group O, ii , and the mother is group AB, $I^A I^B$. The father produces only i gametes; the mother produces I^A and I^B gametes. Thus their children can be group A, $I^A i$, or group B, $I^B i$, with equal probability. Individual 1 can therefore be either A or B. The blood group of her brother does not determine which maternal allele she inherited.

Step 2: Find the possibilities for individual 2 The group A son in Generation II must be $I^A i$, since his father contributed i . His group O partner is ii . The cross $I^A i \times ii$ gives $I^A i$ and ii in the ratio 1 : 1. Hence individual 2 can have group A ($I^A i$) or group O (ii).

Step 3: Find the possibilities for individual 3 The partner of individual 1 is labelled AA, i.e. $I^A I^A$, and supplies only I^A . If individual 1 is $I^A i$, the children are $I^A I^A$ or $I^A i$, both group A. If she is $I^B i$, the children are $I^A I^B$ (group AB) or $I^A i$ (group A). Thus all possibilities for individual 3 are group A with $I^A I^A$ or $I^A i$, and group AB with $I^A I^B$.

Step 4: Conclusion (a) Individual 1: A, $I^A i$, or B, $I^B i$. (b) Individual 2: A, $I^A i$, or O, ii . Individual 3: A, $I^A I^A$ or $I^A i$, or AB, $I^A I^B$. The chart does not uniquely identify individual 1.

Quick Tip to Solve: An O parent passes only i ; list both alleles the AB parent can pass before following the pedigree.

24. (a) Name the enzyme responsible for the transcription of tRNA.

(b) Draw a labelled diagram of an initiator tRNA charged with its respective amino acid.

(c) Explain the role of the initiator tRNA in initiation of protein synthesis.

[3 marks]

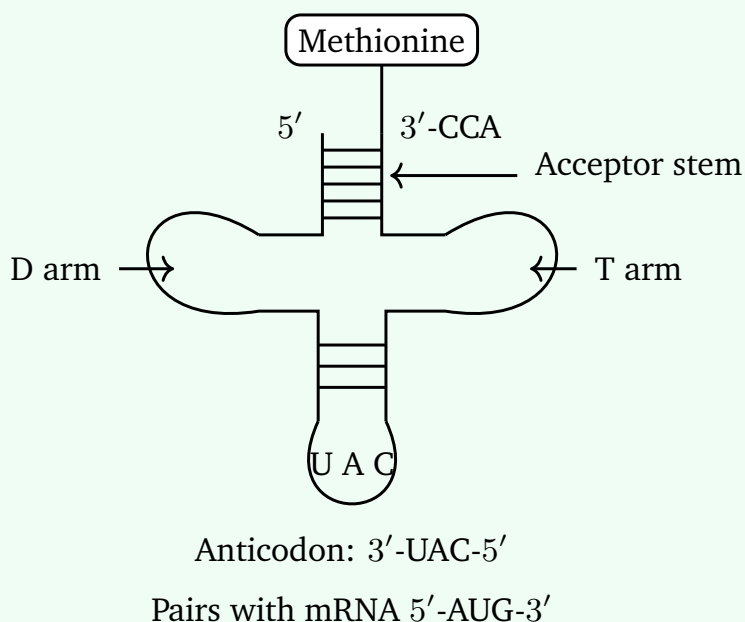
Solution:

Concept:

- In eukaryotes, RNA polymerase III transcribes tRNA genes. The mature tRNA acts as an adaptor between an mRNA codon and its corresponding amino acid.
- A charged initiator tRNA carries methionine at its 3'-CCA acceptor end. Its anticodon 3'-UAC-5' pairs with the start codon 5'-AUG-3'.

Step 1: Name the transcription enzyme (a) The enzyme is RNA polymerase III, in the eukaryotic transcription system. Aminoacyl-tRNA synthetase instead charges tRNA with its amino acid.

Step 2: Identify the charged initiator tRNA (b) The labelled cloverleaf diagram shows initiator tRNA charged with methionine. The amino acid attaches to the terminal adenosine of the 3'-CCA end, whereas the anticodon lies in the opposite loop. The acceptor stem, D arm, T arm and anticodon loop are labelled.



Initiator tRNA charged with methionine (schematic cloverleaf).

Step 3: Explain initiation of translation (c) The small ribosomal subunit associates with mRNA and the initiator tRNA recognizes the start codon AUG by complementary anticodon pairing. The charged initiator tRNA occupies the P site of the assembled initiation complex, and the large subunit joins. This fixes the reading frame and positions methionine as the first amino acid of the growing polypeptide. During elongation, the next charged tRNA enters the A site.

Step 4: Conclusion (a) RNA polymerase III. (b) Methionine-charged initiator tRNA has a 3'-CCA acceptor end and UAC anticodon. (c) It recognizes AUG, establishes the reading frame and brings the first methionine to the ribosomal P site.

Quick Tip to Solve: Put methionine at the CCA acceptor end; put UAC on the anticodon loop opposite it, not beside the amino acid.

25. Differentiate between the explanations given by Darwin and de Vries respectively on the mechanism of evolution. Write any three differences.

[3 marks]

Solution:

Concept:

- Darwin explained evolution through natural selection acting on heritable variations already present in a population.
- Hugo de Vries proposed mutation theory: sudden, heritable changes can produce new forms. His explanation arose from studies on evening primrose.

Step 1: First difference: nature of variation In Darwin's explanation, the variations relevant to evolution are small, continuous differences between individuals. In de Vries's mutation theory, the crucial changes are mutations: large, sudden, discontinuous heritable variations. Thus the two explanations differ in the size and continuity of the variations emphasized.

Step 2: Second difference: rate and mode of evolutionary change Darwin viewed evolution as a gradual process: useful variations accumulate through natural selection over many generations. De Vries proposed that a new species could originate suddenly through a large mutation, a single-step change called saltation. This contrasts gradual accumulation with sudden species formation.

Step 3: Third difference: direction of variation and change In the textbook comparison, Darwinian evolution is directional because natural selection preserves favourable variations and their accumulation guides change in the population. De Vries emphasized that mutations arise randomly and are directionless; they do not appear because an organism needs a particular adaptation. Natural selection can subsequently act on such mutations. Directionality here describes the selective evolutionary outcome, not purposeful production of variation.

Step 4: Conclusion The three contrasts are: small continuous variations versus large discontinuous mutations; gradual evolution versus saltation; and directional change through selection versus random, directionless mutational changes.

Quick Tip to Solve: Use three separate comparison axes: size of variation, pace of evolution, and direction of change.

26. (a) What is gene therapy ?

(b) Describe the procedure of such a therapy that could be a permanent cure for a genetic disease. Name the genetic disease.

[3 marks]

Solution:

Concept:

- Gene therapy treats a genetic disorder by introducing a normal, functional gene into suitable cells of the affected person so that the missing or defective gene product can be produced.
- Adenosine deaminase (ADA) deficiency is caused by a defective gene for ADA, an enzyme essential for normal immune function. Correcting the defect in early embryonic cells offers the possibility of

a lasting cure.

Step 1: (a) Define gene therapy Gene therapy is a collection of methods that allows correction of a gene defect diagnosed in a child or embryo. A functional copy of the gene is delivered into the patient's cells to take over the function of the defective gene and restore production of its normal protein.

Step 2: (b) Describe the therapy and identify the disease The disease is ADA deficiency. In the somatic-cell approach, lymphocytes are removed from the patient's blood and grown in culture. A functional ADA cDNA is introduced into these cells using a retroviral vector, and the genetically engineered lymphocytes are returned to the patient. Since these lymphocytes are not immortal, this infusion must be repeated periodically.

Step 3: Explain the possibility of a permanent cure For a potentially permanent cure, the normal gene isolated from bone-marrow cells that produces ADA must be introduced into cells at an early embryonic stage. The corrected embryonic cells can divide and pass the functional gene to their daughter cells as development proceeds, providing a continuing source of functional ADA. Thus early-embryo correction, rather than repeated transfer into short-lived lymphocytes, is the approach asked for here.

Step 4: Conclusion Gene therapy introduces a functional gene to compensate for a defective one. ADA deficiency could be permanently cured by introducing a normal ADA gene into cells at an early embryonic stage.

Quick Tip to Solve: For ADA deficiency, distinguish repeated engineered-lymphocyte infusions from the potentially permanent correction of early embryonic cells.

27. Differentiate between :

(a) Grazing food chain and Detritus food chain (Any three differences)

(b) Upright pyramid and Inverted pyramid (Any three differences)

[3 marks]

Solution:

Concept:

- A food chain traces the transfer of food and energy between organisms. Its starting material distinguishes a grazing food chain from a detritus food chain.
- An ecological pyramid compares trophic levels using numbers, biomass or energy. Its orientation depends on how the measured quantity changes from producers towards higher consumers.

Step 1: (a) Compare grazing and detritus food chains Three differences are:

1. **Starting material:** A grazing food chain begins with living green plants or other photosynthetic producers; a detritus food chain begins with dead organic matter, such as fallen leaves and animal remains.
2. **First consumers:** Herbivores are the first consumers in a grazing food chain. Decomposers, chiefly bacteria and fungi, and detritivores utilise the starting material in a detritus food chain.
3. **Initial energy pathway:** In a grazing food chain, recently fixed solar energy passes directly

from living producers to herbivores. In a detritus food chain, stored chemical energy in organic remains first enters the decomposer and detritivore pathway before reaching their consumers. For example, grass to deer is a grazing link, whereas fallen leaves to earthworms is a detritus link.

Step 2: (b) Compare upright and inverted pyramids Three differences are:

1. **Relative quantities:** In an upright pyramid, the measured quantity generally decreases from producers to higher trophic levels. In an inverted pyramid, the producer level has less of the measured quantity than the consumer level above it.
2. **Shape:** An upright pyramid has a broad producer base and progressively narrower upper levels. An inverted pyramid has a narrow producer base and a broader consumer level above it.
3. **Examples:** The biomass pyramid of a grassland is upright because plant biomass exceeds herbivore biomass. The biomass pyramid of an aquatic ecosystem may be inverted because the small standing crop of phytoplankton supports a larger standing biomass of zooplankton through rapid renewal.

A pyramid of energy is always upright: energy is lost as heat during transfer, so it cannot show the inverted pattern.

Step 3: Conclusion Grazing and detritus food chains differ in their starting material, first consumers and initial energy pathway. Upright and inverted pyramids differ in the direction of change of the measured quantity, base-to-consumer width and typical examples.

Quick Tip to Solve: State what a pyramid measures before choosing its orientation: aquatic biomass can be inverted, but energy is always upright.

28(a). (i) What are “biodiversity hotspot” regions ? Mention any two criteria used for determining any region as a “hotspot”.

(ii) Name any two hotspots of India.

[3 marks]

Solution:

Concept:

- Species richness is the number of species present in a region. Endemism means that a species is restricted to a particular geographical area and does not occur naturally elsewhere.
- Biodiversity hotspots combine exceptional biodiversity, especially endemic species, with severe habitat loss. They receive conservation priority because loss of these habitats could cause many global extinctions.

Step 1: (i) Define biodiversity hotspot regions Biodiversity hotspots are regions with very high species richness and a high degree of endemism that are also under a high degree of threat. Many of their species occur nowhere else; consequently, destruction of the region’s habitat could eliminate these species from the world, rather than merely reduce their local populations.

Step 2: State two criteria for identification Two central criteria are **exceptionally high species richness** and **a high degree of endemism**. These explain the biological importance of a region. In formal hotspot identification, a region must contain at least 1,500 endemic vascular plant species

and must have lost at least 70% of its original natural vegetation. Thus a hotspot is both biologically irreplaceable and severely threatened; an area with many common, widespread species alone does not qualify.

Step 3: (ii) Name two hotspots of India Two hotspots that include Indian territory are the **Western Ghats and Sri Lanka hotspot** and the **Himalaya hotspot**. The Western Ghats support many endemic plants and animals, while the Himalayan region contains rich biodiversity across its varied habitats. Hotspot boundaries are ecological and may extend across national borders, which is why Sri Lanka forms part of the name of the first hotspot.

Step 4: Conclusion Hotspots are highly species-rich, endemic-rich regions under severe threat. High species richness and endemism are key criteria; the Western Ghats and Sri Lanka hotspot and the Himalaya hotspot are two examples that include India.

Quick Tip to Solve: Link hotspots with both richness and endemism, then name Western Ghats and Sri Lanka and Himalaya as two Indian examples.

OR

28(b). Explain giving three reasons, why tropics show greatest level of species diversity. [3 marks]

Solution:

Concept:

- Species diversity generally increases from the poles towards the equator; tropical regions therefore support more species than temperate regions.
- The main explanations involve evolutionary time, climatic stability and the availability of solar energy.

Step 1: Longer uninterrupted evolutionary history Tropical latitudes have remained relatively undisturbed for millions of years. In contrast, temperate regions have repeatedly experienced glaciations. The longer uninterrupted evolutionary history in the tropics has provided more time for speciation and the accumulation of species.

Step 2: A stable, less seasonal environment Tropical environments are less seasonal, relatively constant and more predictable than temperate environments. Such conditions favour niche specialisation: different species become adapted to particular resources or conditions. This allows a greater number of species to coexist in the same region.

Step 3: Greater solar energy and productivity Tropical regions receive more solar energy. This contributes to higher primary productivity, meaning that producers generate more organic matter. The greater resource supply can support more organisms and a wider variety of consumers, thereby contributing to greater species diversity.

Step 4: Conclusion Tropics have the greatest species diversity because they have had more uninterrupted time for evolution, have relatively stable climates that favour niche specialisation, and receive more solar energy that supports greater productivity.

Quick Tip to Solve: Recall the three linked reasons as time, climatic stability and solar energy; explain how each favours species richness.

Section D (8 marks)

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

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

Restriction endonuclease was isolated for the first time by W. Arber in 1962, in bacteria. DNA, the genetic material can be manipulated by addition or substitution of the desired gene by using a specific restriction endonuclease resulting in rDNA. This is one of the major steps in biotechnology.

Name the first isolated restriction endonuclease. Why are restriction endonucleases so called ?

[1 mark]

Solution:

Concept:

- Restriction endonucleases recognise specific DNA sequences and cut DNA internally.
- In bacteria, restriction enzymes help restrict the multiplication of invading foreign DNA.

Step 1: Name the enzyme The first restriction endonuclease isolated and characterised in the standard NCERT account was Hind II. It recognises a specific sequence of six base pairs.

Step 2: Explain the term They are called restriction enzymes because they restrict the growth of invading bacteriophages by cutting their foreign DNA. They are endonucleases because they cleave phosphodiester bonds at internal positions within a DNA molecule, rather than removing nucleotides only from its ends.

Step 3: Conclusion The enzyme is Hind II. Restriction endonucleases restrict foreign DNA by cleaving it at specific internal sites.

Quick Tip to Solve: For this naming question, distinguish the first enzyme Hind II from the commonly used example EcoRI.

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

Restriction endonuclease was isolated for the first time by W. Arber in 1962, in bacteria. DNA, the genetic material can be manipulated by addition or substitution of the desired gene by using a specific restriction endonuclease resulting in rDNA. This is one of the major steps in biotechnology.

Write the palindrome recognised by EcoRI.

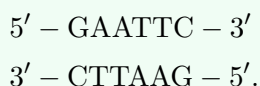
[1 mark]

Solution:

Concept:

- A DNA palindrome has the same sequence when both complementary strands are read in the same direction, from the 5-prime end to the 3-prime end.
- EcoRI recognises a specific six-base-pair sequence in double-stranded DNA.

Step 1: Write the recognised sequence The double-stranded recognition site is



The strands are complementary and antiparallel.

Step 2: Check the palindrome Reading the upper strand from left to right gives GAATTC in the 5-prime to 3-prime direction. Reading the lower strand from right to left, also in the 5-prime to 3-prime direction, gives GAATTC again. Thus this is a palindromic recognition sequence, rather than a sequence read in the same left-to-right direction on both strands.

Step 3: Conclusion The palindrome recognised by EcoRI is $5' - \text{GAATTC} - 3'$, paired with $3' - \text{CTTAAG} - 5'$.

Quick Tip to Solve: Always write both strands with opposite end labels; check the palindrome by reading each strand from its own 5-prime end.

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

Restriction endonuclease was isolated for the first time by W. Arber in 1962, in bacteria. DNA, the genetic material can be manipulated by addition or substitution of the desired gene by using a specific restriction endonuclease resulting in rDNA. This is one of the major steps in biotechnology.

How does restriction endonuclease function ? Explain.

[2 marks]

Solution:

Concept:

- A restriction endonuclease acts as a sequence-specific molecular scissor on double-stranded DNA.
- It hydrolyses phosphodiester bonds in the DNA backbone at defined positions associated with its recognition sequence.

Step 1: Recognise and bind the DNA site The enzyme scans along the DNA molecule and binds when it encounters its specific recognition sequence, usually a palindrome. Each restriction endonuclease recognises a particular base sequence, so it does not cut DNA indiscriminately at every position.

Step 2: Cleave the two strands Once bound, it cuts the phosphodiester backbone of both strands at specific positions. For example, EcoRI recognises $5' - \text{GAATTC} - 3'$ and cuts between G and A on each strand. Because the strands run in opposite directions, the cuts are staggered and produce complementary single-stranded AATT overhangs called sticky ends.

Step 3: Explain the useful product The same enzyme cuts a vector and the desired DNA to produce compatible ends. Complementary sticky ends can base-pair, and DNA ligase can seal the backbone to form recombinant DNA. Cleavage is performed by the restriction enzyme; joining is performed by ligase.

Step 4: Conclusion A restriction endonuclease recognises its specific DNA sequence, binds to it and cleaves the phosphodiester bonds of both strands at defined positions, producing DNA fragments.

Quick Tip to Solve: Explain recognition before cleavage, and keep the cutting role of restriction endonuclease distinct from the joining role of ligase.

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

Restriction endonuclease was isolated for the first time by W. Arber in 1962, in bacteria. DNA, the genetic material can be manipulated by addition or substitution of the desired gene by using a specific restriction endonuclease resulting in rDNA. This is one of the major steps in biotechnology.

Write the convention for naming a restriction endonuclease with the help of an example. [2 marks]

Solution:

Concept:

- Restriction endonuclease names indicate the bacterial source and distinguish enzymes isolated from that source.
- The name uses letters from the genus, species and strain, followed by a Roman numeral indicating the order of isolation.

Step 1: State the naming convention The first letter comes from the genus name of the source bacterium, and the next two letters come from its species name. A following letter identifies the bacterial strain. The Roman numeral at the end indicates the order in which restriction enzymes were isolated from that strain.

Step 2: Apply the convention to EcoRI For EcoRI, E is taken from the genus *Escherichia*, co from the species *coli*, and R from the strain RY13. The final Roman numeral I indicates that it was the first restriction endonuclease isolated from that strain. Thus every part of the name records either the source organism or the isolation order; I is not a count of DNA cuts.

Step 3: Conclusion EcoRI is named from *Escherichia coli*, strain RY13: E = genus, co = species, R = strain, and I = first enzyme isolated from that strain.

Quick Tip to Solve: Break EcoRI into E | co | R | I, then map the four components to genus, species, strain and isolation order.

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

A senior student, sneezing very badly, with watery eyes and having difficulty in breathing was brought to the school medical room by his fellow friends. The medical room nurse enquired as to what had happened. One of the students said “after the football match we all were sweating profusely, one of our friends sprayed deodorant on us. Soon after the deodorant was sprayed on the senior boy, the symptoms appeared.”

What are the symptoms seen in the student indicative of ? Elaborate.

[1 mark]

Solution:

Concept:

- Allergy is an exaggerated immune response to certain environmental antigens called allergens.
- An allergen may be harmless to most people but provoke hypersensitivity in a sensitised individual.

Step 1: Identify the response The sudden sneezing, watery eyes and difficulty in breathing after

exposure to the deodorant indicate an allergic reaction. A component of the sprayed deodorant is the likely allergen in this case.

Step 2: Explain the symptoms The immune system of the sensitised boy overreacts to the allergen. Release of inflammatory mediators causes irritation and increased secretions in the nose and eyes, and narrowing of the airways can produce breathing difficulty. This is hypersensitivity rather than an infectious disease acquired during the match.

Step 3: Conclusion The student is showing allergy, an exaggerated immune response to an allergen, probably a constituent of the deodorant.

Quick Tip to Solve: Link the sudden symptoms after the spray to hypersensitivity to an allergen; sweating alone does not explain this cluster of symptoms.

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

A senior student, sneezing very badly, with watery eyes and having difficulty in breathing was brought to the school medical room by his fellow friends. The medical room nurse enquired as to what had happened. One of the students said “after the football match we all were sweating profusely, one of our friends sprayed deodorant on us. Soon after the deodorant was sprayed on the senior boy, the symptoms appeared.”

State how the cause of such responses can be confirmed.

[1 mark]

Solution:

Concept:

- An allergy is confirmed by identifying the particular allergen that triggers hypersensitivity.
- Small amounts of suspected allergens can be tested individually for a characteristic allergic response.

Step 1: Select the suspected allergens The history points to the deodorant, so its suspected allergenic components should be considered. Timing alone suggests a cause but does not confirm which substance produced the reaction.

Step 2: Perform an allergen test In a medically supervised allergy test, very small doses of suspected allergens are introduced into or onto the skin, one at a time. The substance that produces the characteristic local allergic response, such as redness and swelling, identifies the causative allergen. This controlled test is performed by trained medical personnel.

Step 3: Conclusion The cause can be confirmed by testing very small doses of suspected allergens and identifying the one that produces an allergic response.

Quick Tip to Solve: For confirmation, name the allergen test and its positive response; merely repeating that deodorant was sprayed is insufficient.

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

A senior student, sneezing very badly, with watery eyes and having difficulty in breathing was brought to the school medical room by his fellow friends. The medical room nurse enquired as to what had happened. One of the students said “after the football match we all were sweating profusely, one of our friends sprayed deodorant on us. Soon after the deodorant was sprayed on the senior boy, the symptoms appeared.”

Name the cells in our body and the chemicals produced by them that are responsible for such reactions. Name any two drugs used to reduce these symptoms. [2 marks]

Solution:

Concept:

- Mast cells are immune cells that release mediators involved in an immediate allergic response.
- Histamine and serotonin released from mast cells contribute to the symptoms of allergy.
- Antihistamines and steroids are among the drugs used to reduce allergic symptoms.

Step 1: Name the cells and their chemicals The cells responsible are mast cells. On exposure to an allergen in a sensitised person, these cells release histamine and serotonin. These inflammatory mediators produce effects such as increased vascular permeability and irritation of mucosal surfaces, contributing to watery eyes, sneezing and respiratory discomfort. The chemicals are mediators of the response, whereas the deodorant constituent is the triggering allergen.

Step 2: Name two drugs used for relief Two accepted drug categories are antihistamines and steroids (corticosteroids). Antihistamines counter the actions of histamine, while steroids suppress inflammation and thereby reduce allergic symptoms. Adrenaline is another accepted drug used in severe allergic reactions, but antihistamines and steroids provide the two requested examples here.

Step 3: Conclusion Mast cells release histamine and serotonin. Two drugs used to reduce allergic symptoms are antihistamines and steroids.

Quick Tip to Solve: Keep the three categories separate: mast cells are the cells, histamine and serotonin are mediators, and antihistamines and steroids are drugs.

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

A senior student, sneezing very badly, with watery eyes and having difficulty in breathing was brought to the school medical room by his fellow friends. The medical room nurse enquired as to what had happened. One of the students said “after the football match we all were sweating profusely, one of our friends sprayed deodorant on us. Soon after the deodorant was sprayed on the senior boy, the symptoms appeared.”

‘In recent times there is a rise in such reactions amongst urban human population.’ Do you agree ? Give three reasons in support of your answer. [2 marks]

Solution:

Concept:

- Allergy is hypersensitivity to environmental allergens; its occurrence depends on exposure and susceptibility.
- Modern urban lifestyles and highly protected childhood environments are associated with an increased tendency to allergic responses.

Step 1: State agreement and explain the protected environment Yes, allergic reactions have become more common in urban populations. One reason is the highly protected, sanitised environment in which many children grow up. Reduced early exposure to diverse environmental microbes may affect normal immune-system training and favour hypersensitive responses. This gives the biological basis of the protected-environment explanation.

Step 2: Explain two sources of increased exposure A second reason is greater exposure to urban air pollution, including vehicle exhaust, smoke and suspended particulate matter, which irritate the respiratory tract and can promote allergic responses. A third reason is frequent exposure to chemical-containing consumer products such as deodorants, cosmetics and household sprays. Susceptible individuals encounter potential allergens in these products, as illustrated by the deodorant exposure in the passage. These are three contributing reasons, rather than a claim that every urban resident develops an allergy.

Step 3: Conclusion Yes. A highly protected childhood environment, increased urban air pollution, and greater exposure to potential allergens in chemical-containing consumer products support the rise in allergic reactions.

Quick Tip to Solve: Give three distinct reasons: protected early environment, polluted air, and exposure to products such as sprays; connect each to allergy.

Section E (15 marks)

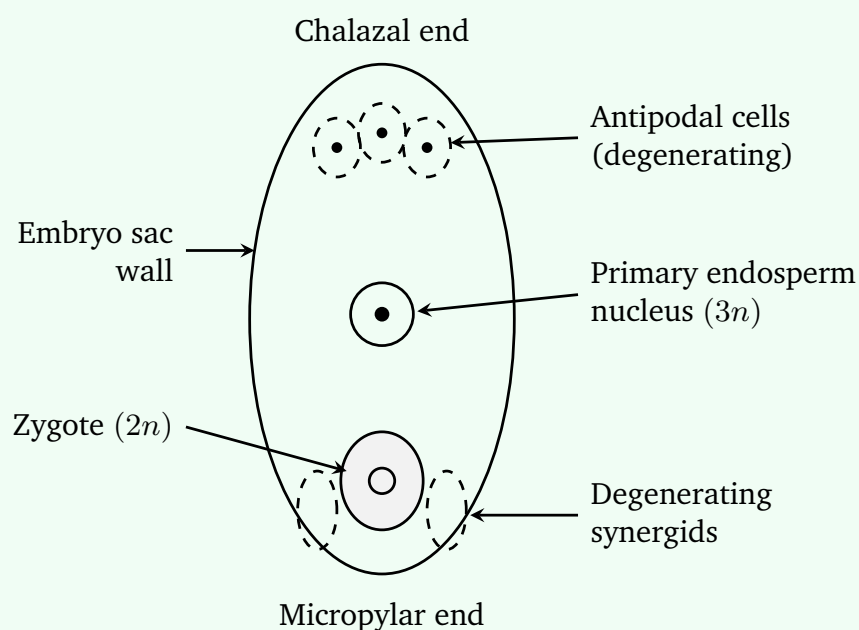
- 31(a). (i) Draw a labelled diagram of a fertilised embryo sac of an angiosperm. (label any four parts)
(ii) Explain double fertilisation in angiospermic plant. [5 marks]

Solution:

Concept:

- Double fertilisation is the occurrence of two fusion events, syngamy and triple fusion, within the same embryo sac of an angiosperm.
- The egg and each male gamete are haploid, n . Syngamy produces a diploid zygote, $2n$, whereas triple fusion produces a triploid primary endosperm nucleus, $3n$.
- After fertilisation, the zygote develops into the embryo and the primary endosperm cell develops into endosperm, which nourishes the developing embryo.

Step 1: (i) Draw the fertilised embryo sac The diagram shows the embryo sac immediately after the two fusions. The diploid zygote occupies the micropylar end, where the egg was present. The triploid primary endosperm nucleus lies in the large central cell. Antipodal cells are at the chalazal end, while the synergids at the micropylar end degenerate. Four principal structures are labelled: zygote, primary endosperm nucleus, degenerating synergids and antipodal cells.



Fertilised embryo sac immediately after double fertilisation (schematic).

Step 2: (ii) Deliver the two male gametes After a compatible pollen grain germinates on the stigma, its pollen tube grows through the style and reaches the ovule. The pollen tube enters the embryo sac through one synergid, guided by its filiform apparatus, and releases two male gametes into the cytoplasm of the synergid. The two male gametes participate in different fusion events in the same embryo sac.

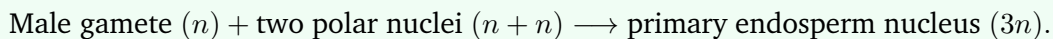
Step 3: Explain syngamy One male gamete moves towards the egg and fuses with it. Fusion of their

haploid nuclei restores the diploid chromosome number and forms the zygote. This fusion is called syngamy.



The zygote subsequently develops into the embryo of the seed.

Step 4: Explain triple fusion The second male gamete fuses with the two polar nuclei in the central cell. Since three haploid nuclei participate, this event is called triple fusion. It produces the triploid primary endosperm nucleus, and the central cell becomes the primary endosperm cell.



If the polar nuclei have already fused to form the diploid secondary nucleus, fusion of the second male gamete with that nucleus gives the same triploid product. The primary endosperm cell develops into the nutritive endosperm, usually before the zygote begins its development.

Step 5: Conclusion Syngamy forms the diploid zygote, while triple fusion forms the triploid primary endosperm nucleus. These two fusions in one embryo sac together constitute double fertilisation, a characteristic feature of flowering plants.

Quick Tip to Solve: Label a fertilised embryo sac with a zygote ($2n$) and a primary endosperm nucleus ($3n$); showing an unfused egg and two separate polar nuclei would represent the stage before fertilisation.

OR

31(b). (i) Draw a labelled diagram of a cross-section of human seminiferous tubule. (label any four parts)

(ii) Explain the hormonal regulation of spermatogenesis.

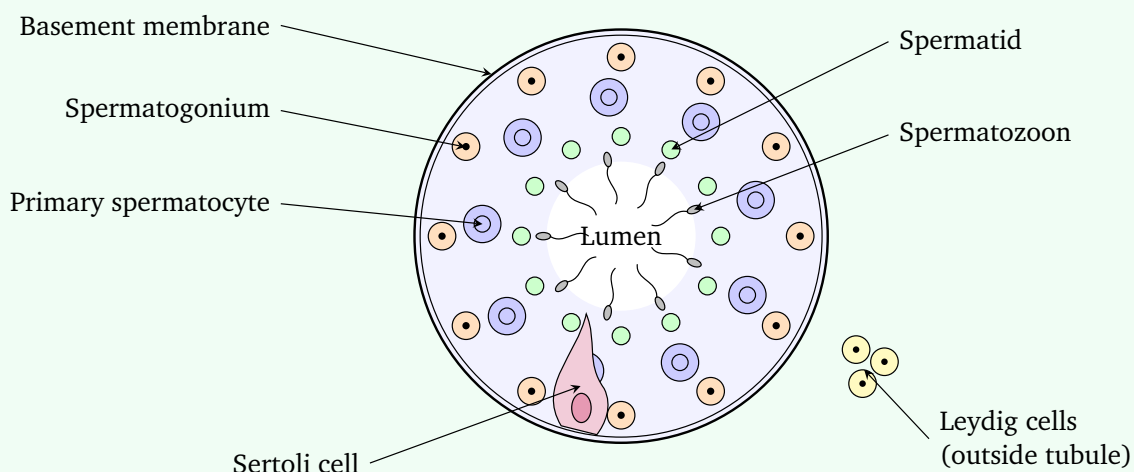
[5 marks]

Solution:

Concept:

- Spermatogenesis is the formation of haploid spermatozoa from diploid spermatogonia in the seminiferous tubules of the testes. It starts at puberty, and germ cells mature from the tubule wall towards its lumen.
- Gonadotropin-releasing hormone (GnRH) from the hypothalamus stimulates the anterior pituitary to release luteinising hormone (LH) and follicle-stimulating hormone (FSH).
- LH acts on interstitial Leydig cells to stimulate androgen secretion, whereas FSH acts on Sertoli cells within the tubules. These hormones coordinate sperm formation and maturation.

Step 1: (i) Cross-section of a human seminiferous tubule The labelled cross-section below shows the basement membrane enclosing the seminiferous epithelium. Spermatogonia lie close to the basement membrane; primary spermatocytes occur further inwards, followed by spermatids and spermatozoa near the lumen. The sperm tails project into the lumen. Sertoli cells extend through the epithelium and provide nourishment and support to the developing germ cells. Leydig cells occur in the interstitial tissue outside the tubule.



Cross-section of a human seminiferous tubule (schematic).

Step 2: (ii) Initiation of hormonal regulation at puberty At puberty, secretion of GnRH by the hypothalamus increases significantly. GnRH stimulates the anterior pituitary gland to release the two gonadotropins, LH and FSH. These reach the testes through the blood and act on different target cells.

Step 3: Action of LH through Leydig cells LH acts on the Leydig cells, also called interstitial cells, located between seminiferous tubules. It stimulates them to synthesise and secrete androgens, mainly testosterone. Androgens stimulate the process of spermatogenesis within the seminiferous tubules.

Step 4: Action of FSH through Sertoli cells FSH acts on Sertoli cells and stimulates the secretion of factors that help in spermiogenesis, the transformation of spermatids into spermatozoa. Sertoli cells also nourish the developing germ cells. Thus, LH supports spermatogenesis indirectly through androgens, while FSH promotes Sertoli-cell activity and sperm differentiation. The two pathways act together to sustain sperm production.

Step 5: Conclusion The seminiferous tubule contains successive stages of developing male germ cells and supporting Sertoli cells. Hormonal control follows the pathways hypothalamus (GnRH) to anterior pituitary, then LH to Leydig cells to androgens, and FSH to Sertoli cells to factors aiding spermiogenesis.

Quick Tip to Solve: Associate LH with Leydig cells and FSH with Sertoli cells; in the tubule drawing, arrange germ cells from spermatogonia at the wall to spermatozoa at the lumen.

32(a). (i) Absence of lactose in the culture medium affects the expression of lac operon in *E. coli*. Why and how ? Explain.

(ii) Write any two ways in which the gene expression is regulated in eukaryotes.

[5 marks]

Solution:

Concept:

- The lac operon is an inducible transcription unit in *Escherichia coli*; its structural genes z , y and a are controlled together by a promoter and an operator.

- The regulator gene *i* produces a repressor. Lactose acts as an inducer by inactivating the repressor; without the inducer, the active repressor binds the operator.
- In eukaryotes, regulation can occur at transcription, RNA processing, transport of mRNA or translation; any two levels can be described.

Step 1: (i) Identify why lactose is needed The lac operon controls the production of proteins required for lactose metabolism. Gene *z* codes for β -galactosidase, which hydrolyses lactose, gene *y* codes for permease, which increases the entry of lactose into the cell, and gene *a* codes for transacetylase. Lactose is the substrate as well as the inducer of this system. When lactose is absent from the culture medium, there is no inducer available to inactivate the repressor. The bacterium therefore does not need to produce these lactose-utilising proteins at an induced level.

Step 2: (i) Explain how the operon is switched off The regulator gene *i* continues to produce the repressor protein constitutively. In the absence of lactose, the repressor remains active and binds to the operator region. The bound repressor prevents RNA polymerase from effectively transcribing the structural genes *z*, *y* and *a*. Thus the polycistronic mRNA is not produced at the induced level, and synthesis of the corresponding enzymes is repressed. This is negative regulation because a repressor prevents transcription. It does not mean that the structural genes have been deleted or permanently inactivated: when lactose becomes available, induction can occur again.

Step 3: (ii) Describe two levels of eukaryotic regulation **Transcriptional regulation:** The formation of the primary RNA transcript is regulated. Control of transcription initiation determines whether a gene is transcribed and how much primary transcript is produced, thereby controlling the eventual amount of protein.

Processing-level regulation: The processing of the primary transcript is regulated, including splicing. Introns must be removed and exons joined to form mature mRNA. Regulation of this processing determines which mature RNA is available for subsequent transport and translation. These are two distinct stages: the first controls RNA synthesis, whereas the second controls the maturation of RNA already synthesised.

Step 4: Conclusion Without lactose, the active repressor binds the lac operator and represses transcription of the structural genes. Two ways of regulating eukaryotic gene expression are control of transcription and control of RNA processing, such as splicing.

Quick Tip to Solve: For lactose absence, trace the chain: no inducer, active repressor, operator occupied, structural-gene transcription repressed. For eukaryotes, name the stage and explain what is controlled there.

- 32(b).** (i) By taking two suitable traits in a pea plant, work out a dihybrid cross up to F_2 generation.
 (ii) State the Mendel's law derived from such a cross only. [5 marks]

Solution:

Concept:

- A dihybrid cross follows the inheritance of two pairs of contrasting traits. In pea, round seed shape R is dominant over wrinkled r , and yellow seed colour Y is dominant over green y .
- True-breeding parents are homozygous. Each gamete receives one allele of each gene; an $RrYy$ plant forms RY , Ry , rY and ry gametes in equal proportions when the genes assort independently.
- Independent assortment gives the characteristic dihybrid F_2 phenotypic ratio $9 : 3 : 3 : 1$ under complete dominance.

Step 1: (i) Cross two true-breeding parents Choose seed shape and seed colour as the two traits. Cross a true-breeding round, yellow-seeded pea plant with a true-breeding wrinkled, green-seeded plant:

$$P : RRY Y \text{ (round yellow)} \times rryy \text{ (wrinkled green)},$$

$$\text{Gametes : } RY \text{ and } ry,$$

$$F_1 : RrYy \text{ (all round yellow)}.$$

Each F_1 offspring receives R and Y from one parent and r and y from the other. Its heterozygous genotype expresses the two dominant traits.

Step 2: (i) Self the F_1 plants and form the F_2 generation Self-pollinate the F_1 plants: $RrYy \times RrYy$. Each parent forms four kinds of gametes, RY , Ry , rY and ry , each with probability $1/4$. Their random fusion gives the following Punnett square; each cell has probability $1/16$:

	RY	Ry	rY	ry
RY	$RRYY$	$RRYy$	$RrYY$	$RrYy$
Ry	$RRYy$	$RRyy$	$RrYy$	$Rryy$
rY	$RrYY$	$RrYy$	$rrYY$	$rrYy$
ry	$RrYy$	$Rryy$	$rrYy$	$rryy$

Here $R_$ denotes either RR or Rr , and $Y_$ denotes either YY or Yy . Classifying the 16 combinations by their expressed traits gives:

$$R_Y_ \quad 9/16 \quad \text{round yellow,}$$

$$R_yy \quad 3/16 \quad \text{round green,}$$

$$rrY_ \quad 3/16 \quad \text{wrinkled yellow,}$$

$$rryy \quad 1/16 \quad \text{wrinkled green.}$$

Thus round green and wrinkled yellow are new combinations of the parental traits. Their appearance shows that seed shape and seed colour are not inherited as an inseparable parental combination.

Step 3: (ii) State the law derived from the cross **Law of independent assortment:** When two pairs of traits are combined in a hybrid, segregation of one pair of characters is independent of the other pair

of characters during gamete formation. In this cross, whether a gamete receives R or r is independent of whether it receives Y or y , accounting for the four equally frequent gamete types.

Step 4: Conclusion The cross $RRYY \times rryy$ produces round yellow $RrYy$ plants in F_1 . Their selfing produces an F_2 phenotypic ratio of 9 round yellow : 3 round green : 3 wrinkled yellow : 1 wrinkled green. This dihybrid cross demonstrates Mendel's law of independent assortment.

Quick Tip to Solve: Write the four gametes in the same order along both sides of the Punnett square, then group the 16 offspring by phenotype to obtain 9:3:3:1.

33(a). Describe the process of wastewater (sewage) treatment under the following heads :

(i) Primary treatment

(ii) Secondary treatment

[5 marks]

Solution:

Concept:

- Sewage treatment removes suspended solids and reduces the organic load before wastewater is released into natural water bodies. Primary treatment is physical; secondary treatment uses microbial activity.
- Biochemical oxygen demand (BOD) measures the oxygen consumed by microorganisms while oxidising organic matter in water. A reduction in BOD indicates a reduction in the biodegradable organic load.

Step 1: (i) Primary treatment: physical removal of particles Sewage is first passed through filters or screens to remove floating debris. It then enters settling tanks, where grit, such as sand and small pebbles, settles by sedimentation. Suspended solids are also allowed to settle. The solids deposited at the bottom constitute the primary sludge; the liquid above them is the primary effluent. Thus, primary treatment removes large and small solid particles through filtration and sedimentation, without depending on microbial decomposition.

Step 2: (ii) Secondary treatment: microbial oxidation in aeration tanks The primary effluent is passed into large aeration tanks. Mechanical agitation and continuous pumping of air favour the vigorous growth of useful aerobic microbes. Bacteria associated with fungal filaments form mesh-like masses called flocs. These microbes consume much of the organic matter in the effluent, substantially lowering its BOD. Aeration continues until the BOD has been sufficiently reduced.

Step 3: Settle the flocs and recycle part of the activated sludge The treated effluent is then transferred to a settling tank, where bacterial flocs sediment. This sediment is called activated sludge. A small portion of the activated sludge is pumped back into the aeration tank as an inoculum, providing the microbes needed to treat fresh primary effluent. The remaining major portion is sent to large anaerobic sludge digesters.

Step 4: Digest the sludge and discharge the treated effluent In the digesters, anaerobic bacteria digest the bacteria and fungi present in the sludge. During digestion, they produce a mixture of gases, including methane, hydrogen sulphide and carbon dioxide, which forms biogas. After secondary treatment has reduced the organic load and BOD, the treated effluent is generally released into natural

water bodies such as rivers and streams.

Step 5: Conclusion Primary treatment separates solid particles by filtration and sedimentation. Secondary treatment uses aerobic microbial flocs to lower BOD, followed by settling, recycling of activated sludge and anaerobic digestion of the excess sludge.

Quick Tip to Solve: Keep the two sediments distinct: primary sludge forms before aeration, whereas activated sludge consists of settled microbial flocs after aeration.

OR

33(b). (i) Explain the sequence of events occurring in a biogas plant.

(ii) Write the components of biogas.

(iii) Write any three advantages of using cow dung as the raw material.

[5 marks]

Solution:

Concept:

- Biogas is produced when microorganisms break down organic matter under anaerobic conditions. Methanogenic bacteria, such as *Methanobacterium*, are important in methane production.
- Cattle dung contains abundant methanogens because these microorganisms occur in the rumen of cattle, where they are associated with the digestion of cellulose-rich food. Dung therefore supplies both organic material and microbial inoculum for a biogas plant.

Step 1: (i) Feed cow-dung slurry into the digester Cow dung is mixed with water in a mixing tank to prepare a slurry. This slurry is fed through an inlet into a closed underground concrete tank or digester. The enclosed digester maintains anaerobic conditions, allowing microbes to decompose the organic material without a continuous supply of oxygen.

Step 2: Produce, collect and use biogas Anaerobic microorganisms break down the organic matter in the slurry. Methanogens act during this decomposition and generate methane-rich biogas. In a floating-drum plant, gas accumulates beneath the floating cover, which rises as the volume of gas increases. A gas outlet pipe supplies the collected biogas to nearby houses for cooking or lighting. As fresh slurry is added, digested slurry leaves through the outlet. This spent slurry is collected and used as manure because it retains useful plant nutrients.

Step 3: (ii) State the components of biogas Biogas consists mainly of methane, CH_4 , along with carbon dioxide, CO_2 , and small amounts of hydrogen, H_2 , and hydrogen sulphide, H_2S . Methane is the principal combustible component responsible for the fuel value of the mixture.

Step 4: (iii) Give three advantages of cow dung as raw material First, cow dung is readily available in large quantities at low cost in cattle-rearing and rural areas, giving a regular local supply of raw material. Second, it contains cellulose-rich organic matter together with methanogenic microorganisms from the cattle rumen; it therefore provides a suitable substrate and a natural microbial inoculum for biogas production. Third, using dung in a biogas plant yields useful fuel while leaving nutrient-rich spent slurry that can be applied as manure. Thus the same raw material provides energy and a useful fertiliser residue.

Step 5: Conclusion Cow-dung slurry undergoes anaerobic digestion in a closed tank, producing methane-rich biogas that is collected and supplied as fuel. Biogas also contains carbon dioxide and small amounts of hydrogen and hydrogen sulphide. Cow dung is inexpensive and available, supplies suitable organic material and methanogens, and yields useful manure after digestion.

Quick Tip to Solve: Present the plant sequence as slurry entry, anaerobic digestion, gas collection and slurry exit; then list gas components and exactly three distinct advantages of dung.