

CBSE Class 12 Biology Question Paper 2009 with Solution PDF-Set 57/2/1

Question Paper with Solutions

Conducted by the Central Board of Secondary Education (CBSE)



Time Allowed: 3 hours

Maximum Marks: 70

General Instructions

- (i) All questions are compulsory.
- (ii) This question paper consists of four Sections **A**, **B**, **C** and **D**. Section **A** contains **8** questions of **one** mark each, Section **B** is of **10** questions of **two** marks each, Section **C** is of **9** questions of **three** marks each and Section **D** is of **3** questions of **five** marks each.
- (iii) There is no overall choice. However, an internal choice has been provided in one question of **2** marks, one question of **3** marks and all the three questions of **5** marks weightage. A student has to attempt only one of the alternatives in such questions.
- (iv) Wherever necessary, the diagrams drawn should be neat and properly labelled.

Section A (8 marks)

1. At which ends do 'capping' and 'tailing' of hnRNA occur respectively?

[1 mark]

Solution:

Concept:

- Eukaryotic hnRNA is processed before it becomes mature messenger RNA.
- Capping and polyadenylation modify opposite ends of the primary RNA transcript.

Step 1: Locate the cap During capping, a modified guanosine nucleotide is attached to the 5-prime end of hnRNA. This cap helps protect the transcript and supports its subsequent use in translation.

Step 2: Locate the tail During tailing, a series of adenylate residues is added to the 3-prime end, forming the poly-A tail. Thus the order asked in the question must be retained.

Step 3: Conclusion Capping occurs at the 5' end and tailing at the 3' end, respectively.

Quick Tip to Solve: Remember the order as 5-prime cap followed by 3-prime poly-A tail.

2. The meiocyte of rice has 24 chromosomes. How many chromosomes are present in its endosperm?

[1 mark]

Solution:

Concept:

- A meiocyte is diploid, whereas its meiotic products are haploid.
- Triple fusion combines one male gamete with the two polar nuclei to form the primary endosperm nucleus.

Step 1: Find the haploid number The rice meiocyte has $2n = 24$ chromosomes. Meiosis halves this chromosome number, so each gamete and each polar nucleus has $n = 12$ chromosomes.

Step 2: Apply triple fusion The primary endosperm nucleus receives n chromosomes from one male gamete and $n + n$ from the two polar nuclei. Therefore the endosperm is $3n = 3 \times 12 = 36$, rather than the diploid chromosome number of the embryo.

Step 3: Conclusion The endosperm contains 36 chromosomes.

Quick Tip to Solve: First halve the meiocyte chromosome count, then multiply by three for endosperm.

3. BOD of two samples of water A and B were 120 mg/L and 400 mg/L respectively. Which sample is more polluted?

[1 mark]

Solution:

Concept:

- Biochemical oxygen demand (BOD) measures oxygen required by aerobic microorganisms to decompose biodegradable organic matter in water.

- Under comparable conditions, greater BOD indicates a greater biodegradable organic pollution load.

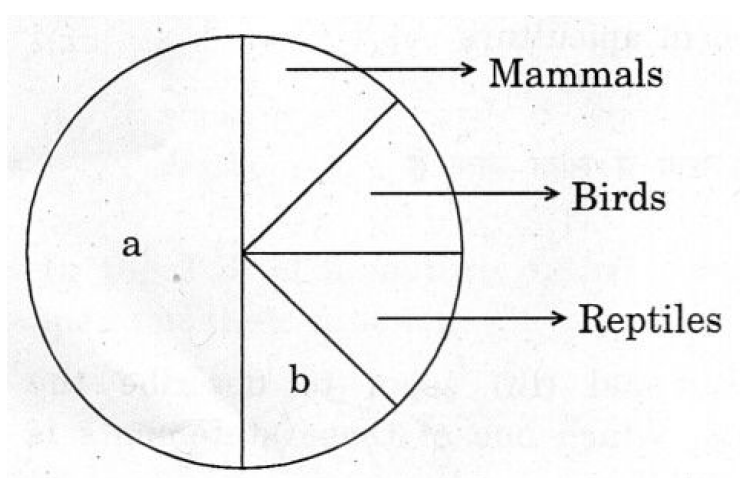
Step 1: Compare the readings Sample A has a BOD of 120 mg/L, while sample B has a BOD of 400 mg/L. Thus the oxygen demand of sample B is higher.

Step 2: Interpret the comparison A higher oxygen requirement means that microbial decomposition of biodegradable organic matter consumes more dissolved oxygen. Hence sample B carries the greater organic pollution load; high BOD does not signify cleaner or more oxygen-rich water.

Step 3: Conclusion Sample B is more polluted, since its BOD is 400 mg/L, higher than that of A.

Quick Tip to Solve: For comparable water samples, choose the higher BOD as more organically polluted.

4. Name the unlabelled areas 'a' and 'b' of the pie chart representing biodiversity of vertebrates showing the proportionate number of species of major taxa. [1 mark]



Solution:

Concept:

- The chart compares the numbers of species in the major vertebrate groups.
- Fishes account for the largest share of vertebrate species in this representation.

Step 1: Identify the largest sector The unlabelled region a occupies the large left-hand sector of the pie chart. Among the vertebrate groups shown, this dominant species-rich group is fishes.

Step 2: Identify the remaining group Mammals, birds and reptiles are already labelled on the right. The remaining unlabelled lower sector b must therefore represent amphibians. Use the given taxon labels as well as the sector sizes to complete the chart.

Step 3: Conclusion a: Fishes; b: Amphibians.

Quick Tip to Solve: Identify fishes in the largest sector; then use the three printed labels to identify amphibians.

5. Are the wing of a bird and the forelimb of a horse homologous or analogous? Name the type of evolution that explains the development of such structures. [1 mark]

Solution:

Concept:

- Homologous organs share a common basic structural plan and evolutionary origin.
- Divergent evolution produces different adaptations from a common ancestral structure.

Step 1: Compare their basic structure The wing of a bird and the forelimb of a horse are modifications of the vertebrate forelimb. Their corresponding bones share the same basic arrangement, indicating common ancestry.

Step 2: Relate structure to function The bird forelimb is adapted for flight, whereas the horse forelimb is adapted for running. Such different functions arising from the same ancestral plan illustrate divergent evolution. Classification here rests on origin and structure, not on their present functions.

Step 3: Conclusion The structures are homologous organs, explained by divergent evolution.

Quick Tip to Solve: Compare the underlying forelimb bones, then link different functions to divergent evolution.

6. Name the type of interaction seen between whale and the barnacles growing on its back. [1 mark]

Solution:

Concept:

- In commensalism, one species benefits while the other is neither helped nor harmed.
- The interaction is represented by the sign pair $+, 0$.

Step 1: Identify the beneficiary Barnacles obtain a surface for attachment on the whale. Movement of the whale also carries them through water where they can obtain suspended food, so the barnacles benefit from this association.

Step 2: Identify the effect on the whale In the standard NCERT example, the whale is neither benefited nor adversely affected by the barnacles on its back. Because only one partner benefits, the association fits commensalism rather than mutualism or parasitism.

Step 3: Conclusion The interaction is commensalism.

Quick Tip to Solve: Assign the effects separately: barnacle benefits, whale unaffected, so choose commensalism.

7. Which one of the following is used in apiculture :

Hilsa, Apis indica, Sonalika

[1 mark]

Solution:

Concept:

- Apiculture is the maintenance and management of honeybee colonies.
- Honeybees are reared for products such as honey and beeswax and also support pollination.

Step 1: Identify the bee Among the listed organisms, *Apis indica* is the Indian honeybee. It is therefore the organism used in bee-keeping, which is the meaning of apiculture.

Step 2: Check the other choices *Hilsa* is a fish and belongs to fisheries. *Sonalika* is a wheat variety and belongs to crop improvement. Neither represents an organism used for maintaining honeybee colonies, so the choice is unambiguous.

Step 3: Conclusion *Apis indica* is used in apiculture.

Quick Tip to Solve: Connect apiculture with *Apis*, the honeybee; exclude the fish and the wheat variety.

8. The following statements (i), (ii) and (iii) seem to describe the water-pollinated submerged plants. Which one of these statements is incorrect?

- (i) The flowers do not produce nectar.
(ii) The pollen grains have mucilaginous covering.
(iii) The brightly coloured female flowers have long stalk to reach the surface.

[1 mark]

Solution:

Concept:

- Water-pollinated flowers do not require colourful petals or nectar to attract animal pollinators.
- A mucilaginous covering protects pollen grains from wetting during transport through water.

Step 1: Check statements (i) and (ii) Statement (i) is correct: nectar is unnecessary because water carries the pollen. Statement (ii) is also correct: the mucilaginous covering protects the pollen grains from getting wetted.

Step 2: Locate the error in statement (iii) Water-pollinated flowers are generally small and inconspicuous, rather than brightly coloured. In *Vallisneria*, the female flower does reach the water surface on a long stalk, but this does not make the description of brightly coloured flowers correct.

Step 3: Conclusion Statement (iii) is incorrect because water-pollinated flowers are not brightly coloured.

Quick Tip to Solve: Check whether a floral feature attracts animals: bright colour is unnecessary in hydrophily.

Section B (20 marks)

9. Name the source organism from which Ti plasmid is isolated. Explain the use of this plasmid in biotechnology. [2 marks]

Solution:

Concept:

- The Ti (tumour-inducing) plasmid is naturally present in the soil bacterium *Agrobacterium tumefaciens*.
- The T-DNA region of this plasmid can be transferred into plant cells and integrated into plant nuclear DNA.

Step 1: Name the source organism The Ti plasmid is isolated from *Agrobacterium tumefaciens*, a bacterium that naturally infects plants and causes crown-gall tumours. Its natural ability to transfer DNA into plant cells makes it useful in genetic engineering.

Step 2: Explain its use as a vector For biotechnology, the plasmid is disarmed by removing or inactivating the tumour-inducing genes while retaining the DNA-transfer machinery. A desired foreign gene is inserted into the transferable DNA region. The modified system delivers that gene into plant cells, where integration and expression can produce the desired trait; transformed cells may then be regenerated into transgenic plants.

Step 3: Conclusion *Agrobacterium tumefaciens* is the source; a disarmed Ti plasmid serves as a vector for introducing desired genes into plants.

Quick Tip to Solve: Link Ti to plant transformation: remove tumour-causing genes but retain DNA transfer.

10. (a) Explain the property that prevents normal cells from becoming cancerous.

(b) All normal cells have inherent characteristic of becoming cancerous. Explain. [2 marks]

Solution:

Concept:

- Normal cells exhibit contact inhibition: contact with neighbouring cells inhibits further uncontrolled proliferation.
- Normal cells possess proto-oncogenes, also called cellular oncogenes, whose abnormal activation can contribute to cancer.

Step 1: (a) Explain contact inhibition Normal cells respond to contact with neighbouring cells by slowing or stopping cell division. This property, called contact inhibition, helps regulate tissue growth and prevents the cells from piling up into an uncontrolled mass. Cancer cells lose this normal control and continue dividing even when surrounded by other cells.

Step 2: (b) Explain the inherent potential for transformation Normal cells contain proto-oncogenes that normally participate in the regulation of growth and division. If these genes become abnormally activated, for example following mutations caused by carcinogens, they can act as oncogenes and

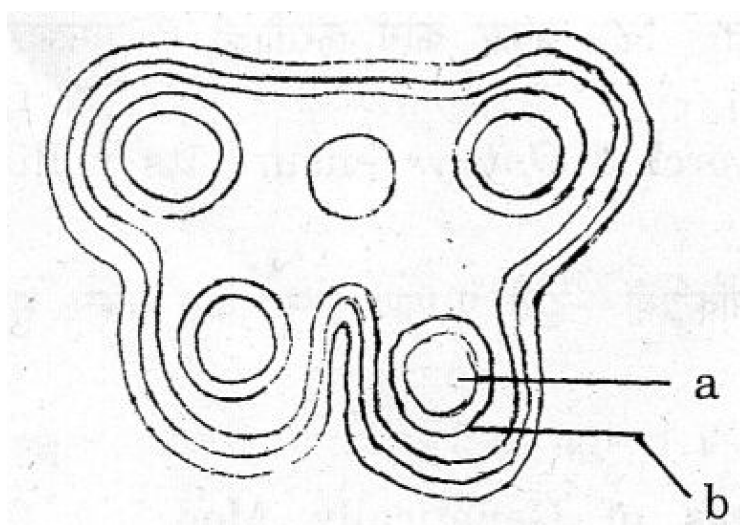
promote uncontrolled proliferation. Thus the genetic potential for cancerous transformation is present in normal cells, although the mere presence of proto-oncogenes does not mean that every normal cell will become cancerous.

Step 3: Conclusion (a) Contact inhibition restrains normal cell proliferation. (b) Activation of proto-oncogenes into oncogenes can transform normal cells into cancerous cells.

Quick Tip to Solve: For the two parts, pair the growth-control property with the genes whose activation disrupts it.

11. In the T.S. of a mature anther given below identify “a” and “b” and mention their function.

[2 marks]



Solution:

Concept:

- Each microsporangium contains central sporogenous tissue surrounded by an anther wall.
- The tapetum is the innermost wall layer and supports the developing male reproductive cells.

Step 1: Identify a and state its function Label a indicates the central sporogenous tissue inside the microsporangium. Its cells differentiate into microspore mother cells (pollen mother cells), which undergo meiosis to form haploid microspores. These microspores subsequently develop into pollen grains, the male gametophytes.

Step 2: Identify b and state its function Label b indicates the tapetum, the innermost layer of the microsporangial wall bordering the sporogenous tissue. It provides nourishment to the developing microspores and pollen grains. Tapetal cells also supply materials and precursors needed for pollen-wall development. Thus the central tissue produces the pollen lineage while the surrounding tapetum supports its development.

Step 3: Conclusion a: sporogenous tissue, which gives rise to microspores and pollen grains; b: tapetum, which nourishes the developing pollen grains.

Quick Tip to Solve: Trace each label inward: the central fertile tissue produces pollen; the adjacent wall layer nourishes it.

12. Name the category of codons UGA belongs to. Mention another codon of the same category. Explain their role in protein synthesis. [2 marks]

Solution:

Concept:

- UGA is a stop codon, also called a termination or nonsense codon; it does not normally specify an amino acid.
- The three standard stop codons in mRNA are UAA, UAG and UGA.

Step 1: Name the category and another member UGA belongs to the category of stop or termination codons. UAA is another codon of the same category; UAG would also be a correct example. These codons are read in the mRNA sequence during translation and signal the end of the protein-coding region.

Step 2: Explain termination of protein synthesis When a stop codon reaches the ribosomal A site, it is recognised by a release factor rather than an aminoacyl-tRNA carrying another amino acid. The release factor promotes cleavage of the bond between the completed polypeptide and the tRNA, releasing the polypeptide. Translation therefore terminates at the stop signal instead of adding a further amino acid to the chain.

Step 3: Conclusion UGA is a stop codon; UAA is another example. They signal termination of translation and release of the completed polypeptide.

Quick Tip to Solve: Remember UAA, UAG and UGA as termination signals, rather than codons for an extra amino acid.

13. How do automobiles fitted with catalytic converters reduce air pollution? Suggest the best fuel for such vehicles. [2 marks]

Solution:

Concept:

- Catalytic converters promote chemical reactions in automobile exhaust that convert major toxic gases into less harmful products.
- Lead compounds poison the catalytic metals; fuel choice must therefore protect the catalyst.

Step 1: Conversion of exhaust pollutants The converter contains precious-metal catalysts such as platinum, palladium and rhodium. As exhaust passes over them, unburnt hydrocarbons are oxidised to carbon dioxide and water, carbon monoxide is oxidised to carbon dioxide, and nitrogen oxides are reduced to nitrogen gas. Thus the amounts of toxic carbon monoxide, nitrogen oxides and unburnt hydrocarbons released into the air decrease.

Step 2: Suitable fuel Use unleaded petrol. Leaded petrol releases lead compounds that coat and inactivate the catalyst, reducing its capacity to treat the exhaust gases. Unleaded petrol allows the catalytic metals to remain effective.

Step 3: Conclusion Catalytic converters reduce toxic exhaust gases by oxidation and reduction reactions; unleaded petrol is the best fuel for these vehicles.

Quick Tip to Solve: Link each exhaust pollutant to its product, then remember that unleaded petrol prevents catalyst poisoning.

14. List the specific symptoms of pneumonia. Name the causative organism.

[2 marks]

Solution:

Concept:

- Pneumonia is an infection of the alveoli, the tiny air sacs where gas exchange takes place in the lungs.
- Fluid accumulation in infected alveoli interferes with oxygen uptake and produces respiratory symptoms.

Step 1: Specific symptoms The characteristic symptoms are fever, chills, cough and headache. The alveoli become filled with fluid, causing difficulty in breathing. In severe cases, inadequate oxygenation makes the lips and fingernails appear greyish to bluish. This colour change is a particularly useful sign of severe respiratory involvement.

Step 2: Causative organisms Common bacterial causes are *Streptococcus pneumoniae* and *Haemophilus influenzae*. Naming *Streptococcus pneumoniae* answers the request for a causative organism. These bacteria infect the lungs and cause the alveolar inflammation and fluid accumulation responsible for the symptoms.

Step 3: Conclusion Pneumonia causes fever, chills, cough, headache and breathing difficulty, with greyish-blue lips and nails in severe cases; *Streptococcus pneumoniae* is a causative bacterium.

Quick Tip to Solve: Recall pneumonia through the alveoli: fluid impairs breathing, and severe oxygen shortage makes lips and nails bluish.

OR

14. How does spleen act as a lymphoid organ? Explain.

[2 marks]

Solution:

Concept:

- The spleen is a secondary lymphoid organ in which immune cells encounter antigens and initiate immune responses.
- Unlike lymph nodes, which filter lymph, the spleen mainly monitors antigens carried in blood.

Step 1: Immune cells in the spleen The spleen is a large, bean-shaped organ containing many lymphocytes and phagocytes. Its lymphoid tissue provides a site where lymphocytes encounter blood-borne antigens, become activated and proliferate. Activated lymphocytes participate in specific immune responses, including antibody production by differentiated B cells.

Step 2: Filtering blood and trapping pathogens Blood passing through the spleen is screened for microorganisms and other foreign material. Its phagocytes trap and engulf blood-borne pathogens, helping to remove them from circulation. The presence of lymphocytes together with this filtering and antigen-trapping function makes the spleen an important secondary lymphoid organ.

Step 3: Conclusion The spleen acts as a secondary lymphoid organ by trapping blood-borne pathogens and providing lymphocytes and phagocytes that mount an immune response.

Quick Tip to Solve: Associate the spleen with blood filtration: trapped blood-borne antigens meet lymphocytes and phagocytes there.

15. How does the Mediterranean orchid *Ophrys* ensure its pollination by bees?

[2 marks]

Solution:

Concept:

- Pollination is transfer of pollen from an anther to a receptive stigma; animal-pollinated flowers can attract visitors by mimicry.
- The Mediterranean orchid *Ophrys* uses sexual deception to obtain pollination by a male bee.

Step 1: Attracting the male bee One petal of the *Ophrys* flower resembles the female bee in size, colour and markings. This resemblance attracts a male bee, which mistakes the flower for a female and attempts to mate with it. This behaviour is called pseudocopulation.

Step 2: Transfer of pollen During the mating attempt, pollen from the flower adheres to the male bee's body. When the same bee visits another *Ophrys* flower and again attempts pseudocopulation, the pollen is transferred to its stigma. Thus the deceptive resemblance brings about pollen transfer between flowers without the bee deliberately collecting pollen.

Step 3: Conclusion *Ophrys* ensures pollination by mimicking a female bee: a male attempts pseudocopulation and carries pollen to the stigma of another flower.

Quick Tip to Solve: Use the sequence female-bee mimicry, male pseudocopulation, pollen attachment and transfer to the next stigma.

16. Highlight any four advantages of Genetically Modified Organisms (GMOs).

[2 marks]

Solution:

Concept:

- Genetic modification introduces selected genes into an organism to obtain useful, heritable traits.
- In agriculture, the benefit depends on the introduced gene: different GM crops can show different improvements in resistance, yield quality or nutritional value.

Step 1: Advantages that protect crop production (1) GM crops can be made more tolerant of abiotic stresses such as drought, salinity, cold and heat. This helps plants survive unfavourable environmental conditions. (2) Pest-resistant GM crops can reduce reliance on chemical pesticides. For example, an insect-resistant crop can protect itself against its target insect pest.

Step 2: Advantages that improve food availability and quality (3) Genetic modification can reduce post-harvest losses, allowing more of the harvested produce to remain available for consumption. (4) It can enhance the nutritional value of food, as in vitamin-A-enriched rice. The useful nutritional trait is introduced through the selected genetic modification.

Step 3: Conclusion Four advantages are increased tolerance to abiotic stresses, reduced dependence on chemical pesticides, reduced post-harvest losses and enhanced nutritional value of food.

Quick Tip to Solve: Recall four distinct benefits: stress tolerance, pest resistance, lower storage losses and improved nutrition.

17. What is Colostrum? Why is it important to be given to the newborn infants?

[2 marks]

Solution:

Concept:

- The mammary glands begin secreting milk around childbirth. Their first secretion differs from the milk produced later in lactation.
- Maternal antibodies supplied in early milk give the newborn passive immunity while its own immune system is still developing.

Step 1: Define colostrum Colostrum is the yellowish milk secreted by the mother's mammary glands during the initial few days after childbirth. It is the first milk available to the newborn, before the secretion changes to mature breast milk.

Step 2: Explain its importance to the newborn Colostrum contains abundant maternal antibodies, especially immunoglobulin A (IgA). These antibodies help protect the infant against infectious agents during early life, when the infant's own immune defences are not fully developed. This is passive immunity because the protective antibodies are transferred from the mother rather than being produced by the infant in response to infection. Therefore, the newborn should receive colostrum through early breastfeeding.

Step 3: Conclusion Colostrum is the initial yellowish milk secreted after childbirth. Its antibody content provides passive immune protection to the newborn against infections.

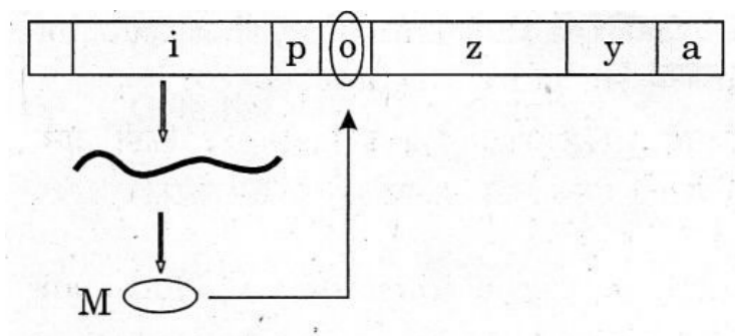
Quick Tip to Solve: Link the first yellowish milk to maternal antibodies and passive immunity when explaining why it must be fed.

18. (a) Name the molecule 'M' that binds with the operator.

(b) Mention the consequences of such binding.

(c) What will prevent the binding of the molecule 'M' with the operator? Mention the event that follows.

[2 marks]



Solution:

Concept:

- The lac operon contains a promoter, an operator and the structural genes *z*, *y* and *a*, whose expression is controlled by a repressor.
- The regulatory gene *i* produces the repressor protein. An inducer changes the repressor's ability to

bind the operator and thereby controls transcription.

Step 1: (a) Identify molecule M Molecule M is the active repressor protein of the lac operon. The diagram shows the regulatory gene *i* being expressed through an RNA intermediate to produce this protein, which then binds the operator *o*.

Step 2: (b) State the effect of operator binding When the repressor binds to the operator, it prevents RNA polymerase from transcribing the structural genes *z*, *y* and *a*. The operon is switched off, so the corresponding enzymes for lactose utilisation are not synthesised through operon expression.

Step 3: (c) Explain induction and the event that follows In the presence of lactose, the inducer binds to and inactivates the repressor, preventing its binding to the operator. More precisely, allolactose, a derivative formed from lactose, is the physiological inducer. With the operator free, RNA polymerase transcribes the structural genes. Translation then produces β -galactosidase, permease and transacetylase, enabling the cell to utilise lactose.

Step 4: Conclusion (a) M is the repressor protein. (b) Its operator binding blocks transcription of the lac structural genes. (c) Lactose acting through its inducer derivative inactivates the repressor, allowing transcription and subsequent enzyme synthesis.

Quick Tip to Solve: Follow the switch: active repressor on operator means OFF; inducer-bound repressor leaves the operator free for transcription.

Section C (27 marks)

19. (a) Identify the figure.

(b) Name the initial cell from which this structure has developed.

(c) Draw the next mature stage and label the parts.

[3 marks]



Solution:

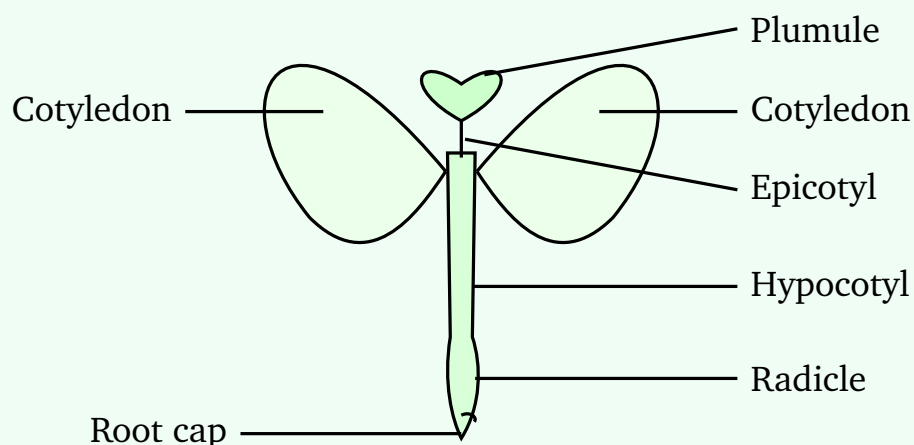
Concept:

- The diploid zygote formed by fertilisation divides mitotically to produce the embryo. In a dicot, development proceeds through proembryo, globular and heart-shaped stages to a mature embryo.
- A mature dicot embryo has two cotyledons and an embryonal axis. The axis bears the plumule at its shoot end and the radicle at its root end.

Step 1: (a) Identify the stage The figure is a globular-stage dicot embryo with its suspensor. The rounded multicellular embryonal mass at one end and the row of suspensor cells distinguish this early embryo from a mature embryo. The suspensor helps position the developing embryo within the nutritive tissue.

Step 2: (b) State the initial cell The embryo develops from the diploid zygote, also called the oospore. The zygote forms when a male gamete fuses with the egg during syngamy. Its subsequent mitotic divisions form the embryo proper and the suspensor; the embryo does not arise from the primary endosperm nucleus.

Step 3: (c) Draw the mature dicot embryo The mature embryo has two cotyledons attached to the embryonal axis. The portion above their attachment is the epicotyl and ends in the plumule. The portion below is the hypocotyl and ends in the radicle, whose tip is protected by a root cap. These parts are shown in the labelled drawing.



Mature dicot embryo

Step 4: Conclusion The structure is a globular dicot embryo developed from the zygote; its mature stage has two cotyledons, a plumule and a radicle on the embryonal axis.

Quick Tip to Solve: Recognise the globular embryo by its spherical embryo proper and suspensor; label both cotyledons and both ends of the mature embryonal axis.

20. A particular species of wild cat is endangered. In order to save them from extinction, which is a desirable approach *in situ* or *ex situ*? Justify your answer and explain the difference between the two approaches. [3 marks]

Solution:

Concept:

- In situ conservation protects threatened organisms within their natural habitats and conserves their ecological surroundings along with them.
- Ex situ conservation protects threatened organisms outside their natural habitats, under human care and management, for example in zoological parks and captive-breeding centres.

Step 1: Select the approach for the endangered cat Ex situ conservation is desirable for a highly endangered species of wild cat needing special protection to avert extinction. Individuals can be maintained in a suitable zoological park or captive-breeding centre, where their survival and reproduction can be managed. Such protection reduces immediate exposure to poaching and other threats in the wild, while veterinary care and controlled breeding help increase the population.

Step 2: Explain in situ conservation In situ means conservation on site: the cat remains in its natural habitat, such as a national park, wildlife sanctuary or biosphere reserve. Habitat protection conserves its prey, shelter and ecological interactions as well as the cat itself. The species continues to live and reproduce in its natural surroundings, together with other members of the ecosystem.

Step 3: Explain ex situ conservation and distinguish it Ex situ means conservation off site: selected individuals are removed from the threatened natural setting and maintained under protected condi-

tions. A captive-breeding programme can maintain a breeding population and may supply animals for later reintroduction into a secure habitat. Thus the central difference is the location and mode of protection: whole-habitat protection in nature versus direct care of selected organisms outside nature. Long-term recovery also requires protection of suitable wild habitat.

Step 4: Conclusion Ex situ conservation, with special care and captive breeding, is desirable to rescue the endangered wild cat; in situ conservation protects it within its natural habitat, whereas ex situ conservation protects it outside that habitat.

Quick Tip to Solve: Use the location test: a sanctuary is in situ; a zoo or captive-breeding centre is ex situ, offering special care to a critically threatened animal.

21. (a) What is EcoRI? What does 'R' represent in this?

(b) Give the palindromic nucleotide sequence recognised by it.

(c) Explain its action.

[3 marks]

Solution:

Concept:

- A restriction endonuclease recognises a specific nucleotide sequence and cuts phosphodiester bonds within a DNA molecule at defined positions.
- In a DNA palindrome, the sequence read in the 5' → 3' direction is the same on both complementary strands. Staggered cuts can produce complementary single-stranded sticky ends.

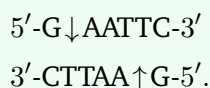
Step 1: (a) Identify EcoRI and the meaning of R EcoRI is a restriction endonuclease isolated from the bacterium *Escherichia coli*. In its name, E refers to the genus and co to the species. The letter R identifies the bacterial strain RY13 from which the enzyme was isolated. The Roman numeral I indicates that it was the first restriction enzyme isolated from this strain; R does not denote the order of isolation.

Step 2: (b) Write the recognition sequence EcoRI recognises the six-base-pair palindromic sequence



Reading the upper strand from left to right and the lower strand from right to left, both in the 5' → 3' direction, gives GAATTC. The opposite strand directions must therefore be shown.

Step 3: (c) Explain the staggered cleavage EcoRI binds its recognition site and cleaves between G and A on each strand, at the corresponding positions shown by the arrows:



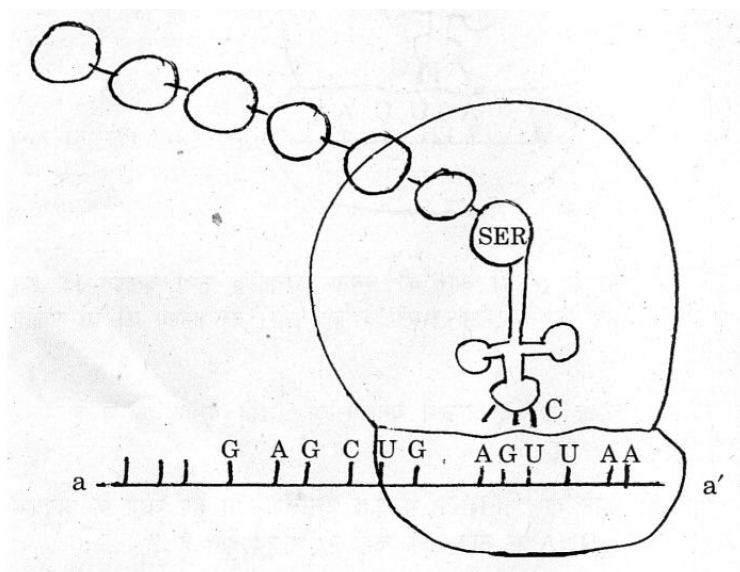
The cuts are staggered, producing DNA fragments with four-nucleotide 5'-AATT overhangs called sticky ends. Complementary sticky ends can pair by hydrogen bonding with ends produced by the same enzyme on another DNA molecule. DNA ligase can then seal the sugar-phosphate backbone

during recombinant DNA formation.

Step 4: Conclusion EcoRI is the RY13-strain restriction endonuclease that recognises GAATTC and cuts between G and A on both strands to form complementary sticky ends.

Quick Tip to Solve: Write both strand directions before marking the cuts: EcoRI leaves AATT overhangs, and R denotes the RY13 strain rather than the enzyme number.

22. (a) Identify the polarity from a to a' in the above diagram and mention how many more amino acids are expected to be added to this polypeptide chain.
- (b) Mention the DNA sequence coding for serine and the anticodon of tRNA for the same amino acid.
- (c) Why are some untranslated sequence of bases seen in mRNA coding for a polypeptide? Where exactly are they present on mRNA? [3 marks]



Solution:

Concept:

- Ribosomes translate mRNA in the $5' \rightarrow 3'$ direction, reading successive triplet codons.
- A tRNA anticodon pairs complementarily and antiparallel to its mRNA codon. Stop codons do not specify amino acids.
- Untranslated regions (UTRs) flank the translated coding sequence and help efficient translation.

Step 1: (a) Determine polarity and the remaining amino acids The ribosome reads the illustrated mRNA from a towards a', so a is the $5'$ end and a' is the $3'$ end. The serine codon under the tRNA is $5' - AGU - 3'$. Immediately after AGU the diagram shows UAA, a termination codon. Thus no further amino acid is to be added after the serine already shown attached to the growing polypeptide; a release factor recognises UAA and terminates translation.

Step 2: (b) Identify the DNA triplet and tRNA anticodon Complementary pairing with the displayed mRNA serine codon gives the DNA template triplet $3' - TCA - 5'$. The corresponding coding (non-template) DNA triplet is $5' - AGT - 3'$, identical to the mRNA codon except that T replaces U. The

tRNA anticodon is $3' - UCA - 5'$, which pairs antiparallel to $5' - AGU - 3'$. Stating strand identities distinguishes the two DNA sequences unambiguously.

Step 3: (c) Locate and explain untranslated regions mRNA contains untranslated regions because these sequences support efficient translation and its regulation without specifying amino acids in the polypeptide. The $5'$ UTR lies before the initiation codon AUG; the $3'$ UTR lies after the termination codon. Neither region is part of the translated open reading frame.

Step 4: Conclusion (a) a to a' is $5' \rightarrow 3'$; no further amino acid follows serine. (b) DNA template: $3' - TCA - 5'$, coding strand: $5' - AGT - 3'$; tRNA anticodon: $3' - UCA - 5'$. (c) UTRs help efficient translation and lie before AUG and after the stop codon.

Quick Tip to Solve: Group the displayed sequence into triplets from the tRNA's AGU: the next triplet is UAA, so it cannot add another amino acid.

23. Why is predation required in a community of different organisms?

[3 marks]

Solution:

Concept:

- Predation is an interaction in which a predator kills and consumes prey, obtaining energy while reducing prey abundance.
- Interactions among trophic levels regulate populations and can maintain community species diversity.

Step 1: Transfer energy through the food chain Predators provide a route for energy fixed by plants to pass to higher trophic levels. For example, energy stored in herbivore biomass becomes available to a carnivore when it consumes the herbivore. Predation therefore connects populations in food chains and food webs, sustaining organisms at higher trophic levels.

Step 2: Keep prey populations under control By consuming prey, predators check excessive increases in prey numbers. This reduces the chance that an abundant prey population will exhaust its food or damage other components of the community. Natural enemies of insect pests illustrate this role: predators can suppress pests and protect plant populations. Such population regulation contributes to community stability.

Step 3: Maintain species diversity Predators can reduce the intensity of competition among competing prey species by keeping the competitively dominant species in check. This allows other species to survive instead of being excluded. For example, removal of the starfish *Pisaster* from an intertidal community led to the disappearance of several invertebrate species through competitive exclusion. Its predatory activity thus helped maintain diversity.

Step 4: Conclusion Predation is required for energy transfer to higher trophic levels, regulation of prey populations and maintenance of species diversity by preventing competitive dominance.

Quick Tip to Solve: Organise the answer around three distinct functions: energy transfer, prey population control and preservation of diversity.

24. (a) Name the virus that causes AIDS in humans.

(b) Explain the sequence of events that follows when this virus attacks to cause immune deficiency in humans. [3 marks]

Solution:

Concept:

- Human immunodeficiency virus (HIV), the causative agent of AIDS, is a retrovirus containing an RNA genome.
- Reverse transcriptase makes viral DNA from viral RNA. Destruction of helper T lymphocytes progressively weakens immunity.

Step 1: (a) Name the causative virus AIDS (acquired immunodeficiency syndrome) is caused by human immunodeficiency virus, abbreviated HIV. HIV is a retrovirus; its genetic material is RNA enclosed within a protein envelope.

Step 2: (b) Establish infection and produce new virus After entering the body, HIV enters macrophages. Its enzyme reverse transcriptase synthesises viral DNA using viral RNA as the template. This viral DNA integrates into the host cell's DNA and directs the infected cell to produce new viral particles. Macrophages continue producing viruses and act as a reservoir or factory for HIV.

Step 3: Destroy helper T lymphocytes and impair immunity HIV also enters helper T lymphocytes, replicates in them and releases progeny viruses that infect further helper T cells. Repeated infection and destruction cause a progressive decline in the number of helper T lymphocytes. Since these cells coordinate immune responses, their depletion severely weakens the body's ability to fight infections. The patient becomes susceptible to opportunistic infections, including infections by bacteria, fungi and parasites, leading to the immune-deficient condition characteristic of AIDS.

Step 4: Conclusion HIV causes AIDS. Reverse transcription, integration of viral DNA and viral multiplication in macrophages and helper T lymphocytes lead to progressive helper T-cell depletion and loss of immune defence.

Quick Tip to Solve: Keep the sequence explicit: HIV RNA to viral DNA, integration, virus production, helper T-cell loss and opportunistic infections.

25. In one family each of the four children has a different blood group. Their mother is group A and the father is group B. Explain this pattern of inheritance with the help of a cross along with the genotypes. [3 marks]

Solution:

Concept:

- The ABO blood group locus has three alleles in the population: I^A , I^B and i . An individual carries only two of them; this is multiple allelism.
- I^A and I^B are codominant to each other, and each is dominant over i . Thus $I^A I^B$ produces group AB, while ii produces group O.

Step 1: Deduce the parental genotypes Since the four children have different groups, they include a

group O child. This child has genotype ii , so each parent must contribute an i allele. The group A mother must therefore be heterozygous $I^A i$, and the group B father must be heterozygous $I^B i$. The mother forms gametes I^A and i , whereas the father forms gametes I^B and i .

Step 2: Perform the cross and identify the offspring The cross is $I^A i \times I^B i$:

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

Each genotype has probability $1/4$; the expected phenotypic ratio is A:B:AB:O = 1 : 1 : 1 : 1. Codominance explains the AB child, and the recessive allele from both parents explains the O child. These probabilities apply independently to each birth: four children need not always include exactly one of each group, but the family described is a possible outcome.

Step 3: Conclusion A heterozygous group A mother ($I^A i$) crossed with a heterozygous group B father ($I^B i$) can produce children of groups A, B, AB and O, with genotypes $I^A i$, $I^B i$, $I^A I^B$ and ii , respectively.

Quick Tip to Solve: Start with the O child: its genotype ii forces both the A and B parents to carry the recessive i allele.

OR

25. Who proposed chromosomal theory of inheritance? Point out any two similarities in the behaviour of chromosomes and genes. [3 marks]

Solution:

Concept:

- The chromosomal theory of inheritance relates Mendel's hereditary factors, now called genes, to the behaviour of chromosomes during meiosis and fertilisation.
- Genes are located on chromosomes. The parallel behaviour of chromosomes and Mendelian factors provided the basis for linking cytology with the laws of inheritance.

Step 1: Name the proposers Walter Sutton and Theodor Boveri proposed the chromosomal theory of inheritance in 1902. Sutton observed that chromosome behaviour during meiosis parallels the behaviour of Mendel's paired factors, and used this parallel to explain inheritance through chromosomes.

Step 2: Similarity 1: occurrence in pairs and segregation In a diploid organism, homologous chromosomes occur in pairs, one member inherited from each parent. Likewise, a gene is represented by a pair of alleles at corresponding loci, one inherited from each parent. During meiosis, homologous chromosomes separate so that a gamete receives only one member of each pair. In parallel, the two alleles segregate, and each gamete receives only one allele of each gene. Fertilisation restores the paired condition.

Step 3: Similarity 2: independent assortment Different homologous chromosome pairs orient

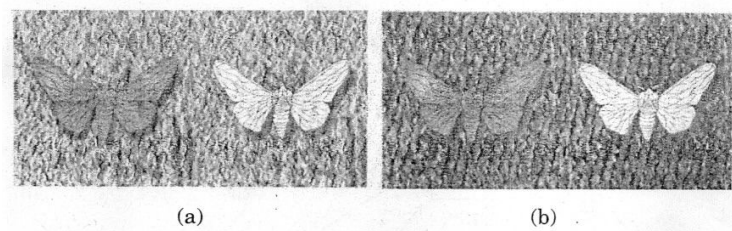
independently at metaphase I and segregate independently during meiosis. Correspondingly, alleles of genes on different chromosome pairs assort independently into gametes. This explains Mendel's law of independent assortment for unlinked genes; genes linked on the same chromosome need not show independent assortment.

Step 4: Conclusion Sutton and Boveri proposed the theory. Two parallels are the paired occurrence and segregation of homologous chromosomes and alleles, and the independent assortment of different chromosome pairs and unlinked genes.

Quick Tip to Solve: Match each chromosome event to its genetic counterpart: separation of homologues means allele segregation, and independent chromosome pairs explain unlinked-gene assortment.

26. What do these pictures 'a' and 'b' illustrate with reference to evolution? Explain.

[3 marks]



Solution:

Concept:

- Natural selection is the differential survival and reproduction of individuals with heritable variations in a particular environment; it changes the frequencies of those variations over generations.
- Industrial melanism in the peppered moth, *Biston betularia*, illustrates how a change in background colour can reverse the selective advantage of light and dark forms.

Step 1: Identify the evolutionary process in the pictures The pictures illustrate natural selection through industrial melanism. Both light-winged and dark-winged moths occur in the population. In picture (a), the lighter background makes the dark moth more conspicuous; in picture (b), the darker background makes the light moth more conspicuous. Birds can more easily detect and eat the moths that contrast with the bark.

Step 2: Explain selection before industrialisation Before industrialisation, tree trunks were relatively light and covered with lichens. Light-coloured moths blended with this background and were less frequently caught by predatory birds. Dark moths were more visible and suffered greater predation. Consequently, light moths survived and reproduced more successfully and predominated in the population.

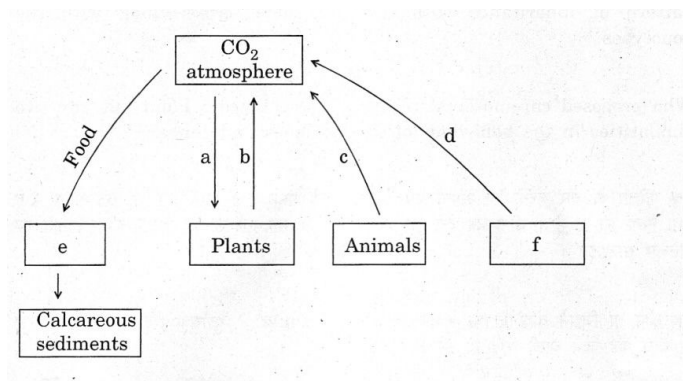
Step 3: Explain the change after industrialisation Industrial soot darkened tree trunks, while pollution reduced lichen growth. Dark moths now had better camouflage and escaped predation more often. Light moths became conspicuous and were eaten more frequently. Dark moths therefore left more offspring, and the frequency of the dark form increased over successive generations. The environmental change selected among existing heritable variants; it did not make individual light moths turn dark in response to need.

Step 4: Conclusion Pictures (a) and (b) show industrial melanism as an example of natural selection: light moths are favoured on a light background, whereas dark moths are favoured on soot-darkened bark because camouflage reduces predation.

Quick Tip to Solve: For each background, identify the less visible moth, then connect reduced bird predation to greater survival, reproduction and frequency in later generations.

27. Draw and complete the following model of carbon cycle filling a, b, c, d, e and f.

[3 marks]



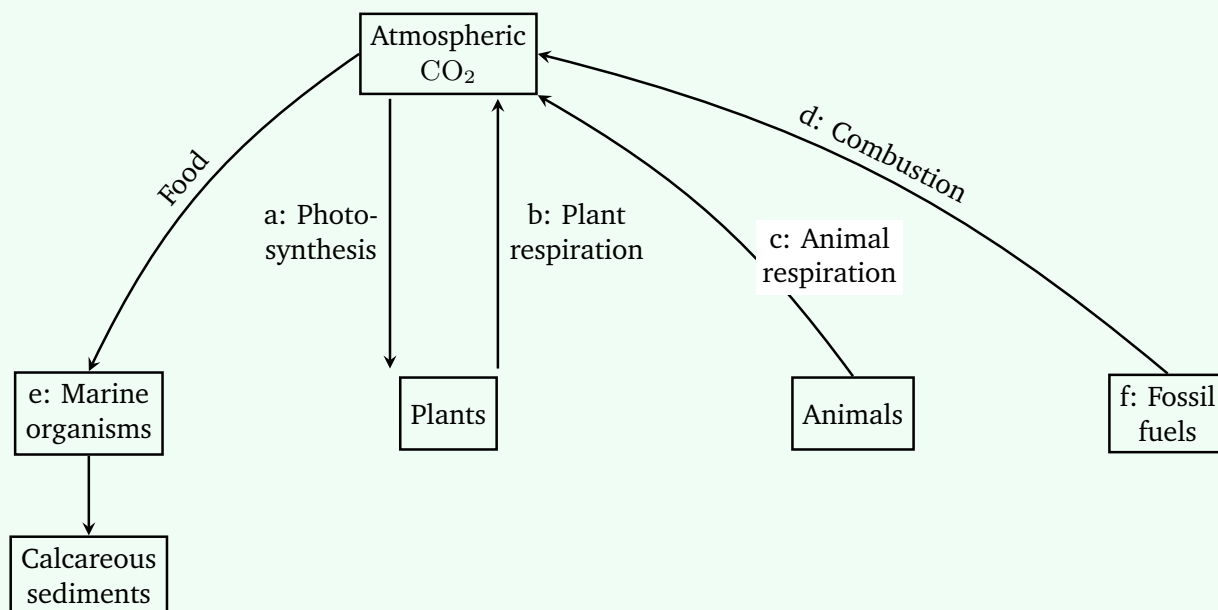
Solution:

Concept:

- Photosynthesis fixes atmospheric carbon dioxide into organic substances; respiration and combustion return carbon dioxide to the atmosphere.
- Marine organisms incorporate carbon into calcareous shells and skeletons; their remains contribute to calcareous sediments.

Step 1: Identify the exchanges involving plants and animals Arrow a points from atmospheric CO_2 to plants, so a is **photosynthesis**. Plants use carbon dioxide to synthesise organic food. Arrow b runs from plants back to atmospheric carbon dioxide, so b is **plant respiration**. Arrow c runs from animals to atmospheric carbon dioxide, so c is **animal respiration**. Both plants and animals oxidise organic substances during cellular respiration and release carbon dioxide; plants therefore have both an incoming and an outgoing carbon pathway.

Step 2: Identify the sedimentary and fuel pathways Box e represents **marine organisms**, whose calcareous shells and skeletons ultimately form calcareous sediments. The food pathway supplies carbon to these organisms. Box f represents **fossil fuels**, a carbon reservoir. Arrow d returns their carbon to the atmosphere and therefore represents **combustion**. Burning coal, petroleum or natural gas oxidises stored carbon and releases carbon dioxide. Complete the model with the six labels as shown below.



Completed carbon-cycle model: a–f identify the missing labels.

Step 3: Conclusion a = photosynthesis; b = plant respiration; c = animal respiration; d = combustion; e = marine organisms; f = fossil fuels.

Quick Tip to Solve: Read the arrowhead first: carbon entering plants means photosynthesis; carbon leaving living organisms means respiration.

Section D (15 marks)

28. (a) Explain the observations of Meselson and Stahl when

(i) they cultured *E. coli* in a medium containing $^{15}\text{NH}_4\text{Cl}$ for a few generations and centrifuged the content.

(ii) they transferred one such bacterium to the normal medium of NH_4Cl .

(b) What does the above experiment prove?

(c) Which is the first genetic material identified?

[5 marks]

Solution:

Concept:

- During semiconservative DNA replication, each daughter double helix retains one parental strand and contains one newly synthesised strand.
- The stable isotope ^{15}N makes DNA denser than DNA containing ^{14}N . Caesium chloride density-gradient centrifugation separates DNA according to its buoyant density.

Step 1: (a)(i) Growth in heavy nitrogen Meselson and Stahl grew *E. coli* for several generations in a medium containing $^{15}\text{NH}_4\text{Cl}$ as the nitrogen source. The bacteria incorporated ^{15}N into the nitrogenous bases of newly synthesised DNA. After repeated generations, both strands of their DNA were labelled with heavy nitrogen. DNA extracted from these cells and centrifuged in a CsCl density

gradient formed a single heavy band, lower in the tube than normal light DNA.

Step 2: (a)(ii) Transfer to normal nitrogen When a labelled bacterium was transferred to medium containing normal $^{14}\text{NH}_4\text{Cl}$, its newly synthesised strands incorporated ^{14}N . After one generation (about 20 minutes), all DNA formed a single intermediate-density band: each molecule contained one old heavy strand and one new light strand. After two generations (about 40 minutes), two bands appeared in equal proportions: hybrid $^{15}\text{N}/^{14}\text{N}$ DNA and light $^{14}\text{N}/^{14}\text{N}$ DNA. No fully heavy DNA remained after the first generation. In subsequent generations, the proportion of light DNA increased.

Step 3: (b) Interpret the result The intermediate band after the first generation excludes conservative replication, which would leave a heavy parental molecule alongside a separate light daughter molecule. The separate hybrid and light bands after the second generation support semiconservative replication and exclude the dispersive model. Each parental strand acts as a template, so every newly formed double helix contains one parental strand and one newly synthesised strand.

Step 4: (c) Identify the earliest genetic material RNA was the first genetic material. It can store genetic information and some RNA molecules act as catalysts (ribozymes), supporting the idea of an early RNA world. DNA subsequently evolved as the more stable material for long-term information storage.

Step 5: Conclusion Heavy medium gives a heavy DNA band; after transfer to light medium the first generation gives hybrid DNA and the second gives equal hybrid and light DNA. This proves semiconservative DNA replication. RNA was the first genetic material.

Quick Tip to Solve: Track the nitrogen in each strand: heavy-heavy becomes heavy-light, then heavy-light plus light-light after the next generation.

OR

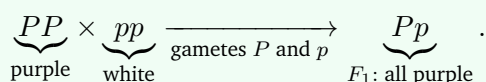
28. Inheritance pattern of flower colour in garden pea plant and snap dragon differs. Why is the difference observed? Explain showing the crosses. [5 marks]

Solution:

Concept:

- Dominance describes how alleles of a gene express themselves in a heterozygote. Complete dominance makes its phenotype identical to that of one homozygote; incomplete dominance gives an intermediate phenotype.
- Alleles segregate during gamete formation and reunite at fertilisation. Both kinds of monohybrid cross give an F_2 genotypic ratio of 1 : 2 : 1, but their phenotypic ratios differ.

Step 1: Garden pea: complete dominance in the parental cross Let P represent the allele for purple (violet) flowers and p the allele for white flowers. In garden pea, P is completely dominant over p . Crossing pure-breeding purple and white plants gives



The recessive allele is present in the hybrid, but its effect is masked: the heterozygote has sufficient pigment production to express the purple phenotype.

Step 2: Self the pea hybrids Each F_1 plant produces P and p gametes in equal proportions. Therefore,

$$Pp \times Pp \longrightarrow \begin{array}{c|cc} & P & p \\ \hline P & PP & Pp \\ p & Pp & pp \end{array}$$

Thus the F_2 genotypic ratio is $1 PP : 2 Pp : 1 pp$. Since both PP and Pp are purple, the phenotypic ratio is 3 purple to 1 white. White reappears because the alleles segregate without being altered or blended.

Step 3: Snapdragon: incomplete dominance in the parental cross Let R and r denote the alleles associated with red and white flowers respectively. In snapdragon (*Antirrhinum*), neither allele completely dominates the other in the heterozygote. The cross is

$$\underbrace{RR}_{\text{red}} \times \underbrace{rr}_{\text{white}} \xrightarrow{\text{gametes } R \text{ and } r} \underbrace{Rr}_{F_1: \text{ all pink}} .$$

The heterozygote produces an intermediate amount of red pigment and is pink. Its phenotype therefore differs from both parental homozygotes.

Step 4: Self the snapdragon hybrids and compare The pink hybrids produce R and r gametes in equal proportions:

$$Rr \times Rr \longrightarrow \begin{array}{c|cc} & R & r \\ \hline R & RR & Rr \\ r & Rr & rr \end{array}$$

The F_2 genotypic ratio is $1 RR : 2 Rr : 1 rr$, and the phenotypic ratio is 1 red to 2 pink to 1 white. The red and white parental phenotypes reappear, showing that incomplete dominance does not mean permanent blending of alleles. Segregation is the same in the two plants; the expression of the heterozygote differs.

Step 5: Conclusion Garden pea shows complete dominance: purple F_1 and a 3 : 1 phenotypic ratio in F_2 . Snapdragon shows incomplete dominance: pink F_1 and a 1 : 2 : 1 phenotypic ratio in F_2 . The difference arises from the different expression of the alleles in heterozygotes.

Quick Tip to Solve: Compare the heterozygote with both parents first: a parental colour indicates complete dominance, while pink between red and white indicates incomplete dominance.

29. (a) Draw a labelled diagram of a mature embryo sac of an angiosperm.

(b) Why does a pollen grain possess two male gametes? Explain.

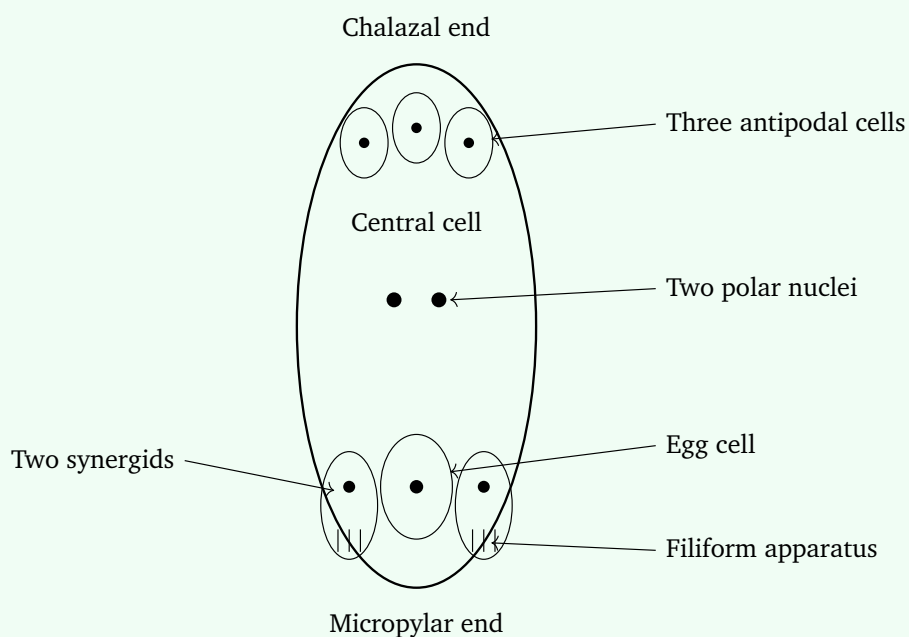
[5 marks]

Solution:

Concept:

- A typical mature angiosperm embryo sac is the female gametophyte. It is seven-celled and eight-nucleate: three antipodal cells, an egg apparatus of three cells, and one large central cell containing two polar nuclei.
- Angiosperms exhibit double fertilisation. The two haploid male gametes delivered by one pollen tube take part in two different fusion events inside the same embryo sac.

Step 1: (a) Identify and draw the mature embryo sac Draw an elongated embryo sac with its chalazal end above and micropylar end below. Three antipodal cells occupy the chalazal end. The egg apparatus lies at the micropylar end and consists of one egg cell and two synergids. Each synergid has a filiform apparatus at its micropylar tip, which helps guide the pollen tube into the embryo sac. The central cell is much larger than the other cells and contains two polar nuclei. The diagram represents the stage before these polar nuclei fuse; hence eight nuclei are visible within seven cells. The micropyle is the opening in the surrounding ovular integuments on the side facing the egg apparatus.



Typical mature angiosperm embryo sac (seven cells and eight nuclei).

Step 2: (b) Explain the role of the first male gamete The generative cell of the pollen grain divides mitotically to produce two haploid male gametes. The pollen tube releases them into a synergid. One male gamete fuses with the haploid egg nucleus. This fusion is called syngamy, and produces the diploid zygote:

$$n \text{ (male gamete)} + n \text{ (egg)} = 2n \text{ (zygote)}.$$

The zygote subsequently develops into the embryo of the seed.

Step 3: Explain the role of the second male gamete The other male gamete fuses with the two polar nuclei in the central cell, or with their already fused diploid secondary nucleus. This event is called triple fusion because three haploid nuclear complements participate:

$$n \text{ (male gamete)} + n + n \text{ (polar nuclei)} = 3n \text{ (primary endosperm nucleus)}.$$

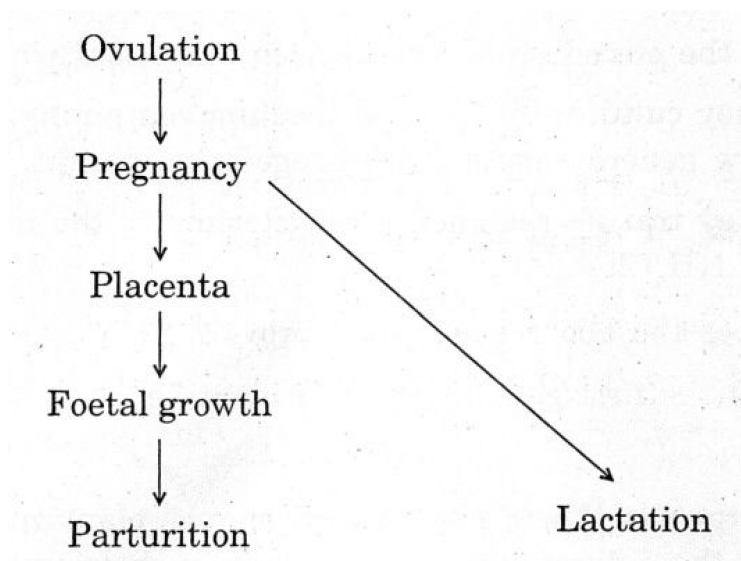
The resulting primary endosperm cell develops into endosperm, which nourishes the developing embryo. Syngamy and triple fusion together constitute double fertilisation. Thus, two male gametes are needed to initiate both the embryo and its nutritive tissue in the same ovule.

Step 4: Conclusion The mature embryo sac has an egg apparatus at the micropylar end, three antipodals at the chalazal end and two polar nuclei in the central cell. Of the two male gametes, one forms the diploid zygote by syngamy and the other forms the triploid primary endosperm nucleus by triple fusion.

Quick Tip to Solve: Count seven cells but eight nuclei; link the two male gametes to embryo formation and endosperm formation separately.

OR

29. Study the flow chart given below. Name the hormones involved at each stage and explain their role. [5 marks]



Solution:

Concept:

- Reproductive hormones coordinate ovulation, maintenance of pregnancy, development of the placenta and foetus, childbirth and milk secretion.
- The source and action of a hormone must be distinguished: prolactin stimulates milk synthesis, whereas oxytocin causes milk ejection and powerful uterine contractions.

Step 1: Ovulation: luteinising hormone A mid-cycle surge of luteinising hormone (LH), secreted by the anterior pituitary, causes the mature Graafian follicle to rupture and release the secondary oocyte. LH also promotes formation of the corpus luteum from the ruptured follicle. Follicle-stimulating hormone (FSH) supports follicular development before ovulation, while oestrogens from the growing follicle promote proliferation of the endometrium.

Step 2: Establishment and maintenance of pregnancy After fertilisation and implantation, human chorionic gonadotropin (hCG), produced by the trophoblast and developing placenta, maintains the corpus luteum in early pregnancy. The corpus luteum secretes progesterone and oestrogens. Progesterone maintains the uterine endometrium, making it suitable for continued development of the embryo and preventing its shedding as menstruation.

Step 3: Placenta and foetal growth The placenta acts as an endocrine tissue, producing hCG, human placental lactogen (hPL), oestrogens and progesterone. Placental progesterone and oestrogens support continued pregnancy and maternal changes, including growth of the uterus and development of the mammary glands. hPL modifies maternal metabolism to support the nutritional demands of the growing foetus and contributes to mammary development. The placenta also transfers nutrients and oxygen from maternal blood to the foetus; hormones support this growth but do not replace this exchange function.

Step 4: Parturition: oxytocin and positive feedback Signals from the fully developed foetus and placenta initiate mild uterine contractions, called the foetal ejection reflex. This stimulates release of oxytocin from the maternal posterior pituitary. Oxytocin strengthens uterine contractions, which stimulate further oxytocin release. This positive-feedback cycle produces increasingly strong contractions and expels the baby. Relaxin, released during pregnancy, helps prepare the pelvic region for childbirth by relaxing pelvic ligaments.

Step 5: Lactation: prolactin and oxytocin Oestrogens, progesterone and hPL help develop the mammary glands during pregnancy. Following delivery, the fall in placental oestrogen and progesterone permits effective milk secretion. Prolactin from the anterior pituitary stimulates milk production. Suckling stimulates oxytocin release, which contracts myoepithelial cells around mammary alveoli and ejects milk into the ducts. Thus milk formation and milk ejection have different hormonal controls.

Step 6: Conclusion The main hormonal links are LH for ovulation; hCG and progesterone for early pregnancy; placental progesterone, oestrogens and hPL for pregnancy support and foetal growth; oxytocin for parturition; and prolactin for milk production with oxytocin for milk ejection.

Quick Tip to Solve: Follow the chart in order and pair every hormone with its action; keep prolactin (milk production) separate from oxytocin (contractions and milk ejection).

30. (a) Why are engineered vectors preferred by biotechnologists for transferring the desired genes into another organism?

(b) Explain how do “ori”, “selectable markers” and “cloning sites” facilitate cloning into a vector.

[5 marks]

Solution:

Concept:

- A cloning vector carries a foreign DNA fragment into a host and allows that fragment to be replicated. Plasmids and bacteriophages can be engineered for this purpose.
- An efficient vector has an origin of replication, a selectable marker and a suitable unique restriction site for insertion of the desired DNA.

Step 1: (a) Why engineered vectors are preferred Naturally occurring vectors are modified to make the transfer and multiplication of a desired gene convenient and efficient. An engineered vector retains the sequences essential for replication and selection, provides suitable sites for foreign-DNA insertion, and can be made small enough to handle and introduce readily into a host. It therefore enables the desired DNA to be carried into the recipient, maintained and amplified, while allowing cells carrying the vector to be identified. For example, a modified plasmid combines an origin of replication, antibiotic-resistance markers and defined restriction sites in one DNA molecule.

Step 2: (b) Origin of replication: ori The origin of replication, or ori, is the DNA sequence from which replication begins. Any DNA linked to this sequence can replicate inside the host cell. Thus, once the desired gene is inserted into the vector, it is copied along with the vector. The origin also controls the copy number of the linked DNA; choosing a suitable origin can therefore provide many copies of the desired gene.

Step 3: Selectable markers A selectable marker helps identify and select cells that have received the vector (transformants) and eliminate cells that have not (non-transformants). For example, an antibiotic-resistance gene permits transformed bacteria to grow on medium containing the corresponding antibiotic, whereas susceptible non-transformants do not grow. Markers can also help distinguish recombinants from non-recombinants by insertional inactivation: insertion of foreign DNA into a marker disrupts its activity. In a suitable vector with two resistance markers, one marker can select transformants and disruption of the other can identify recombinants by comparison of growth on the two antibiotic media.

Step 4: Cloning sites A cloning site is a recognition sequence for a restriction enzyme at which foreign DNA can be inserted. A vector should have very few, preferably a single, recognition site for the chosen enzyme; multiple sites would cut the vector into several fragments and complicate cloning. The vector and desired DNA are cut with the appropriate restriction enzyme to generate compatible ends, and DNA ligase joins the insert to the vector. Locating the cloning site within a marker gene can also allow recombinant vectors to be detected through insertional inactivation.

Step 5: Conclusion Engineered vectors make gene transfer and cloning efficient: ori permits replication and influences copy number, selectable markers identify transformed cells and can help screen recombinants, and unique cloning sites permit controlled insertion of the desired DNA.

Quick Tip to Solve: Link each vector feature to its job: ori copies the insert, a marker selects or screens cells, and a unique restriction site accepts the insert.

30. (a) How is a transgenic tobacco plant protected against *Meloidogyne incognita*?

(b) Explain the procedure of making such plants.

[5 marks]

Solution:

Concept:

- RNA interference (RNAi) is sequence-specific silencing of a gene by double-stranded RNA (dsRNA) complementary to its messenger RNA (mRNA). Silencing prevents production of the corresponding protein.
- A transgenic plant contains an introduced gene construct. Expression of nematode-derived sequences in both sense and antisense orientations produces complementary RNAs that can form dsRNA.

Step 1: (a) Identify the pest and the protective mechanism The root-knot nematode, *Meloidogyne incognita*, infects tobacco roots and reduces plant yield. The transgenic tobacco plant is protected by RNA interference directed against a nematode gene needed for its survival. It does not obtain this protection by producing a Bt toxin; the defence described here depends on sequence-specific RNA silencing.

Step 2: (a) Explain how silencing stops the parasite The plant produces dsRNA corresponding to a specific nematode mRNA. When the nematode feeds on the plant tissue, this RNA triggers silencing of the complementary mRNA in the parasite. In the RNAi pathway, dsRNA is processed into short interfering RNAs, which guide a silencing complex to matching mRNA. The target mRNA is degraded, preventing its translation and therefore the formation of an essential nematode protein. As a result, the parasite cannot survive successfully in the transgenic host.

Step 3: (b) Prepare and introduce the gene construct Select a suitable nematode gene sequence whose silencing will impair the parasite. Prepare a construct that will express both the sense and antisense RNA sequences in tobacco cells. Introduce the nematode-specific DNA sequences into plant cells using an engineered *Agrobacterium* vector, whose transferred DNA carries the desired construct into the plant genome.

Step 4: (b) Regenerate and express the resistant plant Select the transformed tobacco cells and regenerate whole plants by tissue culture. In these transgenic plants, transcription of the introduced sequences produces sense and antisense RNAs. Because their base sequences are complementary, they pair to form dsRNA. The dsRNA initiates RNA interference against the matching nematode mRNA when the parasite feeds. Plants expressing the construct thereby prevent successful nematode infestation and are protected from the root damage it normally causes.

Step 5: Conclusion (a) Transgenic tobacco is protected against the root-knot nematode by RNA interference, which silences a vital nematode mRNA and prevents synthesis of its protein. (b) Nematode-specific sequences are introduced using an *Agrobacterium* vector and expressed as sense and antisense RNAs; their pairing generates the dsRNA responsible for resistance.

Quick Tip to Solve: Remember the sequence: nematode gene construct, sense and antisense RNA, dsRNA, complementary mRNA silencing, and failure of the parasite to survive.