

CBSE Class 12 Biology Question Paper 2008 with Solution PDF-Set 57/1



Question Paper with Solutions

Conducted by the Central Board of Secondary Education (CBSE)

General Instructions

- (i) In the marking scheme the marking points are separated by commas, one oblique line (/) indicates acceptable alternative, two obliques (//) indicate complete acceptable alternative set of marking points.
- (ii) Any words/phrases given within brackets do not have marks.
- (iii) Allow spelling mistakes unless the misspelt word has another biological meaning. Ignore plurals unless otherwise stated in the marking scheme.
- (iv) In any question exclusively on diagram no marks on any description. But in questions on descriptions, same value points may be marked on the diagrams as a substitute.
- (v) All awarded marks are to be written in the left hand margin at the end of the question or its part.
- (vi) Place a tick (✓) in red directly on the key/operative term or idea provided it is in correct context. Place "Half-tick" $\frac{1}{2}$ wherever there is $\frac{1}{2}$ mark in the marking scheme. (Do not place tick indiscriminately just to show that you have read the answer).
- (vii) If no marks are awarded to any part or question put a cross (×) at incorrect value portion and mark it zero (in words only).
- (viii) Add up ticks or the half ticks for a part of the question, do the calculation if any, and write the part total or the question total in the left hand margin.
- (ix) Add part totals of the question and write the question total at the end. Count all the ticks for the entire question as a recheck and draw a circle around the question total to confirm correct addition.
- (x) If parts have been attempted at different places do the totalling at the end of the part attempted last.
- (xi) If any extra part is attempted or any question is reattempted, score out the last one and write "extra".
- (xii) In questions where only a certain number of items are asked evaluate only that many numbers in sequence as is asked ignoring all the extra ones even if correct.
- (xiii) Transcribe the marks on the cover page. Add up question totals. Recheck the script total by adding up circled marks in the script.
- (xiv) Points/answer given in brackets in marking scheme are not important and may be ignored for marking.

Section A (8 marks)

Q.Nos. 1 - 8 are of one mark each.

1. Name any two vertebrate body parts that are homologous to human forelimbs.

[1 mark]

Solution:

Concept:

- Homologous organs share a basic structural plan and common evolutionary origin, although their functions may differ.
- The vertebrate forelimb plan includes a humerus, radius and ulna, followed by wrist and digit bones.

Step 1: Identify a terrestrial example The forelimb of a horse has the same underlying skeletal arrangement as the human forelimb. It is modified mainly for supporting the body and running.

Step 2: Identify an aquatic example The flipper of a whale is another modified vertebrate forelimb. Its bones correspond to those of the human arm, although the flipper is used for swimming.

Step 3: Conclusion Two examples are the forelimb of a horse and the flipper of a whale.

Quick Tip to Solve: Choose modified forelimbs, such as a horse's front leg and a whale's flipper; compare their common bone plan.

2. When and why do some animals like snails go into aestivation?

[1 mark]

Solution:

Concept:

- Aestivation is a period of dormancy during unfavourable hot, dry conditions.
- Reduced activity and metabolism help an animal conserve water and energy.

Step 1: Identify the unfavourable season Snails enter aestivation during summer, especially when the surroundings become very hot and dry. These conditions make remaining active difficult.

Step 2: Explain the survival advantage Dormancy lowers activity and reduces water loss. The snail thereby avoids excessive heat and desiccation until favourable environmental conditions return.

Step 3: Conclusion Snails aestivate in hot, dry summer conditions to survive the heat and prevent desiccation.

Quick Tip to Solve: Remember aestivation as summer dormancy: state both the hot, dry season and protection from water loss.

3. What is the economic value of *Spirulina*?

[1 mark]

Solution:

Concept:

- Single-cell protein is microbial biomass used as a protein-rich food or feed supplement.
- *Spirulina* is a protein-rich cyanobacterium that can be cultivated on a large scale.

Step 1: Identify its useful product The biomass of *Spirulina* is rich in protein and is used as single-cell protein. This makes it useful as a nutritional supplement for humans and as animal feed.

Step 2: Explain its economic importance Large-scale cultivation provides a relatively inexpensive source of protein-rich biomass. It can grow using suitable nutrient-rich waste streams, also helping to reduce their pollution load.

Step 3: Conclusion *Spirulina* has economic value as a protein-rich food supplement, or single-cell protein.

Quick Tip to Solve: For the economic value of *Spirulina*, connect its protein-rich biomass directly with single-cell protein.

4. What was the speciality of the milk produced by the transgenic cow Rosie?

[1 mark]

Solution:

Concept:

- A transgenic animal carries and expresses an introduced gene.
- An introduced human milk-protein gene can change the nutritional composition of cow milk.

Step 1: Identify the special protein Rosie produced milk containing human α -lactalbumin. This human protein was present because the cow expressed the introduced gene.

Step 2: Relate the protein to nutrition The human-protein-enriched milk was more nutritionally balanced for human babies than normal cow milk. Thus, the special feature was its altered protein composition, rather than simply a greater volume of milk.

Step 3: Conclusion Rosie's milk contained human α -lactalbumin and was more nutritionally balanced for human babies than ordinary cow milk.

Quick Tip to Solve: Link Rosie with human α -lactalbumin, then state the improved nutritional balance of her milk.

5. How do neutrophils act as a cellular barrier to pathogens in humans?

[1 mark]

Solution:

Concept:

- Neutrophils are phagocytic white blood cells belonging to innate immunity.
- A cellular barrier uses defensive cells to destroy invading pathogens.

Step 1: Recognise and engulf the invader Neutrophils move to sites of infection and surround invading microbes with their cell membrane. They engulf the pathogens by phagocytosis, enclosing them within the cell.

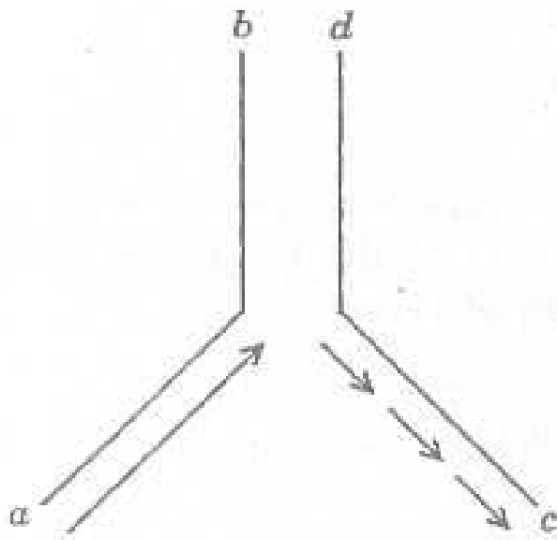
Step 2: Destroy the engulfed pathogen The engulfed microbe is exposed to intracellular digestive and antimicrobial mechanisms. Its destruction prevents it from multiplying and spreading, providing an immediate cellular defence.

Step 3: Conclusion Neutrophils act as a cellular barrier by phagocytosing and destroying invading pathogens.

Quick Tip to Solve: Use the action word phagocytosis: neutrophils engulf microbes first and then destroy them inside the cell.

6. Mention the polarity of the DNA strands a-b and c-d shown in the replicating fork given below.

[1 mark]



Solution:

Concept:

- DNA polymerase adds nucleotides only to a free 3' end, so a new strand grows $5' \rightarrow 3'$.
- The template and newly synthesised DNA strands are antiparallel.

Step 1: Read the continuous synthesis arrow On the left arm, the new strand is synthesised continuously towards the fork. Its template must therefore run in the opposite polarity, from 3' at *a* to 5' at *b*.

Step 2: Read the discontinuous synthesis arrows On the right arm, the short arrows show synthesis away from the fork. Since each new segment still grows $5' \rightarrow 3'$, the corresponding template has 5' at *c* and 3' at *d*.

Step 3: Conclusion Along *a* to *b*, the polarity is $3' \rightarrow 5'$; along *c* to *d*, it is $5' \rightarrow 3'$.

Quick Tip to Solve: First read the new-strand arrows as $5' \rightarrow 3'$, then assign the opposite polarity to each template.

7. Mention any two significant roles predation plays in nature.

[1 mark]

Solution:

Concept:

- Predation is an interaction in which a predator kills and consumes its prey.
- Predators link trophic levels and regulate the abundance of prey in communities.

Step 1: Trace the transfer of energy When a predator eats prey, energy stored in the prey's biomass passes to the predator. Predators therefore act as conduits of energy to the next trophic level in a food chain.

Step 2: Explain population regulation Predators keep prey populations under control by consuming individuals. This checks excessive population growth and can prevent a competitively dominant prey species from excluding other species.

Step 3: Conclusion Predation transfers energy to higher trophic levels and keeps prey populations under control.

Quick Tip to Solve: Give two distinct roles: energy transfer through feeding and control of prey abundance through consumption.

8. Why is the polar region not a suitable habitat for tiny humming birds?

[1 mark]

Solution:

Concept:

- The rate of heat loss depends on exposed surface area, whereas heat production is related to the volume of metabolically active tissue.
- Small animals have a large surface-area-to-volume ratio, so they lose heat rapidly in a cold environment.

Step 1: Relate body size to heat loss A tiny hummingbird has a large body surface compared with its small body volume. Therefore, it loses a relatively large amount of heat to its surroundings.

Step 2: Apply this to the polar climate In the extreme cold of polar regions, the bird would need a very high metabolic expenditure to generate enough heat to maintain its body temperature. This makes thermal regulation energetically difficult.

Step 3: Conclusion Polar regions are unsuitable because hummingbirds lose heat rapidly owing to their high surface-area-to-volume ratio and cannot economically replace that heat.

Quick Tip to Solve: For a tiny animal in a cold habitat, connect small size to rapid heat loss through a high surface-area-to-volume ratio.

Section B (20 marks)

Q.Nos. 9 - 18 are of 2 marks each.

9. (a) Expand IUD. (b) Why is hormone releasing IUD considered a good contraceptive to space children? [2 marks]

Solution:

Concept:

- An intrauterine device is a contraceptive placed inside the uterus by a trained healthcare professional.
- Hormone-releasing IUDs provide long-term but reversible contraception by making the reproductive tract unfavourable for sperm and implantation.

Step 1: Expand IUD IUD stands for intrauterine device.

Step 2: Explain the contraceptive action Hormone-releasing IUDs make the cervical mucus thick and the cervix hostile to sperm, hindering their passage. They also make the uterine lining unsuitable for implantation, thereby preventing pregnancy.

Step 3: Explain suitability for spacing children The device can remain effective for an extended period without requiring action at each act of intercourse. Its contraceptive action is reversible: it can be removed when the couple wishes to have another child, making it useful for spacing births.

Step 4: Conclusion IUD means intrauterine device. A hormone-releasing IUD is a good spacing method because it gives effective, sustained and reversible contraception by making the cervix hostile to sperm and the uterus unsuitable for implantation.

Quick Tip to Solve: For birth spacing, state both how the IUD prevents pregnancy and why its reversibility permits a later pregnancy.

10. Name the interaction in each of the following: (a) *Cuscuta* growing on a shoe flower plant (b) Mycorrhizae living on the roots of higher plants (c) Clown fish living among the tentacles of sea anemone (d) Koel laying her eggs in crow's nest. [2 marks]

Solution:

Concept:

- In interspecific interactions, the effect on each partner distinguishes parasitism, mutualism and commensalism.
- A parasite benefits at its host's expense; mutualism benefits both partners; commensalism benefits one while the other is neither benefited nor harmed.

Step 1: Identify the plant interactions (a) *Cuscuta* on a shoe flower plant: **parasitism**. *Cuscuta* obtains nourishment from the host, harming it. (b) Mycorrhizae on roots: **mutualism**. The fungus helps absorb water and minerals, especially phosphorus, while the plant supplies organic food.

Step 2: Identify the animal interactions (c) Clown fish among sea anemone tentacles: **commensalism**.

The fish gains protection from predators, while the anemone is considered unaffected in the textbook example. (d) Koel laying eggs in a crow's nest: **brood parasitism**. The crow incubates the eggs and rears the koel's young, saving the koel parental effort.

Step 3: Conclusion The interactions are (a) parasitism, (b) mutualism, (c) commensalism and (d) brood parasitism.

Quick Tip to Solve: First ask who benefits and who is harmed; when another bird rears the parasite's young, specify brood parasitism.

11. A plant of *Antirrhinum majus* with red flowers was crossed with another plant of the same species with white flowers. The plants of the F_1 generation bore pink flowers. Explain the pattern of inheritance with the help of a cross. [2 marks]

Solution:

Concept:

- Incomplete dominance occurs when neither allele is completely dominant in a heterozygote; its phenotype is intermediate between the two homozygotes.
- In *Antirrhinum majus*, use RR for red flowers, rr for white flowers and Rr for pink flowers. The alleles remain distinct even though the heterozygous phenotype is intermediate.

Step 1: Write the parental cross The homozygous red-flowered plant produces only R gametes, and the homozygous white-flowered plant produces only r gametes:

$$\begin{aligned} P &: RR \text{ (red)} \times rr \text{ (white)} \\ \text{Gametes} &: R \quad r. \end{aligned}$$

Step 2: Obtain and interpret the first generation Fertilisation combines one allele from each parent:

$$F_1 : Rr \quad (\text{all pink-flowered plants}).$$

Red is not completely dominant over white, so the heterozygote has pink flowers. This is incomplete dominance; the pink phenotype does not mean that the alleles have blended irreversibly.

Step 3: Conclusion The cross $RR \times rr$ gives only Rr pink offspring in F_1 , demonstrating incomplete dominance.

Quick Tip to Solve: Show the parental genotypes, their gametes and the heterozygous pink offspring; pink alone does not explain the cross.

11. A woman with blood group O married a man with AB group. Show the possible blood groups of the progeny. List the alleles involved in this inheritance. [2 marks]

Solution:

Concept:

- The ABO blood group gene has three alleles in the population: I^A , I^B and i . Each person carries only two of these alleles.
- I^A and I^B are codominant with each other, and each is dominant over i . Group O is ii , while group AB is $I^A I^B$.

Step 1: Write parental genotypes and gametes The mother with blood group O has genotype ii , so all her ova carry i . The father with blood group AB has genotype $I^A I^B$, so half his sperm carry I^A and half carry I^B .

Step 2: Show the possible offspring The cross is

$$ii \times I^A I^B \longrightarrow I^A i \quad \text{or} \quad I^B i,$$

Blood groups : A B.

The two combinations are equally likely, so the expected ratio is $A : B = 1 : 1$. No child can have group O because the father cannot contribute i ; no child can have group AB because the mother cannot contribute I^A or I^B .

Step 3: Conclusion The progeny may have group A ($I^A i$) or group B ($I^B i$), each with probability $1/2$. The alleles involved are I^A , I^B and i .

Quick Tip to Solve: Start with group O = ii and AB = $I^A I^B$: every child receives i from the mother, then either paternal A or paternal B.

12. Why do sportspersons often fall a victim to cocaine addiction? [2 marks]

Solution:

Concept:

- Cocaine is a powerful stimulant of the central nervous system and can produce a feeling of euphoria and increased energy.
- Repeated drug use for its rewarding effects can lead to psychological dependence and addiction.

Step 1: Identify the attraction of the stimulant Sportspersons may take cocaine because its stimulant action makes them feel more alert, energetic and confident. It temporarily reduces the feeling of fatigue, so they may perceive an enhancement of their performance and use it to cope with the pressure to perform well.

Step 2: Connect repeated use with addiction The pleasurable and stimulating effects encourage repeated consumption. Cocaine interferes with the transport of the neurotransmitter dopamine, intensifying reward-related signals in the brain. As a result, a person may develop a strong desire to

repeat the experience and become dependent on the drug. This explains why taking it in the hope of improving performance can lead to addiction.

Step 3: Conclusion Sportspeople may fall victim to cocaine addiction because cocaine acts as a stimulant, giving a temporary sense of increased energy and enhanced performance; repeated use for these effects leads to dependence.

Quick Tip to Solve: Link the two required ideas explicitly: stimulant action and perceived performance enhancement encourage repeated use and addiction.

13. State the difference between the first trophic levels of detritus food chain and grazing food chain. [2 marks]

Solution:

Concept:

- A food chain describes the transfer of food and energy from its starting material or organisms to successive consumers.
- A detritus food chain begins with dead organic matter, whereas a grazing food chain begins with living autotrophic producers.

Step 1: State the starting level of the detritus food chain The first trophic level or starting point of the detritus food chain consists of detritus: dead and decaying organic matter, such as fallen leaves and the dead remains of plants and animals. Decomposers obtain their food from this material. Thus, this chain begins with organic matter that has already been produced by living organisms.

Step 2: Contrast it with the grazing food chain The first trophic level of the grazing food chain consists of living green plants or other photosynthetic producers. These producers capture solar energy and synthesise organic food, which is then eaten by herbivores. The distinction is therefore between dead organic material at the start of the detritus chain and living producers at the start of the grazing chain.

Step 3: Conclusion Detritus food chain: dead and decaying organic matter. Grazing food chain: living green plants or producers.

Quick Tip to Solve: For the first trophic level, contrast the starting food source: dead organic matter in DFC and living producers in GFC.

14. Coconut palm is monoecious while date palm is dioecious. Why are they called so? [2 marks]

Solution:

Concept:

- A unisexual flower has either stamens, making it male, or a pistil, making it female.
- Monoecious plants bear both male and female flowers on one plant; dioecious plants bear the two kinds of flowers on separate plants.

Step 1: Explain the condition in coconut palm A coconut palm bears separate male and female flowers on the same individual plant. Each flower is unisexual, but a single coconut palm has both kinds of flowers. It is therefore described as monoecious. The term refers to the distribution of the flowers on the plant, rather than to both sex organs being present within one flower.

Step 2: Explain the condition in date palm In date palm, male flowers and female flowers occur on different individual plants. One plant bears the male flowers, while another bears the female flowers. It is consequently called dioecious. Here the sexes are separated between plants, unlike coconut, where the separate male and female flowers occur on the same plant.

Step 3: Conclusion Coconut is monoecious because one plant bears both male and female flowers. Date palm is dioecious because male and female flowers are borne on separate plants.

Quick Tip to Solve: Check whether the two kinds of unisexual flowers occur on one plant or on separate plants; do not confuse monoecious with bisexual flowers.

15. How can DNA segments, separated by gel electrophoresis, be visualised and isolated? [2 marks]

Solution:

Concept:

- Agarose gel electrophoresis separates DNA fragments according to size; smaller fragments move farther through the gel.
- DNA bands can be detected after staining with ethidium bromide and exposure to ultraviolet light, and recovered from the gel by elution.

Step 1: Visualise the separated DNA bands Stain the separated DNA fragments with ethidium bromide and expose the gel to ultraviolet radiation. The stained DNA appears as bright orange bands against the gel background. This makes the positions of the separated DNA fragments visible, so the band containing the desired fragment can be located.

Step 2: Isolate the required DNA fragment Cut out the piece of agarose gel containing the required DNA band. Then extract the DNA from this gel piece by the process called elution. This recovers the selected DNA fragment, which can subsequently be used for further work, such as joining it to a cloning vector. Cutting the band selects the desired size fraction; elution releases its DNA from the agarose.

Step 3: Conclusion Visualise DNA as bright orange bands by ethidium bromide staining under ultraviolet light. Excise the desired band from the agarose gel and recover its DNA by elution.

Quick Tip to Solve: Remember the sequence: stain with ethidium bromide, view under UV, cut the desired band, and elute the DNA.

16. How do Darwin's finches illustrate adaptive radiation?

[2 marks]

Solution:**Concept:**

- Adaptive radiation is the evolution of several species from a common ancestor in a geographical area, each becoming adapted to a different ecological niche.
- Natural selection favours inherited variations that improve the use of locally available food resources.

Step 1: Identify the common ancestral stock Darwin's finches of the Galapagos Islands are believed to have evolved from a common ancestral stock of seed-eating birds. Descendants spread into different island habitats, where food resources and feeding opportunities differed.

Step 2: Relate beak diversity to different food sources In the different habitats, natural selection favoured different inherited beak structures and feeding habits. Strong, broad beaks suited cracking seeds, whereas other beak forms suited feeding on insects or other available foods. Over many generations the descendants diverged into several finch species, each adapted to its own niche. Their different beaks therefore represent modification of an ancestral structure for different ways of obtaining food.

Step 3: Conclusion Darwin's finches illustrate adaptive radiation because one ancestral seed-eating stock diversified into several species with different beaks and feeding habits in the Galapagos Islands.

Quick Tip to Solve: Link three points in order: common ancestor, different food niches, and different adapted beaks.

17. Name the blank spaces a, b, c and d from the table given below:

[2 marks]

Type of Microbe	Scientific name	Commercial product
Bacterium	a	Lactic acid
Fungus	b	Cyclosporin A
c	<i>Monascus purpureus</i>	Statin
Fungus	<i>Penicillium notatum</i>	d

Solution:**Concept:**

- Industrial microorganisms are identified by both their scientific names and the useful products obtained from them.
- A microbial type, such as bacterium or yeast, is a category; it is distinct from the organism's scientific name and its commercial product.

Step 1: Complete the scientific names a and b In the first row, the bacterium producing lactic acid is *Lactobacillus*; hence a is *Lactobacillus*. In the second row, the fungus producing cyclosporin A is *Trichoderma polysporum*; hence b is *Trichoderma polysporum*. Cyclosporin A is used as an immunosuppressive agent in organ transplantation.

Step 2: Identify the microbial type c and commercial product d The organism *Monascus purpureus* is a yeast, so c is yeast. It produces statins, used to lower blood cholesterol by inhibiting the enzyme

involved in cholesterol synthesis. The fungus *Penicillium notatum* produces the antibiotic penicillin, so d is penicillin. Thus the third blank asks for a type of microbe, whereas the fourth asks for a product.

Step 3: Conclusion a: *Lactobacillus*; b: *Trichoderma polysporum*; c: yeast; d: penicillin.

Quick Tip to Solve: Check the column heading before filling each blank: a and b are names, c is a microbial type, and d is a product.

18. DDT content in the water of a lake that supplies drinking water to the nearby villages, is found to be 0.003 ppm. The kingfishers of that area are reported to have 2 ppm of DDT. Why has the concentration increased in these birds? What harm will this cause to the bird population? Name the phenomenon. [2 marks]

Solution:

Concept:

- Biomagnification is the progressive increase in the concentration of a persistent toxic substance at successive trophic levels of a food chain.
- DDT is poorly metabolised and excreted, so it accumulates in tissues and is transferred to consumers through food.

Step 1: Trace DDT through the aquatic food chain DDT present in lake water enters aquatic organisms and passes through the food chain to fish and then to fish-eating kingfishers. Each bird consumes many contaminated prey. Because the pesticide is not effectively broken down or eliminated, its accumulated concentration becomes much greater in the bird than in the water: here it rises from 0.003 ppm in water to 2 ppm in kingfishers. This increase across trophic levels is biomagnification.

Step 2: Explain the effect on reproduction High DDT concentrations interfere with calcium metabolism in birds. This causes thinning of eggshells, making the eggs liable to break prematurely during incubation. Fewer young hatch successfully, reducing reproductive success and causing a decline in the bird population.

Step 3: Conclusion The rise in DDT concentration is due to biomagnification. DDT disrupts calcium metabolism, causes thin eggshells and premature egg breakage, and consequently reduces the kingfisher population.

Quick Tip to Solve: For DDT in fish-eating birds, connect food-chain accumulation to calcium metabolism, thin shells and reduced hatching.

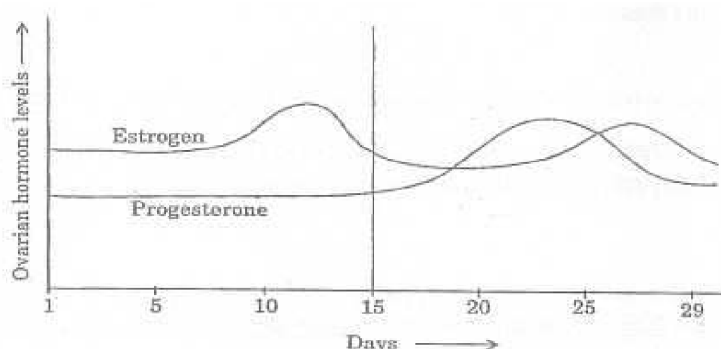
Section C (27 marks)

Q.Nos. 19 - 27 are of 3 marks each.

19. (a) Read the graph given above and correlate the uterine events that take place according to the hormonal levels on (i) 6–15 days (ii) 16–25 days (iii) 26–28 days (if the ovum is not fertilised).

(b) Specify the sources of the hormones mentioned in the graph.

[3 marks]



Solution:

Concept:

- Ovarian estrogen stimulates regeneration and proliferation of the uterine endometrium after menstruation.
- Progesterone from the corpus luteum maintains a thick, vascular and secretory endometrium suitable for implantation. Withdrawal of ovarian hormones leads to its breakdown.

Step 1: Correlate days 6–15 with endometrial regeneration (a)(i) During days 6–15, the developing ovarian follicles secrete increasing estrogen. The endometrium regenerates after the previous menstrual shedding, and its cells proliferate. The uterine lining becomes progressively thicker, with growth of its glands and blood vessels. This is the proliferative phase of the uterine cycle.

Step 2: Correlate days 16–25 with preparation for implantation (a)(ii) After ovulation, the ruptured follicle forms the corpus luteum and progesterone levels rise. Progesterone maintains the endometrium, making it thick, highly vascular and secretory. Uterine glands become active, preparing the lining to receive and nourish an implanting embryo. This is the secretory phase.

Step 3: Explain the changes on days 26–28 without fertilisation (a)(iii) If fertilisation does not occur, the corpus luteum degenerates. Progesterone and estrogen secretion fall, so the endometrium loses hormonal support and begins to disintegrate. The lining and its blood vessels break down, leading to menstrual shedding at the start of the next cycle.

Step 4: State the ovarian sources of the hormones (b) Estrogen is secreted mainly by the growing ovarian follicles. Progesterone is secreted mainly by the corpus luteum formed after ovulation. The corpus luteum also secretes some estrogen during the luteal phase.

Step 5: Conclusion Days 6–15: regeneration of the endometrium; days 16–25: a vascular, secretory lining ready for implantation; days 26–28 without fertilisation: endometrial breakdown as hormone levels fall. Estrogen comes mainly from ovarian follicles and progesterone from the corpus luteum.

Quick Tip to Solve: Match estrogen with endometrial growth, progesterone with maintenance and secretion, and a fall in both with menstrual breakdown.

20. Explain the role of baculoviruses as biological control agents. Mention their importance in organic farming. [3 marks]

Solution:

Concept:

- Biological control uses a pest's natural enemies or pathogens to reduce its population instead of depending on chemical pesticides.
- Baculoviruses are insect-pathogenic viruses; nucleopolyhedroviruses are especially useful because their action is highly species-specific and has a narrow host range.

Step 1: Explain how baculoviruses control pests Baculoviruses infect insects and other arthropods. Suitable baculovirus preparations are applied to crops as biological insecticides; susceptible pest larvae become infected and die, reducing the pest population and the damage it causes to the crop. Nucleopolyhedroviruses are widely used for this purpose. Their narrow spectrum means that a virus selected for a particular pest attacks that susceptible host rather than indiscriminately killing organisms in the field.

Step 2: Relate their selectivity to organic farming Their species-specific action has no adverse impact on non-target plants, mammals, birds, fish or beneficial insects. Thus pollinators and natural predators of pests are conserved. This is particularly valuable in organic farming, which avoids synthetic chemical pesticides and maintains ecological balance. Baculoviruses reduce reliance on chemical insecticides and are suitable components of integrated pest management, especially where beneficial insects must be protected.

Step 3: Conclusion Baculoviruses, especially nucleopolyhedroviruses, provide highly specific biological control of insect pests. They support organic farming by conserving useful organisms and reducing the need for chemical pesticides.

Quick Tip to Solve: Link the narrow host range to two benefits: selective pest killing and conservation of beneficial insects.

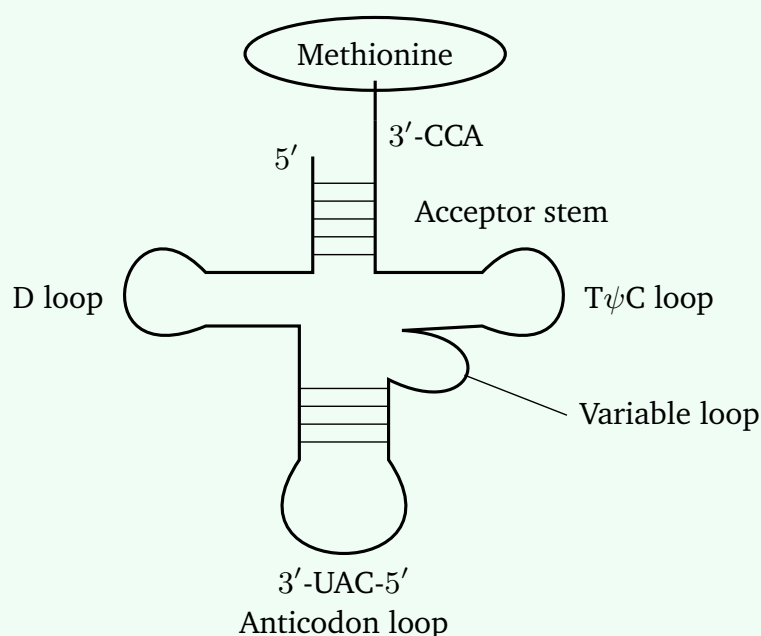
21. (a) Draw the structure of the initiator tRNA adaptor molecule. (b) Why is tRNA called an adaptor molecule? [3 marks]

Solution:

Concept:

- Transfer RNA (tRNA) has an amino-acid attachment site at its 3'-CCA end and an anticodon loop that recognises the complementary codon of messenger RNA (mRNA).
- Initiator tRNA carries methionine and recognises the initiation codon 5'-AUG-3' through its complementary anticodon 3'-UAC-5'.

Step 1: (a) Draw the initiator tRNA The secondary structure is represented as a clover leaf. Its paired acceptor stem brings the 5' end near the 3'-CCA end, where methionine is attached. The anticodon loop at the opposite end bears UAC. The two lateral arms form the D loop and the T ψ C loop, with a small variable loop between the anticodon arm and the T ψ C arm. These loops and stems arise from intramolecular base pairing of the single RNA strand.



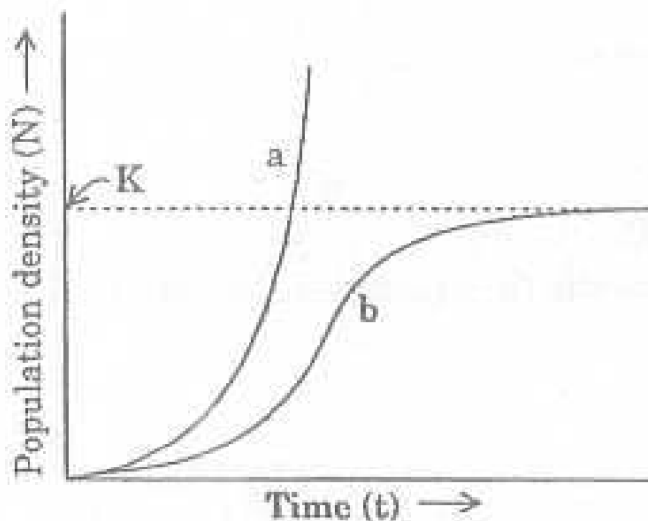
Clover-leaf secondary structure of initiator tRNA (schematic).

Step 2: (b) Explain the adaptor function tRNA connects the nucleotide language of mRNA with the amino-acid sequence of a protein. At one end, its anticodon reads a specific mRNA codon by complementary base pairing; at the other end, it carries the corresponding specific amino acid. Thus the initiator tRNA recognises AUG and delivers methionine to begin translation. This simultaneous recognition of a codon and carriage of its amino acid makes tRNA an adaptor molecule.

Step 3: Conclusion Initiator tRNA is a clover-leaf-shaped RNA bearing methionine at the 3'-CCA end and the UAC anticodon in its anticodon loop. It acts as an adaptor by linking a particular mRNA codon to its specified amino acid.

Quick Tip to Solve: Put methionine at the CCA end and UAC in the opposite loop; then explain that the two ends link codon to amino acid.

22. Study the population growth curves shown above. (i) Identify curves 'a' and 'b'. (ii) Mention the conditions responsible for the curves 'a' and 'b' respectively. (iii) Give the necessary equation for the curve 'b'. [3 marks]



Solution:

Concept:

- Exponential growth occurs when resources do not limit population increase; logistic growth accounts for limited resources and the environment's carrying capacity.
- In population equations, N is population density at time t , r is the intrinsic rate of natural increase, and K is the carrying capacity, the maximum population density the habitat can sustain.

Step 1: (i) Identify the two curves Curve a is the J-shaped exponential growth curve, with an increasingly steep slope. Curve b is the S-shaped or sigmoid logistic growth curve: growth finally slows as the population approaches the horizontal level marked K .

Step 2: (ii) State the conditions for each pattern Curve a results when resources such as food and space are unlimited and environmental conditions are favourable, so resource shortage does not restrict growth. Curve b results when resources are limited. Increasing competition for resources reduces the rate of growth. The population consequently approaches the habitat's carrying capacity.

Step 3: (iii) Write the equation for curve b The Verhulst-Pearl logistic growth equation is

$$\frac{dN}{dt} = rN \left(\frac{K - N}{K} \right) = rN \left(1 - \frac{N}{K} \right).$$

Here dN/dt is the rate of population growth. The resource-limiting factor $(K - N)/K$ decreases as N approaches K . At $N = K$, net growth is zero, explaining the plateau.

Step 4: Conclusion Curve a is exponential growth under unlimited resources; curve b is logistic growth under limited resources. Curve b follows $dN/dt = rN(K - N)/K$, approaching the carrying capacity K .

Quick Tip to Solve: Read the plateau first: a curve approaching K is logistic, so its equation must include the factor $(K - N)/K$.

23. Why is *Agrobacterium tumefaciens* a good cloning vector? Explain.

[3 marks]

Solution:

Concept:

- *Agrobacterium tumefaciens* naturally transfers a segment of its Ti (tumour-inducing) plasmid, called T-DNA, into plant cells.
- A cloning vector carries foreign DNA into a host, where the introduced DNA can be maintained and expressed. A useful plant vector retains DNA-transfer ability while its disease-causing functions are removed.

Step 1: Identify the natural gene-transfer system *Agrobacterium tumefaciens* infects several dicot plants. In nature, its Ti plasmid delivers T-DNA into the plant cell, where it becomes integrated into the plant's nuclear DNA. This natural capacity to transfer genetic material across species makes the bacterium an effective vehicle for introducing a desired gene into a plant.

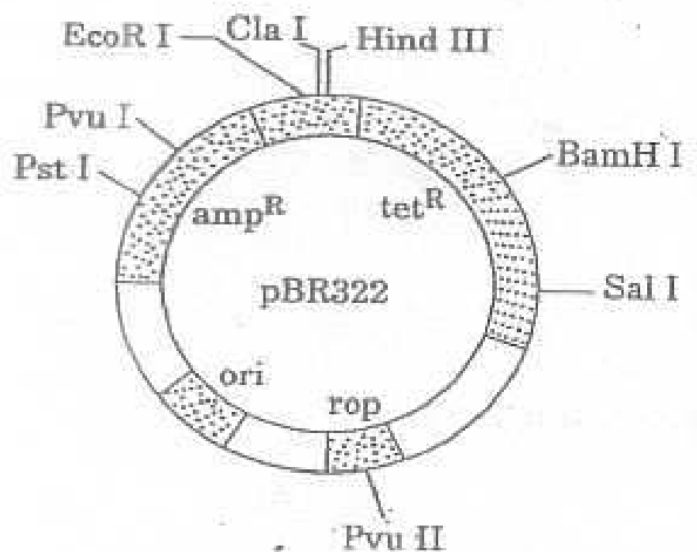
Step 2: Disarm the plasmid and insert the desired gene The tumour-inducing genes are removed or inactivated so that the vector does not cause crown-gall disease. The desired foreign gene is inserted into the transferable DNA region, while the functions needed for transfer are retained. Thus, the modified bacterium transfers useful DNA instead of producing tumours.

Step 3: Establish the introduced gene in the plant After transfer and stable integration, transformed plant cells can be selected and regenerated into plants. The introduced gene is copied along with the plant genome and can express the desired trait or product. The Ti plasmid therefore provides a naturally efficient system for genetic transformation of susceptible plant hosts.

Step 4: Conclusion A disarmed Ti plasmid of *Agrobacterium tumefaciens* is a good plant cloning vector because it delivers a desired foreign gene into plant cells, permits stable integration and expression, and can do so without causing tumour disease.

Quick Tip to Solve: Link the three ideas in order: natural T-DNA transfer, removal of tumour genes, and introduction and expression of the desired gene.

23. Explain the importance of (a) *ori*, (b) amp^R and (c) *rop* in the *E. coli* vector shown below. [3 marks]



Solution:

Concept:

- pBR322 is a plasmid cloning vector used in *Escherichia coli*. Replication and selection are distinct requirements for maintaining a vector in its host.
- The origin of replication starts plasmid DNA replication, a selectable marker identifies host cells carrying the plasmid, and regulatory proteins help control plasmid replication.

Step 1: Explain the role of *ori* (a) ***ori*** is the origin of replication: the specific DNA sequence from which replication of the plasmid begins in the host. Any foreign DNA physically linked to this origin is replicated along with the vector. The origin also influences the copy number of the linked DNA, so its presence allows the desired insert to be maintained and multiplied in bacterial cells.

Step 2: Explain the role of the ampicillin-resistance gene (b) amp^R is the ampicillin-resistance gene. It acts as a selectable marker: bacteria carrying a functional copy can grow on a medium containing ampicillin, whereas susceptible non-transformed cells do not grow. It therefore helps identify cells that have taken up the plasmid. If an insert disrupts this gene, loss of resistance can also assist in screening recombinants using another suitable marker.

Step 3: Explain the role of *rop* (c) ***rop*** codes for a protein involved in regulating plasmid replication. The Rop protein helps control initiation of replication and therefore maintains the plasmid copy number in the host. Thus, *rop* contributes to replication control rather than antibiotic resistance or the actual starting site for DNA synthesis.

Step 4: Conclusion In pBR322, *ori* initiates replication and influences copy number; amp^R provides ampicillin resistance for selection; and *rop* encodes a protein involved in regulating plasmid replication.

Quick Tip to Solve: Match *ori* with the replication start, *amp*-resistance with selection, and *rop* with the protein controlling plasmid replication.

24. Study the mRNA segment given above which is complete to be translated into a polypeptide chain. (i) Write the codons 'a' and 'b'. (ii) What do they code for? (iii) How is peptide bond formed between two amino acids in the ribosome? [3 marks]



Solution:

Concept:

- Translation reads mRNA codons in the 5' to 3' direction, beginning at an initiation codon and ending at a termination codon.
- AUG is the usual initiation codon and specifies methionine. UAA, UAG and UGA are stop codons; they do not specify amino acids.
- During elongation, the ribosome positions aminoacyl-tRNAs so that the growing peptide chain can be transferred to the next amino acid by peptide-bond formation.

Step 1: Identify codons a and b (i) The given segment represents a complete coding sequence, so its first triplet, labelled a, must be the initiation codon AUG. The final triplet, labelled b, must be a termination codon: UAA, UAG or UGA. Any one of these three is a valid answer for b because the diagram does not specify its bases.

Step 2: State what the two codons specify (ii) AUG codes for methionine and also signals initiation of translation. In contrast, the stop codon b codes for no amino acid. A release factor recognises it and brings translation to an end, releasing the completed polypeptide. A stop signal is therefore not an additional amino acid at the end of the chain.

Step 3: Explain peptide-bond formation in the ribosome (iii) Codon-anticodon pairing positions the charged tRNAs at adjacent ribosomal sites, bringing their amino acids close together. The peptidyl-transferase activity of rRNA in the large ribosomal subunit catalyses formation of a peptide bond between the carboxyl end of the growing peptide on the P-site tRNA and the amino group of the incoming amino acid on the A-site tRNA. The growing chain is transferred to the A-site tRNA; energy stored during amino-acid activation supports this process. The ribosome thus acts as a ribozyme during peptide-bond formation.

Step 4: Conclusion Codon a is AUG, specifying methionine; codon b is UAA, UAG or UGA, specifying termination without an amino acid. Ribosomal rRNA catalyses peptide-bond formation between amino acids brought together by their tRNAs.

Quick Tip to Solve: At the ends of a complete coding sequence, look for AUG first and a stop triplet last; do not assign an amino acid to the stop codon.

25. (a) Name the infective stage of *Plasmodium* which *Anopheles* mosquito takes in along with the blood meal from an infected human. (b) Why does the infection cause fever in humans? (c) Give a flow chart of the part of the life-cycle of this parasite passed in the insect. [3 marks]

Solution:

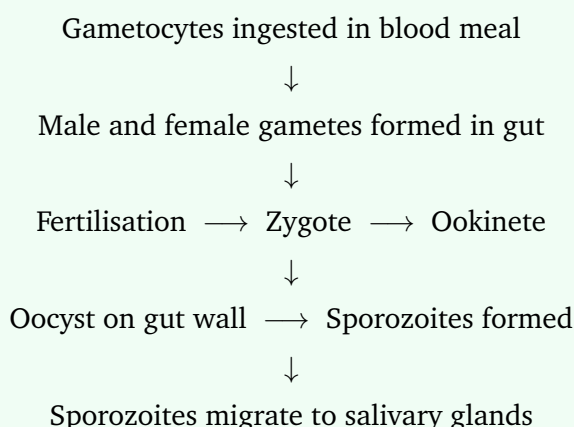
Concept:

- Malaria is caused by *Plasmodium*; the female *Anopheles* mosquito is its vector and the host in which sexual reproduction occurs.
- Gametocytes infect the mosquito, whereas sporozoites introduced with mosquito saliva infect a human host.

Step 1: (a) Identify the stage ingested by the mosquito The mosquito takes in male and female **gametocytes** of *Plasmodium* along with the blood meal of an infected human. These sexual stages develop in human red blood cells and survive ingestion to continue development in the mosquito gut.

Step 2: (b) Explain the fever in humans The parasite multiplies inside red blood cells. Rupture of the infected cells releases the toxic substance **haemozoin**, together with the newly formed parasites. Haemozoin triggers the characteristic bouts of chills and high fever. Repeated, relatively synchronised rupture of infected red blood cells accounts for the recurring attacks.

Step 3: (c) Trace development in the insect The mosquito phase can be represented by the following flow chart. Fertilisation occurs in the mosquito gut; the resulting motile ookinete penetrates the gut wall and develops into an oocyst.



During a subsequent bite, these sporozoites enter another human with the saliva, completing transmission from the insect.

Step 4: Conclusion The mosquito ingests gametocytes; haemozoin released on red-cell rupture causes fever. Sexual reproduction and sporozoite formation occur in the mosquito, and sporozoites finally reach its salivary glands.

Quick Tip to Solve: Keep the two infective stages separate: gametocytes enter the mosquito in blood, while sporozoites enter humans with mosquito saliva.

26. A factory drains its waste water into the nearby lake. It has caused algal bloom. (a) How was the algal bloom caused? (b) What would be the consequences? (c) Name the phenomenon that caused it.

[3 marks]

Solution:

Concept:

- Nutrient enrichment of a water body, especially with nitrogen and phosphorus compounds, promotes excessive growth of planktonic algae.
- Biochemical oxygen demand (BOD) measures the oxygen required by microorganisms to decompose organic matter; increased decomposition can deplete dissolved oxygen.

Step 1: (a) Explain the cause of the bloom Nutrients carried in the factory wastewater enter the lake. In particular, nitrogen and phosphorus nutrients remove limitations on algal growth, so planktonic or free-floating algae proliferate rapidly. This excessive growth produces an **algal bloom**, often visible as a dense green covering or scum on the water surface.

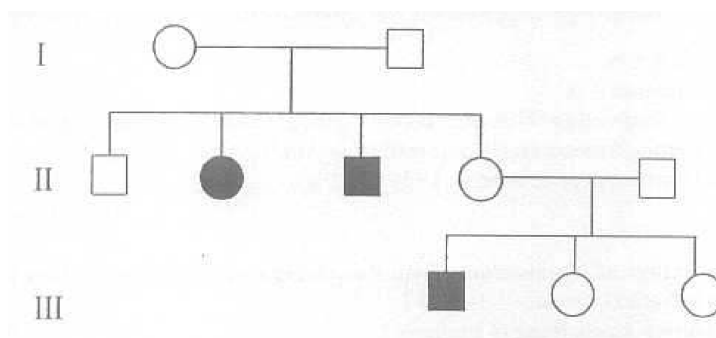
Step 2: (b) Describe the consequences for the lake Dense algal growth reduces light penetration and harms submerged plants. When algae and plants die, their organic remains are decomposed by aerobic microorganisms. This raises the **BOD** and consumes dissolved oxygen. Algal respiration also consumes oxygen, particularly at night. Oxygen depletion can kill fish and other oxygen-dependent aquatic animals, causing high mortality and loss of biodiversity. Accumulated scum, decaying material and unpleasant odours deteriorate the quality of the lake water and can eventually choke the lake. Some bloom-forming organisms may also release toxins harmful to animals and humans.

Step 3: (c) Name the phenomenon The nutrient enrichment and consequent excessive biological growth constitute **eutrophication**. Because the enrichment here results from human discharge of factory wastewater and accelerates the lake's natural ageing, it is specifically called **cultural or accelerated eutrophication**.

Step 4: Conclusion Nutrient-rich factory effluent causes the bloom. Increased BOD, oxygen depletion, aquatic mortality, scum and foul odour degrade the lake; the phenomenon is eutrophication, specifically accelerated eutrophication in this case.

Quick Tip to Solve: Link the events in order: excess nutrients, algal bloom, decomposition, higher BOD, lower dissolved oxygen, and fish mortality.

27. Study the given pedigree chart and answer the questions that follow. (a) Is the trait recessive or dominant? (b) Is the trait sex-linked or autosomal? (c) Give the genotypes of the parents in generation I and of their third and fourth child in generation II. [3 marks]



Solution:

Concept:

- In a pedigree, squares represent males, circles represent females, and filled symbols represent individuals expressing the trait.
- A recessive trait can appear in children of two unaffected carrier parents. For an autosomal recessive trait, AA and Aa are unaffected, while aa is affected.
- Under ordinary Mendelian inheritance, an X-linked recessive affected daughter must receive the recessive allele from an affected father as well as from her mother.

Step 1: (a) Determine whether the trait is recessive Both parents in generation I are unaffected, yet their second and third children in generation II are affected. Thus an allele can be present without being expressed in either parent. The trait is **recessive**: both parents carry the recessive allele, and an affected child receives one copy from each. A dominant trait would ordinarily require an affected parent.

Step 2: (b) Determine whether the trait is autosomal The trait is **autosomal**. The affected daughter in generation II has an unaffected father, which rules out ordinary X-linked recessive inheritance: an affected daughter would need a recessive X chromosome from her father, making him affected. Y-linked inheritance is also ruled out because a female is affected. The occurrence of affected individuals of both sexes is consistent with autosomal recessive inheritance.

Step 3: (c) Assign the requested genotypes Let A be the dominant normal allele and a the recessive allele for the trait. The unaffected parents in generation I must both be Aa , because each has contributed a to their affected children:



Their third child, the affected son in generation II, is aa . Their fourth child, the unaffected daughter, must be Aa , rather than AA , because she has an affected aa son in generation III and must therefore contribute a . Her unaffected husband must likewise be a carrier.

Step 4: Conclusion The trait is autosomal recessive. Both parents in generation I are Aa ; their third child in generation II is aa , and their fourth child is Aa .

Quick Tip to Solve: First find affected children of unaffected parents. Then use an affected daughter with an unaffected father to exclude X-linked recessive inheritance.

Section D (15 marks)

Q.Nos. 28 - 30 are of 5 marks each.

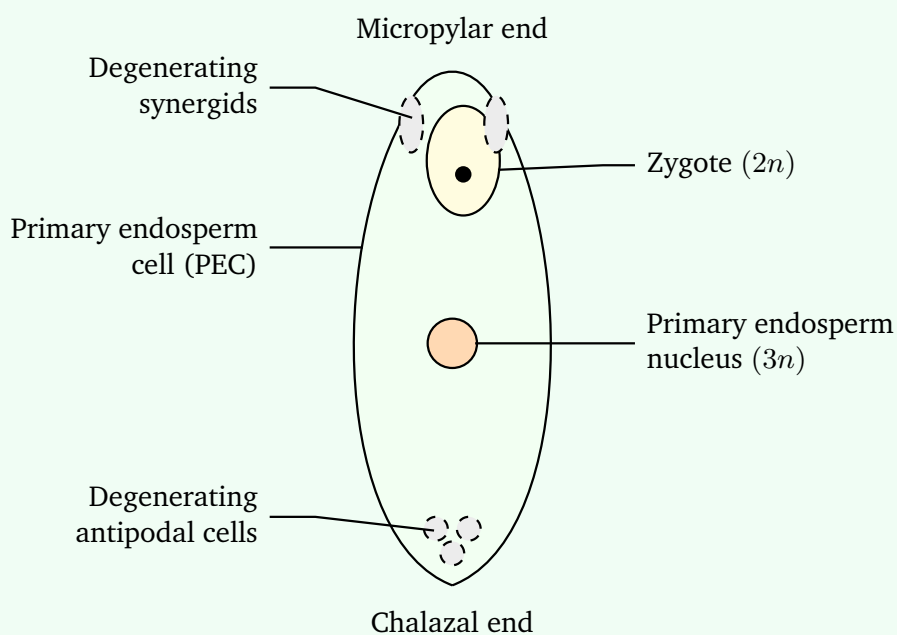
28. (a) Draw a schematic labelled diagram of a fertilised embryo sac of an Angiosperm. (b) Describe the stages in embryo development in a dicot plant. [5 marks]

Solution:

Concept:

- Double fertilisation produces a diploid zygote ($2n$) by syngamy and a triploid primary endosperm nucleus ($3n$) by triple fusion; n denotes one chromosome set.
- The zygote develops into the embryo, whereas the primary endosperm cell forms the nutritive endosperm. The synergids and antipodal cells generally degenerate after fertilisation.
- A dicot embryo develops through proembryo, globular and heart-shaped stages, finally differentiating into two cotyledons and an embryonal axis.

Step 1: (a) Identify the parts of the fertilised embryo sac Draw the zygote near the micropylar end and the primary endosperm nucleus within the large primary endosperm cell. Label their ploidy as $2n$ and $3n$, respectively. Show the degenerating synergids beside the zygote and the degenerating antipodal cells at the chalazal end. The schematic below represents the embryo sac shortly after double fertilisation, before extensive embryo and endosperm development.



Schematic fertilised embryo sac of an angiosperm

Step 2: (b) Form the proembryo and suspensor The zygote usually begins dividing after some endosperm has formed, ensuring a source of nutrition for the developing embryo. Its first division is transverse and unequal, producing a smaller terminal cell towards the interior of the embryo sac and a larger basal cell towards the micropyle. The terminal cell undergoes repeated divisions to form the embryo proper, first as a proembryo and then as a globular mass of cells. The basal cell divides

transversely to form a short filament called the suspensor, which pushes the young embryo into the nourishing endosperm. The suspensor cell adjoining the embryo contributes to the root tip region.

Step 3: Differentiate the dicot embryo Two cotyledon primordia arise from the globular embryo, giving it a characteristic heart-shaped appearance. Continued growth produces a mature embryo with two cotyledons attached to an embryonal axis. The part of the axis above the cotyledon attachment is the epicotyl and terminates in the plumule, the future shoot. The part below the cotyledon attachment is the hypocotyl and terminates in the radicle, the future root; a root cap covers the root tip. The suspensor eventually degenerates as the embryo matures. Thus, the successive stages are proembryo, globular embryo, heart-shaped embryo and mature dicot embryo.

Step 4: Conclusion The fertilised embryo sac contains a diploid zygote and a triploid primary endosperm nucleus. The zygote forms a mature dicot embryo with two cotyledons, an epicotyl ending in the plumule, and a hypocotyl ending in the radicle.

Quick Tip to Solve: In the embryo-sac sketch, put the zygote at the micropylar end and antipodals at the opposite end; remember that two emerging cotyledons produce the heart-shaped dicot embryo.

OR

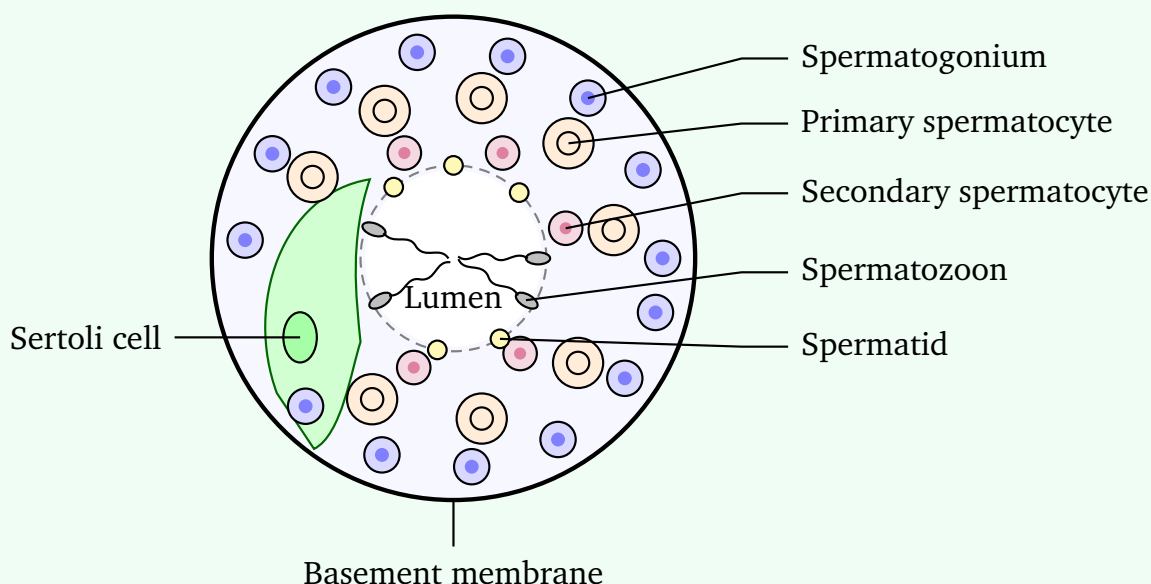
28. (a) Draw a labelled diagram of a sectional view of human seminiferous tubule. (b) Differentiate between gametogenesis in human males and females on the basis of: (i) time of initiation of the process. (ii) products formed at the end of the process. [5 marks]

Solution:

Concept:

- Spermatogenesis occurs in the germinal epithelium of seminiferous tubules. Germ cells mature from the basement membrane towards the lumen; Sertoli cells support and nourish them.
- Gametogenesis forms haploid gametes by meiosis. Spermatogenesis begins at puberty, whereas oogenesis begins during foetal life.
- Equal meiotic divisions in males produce four functional sperms from one primary spermatocyte; unequal divisions in females retain most cytoplasm in one functional ovum and produce polar bodies.

Step 1: (a) Draw and label the seminiferous tubule The sectional view below shows the basement membrane surrounding the germinal epithelium and a central lumen. Spermatogonia occupy the outermost germ-cell layer, next to the basement membrane. Primary spermatocytes lie inward from them, followed by secondary spermatocytes and spermatids. Spermatozoa are nearest the lumen, with their tails projecting into it. A Sertoli cell extends through the germinal epithelium and supports developing germ cells. The positions of the labels show this orderly progression towards the lumen.



Schematic sectional view of a human seminiferous tubule (selected cells enlarged).

Step 2: (b)(i) Compare the time of initiation In human males, spermatogenesis starts at puberty, when increased gonadotropin secretion activates the testes and spermatogonia begin producing spermatocytes. In human females, oogenesis starts during the embryonic or foetal stage: oogonia develop into primary oocytes before birth. These enter meiosis I and remain arrested in prophase I until later reproductive life. Thus, initiation of oogenesis must not be confused with its resumption after puberty.

Step 3: (b)(ii) Compare the products formed In males, the functional gametes are sperms or spermatozoa. One diploid primary spermatocyte undergoes meiosis I to form two haploid secondary spermatocytes; meiosis II produces four haploid spermatids, which differentiate into four spermatozoa by spermiogenesis.

In females, the functional gamete is an ovum. Unequal cytokinesis conserves cytoplasm in one large cell and forms small polar bodies, so one primary oocyte ultimately yields only one functional ovum. The secondary oocyte completes meiosis II after sperm entry, forming the ovum and second polar body. Polar bodies are not functional female gametes.

Step 4: Conclusion The labelled section shows germ cells maturing from the basement membrane towards the lumen, supported by Sertoli cells. Male gametogenesis starts at puberty and produces spermatozoa; female gametogenesis starts in foetal life and ultimately produces an ovum. Per primary meiocyte, the functional output is four sperms in males but one ovum in females.

Quick Tip to Solve: Label the tubule from outside inward: spermatogonia, primary spermatocytes, secondary spermatocytes, spermatids, spermatozoa. Pair puberty with males and foetal life with females.

29. Explain the steps involved in the production of genetically engineered insulin.

[5 marks]

Solution:

Concept:

- Human insulin consists of two polypeptide chains, A and B, joined by disulphide bonds. The A chain contains 21 amino acids and the B chain contains 30 amino acids.
- In humans, insulin is first made as proinsulin, which contains an additional connecting segment called the C peptide. Removal of the C peptide produces mature, functional insulin.
- Recombinant DNA technology allows the two human insulin chains to be produced separately in bacteria and then assembled into functional insulin.

Step 1: Prepare the DNA sequences for the two insulin chains Two DNA sequences corresponding to the A and B chains of human insulin are prepared separately. Each sequence specifies the amino acid sequence of one chain of mature human insulin. Preparing the chains separately avoids the need for the bacterial host to remove the C peptide from human proinsulin.

Step 2: Construct recombinant plasmids The DNA sequence for the A chain is inserted into a suitable bacterial plasmid, and the DNA sequence for the B chain is inserted into another plasmid. Restriction enzymes and DNA ligase are used to construct these recombinant DNA molecules. The plasmids carry expression signals that allow the inserted sequences to be expressed in the bacterial host.

Step 3: Introduce the recombinant plasmids into bacteria The recombinant plasmids are introduced separately into suitable *Escherichia coli* cells. The transformed bacteria carrying the respective recombinant plasmids are selected. Thus, one bacterial culture produces the A chain while a separate culture produces the B chain.

Step 4: Culture the bacteria and recover the chains The selected bacteria are grown under suitable controlled conditions on a large scale. As the cells express the inserted human DNA sequences, the two cultures produce the A and B polypeptide chains separately. The chains are then extracted from their respective cultures and purified.

Step 5: Assemble mature human insulin The purified A and B chains are combined under suitable conditions so that the correct disulphide bonds form between them. These bonds link the chains in the functional arrangement found in human insulin. The assembled insulin is purified and checked for quality before being prepared for therapeutic use. Eli Lilly used this approach to produce human insulin by recombinant DNA technology.

Step 6: Conclusion Genetically engineered insulin is produced by expressing the DNA sequences for the human A and B chains separately in *E. coli*, extracting and purifying the chains, and joining them through the correct disulphide bonds to form mature human insulin.

Quick Tip to Solve: Remember the order: prepare A- and B-chain DNA, insert into separate plasmids, express in bacteria, purify the chains, and join them by disulphide bonds. C peptide is absent from mature insulin.

29. (a) Name the nematode that infests and damages tobacco roots. (b) How are transgenic tobacco plants produced to solve this problem? [5 marks]

Solution:

Concept:

- RNA interference (RNAi) is a cellular defence mechanism in which double-stranded RNA complementary to a particular messenger RNA brings about sequence-specific silencing of that mRNA.
- A transgenic plant carries an introduced gene construct. In nematode-resistant tobacco, this construct produces complementary RNA strands corresponding to an essential nematode gene, preventing successful parasitism.

Step 1: (a) Identify the root parasite The root-knot nematode is *Meloidogyne incognita*. It infests the roots of tobacco plants and damages them, reducing the yield. Resistance is developed by targeting the expression of an essential gene of this nematode.

Step 2: (b) Introduce nematode-specific genetic material A suitable nematode-specific gene sequence is isolated and cloned. Using an *Agrobacterium* vector, this sequence is introduced into tobacco plant cells in a construct designed to produce both sense and antisense RNA. Transformed cells are selected and regenerated into transgenic tobacco plants carrying the construct.

Step 3: Produce complementary RNA and initiate RNA interference Expression of the introduced DNA in the host plant produces sense RNA and antisense RNA. These RNA molecules have complementary base sequences and pair to form double-stranded RNA (dsRNA). The dsRNA initiates RNA interference directed specifically against the corresponding nematode mRNA.

Step 4: Silence the nematode message and protect the plant When the nematode feeds on the transgenic plant, the RNAi response causes silencing of its complementary target mRNA. The dsRNA is processed into small interfering RNAs that guide sequence-specific destruction of the target mRNA. The message therefore cannot be translated into the essential protein. With this essential gene expression blocked, the parasite cannot survive successfully in the transgenic host. The tobacco plant is consequently protected against nematode infestation.

Step 5: Conclusion (a) The nematode is *Meloidogyne incognita*. (b) Tobacco plants are made resistant by introducing nematode-specific sequences that produce sense and antisense RNA; their dsRNA triggers RNAi, silences the nematode's target mRNA and prevents its survival in the host.

Quick Tip to Solve: Recall the sequence: nematode gene construct, sense plus antisense RNA, dsRNA, RNAi, silenced nematode mRNA, resistant tobacco.

30. What is 'semi-conservative' DNA replication? How was it experimentally proved and by whom?

[5 marks]

Solution:

Concept:

- In semi-conservative replication, the two parental DNA strands separate and each serves as a template for synthesis of a complementary new strand. Each daughter DNA double helix therefore contains one parental strand and one newly synthesised strand.
- Nitrogen is a constituent of DNA bases. DNA containing the stable heavy isotope ^{15}N has a greater density than DNA containing ^{14}N ; the two can be distinguished by equilibrium density-gradient centrifugation in caesium chloride (CsCl).
- A hybrid DNA molecule contains one heavy parental strand and one light newly synthesised strand. Its density is intermediate between that of fully heavy DNA and fully light DNA.

Step 1: Define the mode of replication and identify the scientists Semi-conservative replication conserves one complete strand of the original DNA molecule in each daughter molecule. The complementary new strand is assembled using the parental strand as its template. Thus, neither daughter molecule contains two newly made strands after the first replication. Matthew Meselson and Franklin Stahl experimentally demonstrated this mode of DNA replication in *Escherichia coli* in 1958.

Step 2: Label the parental DNA with heavy nitrogen They grew *E. coli* for several generations in a medium containing $^{15}\text{NH}_4\text{Cl}$, which supplied heavy nitrogen. The bacteria incorporated ^{15}N into their DNA bases, so that both strands of the parental DNA became heavy. DNA extracted from these bacteria formed a heavy-density band on centrifugation in a CsCl density gradient.

Step 3: Transfer the bacteria to light nitrogen and examine the first generation The labelled bacteria were transferred to a medium containing normal $^{14}\text{NH}_4\text{Cl}$. DNA was extracted after one generation, approximately 20 minutes, and separated by CsCl density-gradient centrifugation. Only one band appeared, at an intermediate density. Each DNA molecule had one old ^{15}N -labelled strand and one new ^{14}N -containing strand. If replication had been conservative, the original heavy double helix would have remained intact and a separate light double helix would have formed, producing two distinct bands at this stage. The single intermediate band ruled out that prediction.

Step 4: Examine the second generation and interpret the two bands After two generations in the light medium, approximately 40 minutes after transfer, the extracted DNA produced two bands: one intermediate-density band and one light-density band, in approximately equal amounts. Each first-generation hybrid molecule produced one hybrid daughter molecule and one fully light daughter molecule. Hence, half of the DNA molecules contained one heavy and one light strand, while the other half contained two light strands. There was no fully heavy band. A dispersive mechanism would instead have produced DNA with heavy material distributed through both strands and a single band shifting progressively towards the light position. The distinct hybrid and light bands supported conservation of an intact parental strand in each daughter molecule.

Step 5: Conclusion Meselson and Stahl proved semi-conservative DNA replication in *E. coli*: each daughter DNA molecule contains one parental strand and one newly synthesised strand. The decisive observations were a single hybrid-density band after the first generation and equal amounts of hybrid and light DNA after the second generation in ^{14}N medium.

Quick Tip to Solve: Track individual strands: heavy-heavy parental DNA gives only heavy-light DNA after one generation, then equal numbers of heavy-light and light-light molecules after two generations.

30. A homozygous tall pea plant with green seeds is crossed with a dwarf pea plant with yellow seeds. (i) What would be the phenotype and genotype of F_1 ? (ii) Work out the phenotypic ratio of F_2 generation with the help of a Punnett square. [5 marks]

Solution:

Concept:

- In pea plants, tallness T is dominant over dwarfness t , and yellow seed colour Y is dominant over green seed colour y . A recessive phenotype therefore identifies a homozygous recessive genotype.
- A dihybrid cross follows two gene pairs. During gamete formation, the alleles of each pair segregate, and the two pairs assort independently, producing four equally frequent gamete types from $TtYy$.
- Fertilisation combines one gamete from each parent. A Punnett square lists all equally likely combinations, after which dominance determines the phenotype of each offspring.

Step 1: Set up the parental cross For the pure parental lines used in this dihybrid cross, the homozygous tall, green-seeded plant is $TTyy$, while the dwarf, yellow-seeded plant is $ttYY$. Green seeds require yy , and dwarfness requires tt . Thus the parental cross and their gametes are

$$P : TTyy \text{ (tall, green)} \times ttYY \text{ (dwarf, yellow)},$$

$$\text{Gametes : } Ty \qquad tY.$$

Each parental plant contributes only one type of gamete because both gene pairs are homozygous.

Step 2: Determine the first filial generation Every union of Ty with tY produces the same combination, $TtYy$. Therefore all F_1 plants are heterozygous for both characters. Each has the dominant allele T , so it is tall, and the dominant allele Y , so its seeds are yellow. The recessive alleles t and y remain present but are masked in the phenotype.

Step 3: Form the gametes for the second filial generation Self-pollinate the F_1 plants:

$$TtYy \times TtYy.$$

By independent assortment, either height allele can accompany either seed-colour allele. Each parent therefore produces TY , Ty , tY and ty gametes, each with probability $1/4$. Place these four gametes along both sides of the Punnett square.

Step 4: Complete the Punnett square and classify the offspring The sixteen equally likely fertilisation combinations are

	TY	Ty	tY	ty
TY	$TTY Y$	$TTY y$	$TtY Y$	$TtY y$
Ty	$TTY y$	$TTyy$	$TtY y$	$Ttyy$
tY	$TtY Y$	$TtY y$	$ttY Y$	$ttY y$
ty	$TtY y$	$Ttyy$	$ttY y$	$tt yy$

An underscore below denotes either possible second allele. Counting the cells gives nine $T_Y_$ plants (tall, yellow), three T_yy plants (tall, green), three $ttY_$ plants (dwarf, yellow), and one $tt yy$ plant (dwarf, green). Both parental combinations and new combinations occur because the two allele pairs

assort independently.

Step 5: Conclusion (i) All F_1 plants have genotype $TtYy$ and phenotype tall with yellow seeds. (ii) The F_2 phenotypic ratio is 9 tall yellow : 3 tall green : 3 dwarf yellow : 1 dwarf green.

Quick Tip to Solve: Write the four gametes in the same order along both sides of the square. Count tall yellow first: yellow, rather than green, is the dominant seed colour in peas.