

CBSE Class 12 Biology Question Paper 2014 with Solution PDF-Set 57/1

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. Name the part of the flower which the tassels of the corn-cob represent.

[1 mark]

Solution:

Concept:

- The stigma is the pollen-receptive part of the pistil, while the style connects it to the ovary.
- In maize, the long silky structures of the female inflorescence extend outside the cob to receive wind-borne pollen.

Step 1: Identify the floral structure The hair-like tassels or silks projecting from the corn-cob belong to the female flowers. Each silk is associated with an ovule in the cob.

Step 2: Relate its structure to pollination The elongated style and stigma project beyond the enclosing leaves. Their exposed pollen-receptive surface helps trap airborne pollen grains during wind pollination.

Step 3: Conclusion The tassels of the corn-cob represent the elongated styles and stigmas of the female flowers.

Quick Tip to Solve: Associate the silk of a corn-cob with pollen reception: style and stigma.

2. Mention any two contrasting traits with respect to seeds in pea plant that were studied by Mendel.

[1 mark]

Solution:

Concept:

- Mendel studied pairs of contrasting, heritable characters in the garden pea, *Pisum sativum*.
- Seed shape and seed colour are distinct characters; each has two contrasting forms.

Step 1: State the contrast in seed shape For seed shape, Mendel studied round seeds and wrinkled seeds. Round is the dominant form and wrinkled is the recessive form.

Step 2: State the contrast in seed colour For seed colour, he studied yellow seeds and green seeds. Yellow is the dominant form and green is the recessive form. These pairs concern seeds, as required, rather than flower colour or pod shape.

Step 3: Conclusion The contrasting seed traits were round versus wrinkled seed shape, and yellow versus green seed colour.

Quick Tip to Solve: For seed traits, remember two pairs: round/wrinkled and yellow/green.

3. Why is secondary immune response more intense than the primary immune response in humans?

[1 mark]

Solution:

Concept:

- The primary immune response is produced on the first encounter with a particular antigen.
- Adaptive immunity has memory: antigen-specific memory B and T lymphocytes persist after the first response.

Step 1: Explain what the first exposure leaves behind During the primary response, lymphocytes specific to the antigen become activated and multiply. Some of these cells persist as memory cells even after the infection has been controlled.

Step 2: Explain the response to a later exposure On subsequent exposure to the same antigen, memory cells recognise it and mount a faster, much stronger response. Memory B cells rapidly give rise to antibody-producing plasma cells, so antibody production is greater than during the first encounter.

Step 3: Conclusion The secondary immune response is more intense because memory cells formed during the primary response rapidly respond to the same antigen.

Quick Tip to Solve: Link the stronger second response to antigen-specific memory cells formed on first exposure.

4. Why is it not possible for an alien DNA to become part of a chromosome anywhere along its length and replicate normally?

[1 mark]

Solution:

Concept:

- DNA replication begins at a specific sequence called the origin of replication, or ori.
- A foreign DNA fragment must be linked to DNA with a functional origin to be maintained and copied in a suitable host.

Step 1: Identify the requirement for replication An arbitrary DNA sequence is not a site from which replication can initiate. Initiation requires a functional origin of replication recognised by the host replication machinery.

Step 2: Apply this requirement to alien DNA Merely introducing alien DNA at an arbitrary location does not ensure its stable linkage to a replicating DNA molecule. In recombinant DNA technology, it is linked to a vector bearing a suitable ori; replication of that molecule then copies the inserted DNA as well.

Step 3: Conclusion Normal multiplication of alien DNA requires its linkage to a replicating DNA molecule with a functional origin of replication (ori); an arbitrary DNA site is not an origin.

Quick Tip to Solve: For replication of alien DNA, identify the vector sequence ori, not the selectable marker.

5. State the role of C peptide in human insulin.

[1 mark]

Solution:

Concept:

- Human insulin is initially synthesised as proinsulin, which contains an additional connecting segment called C peptide.
- Mature insulin consists of A and B polypeptide chains linked by disulphide bonds; C peptide is removed during maturation.

Step 1: Describe its role in the precursor C peptide connects the A-chain and B-chain regions in proinsulin. This connecting segment helps the precursor fold so that the appropriate disulphide bonds between the future insulin chains can form.

Step 2: Explain what happens during maturation During processing of proinsulin, C peptide is cleaved away. The A and B chains remain joined by disulphide bonds to form mature, functional insulin; the connecting peptide is not part of this mature hormone.

Step 3: Conclusion C peptide connects the A and B chains in proinsulin and aids proper folding; it is removed when proinsulin matures into insulin.

Quick Tip to Solve: Distinguish proinsulin from mature insulin by the presence or removal of C peptide.

6. Name the enzymes that are used for the isolation of DNA from bacterial and fungal cells for recombinant DNA technology.

[1 mark]

Solution:

Concept:

- Isolation of DNA begins by breaking the cell wall and opening the cell to release its genetic material.
- The enzyme chosen depends on the composition of the cell wall: bacterial walls contain peptidoglycan, while fungal walls contain chitin.

Step 1: Choose the enzyme for bacterial cells Bacterial cells are treated with lysozyme. It breaks down peptidoglycan in the bacterial cell wall, allowing the cells to be lysed and their contents, including DNA, to be released.

Step 2: Choose the enzyme for fungal cells Fungal cells are treated with chitinase. It hydrolyses chitin in the fungal cell wall and helps release the cell contents for subsequent DNA purification. These enzymes disrupt walls; they are not used to cut the isolated DNA.

Step 3: Conclusion Lysozyme is used for bacterial cells, and chitinase is used for fungal cells.

Quick Tip to Solve: Match the wall to its enzyme: bacterial peptidoglycan–lysozyme; fungal chitin–chitinase.

7. State Gause's Competitive Exclusion Principle.

[1 mark]

Solution:

Concept:

- Competition occurs when organisms depend on the same limited resource.
- Gause's principle concerns the long-term coexistence of species with identical resource requirements.

Step 1: Identify the condition Consider two closely related species occupying the same ecological niche and competing for the same limiting resources under constant environmental conditions.

Step 2: State the outcome of competition Such species cannot coexist indefinitely; the competitively superior species eventually eliminates the inferior species locally. The principle applies when the resource is limiting; differences in resource use can permit coexistence.

Step 3: Conclusion Gause's Competitive Exclusion Principle states that two closely related species competing for the same limiting resources cannot coexist indefinitely; the competitively inferior species is eventually excluded.

Quick Tip to Solve: Include both the limiting resource and eventual exclusion when stating Gause's principle.

8. Name the type of association that the genus *Glomus* exhibits with higher plants.

[1 mark]

Solution:

Concept:

- Mycorrhiza is an association between a fungus and the roots of a higher plant.
- In mutualism, both participating organisms benefit from the association.

Step 1: Name the partners The genus *Glomus* is a fungus that associates with the roots of higher plants, forming mycorrhiza.

Step 2: Explain the reciprocal benefit The fungal partner helps the plant absorb phosphorus and water from the soil. In return, the plant supplies the fungus with organic food produced by photosynthesis, so both partners benefit.

Step 3: Conclusion *Glomus* exhibits a mutualistic symbiotic association, called mycorrhiza, with the roots of higher plants.

Quick Tip to Solve: Link *Glomus* to mycorrhiza: the fungus supplies mineral nutrients and the plant supplies food.

Section B (20 marks)

9. Why are the human testes located outside the abdominal cavity? Name the pouch in which they are present. [2 marks]

Solution:

Concept:

- Spermatogenesis is the formation of sperm in the seminiferous tubules of the testes.
- Normal sperm formation requires a temperature below the internal body temperature.

Step 1: Explain the location of the testes Human testes are situated outside the abdominal cavity to maintain a temperature about 2–2.5 °C lower than the normal internal body temperature. This lower temperature is essential for normal spermatogenesis. The abdominal cavity is too warm for efficient sperm formation; the external position allows heat exchange with the surroundings.

Step 2: Name the enclosing pouch The testes lie in a pouch of skin called the scrotum, or scrotal sac. The scrotum provides the cooler environment needed for sperm production. Thus, the question asks about temperature regulation for spermatogenesis, rather than simply physical accommodation of the testes.

Step 3: Conclusion The testes lie outside the abdominal cavity to maintain the lower temperature required for spermatogenesis. They are present in the scrotum (scrotal sac).

Quick Tip to Solve: Connect the external location to sperm formation and name the pouch as the scrotum.

10. In Snapdragon, a cross between true-breeding red flowered (RR) plants and true-breeding white flowered (rr) plants showed a progeny of plants with all pink flowers. (a) The appearance of pink flowers is not known as blending. Why? (b) What is this phenomenon known as? [2 marks]

Solution:

Concept:

- Alleles are alternative forms of a gene; they retain their identities during inheritance.
- Incomplete dominance produces an intermediate phenotype in the heterozygote.

Step 1: (a) Explain why this is not blending The cross $RR \times rr$ produces only Rr plants in the F_1 , and these have pink flowers. However, the alleles R and r do not permanently mix or lose their identities. On selfing the pink plants, $Rr \times Rr$, the F_2 genotypes are $RR : Rr : rr = 1 : 2 : 1$, giving red, pink and white flowers in the same ratio. The reappearance of both parental colours demonstrates segregation of intact alleles, which would not occur under permanent blending.

Step 2: (b) Name the inheritance pattern Neither allele completely dominates the other in the heterozygote. Consequently, the Rr flower colour is intermediate between that of the two homozygotes. This phenomenon is called incomplete dominance.

Step 3: Conclusion (a) It is not blending because the alleles retain their identities and red and white flowers reappear in the F_2 generation. (b) The phenomenon is incomplete dominance.

Quick Tip to Solve: Use the reappearance of red and white flowers in the F_2 generation to rule out blending.

11. With the help of one example, explain the phenomena of co-dominance and multiple allelism in human population. [2 marks]

Solution:

Concept:

- Co-dominance means that both alleles express themselves in a heterozygote.
- Multiple allelism means that a gene has more than two alternative alleles in a population, although a diploid individual carries only two.

Step 1: Explain co-dominance using ABO blood groups In the human ABO blood-group system, I^A and I^B are co-dominant. A person with genotype $I^A I^B$ has blood group AB and expresses both A and B antigens on red blood cells. Both alleles express their effects together; neither masks the other, and no intermediate antigen is formed.

Step 2: Explain multiple allelism using the same example The ABO blood-group gene has three alleles in the human population: I^A , I^B and i . The presence of these three alternatives at one locus illustrates multiple allelism. Each person inherits only two alleles, one from each parent; the three alternatives exist across the population. Both I^A and I^B are dominant over i .

Step 3: Conclusion Human ABO blood groups illustrate both phenomena: $I^A I^B$ expresses co-dominance, while the three population alleles I^A , I^B and i demonstrate multiple allelism.

Quick Tip to Solve: Use AB to show simultaneous expression, and list all three ABO alleles to show multiple allelism.

12. Write the scientific name of the fruit-fly. Why did Morgan prefer to work with fruit-flies for his experiments? State any three reasons. [2 marks]

Solution:

Concept:

- A suitable experimental organism permits controlled breeding and observation of inherited traits over many generations.
- The scientific name is written with the genus capitalised and the species in lower case; both are italicised.

Step 1: Name the experimental organism The fruit-fly used by Morgan was *Drosophila melanogaster*. Morgan studied the inheritance of visible characters in this organism by making controlled crosses.

Step 2: State three advantages for breeding experiments First, fruit-flies can be grown easily in the laboratory on a simple synthetic medium, so cultures can be maintained economically. Second, their life cycle is short, about two weeks, allowing Morgan to follow several generations in a short time. Third, a single mating produces a large number of offspring, providing enough individuals to detect inheritance patterns and compare observed ratios reliably.

Step 3: Conclusion The fruit-fly is *Drosophila melanogaster*. Easy laboratory culture, a short life cycle and numerous offspring per mating made it suitable for Morgan's experiments.

Quick Tip to Solve: Remember three breeding advantages: easy culture, a two-week life cycle and many offspring.

12. Linkage and crossing-over of genes are alternatives of each other. Justify with the help of an example. [2 marks]

Solution:

Concept:

- Linkage is the tendency of genes on the same chromosome to be inherited together, preserving parental combinations.
- Crossing-over is the exchange of corresponding segments between non-sister chromatids of homologous chromosomes during prophase I of meiosis; it can generate recombinant combinations.

Step 1: Explain the opposite effects Linked genes tend to pass into the same gamete together. Crossing-over between the two gene loci can break their association and produce new combinations of alleles. Thus linkage favours parental combinations, whereas crossing-over produces recombination. In this sense they are alternatives in their effect on inheritance; linkage does not mean that crossing-over is impossible.

Step 2: Illustrate with linked genes in fruit-flies Consider the linked genes for body colour and wing size in *Drosophila*. A heterozygous female with grey body and normal wings, carrying the grey-normal alleles together and the black-vestigial alleles together, can produce parental grey-normal and black-vestigial combinations through linkage. Crossing-over between these loci can instead produce grey-vestigial and black-normal combinations. Parental combinations are more frequent because these genes are linked.

Step 3: Conclusion Linkage maintains parental gene combinations, while crossing-over breaks that association and yields recombinant combinations, as illustrated by body colour and wing size in fruit-flies.

Quick Tip to Solve: For an example, name two linked traits and contrast the parental combinations with the recombinant combinations.

13. List the symptoms of Ascariasis. How does a healthy person acquire this infection? [2 marks]

Solution:

Concept:

- Ascariasis is a helminthic disease caused by the intestinal roundworm *Ascaris lumbricoides*.
- Its infective eggs can enter the body through food or water contaminated with human faecal matter.

Step 1: List the symptoms Ascariasis may cause internal bleeding, muscular pain, fever, anaemia and blockage of the intestinal passage. The blockage is associated with the presence of worms in the intestine; these manifestations describe the disease rather than the route by which it spreads.

Step 2: Explain acquisition of the infection An infected person passes parasite eggs in faeces. These eggs can contaminate soil, water, vegetables and other food. A healthy person becomes infected by swallowing infective eggs with contaminated drinking water or inadequately washed food. This is a faeco-oral route of transmission; the infection is not acquired merely by standing near an infected

person.

Step 3: Conclusion Symptoms include internal bleeding, muscular pain, fever, anaemia and intestinal blockage. Infection is acquired by ingesting infective eggs in faecally contaminated food or water.

Quick Tip to Solve: Link the two parts: list the NCERT symptoms, then trace eggs from faeces to contaminated food or water.

14. Explain the significant role of the genus *Nucleopolyhedrovirus* in an ecological sensitive area.

[2 marks]

Solution:

Concept:

- *Nucleopolyhedrovirus* is a genus of baculoviruses used as biological control agents against insect pests.
- An effective biocontrol agent should suppress the target pest while conserving useful organisms and ecological balance.

Step 1: Explain its pest-control action Viruses of the genus *Nucleopolyhedrovirus* act as species-specific, narrow-spectrum insecticidal agents. They infect susceptible target insects and help reduce the pest population. Their restricted host range makes them useful where pest control must be selective.

Step 2: Explain its ecological importance These baculoviruses have no negative impacts on plants, mammals, birds, fish or non-target insects. Beneficial insects are therefore conserved, including the natural enemies that help control other pests. This property is especially valuable in ecologically sensitive areas, where indiscriminate pest control can disturb biodiversity and food webs. They are also useful in integrated pest management programmes that conserve beneficial insects.

Step 3: Conclusion *Nucleopolyhedrovirus* provides selective biological control of insect pests while sparing non-target organisms, making it valuable in ecologically sensitive areas and integrated pest management.

Quick Tip to Solve: Connect narrow host specificity with conservation of non-target organisms and beneficial insects.

15. How does a restriction nuclease function? Explain.

[2 marks]

Solution:

Concept:

- Restriction endonucleases cut DNA internally at specific recognition sequences; exonucleases instead remove nucleotides from DNA ends.
- A recognition sequence is commonly a short palindromic DNA sequence: its two strands read the same in the 5'-to-3' direction.

Step 1: Recognition of the target sequence The restriction endonuclease first binds to DNA and

scans its length. It recognises its specific sequence, usually a short palindrome, and binds at that site. Recognition makes the action sequence-specific rather than random.

Step 2: Cleavage of the DNA backbone At the recognised site, or at a characteristic position near it, the enzyme hydrolyses phosphodiester bonds in both DNA strands. For example, EcoRI recognises 5'-GAATTC-3' and cuts between G and A on each strand. The staggered cuts produce complementary single-stranded sticky ends; other restriction enzymes can produce blunt ends. These fragments can subsequently be joined to compatible DNA by DNA ligase.

Step 3: Conclusion Thus, a restriction endonuclease acts as a sequence-specific molecular scissor, recognising a particular DNA sequence and cleaving the two DNA strands to form defined fragments.

Quick Tip to Solve: Describe recognition first and phosphodiester-bond cleavage second; sticky ends are the result for enzymes such as EcoRI.

16. How have transgenic animals proved to be beneficial in: (a) Production of biological products (b) Chemical safety testing [2 marks]

Solution:

Concept:

- A transgenic animal contains and expresses an introduced foreign gene, allowing a chosen protein or biological response to be studied.
- Such animals can produce useful human proteins and can serve as sensitive experimental models for toxicity testing.

Step 1: Production of biological products A gene encoding a useful human protein can be introduced into an animal so that the protein is expressed, for example, in its milk. The product can then be collected and purified for medical use. Transgenic animals have been used to produce human α -1-antitrypsin, which is used to treat emphysema. Thus, the animal becomes a source of a therapeutic biological product.

Step 2: Chemical safety testing Transgenic animals can be made to carry genes that make them more sensitive to toxic substances than ordinary animals. They are exposed to a chemical under controlled conditions, and the resulting effects are observed. This helps assess the toxicity or safety of the chemical and can yield results in less time than conventional animal testing.

Step 3: Conclusion Transgenic animals therefore help manufacture therapeutic biological products and provide sensitive models for testing chemical toxicity.

Quick Tip to Solve: For each use, state what the introduced gene enables: protein production in one case and increased toxicant sensitivity in the other.

17. Describe the mutual relationship between fig tree and wasp and comment on the phenomenon that operates in their relationship. [2 marks]

Solution:

Concept:

- Mutualism is an interaction in which both participating species benefit.
- Coevolution occurs when interacting species undergo reciprocal evolutionary adaptations in response to each other.

Step 1: Explain the benefits to both partners A female fig wasp enters the fig inflorescence to lay her eggs. She uses the fig as an oviposition site, and the developing larvae obtain nourishment from some of the developing seeds. While searching for suitable sites and laying eggs, the wasp transfers pollen and pollinates the fig flowers. The fig gains pollination, while the wasp gains a protected breeding site and food for its offspring.

Step 2: Identify the phenomenon This highly specific pollinator relationship illustrates coevolution. Particular fig species and their associated wasp species have evolved adaptations suited to one another. The wasp depends on the fig for reproduction, and the fig depends on its wasp pollinator for successful pollination. Reciprocal selection maintains this close association; the benefit to the fig outweighs the loss of some seeds to larvae.

Step 3: Conclusion The fig and wasp exhibit mutualism, and the specificity of their association reflects coevolution between the plant and its pollinator.

Quick Tip to Solve: Name both gains before naming coevolution: the fig receives pollination; the wasp receives a breeding site and larval food.

18. Construct an age pyramid which reflects an expanding growth status of human population.

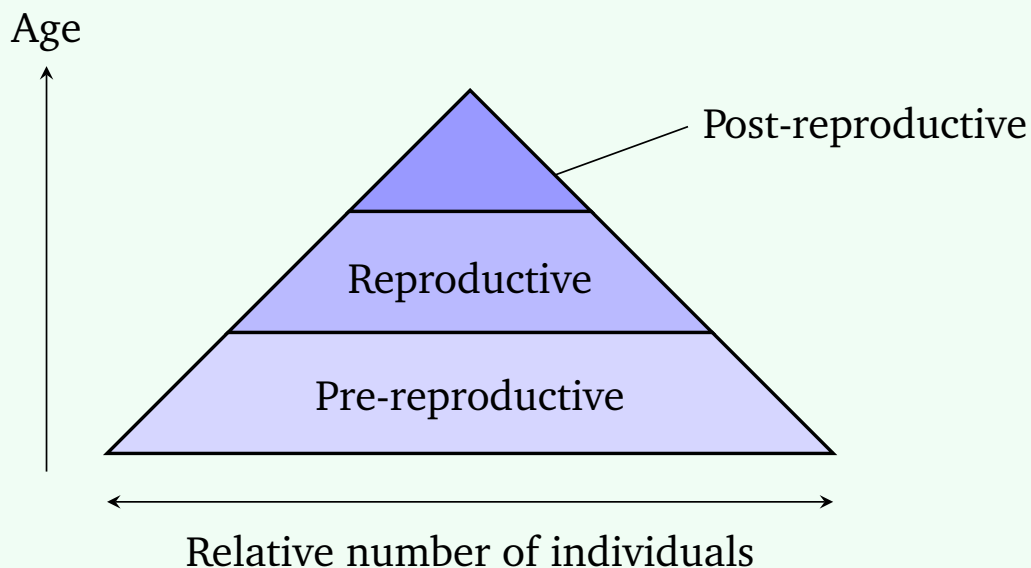
[2 marks]

Solution:

Concept:

- An age pyramid represents the relative proportions of individuals in pre-reproductive, reproductive and post-reproductive age groups.
- An expanding population has a broad pre-reproductive base, a narrower reproductive middle and a small post-reproductive apex.

Step 1: Construct the expanding pyramid Draw a triangular age pyramid with its widest tier at the base. Label this tier pre-reproductive, the middle tier reproductive, and the narrow upper tier post-reproductive. The horizontal width of each tier represents the relative number of people in that age group. The labelled schematic below shows the required pattern; its widths indicate relative proportions rather than measured census values.



Expanding human population: relative age-group proportions

Step 2: Interpret the growth status The pre-reproductive group is larger than the reproductive group, so a large number of young individuals will enter reproductive ages in the future. The progressively narrower tiers towards older ages produce the characteristic triangular outline. This youthful age structure therefore indicates an expanding population and the potential for continued population increase.

Step 3: Conclusion A triangular age pyramid with a broad pre-reproductive base and a narrow post-reproductive apex represents an expanding human population.

Quick Tip to Solve: Check the base first: an expanding population must contain more pre-reproductive individuals than reproductive individuals.

Section C (27 marks)

19. Make a list of any three outbreeding devices that flowering plants have developed and explain how they help to encourage cross-pollination. [3 marks]

Solution:

Concept:

- Outbreeding devices are adaptations that prevent self-pollination or prevent self pollen from achieving fertilisation, thereby favouring cross-pollination.
- Autogamy is pollen transfer within the same flower; geitonogamy is pollen transfer between flowers of the same plant. Xenogamy involves flowers of different plants of the same species.

Step 1: Explain dichogamy In dichogamy, pollen release from the anther and receptivity of the stigma of the same flower are not synchronised. The anthers may mature before the stigma becomes receptive, or the stigma may become receptive before the anthers mature. Consequently, self pollen is

not available when that flower's stigma is receptive, preventing autogamy and favouring receipt of pollen from another flower.

Step 2: Explain herkogamy In herkogamy, the anthers and stigma occupy different positions in the flower. This spatial separation prevents the flower's own pollen from coming into contact with its stigma. A pollinating agent can instead bring pollen from another flower to the stigma, so the arrangement discourages autogamy and encourages cross-pollination.

Step 3: Explain self-incompatibility Self-incompatibility is a genetically controlled mechanism by which the pistil recognises and rejects self pollen. Rejection may inhibit pollen germination on the stigma or stop pollen-tube growth in the pistil. Thus even if self pollen reaches the stigma, it cannot fertilise the ovule; compatible pollen from another plant is required for successful fertilisation.

Step 4: Conclusion Three outbreeding devices are dichogamy, herkogamy and self-incompatibility. They act respectively through separation in time, separation in position and genetic rejection of self pollen.

Quick Tip to Solve: Link each device to its mechanism: dichogamy means time separation, herkogamy means spatial separation, and self-incompatibility means rejection of self pollen.

OR

19. Why are angiosperm anthers called dithecal? Describe the structure of its microsporangium.

[3 marks]

Solution:

Concept:

- A typical angiosperm anther is bilobed and dithecal, with two thecae. Its transverse section shows four microsporangia, two in each lobe.
- A microsporangium contains central sporogenous tissue surrounded by a wall of four layers, which support pollen formation and anther function.

Step 1: Explain the term dithecal A typical angiosperm anther has two lobes, joined by connective tissue. It is called dithecal because it has two thecae. A longitudinal groove commonly separates the two thecae. In transverse section, the anther is approximately four-sided and has four microsporangia located towards its corners, with two microsporangia in each lobe. The microsporangia develop into pollen sacs.

Step 2: Describe the microsporangial wall From outside to inside, the microsporangium is surrounded by four wall layers: epidermis, endothecium, middle layers and tapetum. The outermost epidermis provides protection. The endothecium develops characteristic thickenings that help the mature anther dehisce and release pollen. The middle layers assist during early development and usually degenerate as the anther matures. The innermost layer, the tapetum, nourishes the developing pollen grains; its cells have dense cytoplasm and commonly more than one nucleus.

Step 3: Describe the central tissue A young microsporangium contains a compact mass of homogeneous sporogenous tissue at its centre. As the anther develops, sporogenous cells differentiate into

microspore mother cells, also called pollen mother cells. Each diploid mother cell undergoes meiosis to form a tetrad of haploid microspores. The microspores separate and develop into pollen grains within the pollen sac.

Step 4: Conclusion The anther is dithecal because it has two thecae. Each microsporangium consists of a four-layered wall enclosing sporogenous tissue that produces microspores by meiosis.

Quick Tip to Solve: Recall the wall from outside inward as epidermis, endothecium, middle layers and tapetum; place the pollen mother cells at the centre.

20. If implementation of better techniques and new strategies are required to provide more efficient care and assistance to people, then why is there a statutory ban on amniocentesis? Write the use of this technique and give reason to justify the ban. [3 marks]

Solution:

Concept:

- Amniocentesis is a prenatal diagnostic technique in which a sample of amniotic fluid containing foetal cells is collected for examination.
- A medical technique can benefit maternal and foetal care while still requiring restriction of a harmful use. The statutory prohibition referred to here concerns misuse for prenatal sex determination and sex-selective abortion.

Step 1: State the diagnostic use The amniotic fluid surrounding the developing foetus contains cells shed by the foetus. These cells can be examined for their chromosomes and tested for certain genetic abnormalities. Thus amniocentesis is used for prenatal diagnosis of chromosomal disorders, such as Down's syndrome, and certain inherited disorders. Such information can assist medical assessment and counselling concerning the pregnancy.

Step 2: Identify the misuse Examination of the foetal chromosomes can also reveal the sex of the foetus. The technique was misused to identify female foetuses so that pregnancies could be selectively terminated because of a preference for sons. This use does not provide treatment or improve the health of the foetus; it facilitates discrimination against the girl child before birth.

Step 3: Justify the statutory restriction Prenatal sex determination for sex selection and the resulting female foeticide undermine the equal value of girls and boys and disturb the population sex ratio. A statutory ban on this misuse is therefore necessary to prevent sex-selective abortions and protect the girl child. The question's reference to a ban should be understood in this context: legitimate prenatal diagnosis of genetic abnormalities has a beneficial medical purpose, whereas using the technique to select a child's sex is prohibited.

Step 4: Conclusion Amniocentesis is useful for detecting foetal chromosomal and genetic disorders. Its misuse for prenatal sex determination leading to female foeticide justifies the statutory prohibition on that use.

Quick Tip to Solve: Separate the legitimate use, prenatal diagnosis of genetic disorders, from the banned misuse, sex determination followed by sex-selective abortion.

21. Why is pedigree analysis done in the study of human genetics? State the conclusions that can be drawn from it. [3 marks]

Solution:

Concept:

- A pedigree is a record of the occurrence of a particular trait in members of a family over several generations.
- Inheritance patterns are inferred by comparing affected and unaffected relatives, their sex, and the transmission of the trait from parents to offspring.

Step 1: Explain why pedigree analysis is needed Controlled crosses cannot be performed in humans as they are in experimental organisms. Human generation time is long and families usually have few offspring, so experimental study of inheritance is also impractical. Pedigree analysis uses the existing family history to trace the inheritance of a trait or genetic disorder through successive generations.

Step 2: Identify the pattern of inheritance From the distribution of affected individuals, one can infer whether a trait is dominant or recessive and whether it is autosomal or sex-linked. For example, unaffected parents producing an affected child suggest recessive inheritance under a simple Mendelian model. A dominant trait commonly appears in successive generations, while characteristic differences in transmission through males and females help identify sex linkage.

Step 3: Infer genotypes and inheritance risk Once the inheritance pattern is established, the pedigree helps infer possible genotypes of relatives and identify carriers of recessive alleles where the family relationships permit. It can also help estimate the probability that future offspring will inherit or express the disorder. These conclusions support genetic counselling; an unaffected appearance alone does not always exclude carrier status.

Step 4: Conclusion Pedigree analysis is used because controlled human crosses are not feasible. It reveals the mode of inheritance of a trait, helps infer affected and carrier genotypes, and assists in estimating the risk to offspring.

Quick Tip to Solve: Link the need to the impossibility of controlled human crosses, then list inheritance pattern, carrier detection and offspring risk.

22. Identify 'a', 'b', 'c', 'd', 'e' and 'f' in the table given below :

No.	Syndrome	Cause	Characteristics of affected individuals	Sex (Male/Female/Both)
1.	Down's	Trisomy of 21	'a' (i) (ii)	'b'
2.	'c'	XXY	Overall masculine development	'd'
3.	Turner's	45 with XO	'e' (i) (ii)	'f'

[3 marks]

Solution:

Concept:

- Aneuploidy is an abnormal number of individual chromosomes, commonly resulting from failure of chromosome segregation during cell division.
- Down's syndrome involves an extra chromosome 21, whereas Klinefelter's and Turner's syndromes involve abnormal sex-chromosome complements.

Step 1: Fill the blanks for Down's syndrome The printed cause is trisomy of chromosome 21, so the affected individual has three copies of chromosome 21 and usually a total of 47 chromosomes. For *a*, two characteristic features are (i) short stature with a small, round head and (ii) a partially open mouth with a protruding, furrowed tongue. Since the extra chromosome is an autosome, the syndrome can affect either sex. Thus *b* is Both (male and female).

Step 2: Identify the syndrome associated with XXY The sex-chromosome constitution *XXY* identifies Klinefelter's syndrome, so *c* is Klinefelter's syndrome. The presence of the Y chromosome produces overall masculine development, as stated in the table. The extra X chromosome is associated with underdeveloped testes and sterility, and breast development may occur. Hence the affected sex, *d*, is Male.

Step 3: Fill the blanks for Turner's syndrome Turner's syndrome has a total of 45 chromosomes, with only one X chromosome; *XO* denotes the absence of a second sex chromosome. For *e*, two features are (i) rudimentary ovaries causing sterility and (ii) poorly developed female secondary sexual characteristics. The affected individual is female, so *f* is Female. Here *O* represents an absent chromosome, rather than a chromosome type.

Step 4: Conclusion *a*: (i) short stature with a small, round head, (ii) partially open mouth with a protruding, furrowed tongue; *b*: Both; *c*: Klinefelter's syndrome; *d*: Male; *e*: (i) rudimentary ovaries and sterility, (ii) poorly developed female secondary sexual characteristics; *f*: Female.

Quick Tip to Solve: Separate autosomal trisomy 21 (both sexes) from XXY (male) and XO (female) before filling the characteristic features.

23. Community Service department of your school plans a visit to a slum area near the school with an objective to educate the slum dwellers with respect to health and hygiene. (a) Why is there a need to organise such visits? (b) Write the steps you will highlight, as a member of this department, in your interaction with them to enable them to lead a healthy life. [3 marks]

Solution:

Concept:

- Personal hygiene and community sanitation reduce exposure to pathogens and interrupt the routes by which infectious diseases spread.
- Health education helps people adopt preventive habits and obtain vaccination, timely treatment and other available health services.

Step 1: (a) Explain the need for the visit Overcrowding, unsafe drinking water, inadequate sanitation, poor waste disposal and limited access to health information can increase the risk of infectious diseases in a slum area. Such a visit helps residents understand how diseases spread and how practical preventive habits protect the whole community. It also creates awareness of available health services and encourages early medical attention.

Step 2: (b) Highlight safe water, food and personal hygiene Use safe drinking water; boil or appropriately treat water when its safety is uncertain, and store it in clean, covered containers. Wash hands with soap before preparing or eating food and after using the toilet. Keep food covered, wash fruits and vegetables, cook food properly, bathe regularly and maintain clean clothes and surroundings. These measures reduce contamination and the spread of water-borne and food-borne infections.

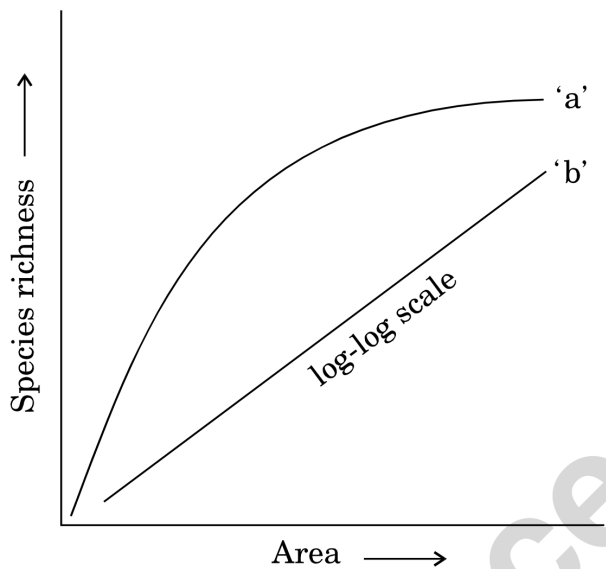
Step 3: (b) Highlight sanitation and preventive health care Use sanitary toilets, dispose of garbage and sewage safely, and prevent stagnation of water to reduce mosquito breeding. Keep drains clear and use mosquito nets where needed. Encourage age-appropriate vaccination, a balanced diet, adequate rest and exercise. Advise residents to seek qualified medical care promptly for persistent fever, diarrhoea or other symptoms, and explain where nearby health centres can be accessed. Community participation is necessary because shared water supplies, drains and waste-disposal areas affect everyone's health.

Step 4: Conclusion Such visits build health awareness and help prevent disease. The key messages are safe water and food, handwashing and personal cleanliness, proper sanitation and waste disposal, mosquito control, vaccination, balanced nutrition and timely medical care.

Quick Tip to Solve: Organise the advice around routes of infection: contaminated food and water, dirty hands, unsafe waste disposal and mosquito breeding.

24. The following graph shows the species-area relationship. Answer the following questions as directed.

(a) Name the naturalist who studied the kind of relationship shown in the graph. Write the observations made by him. (b) Write the situations as discovered by the ecologists when the value of 'Z' (slope of the line) lies between (i) 0.1 and 0.2 (ii) 0.6 and 1.2. What does 'Z' stand for? (c) When would the slope of the line 'b' become steeper? [3 marks]



Solution:

Concept:

- Species richness S increases with the area A sampled, within a region, up to a limit. The species-area relationship is expressed as $S = CA^Z$, where C is a constant and Z is the regression coefficient.
- On logarithmic axes, $\log S = \log C + Z \log A$. Thus Z is the slope of the straight line, expressing the rate at which species richness increases with area on a log-log scale.

Step 1: (a) Identify the naturalist and his observation Alexander von Humboldt studied this relationship during his explorations of the South American jungles. He observed that, within a region, species richness increased with increasing explored area, but only up to a limit. On an ordinary scale, the relationship is represented by the curved line 'a'; plotting the relationship on a log-log scale gives the straight line 'b'.

Step 2: (b) Relate the values of Z to the area studied (i) For small areas within a region, ecologists found Z values between 0.1 and 0.2, irrespective of the taxonomic group or region studied.

(ii) When very large areas, such as entire continents, are considered, the slope becomes much steeper and Z lies between 0.6 and 1.2.

Here Z stands for the regression coefficient, or slope of the species-area relationship on a logarithmic scale.

Step 3: (c) State when line b becomes steeper The slope of line 'b' becomes steeper when the analysis covers very large areas, such as entire continents, rather than small areas within a region. In the

log-log equation, the larger value of Z directly gives the steeper straight line.

Step 4: Conclusion Humboldt described increasing species richness with increasing area. Small regional areas have $Z = 0.1-0.2$, whereas very large continental areas have $Z = 0.6-1.2$; the latter produce a steeper log-log line.

Quick Tip to Solve: Match the two ranges to spatial scale: small regional areas give small Z ; continental areas give a much steeper log-log line.

25. Name and describe the technique that helps in separating the DNA fragments formed by the use of restriction endonuclease. [3 marks]

Solution:

Concept:

- Gel electrophoresis separates DNA fragments according to their size by moving them through a porous gel in an electric field.
- DNA has a negative charge due to its phosphate backbone, so it migrates towards the positively charged electrode, the anode. The gel acts as a molecular sieve.

Step 1: Name the technique and set up the separation The technique is agarose gel electrophoresis. Agarose is a natural polymer extracted from seaweeds. The DNA fragments produced by restriction endonuclease digestion are loaded into wells in an agarose gel. The wells are positioned near the negative electrode, and an electric field is applied across the gel in a suitable buffer.

Step 2: Explain how different fragments separate Negatively charged DNA fragments move through the gel towards the anode. The porous agarose matrix offers greater resistance to larger fragments. Smaller fragments therefore move farther through the gel than larger fragments during the same time. Fragments of similar size collect together as distinct bands, producing separation according to fragment length.

Step 3: Visualise and recover the required DNA The separated DNA fragments can be visualised after staining with ethidium bromide and exposing the gel to ultraviolet radiation. They appear as bright orange bands. If a particular fragment is needed for further work, its band is cut out of the gel and the DNA is extracted from the gel piece by elution.

Step 4: Conclusion Agarose gel electrophoresis separates restriction-generated DNA fragments by size: negatively charged DNA moves towards the anode, with smaller fragments travelling farther through the gel than larger ones.

Quick Tip to Solve: Always connect the three points: negative DNA, movement towards the positive anode, and smaller fragments travelling farther in agarose.

26. State the function of a reservoir in a nutrient cycle. Explain the simplified model of carbon cycle in nature.

[3 marks]

Solution:

Concept:

- A nutrient cycle is the repeated movement of an element between organisms and the physical environment. Its reservoir is the large store that supplies the nutrient to the cycling pool and buffers imbalances in nutrient flow.
- Carbon enters living organisms through photosynthesis and returns mainly through respiration, decomposition and combustion. Atmospheric carbon dioxide and dissolved carbon in oceans are major stores involved in this exchange.

Step 1: State the function of a reservoir A reservoir stores a substantial quantity of a nutrient and meets any deficit that results from an imbalance between the rate of influx and the rate of efflux. It thus maintains a continuing supply of the nutrient to the ecosystem and helps sustain the nutrient cycle.

Step 2: Explain carbon fixation and transfer through organisms Terrestrial plants absorb atmospheric CO_2 , while aquatic producers use carbon dioxide available in water. Through photosynthesis they fix this inorganic carbon into organic compounds. Carbon then passes from producers to herbivores and to higher consumers through feeding. Dead plant and animal material, together with organic wastes, transfers carbon to the detritus pool.

Step 3: Explain the return of carbon and long-term storage Respiration by producers, consumers and decomposers releases CO_2 back into the atmosphere or water. Microbial decomposition of dead organisms also returns carbon through decomposer respiration. Some carbon is stored for long periods in sediments and fossil fuels. Combustion of wood and fossil fuels, forest fires and volcanic activity release carbon dioxide to the atmosphere. Carbon dioxide also exchanges between the atmosphere and oceans, completing the simplified model of carbon circulation.

Step 4: Conclusion Reservoirs store nutrients and compensate for deficits in their cycling supply. In the carbon cycle, photosynthesis fixes carbon dioxide, feeding transfers carbon through organisms, and respiration, decomposition and combustion return it to the environment.

Quick Tip to Solve: Trace carbon in a loop: carbon dioxide to producers to consumers or detritus, then back by respiration, decomposition and combustion.

27. Since the origin of life on Earth, there were five episodes of mass extinction of species. (i) How is the ‘Sixth Extinction’, presently in progress, different from the previous episodes? (ii) Who is mainly responsible for the ‘Sixth Extinction’? (iii) List any four points that can help to overcome this disaster.

[3 marks]

Solution:

Concept:

- Mass extinction is the loss of a large number of species over a relatively short geological interval. Present-day extinction is greatly accelerated above the natural background rate.
- Habitat loss and fragmentation, over-exploitation, alien species invasions and co-extinctions are major human-associated causes of biodiversity loss.

Step 1: (i) Compare the present extinction with earlier episodes The Sixth Extinction is proceeding at an exceptionally rapid rate: current species extinction rates are estimated to be 100–1000 times the pre-human background rate. The earlier five episodes occurred in the geological past, whereas the present crisis is largely driven by human activities. Thus, its rapid, human-induced character distinguishes the present episode.

Step 2: (ii) Identify the principal agent Human beings are mainly responsible. Destruction of forests and other habitats, excessive harvesting and hunting, and introduction of invasive alien species reduce populations and can eliminate species. Loss of one species can also endanger another species that depends on it.

Step 3: (iii) State four preventive measures 1. Prevent habitat destruction and fragmentation by conserving natural habitats, restoring degraded areas and maintaining protected areas and habitat corridors.

2. Prevent over-exploitation by regulating harvesting, hunting and trade, and using biological resources sustainably.

3. Prevent alien species invasions through quarantine and control of invasive species that threaten native organisms.

4. Prevent co-extinctions by conserving interacting species together, including hosts and their dependent species and plants with their specialised pollinators.

Step 4: Conclusion The Sixth Extinction is an accelerated, predominantly human-induced biodiversity crisis. Habitat protection, sustainable resource use, control of invasive alien species and conservation of dependent species can help counter it.

Quick Tip to Solve: Match each preventive measure to one of the four major causes of biodiversity loss: habitat loss, over-exploitation, alien invasions and co-extinctions.

Section D (15 marks)

28. (a) Where does fertilization occur in humans? Explain the events that occur during this process. (b) A couple where both husband and wife are producing functional gametes, but the wife is still unable to conceive, is seeking medical aid. Describe any one method that you can suggest to this couple to become happy parents. [5 marks]

Solution:

Concept:

- Human fertilization is the fusion of a haploid sperm with a haploid secondary oocyte at the ampullary-isthmic junction of the fallopian tube, producing a diploid zygote.
- The acrosomal reaction assists sperm penetration; changes in the zona pellucida prevent entry of additional sperm and thereby ensure monospermy.
- In vitro fertilization followed by embryo transfer (IVF-ET) brings functional gametes together outside the body and transfers the developing embryo into the female reproductive tract.

Step 1: (a) State the site and initial events of fertilization Fertilization normally occurs at the ampullary-isthmic junction of the fallopian tube. The ovulated secondary oocyte reaches this region, and sperm deposited in the vagina travel through the cervix and uterus into the tube. Fertilization is possible when sperm and the oocyte reach the junction at the same time.

A sperm contacts the zona pellucida surrounding the oocyte. Enzymes released from its acrosome help it penetrate the surrounding coverings and reach the oocyte plasma membrane. The sperm and oocyte membranes fuse, allowing the sperm contents to enter the oocyte. The interaction induces changes in the zona pellucida that block entry of other sperm, preventing polyspermy.

Step 2: (a) Explain completion of meiosis and formation of the zygote Sperm entry induces the secondary oocyte to complete its second meiotic division. This unequal division produces a haploid ovum and a small second polar body. The male and female haploid nuclei then unite, restoring the diploid chromosome number and forming the zygote:

$$n + n = 2n, \quad 23 + 23 = 46 \text{ chromosomes.}$$

Thus, fertilization combines genetic material from both parents. The resulting zygote begins cleavage as it moves along the fallopian tube towards the uterus.

Step 3: (b) Suggest IVF followed by embryo transfer One suitable assisted reproductive method is **in vitro fertilization followed by embryo transfer (IVF-ET)**, commonly called the test-tube baby programme. Since both partners produce functional gametes, ova collected from the wife and sperm collected from the husband can be brought together under simulated physiological conditions in the laboratory. Fertilization occurs outside the body, and the early embryo is cultured.

A zygote or early embryo with up to eight blastomeres can be transferred into a suitable fallopian tube (zygote intrafallopian transfer, ZIFT). An embryo with more than eight blastomeres is transferred into the uterus (intrauterine transfer, IUT). For example, transfer of the cultured embryo into the wife's uterus can allow implantation and subsequent development to term when the uterine conditions are suitable. A test tube is used only for fertilization and early development; the fetus develops in the uterus.

Step 4: Conclusion Fertilization occurs at the ampullary-isthmic junction and involves sperm entry, prevention of polyspermy, completion of oocyte meiosis and fusion of the haploid nuclei. IVF-ET using this couple's own functional gametes can help them achieve pregnancy.

Quick Tip to Solve: Link the site of embryo transfer to its stage: up to eight blastomeres goes to the tube; more than eight blastomeres goes to the uterus.

OR

28. (a) Explain the different ways apomictic seeds can develop. Give an example of each. (b) Mention one advantage of apomictic seeds to farmers. (c) Draw a labelled mature stage of a dicotyledonous embryo. [5 marks]

Solution:

Concept:

- Apomixis is the formation of seeds without fertilisation. It is a form of asexual reproduction that mimics seed formation during sexual reproduction.
- An embryo may develop from an unreduced diploid egg without fusion with a male gamete, or directly from a diploid somatic cell of the ovule.
- A mature dicotyledonous embryo consists of two cotyledons and an embryonal axis, with a plumule at the shoot end and a radicle at the root end.

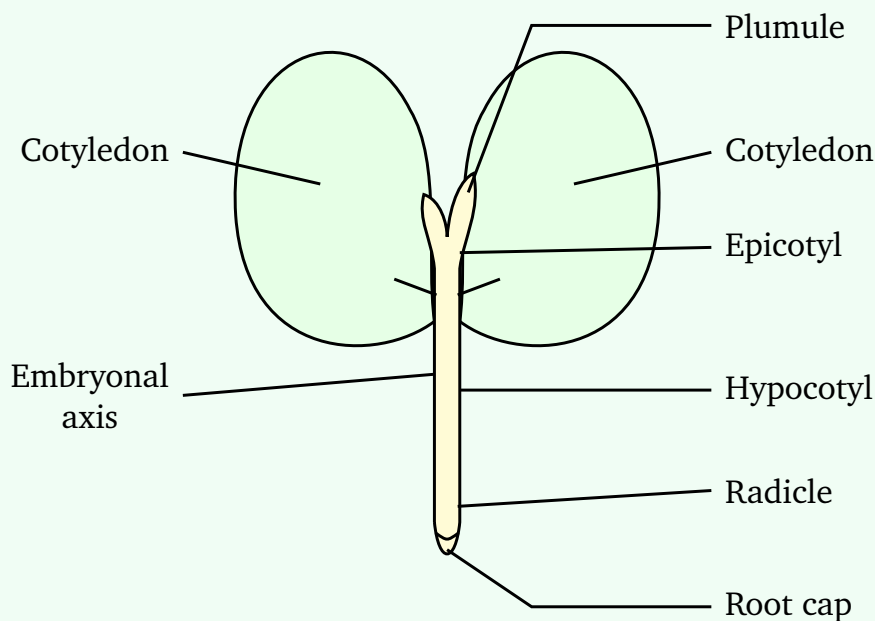
Step 1: (a) Development from an unreduced egg In one pathway, meiosis does not reduce the chromosome number during formation of the embryo sac. Consequently, the egg retains the diploid chromosome complement, $2n$, of the parent plant. This diploid egg develops into an embryo without fertilisation, a process called parthenogenesis. The ovule subsequently becomes an apomictic seed. Dandelion (*Taraxacum*), a member of Asteraceae, is an example. The important distinction is that the embryo is produced from an egg, but there is no fusion of male and female gametes.

Step 2: (a) Development from somatic ovular cells In another pathway, diploid cells of the nucellus surrounding the embryo sac begin to divide and form embryos directly. They protrude into the embryo sac and develop alongside any embryo already present there. This is adventive or nucellar embryony, as seen in *Citrus* and mango. Because several nucellar cells can form embryos, more than one embryo may occur within one seed; this condition is called polyembryony. These additional embryos arise from maternal tissue without fertilisation of an egg.

Step 3: (b) Advantage to farmers Apomixis can preserve the desirable hybrid combination through successive seed generations because the embryo forms without meiosis and fertilisation. Thus, if apomixis is introduced into a hybrid crop, its desirable characters and hybrid vigour need not segregate in the next generation. Farmers can retain seeds from the hybrid crop for sowing again, reducing the expense of purchasing fresh hybrid seed each season.

Step 4: (c) Mature dicotyledonous embryo The labelled diagram shows two cotyledons attached to the embryonal axis. The portion of the axis above their attachment is the epicotyl, ending in the plumule, which forms the shoot. The portion below their attachment is the hypocotyl, ending in the radicle, which forms the primary root. A root cap protects the tip of the radicle. The cotyledons

commonly provide stored food to the developing seedling.



Mature dicotyledonous embryo (schematic)

Step 5: Conclusion Apomictic embryos form either from an unfertilised diploid egg, as in dandelion, or from nucellar cells, as in *Citrus* and mango. Apomixis allows farmers to reuse hybrid seed while retaining desirable hybrid characters. A mature dicot embryo has two cotyledons, an embryonal axis, a plumule and a radicle.

Quick Tip to Solve: Distinguish the two embryo origins: unreduced egg versus nucellar cell. In the drawing, put the epicotyl above the cotyledon junction and the hypocotyl below it.

29. (a) Describe the various steps of Griffith's experiment that led to the conclusion of the 'Transforming Principle'. (b) How did the chemical nature of the 'Transforming Principle' get established?

[5 marks]

Solution:

Concept:

- Transformation is a heritable change produced when a bacterial cell takes up genetic material from another source. Griffith demonstrated transformation in *Streptococcus pneumoniae*, the pneumococcus.
- The smooth (S) strain has a polysaccharide capsule and is virulent; the rough (R) strain lacks the capsule and is non-virulent. Their different effects on mice allow transformation to be detected.
- To identify the transforming substance, remove candidate molecules selectively with enzymes and test whether the remaining extract still transforms living R cells.

Step 1: (a) Establish the effects of the two living strains In 1928, Frederick Griffith injected mice with living S-strain bacteria. The mice developed pneumonia and died. When he injected living R-strain

bacteria into another group of mice, the mice survived. Thus the encapsulated S cells were pathogenic, whereas the non-encapsulated R cells were not. The S and R designations refer to the smooth and rough appearances of their colonies, respectively.

Step 2: (a) Test heat-killed S bacteria and the mixed inoculum Griffith next killed S-strain bacteria by heating and injected them into mice. These mice survived, showing that the heat-killed S cells alone could not cause the disease. However, when he mixed heat-killed S bacteria with living R bacteria and injected this mixture, the mice died. He recovered living S-strain bacteria from the dead mice. The recovered S bacteria were therefore not simply the original heat-killed cells: living R bacteria had acquired the capacity to form the S type and cause disease.

Step 3: (a) Infer the transforming principle A substance from the dead S bacteria had entered the living R bacteria and transformed them into virulent S bacteria. The acquired S character was inherited by their descendants. Griffith called the responsible substance the transforming principle. His experiment established transformation, but did not identify the chemical nature of the substance responsible.

Step 4: (b) Identify the molecule by biochemical tests Oswald Avery, Colin MacLeod and Maclyn McCarty investigated the transforming principle during 1933–1944. They purified biochemical components from heat-killed S bacteria and tested their ability to transform living R bacteria. The DNA-containing fraction could bring about transformation. Treatment with proteases, which digest proteins, or RNases, which digest RNA, did not prevent transformation. Thus neither protein nor RNA was responsible for the transforming activity. In contrast, treatment with DNase, which digests DNA, abolished transformation: the R bacteria could no longer be converted into S bacteria by that treated preparation. Since destroying DNA specifically removed the activity, they concluded that DNA was the transforming principle and the hereditary material in this experiment.

Step 5: Conclusion Griffith showed that material from heat-killed S pneumococci heritably transformed living R pneumococci into virulent S cells. Avery, MacLeod and McCarty established that this transforming material was DNA, because DNase abolished transformation whereas protease and RNase did not.

Quick Tip to Solve: Recall the four inocula in order: live S, live R, dead S, and dead S plus live R. Then identify DNA by the single enzyme, DNase, that stops transformation.

OR

29. Describe how the lac operon operates, both in the presence and absence of an inducer in *E.coli*.

[5 marks]

Solution:

Concept:

- The lac operon in *E. coli* is an inducible system: a common control region regulates the coordinated expression of genes needed for lactose utilisation.
- A repressor prevents transcription by binding the operator. An inducer binds the repressor and prevents this binding, permitting transcription of the structural genes.

Step 1: Identify the regulatory and structural components The operon includes a promoter p , where RNA polymerase binds, an operator o , and three structural genes z , y and a . The associated regulatory gene i is expressed constitutively and produces the repressor protein. The z gene codes for β -galactosidase, which hydrolyses lactose into glucose and galactose; y codes for permease, which increases entry of lactose into the cell; and a codes for transacetylase. These structural genes are transcribed together into a polycistronic mRNA.

Step 2: Explain the absence of inducer When lactose is absent, there is no inducer to inactivate the repressor. The active repressor binds the operator adjacent to the promoter and blocks transcription of the structural genes by RNA polymerase. Consequently, the enzymes for lactose utilisation are not produced in appreciable amounts and the operon is functionally switched off. This avoids unnecessary expenditure on enzymes when their substrate is unavailable. A very low basal expression accounts for the small amount of permease and β -galactosidase available when lactose first enters the medium.

Step 3: Explain the presence of inducer When lactose becomes available, some enters the cell through the basal permease. Lactose acts as the inducer in the standard description; more precisely, its derivative allolactose binds the repressor. Binding changes the repressor's conformation so that it cannot bind the operator. The operator is therefore accessible and RNA polymerase can transcribe z , y and a into the polycistronic mRNA. Translation produces the three enzymes: permease promotes further lactose entry and β -galactosidase breaks down lactose. Thus the substrate induces production of the enzymes needed for its own utilisation. Strong expression is favoured when lactose is available and glucose is scarce.

Step 4: Explain how the operon switches off again As lactose is consumed, the inducer concentration falls. The repressor is no longer maintained in its inactive form and can bind the operator again, stopping further substantial transcription. Induction therefore changes the activity of the repressor, rather than stopping production of the repressor by the i gene. Since regulation is exerted through a repressor, this is negative regulation.

Step 5: Conclusion Without inducer, the active repressor occupies the operator and the lac structural genes are switched off. With inducer, the repressor is inactivated, permitting coordinated transcription and production of the lactose-utilising enzymes.

Quick Tip to Solve: Follow the sequence inducer binds repressor, operator becomes free, and structural genes are transcribed; do not say that lactose binds the operator.

30. With advancements in genetics, molecular biology and tissue culture, new traits have been incorporated into crop plants. Explain the main steps in breeding a new genetic variety of a crop.

[5 marks]

Solution:

Concept:

- Plant breeding is the purposeful manipulation of plant species to develop varieties with desirable characters, such as higher yield, better quality and resistance to diseases or environmental stress.
- A breeding programme combines useful genetic variation through hybridisation and fixes the

desired combination by selection and repeated self-pollination. The resulting variety must be tested before release.

Step 1: Collection of variability Collect and conserve the different genetic forms of the crop and its relatives. These include cultivated varieties, landraces and wild relatives carrying useful characters. The entire collection of plants or seeds with the different alleles for the genes of a crop is called its germplasm collection. It provides the genetic variability from which suitable breeding material can be chosen.

Step 2: Evaluation and selection of parents Evaluate the germplasm to identify plants possessing the desired combination of characters. Select suitable parents, for example one with high yield and another with disease resistance. The selected plants are multiplied, and pure lines are developed wherever possible so that the desired characters can be used reliably in crossing.

Step 3: Cross-hybridisation among selected parents Cross the selected parents to bring their useful characters together in a single plant. In an appropriate bisexual flower, remove the anthers before pollen release and bag the flower to prevent unwanted pollination. Transfer pollen from the chosen male parent to the receptive stigma and bag it again. Such controlled hybridisation aims, for example, to combine the high yield of one parent with the disease resistance of the other. Only a small proportion of progeny may possess the desired combination, so many crosses may be necessary.

Step 4: Selection and testing of superior recombinants Select from the hybrid progeny those plants that combine the desirable characters of both parents and are superior to them for the breeding objective. Grow and assess their progeny. Repeated self-pollination and selection over several generations produce plants that are sufficiently homozygous and uniform, with the desired traits expressed consistently in successive generations.

Step 5: Testing, release and commercialisation First test the selected lines in research fields under suitable management, recording yield, quality, disease resistance and other relevant agronomic characters. Then test them in farmers' fields at several locations representing the agroclimatic zones where the crop will be grown, for at least three growing seasons. Compare performance with the best available local check variety. A line that shows superior and stable performance is released as a new variety, followed by seed multiplication and distribution for commercial cultivation.

Step 6: Conclusion The main sequence is germplasm collection, evaluation and selection of parents, cross-hybridisation, selection of superior recombinants, and testing followed by release and commercialisation. Together these steps produce a stable crop variety with the desired genetic improvement.

Quick Tip to Solve: Recall the five stages in order: collect variability, choose parents, cross, select recombinants, and test before release; distinguish choosing parents from selecting their hybrid progeny.

30. (a) State the objective of animal breeding. (b) List the importance and limitations of inbreeding. How can the limitations be overcome? (c) Give an example of a new breed each of cattle and poultry. [5 marks]

Solution:

Concept:

- Animal breeding uses selection and mating to increase the quantity and improve the quality of useful animal products, while developing desirable inherited traits.
- Inbreeding is mating between closely related animals of the same breed for four to six generations. It increases homozygosity, that is, the presence of identical alleles at a gene locus.
- Outcrossing mates unrelated animals of the same breed and can restore vigour when prolonged inbreeding causes inbreeding depression.

Step 1: (a) Objective of animal breeding The objective is to develop improved breeds with a higher yield and better quality of useful products, such as milk, meat and eggs. Breeders select animals carrying desirable traits and mate them so that these traits are transmitted to the progeny. Selection may also favour disease resistance, fertility and adaptation to local conditions, because these traits support sustained productivity.

Step 2: (b) Importance of inbreeding Inbreeding increases homozygosity and helps to develop a pure line within a breed. It exposes harmful recessive alleles, which can remain hidden in heterozygotes; animals expressing such defects can then be excluded from further breeding. With careful selection, inbreeding also helps accumulate superior genes and eliminate undesirable genes. Selecting superior males and females from the resulting progeny and mating them can therefore improve the productivity of the inbred population.

Step 3: (b) Limitation and its remedy Continued close inbreeding may lead to inbreeding depression: fertility and productivity decline, and the animals may show reduced vigour. This happens because increased homozygosity allows deleterious recessive alleles to be expressed more frequently.

To overcome this limitation, selected animals of the breeding population are mated with unrelated superior animals of the same breed. This is outcrossing; the mates should have no common ancestors on either side of their pedigree for four to six generations. It introduces genetic variation and helps restore fertility and yield. A single outcross often helps overcome inbreeding depression, after which suitable progeny can be selected for breeding.

Step 4: (c) Examples of improved breeds An example of an improved cattle breed is Karan Swiss, developed by crossing Brown Swiss with Sahiwal cattle. An example of an improved poultry breed is Vanaraja, developed for rural backyard poultry production. Thus, selective breeding can produce useful combinations of traits in both cattle and poultry.

Step 5: Conclusion Animal breeding improves the yield and quality of animal products. Inbreeding fixes desirable traits and exposes harmful recessives, but prolonged inbreeding can reduce fertility and productivity; outcrossing within the same breed can remedy this depression. Examples of improved breeds are Karan Swiss in cattle and Vanaraja in poultry.

Quick Tip to Solve: Link inbreeding with increased homozygosity, and name outcrossing within the same breed as the direct remedy for inbreeding depression.