

CBSE Class 12 Biology Question Paper 2011 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) This question paper contains 30 questions. All questions are compulsory.
- (ii) There is no overall choice. An internal choice is provided in 5 questions (Q14, Q26, Q28, Q29, Q30); attempt only one of the alternatives in such questions.
- (iii) Marks for each question are indicated against it.

1. Name the embryonic stage that gets implanted in the uterine wall of a human female. [1 mark]

Solution:

Concept:

- Cleavage produces a morula, which subsequently develops into a hollow blastocyst.
- Implantation is attachment and embedding of the embryo in the uterine endometrium.

Step 1: Identify the stage After cleavage, the embryo forms a blastocyst with an outer trophoblast and an inner cell mass.

Step 2: Relate it to implantation The trophoblast of the blastocyst attaches to the endometrium and helps the embryo become embedded in the uterine wall. The morula is an earlier stage and is not the stage named for implantation.

Step 3: Conclusion The embryonic stage implanted in the uterine wall is the blastocyst.

Quick Tip to Solve: Associate implantation with the blastocyst and its outer trophoblast layer.

2. State the importance of biofortification. [1 mark]

Solution:

Concept:

- Biofortification is breeding food crops to improve their nutritional quality.
- Targets include increased protein quality or content, vitamins, minerals and healthier fats.

Step 1: Identify the improvement Biofortification increases the nutritional value of edible crop parts through plant breeding.

Step 2: Explain its importance Consumption of these improved staple foods helps supply essential nutrients and combat dietary deficiencies and malnutrition, especially where diets lack diversity.

Step 3: Conclusion Biofortification improves the nutritional quality of food crops and helps reduce malnutrition and nutrient deficiencies.

Quick Tip to Solve: For importance, connect nutrient-rich crops directly with prevention of dietary deficiencies.

3. Biotechnologists refer to *Agrobacterium tumefaciens* as a natural genetic engineer of plants. Give reasons to support the statement. [1 mark]

Solution:

Concept:

- *Agrobacterium tumefaciens* transfers a segment of its tumour-inducing (Ti) plasmid into susceptible plant cells.
- Transferred DNA, called T-DNA, integrates into the plant genome and can be expressed there.

Step 1: Describe natural gene transfer During infection, the bacterium delivers its T-DNA into a plant cell; this DNA becomes integrated into the plant chromosome.

Step 2: Explain the genetic engineering Expression of the transferred genes changes the normal plant cell into a tumour cell and causes crown gall disease. Thus the bacterium naturally introduces foreign genetic material and changes the genetic behaviour of plant cells.

Step 3: Conclusion Agrobacterium tumefaciens is a natural genetic engineer because it transfers T-DNA into the plant genome and genetically transforms plant cells.

Quick Tip to Solve: Remember the sequence Ti plasmid, T-DNA transfer, integration and transformation.

4. How do algal blooms affect the life in water bodies?

[1 mark]

Solution:

Concept:

- An algal bloom is excessive growth of algae, usually promoted by nutrient enrichment of water.
- Dissolved oxygen is needed for aerobic respiration by fish and other aquatic organisms.

Step 1: Trace the oxygen depletion When the abundant algae die, decomposer microbes break down their organic matter and consume dissolved oxygen. Dense blooms can also reduce light reaching submerged plants.

Step 2: State the effect on aquatic life The resulting oxygen shortage can suffocate fish and other aquatic animals and cause their death. Some bloom-forming organisms also release toxins that harm aquatic life.

Step 3: Conclusion Algal blooms deplete dissolved oxygen and may release toxins, harming or killing aquatic organisms.

Quick Tip to Solve: Link excess algae to decomposition, oxygen depletion and fish mortality.

5. Name the common ancestor of the great apes and man.

[1 mark]

Solution:

Concept:

- Evolution involves descent from ancestral populations with modification over generations.
- Dryopithecus is identified in the school-level evolutionary account as an ancestral ape associated with the ancestry of great apes and humans.

Step 1: Identify the ancestral form The ancestral form required here is Dryopithecus, an extinct ape-like primate.

Step 2: Place the answer in context The question asks for an ancestral form shared by the evolutionary lineages, rather than a present-day ape. Humans do not descend from any living great ape species; the groups share an ancestral lineage.

Step 3: Conclusion Dryopithecus is the common ancestor of the great apes and humans expected here.

Quick Tip to Solve: Name the extinct ancestral form Dryopithecus; do not name a living ape.

6. Write a difference between net primary productivity and gross productivity.

[1 mark]

Solution:

Concept:

- Gross primary productivity (GPP) is the total rate at which producers form organic matter through photosynthesis.
- Net primary productivity (NPP) equals GPP minus the respiratory loss of producers, denoted by R .

Step 1: Define gross production GPP includes all organic matter produced by photosynthetic producers before any allowance for their own respiration.

Step 2: Define net production NPP is the organic matter remaining after producer respiration: $NPP = GPP - R$. It is the production available for consumption by herbivores and decomposers or for accumulation as plant biomass.

Step 3: Conclusion GPP is total photosynthetic production, whereas NPP is the production remaining after respiratory losses of producers.

Quick Tip to Solve: Subtract producer respiration from gross production to obtain net production.

7. Mention the contribution of genetic maps in human genome project.

[1 mark]

Solution:

Concept:

- A genetic map shows the relative positions of genes or DNA markers on chromosomes.
- Recombination frequencies provide information on relative distances between linked loci.

Step 1: Identify what maps provide Genetic maps locate genes and markers in a relative order along human chromosomes.

Step 2: Connect maps with genome study These markers served as reference points for locating genes and assigning DNA sequences to chromosome regions in the Human Genome Project. Maps also helped identify the chromosomal regions associated with inherited disorders.

Step 3: Conclusion Genetic maps provided the positions and relative distances of genes or markers, helping locate genes and organise the human genome sequence.

Quick Tip to Solve: Think of mapped markers as chromosome reference points used to locate genes and sequences.

8. Name the phase all organisms have to pass through before they can reproduce sexually.

[1 mark]

Solution:

Concept:

- An organism must complete a period of growth and development before attaining sexual maturity.
- This pre-reproductive period is called the juvenile phase in animals and the vegetative phase in

plants.

Step 1: Identify the period before maturity A newly formed organism is not immediately capable of producing functional gametes. It first grows and develops the reproductive structures and physiological capacity needed for sexual reproduction.

Step 2: Use the appropriate biological term The period preceding reproductive maturity is the juvenile phase. In plants, the same developmental period is commonly called the vegetative phase; its end is associated with entry into reproductive development, such as flowering.

Step 3: Conclusion The phase is the juvenile phase, called the vegetative phase in plants.

Quick Tip to Solve: For a question asking the phase before sexual reproduction, write juvenile; add vegetative for plants.

9. Name the enzyme produced by Streptococcus bacterium. Explain its importance in medical sciences. [2 marks]

Solution:

Concept:

- Streptococcus produces streptokinase, a microbial enzyme used as a clot buster after suitable modification by genetic engineering.
- A clot inside a coronary blood vessel can obstruct blood supply to heart muscle and cause myocardial infarction.

Step 1: Name the microbial product The enzyme produced by Streptococcus is streptokinase. It is obtained from the bacterium and suitably modified by genetic engineering for therapeutic use. Thus, the organism is a useful source of a medically important microbial product.

Step 2: Explain its medical role Streptokinase is used to dissolve blood clots in patients who have suffered myocardial infarction, commonly called a heart attack. It promotes the conversion of plasminogen into plasmin; plasmin breaks down the fibrin mesh of a clot. Dissolution of the clot helps restore flow through the affected blood vessel and improves oxygen delivery to the heart muscle.

Step 3: Conclusion Streptokinase, produced by Streptococcus, is used as a clot buster to remove clots from blood vessels in myocardial infarction patients.

Quick Tip to Solve: Link Streptococcus with streptokinase, and explain clot dissolution in heart attack patients.

10. How is 'Rosie' considered different from a normal cow? Explain. [2 marks]

Solution:

Concept:

- A transgenic animal carries and expresses an introduced foreign gene.
- An introduced gene can change the composition of milk by directing synthesis of a human protein.

Step 1: Identify the genetic difference Rosie was the first transgenic cow, produced in 1997. Unlike a normal cow, she carried an introduced human gene and could express it in her mammary glands. This made her milk contain the human protein alpha-lactalbumin.

Step 2: Explain the difference in milk Rosie produced milk enriched with human alpha-lactalbumin at a concentration of about 2.4 g L^{-1} . This human-protein-enriched milk was nutritionally more balanced for human babies than normal cow milk. The relevant difference is therefore a genetically engineered change in milk composition, rather than merely a change in the quantity of milk.

Step 3: Conclusion Rosie was a transgenic cow whose milk contained human alpha-lactalbumin, about 2.4 g L^{-1} , making it nutritionally more balanced for human babies than normal cow milk.

Quick Tip to Solve: Remember Rosie by three linked facts: transgenic cow, human alpha-lactalbumin and 2.4 g per litre.

11. State the use of Biodiversity in modern agriculture.

[2 marks]

Solution:

Concept:

- Biodiversity includes the genetic variation within crop species and their wild relatives.
- Breeders use useful heritable traits from diverse germplasm to improve cultivated varieties.

Step 1: Provide a genetic resource for crop improvement Biodiversity supplies a wide gene pool for modern agriculture. Traditional varieties and wild relatives may carry genes for disease resistance, pest resistance, drought tolerance or other desirable characters. Conserving this diversity preserves useful traits that may be absent from a widely grown crop variety.

Step 2: Use the diversity in plant breeding Plant breeders select suitable parents from this diverse germplasm and cross them to combine desirable traits. Selection can then produce improved varieties with higher productivity, better quality or greater resistance to environmental stress. Thus biodiversity supports the development of improved crops and reduces the risk posed by depending on a narrow genetic base.

Step 3: Conclusion Biodiversity provides genetic resources for breeding improved crop varieties, including high-yielding, disease-resistant, pest-resistant and stress-tolerant crops.

Quick Tip to Solve: For modern agriculture, connect biodiversity to a gene pool and then to improved crop varieties.

12. Write the full form of VNTR. How is VNTR different from 'Probe'?

[2 marks]

Solution:

Concept:

- VNTR stands for Variable Number of Tandem Repeats: a DNA region containing repeated sequence units whose number varies among individuals.
- A probe is a labelled single-stranded DNA or RNA sequence that detects a complementary nucleic-

acid sequence by hybridisation.

Step 1: Expand VNTR and describe it VNTR means Variable Number of Tandem Repeats. At a VNTR locus, a short DNA sequence is repeated consecutively. Different individuals may possess different numbers of these repeat units, so the DNA fragments containing the locus differ in length. This polymorphism is useful in DNA fingerprinting.

Step 2: Distinguish a VNTR from a probe A VNTR is the variable repetitive DNA region being analysed. A probe is the labelled nucleic-acid tool used to detect a complementary DNA sequence. During DNA fingerprinting, a suitable labelled probe hybridises with complementary repetitive sequences on the membrane and reveals bands. Therefore, the VNTR provides the inherited variation, whereas the probe enables its detection.

Step 3: Conclusion VNTR is Variable Number of Tandem Repeats. It is a variable repetitive DNA region; a probe is a labelled single-stranded nucleic acid used to detect a complementary DNA sequence.

Quick Tip to Solve: Distinguish the variable DNA target, VNTR, from the labelled detection tool, the probe.

13. Differentiate between benign and malignant tumours.

[2 marks]

Solution:

Concept:

- Tumours are masses of cells formed by abnormal, uncontrolled cell division.
- The main distinguishing features are invasion of neighbouring tissues and the ability to spread to distant sites.

Step 1: Benign tumour A benign tumour remains confined to its original location and does not invade neighbouring tissues. It does not spread to distant organs by metastasis. Such a tumour generally causes little damage, although its size or location can press on nearby tissues and interfere with their function.

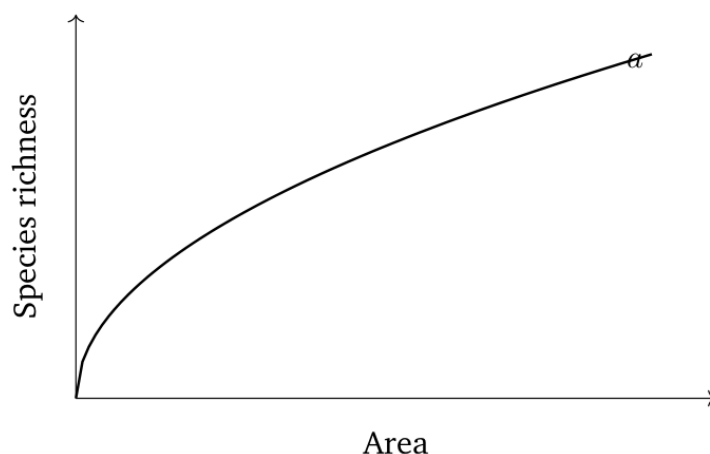
Step 2: Malignant tumour A malignant tumour consists of cancerous cells that proliferate rapidly and invade and damage surrounding normal tissues. Some cells break away, enter the blood or lymph, and reach distant organs, where they establish secondary tumours. This spread is called metastasis and makes malignant tumours especially dangerous.

Step 3: Conclusion Benign tumours are localised and non-invasive, whereas malignant tumours invade surrounding tissues and can metastasise to distant parts of the body.

Quick Tip to Solve: Compare location, tissue invasion and metastasis; metastasis is the clearest distinction.

14. The graph shows Species-Area relationship. Write the equation of the curve 'a' and explain.

[2 marks]



Solution:

Concept:

- The species-area relationship describes how species richness increases with the area explored within a region.
- The power relationship is $S = CA^Z$, where S is species richness, A is area, C is a constant and Z is the regression coefficient.

Step 1: Equation of curve a The curved species-area relationship on ordinary arithmetic axes is

$$S = CA^Z.$$

Alexander von Humboldt observed that, within a region, the number of species increases as the explored area increases, but only up to a limit. Thus larger sampled areas generally contain more species, while the increase becomes less rapid along the curve.

Step 2: Meaning of the constants and logarithmic form Here C depends on the region and group of organisms studied, and Z describes how rapidly richness changes with area. For many taxonomic groups within a region, Z lies between 0.1 and 0.2. Taking logarithms gives

$$\log S = \log C + Z \log A.$$

Therefore the curved relationship becomes a straight line on a log-log plot, with slope Z and intercept $\log C$.

Step 3: Conclusion Curve a is represented by $S = CA^Z$: species richness increases with the area explored; on logarithmic axes its equation is $\log S = \log C + Z \log A$.

Quick Tip to Solve: Remember S for species richness and A for area; the exponent Z becomes the slope only on a log-log plot.

14. Differentiate between in situ and ex situ approaches of conservation of biodiversity.

[2 marks]

Solution:**Concept:**

- In situ conservation protects species within their natural habitats and ecosystems.
- Ex situ conservation protects threatened organisms outside their natural habitats under human care.

Step 1: In situ approach In situ means conservation on site. Organisms are protected in the natural ecosystem where they normally occur, along with their habitats, associated species and ecological interactions. National parks, wildlife sanctuaries and biosphere reserves are examples. Protecting a forest habitat can conserve many species together and permit their natural breeding and evolution.

Step 2: Ex situ approach Ex situ means conservation off site. Threatened plants or animals are taken out of their natural habitats and protected in specially managed places. Zoological parks, botanical gardens and seed banks are examples. Captive breeding and storage of seeds or gametes help conserve selected species when their survival in the wild is seriously threatened.

Step 3: Conclusion In situ conservation protects biodiversity in natural habitats, for example in national parks; ex situ conservation protects organisms outside those habitats, for example in zoos or seed banks.

Quick Tip to Solve: Link in situ with habitat protection and ex situ with managed collections outside the habitat.

15. The cell division involved in gamete formation is not of the same type in different organisms. Justify.

[2 marks]

Solution:**Concept:**

- Gametes must contain a haploid chromosome complement, written as n .
- The division producing gametes depends on whether the gamete-producing organism or cell is haploid (n) or diploid ($2n$).

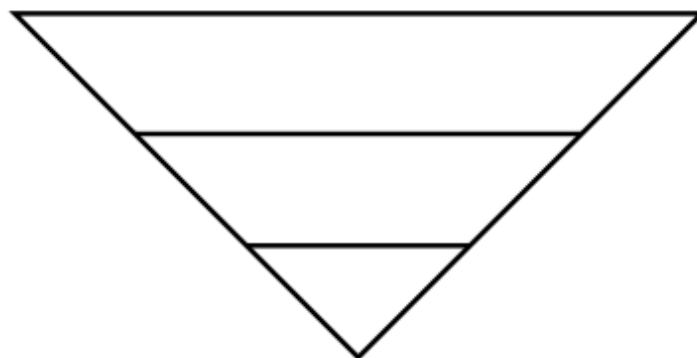
Step 1: Haploid organisms form gametes by mitosis In a haploid organism, the parent already has one set of chromosomes. Gamete formation therefore does not require a reduction in chromosome number. Mitosis maintains the haploid number: $n \rightarrow n$. Haploid organisms such as certain algae, for example *Chlamydomonas*, produce gametes by mitotic division.

Step 2: Diploid organisms require meiosis In diploid organisms, specialised gamete mother cells have two sets of chromosomes. Meiosis reduces this number from $2n$ to n ; diploid animals such as humans form haploid gametes in this way. Reduction is essential because fusion of two haploid gametes restores the diploid number at fertilisation, rather than doubling the chromosome number in every generation.

Step 3: Conclusion Gametes arise by mitosis in haploid organisms but by meiosis in diploid organisms with diploid gamete mother cells; the difference depends on the chromosome number of the parent cells.

Quick Tip to Solve: Check the ploidy of the gamete-producing cell first: haploid cells retain n , while diploid cells must reduce $2n$ to n .

16. Identify the type of the given ecological pyramid and give one example each of pyramid of number and pyramid of biomass in such cases. [2 marks]



Solution:

Concept:

- An inverted ecological pyramid has a narrow producer level and progressively wider upper trophic levels. Its shape depends on whether numbers or standing biomass are being represented.
- A pyramid of energy is always upright; inversion is possible for number or biomass because these measure different properties.

Step 1: Identify the pyramid The given outline is an inverted ecological pyramid: its base is narrower than its upper levels. Each horizontal level represents a trophic level. A wider tier represents a greater number of organisms or greater standing biomass, according to the quantity being plotted.

Step 2: Give the two examples For a pyramid of numbers, a parasitic food chain is an example: one large tree supports many herbivorous birds, which in turn carry numerous parasites. The number increases towards the higher levels. For a pyramid of biomass, an aquatic ecosystem is an example: the standing biomass of phytoplankton can be smaller than that of the zooplankton feeding on them. Phytoplankton reproduce rapidly and are consumed rapidly, so their small standing crop can support a larger consumer biomass.

Step 3: Conclusion The pyramid is inverted. Examples are a parasitic food chain for the pyramid of numbers and an aquatic ecosystem for the pyramid of biomass.

Quick Tip to Solve: For inversion, pair numbers with a tree-based parasitic chain and biomass with a phytoplankton-based aquatic chain.

17. Describe the Lactational Amenorrhea method of birth control.

[2 marks]

Solution:

Concept:

- Lactational amenorrhoea is a natural contraceptive method based on the suppression of ovulation and menstruation during intense breast-feeding after childbirth.
- It is effective only for a limited period and under strict conditions: exclusive breast-feeding, absence of menstruation and a baby younger than six months.

Step 1: Explain the mechanism After delivery, frequent and intense suckling maintains high prolactin secretion. This suppresses the normal hormonal activity that leads to ovulation. Because an ovum is not normally released during this period, fertilisation and a fresh pregnancy are less likely; menstruation also remains absent. This absence of menstruation during lactation is called lactational amenorrhoea.

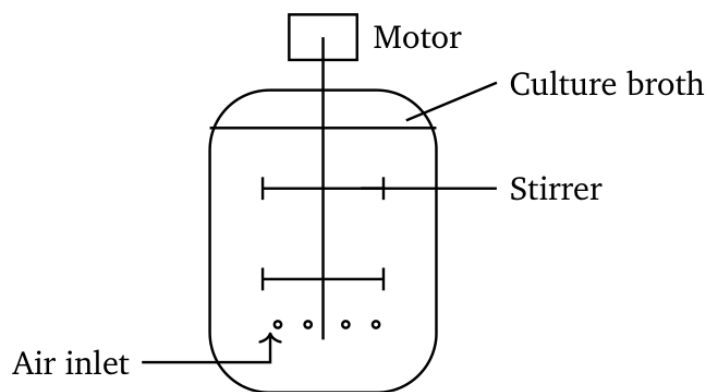
Step 2: State the conditions and limitation The mother must exclusively breast-feed the infant, with frequent feeds by day and night, and menstruation must not have resumed. This method is useful only up to about six months following childbirth while these conditions hold. It requires no contraceptive device or drug. Its reliability falls when supplementary feeding begins, feeds become infrequent, menstruation returns or the infant reaches six months; another contraceptive method is then needed.

Step 3: Conclusion Lactational amenorrhoea prevents conception by suppressing ovulation during intense, exclusive breast-feeding, for up to about six months after delivery while menstruation remains absent.

Quick Tip to Solve: Remember all three conditions together: exclusive feeding, no return of periods, and less than six months since delivery.

18. Name the type of bioreactor shown. Write the purpose for which it is used.

[2 marks]



Solution:

Concept:

- A bioreactor is a vessel in which biological raw materials are converted into specific products using microorganisms, plant or animal cells, or their enzymes.
- A stirred-tank bioreactor mixes the culture to provide uniform conditions, while aeration supplies

oxygen required by an aerobic culture.

Step 1: Identify the bioreactor The diagram shows a stirred-tank bioreactor. The central shaft carrying stirrer blades mixes the culture broth. The air inlet introduces air into the vessel; together, agitation and aeration improve the distribution of nutrients and oxygen throughout the culture. This is the standard arrangement used to grow cells under controlled conditions.

Step 2: Explain its purpose It is used for large-scale cultivation of microorganisms or cells to obtain useful biological products, such as enzymes, antibiotics or recombinant proteins. The bioreactor maintains suitable growth and production conditions, including temperature, pH, oxygen supply and nutrient availability. Mixing helps prevent local differences in these conditions, allowing the culture to function efficiently and giving a high yield of the desired product.

Step 3: Conclusion It is a stirred-tank bioreactor, used for large-scale production of useful biological products by growing microorganisms or cells under controlled conditions.

Quick Tip to Solve: Look for a central shaft with mixing blades: it identifies the stirred-tank design and links directly to uniform mixing and oxygen supply.

19. Draw a labelled diagram of the reproductive system in a human female.

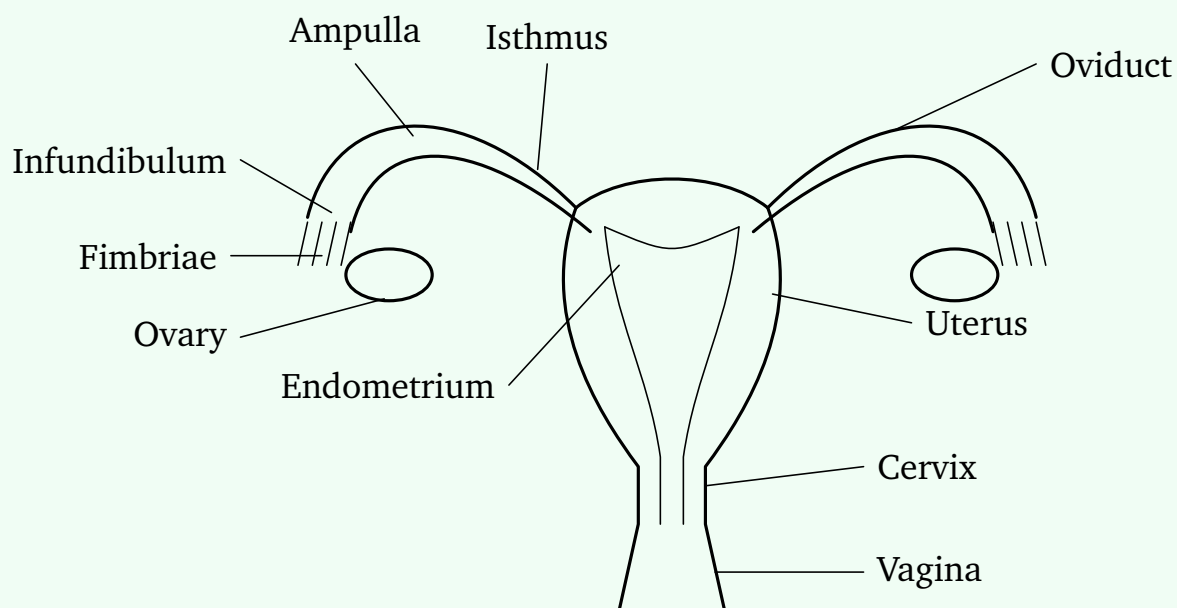
[3 marks]

Solution:

Concept:

- The human female reproductive system comprises paired ovaries and oviducts, a uterus, cervix and vagina.
- Each oviduct consists of an infundibulum with fimbriae, an ampulla and an isthmus; it opens into the uterus.

Step 1: Identify the organs in the labelled diagram The ovaries lie on either side of the uterus. They produce ova and secrete the ovarian hormones. The oviduct provides the passage along which the ovum travels towards the uterus; the ampullary-isthmic junction is the usual site of fertilisation. The finger-like fimbriae of the infundibulum lie close to each ovary and help collect the ovum after ovulation. Each oviduct extends from the region of the ovary towards the upper part of the uterus. The broad ampulla narrows into the isthmus before joining the uterus.



Human female reproductive system (schematic anterior view)

Step 2: Trace the lower reproductive tract The two oviducts open into the muscular uterus. Its inner lining is the endometrium, where implantation takes place. The uterus narrows inferiorly into the cervix; the cervical canal opens into the vagina. In the diagram, the paired organs, uterine cavity, cervix and vagina are separately identified so that the continuity of the tract is clear.

Step 3: Conclusion The labelled diagram shows the ovaries, fimbriae, infundibula, ampullae, isthuses, uterus, cervix and vagina.

Quick Tip to Solve: Draw the uterus centrally first, add the paired oviducts and ovaries, and finish with the cervix and vagina.

20. Branching descent and natural selection are the two key concepts of Darwinian Theory of Evolution. Explain each concept with the help of a suitable example. [3 marks]

Solution:

Concept:

- Branching descent means that different species arise through divergence from common ancestors.
- Natural selection is differential survival and reproduction of individuals with heritable variations that are advantageous in a given environment.

Step 1: Branching descent: Darwin's finches Descendants of a common ancestral population can become separated into different habitats. Over many generations, inherited differences accumulate as the populations adapt to different ways of life. Their evolutionary histories therefore form branches from a shared ancestral stock. Darwin's finches on the Galapagos Islands illustrate this: several species evolved from a common ancestral finch, with different beak shapes suited to different food sources, such as seeds and insects. Their shared ancestry explains similarities, while divergence explains

differences.

Step 2: Natural selection: industrial melanism Before industrial pollution in England, light-coloured moths were well camouflaged on lichen-covered tree trunks, while dark moths were more easily seen and eaten by birds. Pollution killed lichens and darkened trunks. Dark moths then became less conspicuous and survived predation more often than light moths. Because colour variation was heritable, the better-surviving dark moths reproduced and increased in frequency over generations. Thus the environment selected an already existing favourable variant; it did not cause moths to turn dark because they needed to.

Step 3: Conclusion Branching descent explains diversification from common ancestry, while natural selection explains the increase of favourable inherited variants through differential reproductive success.

Quick Tip to Solve: For each concept, state the process and link the example to it: finch divergence for branching, moth survival for selection.

21. Scientists have succeeded in recovering healthy sugarcane plants from a diseased one. (a) Name the part of the plant used as explant by the scientists. (b) Describe the procedure the scientists followed to recover the healthy plants. (c) Name this technology used for crop improvement.

[3 marks]

Solution:

Concept:

- Meristem culture uses an actively dividing shoot meristem as an explant to regenerate a whole plant.
- Plant cells show totipotency: under suitable culture conditions they can develop into complete plants. Shoot meristems can remain virus-free even when the parent plant is infected.

Step 1: (a) Select the explant The scientists use the apical or axillary meristem of the diseased sugarcane plant as the explant. A small shoot-tip meristem is selected because this region can be free of the virus infecting the rest of the plant. Taking ordinary infected mature tissue would risk carrying the pathogen into the regenerated plants.

Step 2: (b) Culture and regenerate healthy plants Excise the meristem carefully under aseptic conditions after suitable surface sterilisation. Place it on a sterile nutrient medium containing mineral salts, a carbon source such as sucrose, vitamins and appropriate plant growth regulators. Maintain the culture under controlled conditions to permit cell division and shoot multiplication. Transfer the shoots to a suitable rooting medium to obtain complete plantlets. Harden the plantlets gradually so that they acclimatise to conditions outside the culture vessel, and then transfer them to soil. The regenerated plants are checked for freedom from the infecting virus.

Step 3: (c) Name the technology The technology is plant tissue culture, specifically meristem culture for obtaining virus-free plants. Rapid multiplication of the regenerated plants through tissue culture is called micropropagation; it produces many plants from a small amount of starting material.

Step 4: Conclusion Apical or axillary meristem culture, using tissue culture and micropropagation,

produces healthy sugarcane plants from a diseased parent.

Quick Tip to Solve: For recovery of virus-free plants, specify the meristem first, then give sterile culture, regeneration, rooting and hardening in order.

22. (i) Name the enzyme that catalyses the transcription of hnRNA. (ii) Why does the hnRNA need to undergo changes? List the changes hnRNA undergoes and where in the cell such changes take place. [3 marks]

Solution:

Concept:

- Eukaryotic transcription first produces a primary transcript called heterogeneous nuclear RNA (hnRNA). RNA polymerase II transcribes the precursor of messenger RNA.
- A functional messenger RNA must contain a continuous coding sequence and appropriate modifications at its ends. Processing occurs in the nucleus before the mature mRNA is exported for translation.

Step 1: Identify the enzyme: part (i) RNA polymerase II catalyses transcription of hnRNA in a eukaryotic cell. It uses the DNA template to synthesize the primary RNA transcript. This product is a precursor of mRNA rather than the final molecule ready for translation.

Step 2: Explain why processing is required: part (ii) The primary transcript contains both exons, which are retained in mature mRNA, and introns, which interrupt the exon sequences and are removed. Thus, hnRNA needs processing to form a mature, functional mRNA with its exon sequences joined in the correct order.

Step 3: List the changes and their location The hnRNA undergoes three major processing changes in the nucleus. During splicing, introns are removed and exons are joined. During capping, a methyl guanosine triphosphate cap is added at the 5' end. During tailing, about 200–300 adenylate residues are added at the 3' end to form a poly-A tail. The processed mRNA is then transported from the nucleus to the cytoplasm for translation.

Step 4: Conclusion RNA polymerase II transcribes hnRNA. Nuclear processing converts it into functional mRNA by splicing, capping at the 5' end and polyadenylation at the 3' end.

Quick Tip to Solve: Remember the three changes as splice, cap and tail; place all three in the nucleus before mRNA export.

23. (i) Write the scientific names of the two species of filarial worms causing filariasis. (ii) How do they affect the body of infected person(s)? (iii) How does the disease spread? [3 marks]

Solution:

Concept:

- Filariasis is a helminthic disease caused by filarial worms that live in the lymphatic system of humans.
- A mosquito serves as the vector: it acquires the parasite from an infected person and transfers infective larvae to another person during a later blood meal.

Step 1: Name the two filarial worms: part (i) The two species are *Wuchereria bancrofti* and *Wuchereria malayi*. The latter is also known as *Brugia malayi*. These parasitic worms are responsible for lymphatic filariasis.

Step 2: Describe the effects on the body: part (ii) The worms affect the lymphatic vessels, especially those of the lower limbs. Their presence causes chronic inflammation and obstruction of lymph flow. As lymph drainage is impaired, the affected tissues develop severe swelling and thickening, producing the condition called elephantiasis. The genital organs may also be affected and become swollen or deformed; it is therefore not a disease confined to the legs.

Step 3: Explain transmission: part (iii) The disease spreads through the bite of an infected female mosquito, commonly a *Culex* mosquito. When a mosquito feeds on an infected person, it takes up microfilariae with the blood. The parasites develop into infective larvae within the mosquito and are passed to a new person during a subsequent bite. Thus, the mosquito connects infected and susceptible humans; ordinary contact with an affected limb does not transmit filariasis.

Step 4: Conclusion Filariasis is caused by *W. bancrofti* and *W. malayi* (*Brugia malayi*). It damages lymphatic vessels, causing elephantiasis and possible genital deformity, and spreads through infected female mosquitoes.

Quick Tip to Solve: Connect the three parts: *Wuchereria* species, lymphatic obstruction and the female mosquito vector.

24. Name the genus to which baculoviruses belong. Describe their role in the integrated pest management programmes. [3 marks]

Solution:

Concept:

- Biological control uses living organisms or their products to control pests. Integrated pest management combines compatible control methods to limit crop damage while reducing unnecessary pesticide use.
- Baculoviruses infect insects and other arthropods. Their narrow host specificity allows selected pest populations to be targeted while conserving useful organisms.

Step 1: Name the genus The genus is *Nucleopolyhedrovirus*. The baculoviruses used as biological control agents belong mainly to this genus and are used against susceptible insect pests.

Step 2: Explain their action in pest control An appropriate baculovirus preparation is applied against its particular target pest. After susceptible insects acquire the virus, it multiplies in them and causes disease and death, reducing the pest population. Since these viruses have narrow-spectrum insecticidal activity, the virus must be matched to the pest species rather than treated as a general insecticide.

Step 3: Describe their value in integrated pest management Baculoviruses are particularly useful in integrated pest management because they have no negative impact on plants, mammals, birds, fish or even non-target insects. They therefore help conserve beneficial insects and natural enemies of pests while controlling the susceptible pest. This makes them desirable when an ecologically sensitive area is treated or when beneficial insects are being conserved. Their use can be combined with other compatible management methods and reduces reliance on broad-spectrum chemical insecticides.

Step 4: Conclusion Baculoviruses of the genus *Nucleopolyhedrovirus* provide species-specific, narrow-spectrum biological pest control. They are valuable in integrated pest management because they control target pests while conserving non-target organisms and beneficial insects.

Quick Tip to Solve: For IPM, link narrow host range to conservation of natural enemies; include the genus name explicitly.

25. Unambiguous, universal and degenerate are some of the terms used for the genetic code. Explain the salient features of each one of them. [3 marks]

Solution:

Concept:

- The genetic code is the relationship between an mRNA codon (a sequence of three nucleotides) and the amino acid incorporated during translation.
- Unambiguous describes the meaning of one codon; degeneracy describes how many codons may specify the same amino acid. Universality compares the meaning of a codon in different organisms.

Step 1: Unambiguous and specific Each amino-acid-coding codon specifies only one particular amino acid. For example, UUU specifies phenylalanine and does not also specify another amino acid. Thus a ribosome can interpret a given codon without choosing between two different amino acids. This property does not mean that an amino acid has only one codon.

Step 2: Nearly universal A particular codon generally specifies the same amino acid in organisms ranging from bacteria to humans. For example, UUU codes for phenylalanine in both. The code is therefore described as universal, although a few exceptions occur, such as certain mitochondrial codons and some protozoan codons.

Step 3: Degenerate Most amino acids are specified by more than one codon. For example, UUU and UUC both code for phenylalanine. These are synonymous codons: their different nucleotide sequences give the same amino acid. Methionine (AUG) and tryptophan (UGG) each have a single codon in the standard code, so degeneracy does not apply equally to every amino acid.

Step 4: Conclusion The code is unambiguous because each sense codon has one amino acid meaning, nearly universal because that meaning is generally conserved across organisms, and degenerate because most amino acids have several codons.

Quick Tip to Solve: Compare UUU with UUC: each has one meaning, both mean phenylalanine, and that meaning is conserved across organisms.

26. Water is very essential for life. Write any three features both for plants and animals which enable them to survive in water scarce environment. [3 marks]

Solution:

Concept:

- Organisms in dry habitats must obtain sufficient water and reduce its loss. Xerophytic plants and desert animals have structural, physiological and behavioural adaptations that maintain water balance.
- For plants, reducing transpiration conserves water; for animals, reducing evaporative and excretory losses and obtaining metabolic water are important.

Step 1: Three features in plants (i) A thick waxy cuticle reduces evaporation from the leaf surface. (ii) Stomata situated in sunken pits retain relatively moist air around them and reduce the water-vapour gradient, thereby limiting transpiration. (iii) CAM plants open stomata mainly at night, when it is cooler, and initially fix carbon dioxide into organic acids. During the day, their stomata remain closed while stored carbon dioxide is used for photosynthesis. These adaptations allow carbon fixation with reduced water loss.

Step 2: Three features in animals (i) Desert rodents such as kangaroo rats obtain much of their water metabolically, through oxidation of stored fat, so they can survive with little or no drinking water. (ii) Their efficient kidneys produce highly concentrated urine, allowing nitrogenous wastes to be removed with very little water. (iii) Many desert animals are nocturnal and remain in cool burrows during the hot daytime. Avoiding peak heat reduces the need for evaporative cooling and therefore conserves water.

Step 3: Conclusion Plants conserve water through a thick cuticle, sunken stomata and CAM photosynthesis. Desert animals survive using metabolic water, concentrated urine and nocturnal or burrowing behaviour.

Quick Tip to Solve: Give three distinct plant features and three animal features, linking each feature explicitly to reduced water loss or water supply.

OR

26. How do organisms cope with stressful external environmental conditions which are localised or of short duration? [3 marks]

Solution:

Concept:

- When unfavourable environmental conditions are localised or temporary, organisms may avoid the stress by migration or survive it by suspending activity and development.
- Migration involves moving to a favourable habitat; suspension lowers activity or metabolism until favourable conditions return.

Step 1: Migration away from local stress An organism can temporarily move from a stressful habitat

to a more suitable one and return when the stressful period is over. Many birds migrate seasonally to warmer or otherwise favourable regions. For example, migratory birds visit Keoladeo National Park at Bharatpur during winter. Such movement permits them to escape adverse conditions without permanently abandoning their usual habitat.

Step 2: Suspension through resistant stages Bacteria, fungi and lower plants can form thick-walled spores that withstand unfavourable conditions and germinate when conditions improve. Seeds and some other vegetative reproductive structures of higher plants can remain dormant through stressful periods. Their greatly reduced activity allows survival until water, temperature and other conditions become suitable for growth.

Step 3: Suspension in animals Some animals reduce their activity and metabolic rate during adverse seasons. Bears undergo hibernation during winter, while some snails and fish undergo aestivation during summer to escape heat and desiccation. Many zooplankton enter diapause, a stage of suspended development, in unfavourable conditions. These responses allow the organism to wait out a temporary period of stress.

Step 4: Conclusion Organisms cope with localised or short-term stress by migrating to favourable habitats or suspending activity through spores, dormancy, hibernation, aestivation or diapause.

Quick Tip to Solve: Organise the answer under migration and suspension; pair winter with hibernation, summer with aestivation, and suspended development with diapause.

27. (i) State the consequence if the electrostatic precipitator of a thermal plant fails to function. (ii) Mention any four methods by which the vehicular air pollution can be controlled. [3 marks]

Solution:

Concept:

- An electrostatic precipitator removes particulate matter from thermal power-plant exhaust by charging particles and collecting them on plates.
- Vehicular pollution can be reduced by cleaner fuels, effective exhaust treatment, proper combustion and reducing individual vehicle journeys.

Step 1: (i) Consequence of precipitator failure If the electrostatic precipitator stops working, fly ash and other suspended particulate matter escape with the flue gases instead of being collected. Thus, the thermal plant releases much more particulate pollution into the atmosphere. These fine particles lower air quality and visibility and can enter the respiratory tract, causing irritation and respiratory illness. The immediate consequence is increased particulate emissions: a precipitator primarily removes particles from exhaust gases.

Step 2: (ii) Four methods of vehicular pollution control 1. Use cleaner fuels such as compressed natural gas (CNG) in suitable vehicles. CNG burns more cleanly than diesel and produces much less particulate pollution.

2. Fit catalytic converters. These convert unburnt hydrocarbons into carbon dioxide and water, carbon monoxide into carbon dioxide, and nitrogen oxides into nitrogen. Use unleaded petrol because lead in fuel inactivates the catalyst.

3. Maintain and service vehicles regularly and obtain emission checks. Correct engine tuning and efficient combustion reduce carbon monoxide and unburnt hydrocarbon emissions.
4. Use public transport, car pools, cycling or walking whenever possible. Fewer individual vehicle journeys reduce total fuel consumption and exhaust emissions.

Step 3: Conclusion (i) Failure causes fly ash and other particles to escape, increasing air pollution. (ii) Cleaner fuels, catalytic converters with unleaded petrol, regular maintenance and emission checks, and shared or non-motorised transport control vehicular pollution.

Quick Tip to Solve: Link the precipitator specifically to particulate matter, then list four distinct measures for controlling vehicle emissions.

28. Give reasons why: (i) most zygotes in angiosperms divide only after certain amount of endosperm is formed. (ii) groundnut seeds are exalbuminous and castor seeds are albuminous. (iii) Micropyle remains as a small pore in the seed coat of a seed. (iv) integuments of an ovule harden and the water content is highly reduced, as the seed matures. (v) apple and cashew are not called true fruits.

[5 marks]

Solution:

Concept:

- Following double fertilisation, the primary endosperm nucleus forms the endosperm, which supplies nutrition to the developing embryo.
- An albuminous seed retains endosperm at maturity; an exalbuminous seed has consumed it during embryo development.
- The ovule develops into a seed. Its integuments become the seed coat, while the ovary normally forms the fruit.

Step 1: (i) Endosperm formation precedes zygote division Most angiosperm zygotes remain temporarily inactive until a certain amount of endosperm has formed. The endosperm provides the food needed by the developing embryo. Its prior development ensures that nutrition is available when the zygote begins dividing and the young embryo grows. Thus, embryo development is coordinated with the establishment of its nutritive tissue.

Step 2: (ii) Groundnut is exalbuminous; castor is albuminous In groundnut, the developing embryo consumes the endosperm completely, so the mature seed lacks residual endosperm and is called exalbuminous or non-albuminous. Food reserves are stored mainly in its cotyledons. In castor, the embryo does not consume all the endosperm during development. A substantial endosperm remains in the mature seed as stored food; hence castor is albuminous or endospermic. The distinction concerns retention of endosperm at maturity, rather than whether endosperm was initially formed.

Step 3: (iii) Persistence of the micropyle The micropyle persists as a small pore in the seed coat. It allows the entry of water and oxygen during germination. Water uptake rehydrates the seed and activates its metabolism, while oxygen supports respiration needed for the growth of the embryo.

Step 4: (iv) Hardening of integuments and reduction of water The integuments harden to form a tough protective seed coat. This protects the embryo against mechanical injury and unfavourable

external conditions. As the seed matures, its water content falls greatly and the metabolic activity of the embryo slows down. The resulting dry, relatively inactive state helps the seed survive adverse conditions until favourable conditions permit germination.

Step 5: (v) Apple and cashew are false fruits A true fruit develops from the ovary alone. In apple and cashew, floral parts other than the ovary also contribute to the conspicuous fleshy fruit structure, so these are described as false or accessory fruits. In apple the thalamus forms much of the edible fleshy portion. In cashew the swollen fleshy peduncle forms the cashew apple; the actual ovary-derived fruit is the attached kidney-shaped structure containing the seed.

Step 6: Conclusion Endosperm supports the young embryo; its absence or persistence distinguishes groundnut from castor. The micropyle aids water and oxygen entry. A hard seed coat and dehydration aid protection and survival. Apple and cashew include accessory floral tissue in their fleshy structures.

Quick Tip to Solve: For each reason, connect the developmental change to its function; classify seeds by endosperm remaining at maturity, and fruits by the tissues forming them.

OR

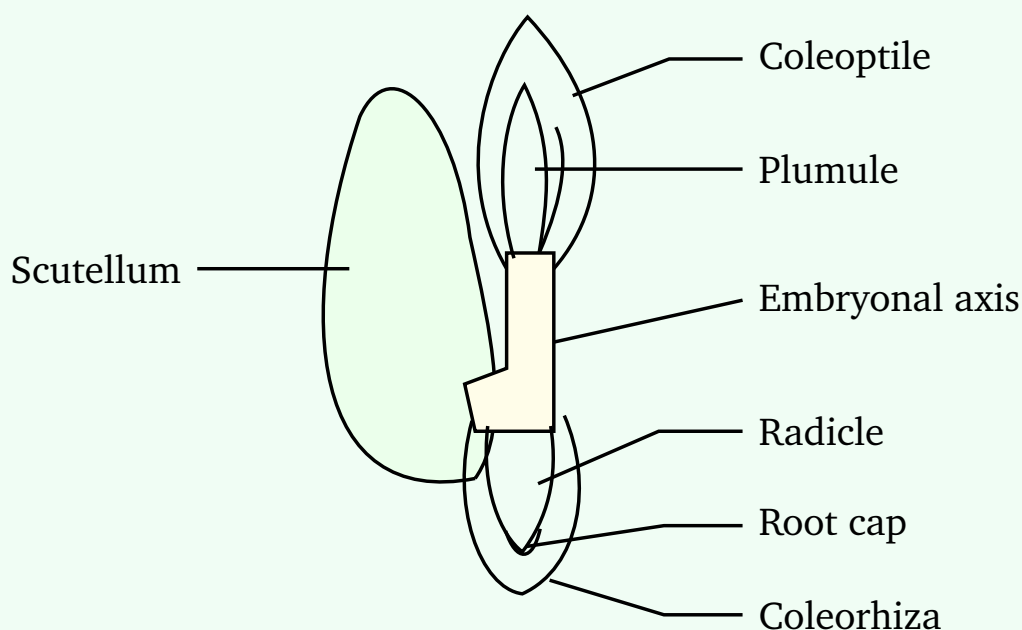
28. (a) Draw a labelled diagram of L.S. of an embryo of grass (any six labels). (b) Give reason for each of the following: (i) Anthers of angiosperm flowers are described as dithecal. (ii) Hybrid seeds have to be produced year after year. [5 marks]

Solution:

Concept:

- A grass embryo is monocotyledonous: its single, shield-shaped cotyledon is the scutellum, situated on one side of the embryonal axis.
- The embryonal axis bears a plumule at its upper end and a radicle at its lower end. The coleoptile protects the plumule, while the coleorhiza encloses the radicle and root cap.
- Anther structure concerns the arrangement of thecae and pollen sacs; maintenance of hybrid vigour depends on preserving the parental cross rather than sowing the hybrid's segregating progeny.

Step 1: (a) Label the longitudinal section of a grass embryo The diagram shows the scutellum lying laterally beside the embryonal axis. At the upper end, the young shoot or plumule is enclosed by the hollow coleoptile. The lower end bears the radicle and its root cap, enclosed by the coleorhiza. These protective sheaths are distinct from the single cotyledon. The labelled structures identify both the shoot and root poles and the characteristic lateral position of the grass cotyledon.



L.S. of a grass embryo (schematic)

Step 2: (b)(i) Explain why the anther is dithecous A typical angiosperm anther is bilobed and has two thecae; hence it is called dithecous (di = two). In transverse section, each lobe contains two microsporangia or pollen sacs, so a typical anther has four microsporangia in all. Thus, the description dithecous refers to its two-theca organisation; it does not mean that the anther contains only two pollen sacs.

Step 3: (b)(ii) Explain why hybrid seed is produced afresh each year Hybrid seeds produce the first filial, or F_1 , generation from a cross between selected parents. These hybrids are generally heterozygous and may show hybrid vigour, such as high yield and desirable uniformity. If seeds harvested from these plants are sown, they give the F_2 generation. Segregation and recombination during sexual reproduction break up the favourable parental gene combinations, so the offspring are variable and do not reliably retain the hybrid's superior characters. Therefore, the original selected parental cross is repeated to produce fresh F_1 hybrid seeds each year.

Step 4: Conclusion The grass embryo has one lateral scutellum, with the plumule and radicle protected by the coleoptile and coleorhiza respectively. A typical anther is dithecous because it has two thecae. Fresh hybrid seed is required because saved seed produces a segregating generation that does not retain the uniform hybrid performance.

Quick Tip to Solve: Pair coleoptile with plumule and coleorhiza with radicle; for hybrid seeds, contrast uniform F_1 plants with segregating F_2 progeny.

Solution:**Concept:**

- The ABO blood group is controlled by the autosomal gene I , which has three alleles in the human population: I^A , I^B and i . An individual carries only two of these alleles, one inherited from each parent.
- I^A and I^B are codominant: both are expressed together in a heterozygote. Each is dominant over i , which is recessive.

Step 1: Relate the alleles to antigens on red blood cells The I^A allele produces a functional glycosyltransferase that forms the A antigen on red blood cells; I^B produces a different functional glycosyltransferase that forms the B antigen. The allele i does not produce an enzyme that forms either A or B antigen. Thus, the inherited pair of alleles determines the ABO phenotype through the antigens present on the red blood cell surface.

Step 2: Explain the genotype and phenotype combinations The three alleles give six possible genotypes but only four blood group phenotypes:

Genotype	Blood group	RBC antigens
$I^A I^A$ or $I^A i$	A	A
$I^B I^B$ or $I^B i$	B	B
$I^A I^B$	AB	A and B
ii	O	Neither A nor B

In $I^A i$ and $I^B i$, the dominant allele is expressed despite the presence of i . In $I^A I^B$, neither allele masks the other, so both antigens appear. This is codominance, not blending of the two antigens. The occurrence of three alleles for this gene in the population illustrates multiple allelism; it does not mean that any person has three alleles.

Step 3: Show segregation and inheritance using a cross Consider a heterozygous group A parent and a heterozygous group B parent:

$$I^A i \times I^B i.$$

During gamete formation the two alleles in each parent segregate. The first parent produces gametes carrying I^A or i , and the second produces gametes carrying I^B or i , in equal proportions. Random fertilisation gives

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

Each genotype has probability $1/4$, so this particular cross can produce children of all four blood groups in the ratio $AB : A : B : O = 1 : 1 : 1 : 1$. Other parental genotypes give different possible offspring groups; the ratio is specific to this cross.

Step 4: Conclusion ABO inheritance illustrates multiple allelism and codominance: $I^A = I^B > i$ in dominance relationships. Mendelian segregation of the parental alleles produces six genotypes corresponding to the four blood groups A, B, AB and O.

Quick Tip to Solve: First list the six genotypes: two each for A and B, one for AB and one for O. Remember that three alleles exist in the population, while each person inherits only two.

29. (a) Why is haemophilia generally observed in human males? Explain the conditions under which a human female can be haemophilic. (b) A pregnant human female was advised to undergo M.T.P. It was diagnosed by her doctor that the foetus she is carrying has developed from a zygote formed by an XX-egg fertilized by Y-carrying sperm. Why was she advised to undergo M.T.P.? [5 marks]

Solution:

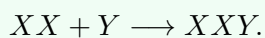
Concept:

- Haemophilia is an X-linked recessive disorder in which deficiency of a blood-clotting factor causes delayed clotting. Let X^H carry the normal allele and X^h carry the haemophilia allele.
- A male has one X chromosome and one Y chromosome, whereas a female normally has two X chromosomes. A recessive X-linked allele is expressed in a male because the Y chromosome lacks a corresponding normal allele.
- Nondisjunction can produce a gamete with an abnormal number of sex chromosomes. An XX egg fertilised by a Y -bearing sperm produces a $47, XXY$ zygote.

Step 1: (a) Explain the higher frequency in males A male with genotype X^hY is haemophilic because his single X chromosome carries the recessive disease allele. He receives this X chromosome from his mother. There is no second X chromosome carrying a normal allele to mask its expression. A female with genotype $X^H X^h$, however, is generally an unaffected carrier because the normal allele is dominant. Thus one affected X is sufficient in a male, while two affected X chromosomes are required for the usual haemophilic female genotype. This makes the disorder much more commonly observed in males.

Step 2: (a) State the conditions for a haemophilic daughter A female is haemophilic when her genotype is $X^h X^h$: she must inherit one affected X chromosome from each parent. Her father must therefore be haemophilic, X^hY , and her mother must be either a carrier, $X^H X^h$, or haemophilic, $X^h X^h$. For a carrier mother and haemophilic father, half the daughters are expected to be $X^h X^h$ and half $X^H X^h$. If both parents are haemophilic, all daughters inherit the affected allele from both parents. A haemophilic father alone is insufficient if the mother supplies a normal X chromosome.

Step 3: (b) Identify the chromosomal condition and the reason given The abnormal egg contains two X chromosomes instead of one. Fertilisation gives



The zygote therefore has 44 autosomes and three sex chromosomes, making 47 chromosomes in total. This is Klinefelter syndrome. The individual develops as a male because a Y chromosome is present, but typically has underdeveloped testes, impaired sperm production and sterility; feminine secondary features such as breast development may also occur. In the context of the question, the doctor's advice for medical termination of pregnancy (M.T.P.) was based on the diagnosis of this sex-chromosome abnormality and its developmental and reproductive consequences. The chromosomal finding identifies the syndrome; it does not mean that termination is biologically compulsory.

Step 4: Conclusion (a) Haemophilia is usually seen in males because it is X-linked recessive; a haemophilic female must inherit X^h from both a haemophilic father and a carrier or haemophilic

mother. (b) The XXY , 47-chromosome foetus has Klinefelter syndrome, the chromosomal disorder underlying the advice described in the question.

Quick Tip to Solve: Write the sex-chromosome combinations first: one affected X gives haemophilia in XY, two are needed in XX, and XX plus Y gives Klinefelter syndrome.

30. (i) Describe the characteristics a cloning vector must possess. (ii) Why DNA cannot pass through the cell membrane? Explain. How is a bacterial cell made 'competent' to take up recombinant DNA from the medium? [5 marks]

Solution:

Concept:

- A cloning vector carries foreign DNA into a host and enables the inserted DNA to be replicated along with the vector.
- The essential vector features are an origin of replication, a selectable marker and suitable unique recognition sites for restriction endonucleases.
- DNA is a large, negatively charged, hydrophilic molecule; it cannot freely diffuse through the hydrophobic lipid interior of the plasma membrane. Competence is the ability of a cell to take up external DNA.

Step 1: (i) Origin of replication A cloning vector must have an origin of replication (ori), the sequence at which replication begins. DNA linked to this sequence can be replicated inside the host cell. The ori also influences the number of copies of the linked DNA maintained in the cell. Therefore, an appropriate ori allows the desired gene to be multiplied in the chosen host.

Step 2: (i) Selectable marker and cloning sites A selectable marker permits identification of transformants and elimination of cells that have not received the vector. For example, antibiotic-resistance genes such as ampicillin-resistance or tetracycline-resistance genes serve this purpose in bacterial plasmids. An untransformed cell fails to grow on medium containing the corresponding antibiotic, whereas a transformed cell carrying the functional resistance gene can grow.

The vector should possess one or a few suitable restriction-enzyme recognition sites, preferably unique sites for the selected enzyme, where foreign DNA can be inserted. Multiple recognition sites for the same enzyme would cut the vector into several fragments and complicate cloning. Insertion into an appropriate marker can also cause insertional inactivation, helping distinguish recombinant colonies from non-recombinant transformants. A vector should be small and convenient to isolate and manipulate so that recombinant DNA can be prepared and introduced efficiently.

Step 3: (ii) Why DNA does not freely enter a bacterial cell DNA has a negatively charged phosphate backbone and is hydrophilic. The cell membrane has a hydrophobic lipid interior that does not allow such a large, charged molecule to cross by simple diffusion. Consequently, merely adding recombinant DNA to an untreated bacterial culture does not normally ensure efficient entry into the cells.

Step 4: (ii) Making cells competent and introducing recombinant DNA Bacterial cells are treated with a specific concentration of a divalent cation, commonly calcium ions supplied as calcium chloride. This treatment increases the efficiency with which DNA enters through pores in the cell wall and

prepares the cells for transformation.

The competent bacteria are mixed with recombinant DNA and kept on ice. They are then briefly exposed to a heat shock at 42 °C, followed by a return to ice. This sequence enables recombinant DNA to enter the bacterial cells. The cells are allowed to recover and are then grown on an appropriate selective medium to identify those that have taken up the vector.

Step 5: Conclusion A useful cloning vector has an ori, a selectable marker and suitable unique cloning sites. DNA cannot freely cross the membrane because of its large size and hydrophilic, negatively charged nature; calcium-ion treatment followed by an ice–heat-shock–ice sequence makes bacterial uptake of recombinant DNA possible.

Quick Tip to Solve: Recall the vector features as ori, marker and cloning site; write the competence sequence as calcium treatment, ice, brief heat shock at 42 degrees Celsius, then ice again.

OR

30. If a desired gene is identified in an organism for some experiments, explain the process of the following: (i) Cutting this desired gene at specific location. (ii) Synthesis of multiple copies of this desired gene. [5 marks]

Solution:

Concept:

- Restriction endonucleases recognise particular DNA sequences and cleave phosphodiester bonds at defined positions within or near these recognition sites.
- Polymerase chain reaction (PCR) amplifies a selected DNA segment in vitro using two primers, a template, nucleotides and a thermostable DNA polymerase.

Step 1: (i) Isolate the DNA containing the desired gene First isolate DNA from the organism by breaking open its cells and removing proteins, RNA and other cellular materials. The purified DNA contains the desired gene. Choose a suitable restriction endonuclease whose recognition sites occur at the required positions flanking that gene, so that digestion releases the desired DNA fragment without disrupting its sequence.

Step 2: Recognise the specific site and cut the DNA A restriction endonuclease binds to its specific recognition sequence, commonly a short palindromic DNA sequence. Such a sequence reads the same on the two complementary strands when each is read in the 5' to 3' direction. Incubate the DNA with the selected enzyme under its appropriate reaction conditions. The enzyme cuts the sugar-phosphate backbone at its defined sites. For example, EcoRI recognises 5'-GAATTC-3' and cuts between G and A on each strand, producing complementary sticky ends. Different restriction enzymes may produce sticky or blunt ends. Separate the resulting fragments by agarose gel electrophoresis, identify the fragment containing the desired gene and recover it from the gel by elution.

Step 3: (ii) Set up PCR for the desired gene Use the isolated desired DNA as the template. Add two short synthetic oligonucleotide primers complementary to sequences at the two ends of the target region, all four deoxyribonucleoside triphosphates, a suitable buffer containing magnesium ions, and

thermostable Taq DNA polymerase obtained from *Thermus aquaticus*. The primers bind to opposite template strands with their extending ends directed into the region to be amplified.

Step 4: Repeat denaturation, annealing and extension Heat the mixture to about 94-95 °C to separate the two DNA strands (denaturation). Lower the temperature, commonly to about 50-65 °C, so the primers bind to their complementary sites (annealing). Raise it to about 72 °C; Taq polymerase extends each primer by adding nucleotides in the 5' to 3' direction (extension). Taq tolerates the repeated heating, so it remains usable through successive cycles. Repeat these stages for about 30 cycles. Each newly formed DNA molecule can act as a template in the next cycle; ideally the amount approximately doubles per cycle, yielding millions to billions of copies of the target sequence.

Step 5: Conclusion The desired gene is released by sequence-specific cleavage with a suitable restriction endonuclease and recovered after electrophoresis. Its multiple copies are then synthesised by repeated PCR cycles of denaturation, primer annealing and extension by thermostable DNA polymerase.

Quick Tip to Solve: Keep the two tools distinct: restriction endonuclease cuts at recognition sites, whereas PCR uses primers and Taq polymerase to copy the selected gene.