

CBSE Class 12 Biology Question Paper 2026 with Solution PDF-Set 57-4-1

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 **33** questions. **All** questions are **compulsory**.
- (ii) Question paper is divided into **five** sections – Sections **A, B, C, D** and **E**.
- (iii) **Section A** – questions number **1** to **16** are Multiple Choice Type Questions. Each question carries **1** mark.
- (iv) **Section B** – questions number **17** to **21** are Very Short Answer Type Questions. Each question carries **2** marks.
- (v) **Section C** – questions number **22** to **28** are Short Answer Type Questions. Each question carries **3** marks.
- (vi) **Section D** – questions number **29** and **30** are Case-Based questions. Each question carries **4** marks. Each question has subparts with internal choice in one of the subparts.
- (vii) **Section E** – questions number **31** to **33** are Long Answer Type Questions. Each question carries **5** marks.
- (viii) There is no overall choice. However, an internal choice has been provided in Sections B, C, D and E of the question paper. A candidate has to write answer for only **one** of the alternatives in such questions.
- (ix) Kindly note that there is a separate question paper for Visually Impaired candidates.
- (x) Wherever necessary, neat and properly labelled diagrams should be drawn.

Section A (16 marks)

Questions no. 1 to 16 are Multiple Choice Type Questions, carrying 1 mark each. Choose the best option.
 $16 \times 1 = 16$

1. Choose the option that gives the correct number of pollen grains that will be formed after 325 microspore mother cells undergo microsporogenesis. [1 mark]

- (A) 325
- (B) 650
- (C) 1300
- (D) 975

Correct Answer: (C) 1300

Solution:

Concept:

- Microsporogenesis is the formation of haploid microspores from diploid microspore mother cells by meiosis.
- Each microspore mother cell produces a tetrad of four microspores; each microspore develops into one pollen grain.

Step 1: Count the products of one mother cell One diploid microspore mother cell undergoes two successive meiotic divisions to form four haploid microspores. Thus the number of pollen grains formed per mother cell is four, not one or two.

Step 2: Multiply by the number of mother cells For the given 325 mother cells, the pollen-grain count is

$$N = 325 \times 4 = 1300.$$

The alternatives 325, 650 and 975 correspond to multiplying by one, two and three respectively; none represents the four microspores in a meiotic tetrad.

Step 3: Conclusion The 325 microspore mother cells form 1300 pollen grains. Hence, the correct option is (C).

Quick Tip to Solve: For pollen-grain counts from microspore mother cells, multiply by four because all four meiotic products become microspores.

2. Select the phase of menstrual cycle in which the remaining parts of Graafian follicle transform into the corpus luteum. [1 mark]

- (A) Secretory phase
- (B) Proliferative phase
- (C) Menstrual phase
- (D) Ovulatory phase

Correct Answer: (A) Secretory phase

Solution:

Concept:

- After ovulation, the remaining follicular tissue develops into the corpus luteum under the influence of luteinising hormone (LH).
- The corpus luteum secretes progesterone, which maintains the uterine endometrium in its secretory state.

Step 1: Locate corpus luteum formation in the cycle Ovulation releases the secondary oocyte from the mature Graafian follicle. The tissue left behind then transforms into the corpus luteum during the luteal phase of the ovarian cycle, corresponding to the secretory phase of the uterine cycle.

Step 2: Distinguish the other phases The proliferative phase involves growth of follicles and rebuilding of the endometrium. The menstrual phase involves shedding of the endometrium. The ovulatory phase is the rupture and release event itself; development of the remaining follicular tissue follows it.

Step 3: Conclusion Transformation of the remaining Graafian follicle into the corpus luteum occurs in the secretory phase. Hence, the correct option is (A).

Quick Tip to Solve: Link corpus luteum with progesterone and the post-ovulatory secretory phase; link follicular growth with the proliferative phase.

3. A female undergoing IVF treatment has blocked fallopian tube. The technique by which the embryo with more than 8 blastomeres will be transferred into the female for further development is: [1 mark]

- (A) ZIFT
- (B) GIFT
- (C) IUT
- (D) AI

Correct Answer: (C) IUT

Solution:

Concept:

- In vitro fertilisation (IVF) produces an embryo outside the female body; embryo transfer places it at an appropriate site for further development.
- Embryos with up to eight blastomeres can be transferred to the fallopian tube, whereas embryos with more than eight blastomeres are transferred to the uterus.

Step 1: Use the embryo's stage to select the site The embryo has more than eight blastomeres, so its transfer site is the uterus. This procedure is called intrauterine transfer (IUT). Transfer directly into the uterus also bypasses the blocked fallopian tube.

Step 2: Eliminate the other techniques ZIFT transfers a zygote or an early embryo into the fallopian tube. GIFT transfers gametes into the fallopian tube and requires a suitable tube. Artificial insemination (AI) introduces semen into the female reproductive tract; it does not transfer an already formed embryo.

Step 3: Conclusion The required technique is intrauterine transfer (IUT). Hence, the correct option is (C).

Quick Tip to Solve: Use the eight-blastomere boundary: up to eight suggests tubal transfer, while more than eight indicates uterine transfer.

4. Select the correct statement. All genes located on the same chromosome:

[1 mark]

- (A) form different groups depending upon their relative distance.
- (B) form one linkage group.
- (C) will not form linkage groups.
- (D) form interactive groups that affect the phenotype.

Correct Answer: (B) form one linkage group.

Solution:

Concept:

- Linkage is the physical association of genes located on the same chromosome, which gives them a tendency to be inherited together.
- A linkage group comprises the genes on one chromosome; the distance between genes influences recombination frequency, not their membership of that group.

Step 1: Apply the definition of a linkage group All the stated genes occupy the same chromosome. They therefore belong to a single linkage group even though crossing over may produce recombinant combinations between particular loci.

Step 2: Separate linkage from distance and interaction Greater distance can weaken the observed linkage between two genes, but it does not divide a chromosome into several linkage groups, so (A) is incorrect. Option (C) contradicts physical linkage. Phenotypic gene interaction, mentioned in (D), is a different concept and is not guaranteed merely by a shared chromosome.

Step 3: Conclusion All genes located on the same chromosome form one linkage group. Hence, the correct option is (B).

Quick Tip to Solve: Decide linkage-group membership from the chromosome; use the distance between loci only to judge recombination frequency.

5. Choose the correct statements:

- (i) Polycistronic mRNA is generally found in eukaryotes.
(ii) The RNA polymerase II transcribes precursor of mRNA, the hnRNA.
(iii) The process of translation of mRNA begins when the mRNA encounters the large subunit of ribosomes.
(iv) Stop codons do not have any tRNAs. [1 mark]

- (A) (i) and (ii)
(B) (ii) and (iii)
(C) (ii) and (iv)
(D) (i), (ii) and (iv)

Correct Answer: (C) (ii) and (iv)

Solution:

Concept:

- Eukaryotic mRNA is generally monocistronic, whereas polycistronic mRNA is characteristic of prokaryotes. RNA polymerase II transcribes hnRNA, the precursor of eukaryotic mRNA.
- Translation initiation involves binding of mRNA to the small ribosomal subunit. Stop codons are recognised by release factors rather than by aminoacyl-tRNAs.

Step 1: Evaluate statements (i) and (ii) Statement (i) reverses the usual distribution of polycistronic mRNA, so it is false. Statement (ii) correctly identifies both RNA polymerase II and its primary transcript, hnRNA, so it is true.

Step 2: Evaluate statements (iii) and (iv) Statement (iii) is false because the small ribosomal subunit initially binds the mRNA; the large subunit joins subsequently. Statement (iv) is true because stop codons have no corresponding tRNAs and instead recruit release factors. Options (A), (B) and (D) all include at least one of the false statements (i) and (iii).

Step 3: Conclusion Only statements (ii) and (iv) are correct. Hence, the correct option is (C).

Quick Tip to Solve: Remember the paired checks: polymerase II makes hnRNA, the small subunit initiates, and release factors recognise stop codons.

6. Name the extinct ancestor of humans who ate only fruits and hunted with stone weapons. [1 mark]

- (A) *Ramapithecus*
- (B) *Australopithecus*
- (C) *Dryopithecus*
- (D) *Homo erectus*

Correct Answer: (B) *Australopithecus*

Solution:

Concept:

- NCERT associates the australopithecines of East African grasslands with hunting using stone weapons and an essentially fruit-based diet.
- Human-evolution questions are identified by matching the stated combination of traits to the textbook description of the ancestor.

Step 1: Match the two stated traits The question combines the use of stone weapons with eating fruits. This is the NCERT description associated with australopithecines, represented in the options by *Australopithecus*.

Step 2: Distinguish the other ancestors *Ramapithecus* and *Dryopithecus* are earlier primates described as more man-like and more ape-like respectively; the given paired traits do not identify them. *Homo erectus* is associated with a later stage, a larger brain and probable meat consumption, so it does not match the fruit-only description in the question.

Step 3: Conclusion The ancestor is *Australopithecus*. Hence, the correct option is (B).

Quick Tip to Solve: Match the combined textbook clues of stone weapons and a fruit diet to australopithecines, rather than choosing from the tool-use clue alone.

7. Nicotine affects blood pressure and heart rate due to release of certain adrenal hormones. Following are some of the adrenal hormones:

- (i) Adrenaline
- (ii) Cortisol
- (iii) Noradrenaline
- (iv) Aldosterone

Select the correct option:

[1 mark]

- (A) (i) and (ii)
- (B) (i) and (iv)
- (C) (ii) and (iii)
- (D) (i) and (iii)

Correct Answer: (D) (i) and (iii)

Solution:

Concept:

- Nicotine stimulates the adrenal glands to release adrenaline and noradrenaline into the blood.
- These adrenal-medullary catecholamines produce sympathetic effects, including increased heart rate and blood pressure.

Step 1: Identify the hormones released in response to nicotine The cardiovascular effect described follows the release of adrenaline, listed as (i), and noradrenaline, listed as (iii). Their actions prepare the body for an emergency response and increase cardiac activity.

Step 2: Exclude the adrenal-cortical hormones Cortisol is a glucocorticoid involved in metabolism and stress responses; aldosterone is a mineralocorticoid involved in salt and water balance. Although both are adrenal hormones, they are not the pair responsible for the nicotine effect asked here. Options (A), (B) and (C) each include one of these cortical hormones.

Step 3: Conclusion Adrenaline and noradrenaline, statements (i) and (iii), are the required hormones. Hence, the correct option is (D).

Quick Tip to Solve: For nicotine's rise in heart rate and blood pressure, select the two adrenal-medullary catecholamines: adrenaline and noradrenaline.

8. Microbes used for biocontrol of pest butterfly caterpillars is:

[1 mark]

- (A) *Saccharomyces cerevisiae*
- (B) *Bacillus thuringiensis*
- (C) *Streptococcus* sp.
- (D) *Trichoderma*

Correct Answer: (B) *Bacillus thuringiensis*

Solution:

Concept:

- Biological control uses living organisms or their products to control pests.
- *Bacillus thuringiensis* (Bt) produces insecticidal proteins that kill susceptible insect larvae when ingested.

Step 1: Identify the caterpillar biocontrol agent Bt spores and toxin preparations are sprayed on plants. Butterfly caterpillars ingest them while feeding on leaves. The toxin becomes active in the alkaline gut, damages the gut epithelium and kills the susceptible larvae.

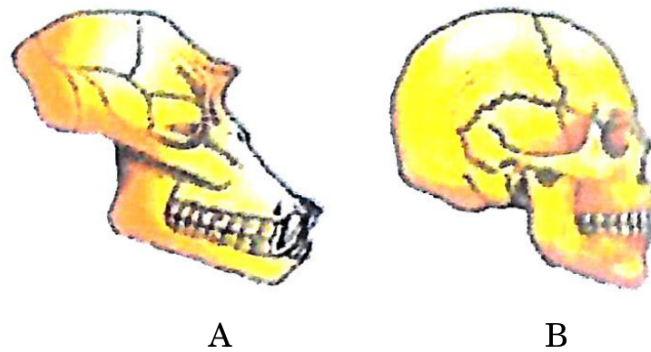
Step 2: Eliminate the other microbes *Saccharomyces cerevisiae* is the yeast used in baking and fermentation. *Streptococcus* species are not the listed caterpillar biocontrol agent. *Trichoderma* is a fungal biocontrol agent chiefly used against plant pathogens, rather than butterfly caterpillars.

Step 3: Conclusion *Bacillus thuringiensis* controls pest butterfly caterpillars. Hence, the correct option is (B).

Quick Tip to Solve: Associate caterpillars with Bt toxin; associate *Trichoderma* with control of plant pathogens.

9. The given diagram shows the skulls of two different mammals.

Which of the following options accurately describes the differences between these skulls? [1 mark]



- (A) Skull B is the ancestor of skull A.
(B) Skull A has more brain capacity than skull B.
(C) Skull A is of a human and skull B is of an adult chimpanzee.
(D) Skull A is of an adult chimpanzee and skull B is of a human.

Correct Answer: (D) Skull A is of an adult chimpanzee and skull B is of a human.

Solution:

Concept:

- Human and chimpanzee skulls differ in cranial size, facial projection and jaw development.
- A human skull has a larger, rounded braincase and a flatter face; an adult chimpanzee has a smaller braincase and projecting jaws.

Step 1: Compare the visible skull features Skull A has a relatively small cranial vault and a markedly projecting muzzle and jaws. Skull B has a large rounded cranial vault, a more vertical forehead and a less projecting face. These features identify A as an adult chimpanzee and B as a human.

Step 2: Test the alternative descriptions Option (B) reverses the brain-capacity comparison, and option (C) reverses the identities. Option (A) is also incorrect: living humans and chimpanzees share a common ancestor; the human skull shown is not the ancestor of the chimpanzee skull shown.

Step 3: Conclusion Skull A is of an adult chimpanzee and skull B is of a human. Hence, the correct option is (D).

Quick Tip to Solve: First compare the braincase and jaw projection: the larger rounded vault with the flatter face identifies the human skull.

10. In RNAi, genes are silenced using which of the following biomolecules?

[1 mark]

- (A) ssDNA
- (B) dsDNA
- (C) dsRNA
- (D) ssRNA

Correct Answer: (C) dsRNA

Solution:

Concept:

- RNA interference (RNAi) is sequence-specific gene silencing at the level of messenger RNA (mRNA).
- Double-stranded RNA (dsRNA), complementary in sequence to the target transcript, initiates the silencing process.

Step 1: Identify the RNAi trigger In RNAi, dsRNA provides the sequence information for recognition of a specific mRNA. It is processed into small interfering RNAs that guide the silencing machinery to the matching transcript, causing its degradation and preventing translation.

Step 2: Distinguish the offered biomolecules Neither single-stranded DNA (ssDNA) nor double-stranded DNA (dsDNA) is the RNA trigger described in RNAi. Although a single RNA guide strand functions within the silencing machinery, the biomolecule used to initiate the process in this question is dsRNA, rather than ssRNA.

Step 3: Conclusion Genes are silenced using double-stranded RNA in RNAi. Hence, the correct option is (C).

Quick Tip to Solve: For an RNAi question, identify dsRNA as the trigger and mRNA as the target whose translation is prevented.

11. Connell's elegant field experiments on the rocky seacoast of Scotland, found that larger barnacles *Balanus* dominated the intertidal area and removed the smaller barnacles *Chthamalus*. This happened due to:

[1 mark]

- (A) Parasitism
- (B) Predation
- (C) Mutualism
- (D) Competition

Correct Answer: (D) Competition

Solution:

Concept:

- Interspecific competition occurs when different species use a shared limiting resource, such as space for attachment.
- A competitively superior species can exclude an inferior competitor from part of its potential habitat.

Step 1: Identify the interaction in the experiment The barnacles require attachment space on the rocky shore. The larger *Balanus* excludes the smaller *Chthamalus* from the lower intertidal region. Removal of *Balanus* allows the smaller barnacle to occupy that region, demonstrating competitive exclusion.

Step 2: Distinguish competition from the other interactions *Balanus* does not eat the smaller barnacle, so this is not predation. It does not live as a parasite on it, and the exclusion does not benefit both species, ruling out parasitism and mutualism. The decisive interaction is their competition for space.

Step 3: Conclusion The larger barnacles exclude the smaller barnacles through interspecific competition. Hence, the correct option is (D).

Quick Tip to Solve: In Connell's barnacle experiment, link expansion after competitor removal with competition for rocky-shore space.

12. Protein encoded by gene Cry-I Ab controls the infestation of which of the following? [1 mark]

- (A) Cotton bollworms
- (B) Mosquitoes
- (C) Corn borer
- (D) Agrobacterium

Correct Answer: (C) Corn borer

Solution:

Concept:

- The bacterium *Bacillus thuringiensis* produces Cry proteins with insecticidal activity against particular insect groups.
- Different *cry* genes encode proteins with different target specificities; the Cry-I Ab protein targets corn borer.

Step 1: Match the Cry protein with its target The protein encoded by *cryIAb*, corresponding to Cry-I Ab in the question, is used to control corn borer. The insecticidal protein acts after susceptible larvae ingest it, protecting the crop against larval infestation.

Step 2: Eliminate the alternative targets Cotton bollworm control is associated with the proteins encoded by *cryIAc* and *cryIIAb*, not the gene specified here. Mosquito control involves other Bt toxin specificities. *Agrobacterium* is a bacterium used as a gene-transfer vector and is not the target insect pest of Cry-I Ab.

Step 3: Conclusion The protein encoded by Cry-I Ab controls corn borer infestation. Hence, the correct option is (C).

Quick Tip to Solve: Keep the gene-target pairs separate: *cryIAb* for corn borer; *cryIAc* and *cryIIAb* for cotton bollworms.

13. Assertion (A): Cleistogamous flowers have assured seed set.

Reason (R): Cleistogamous flowers are invariably autogamous and do not depend on any pollinating agents. [1 mark]

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

Correct Answer: (A) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of the Assertion (A).

Solution:

Concept:

- Cleistogamous flowers remain closed, with anthers and stigma close to each other inside the flower.
- Autogamy is transfer of pollen from the anther to the stigma of the same flower; it does not require an external pollinating agent in cleistogamous flowers.

Step 1: Evaluate the assertion The assertion is true. Cleistogamous flowers have assured seed set because their closed floral structure ensures self-pollination even when pollinating agents are absent.

Step 2: Evaluate the reason The reason is true. These flowers do not open, and pollen released from their anthers reaches the stigma within the same flower. They are invariably autogamous and independent of external pollinating agents.

Step 3: Test the explanatory link Assured autogamy removes dependence on uncertain visits by pollinators. Thus the reason directly explains the assured seed set stated in the assertion; the statements are not merely two unrelated true facts.

Step 4: Conclusion Both Assertion (A) and Reason (R) are true, and Reason (R) correctly explains Assertion (A). Hence, the correct option is (A).

Quick Tip to Solve: For cleistogamy, trace the chain: closed flower, obligatory self-pollination, independence from pollinators, assured seed set.

14. Assertion (A): The human blood group 'AB' exemplifies co-dominance.

Reason (R): The gene for human blood group trait exists in three allelic forms I^A , I^B and i . [1 mark]

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

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

Solution:

Concept:

- Co-dominance means that both alleles in a heterozygote express their effects without either masking the other.
- Multiple allelism means that a gene has more than two alternative alleles in a population, although a diploid individual carries only two of them.

Step 1: Evaluate the assertion The assertion is true. A person with blood group AB has genotype $I^A I^B$. Both alleles are expressed, producing both A and B antigens on red blood cells. This simultaneous expression demonstrates co-dominance.

Step 2: Evaluate the reason The reason is true. The human ABO blood-group gene has three allelic forms, I^A , I^B and i , in the population. This fact illustrates multiple allelism.

Step 3: Test the explanatory link The existence of three alleles does not itself explain why I^A and I^B are both expressed in the same person. The assertion concerns their expression relationship, whereas the reason concerns the number of allelic forms. The reason is therefore not the correct explanation.

Step 4: Conclusion Both the assertion and the reason are true, but the reason does not correctly explain the assertion. Hence, the correct option is (B).

Quick Tip to Solve: Distinguish the number of alleles in the population from their expression in an individual: three alleles means multiple allelism, AB means co-dominance.

15. Assertion (A): Nucleopolyhedrovirus are useful as they are good biocontrol agents.

Reason (R): They are species-specific, narrow spectrum bioinsecticides.

[1 mark]

(A) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of the Assertion (A).

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

(C) Assertion (A) is true, but Reason (R) is false.

(D) Assertion (A) is false, but Reason (R) is true.

Correct Answer: (A) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of the Assertion (A).

Solution:

Concept:

- Baculoviruses infect insects and other arthropods. Most baculoviruses used in biological control belong to the genus *Nucleopolyhedrovirus*.
- A species-specific bioinsecticide targets a narrow range of pests while sparing beneficial organisms.

Step 1: Evaluate the assertion Assertion (A) is true. Nucleopolyhedroviruses act as biological control agents by infecting and controlling susceptible insect pests, reducing dependence on chemical insecticides.

Step 2: Evaluate the reason Reason (R) is true. These viruses are species-specific, narrow-spectrum bioinsecticides. They do not adversely affect plants, mammals, birds, fish or non-target insects in the way broad-spectrum chemical insecticides can.

Step 3: Connect the reason to the assertion Selective action is precisely why these viruses are valuable in biological control: the target pest is controlled while beneficial insects and natural enemies are conserved. Thus R explains A. Option (B) wrongly denies this explanatory link, while (C) and (D) wrongly reject a true statement.

Step 4: Conclusion Both A and R are true, and R correctly explains A. Hence, the correct option is (A).

Quick Tip to Solve: Link the words “species-specific” to protection of non-target organisms; that selectivity explains the value of nucleopolyhedroviruses in biocontrol.

16. Assertion (A): The pyramid of biomass in a pond aquatic ecosystem is always inverted.

Reason (R): The biomass of consumers like fishes far exceeds that of the producers like phytoplanktons.

[1 mark]

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

Correct Answer: (D) Assertion (A) is false, but Reason (R) is true.

Solution:

Concept:

- A pyramid of biomass represents the standing biomass at successive trophic levels at a particular time, rather than the total production over a period.
- An inverted biomass pyramid can occur when a small standing crop of rapidly reproducing phytoplankton supports a larger consumer biomass. Biomass pyramids need not have the same shape in every ecosystem.

Step 1: Evaluate the assertion carefully Assertion (A) is false because of the word “always”. A pond’s biomass pyramid is not necessarily inverted: its shape depends on the producer community and standing biomass at different trophic levels. A pond with substantial rooted or other large aquatic vegetation can have an upright biomass pyramid.

Step 2: Evaluate the reason Reason (R) describes the standard inverted aquatic biomass pyramid and is true in that context. The standing biomass of consumers such as fishes can far exceed that of phytoplankton. Rapid reproduction and turnover replenish phytoplankton as they are consumed, allowing their small standing crop to support a larger consumer biomass.

Step 3: Test the explanatory link R explains how an inverted aquatic biomass pyramid is possible; it does not establish that every pond must always have one. Options (A) and (B) accept the unjustified universal assertion, while (C) reverses the truth values. Do not confuse this with the energy pyramid, which is always upright.

Step 4: Conclusion A is false, while R is true for the described inverted aquatic biomass pyramid. Hence, the correct option is (D).

Quick Tip to Solve: Check absolute words such as “always”: only the energy pyramid is invariably upright; a biomass pyramid depends on the ecosystem and its standing crop.

Section B (10 marks)

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

Solution:

Concept:

- Hormonal contraceptives use progestogens, alone or in combination with oestrogens, to interfere with the events necessary for pregnancy.
- An implant placed beneath the skin provides a sustained release of contraceptive hormone, maintaining its action for a prolonged period.

Step 1: Explain the contraceptive action Hormone-containing implants are inserted under the skin of the female. Their gradual release of progestogen, alone or with oestrogen, inhibits ovulation, so an ovum is not available for fertilisation. They also alter the cervical mucus to impede the entry and transport of sperms and make the uterine endometrium unsuitable for implantation. Their basic mode of action is therefore similar to that of hormonal contraceptive pills.

Step 2: State an advantage over pills Implants act for a much longer duration after a single insertion. Unlike oral contraceptive pills, they do not require the woman to remember a daily dose. This prolonged action reduces contraceptive failure due to forgetting tablets and makes them convenient for long-term, reversible contraception.

Step 3: Conclusion Implants release hormones that inhibit ovulation and create conditions unfavourable for sperm entry and implantation. Their advantage over pills is prolonged protection without daily dosing.

Quick Tip to Solve: Separate the answer into hormonal action and duration: implants act like hormonal pills but release the hormone over a prolonged period after insertion.

18. (a) Write one way by which apomictic seeds can be developed.

(b) Why do farmers prefer apomictic seeds over hybrid seeds? [2 marks]

Solution:

Concept:

- Apomixis is seed formation without fertilisation. It mimics sexual reproduction but is a form of asexual reproduction.
- Sexual reproduction in a hybrid can cause segregation of traits in the next generation; apomictic reproduction can preserve the parental hybrid genotype.

Step 1: Describe one way of forming an apomictic seed (a) A diploid egg cell can be formed without reduction division, that is, without meiosis. This unreduced egg develops directly into an embryo without fertilisation. The ovule then develops into a seed containing that embryo. Since there is no fusion of gametes, this is apomictic seed development.

Step 2: Explain the benefit to farmers (b) Seeds produced by ordinary hybrid plants through sexual

reproduction show segregation in the next generation and may lose the desirable combination of hybrid characters. If the hybrid is made apomictic, its progeny retain that desirable genotype and hybrid vigour without segregation. Farmers can therefore collect and sow the seeds from their crop in subsequent seasons while retaining the hybrid's useful traits, instead of purchasing costly fresh hybrid seeds every year.

Step 3: Conclusion An unreduced diploid egg can develop into an embryo without fertilisation to form an apomictic seed. Apomictic hybrid seeds preserve desirable hybrid characters and allow repeated use of farm-saved seeds.

Quick Tip to Solve: For the advantage of apomixis, trace the chain: no sexual segregation, retained hybrid characters, and no need to buy fresh hybrid seeds each season.

19. A laboratory assistant collected three water samples, namely river water, untreated sewage water and secondary effluent discharged from a sewage treatment plant. But the laboratory attendant did not note which was which. The samples were labelled A, B and C and subjected to a BOD test. The BOD values of the three samples A, B and C were recorded as 30 mg/L, 8 mg/L and 400 mg/L respectively.

(a) Which sample of the water is most polluted?

(b) Can you assign the correct label to each, assuming the river water is relatively clean? [2 marks]

Solution:

Concept:

- Biochemical oxygen demand (BOD) measures the oxygen required by microorganisms to decompose biodegradable organic matter in a water sample under specified conditions.
- A higher BOD indicates a larger biodegradable organic load and greater organic pollution. Biological secondary treatment removes much of this load and reduces BOD.

Step 1: Compare the BOD values (a) The values are $A = 30 \text{ mg/L}$, $B = 8 \text{ mg/L}$ and $C = 400 \text{ mg/L}$. Their order is $C > A > B$. Sample C has by far the greatest oxygen demand, indicating the greatest biodegradable organic load. It is therefore the most polluted of these samples according to the BOD test.

Step 2: Match each sample to its source (b) Untreated sewage contains abundant organic waste, so it corresponds to C with the highest BOD of 400 mg/L. The relatively clean river water must be B with the lowest BOD of 8 mg/L. The remaining sample A, with BOD 30 mg/L, is the secondary effluent: microbial treatment has greatly reduced its organic load compared with untreated sewage, although its BOD remains above that of the river water.

Step 3: Conclusion (a) Sample C is the most polluted. (b) A is secondary effluent, B is river water and C is untreated sewage water.

Quick Tip to Solve: Rank the BOD values first: highest means untreated sewage, lowest means the relatively clean river, and the intermediate value identifies the treated effluent.

20. Write the role of 'ori' and 'restriction' site in a cloning vector pBR322.

[2 marks]

Solution:

Concept:

- A cloning vector carries a foreign DNA fragment into a host and allows that fragment to be replicated along with the vector.
- The origin of replication and restriction sites perform different functions: replication starts at the former, whereas a restriction enzyme recognises and cuts the latter.

Step 1: Explain the role of ori The **ori** is the DNA sequence from which replication of pBR322 begins. Any foreign DNA linked to this sequence is also replicated inside the host. The origin also controls the copy number of the linked DNA, thereby determining how many copies can be maintained in the host cell.

Step 2: Explain the role of a restriction site A **restriction site** is a specific recognition sequence at which the corresponding restriction endonuclease cuts pBR322. Cutting at a suitable, preferably unique site opens the plasmid so that foreign DNA with compatible ends can be joined to it by DNA ligase. Thus, the site provides an insertion point for forming recombinant DNA.

Step 3: Conclusion In pBR322, ori enables replication and controls copy number, while a restriction site permits specific cutting and insertion of foreign DNA.

Quick Tip to Solve: Link ori with copying DNA and the restriction site with opening the vector for insertion; these are separate functions.

21(a). Biodiversity must be conserved as it plays an important role in many ecosystem services that nature provides. Explain any two ecosystem services.

[2 marks]

Solution:

Concept:

- Ecosystem services are benefits that humans obtain from the functioning of natural ecosystems.
- Biodiversity supports these services because different organisms perform complementary ecological roles. Conserving species helps maintain these processes.

Step 1: Explain pollination as an ecosystem service Bees, butterflies and other animal pollinators transfer pollen from anthers to receptive stigmas while visiting flowers. This enables fertilisation and the formation of seeds and fruits in many flowering plants, including crops. Conserving the diversity of pollinators therefore supports plant reproduction and food production.

Step 2: Explain oxygen production as an ecosystem service Green plants and other photosynthetic organisms release oxygen during photosynthesis. Forests and other producer communities consequently contribute to the supply of atmospheric oxygen required for aerobic respiration. Conserving these organisms maintains a major life-supporting function of ecosystems.

Step 3: Conclusion Two ecosystem services supported by biodiversity are animal-mediated pollination, which helps produce seeds and fruits, and photosynthetic oxygen production, which supports aerobic life.

Quick Tip to Solve: For each service, name the organisms involved and then explain the benefit: pollinators enable reproduction; producers release oxygen.

21(b). (i) State, what does 'standing crop' of a trophic level represent.

(ii) List any two ways of measuring the standing crop of a trophic level.

[2 marks]

Solution:

Concept:

- Each trophic level contains a certain quantity of living material at a particular time; this is its standing crop.
- Standing crop is a stock present at a given moment. It differs from productivity, which measures the rate of production of biomass over time.

Step 1: State what standing crop represents (i) The standing crop of a trophic level represents the quantity of living material present at that trophic level at a given time. For example, the living grasses present in a defined grassland area at the time of sampling constitute part of the producers' standing crop. It is not the total material produced throughout the year.

Step 2: List two ways to measure standing crop (ii) It can be measured as **the number of organisms per unit area** or as **the biomass per unit area**. Biomass is the mass of living material, and it may be expressed as fresh mass or dry mass. Dry mass is generally more accurate for comparison because the water content of organisms varies; an example of a biomass unit is g m^{-2} .

Step 3: Conclusion Standing crop is the living material present at a trophic level at a given time; it is measured by the number of organisms or their biomass per unit area.

Quick Tip to Solve: Remember standing crop as a snapshot: report numbers or biomass, and do not add a per-year term that would indicate productivity.

Section C (21 marks)

22. Differentiate between wind-pollinated and insect-pollinated flowers. Give an example of each type.

[3 marks]

Solution:

Concept:

- Pollination is the transfer of pollen grains from the anther to the stigma of a flower. Wind and insects are two different agents of pollen transfer.
- Floral adaptations facilitate pollen dispersal and reception by the particular agent: wind transport requires easily airborne pollen, while insect transport requires attraction and attachment.

Step 1: Compare floral attraction and rewards **Wind-pollinated flowers** are generally small and inconspicuous, with reduced petals; they usually lack fragrance and nectar because wind need not be attracted. **Insect-pollinated flowers** are often conspicuous or brightly coloured and fragrant. They commonly offer nectar or pollen as a reward, encouraging insects to visit and carry pollen between flowers.

Step 2: Compare pollen and reproductive structures In wind-pollinated flowers, pollen grains are

light, dry and non-sticky and are produced in large quantities because much pollen is lost during dispersal. Stamens are often well exposed, and large, feathery stigmas intercept airborne pollen. In insect-pollinated flowers, pollen is usually sticky or has a sculptured surface that helps it adhere to an insect's body. The stigma is generally sticky, and the anthers and stigma are positioned so that visiting insects contact them. Pollen transfer is more directed than in wind pollination.

Step 3: Give an example of each type **Maize** is wind-pollinated: exposed anthers release pollen into the air, and the elongated stigmas, or silks, receive it. **Sunflower** is insect-pollinated: its conspicuous flower head attracts insects, including bees, which transfer pollen as they visit the florets.

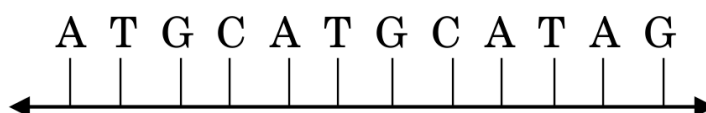
Step 4: Conclusion Wind-pollinated flowers, such as maize, favour airborne pollen release and capture; insect-pollinated flowers, such as sunflower, attract insects and transfer pollen through contact with their bodies.

Quick Tip to Solve: Compare the same features in both types: attraction, pollen properties and stigma structure; then attach maize to wind and sunflower to insects.

23. (a) Construct a complete transcription unit with promoter and terminator on the basis of the hypothetical coding strand given below:

(b) Write the RNA strand transcribed from the above transcription unit along with its polarity.

[3 marks]



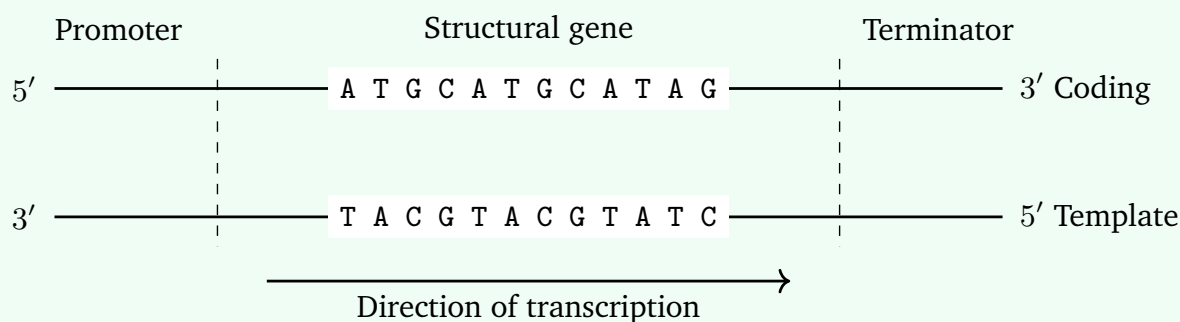
Solution:

Concept:

- A transcription unit consists of a promoter, a structural gene and a terminator. The promoter specifies the start and direction of transcription.
- DNA strands are complementary and antiparallel. RNA polymerase reads the template strand in the $3' \rightarrow 5'$ direction and synthesises RNA in the $5' \rightarrow 3'$ direction.

Step 1: (a) Construct the complementary DNA strand Write the given coding sequence in the conventional $5' \rightarrow 3'$ direction from left to right. Using the base-pairing rules A–T and G–C, its complementary template is $3'\text{-TACGTACGTATC-}5'$. Each base of the coding strand pairs with the corresponding base of the template; the strands must not be labelled with the same polarity.

Step 2: Position the promoter and terminator Place the promoter upstream, towards the $5'$ end of the coding strand, and the terminator downstream, towards its $3'$ end. RNA polymerase binds at the promoter and moves along the template towards the terminator. The sequence given in the question represents the structural-gene segment; the promoter and terminator flank this segment as shown.



Transcription unit with antiparallel strands and the direction of transcription.

Step 3: (b) Transcribe the template strand Complement the template in its 3' → 5' reading direction, using uracil in RNA in place of thymine. The RNA therefore has the same base sequence as the coding strand except that each T is replaced by U:

5'-AUGCAUGCAUAG-3'.

There are twelve nucleotides in both the supplied coding segment and the corresponding RNA segment. The coding strand itself is not the strand read by RNA polymerase.

Step 4: Conclusion The transcription unit is promoter–structural gene–terminator, with coding strand 5'-ATGCATGCATAG-3' and template strand 3'-TACGTACGTATC-5'. The transcribed RNA is 5'-AUGCAUGCAUAG-3'.

Quick Tip to Solve: When a coding strand is supplied in the 5' → 3' direction, retain its sequence and replace T with U to obtain the RNA; complement only when finding the template.

24. Explain the three different ways in which natural selection operates. Explain with the help of graphs. [3 marks]

Solution:

Concept:

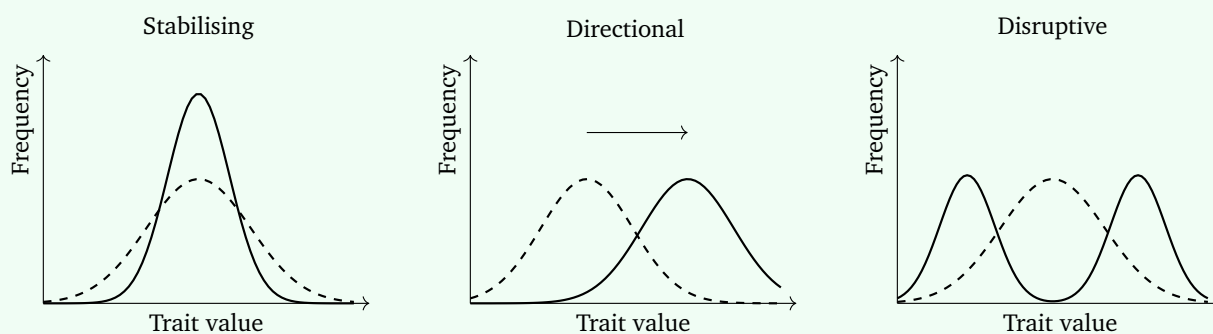
- Natural selection produces differential survival and reproduction of individuals with heritable variations. The favoured phenotypes contribute more offspring to the next generation.
- Selection may favour the average phenotype, one extreme, or both extremes. Plot phenotype or trait value on the horizontal axis and frequency of individuals on the vertical axis to compare the distributions.

Step 1: Explain stabilising selection Individuals with intermediate or average phenotypes are favoured, while those at both extremes are selected against. Consequently, more individuals acquire the mean character value over generations: the distribution becomes narrower and more concentrated around approximately the same mean. For example, intermediate human birth weights generally have a survival advantage over very low or very high birth weights.

Step 2: Explain directional selection Individuals at one extreme of the existing phenotypic range have

greater reproductive success. The population mean therefore shifts towards that favoured extreme, producing a peak displaced to one side of the original curve. Selection favouring darker moths in polluted industrial regions illustrates this process; the opposite extreme is selected against.

Step 3: Explain disruptive selection Individuals at both phenotypic extremes are favoured over intermediate individuals. The initially single-peaked distribution develops two peaks, with a lower frequency near the former mean. This increases divergence within the population; for example, environments with mostly small and large seeds can favour small-beaked and large-beaked birds over birds with intermediate beaks. In the graphs, dashed curves show the initial distribution and solid curves the distribution after selection.



Three modes of natural selection. Dashed: before selection; solid: after selection.

Step 4: Conclusion Stabilising selection favours the mean, directional selection shifts the mean towards one extreme, and disruptive selection favours both extremes and produces two peaks.

Quick Tip to Solve: Identify the favoured phenotype first: middle means stabilising, one end means directional, and both ends mean disruptive selection.

25. (a) How do some viruses cause cancer in humans?

(b) How do benign tumours turn malignant? How do malignant tumours harm the human body?

[3 marks]

Solution:

Concept:

- Cancer results when normal control of cell growth and division is lost. Cancer cells lose contact inhibition and continue dividing even when they contact neighbouring cells.
- A benign tumour remains localised and does not invade distant tissues. A malignant tumour consists of proliferating cells that invade surrounding tissues and can spread to other body sites.

Step 1: (a) Explain the action of oncogenic viruses Cancer-causing viruses are called oncogenic viruses. They can introduce or express viral oncogenes in infected human cells. Viral gene products can disrupt the normal regulation of the cell cycle, including cellular mechanisms that restrain division. The affected cells may thus undergo uncontrolled proliferation and develop into a tumour. Infection is a cause of cellular transformation, rather than cancer being transferred as an ordinary contagious disease.

Step 2: (b) Describe the change from benign to malignant A benign tumour is a localised mass whose cells remain at their original site. If its cells undergo additional genetic changes affecting growth control, they may acquire uncontrolled proliferation, loss of contact inhibition and the ability to invade adjacent tissue. The tumour then becomes malignant. This progression is possible in some tumours; it is not an inevitable fate of every benign tumour. The decisive distinction is invasive behaviour, not merely the tumour's size.

Step 3: Explain how a malignant tumour harms the body Rapidly dividing malignant cells invade and damage neighbouring normal tissues. They compete with normal cells for vital nutrients, impairing tissue function. Some cells detach from the original tumour, enter the blood or lymph and travel to distant sites, where they establish secondary tumours. This spread is called **metastasis**. Tissue destruction and secondary growths can disrupt the functioning of vital organs.

Step 4: Conclusion Oncogenic viruses can disturb cell-division control through oncogenes. Acquisition of invasive growth makes a tumour malignant; malignant cells harm the body by tissue invasion, nutrient competition and metastatic spread.

Quick Tip to Solve: Distinguish benign from malignant by invasion and spread, then name metastasis when tumour cells form secondary growths at distant sites.

26. (a) How is insulin different from proinsulin?

(b) Explain all the stages of how human insulin is produced through rDNA technology.

[3 marks]

Solution:

Concept:

- Mature human insulin consists of two short polypeptide chains, A and B, joined by disulphide bridges.
- Proinsulin is the inactive precursor of insulin and contains an additional connecting segment called the C-peptide. Processing removes this segment to form mature insulin.
- Recombinant DNA technology enables bacteria to produce the human insulin chains from the corresponding introduced DNA sequences.

Step 1: (a) Compare insulin with proinsulin Proinsulin is initially synthesised as a single polypeptide containing the A-chain and B-chain regions connected by the C-peptide. The C-peptide is removed during maturation. Thus, mature, functional insulin has A and B chains linked by disulphide bridges and has no C-peptide, whereas proinsulin still contains the C-peptide and requires processing to become active.

Step 2: (b) Prepare and introduce the recombinant DNA Two DNA sequences corresponding to the A and B chains of human insulin are prepared separately. Each sequence is inserted into a bacterial plasmid vector to make recombinant DNA. The recombinant plasmids are introduced into separate cultures of *Escherichia coli*, so that one bacterial culture produces chain A and the other produces chain B. This is the approach used by Eli Lilly in 1983.

Step 3: Produce, recover and assemble the chains The transformed bacteria are cultured under suitable conditions to express the introduced sequences. The A and B polypeptide chains are produced

separately, extracted from the bacterial cultures and purified. The purified chains are then combined under conditions that allow the appropriate disulphide bridges to form between them, producing mature human insulin. Producing the chains separately avoids requiring the bacteria to remove a human C-peptide from proinsulin.

Step 4: Conclusion Proinsulin contains a C-peptide that mature insulin lacks. Recombinant human insulin is obtained by separately producing the A and B chains in *E. coli*, extracting and purifying them, and joining them by disulphide bridges.

Quick Tip to Solve: Remember the order: A- and B-chain DNA separately, plasmids, bacterial expression, purification, then disulphide-linked assembly.

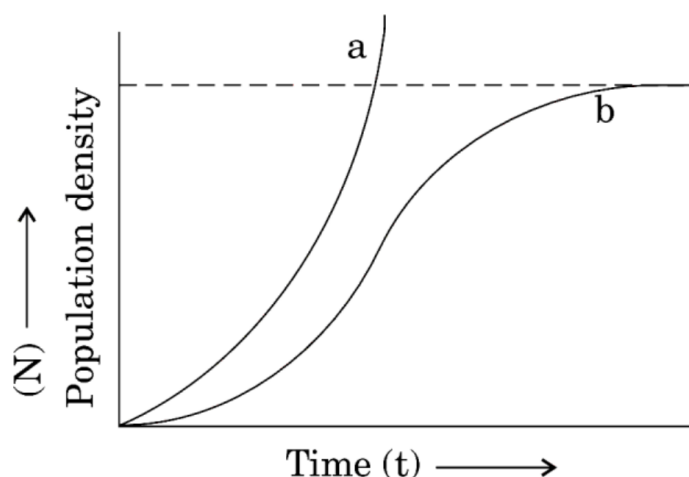
27(a). Study the graph given below and answer the questions that follow:

(i) Write the status of food and space in the curves a and b.

(ii) In the absence of predators, which one of the two curves would appropriately depict the prey population?

(iii) 'Time' has been shown on x-axis and there is a parallel dotted line above it. Give the significance of this dotted line.

[3 marks]



Solution:

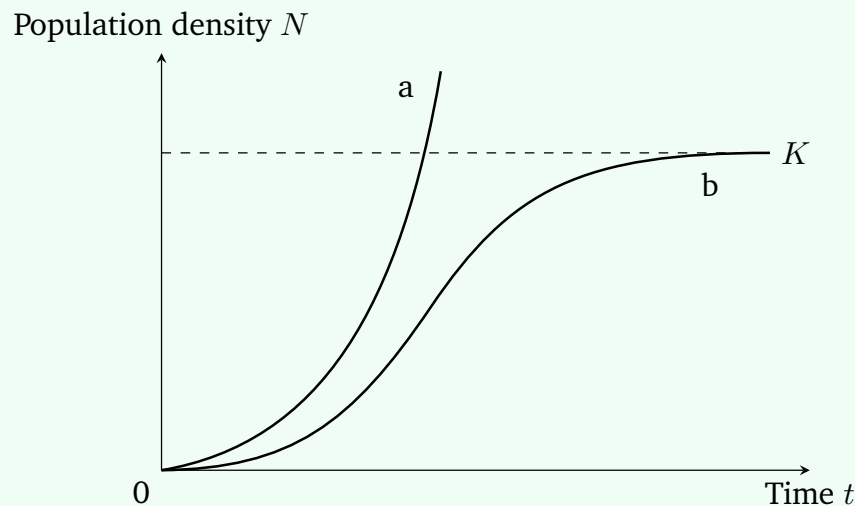
Concept:

- Exponential growth gives a J-shaped curve when food and space are unlimited; its rate is $dN/dt = rN$, where N is population density and r is the intrinsic rate of natural increase.
- Logistic growth gives an S-shaped curve when resources are limited: $dN/dt = rN(1 - N/K)$, where K is the habitat's carrying capacity.

Step 1: (i) Identify resource availability in each curve Curve a is J-shaped and represents exponential growth. In this model, food and space are available without limitation, so population increase is not restricted by resource shortage. Curve b is S-shaped and represents logistic growth. Here food and space are limited; as population density increases, competition for these resources increases and the rate of growth eventually declines.

Step 2: (ii) Identify the curve without predation Curve a appropriately represents the prey population in the comparison given. Removing predators removes a major check on prey numbers, allowing a rapid, exponential increase when resources remain adequate. In a natural habitat, resource limitation can ultimately restrain even a predator-free population; the J-shaped curve represents its unchecked growth phase.

Step 3: (iii) Interpret the horizontal dotted line The dotted line indicates the carrying capacity, K : the maximum population density that the habitat can support sustainably with its available food, space and other resources. Curve b approaches this level as growth slows. At $N = K$, the factor $1 - N/K$ is zero, so the logistic model predicts zero net population growth; births and deaths balance in the idealised stable population.



Exponential curve a and logistic curve b relative to carrying capacity K.

Step 4: Conclusion (i) Curve a: unlimited food and space; curve b: limited food and space. (ii) Curve a depicts unchecked prey growth without predators. (iii) The dotted line denotes carrying capacity, K .

Quick Tip to Solve: Identify J versus S first: J means unchecked increase, while the upper plateau of S identifies the habitat's carrying capacity.

27(b). Answer the following questions:

(i) Define 'predation'.

(ii) Why is predation required in a community of different organisms? Give any two points.

(iii) Why are predators 'prudent' in nature?

[3 marks]

Solution:

Concept:

- Predation is an interspecific interaction in which a predator feeds on another organism, its prey. The predator benefits and the prey is harmed, so the interaction is represented as (+, -).
- Predator-prey interactions regulate population size and can maintain species diversity by restricting competitively dominant prey species.

Step 1: (i) Define predation Predation is an interaction between two species in which one organism, the predator, captures, kills and eats the other, the prey, for food. For example, a tiger feeding on a deer benefits by obtaining energy, while the deer is harmed. In the broad ecological sense, herbivores feeding on plants are also considered predators.

Step 2: (ii) Explain two roles in the community First, predators keep prey populations under control. This prevents unchecked multiplication of prey and excessive use of the habitat's resources; biological control of crop pests uses this role of natural predators. Second, predators help maintain species diversity by reducing the intensity of competition among competing prey species. By controlling a competitively dominant prey species, they prevent it from excluding other species from the community.

Step 3: (iii) Explain why predators are prudent A predator depends on its prey as a source of food. If it were so efficient that it overexploited the prey and drove the prey to extinction, the predator would lose its food source and could itself become extinct. Therefore, successful natural predator-prey interactions generally allow some prey to survive and reproduce. This ecological restraint is described as prudence; it does not imply conscious planning by the predator.

Step 4: Conclusion Predation benefits the predator at the prey's expense. Predators regulate prey numbers and help maintain community diversity. They are described as prudent because eliminating their prey would destroy their own food supply and threaten their survival.

Quick Tip to Solve: For the two community roles, give population control and maintenance of diversity; link prudence directly to dependence on a continuing prey supply.

28. There are many animals, which have become extinct in the wild, but continue to be maintained in zoological parks. Answer the questions that follow:

(a) What type of bio-diversity conservation is observed in this case?

(b) Explain any other two ways which help in this type of conservation.

(c) Besides zoological parks, mention one place that serves this purpose.

[3 marks]

Solution:

Concept:

- Ex-situ conservation protects threatened species outside their natural habitats, under human care and controlled conditions.
- Preserving viable reproductive material and multiplying threatened organisms can maintain biodiversity even when natural populations decline.

Step 1: Identify the conservation strategy in part (a) The animals are maintained in zoological parks rather than in their natural ecosystems. This is **ex-situ conservation**. Such protected populations can survive and breed under human supervision even after the species has disappeared from the wild. In-situ conservation, in contrast, would protect the species within its natural habitat.

Step 2: Explain two other methods for part (b) **Cryopreservation:** Gametes of threatened species can be preserved in a viable and fertile condition for long periods at very low temperatures. This stores reproductive material for future breeding and helps conserve the genetic resources of the species.

Tissue culture: Small pieces of plant tissue are grown aseptically on a suitable nutrient medium. This permits rapid multiplication of threatened plants and the maintenance of living plants outside their natural habitats. The regenerated plants can be grown and maintained in protected collections.

Step 3: Name another conservation site for part (c) A **botanical garden** serves this purpose for plants. It maintains living collections of plant species outside their natural habitats, supports their propagation and helps conserve rare or threatened plant diversity. Unlike a national park, it is an example of ex-situ conservation.

Step 4: Conclusion (a) Ex-situ conservation. (b) Cryopreservation of viable gametes and propagation of threatened plants by tissue culture are two methods. (c) A botanical garden is another ex-situ conservation site.

Quick Tip to Solve: Check where the organism is protected: a zoo or botanical garden means ex-situ; protection within its natural habitat means in-situ.

Section D (8 marks)

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

29. Read the following passage and answer the questions that follow:

Gene expresses itself in a cell system as a protein/enzyme. How an expression of gene occurs in a cell system, when it needs to occur and how the gene expression is regulated in prokaryotic cell system was studied by the combined efforts of Francois Jacob, a geneticist and Jacques Monod, a biochemist. For their work on lactose metabolism in *E. coli* and introducing the concept of 'lac operon', they were awarded the Nobel Prize in 1965. [4 marks]

29(a). It is said that 'lac operon' has to be operational at a very low level in the bacterial cell all the time. Justify. [1 mark]

Solution:

Concept:

- The lac operon is inducible, but a small basal level of its structural-gene expression persists even when lactose is absent.
- The lacY gene encodes permease, which facilitates the entry of lactose into the bacterial cell.

Step 1: Identify the initial requirement Lactose must first enter the cell to induce the lac operon. Its efficient entry requires a small amount of permease already present in the cell membrane.

Step 2: Explain the basal activity Very low expression ensures that some permease is always available. When lactose appears in the surroundings, it can enter through this permease and bring about induction; if the operon were completely silent, the cell would lack this initial transport capacity.

Step 3: Conclusion The lac operon remains operational at a very low level to maintain a small amount of permease, enabling lactose to enter the cell and induce the operon.

Quick Tip to Solve: For basal lac-operon activity, connect permease already present with the first entry of lactose.

29(b)(i). How are the structural genes activated in the lac operon in *E. coli*? [1 mark]

Solution:

Concept:

- The lac operon is controlled by a repressor protein that can bind the operator and prevent transcription of the structural genes.
- Lactose acts as the inducer in the NCERT account of the lac operon.

Step 1: Inactivate the repressor When lactose is available and enters the bacterial cell, the inducer binds to the repressor and inactivates it. The inactive repressor cannot bind the operator.

Step 2: Permit structural-gene transcription The operator is thus freed, allowing RNA polymerase to transcribe the structural genes *z*, *y* and *a* from the promoter. Translation of their common messenger

RNA produces the enzymes required for lactose metabolism.

Step 3: Conclusion Lactose inactivates the repressor, freeing the operator and allowing RNA polymerase to transcribe the lac structural genes.

Quick Tip to Solve: Follow the activation sequence: inducer binds repressor, operator becomes free, transcription proceeds.

OR

29(b)(ii). Why is the regulation of operon called negative regulation?

[1 mark]

Solution:

Concept:

- Negative regulation means that a regulatory protein suppresses gene expression when it is active.
- In the lac operon, the regulatory gene produces a repressor that acts on the operator.

Step 1: Identify the inhibitory regulator In the absence of an inducer, the active repressor binds to the operator. This prevents RNA polymerase from effectively transcribing the structural genes, so their expression is inhibited.

Step 2: Relate induction to removal of inhibition When lactose is present, the inducer inactivates the repressor and removes this block. Gene expression is permitted by lifting repression; the repressor itself does not activate transcription.

Step 3: Conclusion It is called negative regulation because the active repressor negatively controls the operon by binding the operator and blocking structural-gene transcription.

Quick Tip to Solve: Ask what the active regulatory protein does: if it blocks transcription, the control is negative.

29(c). Why is lac operon said to be a transcriptionally regulated system?

[2 marks]

Solution:

Concept:

- Gene expression includes transcription of DNA into messenger RNA, followed by translation of the messenger RNA into protein.
- In the lac operon, the operator-repressor interaction determines whether RNA polymerase transcribes the structural genes.

Step 1: Explain the switched-off state When lactose is absent, the repressor is active and binds to the operator. This obstructs transcription by RNA polymerase, so very little messenger RNA for the lactose-metabolising enzymes is produced. Control is therefore exercised before the protein-synthesis step.

Step 2: Explain the switched-on state When lactose is present, the inducer binds to and inactivates

the repressor, which can no longer occupy the operator. RNA polymerase can then transcribe z , y and a into a common messenger RNA. This messenger RNA is subsequently translated into the corresponding enzymes.

Step 3: Conclusion The lac operon is transcriptionally regulated because its control mechanism permits or prevents the synthesis of structural-gene messenger RNA by RNA polymerase, thereby controlling enzyme production.

Quick Tip to Solve: Name the controlled product first: regulation of messenger-RNA formation identifies transcriptional control.

30. Read the following passage and answer the questions that follow:

Immunity in our body is of two types (i) Innate immunity, and (ii) Acquired immunity. Innate immunity is a non-specific defence mechanism, whereas Acquired immunity is pathogen specific. Acquired immunity is characterised by memory. Antibodies are specific to antigens and there are four types of antibodies produced in our body — IgA, IgE, IgG and IgM. It shows primary response where it encounters the pathogen for the first time and secondary response during the subsequent encounters with the same antigen/pathogen. These immune responses are carried out with the help of two special types of lymphocytes present in the blood. [4 marks]

30(a). Name the two types of specialised cells which carry out the primary and secondary responses. [1 mark]

Solution:

Concept:

- Acquired immunity is antigen specific and has memory, which enables a stronger response on subsequent exposure to the same antigen.
- Lymphocytes are specialised white blood cells involved in acquired immune responses.

Step 1: Identify the antibody-related cells B-lymphocytes participate in humoral immunity. On activation, they differentiate into plasma cells that secrete antibodies; some become memory B cells that contribute to a faster later response.

Step 2: Identify the cell-mediated cells T-lymphocytes participate in cell-mediated immunity and help coordinate immune responses. Memory T cells formed after activation also contribute to responses when the same antigen is encountered again.

Step 3: Conclusion The two specialised cell types are B-lymphocytes and T-lymphocytes.

Quick Tip to Solve: For the two lymphocyte types in acquired immunity, recall B cells for antibodies and T cells for cellular immunity.

30(b)(i). Name any two barriers present in our body that provide innate immunity.

[1 mark]

Solution:

Concept:

- Innate immunity is present from birth and provides non-specific protection against pathogens.
- Innate defences include barriers that prevent entry or make conditions unfavourable for invading microbes.

Step 1: Name a physical barrier The skin is a physical barrier. Its intact outer surface blocks the entry of many microbes into the body; mucus-coated epithelial surfaces also help trap microbes.

Step 2: Name a physiological barrier Acid in the stomach is a physiological barrier. The acidic environment inhibits or kills many microbes entering with food and water, providing protection without a prior encounter with a particular pathogen.

Step 3: Conclusion Two examples are the skin (physical barrier) and stomach acid (physiological barrier).

Quick Tip to Solve: Give a barrier category with its example: physical–skin; physiological–stomach acid.

OR

30(b)(ii). The organ transplants (grafts) are often rejected if not taken from suitable compatible persons. Mention the characteristic of our immune system that is responsible for the rejection.

[1 mark]

Solution:

Concept:

- The acquired immune system can distinguish the body's own components (self) from foreign components (non-self).
- A transplanted organ carries surface antigens that may differ from those of the recipient.

Step 1: Recognise the foreign tissue If donor and recipient tissues are incompatible, the recipient's immune system recognises the graft antigens as non-self rather than as its own body tissues.

Step 2: Explain rejection This recognition stimulates an immune attack against the graft, in which T-lymphocyte-mediated cellular responses play a major role. The resulting damage can cause graft rejection; compatibility testing reduces this risk.

Step 3: Conclusion The responsible characteristic is the immune system's ability to distinguish self from non-self and mount a response against foreign tissue.

Quick Tip to Solve: For graft rejection, state self/non-self discrimination first; then link foreign tissue to an immune attack.

30(c). How is active immunity different from passive immunity? Write any two differences. [2 marks]

Solution:

Concept:

- Active immunity develops when exposure to an antigen stimulates the recipient's own immune system.
- Passive immunity results from the transfer of ready-made antibodies to the recipient.

Step 1: Compare the source of antibodies In **active immunity**, the body produces its own antibodies after an infection or vaccination. In **passive immunity**, antibodies made elsewhere are supplied, for example through maternal colostrum or an injection of antiserum. Thus, active protection requires the recipient to mount an immune response, whereas passive protection supplies its products directly.

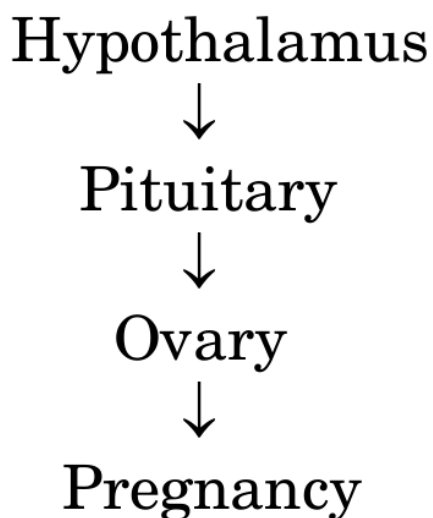
Step 2: Compare the onset and persistence Active immunity usually develops slowly because lymphocytes must be activated and multiply; it is generally long-lasting and involves immunological memory. Passive immunity provides immediate protection but is short-lived because the supplied antibodies are gradually broken down, and their transfer does not generate a memory response in the recipient.

Step 3: Conclusion Two differences are: active immunity involves self-produced antibodies and develops slowly with long-lasting memory; passive immunity involves transferred antibodies and gives immediate, short-lived protection without generating memory.

Quick Tip to Solve: Compare active and passive immunity using matched headings: antibody source, then onset and duration of protection.

Section E (15 marks)

31(a). Study the flow chart given below. Name the hormones involved at each stage and explain their functions. [5 marks]



Solution:

Concept:

- The hypothalamus controls the anterior pituitary, whose gonadotropins regulate follicular development, ovulation and ovarian hormone secretion.
- Ovarian oestrogens prepare the uterine endometrium, while progesterone supports its maintenance for implantation and pregnancy.
- Once implantation occurs, the developing placenta secretes hormones that help maintain pregnancy; these are distinct from the hormones initiating the ovarian cycle.

Step 1: Identify the hypothalamic hormone The hypothalamus secretes **gonadotropin-releasing hormone (GnRH)**. Its pulsatile release stimulates the anterior pituitary to secrete the two gonadotropins, follicle-stimulating hormone and luteinising hormone. Thus GnRH provides the hormonal link between the hypothalamus and pituitary in the chart.

Step 2: Explain the anterior pituitary hormones **Follicle-stimulating hormone (FSH)** promotes the growth and maturation of ovarian follicles and stimulates oestrogen secretion from the growing follicles. **Luteinising hormone (LH)** acts on the ovary; its mid-cycle surge induces rupture of the mature Graafian follicle and release of the ovum, that is, ovulation. LH also promotes formation of the corpus luteum from the ruptured follicle and supports its secretion of progesterone.

Step 3: Explain the ovarian hormones Growing ovarian follicles secrete **oestrogens**, which stimulate proliferation and repair of the uterine endometrium and support female secondary sexual characters. After ovulation, the corpus luteum secretes mainly **progesterone**. Progesterone maintains the thick, glandular endometrium, preparing it for implantation and providing suitable conditions for continued pregnancy if fertilisation and implantation occur. It also supports mammary-gland development for later milk secretion.

Step 4: Link hormone action to pregnancy Following implantation, the developing placenta secretes **human chorionic gonadotropin (hCG)**, which maintains the corpus luteum and its progesterone secretion during early pregnancy. The placenta subsequently also produces progesterone and oestrogens that support pregnancy. Placental **human placental lactogen (hPL)** contributes to mammary development and maternal metabolic changes that support foetal nutrition. These placental hormones sustain an established pregnancy; ovulation alone does not cause pregnancy, since fertilisation and implantation are also required.

Step 5: Conclusion The principal sequence is **hypothalamic GnRH**, then **pituitary FSH and LH**, then **ovarian oestrogens and progesterone**. Together they regulate follicular maturation, ovulation and preparation and maintenance of the endometrium. After implantation, placental hCG supports the corpus luteum, and placental hormones help sustain pregnancy.

Quick Tip to Solve: Follow each arrow by naming the gland, its hormone and its target: GnRH to pituitary, FSH/LH to ovary, and ovarian hormones to endometrium.

OR

31(b). (i) Draw a diagram of L.S. of maize grain and label its any six parts.

(ii) Differentiate between perisperm and endosperm giving one example of each.

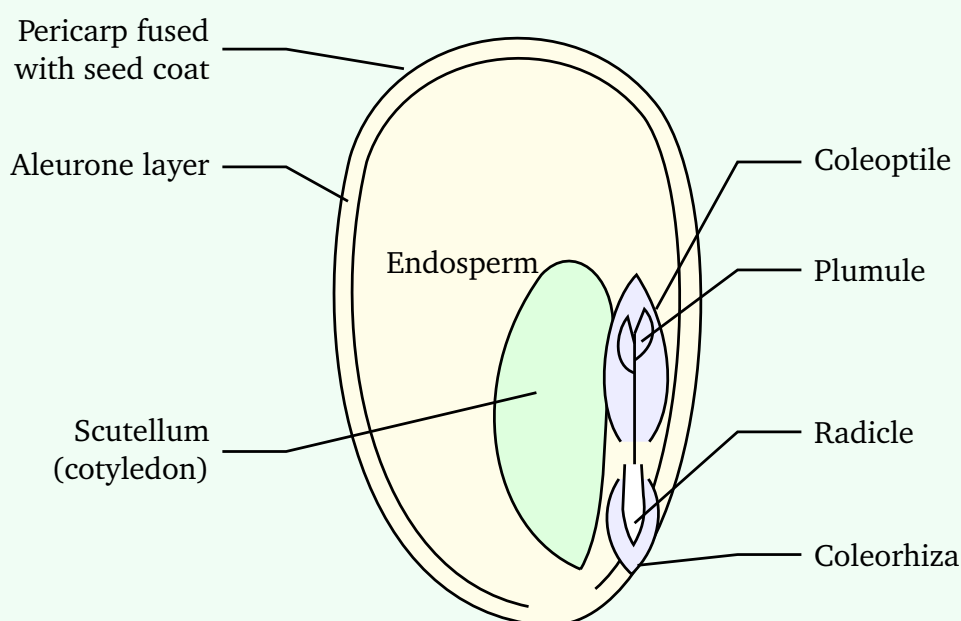
[5 marks]

Solution:

Concept:

- Maize grain is a caryopsis: the fruit wall (pericarp) is fused with the seed coat. It is an endospermic seed with a single cotyledon, the scutellum.
- The embryo has a plumule and radicle protected by the coleoptile and coleorhiza, respectively. The scutellum lies between the embryonal axis and the endosperm.
- Perisperm is the persistent nucellus of the ovule; endosperm develops from the primary endosperm nucleus formed by triple fusion.

Step 1: (i) Draw and label the longitudinal section The labelled L.S. below shows the large food-storing endosperm occupying most of the maize grain. Its outer protein-rich layer is the aleurone layer. The embryo lies on one side towards the lower end, with its shield-shaped scutellum facing the endosperm. The plumule points towards the upper end and the radicle towards the lower end. The drawing labels more than the six parts requested, including their protective sheaths.



Labelled longitudinal section of a maize grain (schematic).

Step 2: Identify the embryo and its protective structures The scutellum is the single cotyledon of the monocot embryo; during germination it helps transfer food from the endosperm to the growing embryo. The plumule develops into the shoot and is enclosed in the coleoptile. The radicle develops into the root and is enclosed in the coleorhiza. Distinguish these sheaths from the outer covering of the entire grain: the latter is the fused pericarp and seed coat. Also distinguish the scutellum from the much larger endosperm, which is the principal food reserve.

Step 3: (ii) Differentiate between perisperm and endosperm

Feature	Perisperm	Endosperm
Origin	Remnant of the nucellus that persists in the mature seed.	Develops from the primary endosperm nucleus after triple fusion.
Genetic nature	Maternal sporophytic tissue; usually diploid, $2n$.	Usually triploid, $3n$, because one male gamete fuses with the two polar nuclei or the diploid secondary nucleus.
Relation to fertilisation	Nucellus exists before fertilisation; its persistence produces perisperm.	Its formation normally follows fertilisation of the central cell.
Example	Black pepper.	Maize.

Both can contribute to food storage, but they differ in developmental origin. Thus the presence of

stored food alone is not enough to identify the tissue; one must ask whether it came from the nucellus or from the fertilised central cell.

Step 4: Conclusion The L.S. identifies the coverings, endosperm and monocot embryo of maize. Perisperm is persistent maternal nucellus, as in black pepper, whereas endosperm is the usually triploid product of triple fusion, as in maize.

Quick Tip to Solve: In a maize L.S., place the scutellum between the endosperm and embryonal axis; pair plumule with coleoptile and radicle with coleorhiza. For the tissue comparison, remember nucellus versus triple fusion.

32(a). Write the types and locations of the genes causing thalassemia in humans. State the cause and symptoms of the disease. How is sickle-cell anemia different from this disease? [5 marks]

Solution:

Concept:

- Thalassemia is an inherited autosomal recessive disorder in which synthesis of an alpha or beta globin chain of haemoglobin is reduced or absent.
- Normal adult haemoglobin contains two alpha and two beta polypeptide chains, represented as $\alpha_2\beta_2$. Balanced production of these chains is needed for normal red blood cells.
- Thalassemia is primarily a quantitative globin-synthesis defect, whereas sickle-cell anaemia is a qualitative defect in the beta-globin structure.

Step 1: Identify the two types and their gene locations In **alpha-thalassemia**, synthesis of alpha-globin is affected. It is controlled by two closely linked genes, *HBA1* and *HBA2*, on chromosome 16. Thus, a diploid human has four alpha-globin gene copies, two on each homologous chromosome 16. Mutation or deletion affecting one or more copies produces different degrees of reduced alpha-chain synthesis.

In **beta-thalassemia**, synthesis of beta-globin is affected. The beta-globin gene, *HBB*, is on chromosome 11, with one copy on each homologous chromosome, giving two copies in a diploid individual.

Step 2: Explain the cause and symptoms Mutations or deletions in globin genes reduce or prevent production of the corresponding globin chains. The resulting imbalance interferes with normal haemoglobin formation and red-cell survival. Thalassemia follows an autosomal recessive pattern: the severe disease commonly occurs when defective alleles are inherited from both parents, while carriers may show little or mild anaemia.

Reduced functional haemoglobin and destruction of red blood cells cause **anaemia**, with pallor, tiredness, weakness and breathlessness. Severe forms may also cause poor growth, jaundice and enlargement of the spleen. The severity varies with the number and nature of the affected genes; all carriers do not have the severe symptoms.

Step 3: Distinguish sickle-cell anaemia from thalassemia In sickle-cell anaemia, a point mutation in the beta-globin gene changes the sixth amino acid from glutamic acid to valine. The coding-strand DNA triplet changes from GAG to GTG, producing abnormal haemoglobin, HbS. At low oxygen tension, HbS molecules polymerise and the red cells become sickle-shaped, which promotes red-cell

destruction and obstruction of small blood vessels.

Thus, sickle-cell anaemia changes the **quality or structure** of the beta chain; thalassemia reduces the **quantity** of alpha or beta chains synthesised. Both are inherited autosomal recessive disorders associated with anaemia, but their molecular defects are different.

Step 4: Conclusion Alpha-thalassemia involves alpha-globin genes on chromosome 16; beta-thalassemia involves the beta-globin gene on chromosome 11. Reduced globin synthesis causes anaemia and related symptoms. Sickle-cell anaemia instead produces structurally abnormal beta-globin with valine replacing glutamic acid at position six.

Quick Tip to Solve: Pair alpha with chromosome 16 and beta with chromosome 11; distinguish thalassemia by reduced chain quantity and sickle-cell anaemia by altered chain quality.

OR

32(b). (i) Enlist any four prime goals of the Human Genome Project (HGP).

(ii) List the two methodologies which were involved in the human genome project. Mention how they were used.

(iii) Expand 'YAC' and mention what it was used for.

[5 marks]

Solution:

Concept:

- The Human Genome Project (HGP) aimed to determine the human genome's DNA sequence and identify its genes, while developing resources to store and analyse the information.
- Expressed Sequence Tags identify expressed genes, whereas sequence annotation assigns functions to sequences after DNA has been sequenced.
- Cloning vectors allow large DNA fragments to be maintained and multiplied in host cells before sequencing and assembly.

Step 1: State four prime goals of HGP (i) Any four prime goals were:

1. Identify all the approximately 20,000–25,000 genes in human DNA.
2. Determine the sequence of about three billion chemical base pairs making up human DNA.
3. Store the resulting information in databases so that the genome data can be accessed and compared.
4. Improve tools for analysing the data, including computational methods for sequence comparison and gene identification.

These goals concern both collecting the sequence information and making it usable for biological research; identifying genes and sequencing all DNA are related but distinct tasks.

Step 2: Describe the two methodologies and their uses (ii) **Expressed Sequence Tags (ESTs):** This approach focused on identifying all genes that are expressed as RNA. Short sequence tags obtained from complementary DNA (cDNA), made from expressed RNA, were used to recognise expressed genes. Because this approach starts with RNA expression, it targets the expressed portion of the genome.

Sequence annotation: The second approach sequenced the whole genome, including both coding

and non-coding sequences. Functions were then assigned to different regions in the sequence using sequence features and comparisons with known sequences. Thus, DNA was first sequenced and the resulting information was analysed to identify genes and interpret the roles of genomic regions.

The key distinction is the starting material and scope: the EST approach begins with expressed RNA, whereas the whole-genome approach obtains the complete DNA sequence before assigning functions by annotation.

Step 3: Expand YAC and explain its use (iii) YAC stands for **Yeast Artificial Chromosome**. It was used as a cloning vector for large fragments of human DNA in yeast cells. Human DNA was broken into suitable fragments, inserted into vectors and propagated in a host to produce enough copies for further work. YACs enabled large inserts to be maintained, supporting the preparation of genomic libraries and the mapping and sequencing work of HGP. Overlapping fragment sequences could subsequently be arranged to reconstruct the genomic sequence.

Step 4: Conclusion Four HGP goals were gene identification, sequencing all base pairs, database storage and improvement of data-analysis tools. The two methodologies were EST-based identification of expressed genes and whole-genome sequencing followed by sequence annotation. YAC means Yeast Artificial Chromosome and served as a vector for cloning large human DNA fragments in yeast.

Quick Tip to Solve: Separate the three demands: give four goals, contrast RNA-based ESTs with whole-genome sequence annotation, then expand YAC and name its cloning role.

33(a). (i) **EcoR I has played a very important role in rDNA technology.**

(I) **Explain the convention for naming EcoR I.**

(II) **Write the recognition site of this endonuclease restriction enzyme.**

(ii) **Name the overhanging stretches of DNA produced by these restriction enzymes. Describe their role in the formation of rDNA.** [5 marks]

Solution:

Concept:

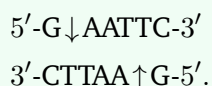
- Restriction endonucleases recognise specific DNA sequences and cleave phosphodiester bonds within DNA. EcoR I recognises a six-base-pair palindromic sequence.
- Complementary single-stranded overhangs can pair through hydrogen bonds. DNA ligase then seals the sugar-phosphate backbones to produce stable recombinant DNA (rDNA).

Step 1: (i)(I) Decode the name EcoR I The enzyme is isolated from the bacterium *Escherichia coli* strain RY13. The first letter, **E**, comes from the genus *Escherichia*; the next two letters, **co**, come from the species *coli*. The letter **R** identifies the strain RY13. The Roman numeral **I** indicates that it was the first restriction endonuclease isolated from this strain. Thus the name records the source organism, its strain and the order in which the enzyme was isolated.

Step 2: (i)(II) Write the recognition sequence and cleavage positions EcoR I recognises the following double-stranded DNA sequence:



Reading either strand in the 5' to 3' direction gives GAATTC, so this sequence is palindromic. EcoR I cleaves between G and A on each strand, making staggered cuts:



Because the two cuts are offset, the fragments have short single-stranded 5' overhangs with the sequence AATT.

Step 3: (ii) Explain how the overhangs help form recombinant DNA These overhanging stretches are called **sticky ends**. The vector DNA and the foreign DNA to be inserted are cut with the same restriction enzyme, such as EcoR I, to obtain compatible sticky ends. On mixing, the complementary bases of the overhangs pair by hydrogen bonding: A pairs with T. This holds the foreign DNA and the vector together in the correct alignment. DNA ligase then forms phosphodiester bonds at the remaining nicks in the sugar-phosphate backbones, covalently joining the fragments. The resulting DNA molecule combines DNA from different sources and is therefore recombinant DNA. Restriction endonuclease provides compatible ends, whereas ligase completes the stable joining.

Step 4: Conclusion EcoR I is named after *E. coli* RY13 and its order of isolation. It recognises 5'-GAATTC-3', produces complementary sticky ends and enables foreign DNA to anneal to a vector before DNA ligase seals the recombinant molecule.

Quick Tip to Solve: Write the two recognition strands antiparallel, then mark G–A cleavage on each; distinguish sticky-end hydrogen bonding from ligase-mediated backbone sealing.

OR

33(b). (i) Insertional inactivation is a method to detect the recombinant DNA. Explain this method.

(ii) Name the commonly used vector for transferring genes in plants from bacteria.

(iii) How is this able to transform a normal plant cell into a tumour?

[5 marks]

Solution:

Concept:

- Insertional inactivation detects recombinant DNA through the loss of function of a marker gene disrupted by insertion of foreign DNA.
- The Ti (tumour-inducing) plasmid of *Agrobacterium tumefaciens* naturally transfers a segment of DNA into plant cells. A disarmed Ti plasmid is used as a vector in plant genetic engineering.

Step 1: (i) Explain how insertion disrupts a marker gene A cloning vector carries a marker gene with a suitable restriction site within it. When foreign DNA is inserted at this site, it interrupts the marker's coding sequence and prevents production of its functional product. The vector carrying the insert is recombinant and has an inactive marker; a vector that has closed without an insert remains non-recombinant and retains marker activity. This detectable loss of gene function is called **insertional inactivation**.

Step 2: (i) Distinguish recombinant and non-recombinant colonies For example, insertion within

the vector's β -galactosidase marker disrupts enzyme activity. Transformants are grown on medium containing the appropriate chromogenic substrate. Colonies with a non-recombinant vector possess functional β -galactosidase and produce a blue colour. Colonies carrying a recombinant vector cannot produce the functional enzyme and therefore remain white or colourless. These white colonies are selected as putative recombinants. An antibiotic-resistance marker is used to select cells that have taken up the vector; the colour test then distinguishes recombinant from non-recombinant transformants. Thus the absence of blue colour is meaningful among the selected transformant colonies, rather than among arbitrary bacterial cells.

Step 3: (ii) Identify the plant gene-transfer vector The commonly used vector is the **Ti plasmid of *Agrobacterium tumefaciens***. In genetic engineering, its tumour-inducing genes are removed or inactivated, while the DNA-transfer machinery is retained. This disarmed vector carries the desired foreign gene into plant cells without causing a tumour.

Step 4: (iii) Explain natural tumour formation In its natural pathogenic form, *A. tumefaciens* transfers a DNA segment called **T-DNA** from its Ti plasmid into a susceptible plant cell, where it integrates into the plant's nuclear genome. Expression of tumour-inducing genes alters growth regulation, including auxin and cytokinin production, causing uncontrolled cell division and a crown-gall tumour. The transformed cells are also directed to produce substances used by the bacterium. It is the natural tumour-inducing T-DNA that causes this transformation; the disarmed Ti vector used for crop gene transfer has had this tumour-causing ability removed.

Step 5: Conclusion Insertional inactivation identifies recombinants through disruption of a marker, exemplified by white colonies in the β -galactosidase colour test. The Ti plasmid of *A. tumefaciens* is the plant vector; its natural T-DNA can induce uncontrolled cell division and tumours, while its disarmed form transfers useful genes.

Quick Tip to Solve: In the colour test, an intact marker gives blue colonies and an inserted gene gives white colonies; distinguish natural tumour-inducing Ti plasmids from disarmed vectors.