Biology (044)

CBSE Class 12 Board Examination 2027 – Practice Paper No. 2

Model Answer Paper

Time: 3 hours **Max. Marks: 70**

Model answers show one correct method; any other correct method gets full marks.

SECTION A Q. Nos. 1 to 12 are multiple choice questions; only one of the choices is correct. Select and write the correct choice as well as the answer. Q. Nos. 13 to 16 consist of two statements – Assertion (A) and Reason (R); answer them by selecting the appropriate option (A), (B), (C) or (D) given with each. (1 mark each) **[16]**

1 In a village pond, the female flowers of a submerged plant reach the surface of the water on long stalks. The male flowers or pollen grains are released on to the water surface and are carried passively by water currents, and some of them reach the stigmas. Identify the plant and the type of pollination.

(A) Water lily; pollination by insects
(B) Water hyacinth; pollination by water
(C) *Vallisneria*; pollination by water
(D) *Vallisneria*; pollination by wind

Answer (1 mark)
(C) *Vallisneria*; pollination by water
In *Vallisneria* the female flower reaches the water surface on a long stalk, and male flowers/pollen released on the surface are carried passively by water currents (water pollination). Water hyacinth and water lily flowers emerge above the water and are pollinated by insects or wind.

2 A nurse explains to a new mother how milk reaches the nipple during breastfeeding. Select the correct sequence of structures through which milk passes after it is secreted.

(A) Mammary alveoli → mammary duct → mammary tubules → lactiferous duct → mammary ampulla
(B) Mammary alveoli → mammary tubules → mammary duct → mammary ampulla → lactiferous duct
(C) Mammary tubules → mammary alveoli → mammary ampulla → mammary duct → lactiferous duct
(D) Mammary alveoli → mammary ampulla → mammary tubules → mammary duct → lactiferous duct

Answer (1 mark)
(B) Mammary alveoli → mammary tubules → mammary duct → mammary ampulla → lactiferous duct
The cells of the alveoli secrete milk; the alveoli open into mammary tubules; the tubules of each lobe join to form a mammary duct; several mammary ducts join to form the wider mammary ampulla, which is connected to the lactiferous duct opening at the nipple.

3 A woman consults a doctor the morning after an unprotected intercourse because she does not want to become pregnant. Which of the following is an effective emergency contraceptive measure for her?

(A) Vasectomy of her partner within 72 hours

(B) Medical termination of pregnancy within the first 72 hours

(C) Lactational amenorrhoea for the next six months

(D) Progestogens or progestogen–estrogen combinations, or an IUD, within 72 hours of coitus

Answer (1 mark)
(D) Progestogens or progestogen–estrogen combinations, or an IUD, within 72 hours of coitus
Administration of progestogens or progestogen–estrogen combinations or IUDs within 72 hours of coitus is very effective as emergency contraception. Vasectomy is a terminal method, MTP is termination of an established pregnancy, and lactational amenorrhoea applies only to a breastfeeding mother after delivery.

4 A drone (male honey bee) has 16 chromosomes in each of its body cells. How many chromosomes will be present in (i) a body cell of a worker bee of the same species and (ii) a sperm produced by the drone?

(A) 32 and 8

(B) 16 and 8

(C) 32 and 16

(D) 16 and 16

Answer (1 mark)
(C) 32 and 16
Honey bees show haplodiploid sex determination: a drone develops from an unfertilised egg and is haploid (16), while females (queen and workers) develop from fertilised eggs and are diploid (32). Drones produce sperms by mitosis, so a sperm also has 16 chromosomes.

5 Which one of the following is a correct finding of the Human Genome Project?

(A) Less than 2 per cent of the human genome codes for proteins.

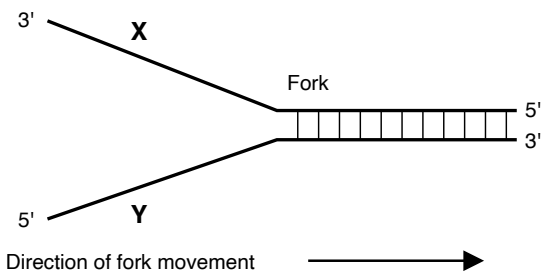
(B) The human genome contains about 80,000 to 1,40,000 genes.

(C) The Y chromosome has the largest number of genes.

(D) About 99.9 per cent of the nucleotide bases differ from person to person.

Answer (1 mark)
(A) Less than 2 per cent of the human genome codes for proteins.
The total number of genes is estimated at about 30,000 (much lower than the earlier estimates of 80,000–1,40,000); chromosome 1 has the most genes (2968) and Y the fewest (231); 99.9 per cent of the bases are exactly the same in all people.

6 The figure given below shows a replication fork in a DNA molecule; X and Y are the two parental template strands. On which template strand will the new DNA be synthesised discontinuously, and which enzyme will join the short fragments so formed?



(A) X; DNA ligase
(B) Y; DNA ligase
(C) X; DNA polymerase
(D) Y; RNA polymerase

For visually impaired candidates (in lieu of the above):

During DNA replication, on which template strand is the new strand synthesised discontinuously, and which enzyme joins the fragments?

(A) The template with polarity 3'→5'; DNA ligase
(B) The template with polarity 5'→3'; DNA ligase
(C) The template with polarity 5'→3'; DNA polymerase
(D) The template with polarity 3'→5'; RNA polymerase

Answer (1 mark)

(B) Y; DNA ligase

DNA polymerase can polymerise only in the 5'→3' direction. Read in the direction of fork movement, X has polarity 3'→5', so its new strand is made continuously; Y has polarity 5'→3', so its new strand is made discontinuously as short fragments, which are later joined by DNA ligase.

Visually impaired alternative: (B) the template with polarity 5'→3'; DNA ligase.

7 In a laboratory experiment, an electric discharge was passed through a closed flask containing CH_4, H_2, NH_3 and water vapour at 800 °C. After some time, amino acids were found in the flask.

This experiment supports the idea that

(A) life arose spontaneously from decaying and rotting matter.
(B) the first living units came to the earth from outer space as spores.
(C) new species arise by natural selection of favourable variations.
(D) the first organic molecules could have formed from inorganic constituents under the conditions of the early earth.

Answer (1 mark)

(D) the first organic molecules could have formed from inorganic constituents under the conditions of the early earth.

This is S.L. Miller's experiment (1953), which recreated the reducing atmosphere and energy sources of the early earth; the formation of amino acids supports chemical evolution (Oparin and Haldane).

8 A patient complains of constipation, abdominal pain and cramps; his stools contain excess mucus and blood clots. Several houseflies were seen around the uncovered food at his home. Identify the causative organism and the role of the houseflies.

(A) *Entamoeba histolytica*; houseflies act as mechanical carriers of the parasite
(B) *Salmonella typhi*; houseflies are the intermediate host
(C) *Entamoeba histolytica*; houseflies inject the parasite when they bite
(D) *Ascaris*; houseflies carry the larvae in their salivary glands

Answer (1 mark)

(A) *Entamoeba histolytica*; houseflies act as mechanical carriers of the parasite

These are symptoms of amoebiasis (amoebic dysentery), caused by the protozoan *Entamoeba histolytica* in the large intestine. Houseflies transmit the parasite from the faeces of an infected person to food and food products.

9 Along with chemotherapy, a cancer patient is given α-interferon. What is the role of α-interferon in this treatment?

(A) It kills the rapidly dividing cancer cells by damaging their DNA.
(B) It is an antibody that binds to the tumour and blocks its blood supply.
(C) It is a biological response modifier that activates the patient's immune system to help destroy the tumour.
(D) It suppresses the immune system so that the side-effects of chemotherapy are reduced.

Answer (1 mark)
(C) It is a biological response modifier that activates the patient's immune system to help destroy the tumour.
Tumour cells avoid detection by the immune system, so patients are given biological response modifiers such as α-interferon, which activate the immune system.

10 A scientist removes the 'ori' sequence from a plasmid cloning vector, then ligates a foreign gene into it and introduces it into *E. coli* cells. What is the most likely result?

(A) The plasmid carrying the foreign gene will not be able to replicate within the host cells.
(B) The host cells will lose resistance to all antibiotics.
(C) The vector can no longer be cut by any restriction enzyme.
(D) The foreign gene will be present in a very high copy number.

Answer (1 mark)
(A) The plasmid carrying the foreign gene will not be able to replicate within the host cells.
'ori' is the sequence from where replication starts; any DNA linked to it can replicate within the host, and it also controls the copy number of the linked DNA. Without ori, the recombinant plasmid cannot multiply.

11 A child with adenosine deaminase (ADA) deficiency is treated by gene therapy: lymphocytes from his blood are grown in culture, a functional ADA cDNA is introduced into them using a retroviral vector, and they are returned to his body. Why does the child need such infusions periodically?

(A) The retroviral vector destroys the ADA gene after some time.
(B) The ADA enzyme made by the lymphocytes is digested in the stomach.
(C) The child's immune system rejects his own lymphocytes.
(D) The genetically engineered lymphocytes are not immortal.

Answer (1 mark)
(D) The genetically engineered lymphocytes are not immortal.
The engineered lymphocytes die after some time, so they have to be given periodically. A permanent cure is possible only if the ADA gene from marrow cells is introduced into cells at early embryonic stages.

12 In a park in Pune, a pair of house crows was seen feeding a chick that later grew into an Asian koel. The koel had laid its egg in the crows' nest and left the crows to incubate it. Which option correctly names this interaction and explains why the crows did not throw the koel's egg out of the nest?

(A) Commensalism; the koel benefits, while the crows are neither harmed nor benefited.

(B) Brood parasitism; the koel's egg resembles the crows' eggs in size and colour, which reduces the chance of the crows detecting and ejecting it.

(C) Mutualism; both the koel and the crows benefit from sharing the same nest.

(D) Brood parasitism; the koel's egg is much larger than the crows' eggs, so the crows prefer to incubate it.

Answer (1 mark)

(B) Brood parasitism; the koel's egg resembles the crows' eggs in size and colour, which reduces the chance of the crows detecting and ejecting it.

Brood parasitism is a kind of parasitism in birds: the parasitic bird (koel/cuckoo) lays its eggs in the host's nest and lets the host incubate them. During evolution the parasite's eggs have come to resemble the host's eggs in size and colour, so the host is less likely to detect and eject them. The crows lose time and food (−) while the koel gains (+), so it is not commensalism or mutualism.

13 **Assertion (A):** 'Saheli', the oral contraceptive for females, is a 'once a week' pill.
Reason (R): 'Saheli' contains a steroidal preparation of progestogen and estrogen.

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

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

(C) A is true but R is false.

(D) A is false but R is true.

Answer (1 mark)

(C) A is true but R is false.

'Saheli' is a once-a-week pill with very few side effects and high contraceptive value, but it contains a non-steroidal preparation.

14 **Assertion (A):** Thalassemia is a quantitative problem of haemoglobin, whereas sickle-cell anaemia is a qualitative problem.
Reason (R): In thalassemia too few globin molecules are synthesised, whereas in sickle-cell anaemia an incorrectly functioning globin is synthesised.

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

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

(C) A is true but R is false.

(D) A is false but R is true.

Answer (1 mark)

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

Thalassemia reduces the rate of synthesis of a globin chain (α or β) – too little globin (quantity). Sickle-cell anaemia results from a single base substitution (GAG → GUG; Glu → Val at the sixth position of the β-globin chain) giving an abnormal globin (quality).

15 **Assertion (A):** Cyanobacteria are used as an important biofertiliser mainly in the wheat fields of north India.
Reason (R): Cyanobacteria are autotrophic microbes, many of which can fix atmospheric nitrogen.

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

Answer (1 mark)
(D) A is false but R is true.
Cyanobacteria (e.g. *Anabaena*, *Nostoc*, *Oscillatoria*) are autotrophic and many fix atmospheric nitrogen, but they serve as an important biofertiliser in paddy (rice) fields, where they grow in water.

16 **Assertion (A):** Earthworms are detritivores that break down detritus into smaller particles.
Reason (R): Humus is highly resistant to microbial action and decomposes at an extremely slow rate.

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

Answer (1 mark)
(B) Both A and R are true but R is not the correct explanation of A.
Fragmentation of detritus by detritivores such as earthworms is the first step of decomposition; the slow decomposition of humus is a separate fact about humification and does not explain fragmentation.

SECTION B Q. Nos. 17 to 21 are short answer questions carrying 2 marks each. **[10]**

17 Attempt either option A or B.

A. A plant breeder crossed a pure-breeding pea plant with round seeds (BB) with one having wrinkled seeds (bb). All the F_1 seeds were round, but under the microscope their starch grains were of intermediate size between those of the two parents. (i) Explain how the same pair of alleles shows dominance for one phenotype and incomplete dominance for another. (ii) In the F_2 generation, what will be the ratio of seeds with large, intermediate and small starch grains, and the ratio of round to wrinkled seeds?

OR

B. The karyotype of a 16-year-old girl shows 45 chromosomes, with only one X chromosome. (i) Name the disorder and explain how such a change in chromosome number arises. (ii) State two features of this disorder.

Answer (2 marks)
A. (i) The gene controls starch synthesis. BB plants synthesise starch efficiently and form large starch grains (round seeds); bb plants are less efficient and form small grains (wrinkled seeds). Bb produces enough starch for the seeds to be round, so for seed shape B is dominant; but its starch grains are intermediate in size, so for starch-grain size the alleles show incomplete dominance. Dominance is therefore not an autonomous feature of a gene – it depends on the gene product and on the phenotype we choose to examine.
(ii) F_1 Bb × Bb → 1 BB : 2 Bb : 1 bb.
Starch grains – large : intermediate : small = 1 : 2 : 1.
Seed shape – round : wrinkled = 3 : 1.
OR

B. (i) Turner's syndrome (45, X0). It is a chromosomal disorder caused by aneuploidy: failure of segregation of chromatids/chromosomes during cell division (meiosis) produces a gamete without a sex chromosome, and fertilisation with a normal X-bearing gamete gives a 45, X0 zygote (loss of one X chromosome).
(ii) Such females are sterile, as their ovaries are rudimentary; they also lack other secondary sexual characters.

Marking: A: (i) dominance for shape and incomplete dominance for starch-grain size, with reason – 1 mark; (ii) 1 : 2 : 1 – ½ mark, 3 : 1 – ½ mark · OR B: (i) Turner's syndrome – ½ mark, failure of segregation/aneuploidy (loss of an X) – ½ mark; (ii) two features – ½ + ½ mark

Examiner tip: In A, give both ratios separately – one for starch-grain size (1 : 2 : 1) and one for seed shape (3 : 1). Writing only one ratio loses ½ mark.

18 The approximate brain capacities of three fossil hominids P, Q and R are given below.

Fossil	Brain capacity (cc)
P	about 650 to 800
Q	about 900
R	about 1400

(i) Identify P, Q and R.
(ii) Which of them probably did not eat meat, and which used hides to protect the body and buried their dead?

Answer (2 marks)
(i) P – *Homo habilis* (the first human-like being, the hominid); Q – *Homo erectus* (fossils discovered in Java in 1891; about 1.5 mya); R – Neanderthal man (lived in the near east and central Asia between 1,00,000 and 40,000 years ago).
(ii) P, *Homo habilis*, probably did not eat meat (*Homo erectus* probably ate meat). R, the Neanderthal man, used hides to protect the body and buried their dead.

Marking: (i) P, Q and R correctly identified – ½ mark for any two, 1 mark for all three · (ii) P did not eat meat – ½ mark; R used hides and buried the dead – ½ mark

Examiner tip: Write the full scientific names (*Homo habilis*, *Homo erectus*); 'early man' or 'ape-man' gets no credit.

19 While working on *Staphylococci* bacteria, a scientist noticed a mould growing in one of his unwashed culture plates; the bacteria could not grow around the mould.
(i) Name the scientist, the mould and the chemical responsible. Who later established the full potential of this chemical as an effective antibiotic?
(ii) Why is the excessive and indiscriminate use of antibiotics harmful in the long run?

Answer (2 marks)
(i) Alexander Fleming observed it; the mould was *Penicillium notatum* and the chemical was penicillin (the first antibiotic discovered). Its full potential as an effective antibiotic was established later by Ernest Chain and Howard Florey (it was used extensively to treat soldiers wounded in World War II).
(ii) Antibiotics kill the sensitive bacteria, but any bacteria that happen to carry variations giving resistance survive and multiply. Excessive use thus selects antibiotic-resistant strains in a short time (natural selection), and diseases caused by them become difficult to treat. Hence antibiotics should be used judiciously, only on a doctor's advice.

Marking: (i) Fleming, *Penicillium notatum*/penicillin – ½ mark; Chain and Florey – ½ mark · (ii) Selection of resistant bacteria – ½ mark; consequence (infections hard to treat) – ½ mark

Examiner tip: In (ii) use the word 'selection' – resistance is not 'learnt' by bacteria; resistant variants already present are selected.

20 Attempt either option A or B.

A. A pharmaceutical company plans to use transgenic mice instead of ordinary mice to test whether a new chemical is toxic. (i) How are the transgenic mice made suitable for such testing, and what is the advantage? (ii) Name a human protein produced by transgenic animals that is used to treat emphysema.

OR

B. A scientist wants to introduce a recombinant DNA (i) into the nucleus of an animal cell and (ii) into cells of a plant. Name the method suitable for each case and explain briefly how it works.

Answer (2 marks)

A. (i) Transgenic animals are made to carry genes that make them more sensitive to toxic substances than non-transgenic animals. They are exposed to the chemical and its effects studied (toxicity/safety testing). Because they are more sensitive, the results are obtained in less time.

(ii) α-1-antitrypsin.

OR

B. (i) Micro-injection – the recombinant DNA is injected directly into the nucleus of the animal cell.

(ii) Biolistics or gene gun – plant cells are bombarded with high-velocity micro-particles of gold or tungsten coated with the DNA. (A 'disarmed pathogen' vector such as *Agrobacterium* may also be used for plants.)

Marking: A: (i) genes making them more sensitive – ½ mark, results in less time – ½ mark; (ii) α-1-antitrypsin – 1 mark · OR B: (i) micro-injection with explanation – 1 mark; (ii) biolistics/gene gun with explanation – 1 mark

Examiner tip: In B, name the particles (gold or tungsten) coated with DNA – 'shooting DNA into the cell' alone gets only ½ mark.

21 Attempt either option A or B.

A. Ecologists surveyed frog species in two forest patches of the Western Ghats. Patch M, of area 5 km^2, had 45 frog species; patch N has an area of 160 km^2. (i) Name the relationship between species richness and area described by Alexander von Humboldt and write its equation on a logarithmic scale. (ii) Taking the slope of the regression line (Z) as 0.2 and the same value of C for both patches, calculate the expected number of frog species in patch N.

OR

B. (i) Explain the 'rivet popper hypothesis' given by Paul Ehrlich. (ii) What do the 'rivets on the wings' represent, and why is their loss more serious?

Answer (2 marks)

A. (i) Species–area relationship: within a region, species richness increases with explored area, but only up to a limit. On a log scale: $\log S = \log C + Z \log A$, where S = species richness, A = area, Z = slope of the line (regression coefficient), C = Y-intercept.

(ii) For the same C, $\log S_N - \log S_M = Z(\log A_N - \log A_M)$, i.e. $S_N/S_M = (A_N/A_M)^Z = (160/5)^{0.2} = 32^{0.2} = 2$.

$S_N = 45 \times 2 = 90$ frog species.

OR

B. (i) An ecosystem is compared to an aeroplane whose parts are joined by thousands of rivets (species). If passengers pop out rivets one by one (species become extinct), flight safety (proper functioning of the ecosystem) may not be affected at first, but as more and more rivets are removed, the plane becomes dangerously weak over a period of time.

(ii) Rivets on the wings represent key species that drive major ecosystem functions. Losing them

is a more serious threat to the ecosystem than losing a few rivets on the seats or windows (less critical species).

Marking: A: (i) name – ½ mark, equation with Z – ½ mark; (ii) $(32)^{0.2} = 2$ – ½ mark, 90 species – ½ mark · OR B: (i) analogy explained – 1 mark; (ii) key species – ½ mark, why serious – ½ mark

Examiner tip: In A, C cancels only because the two patches are in the same region; show the ratio step – the bare answer 90 gets only ½ mark.

SECTION C Q. Nos. 22 to 28 are short answer questions carrying 3 marks each. **[21]**

22 A couple who have been trying to have a baby are told by their doctor that the woman ovulates normally and the man's semen has healthy sperms, yet fertilisation does not happen in every cycle.

(a) Where in the female reproductive tract does fertilisation normally take place? Why do not all copulations lead to fertilisation?

(b) Several sperms reach the ovum, but only one fertilises it. How does a sperm enter the ovum, and what prevents the entry of additional sperms?

(c) Which event in the ovum is completed after the entry of the sperm? Name its products.

Answer (3 marks)

(a) In the ampullary region of the fallopian tube (oviduct). Fertilisation can occur only if the ovum and the sperms are transported simultaneously to the ampullary region; if they do not reach it at the same time, fertilisation does not take place.

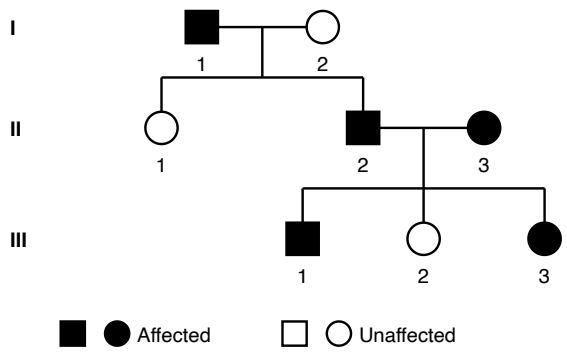
(b) The secretions of the acrosome help the sperm enter the cytoplasm of the ovum through the zona pellucida and the plasma membrane. When a sperm comes in contact with the zona pellucida, it induces changes in the membrane that block the entry of additional sperms, so only one sperm fertilises the ovum.

(c) The entry of the sperm induces the completion of the second meiotic division of the secondary oocyte. This forms a large haploid ovum (ootid) and a small second polar body. The haploid nucleus of the sperm and that of the ovum then fuse to form a diploid zygote.

Marking: (a) Ampullary region – ½ mark; simultaneous transport of ovum and sperms – ½ mark · (b) Acrosome secretions – ½ mark; changes in zona pellucida/membrane block other sperms – ½ mark · (c) Completion of meiosis II of secondary oocyte – ½ mark; ovum (ootid) + second polar body – ½ mark

Examiner tip: The ovum released at ovulation is a secondary oocyte arrested in meiosis II; meiosis II is completed only after sperm entry – do not write 'meiosis I'.

23 The pedigree given below shows the inheritance of a trait controlled by a single gene in a family.



(a) Is the trait dominant or recessive? Justify using individuals II-2, II-3 and III-2.
(b) Is the gene autosomal or X-linked? Justify.
(c) Write the genotypes of I-2, II-2 and III-2 (use A/a), and find the probability that the next child of II-2 and II-3 will be unaffected.

For visually impaired candidates (in lieu of the above):
A man (I-1) showing a certain trait married a woman (I-2) who did not show it. They had an unaffected daughter (II-1) and an affected son (II-2). The son (II-2) married an affected woman (II-3); their children are an affected son (III-1), an unaffected daughter (III-2) and an affected daughter (III-3). Answer (a), (b) and (c) given above.

Answer (3 marks)
(a) Dominant. II-2 and II-3 are both affected, but their daughter III-2 is unaffected. If the trait were recessive, both parents would be aa and all their children would be affected. So each parent must carry a recessive normal allele that III-2 received from both – the trait is dominant (both parents Aa).
(b) Autosomal. If it were X-linked dominant, the affected father II-2 (X^AY) would pass X^A to every daughter, so III-2 could not be unaffected. Also, an X-linked recessive trait is ruled out by (a) (two affected parents $X^aY \times X^aX^a$ cannot have a normal daughter). Hence the gene is autosomal (and males and females are both affected).
(c) I-2 – aa (unaffected); II-2 – Aa (affected, but received a from his unaffected mother I-2); III-2 – aa (unaffected).
II-3 is also Aa (she has an unaffected child). Aa × Aa → 1 AA : 2 Aa : 1 aa, so the probability that the next child is unaffected (aa) = 1/4 (25%).
Marking: (a) Dominant with justification from II-2 × II-3 → III-2 – 1 mark · (b) Autosomal with justification (affected father, unaffected daughter) – 1 mark · (c) Three genotypes – ½ mark; probability 1/4 with cross – ½ mark
Examiner tip: Always justify from a specific mating in the pedigree. 'It appears in every generation' alone does not prove dominance and earns no credit.

24 In an experiment like that of Hershey and Chase, one batch of bacteriophages had its protein coat labelled with radioactive sulphur (^{35}S) and another batch had its DNA labelled with radioactive phosphorus (^{32}P). Each batch was allowed to infect *E. coli*; the mixture was then agitated in a blender and centrifuged. The hypothetical distribution of radioactivity is given below.

Phage batch	Radioactivity in supernatant (%)	Radioactivity in pellet (%)
I – protein labelled with ^{35}S	85	15
II – DNA labelled with ^{32}P	30	70

(a) Which fraction contains the bacterial cells and which contains the viral coats? What do the data show about the molecule that entered the bacteria?
(b) Why was the mixture agitated in a blender before centrifugation?
(c) What result would have been expected if protein were the genetic material? State the conclusion of the experiment.

Answer (3 marks)
(a) The heavier bacterial cells settle in the pellet; the lighter virus particles/empty viral coats remain in the supernatant. Most of the ^{35}S (protein) radioactivity stays in the supernatant, while most of the ^{32}P (DNA) radioactivity is in the pellet with the bacteria. So the viral DNA, not the protein, entered the bacteria. (The small amount of ^{35}S in the pellet is due to coats still sticking to the bacteria.)
(b) As the infection proceeds, the viral coats remain attached to the outside of the bacteria.

Agitating in a blender removes these coats from the bacterial surface, so that centrifugation can separate the virus particles from the bacteria.

(c) If protein were the genetic material, the ^{35}S-labelled protein would have entered the bacteria and most of the ^{35}S would be in the pellet (bacteria infected with batch I would be radioactive), while ^{32}P would remain mostly in the supernatant. Conclusion: DNA is the genetic material that passes from the virus to the bacterium.

Marking: (a) Pellet = bacteria, supernatant = viral coats – ½ mark; DNA entered – ½ mark · (b) Removal of viral coats from bacteria before separation – 1 mark · (c) Expected result if protein were genetic – ½ mark; conclusion: DNA is the genetic material – ½ mark

Examiner tip: Do not mix up the two labels: ^{35}S labels protein (DNA has no sulphur) and ^{32}P labels DNA (protein has no phosphorus).

25 Arjun, aged 45, has kidney failure. His sister agrees to donate one kidney, but only after tissue matching and blood-group matching have been done. Even after a successful transplant, Arjun will have to take immunosuppressant drugs all his life.

(a) Why cannot a kidney be taken from just any person?

(b) Which type of immune response is responsible for graft rejection, and which lymphocytes mediate it? Why must Arjun take immunosuppressants?

(c) Which lymphocytes produce antibodies, and why is the antibody-mediated response called the humoral immune response?

Answer (3 marks)

(a) The body is able to differentiate 'self' from 'non-self'. A graft from just any source (animal, another primate or any human) is recognised as non-self and will be rejected sooner or later. Matching the tissue and blood group reduces the difference between donor and recipient.

(b) The cell-mediated immune response (CMI), mediated by T-lymphocytes, is responsible for graft rejection. Since some difference always remains between donor and recipient tissues, immunosuppressants are needed to suppress this response so that the kidney is not rejected.

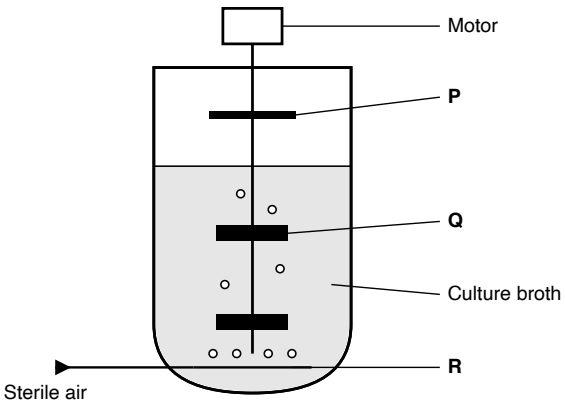
(c) B-lymphocytes produce antibodies (proteins of the type H_2L_2, e.g. IgA, IgM, IgE, IgG).

Because these antibodies are found in the blood (body fluid/humour), the response is called the humoral immune response.

Marking: (a) Self/non-self recognition and rejection of a non-matching graft – 1 mark · (b) Cell-mediated immunity by T-lymphocytes – ½ mark; reason for immunosuppressants – ½ mark · (c) B-lymphocytes – ½ mark; antibodies present in blood – ½ mark

Examiner tip: Graft rejection is cell-mediated (T-cells), not antibody-mediated – this is the most common error in (b).

26 The figure given below shows a sparged stirred-tank bioreactor used by a company to produce a recombinant protein on a large scale.



(a) Identify the parts labelled P, Q and R and give the function of each.
(b) Instead of a single batch, the company plans to multiply the cells in a continuous culture system. How is this done, and why does it give a higher yield of the protein?
(c) Why can the protein collected from the bioreactor not be marketed directly? Name the two processes collectively called downstream processing.
For visually impaired candidates (in lieu of the above):
(a) A sparged stirred-tank bioreactor has three systems: one placed above the culture to control foaming, one that stirs the culture, and one at the base through which air enters. Name each part and give its function.
Answer (b) and (c) given above.

Answer (3 marks)
(a) P – foam breaker (foam control system): breaks the foam formed on the surface of the culture during aeration and stirring.
Q – flat-bladed impeller/stirrer (agitator system): facilitates even mixing and oxygen availability throughout the bioreactor.
R – sparger (oxygen delivery system): sterile air bubbles are sparged (bubbled) through the culture to supply oxygen.
(b) In a continuous culture system, the used medium is drained out from one side while fresh medium is added from the other. This keeps the cells in their physiologically most active log/exponential phase, producing a larger biomass and hence a higher yield of the desired protein.
(c) The product is mixed with cells and medium and is not pure or stable. It must pass through separation and purification (together called downstream processing), be formulated with suitable preservatives, and undergo clinical trials and strict quality control testing before marketing.

Marking: (a) P, Q, R with functions – ½ mark each (for R accept sparger / oxygen delivery system through which sterile air is bubbled) · (b) Draining used medium and adding fresh medium – ½ mark; cells kept in log phase → larger biomass – ½ mark · (c) Product not pure – needs separation and purification (downstream processing) – ½ mark

Examiner tip: For R, say that sterile air is bubbled (sparged) through the culture to supply oxygen; calling it just a 'pipe' without its function loses ½ mark.

27 During a field visit near Satara, students made the following observations and later read about one more case:
P: Cattle and goats graze in an abandoned field but never browse on the *Calotropis* plants growing there.
Q: Birds avoid eating the brightly coloured Monarch butterflies.
R: The prickly pear cactus, introduced into Australia in the early 1920s, spread rapidly into millions of hectares of rangeland.
(a) Explain P.
(b) How does the Monarch butterfly become distasteful to birds in Q?
(c) Why did the cactus in R spread so rapidly, and how was it finally brought under control?

Answer (3 marks)
(a) *Calotropis* produces highly poisonous cardiac glycosides, a chemical defence against herbivores; that is why cattle and goats do not browse on it.
(b) The Monarch butterfly acquires a special chemical during its caterpillar stage by feeding on a poisonous weed. The chemical, present in the body of the adult, makes it highly distasteful to birds (its predators).
(c) The cactus spread rapidly because the invaded land did not have its natural predators

(herbivores that feed on it). It was brought under control only after a cactus-feeding predator (a moth) from its natural habitat was introduced into Australia – the basis of biological control.

Marking: (a) Cardiac glycosides as chemical defence – 1 mark · (b) Chemical acquired by the caterpillar from a poisonous weed – 1 mark · (c) Absence of natural predators – ½ mark; control by introducing a cactus-feeding moth – ½ mark

Examiner tip: In (b), stress that the butterfly does not make the chemical itself – it takes it from the weed eaten by the caterpillar.

28 A student studying a village pond and the forest next to it noted the following:
(i) Dead leaves on the forest floor → earthworms → birds
(ii) Phytoplankton → zooplankton → small fish → kingfisher
(iii) Sparrows eat seeds and fruits, and also insects and worms.
(a) Classify food chains (i) and (ii) as grazing or detritus food chains. Through which type does most of the energy flow in the pond and in the forest?
(b) At which trophic levels does the sparrow function? What does this show about the meaning of a trophic level?
(c) What is meant by the standing crop of a trophic level, and how is it measured?

Answer (3 marks)
(a) (i) is a detritus food chain (DFC) – it begins with dead organic matter (detritus) eaten by detritivores; it is connected with the grazing food chain where birds eat earthworms. (ii) is a grazing food chain (GFC) – it begins with producers. In an aquatic ecosystem (pond) the GFC is the major conduit for energy flow; in a terrestrial ecosystem (forest) a much larger fraction of energy flows through the DFC.
(b) The sparrow is a primary consumer when it eats seeds and fruits, and a secondary consumer when it eats insects and worms. Thus a trophic level represents a functional level, not a species as such; one species may occupy more than one trophic level in the same ecosystem at the same time.
(c) Standing crop is the mass of living material present at each trophic level at a particular time. It is measured as the mass of living organisms (biomass) or the number in a unit area; biomass measured as dry weight is more accurate.

Marking: (a) Correct classification – ½ mark; GFC in pond, DFC in forest – ½ mark · (b) Primary and secondary consumer – ½ mark; trophic level is functional, not a species – ½ mark · (c) Definition – ½ mark; biomass or number per unit area – ½ mark

Examiner tip: Many students wrongly say GFC carries more energy in every ecosystem; on land the detritus food chain carries more.

SECTION D Q. Nos. 29 and 30 are case-based questions carrying 4 marks each. **[8]**

29 Read the passage and answer the questions that follow.

Sunita, aged 26, missed her menstrual period and a home pregnancy test kit gave a positive result. The kit detects a hormone in the urine that is produced by the developing placenta. At the antenatal clinic, the doctor explained how the placenta connects the mother and the foetus, how labour begins when the baby is ready to be born, and why the baby should be breastfed from the very first day.

A. Name the hormone detected by the kit and one other hormone that is produced in women only during pregnancy. (1)

B. How is the placenta formed? State two of its functions. (2)

Attempt either subpart C or D.

C. What is the foetal ejection reflex? How does it lead to parturition? (1)

OR

D. What is the milk produced by the mother during the initial few days of lactation called? Why is it important for the new-born baby? (1)

Answer (4 marks)

A. Human chorionic gonadotropin (hCG). Other hormones produced only during pregnancy: human placental lactogen (hPL) or relaxin (any one).

B. After implantation, finger-like projections called chorionic villi appear on the trophoblast and are surrounded by the uterine tissue and maternal blood. The chorionic villi and the uterine tissue become interdigitated and jointly form a structural and functional unit between the foetus and the mother – the placenta. It is connected to the embryo through the umbilical cord. Functions (any two): supplies oxygen and nutrients to the embryo; removes carbon dioxide and excretory/waste materials produced by the embryo; acts as an endocrine tissue producing hCG, hPL, estrogens and progestogens.

C. The signals for parturition come from the fully developed foetus and the placenta, which induce mild uterine contractions called the foetal ejection reflex. This triggers the release of oxytocin from the maternal pituitary; oxytocin causes stronger uterine contractions, which stimulate further oxytocin secretion. These stronger and stronger contractions expel the baby through the birth canal.

OR

D. Colostrum. It contains several antibodies (mainly IgA) that are absolutely essential to develop resistance in the new-born baby (passive immunity).

Marking: A: hCG – ½ mark; hPL or relaxin – ½ mark · B: chorionic villi interdigitating with uterine tissue – 1 mark; two functions – ½ + ½ mark · C: foetal ejection reflex – ½ mark, oxytocin and stronger contractions – ½ mark OR D: colostrum – ½ mark; antibodies (IgA) giving resistance/passive immunity to the new-born – ½ mark

Examiner tip: Relaxin is secreted by the ovary in the later phase of pregnancy – do not say it comes from the placenta.

30 Read the passage and answer the questions that follow.

Students of a junior college in Nashik visited a dairy co-operative and a fruit-processing unit. At the dairy, a small amount of curd was added to large vessels of warm milk to make curd. In the canteen, idli batter that had been left overnight had puffed up. At the fruit-processing unit, the bottled grape juice was much clearer than juice made at home; the guide said that enzymes made by microbes are used for this, and that citric acid used as a preservative is also made by a microbe.

A. How does a small amount of curd turn warm milk into curd, and how does this improve the nutritional quality of the milk? (1)

B. Why does idli batter puff up when left overnight? Why is bottled juice clearer than home-made juice? (2)

Attempt either subpart C or D.

C. Name the microbe used for the commercial production of citric acid, and state whether it is a bacterium or a fungus. (1)

OR

D. Name the organic acids produced by *Acetobacter aceti* and by *Clostridium butylicum*. (1)

Answer (4 marks)

A. The small amount of curd acts as an inoculum or starter containing millions of lactic acid bacteria (LAB, e.g. *Lactobacillus*). At a suitable (warm) temperature they multiply and produce acids that coagulate and partially digest the milk proteins, converting milk into curd. This improves its nutritional quality by increasing vitamin B_{12}.

B. The batter for idli is fermented by bacteria; the CO_2 gas produced during fermentation gives the dough its puffed-up appearance.

Bottled fruit juices are clarified by the use of enzymes produced by microbes – pectinases and proteases.

C. *Aspergillus niger* – a fungus.

OR

D. *Acetobacter aceti* – acetic acid; *Clostridium butylicum* – butyric acid.

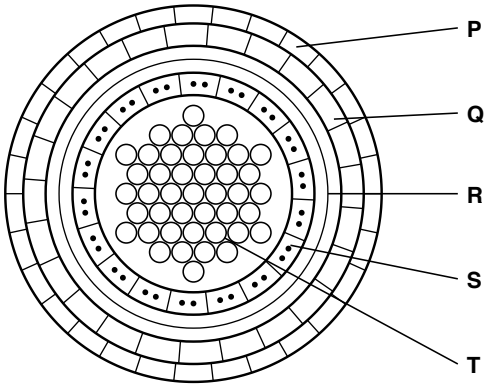
Marking: A: LAB in the starter multiply and coagulate/digest milk proteins – ½ mark; vitamin B_{12} increased – ½ mark · B: fermentation by bacteria – ½ mark, CO_2 produced – ½ mark; pectinases and proteases – 1 mark · C: *Aspergillus niger*, fungus – ½ + ½ mark OR D: acetic acid – ½ mark, butyric acid – ½ mark

Examiner tip: Idli/dosa batter is fermented by bacteria, while bread dough is fermented by baker's yeast – do not mix them up.

SECTION E Q. Nos. 31 to 33 are long answer questions carrying 5 marks each. **[15]**

31 Attempt either option A or B.

A. The figure given below shows the transverse section of one microsporangium of a young anther.



(i) Name the layers labelled P, Q, R and S. State one function common to P, Q and R, and the function of S. (1½)
(ii) Name the tissue labelled T and the process by which its cells form microspore tetrads. If one microsporangium has 64 such cells, each acting as a microspore mother cell, how many pollen grains will be formed, and how many male gametes will these pollen grains finally produce? (1½)
(iii) In over 60 per cent of angiosperms, pollen grains are shed at the 2-celled stage. Name the two cells and state how the male gametes are formed. (1)
(iv) A plant-breeding institute wants to use the pollen of a rare variety in its breeding programme several years later. How can the pollen be kept viable for years, and what is such a store called? (1)

For visually impaired candidates (in lieu of the above):

In lieu of (i) and (ii) above:
(i) Name the four wall layers of a microsporangium from outside to inside. State one function common to the outer three layers, and the function of the innermost layer. (1½)
(ii) Name the tissue present at the centre of a young microsporangium and the process by which its cells form microspore tetrads. If one microsporangium has 64 such cells, each acting as a microspore mother cell, how many pollen grains will be formed, and how many male gametes will these pollen grains finally produce? (1½)
Answer (iii) and (iv) given above.

OR

B. A student soaked bean seeds and castor seeds in water and cut them open. The bean seed had no endosperm left, while the castor seed still had a large endosperm.
(i) Classify the bean and castor seeds on this basis, explain the difference, and give one more example of each type. (1½)
(ii) What happens to the water content and metabolic activity of a seed as it matures? What is the state of inactivity of the embryo called, and why is it important for agriculture? (1)
(iii) A seed of *Lupinus arcticus* excavated from the Arctic Tundra germinated and flowered after an estimated 10,000 years. What does this show about seeds? (1)
(iv) Give three reasons why seeds offer great advantages to angiosperms. (1½)

Answer (5 marks)

A. (i) P – epidermis; Q – endothecium; R – middle layers; S – tapetum.
The outer three wall layers (P, Q, R) perform the function of protection and help in dehiscence of the anther to release the pollen. The tapetum (S) nourishes the developing pollen grains (its cells have dense cytoplasm and generally more than one nucleus).
(ii) T – sporogenous tissue. Each cell (microspore mother cell/pollen mother cell, 2n) undergoes meiosis to form a tetrad of four haploid microspores – microsporogenesis.
64 microspore mother cells × 4 = 256 microspores → 256 pollen grains.
Each pollen grain finally produces 2 male gametes: 256 × 2 = 512 male gametes.
(iii) A large vegetative cell (with abundant food reserve and a large, irregular nucleus) and a small, spindle-shaped generative cell (with dense cytoplasm). The generative cell divides mitotically to give rise to the two male gametes (before shedding in 3-celled pollen; in the pollen tube in 2-celled pollen).
(iv) Pollen grains of many species can be stored for years in liquid nitrogen (−196 °C). Such stored pollen forms a pollen bank (similar to a seed bank) and can be used in crop-breeding programmes.
Visually impaired alternative: (i) Epidermis, endothecium, middle layers and tapetum; the outer three protect and help in dehiscence; the tapetum nourishes the developing pollen grains. (ii) As above – sporogenous tissue; meiosis (microsporogenesis); 256 pollen grains; 512 male gametes.

OR

B. (i) Bean – non-albuminous (ex-albuminous) seed: it has no residual endosperm, as the endosperm is completely consumed during embryo development (the food is stored in the cotyledons). Castor – albuminous seed: it retains a part of the endosperm, as the endosperm is not completely used up during embryo development. Other examples: non-albuminous – pea, groundnut; albuminous – wheat, maize, barley.

(ii) As the seed matures, its water content falls and it becomes relatively dry (10–15 per cent moisture by mass); the general metabolic activity of the embryo slows down. The embryo may enter a state of inactivity called dormancy. Dehydration and dormancy allow seeds to be stored, to be used as food throughout the year and to raise crops in the next season.

(iii) Seeds can remain viable (alive) for very long periods in dormancy and germinate when favourable conditions (adequate moisture, oxygen, suitable temperature) are available; some seeds remain alive for hundreds or even thousands of years.

(iv) Any three: (1) Pollination and fertilisation are independent of water, so seed formation is more dependable. (2) Seeds have better adaptive strategies for dispersal to new habitats, helping the species colonise other areas. (3) Their food reserves nourish young seedlings until they can photosynthesise. (4) The hard seed coat protects the young embryo. (5) Being products of sexual reproduction, they generate new genetic combinations leading to variations.

Marking: A: (i) four layers named – 1 mark (any two – ½ mark); functions of P/Q/R and S – ½ mark · A: (ii) sporogenous tissue and meiosis – ½ mark; 256 pollen grains – ½ mark; 512 male gametes – ½ mark · A: (iii) vegetative and generative cells – ½ mark; mitosis of generative cell – ½ mark · A: (iv) liquid nitrogen at −196 °C – ½ mark; pollen bank – ½ mark · OR B: (i) classification with reason – 1 mark; one more example each – ½ mark · B: (ii) water content/metabolism – ½ mark; dormancy and its importance – ½ mark · B: (iii) long viability/dormancy until favourable conditions – 1 mark · B: (iv) three advantages – ½ mark each

Examiner tip: In A(ii), meiosis gives 4 microspores per mother cell and each pollen grain gives 2 male gametes – show both multiplications; in B(i) the terms 'albuminous' and 'non-albuminous' carry the marks.

32 Attempt either option A or B.

A. In a grassland, a wild plant population of 2500 plants is in Hardy–Weinberg equilibrium for a gene controlling flower colour. Purple flower colour (allele R) is dominant over white (allele r), and 225 plants have white flowers.

(i) Calculate the frequencies of alleles R and r, and the expected numbers of RR and Rr plants. (2)

(ii) State the Hardy–Weinberg principle and what the terms of $p^2 + 2pq + q^2 = 1$ represent. (1)

(iii) Twenty years later, after a highway was built through the grassland, the frequency of allele r was found to be 0.45. What does this change indicate, and how is the extent of the change judged? If the change occurred because white-flowered plants left more progeny along the roadsides, name the process responsible and the type of its operation (stabilisation, directional change or disruption) that this represents. (2)

OR

B. (i) The DNA of a bacterium contains 5.0×10^6 base pairs. Calculate the length of its DNA in millimetres. (1)

(ii) A short stretch of B-DNA has 40 base pairs. How many turns of the helix does it make, and what is its length in nm? Why is a purine always paired with a pyrimidine in the double helix? (2)

(iii) Explain how the long DNA is organised (a) in a bacterium such as *E. coli* and (b) in the nucleus of a eukaryotic cell. (2)

Answer (5 marks)

A. (i) Frequency of white (rr) plants = $q^2 = 225/2500 = 0.09$, so q (frequency of r) = $\sqrt{0.09} = 0.3$. p (frequency of R) = 1 − 0.3 = 0.7.

RR = $p^2 \times 2500 = 0.49 \times 2500 = 1225$ plants.

Rr = 2pq × 2500 = 2 × 0.7 × 0.3 × 2500 = 0.42 × 2500 = 1050 plants.
(Check: 1225 + 1050 + 225 = 2500.)
(ii) Allele frequencies in a population are stable and constant from generation to generation; the gene pool (total genes and their alleles in a population) remains constant – genetic equilibrium. p^2 = frequency of homozygous dominant (RR), 2pq = frequency of heterozygotes (Rr) and q^2 = frequency of homozygous recessive (rr) individuals; the sum of all genotype frequencies is 1 (the binomial expansion of $(p + q)^2$).
(iii) The frequency of r has changed from 0.3 to 0.45 (R from 0.7 to 0.55). The population is no longer in Hardy–Weinberg equilibrium – a change in allele frequency is interpreted as evolution. The extent of the change is judged from the difference between the observed frequency (0.45) and the value expected under equilibrium (0.3).
The process is natural selection: white-flowered plants have greater reproductive success (fitness), so the frequency of allele r rises in the next generations. Since more individuals come to have a value other than the earlier mean (the population shifts in one direction, towards white), it is a directional change.

OR

B. (i) Length = number of bp × distance between two consecutive bp = $5.0 \times 10^6 \times 0.34 \times 10^{-9}$ m = 1.7×10^{-3} m = 1.7 mm.
(ii) The pitch of the helix is 3.4 nm and there are roughly 10 bp in each turn. 40 bp ÷ 10 = 4 turns. Length = 40 × 0.34 nm = 13.6 nm (= 4 × 3.4 nm).
A purine always pairs with a pyrimidine (A with T, G with C); this generates an approximately uniform distance between the two strands of the helix.
(iii) (a) In prokaryotes such as *E. coli*, there is no defined nucleus, but the DNA is not scattered throughout the cell. The negatively charged DNA is held with some proteins that have positive charges in a region called the nucleoid, where it is organised in large loops held by proteins.
(b) In eukaryotes, the DNA is wrapped around positively charged basic proteins called histones (rich in lysine and arginine). Eight histone molecules form a histone octamer; the negatively charged DNA wraps around it to form a nucleosome (about 200 bp of DNA). Repeating nucleosomes form 'beads-on-string' chromatin, which is further packaged into chromatin fibres that coil and condense into chromosomes at metaphase; higher-level packaging needs non-histone chromosomal (NHC) proteins.

Marking: A: (i) q = 0.3 and p = 0.7 – 1 mark; RR = 1225 – ½ mark; Rr = 1050 – ½ mark · A: (ii) statement of the principle – ½ mark; meaning of the three terms – ½ mark · A: (iii) equilibrium disturbed/evolution – ½ mark; difference between observed and expected values – ½ mark; natural selection – ½ mark; directional change – ½ mark · OR B: (i) 1.7 mm with working – 1 mark · B: (ii) 4 turns – ½ mark; 13.6 nm – ½ mark; uniform distance between strands – 1 mark · B: (iii) nucleoid with positively charged proteins – 1 mark; histone octamer/nucleosome/chromatin – 1 mark

Examiner tip: In A(i), start from q^2 (the recessive phenotype is the only class you can count directly) – taking 225/2500 as q is the commonest error.

33 Attempt either option A or B.

A. A linear DNA molecule 6000 bp long has two recognition sites for the restriction enzyme EcoRI, at 1500 bp and 4200 bp from its left end.

(i) Write the recognition sequence of EcoRI on both strands, showing where it cuts, and explain why the ends produced are called 'sticky ends'. (1½)

(ii) How many fragments will be formed when this DNA is completely digested with EcoRI? Give their sizes, and arrange them in the order of the distance they will move from the well in agarose gel electrophoresis, starting with the one that moves farthest. (1½)

(iii) If the same 6000 bp DNA were a circular plasmid with the same two EcoRI sites, how many fragments would be formed and of what sizes? (1)

(iv) Why must the vector and the source DNA be cut with the same restriction enzyme? Which enzyme joins them? (1)

OR

B. A seed company wants to develop a maize variety resistant to the corn borer, using a gene from the soil bacterium *Bacillus thuringiensis*.

(i) In what form is the Bt toxin present in the bacterium? Explain how the toxin kills an insect larva that eats the leaves of the transgenic plant. (2)

(ii) Which *cry* gene should be introduced into maize for this purpose? Why must the gene be chosen according to the crop and the target pest? (1)

(iii) Name any two groups of insects that are killed by different Bt toxins, with one example each. (1)

(iv) Before such a GM crop can be introduced for public use in India, which organisation must approve it, and what is its role? (1)

Answer (5 marks)

A. (i) 5'–G↓AATTC–3'

3'–CTTAA↑G–5'

EcoRI cuts each strand between G and A (5'-G↓AATTC-3' on both strands, read 5'→3'), a little away from the centre of the palindrome. This leaves single-stranded overhanging stretches (5'-AATT) at the ends. They are called sticky ends because they form hydrogen bonds with their complementary cut counterparts; this stickiness helps the enzyme DNA ligase join them.

(ii) Two sites in a linear DNA give 3 fragments: 1500 bp (0–1500), 2700 bp (1500–4200) and 1800 bp (4200–6000). (Check: 1500 + 2700 + 1800 = 6000.)

Smaller fragments move farther through the gel matrix towards the anode, so the order from farthest to nearest the well is: 1500 bp (farthest), then 1800 bp, then 2700 bp (nearest the well).

(iii) Two cuts in a circular DNA give 2 fragments: 4200 − 1500 = 2700 bp and 6000 − 2700 = 3300 bp.

(iv) The same enzyme produces the same kind of complementary sticky ends on the vector and on the source (foreign) DNA, so they can pair with each other. The ends are joined end-to-end by DNA ligase, forming recombinant DNA.

OR

B. (i) *B. thuringiensis* forms protein crystals during a particular phase of its growth; the toxin exists in them as an inactive protoxin. When an insect larva eats the plant, the crystals are solubilised by the alkaline pH of its gut and the protoxin is converted into the active toxin. The activated toxin binds to the surface of the midgut epithelial cells and creates pores, which cause cell swelling and lysis, and eventually the death of the insect.

(ii) *cryIAb*, whose protein controls the corn borer. Most Bt toxins are insect-group specific, so the gene has to be chosen to match the crop and its targeted pest (e.g. *cryIAc* and *cryIIAb* control cotton bollworms, not the corn borer).

(iii) Any two: lepidopterans (e.g. tobacco budworm, armyworm); coleopterans (beetles); dipterans (flies, mosquitoes).
(iv) GEAC – the Genetic Engineering Approval Committee, set up by the Government of India. It decides on the validity of GM research and on the safety of introducing GM organisms for public services.

Marking: A: (i) recognition sequence on both strands with cut site – 1 mark; sticky ends explained – ½ mark · A: (ii) three fragments with sizes – 1 mark; correct order – ½ mark · A: (iii) two fragments, 2700 bp and 3300 bp – 1 mark · A: (iv) complementary sticky ends – ½ mark; DNA ligase – ½ mark · OR B: (i) inactive protoxin – ½ mark; alkaline gut pH activates – ½ mark; binding to midgut cells, pores, lysis – 1 mark · B: (ii) *cryIAb* – ½ mark; insect-group specificity – ½ mark · B: (iii) two groups with examples – ½ + ½ mark · B: (iv) GEAC – ½ mark; its role – ½ mark

Examiner tip: In A(ii)–(iii), remember: n cuts in a linear DNA give n + 1 fragments, but in a circular DNA they give n fragments.

All the best for your exam!