

COMPETISHUN

CBSE Class 12 — Biology (Code 044)

Sample Paper: Questions and Solutions — Session 2026-27

Time: 3 hours Maximum Marks: 70 Questions: 33 Sections: 5

Section A — Q1–16 (1 mark each, 16) | Section B — Q17–21 (2 marks each, 10) | Section C — Q22–28 (3 marks each, 21) | Section D — Q29–30 (case-based, 4 marks each, 8) | Section E — Q31–33 (5 marks each, 15)

All questions are compulsory. There is no overall choice, but internal choices are provided in some questions — attempt only one alternative in such questions. Wherever necessary, neat and properly labelled diagrams should be drawn. Alternative questions printed for visually impaired candidates are answered alongside.

Section A

Questions 1 to 16 • 1 mark each • 16 marks

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 to these questions.

Question 1 — 1 Mark

A researcher observes that in a particular flowering plant, the pistil matures several days before the stamens in all flowers of the plant. What is the most significant consequence of this timing difference?

- A. It guarantees self-pollination
- B. It promotes autogamy
- C. It ensures cross-pollination
- D. It leads to geitonogamy

Answer C. It ensures cross-pollination

Explanation Maturation of the pistil before the anthers is **protogyny**, an outbreeding device. The stigma is receptive when the plant's own pollen is not yet shed, so autogamy and geitonogamy are prevented and pollen must come from another plant.

Marking Scheme 1 mark for the correct option together with the answer text.

Question 2 — 1 Mark

A male patient undergoes a medical procedure where a small section of the vas deferens is cut and tied at both ends. Which of the following effects is the intended and direct result of this procedure?

- A. Blockage of sperm transport into the ejaculatory duct and urethra.
- B. Inhibition of testosterone production by the testes.
- C. Suppression of the formation of seminal plasma by accessory glands.
- D. Prevention of spermatogenesis in the seminiferous tubules.

Answer A. Blockage of sperm transport into the ejaculatory duct and urethra.

Explanation The procedure is **vasectomy**. It interrupts only the passage of sperm; spermatogenesis, testosterone secretion by Leydig cells and the secretions of the accessory glands all continue normally.

Marking Scheme 1 mark for the correct option together with the answer text.

Question 3 — 1 Mark

During the early stage of human embryonic development, the blastomeres are arranged into an outer layer and an inner group of cells known as the Inner Cell Mass (ICM). What is the fundamental significance of the outer layer, the trophoblast?

- A. It is responsible for forming the primary germ layers (ectoderm, mesoderm, endoderm).

- B. It provides essential nutrients to developing embryo and helps in its implantation.
- C. It secretes colostrum which contains antibodies.
- D. It gives rise to all the organs of the future embryo (organogenesis).

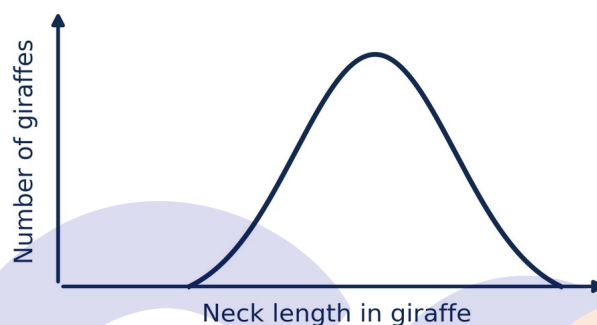
Answer B. It provides essential nutrients to developing embryo and helps in its implantation.

Explanation The trophoblast attaches to the uterine endometrium and later forms the chorionic villi and the placenta. It is the **inner cell mass**, not the trophoblast, that differentiates into the three primary germ layers and the organs of the embryo.

Marking Scheme 1 mark for the correct option together with the answer text.

Question 4 — 1 Mark

Select the option that gives the correct description of the process of natural selection with respect to the length of the neck of the giraffe.



- A. Stabilising selection as giraffes with longer neck lengths are selected further.
- B. Disruptive selection as giraffes with smaller and longer neck lengths are selected.
- C. Directional selection as giraffes with longer neck lengths are selected.
- D. Stabilising selection as giraffes with medium neck lengths are selected.

For visually impaired students — Evolution of antibiotic-resistant bacterial population signifies the information that: A. Acquired traits are inherited. B. Nature selects for fitness. C. Genetic variations are not a prerequisite factor for natural selection. D. The theory of spontaneous generation of life holds true.

Answer C. Directional selection as giraffes with longer neck lengths are selected.

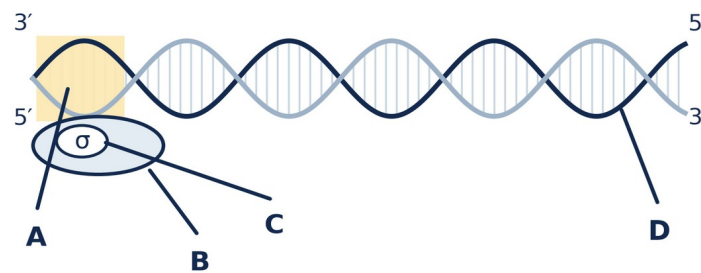
Explanation The distribution of neck length lies towards the **longer-neck end** of the axis — the mean of the population has shifted in one direction. This is **directional selection**, in which individuals at one extreme (here, longer necks) are favoured and the mean of the population moves towards that extreme. Stabilising selection would favour the mean and narrow the curve about it, while disruptive selection would give a two-peaked curve.

Answer (visually impaired version) B. Nature selects for fitness. A few bacteria already carry a resistance mutation; in the presence of the antibiotic only these survive and multiply, so nature selects the fitter variants.

Marking Scheme 1 mark for the correct option together with the answer text.

Question 5 — 1 Mark

The initiation step during the process of transcription in bacteria is shown below. Identify A, B, C and D by selecting the option:



- A. A-RNA polymerase, B-Promoter, C-Sigma factor, D-DNA helix
 B. A-Promoter, B-Sigma factor, C-RNA polymerase, D-DNA helix
 C. A-Promoter, B-RNA polymerase, C-DNA helix, D-Sigma factor
 D. A-Promoter, B-RNA polymerase, C-Sigma factor, D-DNA helix

For visually impaired students — The promoter site and the terminator site for transcription are located at: A. 3' (downstream) end and 5' (upstream) end, respectively of the transcription unit B. 5' (upstream) end and 3' (downstream) end, respectively of the transcription unit C. the 5' (upstream) end D. the 3' (downstream) end

Answer D. A - Promoter, B - RNA polymerase, C - Sigma factor, D - DNA helix

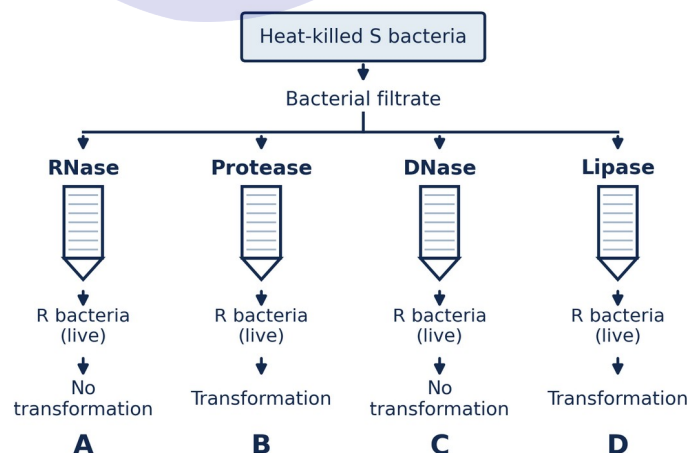
Explanation A marks the highlighted DNA segment towards the upstream end where the enzyme binds — the **promoter**. B marks the large enzyme complex — **RNA polymerase**. C marks the small subunit labelled σ within it — the **sigma initiation factor**. D marks the intact double-stranded region ahead of the enzyme — the **DNA helix**.

Answer (visually impaired version) B. 5' (upstream) end and 3' (downstream) end, respectively of the transcription unit. In a transcription unit the promoter lies at the 5' end of the coding strand and the terminator at the 3' end.

Marking Scheme 1 mark for the correct option together with the answer text.

Question 6 — 1 Mark

Given below is the illustration of the different steps of experiments conducted by MacLeod, McCarty and Avery to find the chemical nature of the 'transforming principle' as DNA. Select the option that **incorrectly** depicts the step of the experiment.



For visually impaired students — In the Griffith experiment, which of the following, when injected into mice, did not cause pneumonia? A. Heat-killed S strain only B. Live R strain only C. Both (A) and (B) D. Live S strain only

Answer A — the RNase tube, which is shown as giving “No transformation”.

Explanation RNase destroys only RNA; the transforming principle (DNA) remains intact, so transformation **does** occur in that tube. The figure therefore depicts step A incorrectly. The other three are correct —

protease (B) and lipase (D) leave DNA untouched so transformation occurs, while DNase (C) destroys DNA so no transformation occurs.

Answer (visually impaired version) C. Both (A) and (B). Heat-killed S strain alone is non-living, and live R strain alone is non-virulent because it lacks the polysaccharide capsule; neither caused pneumonia.

Marking Scheme 1 mark for the correct option together with the answer text.

Question 7 — 1 Mark

A scientist was culturing *E. coli* in a $^{15}\text{NH}_4\text{Cl}$ medium initially, then he shifted *E. coli* to a $^{14}\text{NH}_4\text{Cl}$ medium. The DNA was extracted from *E. coli* after 60 minutes of transfer to the $^{14}\text{NH}_4\text{Cl}$ medium and density gradient centrifugation was performed to check the isotope distribution in newly replicated DNA. What will be the densities of DNA molecules formed?

- A. 25% hybrid and 75% light
- B. 50% hybrid and 50% light
- C. 75% hybrid and 25% light
- D. 85% hybrid and 15% light

Answer A. 25% hybrid and 75% light

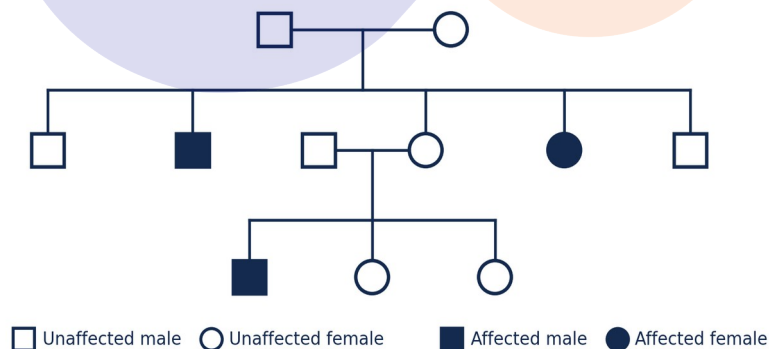
Solution

- Generation (doubling) time of *E. coli* = **20 minutes**, so 60 minutes = **3 generations**.
- Number of DNA molecules formed = $2^3 = 8$.
- Replication is **semi-conservative**, so the two original ^{15}N strands are conserved and end up in two different molecules: **2 hybrid** ($^{15}\text{N}-^{14}\text{N}$) and **6 light** ($^{14}\text{N}-^{14}\text{N}$).
- Hybrid = $2/8 \times 100 = 25\%$; Light = $6/8 \times 100 = 75\%$.

Marking Scheme 1 mark for the correct option together with the answer text.

Question 8 — 1 Mark

Study the given pedigree and identify the disease represented.



- A. Myotonic Dystrophy
- B. Sickle cell anaemia
- C. Haemophilia
- D. Colour blindness

For visually impaired students — If a genetic disease is transferred from a phenotypically normal but carrier female to only some of the male progeny, the disease is: A. Autosomal dominant B. Autosomal recessive C. Sex-linked dominant D. Sex-linked recessive

Answer B. Sickle cell anaemia

Explanation Unaffected parents produce affected children, so the trait is **recessive**. An **affected female** appears although her father is unaffected — impossible for a sex-linked recessive trait, in which an affected

daughter must have an affected father. The trait is therefore **autosomal recessive**, and of the options only sickle cell anaemia is autosomal recessive (myotonic dystrophy is autosomal dominant; haemophilia and colour blindness are X-linked recessive).

Answer (visually impaired version) D. Sex-linked recessive. A carrier female $XA Xa$ is phenotypically normal and passes Xa to half her sons, who are hemizygous and therefore affected.

Marking Scheme 1 mark for the correct option together with the answer text.

Question 9 — 1 Mark

A patient with fever, chest pain, cough and breathing difficulty undergoes a chest X-ray. The film shows patchy opacities and reduced clarity of lung fields. Which observation best supports pneumonia?

- A. Enlarged heart size
- B. Inflammation or fluid buildup in the lungs
- C. Fractured ribs
- D. Air pockets in the lungs

Answer B. Inflammation or fluid buildup in the lungs

Explanation In pneumonia the **alveoli become filled with fluid**, which is why breathing is severely affected. Fluid-filled alveoli block X-rays more than air-filled ones, producing exactly the patchy opacities seen on the film.

Marking Scheme 1 mark for the correct option together with the answer text.

Question 10 — 1 Mark

A stretch of an euchromatin has 200 nucleosomes. How many base pairs (bp) will be there in the stretch and what would be the length of the typical euchromatin?

- A. 20,000 bp and $13,000 \times 10^{-9}$ m
- B. 10,000 bp and $10,000 \times 10^{-9}$ m
- C. 40,000 bp and $13,600 \times 10^{-9}$ m
- D. 40,000 bp and $13,900 \times 10^{-9}$ m

Answer C. 40,000 bp and $13,600 \times 10^{-9}$ m

Solution

- **Given:** 200 nucleosomes; one typical nucleosome contains **200 bp** of DNA helix; length of one base pair = **$0.34 \text{ nm} = 0.34 \times 10^{-9} \text{ m}$** .
- **Base pairs** = $200 \times 200 = 40,000 \text{ bp}$
- **Length** = $40,000 \times 0.34 \times 10^{-9} \text{ m} = 13,600 \times 10^{-9} \text{ m}$ (= 13.6 μm)

Marking Scheme 1 mark for the correct option together with the answer text.

Question 11 — 1 Mark

A biotechnology company grew *Streptomyces* in a fermenter to produce an antibiotic. It was observed that from Day 7 onwards the actual yield drops sharply, even though nutrient level, temperature and aeration remain unchanged. Microscopy also revealed new colonies of bacteria which were not present in the original culture, so the fermenter was stopped. What measures should be taken to prevent the fall in yield in future fermentations?

- A. Increasing temperature only at the end of fermentation to kill contaminants.
- B. Adding antibiotics to the culture so unwanted microbes cannot grow.
- C. Ensuring sterile handling, sterilised equipment, and aseptic transfer before and during fermentation.
- D. Using a genetically modified strain designed to grow faster than contaminants.

Answer C. Ensuring sterile handling, sterilised equipment, and aseptic transfer before and during fermentation.

Explanation The appearance of colonies absent from the original culture shows **contamination**. Contaminants compete for nutrients and lower the yield, and the only reliable remedy is strict asepsis — sterilisation of the medium, vessel and air, and aseptic inoculation and sampling.

Marking Scheme 1 mark for the correct option together with the answer text.

Question 12 — 1 Mark

A rice farmer's field, which typically thrives in waterlogged conditions and requires soil rich in nutrients like phosphorus, is experiencing a severe drought this year. The crop is also susceptible to root infestation by pathogens. Which of the following techniques is best to address all these issues?

- A. Adding nitrogen-fixing bacteria to the soil
- B. Applying chemical fertilizers
- C. Adding spores of *Glomus* to the soil
- D. Flooding the field artificially to mimic normal conditions

Answer C. Adding spores of *Glomus* to the soil

Explanation *Glomus* forms **mycorrhiza**. The fungal hyphae absorb **phosphorus** from the soil and pass it to the plant, and mycorrhizal plants also show **tolerance to drought** and **resistance to root-borne pathogens** — all three problems are addressed at once.

Marking Scheme 1 mark for the correct option together with the answer text.

Questions 13 to 16 — Assertion (A) and Reason (R)

Question No. 13 to 16 consist of two statements — Assertion (A) and Reason (R). Answer these questions selecting the appropriate option given below:

- 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.

Question 13 — 1 Mark

Assertion (A): Spermatogenesis is an ongoing process throughout the reproductive life of a human male, while oogenesis is a discontinuous process.

Reason (R): Oogenesis begins during the embryonic stage, gets arrested at prophase-I, resumes after puberty, and is arrested again at metaphase-II.

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

Explanation A is **true** — spermatogenesis starts at puberty and continues without interruption, whereas oogenesis proceeds in interrupted stages. R is **true** — oogonia form in the foetal ovary, the primary oocyte stops at prophase-I, meiosis-I is completed only after puberty, and the secondary oocyte is arrested again at metaphase-II until fertilisation. These two arrests are precisely what make oogenesis discontinuous, so R correctly explains A.

Marking Scheme 1 mark for the correct option together with the answer text.

Question 14 — 1 Mark

Assertion (A): There is no variation in the percentage recombination due to loosely or tightly linked genes.

Reason (R): Linked genes result in occurrence of higher proportion of parental gene combinations.

Answer D. A is false but R is true.

Explanation A is **false** — recombination frequency depends on the distance between genes: **tightly linked** genes show a **low** percentage of recombination and **loosely linked** genes a **high** percentage; Morgan used exactly this variation to map genes. R is **true** — because linked genes tend to be inherited together, parental (non-recombinant) combinations always outnumber the recombinants.

Marking Scheme 1 mark for the correct option together with the answer text.

Question 15 — 1 Mark

Assertion (A): The primary goal of sewage treatment is to eliminate all organic matter from the effluent.

Reason (R): High BOD indicates a low level of organic matter in the water, which can lead to increased oxygen consumption by microorganisms, potentially harming aquatic life.

Answer C. A is true but R is false.

Explanation A is taken as **true** in the intended sense — the object of sewage treatment is to remove the organic matter and pathogens so that the effluent released has a low BOD. R is **false** and states the exact opposite of the fact: **a high BOD indicates a HIGH level of organic matter**, because BOD measures the oxygen consumed by bacteria in oxidising that organic matter.

Marking Scheme 1 mark for the correct option together with the answer text.

Question 16 — 1 Mark

Assertion (A): Tissue culture is used when traditional breeding technique is insufficient to keep pace with the demand of crop improvement.

Reason (R): Totipotency is the ability of a single plant cell or explant to regenerate into a whole plant under sterile conditions in nutrient media.

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

Explanation A is **true** — conventional breeding is too slow to supply improved planting material on the scale demanded, so tissue culture is adopted. R is **true** — totipotency is correctly defined. However, R only states the property on which tissue culture rests; it does not by itself explain *why* conventional breeding falls short of the demand. Hence R is not the correct explanation of A.

Marking Scheme 1 mark for the correct option together with the answer text.

Section B

Questions 17 to 21 • 2 marks each • 10 marks

Question 17 — 2 Marks

A. Geitonogamy can be compared with cross-pollination as well as self-pollination. Comment.

OR

B. Mohit wants to produce hybrid seeds in a plant in his field in which male and female flowers mature at the same time and are close together. Suggest one strategy to promote only desired cross pollination and justify your answer.

Answer and Solution — A

- Geitonogamy involves the transfer of pollen grains from the anther to the stigma of **another flower of the same plant**. (1)
- Although geitonogamy is **functionally cross-pollination** — it requires a pollinating agent — **genetically it is similar to autogamy**, since the pollen grains come from the same plant and produce no genetic variation. (1)

Answer and Solution — B

- Mohit can **emasculate** (remove the anthers / remove the male flowers) from the selected plant before pollen is released, and then manually pollinate the bagged female flowers with pollen from the chosen male parent. (1)

- This prevents self-pollination and the arrival of unwanted pollen, so only the desired cross produces seeds. (1)

Marking Scheme 1 + 1 = **2 marks**. Only one alternative is to be attempted.

Question 18 — 2 Marks

The movement of landmasses over geological time changed the distribution and evolution of animals. Explain this idea using two examples from different regions of the world.

Answer and Solution

- **South America** once had mammals resembling the horse, hippopotamus, bear and rabbit. Due to continental drift, when South America joined North America, these animals were overridden by the North American fauna. (1)
- **Australia** — due to continental drift a number of Australian marsupials, each different from the other, evolved from an ancestral stock within the Australian island continent. These pouched mammals survived because of the lack of competition from any other mammals. (1)

Marking Scheme 1 mark for each correctly explained example = **2 marks**.

Question 19 — 2 Marks

The following is a realistic example dataset and not a real world patient dataset:

Sample ID	Tumor size (mm ³)	Glucose level mM/litre	Oxygen level (mmHg)	Neighbouring cell's viability / vitality (%)
1	150	2.0	15	60
2	50	4.5	30	85
3	200	1.3	10	50
4	100	3.0	20	70
5	250	0.9	7	40

- Interpret the relationship between tumor size and glucose level.
- Evaluate the data to determine how tumor progression may affect the viability / vitality of neighbouring cells. Provide a brief explanation.

Answer and Solution

- As tumor size increases, the glucose level decreases (4.5 → 0.9 mM/litre as size rises from 50 to 250 mm³). This suggests that larger tumors consume more glucose because of their higher metabolic demand, possibly indicating a more aggressive growth pattern. (1)
- As tumor size increases, the viability of neighbouring cells decreases (85% → 40%). The growing tumor creates a hostile microenvironment: it competes for nutrients and less oxygen remains available (30 → 7 mmHg), so the surrounding normal cells are starved and stressed and many die. (1)

Marking Scheme 1 mark for each correctly interpreted subpart, with reference to the data = **2 marks**.

Question 20 — 2 Marks

A. The table below shows hypothetical data comparing α-lactalbumin concentration in three types of milk, including that of Rosie, a transgenic cow designed to express human milk proteins.

Source of Milk	α-lactalbumin content approximately (g/L)
Normal cow's milk	0.1
Rosie cow's milk	2.4
Human milk	3.5

- Assuming all other nutritional components are identical, which milk would provide the lowest nutritional contribution from α-lactalbumin?

II. If further genetic modification increases α -lactalbumin levels in Rosie to 3.5 g/L, predict one ethical concern that might arise from such a development.

OR

B. A farmer replaces the GM crop with a conventional variety. Predict any two challenges she/he may face. Support your answer with two reasons.

Answer and Solution — A

I. Normal cow's milk (~0.1 g/L) provides the lowest contribution, since its α -lactalbumin content is about 35 times lower than that of human milk. **(1)**

II. Any one ethical concern — (1)

- Genetic modification of organisms beyond a point raises moral questions and may have long-term unpredictable consequences.
- Patenting of such transgenic animals and of the resource they produce.
- Loss of genetic diversity among natural cattle breeds.
- Economic exploitation of farmers and of the animals used as living bioreactors.

Answer and Solution — B

Any **two** challenges with reasons — **(1 + 1)**

- Increased pesticide use, because the conventional variety lacks the introduced pest-resistance gene.
- Lower yield under abiotic stress conditions, because the conventional variety lacks engineered tolerance to drought, cold or salinity.
- Faster depletion of soil nutrients, because of less efficient mineral usage by the conventional variety.

Marking Scheme **A** — I: 1 mark; II: 1 mark for any one valid ethical concern. **B** — 1 + 1 for any two challenges with reasons. **Total 2 marks.**

Question 21 — 2 Marks

A. The table below is hypothetical data on seasonal temperatures seen over two different zones:

Region	Temp. in Spring (°C)	Temp. in Summer (°C)	Temp. in Autumn (°C)	Temp. in Winter (°C)	Primary Productivity (GPP) (g/m ² /year)	Respiration (R) (g/m ² /year)
Region X	27	28	27	26	3500	1300
Region Y	12	20	14	4	2000	800

I. Justify which region will have greater species diversity based on the given data.

II. Calculate the net primary productivity (NPP) of the region mentioned in (I) and give its significance.

OR

B. Following is hypothetical data on plant–pollinator interaction:

Plant	Main Pollinator	Seed set (%) with pollinator	Seed set (%) without pollinator
P1	H1 (Bee)	80	40
P2	H2 (Butterfly)	75	45
P3	H3 (Moth)	85	35

I. From the data above, justify which plant shows the highest dependence on its main pollinator.

II. What kind of ecological interaction is shown in the table above? Define it in one sentence.

Answer and Solution — A

I. Region X (a tropical region) will have greater species diversity. Its temperature is near-constant across the seasons (27 – 28 – 27 – 26 °C), and such stable, non-seasonal conditions promote niche specialisation;

Region X also has the higher productivity (GPP 3500 against 2000 g/m²/year), so more energy is available to support more species. (1)

II. NPP of Region X = GPP – R = 3500 – 1300 = **2200 g/m²/year**. Significance: net primary productivity is the biomass actually **available for consumption by the heterotrophs** (herbivores and decomposers), and it therefore fixes the energy that can pass to the higher trophic levels. (1)

Answer and Solution — B

I. P3 shows the highest dependence — its seed set falls by **50 percentage points** (85% → 35%) in the absence of its main pollinator, the largest drop of the three (P1 falls by 40 and P2 by 30 percentage points). (1)

II. The interaction is **mutualism** — an interaction in which **both** the interacting species benefit; here the plant gains pollination and the pollinator obtains nectar or pollen as food. (1)

Marking Scheme 1 + 1 = **2 marks**. Only one alternative is to be attempted.

Section C

Questions 22 to 28 • 3 marks each • 21 marks

Question 22 — 3 Marks

A couple, A and B, visit a fertility clinic. Examination reveals that female A has a blockage in her fallopian tubes, but her ovaries can produce viable ova. Male B produces sperm with a very low sperm count, making natural fertilization unlikely. Which two different Assisted Reproductive Technologies (ARTs) would a doctor most likely recommend for this couple to increase their chances of conceiving? Justify your selection by briefly stating the principle behind each chosen technique concerning the couple's specific issues.

Answer and Solution

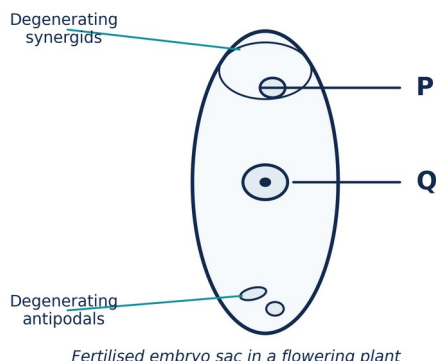
ART 1 — Intracytoplasmic Sperm Injection (ICSI). *Justification:* ICSI addresses Male B's very low sperm count. It is an advanced procedure in which the embryo is formed in vitro by injecting a single sperm directly into the ovum, so millions of sperm are no longer needed. (1.5)

ART 2 — In vitro fertilisation followed by Intra Uterine Transfer (IVF-IUT). *Justification:* This addresses Female A's blocked fallopian tubes. Since the natural path for the ovum and embryo is blocked, fertilisation is carried out outside the body and the embryo (with more than 8 blastomeres) is transferred directly into the uterus. (1.5)

Marking Scheme 1.5 + 1.5 = **3 marks** — each ART named and justified with its principle.

Question 23 — 3 Marks

In the post-fertilization embryo sac shown in the figure, structure 'P' results from the fusion of one male gamete with the egg cell, and structure 'Q' results from the fusion of the other male gamete with the polar nuclei.



- Identify structure 'P' and structure 'Q' and state their ploidy.
- Evaluate the following statement: "The division of 'P' always precedes the division of 'Q'." Justify your evaluation based on the nutritional requirements for seed development.
- Which characteristic feature of endosperm helps in its nutritive role?

For visually impaired students — A. Which two products are formed after double fertilization in the embryo sac of a flowering plant? B. State the ploidy of these two structures. C. Which of these two structures develops first during embryonic development? State its significance.

Answer and Solution

A. Structure P is the zygote (oospore) and is diploid (2n); structure Q is the primary endosperm nucleus (PEN) and is triploid (3n). (1)

B. The statement is false. The primary endosperm nucleus (Q) divides much earlier than the zygote (P) and forms the endosperm tissue, so that ready-made nutrition is already available when the embryo begins to grow. **(1)**

C. The cells of the endosperm tissue are filled with reserve food materials (starch, proteins and oils), which act as the primary source of nutrition for the developing embryo. **(1)**

Answer and Solution — visually impaired version

A. Zygote / embryo and primary endosperm nucleus / endosperm. (1)

B. The zygote / embryo is diploid and the primary endosperm nucleus / endosperm is triploid. (1)

C. The primary endosperm nucleus divides much earlier than the zygote and forms the endosperm tissue, whose cells are filled with reserve food that nourishes the developing embryo. (1)

Marking Scheme 1 mark for each subpart = **3 marks.**

Question 24 — 3 Marks

In mice, the traits for running ability and hair colour assort independently. Running (R) is dominant over walking in circles (r). Black hair (B) is dominant over brown hair (b). A heterozygous running, brown-haired female mouse was artificially inseminated using sperm from a heterozygous running, heterozygous black male.

A. Write the genotypes of both parents and draw a Punnett square showing all possible offspring combinations. (1)

B. Using the Punnett square, state the phenotypic ratio for: Running–Black, Running–Brown, Walking–Black, Walking–Brown. (1)

C. If 64 offspring were produced, calculate how many would be expected to show the Running–Black phenotype. (1)

Answer and Solution — A

Female: heterozygous for running (Rr) and brown-haired (bb, since brown is recessive) → **Rrbb**. **Male:** heterozygous for running (Rr) and heterozygous black (Bb) → **RrBb**.

Gametes — female (Rrbb): Rb, Rb, rb, rb | male (RrBb): RB, Rb, rB, rb

♀ ↓ ♂ —	RB	Rb	rB	rb
Rb	RRBb	RRbb	RrBb	Rrbb
Rb	RRBb	RRbb	RrBb	Rrbb
rb	RrBb	Rrbb	rrBb	rrbb
rb	RrBb	Rrbb	rrBb	rrbb

Answer and Solution — B

Phenotype	Genotypes in the square	Number out of 16
Running – Black	RRBb × 2, RrBb × 4	6
Running – Brown	RRbb × 2, Rrbb × 4	6
Walking – Black	rrBb × 2	2
Walking – Brown	rrbb × 2	2

Ratio = 6 : 6 : 2 : 2, i.e. 3 : 3 : 1 : 1. (1)

Answer and Solution — C

Fraction of Running-Black offspring = $6/16 = 3/8$. Expected number = $(3/8) \times 64 = \mathbf{24 \text{ offspring}}$. (1)

Marking Scheme Genotypes with Punnett square — 1 mark; phenotypic ratio — 1 mark; calculation — 1 mark. **Total 3 marks.**

Question 25 — 3 Marks

How can a single gene defect caused by the mutation result in Phenylketonuria (PKU)? Explain the molecular mechanism underlying pleiotropy.

Answer and Solution

- The disease is caused by a **single gene mutation** resulting in an **inborn error of metabolism**: the affected individual lacks the enzyme **phenylalanine hydroxylase**, which converts the amino acid phenylalanine into tyrosine. (1)
- As a result phenylalanine **accumulates** and is converted into **phenylpyruvic acid** and other derivatives; accumulation of these in the brain results in **mental retardation**, and the failure to form tyrosine also reduces melanin and therefore skin and hair pigmentation. (1)
- In **pleiotropy** a single gene exhibits multiple phenotypic expressions by affecting **different metabolic pathways** — one enzyme block produces several apparently unrelated effects. (1)

Marking Scheme 1 + 1 + 1 = **3 marks.**

Question 26 — 3 Marks

Drug-use disorders often begin with occasional consumption but may progress into a compulsive state. Analyse how addiction differs from dependence in both origin and consequence, and justify why long-term drug intake forces the user to increase dose over time.

Answer and Solution

- **Addiction** — a **psychological** attachment to the effects of drugs and alcohol ($1/2$), driven by the desire for euphoria and a feeling of well-being even when there is **no** real physiological need ($1/2$). (1)
- **Dependence** — a **physical** tendency of the body; it manifests as a characteristic **withdrawal syndrome** (anxiety, shakiness, nausea, sweating) when the drug is stopped, so the user continues the drug to escape withdrawal rather than for pleasure. (1)
- **Reason for increased intake (tolerance)** — repeated drug use raises the **tolerance** level of the body's receptors, which then respond only to higher doses to give the same effect; the dose must therefore be increased over time. (1)

Marking Scheme 1 + 1 + 1 = **3 marks.**

Question 27 — 3 Marks

Pathogens are often considered harmful, yet they have been adapted as powerful tools in genetic engineering. Explain how pathogens have been modified into useful vectors. Describe the role of a similarly modified plant vector and animal vector.

Answer and Solution

- Certain pathogens naturally have the ability to **transfer their DNA into host cells**. Scientists have modified these pathogens by **removing their disease-causing genes** while retaining their ability to deliver DNA, making them useful cloning vectors. (1)
- **Animal vector** — in animals, **retroviruses** have been engineered to remove the cancer-causing genes while keeping their capacity to integrate DNA into the host genome, making them effective vectors for gene delivery (as in gene therapy). (1)
- **Plant vector** — in transgenic plants, nematode-specific genes were introduced via the **Ti plasmid of *Agrobacterium tumefaciens*** to produce dsRNA, which triggered **RNA interference (RNAi)** and silenced the nematode mRNA, protecting the plant from the parasite. (1)

Marking Scheme 1 + 1 + 1 = **3 marks.**

Question 28 — 3 Marks

The nematode *Myrmeconema neotropicum* lives inside the abdomen of certain tropical ants (*Cephalotes atratus*). Inside the ant's body, the nematode develops slowly without killing it. Once mature, it changes the colour of the ant's abdomen to bright red, making it resemble a berry. Birds, mistaking it for a fruit, eat the ant. The nematode's eggs survive in the bird's digestive system and pass out in droppings, which other ants contact while foraging, starting the cycle again.

- Why would harming the ant too early be disadvantageous for the nematode? (1)
- How is natural selection playing a vital role in maintaining this interaction? (1)
- What kind of ecological interaction is seen between nematode and ant? Define it in one sentence. (1)

Answer and Solution

- If the ant dies too soon, the nematode will not complete its development and will not be transmitted to new hosts — the life cycle is broken and the parasite dies with its host. (1)
- Natural selection favours those nematodes that keep the ant alive until it can be eaten by a bird, ensuring better dispersal and survival of the nematode. Since the birds eat only the red-bellied ants, this also ensures complete maturation of the nematode before dispersal and protects the other ants from predation. (1)
- Parasitism** — an interaction in which one organism (the parasite) benefits at the cost of the other (the host), which is harmed. (1)

Marking Scheme 1 mark for each subpart = **3 marks**.

Section D

Questions 29 and 30 • case-based • 4 marks each • 8 marks

Question 29 — 4 Marks

Madhuri, a 17-year-old girl, has been experiencing irregular periods for the past one year. Sometimes her cycles are as short as 20 days and sometimes as long as 45 days. She occasionally has very heavy bleeding that lasts over a week, causing fatigue and weakness. A doctor reviews her menstrual diary and explains that these changes can be linked to hormonal fluctuations in the hypothalamic-pituitary-ovarian (HPO) axis. He shows Madhuri the lack of a clear ovulation peak and low progesterone levels in her recent cycles.

- Madhuri experiences heavy bleeding lasting over a week causing fatigue. What possible complication could arise from this condition? (1)
- Examine how the absence of a distinct LH (luteinizing hormone) surge in the menstrual cycle might explain both the irregularity and heaviness of Madhuri's periods. (2)

Attempt either subpart C or D.

- Madhuri's cycles vary between 20 and 45 days. What might this irregularity indicate about her ovarian function? (1)
- If a doctor suspects hypothalamic-pituitary dysfunction in Madhuri, which hormone secretion pattern would you expect to be disrupted? (1)

Answer and Solution

- Anaemia** due to excessive blood loss — chronic loss of iron produces fatigue, weakness, pallor and breathlessness. (1)
- Without a distinct LH surge, **ovulation may not occur**, so no corpus luteum forms and **progesterone is not secreted** — which is why her progesterone is low. As a result the endometrial lining goes on growing excessively under **unopposed oestrogen** and is then shed unpredictably and heavily, causing both the irregularity and the heaviness of her periods. (2)
- It suggests a **lack of ovulation** due to hormonal imbalance affecting ovarian function — the ovary is not maturing and releasing a follicle at a regular interval. (1)
- The **pulsatile secretion of GnRH** from the hypothalamus, and consequently the secretion of **LH and FSH** from the anterior pituitary, would be disrupted. (1)

Marking Scheme A — 1 mark; B — 2 marks; C or D — 1 mark. **Total 4 marks.** Only one of C and D is to be attempted.

Question 30 — 4 Marks

A tribal farmer is cultivating *Brassica oleracea* (cabbage) in a forest region rich in pollinators and rare butterflies. Recently his crops have been heavily damaged by cabbage looper caterpillars. To manage the pest outbreak he applies Nucleopolyhedrovirus (NPV). After a few weeks the pest population decreases significantly without affecting other insects or animals in the area.

- A. Justify with reasons why the use of Nucleopolyhedrovirus (NPV) was a suitable choice for controlling cabbage looper caterpillars. (1)
 B. Suggest another IPM strategy suitable for controlling caterpillar pests, and briefly describe its mode of action. (2)

Attempt either subpart C or D.

- C. Name the group of pathogens to which Nucleopolyhedrovirus belongs. (1)
 D. Justify why the use of NPV is considered a biocontrol method. (1)

Answer and Solution

- A.** NPV is **species-specific** and affects only the target insect pest — it is a narrow-spectrum insecticide and causes no harm to plants, pollinators, mammals, birds, fish or non-target insects, which makes it ideal in an ecologically sensitive forest region. (1)
B. He could have sprayed the **spores of *Bacillus thuringiensis* (Bt)**. The spores are eaten by the caterpillar along with the leaf; in the **alkaline gut of the larva** the inactive Cry protoxin crystal is solubilised and activated, the toxin binds to the midgut epithelial cells and creates pores, the cells swell and lyse, and the larva stops feeding and dies. (2)
C. Baculovirus (family Baculoviridae) — pathogens that attack insects and other arthropods. (1)
D. Because a **living biological agent** is being used to control a pest population instead of a chemical pesticide; it is species-specific, spares natural enemies and pollinators, leaves no toxic residue and maintains the ecological balance. (1)

Marking Scheme A — 1 mark; B — 2 marks; C or D — 1 mark. **Total 4 marks.** Only one of C and D is to be attempted.

Section E

Questions 31 to 33 • 5 marks each • 15 marks

Question 31 — 5 Marks

A. A short stretch of DNA strand that codes for a polypeptide is shown below:

3' –TACAAAAAGAAGAAAAAGAAGATT – 5'

Due to exposure to harmful UV radiation two different types of errors occurred during DNA replication affecting their sequences of bases in the DNA in two different cells.

- I. What is the term given to a segment of DNA that codes for a polypeptide?
 II. Which type of mutation could have occurred in each of the following due to the error during replication?

- a) 3' – TACAAAAAGAAGAAAAAGAAATT – 5'
 b) 3' – TACAAAAAGAAGAAAAAGAGATT – 5'

III. If DNA strand (a) codes for Methionine and sequences of Phenylalanine, mention the sequence of amino acids that will constitute the polypeptide chain after translation. How many amino acids will be translated from this strand?

IV. If all the codons of the stretch code for Phenylalanine excluding the initiator codon, which feature does it depict?

OR

B.

I. If GUA is an intron, how many amino acids will be translated from the mature or processed RNA? Pick out the untranslated region from the following messenger RNA and mention their location and sequence. What is its significance?

5' ACGUCG AUGACCGUAGCGUUUGUAUCUUUAGUAGUGGUAUUAGUAGGC UAAAAA 3'

II. If AAA is the anticodon of phenylalanine, draw the tRNA adaptor molecule. Mention the position of amino acid Phenylalanine in the sequence of polypeptide counting the triplet codons.

Answer and Solution — A

I. The term given to a segment of DNA that codes for a polypeptide is **cistron**. (0.5)

II. (a) 3' - - TACAAAAAGAAGAAAAAGAAAATT - - 5' — the strand is still 24 bases long and only one base has been replaced, so this is a **point mutation (substitution)**. (1)

(b) 3' - - TACAAAAAGAAGAAAAAGAGATT - - 5' — the strand is now 23 bases long, so one base has been **deleted** and every triplet after that point is read in a wrong grouping: a **frameshift mutation due to deletion**. (1)

III. Reading strand (a) as a template gives the mRNA AUG UUU UUC UUC UUU UUC UUU UAA:

DNA template (3'→5')	TAC	AAA	AAG	AAG	AAA	AAG	AAA	ATT
mRNA codon (5'→3')	AUG	UUU	UUC	UUC	UUU	UUC	UUU	UAA
Amino acid	Met	Phe	Phe	Phe	Phe	Phe	Phe	Stop

Polypeptide: **Methionine – Phenylalanine – Phenylalanine – Phenylalanine – Phenylalanine – Phenylalanine – Phenylalanine**. UAA is a stop codon and codes for no amino acid, so **7 amino acids** are translated. (2)

IV. It depicts the **degeneracy** of the genetic code — both UUU and UUC specify the same amino acid, phenylalanine. (0.5)

Answer and Solution — B

I. Reading from the initiation codon AUG, the coding region is

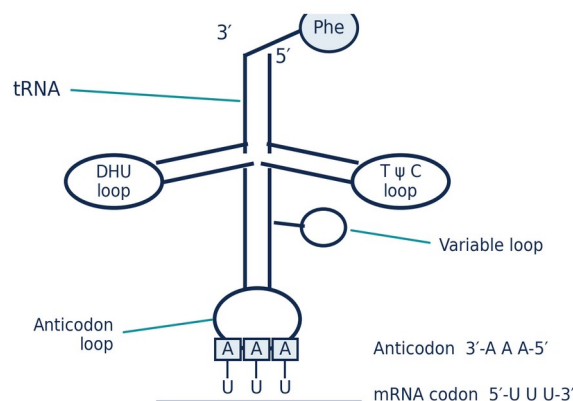
AUG ACC GUA GCG UUU GUA UCU UUA GUA GUG GUA UUA GUA GGC

The **five GUA codons are introns** and are removed during processing, leaving AUG · ACC · GCG · UUU · UCU · UUA · GUG · UUA · GGC. Hence **nine amino acids** will be translated from the mature RNA. (1)

The **untranslated regions (UTRs)** are 5' ACGUCG ----- UAAAAA 3' — located at the **5' end, before the start codon AUG**, with the sequence ACGUCG, and at the **3' end, after the coding sequence**, with the sequence UAAAAA (the stop codon UAA is itself not translated into an amino acid). (2)

Significance: the UTRs are not translated into protein but are **required for efficient translation** — the 5' UTR for correct initiation and ribosome binding, the 3' UTR for efficient termination and for the stability of the mRNA. (0.5)

II. Draw a neat labelled clover-leaf model of the tRNA adaptor molecule with the anticodon 3'-AAA-5':



The anticodon AAA pairs with the mRNA codon UUU, which is the **4th triplet codon** of the processed mRNA (AUG · ACC · GCG · **UUU** ...). Phenylalanine therefore occupies the **4th position** in the polypeptide chain. **(1 + 0.5)**

Marking Scheme **A** — I: 0.5; II: 1 + 1; III: 2; IV: 0.5 = 5 marks. **B** — I: 1 (number of amino acids) + 2 (UTRs with location and sequence) + 0.5 (significance); II: 1 (labelled diagram) + 0.5 (position of phenylalanine) = 5 marks. Only one alternative is to be attempted.

Question 32 — 5 Marks

A. A scientist is screening bacterial transformants engineered with DNA fragments of the β -globin gene. A radioactive DNA probe complementary to the normal β -globin sequence is used. After autoradiography:

- Plates A and C show strong and weak radioactive signals respectively.
- Plate B shows no radioactivity.

Answer the following:

- Why does plate B fail to show radioactivity, while A and C do? **(2)**
- How can this experiment help in distinguishing a normal individual, a carrier, and a patient of sickle cell anaemia? **(2)**
- Name one other commonly used technique (apart from autoradiography) to differentiate recombinants from non-recombinants. **(1)**

OR

B. A student placed DNA from three different sources — bacteria, plant tissue, and fungal cells — in test tubes A, B and C respectively. During the process of isolating and purifying DNA, the student added cellulase to all test tubes.

- Predict and explain in which trial(s) DNA isolation would fail, and why. Also suggest how it could be corrected. **(2)**
- After rectifying the mistake, outline the steps to obtain visible spooled DNA from the sample. **(2)**
- Suggest one application of the spooled DNA in biotechnology. **(1)**

Answer and Solution — A

I. Plate B fails to show radioactivity because the probe **could not hybridise** with the DNA on that plate, indicating the presence of the **mutated β -globin gene** (the sickle mutation). Plates A and C do show signals because their DNA carries the normal sequence complementary to the probe — fully in A, and only partly in C, which is why C's signal is weak. **(2)**

II. Distinguishing the three genotypes **(2)**

Individual	Genotype	Result with the normal-sequence probe
Normal individual	HbA HbA	Probe binds fully → strong radioactivity observed
Carrier (heterozygote)	HbA HbS	Both normal and mutated sequences present → partial hybridisation (mixed / weak pattern)
Patient (homozygous mutant)	HbS HbS	No hybridisation with the probe → no radioactivity seen

III. Insertional inactivation of a selectable marker — for example, insertion within the lacZ gene, so that recombinant colonies appear white and non-recombinants blue on a chromogenic substrate. **(1)**

Answer and Solution — B

I. Where the isolation fails, and the correction **(2)**

Test tube	Source	Cell wall material	Result with cellulase	Correction
A	Bacteria	Peptidoglycan	Isolation fails	Use lysozyme
B	Plant tissue	Cellulose	Succeeds	No change needed
C	Fungal cells	Chitin	Isolation fails	Use chitinase

II. Steps to obtain visible spooled DNA (2)

- **Break open the cells** with the appropriate enzyme — DNA is released along with RNA, proteins, polysaccharides and lipids.
- **Remove the contaminants:** ribonuclease (RNase) digests the RNA and protease digests the proteins; polysaccharides and lipids are removed by other specific treatments.
- **Add chilled ethanol** to the purified solution — the DNA precipitates out as a fine collection of **white threads**, which can be **spooled** on to a glass rod.

III. The spooled DNA can be used in **genetic engineering** (restriction digestion and cloning), **PCR amplification**, **DNA fingerprinting**, or **DNA sequencing**. (1)

Marking Scheme Both alternatives: I — 2 marks; II — 2 marks; III — 1 mark = **5 marks**. Only one alternative is to be attempted.

Question 33 — 5 Marks

A. A Green Valley X, home to rare medicinal plants and several migratory bird species, is facing multiple environmental challenges.

- A luxury brand of cosmetics with little regulation has been sourcing wild medicinal plants from the valley.
 - The company has introduced an ornamental grass species from another country, which has taken over large areas of native grassland.
 - There is also a reported drastic decline in the endemic trees.
 - Large scale forest fire in a part of the valley.
- From the above hypothetical case, identify and explain the four major biodiversity threats. (4)
 - Suggest one in-situ conservation practice that could help protect the biodiversity of Green Valley X, and justify your choice. (1)

OR

B. At a composting ground, after a community clean-up drive, large amounts of vegetable peels, garden leaves, and other organic waste are piled up. Over the next few weeks the volume of the waste decreases noticeably.

- Explain the sequence of processes that could have led to this transformation, and name the major organisms involved at each step. (4)
- If a prolonged dry spell occurs during this composting period, explain how it could affect the rate of the above processes. (1)

Answer and Solution — A (a) The Evil Quartet (4 × 1)

Situation in the valley	Threat	Explanation
I. Unregulated sourcing of wild medicinal plants	Over-exploitation	Humans harvest a natural resource far faster than it can replenish itself; when exploitation is driven by commercial gain the species declines steeply and may be driven to extinction.
II. Introduced ornamental grass taking over native grassland	Alien species invasion	An exotic species introduced deliberately or accidentally may turn invasive, out-compete the indigenous species for space, light and nutrients and cause their decline — as with <i>Parthenium</i> , <i>Lantana</i> and water hyacinth in India.
III. Drastic decline in the endemic trees	Co-extinction	When a species is lost, the plants and animals associated with it in an obligatory way also disappear — the specialised pollinators, epiphytes, insects and birds dependent on these endemic trees are wiped out with them.
IV. Large-scale forest fire	Habitat loss and fragmentation	The most important cause of extinction. Fire destroys the habitat outright and breaks the remainder into small isolated patches; species needing large territories and migratory animals are badly affected.

(b) Declare Green Valley X a **protected area** — a wildlife sanctuary / national park / biosphere reserve (a sacred grove or hotspot designation is equally acceptable). *Justification:* in-situ conservation maintains the species **in their natural habitat**, preserves the ecological interactions between them and allows long-term protection of genetic, species and ecosystem diversity. **(1)**

Answer and Solution — B (I) Decomposition (4)

Step	Process	Major organisms / agent
1	Fragmentation — the detritus is broken into smaller particles, greatly increasing its surface area	Detritivores — earthworms, millipedes, woodlice, mites, insect larvae
2	Leaching — water-soluble inorganic nutrients percolate into the soil and are precipitated as unavailable salts	A physical process brought about by percolating water
3	Catabolism — extracellular enzymes degrade the detritus into simpler inorganic substances	Bacteria and fungi (the decomposers)
4	Humification — accumulation of dark-coloured, amorphous, highly resistant humus , which decomposes slowly and acts as a nutrient reservoir	Chiefly fungi, aided by bacteria
5	Mineralisation — the humus is further degraded and inorganic nutrients are released into the soil	Some microbes — bacteria and fungi

These processes go on **simultaneously** in the heap and together convert the bulky organic waste into a small volume of dark, nutrient-rich compost.

(II) A dry spell would lower the moisture content, slowing microbial activity and enzymatic breakdown, and leaching would stop altogether; the **rate of decomposition therefore falls** and the reduction in waste volume is delayed. **(1)**

Marking Scheme A — (a) 4 × 1 mark for the four threats identified and explained; (b) 1 mark for the in-situ practice with justification. **B** — I: 4 marks for the sequence of processes with the organisms; II: 1 mark. **Total 5 marks.** Only one alternative is to be attempted.