Biology

HSC Board Exam February–March 2027 – Practice Paper

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.1 Select and write the correct answer for the following multiple choice type of questions. **[10]**

(i) The flowers of a tree are dull coloured, have a strong fragrance, secrete abundant nectar and produce a large amount of edible pollen grains. These flowers are most likely pollinated by _____.

(a) insects (b) birds
(c) bats (d) wind

Answer (1 mark)
(c) bats
These are adaptations of chiropterophilous (bat-pollinated) flowers, e.g. kadamb (*Anthocephalus*) and baobab (*Adansonia*). Bird-pollinated flowers are brightly coloured (birds have a poor sense of smell), insect-pollinated flowers are large and showy, and wind-pollinated flowers lack nectar and fragrance.

(ii) In birds, the sex of the offspring is decided by the _____.

(a) sperm, because the male is heterogametic (ZW) (b) egg, because the female is heterogametic (ZW)
(c) sperm, because the male is XY (d) temperature at which the egg is incubated

Answer (1 mark)
(b) egg, because the female is heterogametic (ZW)
In birds sex determination is of the ZW–ZZ type: the male is ZZ (homogametic) and forms only Z sperms, while the female is ZW and forms two types of eggs (50% Z, 50% W). An egg with Z gives a male (ZZ) and an egg with W gives a female (ZW).

(iii) During DNA replication, the short Okazaki fragments formed on the lagging strand are joined together by the enzyme _____.

(a) helicase (b) primase
(c) DNA ligase (d) topoisomerase

Answer (1 mark)
(c) DNA ligase
DNA ligase seals the gaps between adjacent Okazaki fragments by forming phosphodiester bonds.

(iv) In a root, water that moves only through the cell walls and intercellular spaces, without crossing any cell membrane, is said to follow the _____ pathway.

(a) symplast (b) apoplast
(c) transmembrane (d) vacuolar

Answer (1 mark)
(b) apoplast
The apoplast is the non-living continuum of cell walls and intercellular spaces.

(v) The valve that guards the opening between the left atrium and the left ventricle of the human heart is the _____.

(a) tricuspid valve
(b) bicuspid (mitral) valve
(c) pulmonary semilunar valve
(d) aortic semilunar valve

Answer (1 mark)
(b) bicuspid (mitral) valve
The tricuspid valve guards the right atrioventricular aperture; the pulmonary and aortic semilunar valves guard the openings of the pulmonary aorta and the aorta from the ventricles.

(vi) The salt-retaining hormone aldosterone is secreted by the _____.

(a) zona glomerulosa of the adrenal cortex
(b) zona fasciculata of the adrenal cortex
(c) adrenal medulla
(d) posterior pituitary

Answer (1 mark)
(a) zona glomerulosa of the adrenal cortex
The outer zona glomerulosa secretes mineralocorticoids, mainly aldosterone, which balances Na^+–K^+ levels. The zona fasciculata secretes glucocorticoids and the medulla secretes adrenaline and noradrenaline.

(vii) Dengue fever is transmitted from one person to another by the bite of the female _____ mosquito.

(a) *Anopheles*
(b) *Culex*
(c) *Aedes*
(d) *Musca*

Answer (1 mark)
(c) *Aedes*
The mosquito takes up the dengue virus while sucking the blood of a patient and passes it on to a healthy person. *Anopheles* transmits malaria, *Culex* transmits filariasis, and *Musca* is the housefly, not a mosquito.

(viii) The restriction enzyme *Eco*RI cuts the sequence 5′-GAATTC-3′ between G and A on both strands. The single-stranded sticky end left on each fragment has the bases _____.

(a) 5′-AATT-3′
(b) 5′-GAAT-3′
(c) 5′-TTAA-3′
(d) 5′-CTTAAG-3′

Answer (1 mark)
(a) 5′-AATT-3′
Top strand: 5′-G | AATTC-3′; bottom strand (read 5′→3′) is also GAATTC and is cut the same way. Each fragment therefore carries a 4-base single-stranded projection 5′-AATT-3′, which is self-complementary, so the ends are "sticky".

(ix) An interaction between two species in which one species is harmed while the other is neither benefited nor harmed is called _____.

(a) commensalism
(b) amensalism
(c) predation
(d) protocooperation

Answer (1 mark)
(b) amensalism
In amensalism one species is harmed whereas the other is unaffected (– , 0). In commensalism

one benefits and the other is unaffected (+ , 0); in predation one benefits and the other is harmed (+ , –); in protocooperation both benefit (+ , +).

(x) Which one of the following is an **ex-situ** method of conserving biodiversity?

(a) National park (b) Wildlife sanctuary

(c) Seed bank (d) Biosphere reserve

Answer (1 mark)
(c) Seed bank
Seeds are stored outside their natural habitat (ex-situ) under controlled conditions; national parks, wildlife sanctuaries and biosphere reserves protect organisms in their natural habitat (in-situ).

SECTION A – Q.2 Answer the following questions. **[8]**

(i) Name the hormone whose presence in urine is detected by a home pregnancy test kit.

Answer (1 mark)
Human chorionic gonadotropin (hCG), secreted by the trophoblast/placenta.

(ii) The flipper of a seal, the wing of a bat and the arm of a human have the same basic bone plan but perform different functions. Name the type of evolution indicated.

Answer (1 mark)
Divergent evolution (the forelimbs are homologous organs, showing adaptive radiation from a common ancestor).

(iii) Name the plant growth regulator whose effect of delaying senescence (ageing) of leaves was reported by Richmond and Lang (1957).

Answer (1 mark)
Cytokinin (the Richmond–Lang effect).

(iv) What is the normal blood pressure of a healthy adult human?

Answer (1 mark)
120/80 mm Hg (systolic 120 mm Hg / diastolic 80 mm Hg).

(v) Name the part of the human brain that acts as the thermoregulatory centre of the body.

Answer (1 mark)
Hypothalamus.

(vi) Name the bacterium that is inoculated into milk to prepare Indian curd.

Answer (1 mark)
Lactobacillus acidophilus (lactic acid bacteria). (*Lactobacillus* – full credit.)

(vii) Who proposed the ten percent law of energy transfer in a food chain?

Answer (1 mark)
R. Lindeman (1942) – spelt "R. Lindermann" in the textbook; either spelling gets the mark.

(viii) The karyotype of a short-statured female shows 45 chromosomes – 44 autosomes and a single X chromosome. Name the disorder.

Answer (1 mark)
Turner's syndrome (44 + XO), caused by non-disjunction of sex chromosomes.

SECTION B Attempt any EIGHT of the following questions. (2 marks each) **[16]**

Q.3 In a flower, the anthers shed pollen two days before the stigma of the same flower becomes receptive. Name this condition and explain how it favours cross-pollination. Give one example.

Answer (2 marks)

The condition is protandry (a type of dichogamy): the androecium matures before the gynoecium.

Since pollen is released before the stigma of the same flower is ready, self-pollination within the flower is prevented. By the time the stigma becomes receptive, its own pollen has already been shed, so it can receive pollen only from another flower – this promotes cross-pollination.

Example: disc florets of sunflower.

Marking: Name: protandry – ½ mark · Explanation – 1 mark · Example – ½ mark

Examiner tip: Do not confuse protandry (anthers first) with protogyny (stigma first).

Q.4 The human placenta is formed of tissues from two different individuals. (a) Name the foetal part and the maternal part of the placenta. (b) The placenta also acts as an endocrine tissue. Name any two hormones secreted by it and state why they are needed.

Answer (2 marks)

(a) Foetal placenta – formed by the chorionic villi of the embryo.

Maternal placenta – the part of the uterine wall (endometrium) rich in blood supply. (Hence the human placenta is called haemochorial.)

(b) Any two: human chorionic gonadotropin (hCG), progesterone, estrogen, human placental lactogen (HPL).

These hormones are needed for the growth of the foetus and for the maintenance of pregnancy.

Marking: Foetal part (chorionic villi) – ½ mark · Maternal part (uterine wall) – ½ mark · Two hormones – ½ mark · Need: foetal growth / maintenance of pregnancy – ½ mark

Examiner tip: Relaxin is not a correct answer here: the textbook says it is secreted by the ovary, not the placenta.

Q.5 In cattle, the alleles for red coat (R) and white coat (W) are co-dominant; the heterozygote (RW) is roan. A roan bull is crossed with a white cow. Work out the genotypes and phenotypes of the calves using a checkerboard and give the phenotypic ratio.

Answer (2 marks)

Parents: roan bull RW × white cow WW

Gametes: bull – R, W; cow – W

♂ \ ♀	**W**
R	RW (roan)
W	WW (white)

Calves: roan (RW) : white (WW) = 1 : 1. No red calves are produced. In co-dominance, both alleles are expressed in the heterozygote, so the genotypic and phenotypic ratios are the same.

Marking: Correct parental genotypes and gametes – ½ mark · Checkerboard – 1 mark · Phenotypic ratio 1 roan : 1 white – ½ mark

Examiner tip: The white cow gives only W gametes; a 1 : 2 : 1 ratio here is a common error.

Q.6 Explain why red-green colour blindness is seen far more often in men than in women.

Answer (2 marks)

The gene for colour blindness is recessive and located on the X chromosome (X-linked recessive); the Y chromosome has no corresponding allele.

A man (XY) has only one X chromosome, so a single recessive allele (X^cY) makes him colour blind (he is hemizygous).

A woman (XX) is colour blind only when both X chromosomes carry the recessive allele (X^cX^c), which is much rarer; X^CX^c is only a normal-visioned carrier.

Marking: X-linked recessive gene – ½ mark · Male hemizygous, one allele enough – 1 mark · Female needs two alleles / carrier – ½ mark

Examiner tip: Use the words 'X-linked recessive' and 'hemizygous'.

Q.7 Write the three stop codons of the genetic code. Why is AUG called the initiation codon?

Answer (2 marks)

Stop (termination / nonsense) codons: UAA, UAG and UGA. They do not code for any amino acid and signal the end of translation.

AUG is called the initiation (start) codon because translation of every mRNA begins at AUG; it codes for the amino acid methionine (formyl-methionine in prokaryotes), which is the first amino acid of the polypeptide.

Marking: Three stop codons – 1 mark · Reason for AUG – 1 mark

Examiner tip: Write codons in RNA letters (U, not T).

Q.8 A storm carries a few birds from a large mainland population to a distant island, where they start a new population. After many generations, the allele frequencies on the island are very different from those on the mainland. Name this phenomenon and explain why such change is more marked in small populations.

Answer (2 marks)

The phenomenon is genetic drift (Sewall Wright effect); here it is the founder effect, because the few birds that drifted to the island are the "founders" of the new population.

Genetic drift is a random (chance) change in allele frequency. The few founders carry only a small, chance sample of the alleles of the mainland gene pool, so some alleles are lost and others become more common by chance. In a small population, chance events (e.g. death of a few individuals before mating) change allele frequencies much more than in a large population.

Marking: Genetic drift / founder effect – 1 mark · Explanation (chance sample, small population) – 1 mark

Examiner tip: Do not call this natural selection: the change here is random, not due to better adaptation.

Q.9 Early in the morning, a gardener cuts the stem of a well-watered potted plant a few centimetres above the soil. After some time, xylem sap is seen oozing out of the cut stump. (a) Name and define the pressure responsible. (b) Could this pressure alone lift water to the top of a 40 m tall tree? Give a reason.

Answer (2 marks)

(a) Root pressure. It is the hydrostatic pressure developed in the living cells of the root cortex due to continuous absorption of water (an active, osmotic process), which forces water along with dissolved minerals into the xylem and upwards against gravity. The oozing of sap (exudation) from the cut stump is a proof of its existence.

(b) No. The value of root pressure is only about +1 to +2 bars, which can push water up to a height of only about 10–20 m; it is not applicable to plants taller than 20 m (and is almost zero in tall gymnosperm trees). Ascent of sap in tall trees is mainly due to transpiration pull (cohesion–tension).

Marking: Root pressure named – ½ mark · Definition – ½ mark · No, with reason (+1 to +2 bars / only 10–20 m) – 1 mark

Examiner tip: Quote the value of root pressure (+1 to +2 bars, enough for only 10–20 m) when explaining why it cannot lift water in tall trees.

Q.10 Plant P flowers only when it gets 15 hours of light and 9 hours of darkness each day. Plant Q flowers only when it gets 9 hours of light and 15 hours of darkness; Q fails to flower if its dark period is interrupted by a brief flash of light. Classify P and Q on the basis of photoperiod and explain the effect of the light flash on Q.

Answer (2 marks)

P is a long day plant (LDP) – it needs light longer than the critical photoperiod (e.g. wheat, radish).

Q is a short day plant (SDP) – it needs a long uninterrupted dark period (e.g. soybean, Chrysanthemum).

Effect of light flash: SDPs are really "long night plants". A brief flash of (red) light in the middle of the night breaks the critical dark period, which is perceived by the pigment phytochrome; the long dark period is no longer uninterrupted, so Q does not flower.

Marking: P – long day plant – ½ mark · Q – short day plant – ½ mark · Effect: interruption of critical dark period / phytochrome – 1 mark

Examiner tip: The dark period, not the light period, is critical for short day plants.

Q.11 After a heavy lunch, a person rests quietly in a chair. His heart rate slows down and digestion goes on actively. (a) Name the division of the autonomic nervous system that is now dominant and state its other name based on its origin. (b) State its effect on the (i) bronchi, (ii) peristalsis of the gut and (iii) pupil of the eye.

Answer (2 marks)

(a) Parasympathetic nervous system; it is also called the cranio-sacral outflow (branches of cranial nerves III, VII, IX, X and sacral spinal nerves).

(b) (i) Bronchi – constricts the bronchi.

(ii) Peristalsis – stimulates (accelerates) peristalsis.

(iii) Pupil – constricts the pupil.

(It also slows the heart beat and stimulates the flow of saliva and the release of bile.)

Marking: Parasympathetic, cranio-sacral outflow – ½ mark · Each correct effect – ½ mark (3 × ½)

Examiner tip: Do not confuse the two divisions: the sympathetic (thoraco-lumbar) system dilates the bronchi and pupil and inhibits peristalsis; the parasympathetic does the opposite.

Q.12 A farmer growing paddy wants to reduce the use of chemical nitrogen fertilizer. Suggest any two biofertilizers suitable for paddy fields and explain how each one helps the crop.

Answer (2 marks)

(Any two)

1. *Azolla*: a free-floating water fern; filaments of the cyanobacterium *Anabaena* live in its dorsal leaf lobes and fix atmospheric nitrogen. *Azolla* grown in the rice field enriches the water and soil with nitrogen.

2. Blue-green algae (cyanobacteria) such as *Anabaena* / *Nostoc*: fix nitrogen in their heterocysts and also secrete growth-promoting substances, organic acids and vitamins.

3. *Azotobacter*: a free-living, aerobic nitrogen-fixing bacterium associated with the roots of grasses; it is used as a biofertilizer for non-leguminous crops, especially rice, and also supplies antibiotics to the soil.

Benefit: they are cheap, pollution-free and increase soil fertility.

Marking: Each suitable biofertilizer – ½ mark (2 × ½) · How each helps (nitrogen fixation) – ½ mark each (2 × ½)

Examiner tip: *Rhizobium* forms nodules on legumes, not on paddy; it is not the best answer here.

Q.13 A child has severe combined immunodeficiency (SCID) caused by a defective gene in the bone-marrow cells. Doctors remove some of the child's bone-marrow cells, introduce a normal copy of the gene into them using a vector and return the cells to the child. (a) Name this method of gene delivery and this form of gene therapy. (b) Will the child's future children inherit the corrected gene? Give a reason.

Answer (2 marks)
(a) Method of delivery: ex vivo delivery (cells are taken out, the gene is introduced outside the body and the cells are returned).
Form of gene therapy: somatic cell gene therapy.
(b) No. Only somatic (bone-marrow) cells were modified; the germ cells (sperms/eggs) were not changed, so the corrected gene cannot pass to the next generation. (Only germ line gene therapy would be inherited.)
Marking: Ex vivo delivery – ½ mark · Somatic cell gene therapy – ½ mark · Not inherited, with reason – 1 mark
Examiner tip: Germ line gene therapy is not used in humans for technical and ethical reasons.

Q.14 What are biodiversity hotspots? Name any two hotspots that include parts of India.

Answer (2 marks)
Biodiversity hotspots are regions of the world with very high species richness and a high density of species (many of them endemic) which are under threat, so they need strategic protection. About 34 hotspots have been identified.
Indian hotspots (any two): Western Ghats, Eastern Himalaya, Indo-Burma region, Sundaland (Nicobar Islands).
Marking: Definition (high species richness, under threat) – 1 mark · Two hotspots – ½ mark each
Examiner tip: Both conditions – high endemism and habitat loss – must appear in the definition.

SECTION C Attempt any EIGHT of the following questions. (3 marks each) **[24]**

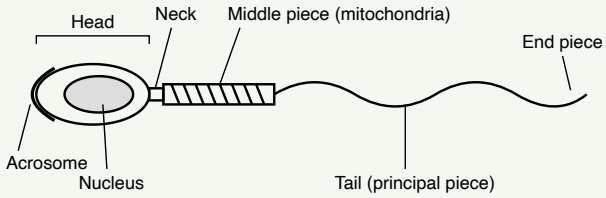
Q.15 A farmer sows seeds of a lemon tree. Many of the seeds each give rise to two or three seedlings, and all these seedlings are exactly like the mother tree. (a) Name this condition and explain how the extra embryos arise. (b) Why are these seedlings identical to the mother tree? (c) State one use of this to a fruit grower.

Answer (3 marks)
(a) The condition is polyembryony (presence of more than one embryo in a seed). In lemon (*Citrus*), some diploid cells of the nucellus (or integument) around the embryo sac develop directly into embryos without fertilization, besides the normal zygotic embryo. This is adventive embryony, a type of apomixis.
(b) These nucellar embryos arise from somatic (diploid) cells of the mother plant by mitosis, without meiosis and syngamy; so they have exactly the same genotype as the mother tree.
(c) Use: genetically identical (true-to-type) plants of a good variety can be produced effectively and rapidly; superior characters, including those of a hybrid, are kept without segregation.
Marking: Polyembryony and origin from nucellus (adventive embryony) – 1 mark · Reason: somatic cells, no meiosis/fertilization – 1 mark · One use – 1 mark
Examiner tip: Only the nucellar embryos are identical to the mother; the zygotic embryo is not.

Q.16 Draw a neat labelled diagram of a human sperm. Write the function of the acrosome and the middle piece.

Answer (3 marks)
Diagram: Human sperm showing head (acrosome, nucleus), neck, middle piece with mitochondria, tail and end piece.

Acrosome: contains hydrolytic enzymes (sperm lysins such as hyaluronidase) that dissolve the coverings of the ovum and help the sperm to enter it.
Middle piece: contains spirally arranged mitochondria that produce ATP (energy) for the movement of the tail (sperm motility).



Marking: Diagram with at least 5 correct labels – 2 marks · Functions of acrosome and middle piece – ½ mark each

Examiner tip: Show mitochondria as a spiral in the middle piece; unlabelled outlines get no credit.

Q.17 In a population of 4000 people in Hardy–Weinberg equilibrium, 360 are albino (aa), albinism being an autosomal recessive trait. Write the Hardy–Weinberg equation and calculate (a) the frequency of allele a, (b) the frequency of allele A and (c) the number of carriers (Aa) in the population.

Answer (3 marks)

Hardy–Weinberg equation: $p^2 + 2pq + q^2 = 1$, where $p + q = 1$ (p = frequency of A, q = frequency of a).

$q^2 = 360 / 4000 = 0.09$

(a) $q = \sqrt{0.09} = 0.3$

(b) $p = 1 - q = 1 - 0.3 = 0.7$

(c) Frequency of carriers $2pq = 2 \times 0.7 \times 0.3 = 0.42$

Number of carriers $= 0.42 \times 4000 = 1680$

(Check: AA $= p^2 \times 4000 = 0.49 \times 4000 = 1960$; $1960 + 1680 + 360 = 4000$.)

Marking: Equation – ½ mark · $q^2 = 0.09$ and $q = 0.3$ – 1 mark · $p = 0.7$ – ½ mark · $2pq = 0.42 \rightarrow 1680$ carriers – 1 mark

Examiner tip: 360/4000 is the frequency of the genotype aa (q^2), not of the allele.

Q.18 In the morning, the K^+ ion content of the guard cells of a leaf rises sharply and the stomata open. Explain this according to the proton transport (K^+ pump) theory of Levitt. What happens to the stomata at night?

Answer (3 marks)

1. During daytime, starch in the guard cells is converted into malic acid, which dissociates into malate and protons (H^+).
2. Protons are transported out to the subsidiary cells and, in exchange, K^+ ions are imported into the guard cells; K^+ uptake is accompanied by Cl^- ions.
3. Potassium malate is formed; this increases the osmolarity (solute concentration) of the guard cells, so water enters them by endosmosis and they become turgid.
4. Turgor pressure stretches the thin, elastic outer (lateral) walls, and the thick inner walls are pulled apart, so the stomatal pore opens.

At night: abscisic acid prevents the uptake of K^+ and Cl^-; water leaves by exosmosis, the guard cells become flaccid and the stoma closes.

Marking: Starch → malic acid, H^+ out and K^+ in – 1 mark · Potassium malate, endosmosis, turgidity, pore opens – 1½ marks · Night: ABA, flaccid, closure – ½ mark

Examiner tip: Mention the exchange of H^+ for K^+; just writing "K^+ enters" earns little.

Q.19 A farmer grows gram (a legume) in a field and then grows wheat in the same field the next season without adding urea. (a) Explain how the gram crop adds nitrogen to the soil and write the overall reaction of biological nitrogen fixation. (b) Name the two steps of nitrification by which ammonia in the soil is changed to nitrate, with the bacteria involved.

Answer (3 marks)

(a) The roots of gram (family Fabaceae) carry root nodules formed by the symbiotic bacterium *Rhizobium*. These bacteria fix atmospheric nitrogen into ammonia, which is converted into amino acids; when the roots and nodules decay, the nitrogen compounds enrich the soil for the next crop.

Reaction: $N_2 + 8H^+ + 8e^- + 16ATP \rightarrow 2NH_3 + H_2 + 16ADP + 16Pi$

(b) Nitrification:

Step 1 – ammonia is oxidised to nitrite by *Nitrosomonas* / *Nitrosococcus*: $2NH_3 + 3O_2 \rightarrow 2HNO_2 + 2H_2O$

Step 2 – nitrite is oxidised to nitrate by *Nitrobacter*: $2HNO_2 + O_2 \rightarrow 2HNO_3$

Marking: *Rhizobium* root nodules fix N_2, enrich soil – 1 mark · Balanced reaction (16 ATP) – 1 mark · Two steps with bacteria – ½ mark each

Examiner tip: Write 16 ATP for one molecule of N_2; many answers write 8 or 12.

Q.20 Explain how carbon dioxide is transported from the tissues to the lungs by blood.

Answer (3 marks)

CO_2 is carried in three forms:

1. Dissolved in plasma (about 7%): a small amount of CO_2 is carried in solution as carbonic acid ($CO_2 + H_2O \rightleftharpoons H_2CO_3$).

2. As carbaminohaemoglobin (about 23%): CO_2 combines with the amino groups of haemoglobin in RBCs ($Hb + CO_2 \rightarrow HbCO_2$).

3. As bicarbonate ions (about 70%): In RBCs, the zinc-containing enzyme carbonic anhydrase speeds up $CO_2 + H_2O \rightleftharpoons H_2CO_3 \rightleftharpoons H^+ + HCO_3^-$. H^+ is buffered by haemoglobin. HCO_3^- diffuses into the plasma and Cl^- ions move into the RBC to keep electrical neutrality (chloride shift / Hamburger's phenomenon).

In the lungs, where pCO_2 is low, these reactions are reversed and CO_2 is released into the alveoli.

Marking: Dissolved form (7%) – ½ mark · Carbaminohaemoglobin (23%) – 1 mark · Bicarbonate (70%) with carbonic anhydrase and chloride shift – 1½ marks

Examiner tip: Give the percentages and name the enzyme carbonic anhydrase.

Q.21 Describe the transmission of a nerve impulse across a chemical synapse.

Answer (3 marks)

1. When the nerve impulse (action potential) reaches the axon terminal (synaptic knob), voltage-gated Ca^{2+} channels open and Ca^{2+} ions enter the knob.

2. Ca^{2+} causes the synaptic vesicles to fuse with the pre-synaptic membrane and release the neurotransmitter (e.g. acetylcholine) into the synaptic cleft by exocytosis.

3. The neurotransmitter diffuses across the cleft and binds to specific receptors on the post-synaptic membrane, opening ligand-gated Na^+ channels.

4. Na^+ enters, the post-synaptic membrane depolarises and a new action potential is generated

in the next neuron.
5. The enzyme acetylcholinesterase then breaks down acetylcholine so that the membrane can repolarise and be ready for the next impulse. Transmission is one-way.

Marking: Ca^{2+} entry and release of neurotransmitter – 1 mark · Binding to receptors and depolarisation – 1 mark · Removal by acetylcholinesterase – 1 mark

Examiner tip: Name the neurotransmitter and the enzyme that destroys it.

Q.22 A pathologist examines two tumours. Tumour X is enclosed in a connective tissue capsule and grows slowly at its site of origin. Cells of tumour Y grow rapidly and are also found in lymph nodes far away from the original site. (a) Identify X and Y and name the process seen in Y. (b) Name the type of cancer that arises from (i) epithelial tissue and (ii) connective tissue. (c) How does immunotherapy help a cancer patient?

Answer (3 marks)

(a) X – benign (non-malignant) tumour; Y – malignant tumour (cancer). The spread of cancer cells through blood or lymph to form secondary tumours at distant sites is called metastasis.
(b) (i) Carcinoma (e.g. breast, lung, skin cancer). (ii) Sarcoma (e.g. osteosarcoma of bone).
(c) Tumour cells avoid detection and destruction by the immune system. In immunotherapy the patient is given biological response modifiers such as α-interferon, which activate the immune system and help it to destroy the tumour.

Marking: X benign, Y malignant – ½ mark; metastasis – ½ mark · Carcinoma and sarcoma – ½ mark each · Immunotherapy (α-interferon activates immune system) – 1 mark

Examiner tip: Benign tumours can still be harmful (e.g. brain tumour); the key difference is metastasis.

Q.23 What is micropropagation? Write the main steps involved in it and any two advantages.

Answer (3 marks)

Micropropagation (clonal propagation) is the rapid multiplication of a large number of genetically identical plants from a small plant part (explant) by plant tissue culture.
Steps: (1) A small explant (shoot tip, leaf piece) is taken from the mother plant and surface-sterilised (e.g. 20% ethyl alcohol, 0.1% $HgCl_2$). (2) It is inoculated under aseptic conditions (laminar air flow) on a sterilised nutrient medium (e.g. MS medium) containing minerals, sugar, vitamins, growth hormones and agar. (3) The cells divide to form an undifferentiated mass, the callus. (4) By changing the auxin : cytokinin ratio, the callus forms shoots (caulogenesis) and roots (rhizogenesis) – organogenesis – giving plantlets. (5) Plantlets are hardened and transferred to the field.
Advantages (any two): rapid multiplication; a large number of plantlets in a short time and small space; plants obtained throughout the year independent of seasons; genetically identical plants (clones); disease-free plants.

Marking: Definition – ½ mark · Steps in correct order (explant, medium, callus, organogenesis, hardening) – 1½ marks · Two advantages – 1 mark

Examiner tip: Mention hardening; students often stop at plantlet formation.

Q.24 Explain the steps by which human insulin was produced using recombinant DNA technology. Why is insulin made this way preferred?

Answer (3 marks)

1. Insulin is a peptide hormone made of two polypeptide chains, A and B.
2. Itakura et al. (1977) (printed "Hakura et al." in the textbook) chemically synthesised the DNA sequences coding for chain A and chain B.
3. The genes for chain A and chain B were inserted separately, next to the β-galactosidase gene, into two pBR322 plasmid vectors, forming recombinant plasmids.

4. The recombinant plasmids were separately transformed into *E. coli* host cells, which were grown in culture.
5. The bacteria produced the insulin chains as part of a fused protein (with β-galactosidase / pre-pro insulin). The chains were separated by enzyme (trypsin) treatment, purified and joined (by disulphide bonds) to form active human insulin.
Preference: it is identical to human insulin, so it does not cause allergy; it can be produced in large amounts quickly and cheaply.

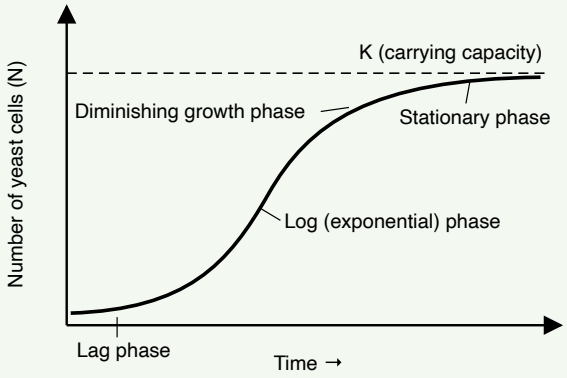
Marking: Synthetic DNA for chains A and B – ½ mark · Insertion into pBR322 plasmids and transformation of *E. coli* – 1 mark · Expression, separation and joining of chains – 1 mark · Advantage – ½ mark

Examiner tip: Name the vector (pBR322) and the host (*E. coli*); vague answers lose a mark.

Q.25 A few yeast cells are introduced into a flask containing a limited amount of nutrient medium, which is not renewed. Draw the curve expected when the number of yeast cells is plotted against time and label its phases. Explain the term 'carrying capacity'. Why is this model of growth considered more realistic than exponential growth?

Answer (3 marks)

Graph: S-shaped (sigmoid) curve of population size (N) against time (Verhulst–Pearl logistic growth) showing lag phase, log (exponential) phase, diminishing growth phase and stationary phase, levelling off at K.
Carrying capacity (K): the maximum number of individuals of a species that a given habitat can support with its available resources (food, space, etc.), beyond which no further growth is possible. As N approaches K, competition for limited resources increases, so the growth rate slows and finally stops.
More realistic: in nature, resources for growth of most populations are finite and become limiting sooner or later; unlimited (exponential) growth is not possible.



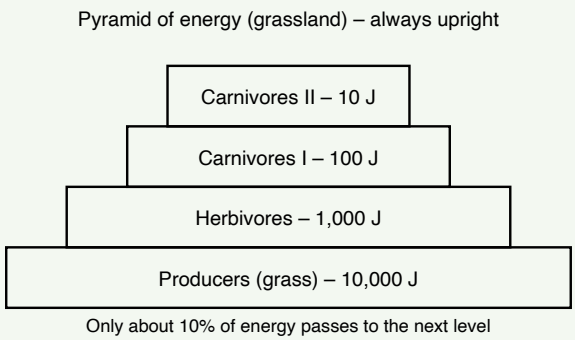
Marking: Sigmoid curve with labelled phases and axes – 1½ marks · Carrying capacity – 1 mark · Reason: resources finite – ½ mark

Examiner tip: Draw K as a horizontal dashed line and label both axes.

Q.26 Draw a pyramid of energy for a grassland ecosystem with four trophic levels. Why is the pyramid of energy always upright?

Answer (3 marks)

Diagram: Upright pyramid – producers (grass) at the base with maximum energy, followed by herbivores, primary carnivores and secondary carnivores at the top; energy values decreasing about ten times at each level (e.g. 10,000 J → 1,000 J → 100 J → 10 J).
Reason: Energy flows in one direction from producers to consumers. At each trophic level a large part of the energy is used in respiration and lost as heat, and only about 10% is transferred to the next level (Lindeman's 10% law). So energy always decreases from the lower to the higher level and the pyramid can never be inverted.



Marking: Labelled pyramid with decreasing energy values – 1½ marks · Reason (unidirectional flow, loss as heat, 10%) – 1½ marks

Examiner tip: Write energy values in each step; a bare triangle earns little.

SECTION D Attempt any THREE of the following questions. (4 marks each) **[12]**

Q.27 Draw a neat labelled diagram of a mature embryo sac of an angiosperm just before fertilization. With what does each of the two male gametes fuse, and what is the ploidy of each product? Why is this process called double fertilization? State one significance.

Answer (4 marks)

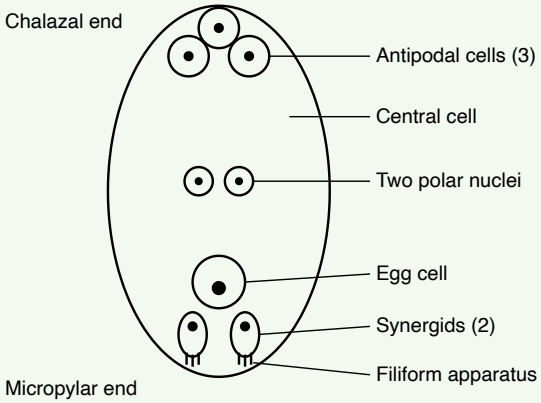
Diagram: 7-celled, 8-nucleate mature embryo sac – egg apparatus (egg cell and two synergids with filiform apparatus) at the micropylar end, central cell with two polar nuclei (or diploid secondary nucleus), and three antipodal cells at the chalazal end.

The pollen tube usually enters the ovule through the micropyle (porogamy), penetrates one of the synergids and releases two male gametes.

1. First male gamete (n) + egg cell (n) → diploid zygote (2n) – syngamy (generative fertilization); the zygote develops into the embryo.
2. Second male gamete (n) + two polar nuclei / diploid secondary nucleus (2n) → triploid primary endosperm nucleus (3n) – triple fusion (vegetative fertilization); PEN develops into the endosperm.

Since both male gametes take part and two fusions (syngamy and triple fusion) occur in the same embryo sac, it is called double fertilization (discovered by Nawaschin).

Significance (any one): the parent plant invests a seed with a food store (endosperm) only if the egg is fertilized; it restores the diploid condition in the zygote; it helps to avoid polyembryony.



Marking: Labelled embryo sac – 1½ marks · Syngamy with ploidy – ½ mark · Triple fusion with ploidy – 1 mark · Why double fertilization – ½ mark · Significance – ½ mark

Examiner tip: Draw the egg apparatus at the micropylar end; reversing the ends is a common error.

Q.28 A woman has a regular 28-day menstrual cycle. Answer the following, naming the hormones involved: (a) Which phase is she in on day 3, and why does the endometrium break down? (b) On day 10, which ovarian hormone is rising, what is its source and what is its effect on the uterus? (c) What event takes place on about day 14, and which hormone triggers it? (d) On day 22, which structure secretes progesterone, what does progesterone do, and what happens to this structure if fertilization does not occur?

Answer (4 marks)

(a) Day 3 – menstrual phase (days 1–5). The levels of progesterone and estrogen have fallen, so prostaglandins are released and the endometrium breaks down; blood, mucus, endometrial lining and the unfertilized oocyte are discharged.

(b) Day 10 – proliferative (follicular) phase. Estrogen is rising; it is secreted by the developing (secondary/Graafian) follicles, whose growth is stimulated by FSH from the anterior pituitary. Estrogen causes regeneration and thickening of the endometrium (glands and blood vessels; 3–5 mm).

(c) Day 14 – ovulation: the mature Graafian follicle ruptures and releases the secondary oocyte. It is triggered by a rapid surge of LH (positive feedback).

(d) Day 22 – secretory (luteal) phase. Progesterone is secreted by the corpus luteum (formed from the ruptured follicle under the effect of LH). Progesterone makes the endometrium thick (8–10 mm), more vascular and glandular (uterine secretions), ready for implantation. If fertilization does not occur, the corpus luteum degenerates into the corpus albicans, progesterone falls and menstruation begins.

Marking: (a) Menstrual phase with hormonal cause – 1 mark · (b) Estrogen, source (follicle/FSH) and effect – 1 mark · (c) Ovulation by LH surge – 1 mark · (d) Corpus luteum, role of progesterone, corpus albicans – 1 mark

Examiner tip: Link each day to a hormone (FSH/estrogen, LH surge, progesterone); a description without hormones gets half credit.

Q.29 *E. coli* cells growing in a medium without lactose make almost no β-galactosidase. Within minutes of adding lactose to the medium, they start making it. Explain this with the help of the lac operon, using a labelled diagram.

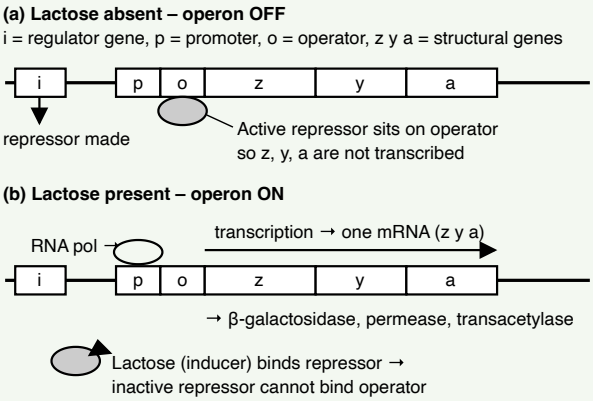
Answer (4 marks)

The lac operon (Jacob and Monod, 1961) is an inducible operon consisting of a regulator gene (i), promoter (p), operator (o) and three structural genes: z (β-galactosidase), y (β-galactoside permease) and a (transacetylase). Lactose is the inducer (not a part of the operon).

(a) Without lactose: The regulator gene i produces a repressor protein. The repressor binds to the operator and blocks it, so RNA polymerase bound at the promoter cannot move to the structural genes. z, y and a are not transcribed – the operon is switched off, so almost no β-galactosidase is made.

(b) After adding lactose: Lactose (inducer) enters the cell and binds to the repressor, changing it so that it cannot bind the operator. The operator is switched on; RNA polymerase transcribes z, y and a into a single polycistronic mRNA, which is translated into β-galactosidase, permease and transacetylase. β-galactosidase digests lactose into glucose and galactose; permease lets more lactose enter the cell.

When lactose is used up, the repressor again binds the operator and the operon is switched off.



Marking: Components of operon – 1 mark · Lactose absent: repressor blocks operator – 1 mark · Lactose present: inducer inactivates repressor, polycistronic mRNA – 1 mark · Diagram – 1 mark

Examiner tip: State the role of lactose as the inducer clearly; many answers forget to say the repressor becomes inactive.

Q.30 Draw a labelled diagram of a normal electrocardiogram (ECG) of one cardiac cycle. Explain what the P wave, QRS complex and T wave represent. Write one use of an ECG.

Answer (4 marks)

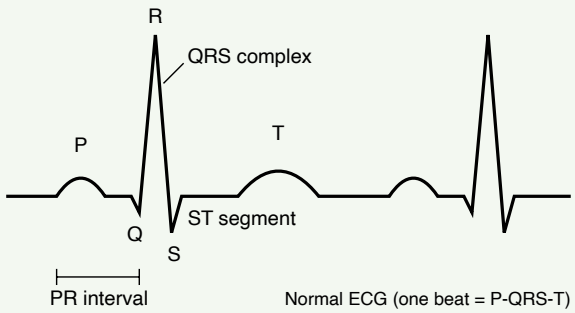
Diagram: Normal ECG trace showing P wave, QRS complex (Q, R, S), T wave, PR interval and ST segment.

P wave: a small upward wave that shows depolarisation of the atria; it leads to atrial contraction (atrial systole).

QRS complex: shows depolarisation of the ventricles; it marks the beginning of ventricular contraction (ventricular systole). (Atrial repolarisation is hidden within it.)

T wave: a dome-shaped wave that shows repolarisation of the ventricles (ventricles return to normal, ventricular diastole begins).

Use (any one): to detect abnormal heart rate or rhythm (arrhythmia), heart block, enlargement of heart chambers or damage to heart muscle after a heart attack (myocardial infarction).



Marking: Labelled ECG – 1½ marks · P, QRS and T explained – ½ mark each (1½ marks) · One use – 1 mark

Examiner tip: Use 'depolarisation' and 'repolarisation' – not just 'contraction' – to describe the waves.

Q.31 Draw a neat labelled diagram of a myelinated neuron. Explain how the resting membrane potential is maintained in a neuron.

Answer (4 marks)

Diagram: Myelinated neuron showing dendrites, cyton with nucleus and Nissl's granules, axon, myelin sheath, nodes of Ranvier, axon terminals and synaptic knobs.

Resting membrane potential: When a neuron is not conducting an impulse, its membrane is polarised – the outside is positive and the inside negative, with a potential difference of about −70 mV.

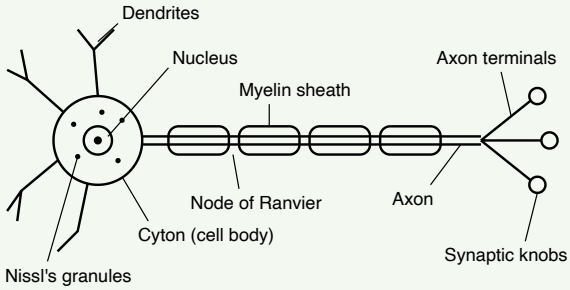
1. The Na^+–K^+ pump (using ATP) actively sends 3 Na^+ ions out for every 2 K^+ ions brought in. So

Na^+ is high outside and K^+ high inside.

2. The resting membrane is more permeable to K^+ than to Na^+, so K^+ leaks out faster than Na^+ leaks in.

3. Large negatively charged proteins and other anions inside the axon cannot move out.

As a result, more positive charges remain outside, and the resting potential is maintained.



Marking: Labelled diagram (at least 6 labels) – 2 marks · Polarised state and −70 mV – ½ mark · Na^+–K^+ pump 3 : 2 – 1 mark · Permeability / anions – ½ mark

Examiner tip: Write the value −70 mV and the 3 Na^+ : 2 K^+ ratio of the pump.

All the best for your exam!