Biology

HSC Board Exam February–March 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.1 Select and write the correct answer for the following multiple choice type of questions. **[10]**

(i) The outer wall (exine) of a pollen grain, which is resistant to chemicals and helps pollen grains to remain preserved as fossils, is made up of _____.

(a) cellulose (b) pectin
(c) sporopollenin (d) lignin

Answer (1 mark)
(c) sporopollenin
The exine is thick and made up of the complex, non-biodegradable substance sporopollenin, which is resistant to chemicals. The inner wall (intine) consists of cellulose and pectin.

(ii) In the seminiferous tubules of the human testis, nutrition to the developing sperms is provided by the _____.

(a) Leydig (interstitial) cells (b) Sertoli (sustentacular) cells
(c) spermatogonia (d) spermatids

Answer (1 mark)
(b) Sertoli (sustentacular) cells
Sertoli cells are large pyramidal cells in the seminiferous tubules that nourish the developing sperms. Leydig cells lie between the tubules and secrete testosterone; spermatogonia and spermatids are stages of spermatogenesis.

(iii) Two persons, each a carrier of sickle-cell anaemia (Hb^AHb^S), marry. Among their children who survive, the ratio of carriers to normal children is expected to be _____.

(a) 1 : 2 : 1 (b) 3 : 1
(c) 2 : 1 (d) 1 : 1

Answer (1 mark)
(c) 2 : 1
The children are born as normal (Hb^AHb^A) : carrier (Hb^AHb^S) : sickle-cell anaemic (Hb^SHb^S) = 1 : 2 : 1. The Hb^SHb^S children die of total anaemia (lethal gene, pleiotropy), so carriers and normals survive in the ratio 2 : 1.

(iv) In eukaryotes, the messenger RNA (primary transcript / hnRNA) is transcribed by _____.

(a) RNA polymerase I (b) RNA polymerase II
(c) RNA polymerase III (d) DNA polymerase

Answer (1 mark)
(b) RNA polymerase II
RNA polymerase I transcribes r-RNA, RNA polymerase III transcribes t-RNA and snRNA, and RNA

polymerase II transcribes m-RNA (hnRNA). DNA polymerase is used in replication, not transcription.

(v) Early in the morning, drops of water are seen along the leaf margins of grasses. This loss of water in liquid form takes place through _____.

(a) stomata
(b) lenticels
(c) hydathodes
(d) cuticle

Answer (1 mark)
(c) hydathodes
Loss of water in liquid form is guttation; it occurs through special structures called water stomata or hydathodes. Stomata, lenticels and cuticle are sites of transpiration (loss of water as vapour).

(vi) 'Brown heart' disease in plants is a deficiency symptom of _____.

(a) boron
(b) copper
(c) zinc
(d) manganese

Answer (1 mark)
(a) boron
Boron is needed for the uptake and utilisation of Ca^{2+}, pollen germination and carbohydrate translocation; its deficiency causes brown heart disease. Copper deficiency causes die-back of shoots, zinc deficiency malformed leaves and manganese deficiency chlorosis with grey spots.

(vii) The vital capacity of human lungs is the sum of _____.

(a) tidal volume and inspiratory reserve volume
(b) tidal volume, inspiratory reserve volume and expiratory reserve volume
(c) tidal volume, expiratory reserve volume and residual volume
(d) inspiratory reserve volume, expiratory reserve volume and residual volume

Answer (1 mark)
(b) tidal volume, inspiratory reserve volume and expiratory reserve volume
Vital capacity is the maximum amount of air that can be breathed out after a maximum inspiration: VC = TV + IRV + ERV (about 4100 to 4600 ml). Residual volume can never be breathed out, so it is not part of vital capacity.

(viii) A patient loses weight and feels weak; his blood shows low sugar, low Na^+ and high K^+, and much Na^+ and water are lost in the urine. This disorder is caused by _____.

(a) hypersecretion of glucocorticoids
(b) hyposecretion of mineralocorticoids and glucocorticoids
(c) hyposecretion of insulin
(d) hypersecretion of thyroxine

Answer (1 mark)
(b) hyposecretion of mineralocorticoids and glucocorticoids
This is Addison's disease: low blood sugar, low Na^+ and high K^+ in plasma, increased loss of Na^+ and water in urine, weight loss and weakness. Hypersecretion of glucocorticoids (Cushing's disease) gives high blood sugar and a rise in Na^+; lack of insulin gives high blood sugar; excess thyroxine raises the metabolic rate.

(ix) In a polymerase chain reaction (PCR), starting from one molecule of the target DNA, the number of copies obtained at the end of 6 cycles is _____.

(a) 12 (b) 36

(c) 64 (d) 128

Answer (1 mark)
(c) 64
The amount of DNA doubles in every cycle, so at the end of n cycles 2^n copies are produced: $2^6 = 64$.

(x) On a forest floor, partly decomposed organic matter builds up as a dark, structureless, colloidal material that microbes break down only very slowly. The step of decomposition that produces this material is _____.

(a) fragmentation (b) leaching

(c) humification (d) mineralisation

Answer (1 mark)
(c) humification
Humification leads to the accumulation of humus, a dark-coloured, amorphous, colloidal substance that resists microbial action and decomposes extremely slowly. Fragmentation is the breaking of detritus into small particles by detritivores, leaching removes water-soluble nutrients, and mineralisation releases inorganic nutrients from humus.

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

(i) Name the condition in which flowers are self-pollinated even before they open, as in the underground flowers of *Commelina benghalensis*.

Answer (1 mark)
Cleistogamy (cleistogamous flowers).

(ii) Two populations of frogs live in the same pond but do not interbreed, because one population breeds in June and the other in September. Name this isolating mechanism.

Answer (1 mark)
Seasonal (temporal) isolation – a pre-mating (pre-zygotic) isolating mechanism.

(iii) Name the compound most widely used as a source of ethylene for ripening fruits.

Answer (1 mark)
Ethephon (Ethrel), which releases ethylene after dissolving in water.

(iv) Name the largest commissure (band of nerve fibres) that connects the two cerebral hemispheres.

Answer (1 mark)
Corpus callosum.

(v) Name the enzyme present in HIV that enables the virus to make DNA from its RNA.

Answer (1 mark)
Reverse transcriptase (HIV is a retrovirus).

(vi) Name the new breed of sheep developed in Punjab by crossing Bikaneri ewes with Marino rams.

Answer (1 mark)
Hisardale (a product of cross-breeding).

(vii) State Gause's competitive exclusion principle.

Answer (1 mark)
Two closely related species competing for the same (limiting) resources cannot co-exist indefinitely; the competitively inferior one is eliminated eventually.

(viii) Why should motor vehicles fitted with a catalytic converter use only unleaded petrol?

Answer (1 mark)
Because lead in the petrol inactivates the catalyst of the catalytic converter.

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

Q.3 A student wants to watch pollen tubes growing from pollen grains placed on a glass slide in a synthetic medium. (a) Name two substances she should add to the medium and state the role of each. (b) From which part of the pollen wall will the pollen tube emerge, and why from there?

Answer (2 marks)
(a) Sucrose – induces pollen germination and pollen tube growth in vitro.
Boric acid – facilitates and accelerates pollen germination.
(b) The pollen tube emerges through a germ pore. Germ pores are places where the exine (made of sporopollenin) is very thin; they are meant for the growth of the emerging pollen tube during germination.

Marking: Sucrose with role – ½ mark · Boric acid with role – ½ mark · Germ pore – ½ mark · Reason: exine very thin there – ½ mark

Examiner tip: Name both substances and their roles; 'sugar solution' alone gets only half credit.

Q.4 Suggest a suitable assisted reproductive technique for each couple and explain it briefly. (a) Couple X: the husband is unable to inseminate the wife because of a very low sperm count. (b) Couple Y: the husband's semen is normal and the wife's ovaries release healthy eggs, but both her oviducts are obstructed along their length, so the sperms can never reach the egg inside her body.

Answer (2 marks)
(a) Couple X – Artificial insemination (AI): sperms are collected from the husband and artificially introduced into the cervix of the wife, so that fertilization takes place inside the body (in vivo). [IUI – intra uterine insemination, in which the sperms are introduced into the uterine cavity instead of the cervix – is also accepted.]
(b) Couple Y – ZIFT (Zygote Intrafallopian Transfer): an egg is removed from the woman's ovary and fertilized with sperms outside the body under sterile conditions (in vitro fertilization) to form a zygote; the zygote is then transferred to the fallopian tube for further development. (ZIFT is the textbook's treatment for a blockage of the fallopian tubes that prevents fertilization of the egg by the sperm. GIFT is not the answer here, because the textbook gives GIFT only for cases in which the entrance or the upper segment of the oviduct is blocked. 'IVF with transfer of the zygote into the fallopian tube' earns full credit.)

Marking: AI / IUI named – ½ mark · AI / IUI explained – ½ mark · ZIFT named – ½ mark · ZIFT explained (IVF, zygote into fallopian tube) – ½ mark

Examiner tip: Do not write just 'test tube baby'; name the exact technique given in the textbook.

Q.5 In the Hershey–Chase experiment, bacteriophages grown on a medium containing radioactive sulphur (^{35}S) were allowed to infect *E. coli*. After blending and centrifugation, where was the radioactivity found – inside the bacteria or in the supernatant? What does this result show? Why was ^{35}S chosen to label these phages?

Answer (2 marks)

Radioactivity was found in the supernatant (with the viral protein coats), not inside the bacterial cells.

This shows that the protein of the phage did not enter the bacteria. (With ^{32}P-labelled phages, the radioactivity was found inside the bacteria, so DNA is the material that passes from virus to bacteria – DNA is the genetic material.)

^{35}S was chosen because sulphur is present in proteins but not in DNA, so it labels only the protein coat.

Marking: Supernatant / not in bacteria – ½ mark · Protein does not enter, hence DNA is the genetic material – 1 mark · Reason for ^{35}S (S in protein, not in DNA) – ½ mark

Examiner tip: Link each isotope to the right molecule: ^{32}P – DNA, ^{35}S – protein.

Q.6 A student claims that the strong muscles a wrestler builds by exercise will be inherited by his son. (a) Which theory of evolution supports this claim? (b) Describe the experiment that disproved this theory and state the conclusion drawn from it.

Answer (2 marks)

(a) Lamarck's theory of inheritance of acquired characters (use and disuse of organs).

(b) August Weismann cut the tails of rats (mice) for many generations, but even after 21 generations the size of the tail in the offspring did not change.

Conclusion: variations produced in somatic cells (somatoplasm) are not inherited, while variations produced in germ cells (germplasm) are inherited. He proposed the theory of continuity of germplasm. Muscles built by exercise are somatic changes, so they are not inherited.

Marking: Lamarck's theory – ½ mark · Weismann's experiment (tails cut for 21 generations) – ½ mark · Conclusion: somatoplasm vs germplasm – 1 mark

Examiner tip: Write the name Weismann and the term 'germplasm'; just saying 'the theory was wrong' gets no credit.

Q.7 A gardener regularly cuts off the shoot tips of the plants in a hedge. After a few weeks the hedge becomes dense and bushy. Name the phenomenon involved and explain it, naming the plant hormones concerned.

Answer (2 marks)

Phenomenon: apical dominance.

In most higher plants the growing apical bud inhibits the growth of the lateral (axillary) buds; this effect is due to auxin produced by the apical bud.

When the shoot tip is cut off, the source of auxin is removed, so the lateral buds are released from inhibition and grow into branches – the hedge becomes bushy.

Cytokinin promotes the growth of lateral buds and reverses the effect of apical dominance.

Marking: Apical dominance named – ½ mark · Auxin from apical bud inhibits lateral buds – ½ mark · Removal of tip → lateral buds grow – ½ mark · Role of cytokinin – ½ mark

Examiner tip: Name auxin as the hormone that causes apical dominance; many answers wrongly write cytokinin.

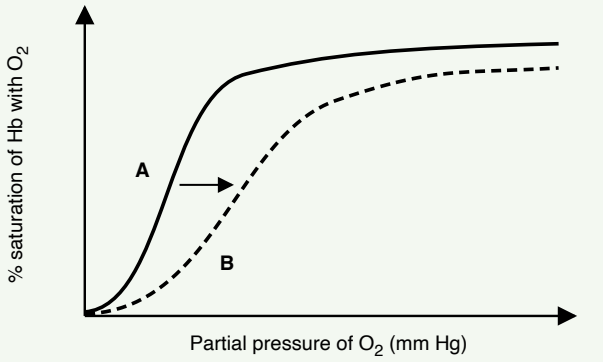
Q.8 During vigorous exercise, the working muscles take more oxygen from the blood than they do at rest. Explain this with the help of the oxygen–haemoglobin dissociation curve and name the effect involved.

Answer (2 marks)

In actively working muscles the partial pressure of CO_2, the H^+ concentration and the temperature increase (and the O_2 tension falls).

These changes shift the sigmoid oxygen–haemoglobin dissociation curve to the right (curve B in the figure). A right shift lowers the affinity of haemoglobin for oxygen, so at the same pO_2 oxyhaemoglobin dissociates more and releases more O_2 to the muscle cells.

The shift of the curve due to a change in the partial pressure of CO_2 in blood is called the Bohr effect.



A – normal curve
B – shifted to the right (more CO_2, more H^+, higher temperature)

Marking: Rise in pCO_2 / H^+ / temperature in muscles – ½ mark · Curve shifts to the right, lower affinity, more O_2 released (sketch optional) – 1 mark · Bohr effect – ½ mark

Examiner tip: State the direction of the shift (to the right) and what it means for the affinity of haemoglobin.

Q.9 In a dark cinema hall you can make out the shapes of people but not the colours of their clothes. Explain this on the basis of the two types of photoreceptor cells of the retina.

Answer (2 marks)

The retina has two types of photoreceptor cells – rods and cones.

Rods function in dim light (scotopic vision). They contain the purple-red photopigment rhodopsin, a vitamin A derivative. Rods do not give colour vision, so in dim light we see only shapes.

Cones are responsible for daylight (photopic) vision and colour vision. They are of three types, with photopigments that respond to red, green and blue light. Cones need bright light, so in the dark they do not work and colours are not seen. (Cones are most dense in the fovea centralis.)

Marking: Rods – dim light vision, rhodopsin, no colour – 1 mark · Cones – bright light, three photopigments, colour vision – 1 mark

Examiner tip: Name the pigment rhodopsin and mention the three types of cones (red, green, blue).

Q.10 A lymphocyte binds to a virus-infected body cell and secretes a substance that makes a hole in the infected cell, killing it. (a) Name this lymphocyte and the substance it secretes. (b) Name any two other types of T-lymphocytes formed in the same clone and state the function of each.

Answer (2 marks)

(a) Killer T-cell (cytotoxic T-cell); it secretes perforins, which form a hole in the infected cell.

(b) Any two:

Helper T-cells – produce lymphokines that cause proliferation of other T-cells and stimulate B-

lymphocytes and macrophages.
Suppressor T-cells – suppress the immune system against attack on the body's own cells.
Memory T-cells – previously sensitised cells that retain the sensitisation memory for a long time.

Marking: Killer / cytotoxic T-cell – ½ mark · Perforins – ½ mark · Two other T-cells with functions – ½ mark each

Examiner tip: Perforins are made by killer T-cells, not by B-cells or helper T-cells.

Q.11 A dairy farmer mates closely related cows and bulls of his herd for five generations to obtain pure lines. (a) Name this type of breeding and give one advantage of it. (b) After some generations the fertility and milk yield of the herd fall. What is this problem called and how can it be overcome?

Answer (2 marks)

(a) Inbreeding – breeding of closely related individuals for 4 to 6 generations.
Advantage (any one): it increases homozygosity, so pure lines are obtained; it helps to eliminate harmful recessive genes; it helps to accumulate superior genes.
(b) Fall in fertility and productivity due to continued inbreeding is called inbreeding depression. It can be overcome by outbreeding – breeding with unrelated animals (same breed but no common ancestors for 4 to 6 generations). The textbook also states that outcrossing (which it describes as breeding between animals of different species, i.e. interspecific hybridization) helps to remove inbreeding depression; either answer earns the mark.

Marking: Inbreeding – ½ mark · One advantage – ½ mark · Inbreeding depression – ½ mark · Remedy: outbreeding / outcrossing – ½ mark

Examiner tip: Inbreeding is useful for pure lines but must not be continued indefinitely; always mention the remedy.

Q.12 A mixture of three DNA fragments of 300 bp, 1200 bp and 4000 bp is loaded into a well of an agarose gel and an electric field is applied. (a) Towards which electrode will the fragments move, and why? (b) Which fragment will be found farthest from the well and which nearest to it? Give a reason.

Answer (2 marks)

(a) Towards the anode (positive electrode), because DNA is negatively charged.
(b) The 300 bp fragment will be farthest from the well and the 4000 bp fragment nearest to it, because small DNA fragments move faster than large ones and so separate faster. (The 1200 bp fragment lies in between.)

Marking: Anode – ½ mark · Reason: DNA negatively charged – ½ mark · 300 bp farthest, 4000 bp nearest – ½ mark · Reason: smaller fragments move faster – ½ mark

Examiner tip: DNA moves to the anode, not the cathode – a very common slip.

Q.13 A herd of spotted deer in a sanctuary had 500 animals at the beginning of a year. During the year 200 fawns were born and 60 deer died; no deer entered or left the sanctuary. (a) Calculate the birth rate and the death rate of the herd per 1000 individuals per year. (b) What is the size of the herd at the end of the year? (c) Which population characteristic has the greatest influence on population growth?

Answer (2 marks)

(a) Birth rate (natality) = number of births / initial population = 200 / 500 = 0.4 per deer per year = 400 per 1000 individuals per year.
Death rate (mortality) = number of deaths / initial population = 60 / 500 = 0.12 per deer per year = 120 per 1000 individuals per year.
(b) Herd at the end of the year = 500 + 200 − 60 = 640 deer (no immigration or emigration).
(c) Natality (birth rate) has the greatest influence on a population's growth.

Marking: Birth rate = 400 per 1000 per year – ½ mark · Death rate = 120 per 1000 per year – ½ mark · Herd size 640 – ½ mark · Natality – ½ mark

Examiner tip: Divide by the population at the start of the year (500), then multiply by 1000 to express the rate per 1000 individuals.

Q.14 The producers of a grassland fix 24,000 kJ of energy per m^2 per year by photosynthesis, and they use 9,600 kJ m^{-2} $year^{-1}$ of it in respiration. Calculate the net primary productivity (NPP). What percentage of the gross primary productivity is lost in respiration, and why is NPP important for the ecosystem?

Answer (2 marks)

GPP = 24,000 kJ m^{-2} $year^{-1}$; R = 9,600 kJ m^{-2} $year^{-1}$

NPP = GPP − R = 24,000 − 9,600 = 14,400 kJ m^{-2} $year^{-1}$

Percentage lost in respiration = (9,600 / 24,000) × 100 = 40%

Importance: NPP is the biomass available for consumption by heterotrophs (herbivores, carnivores and decomposers).

Marking: Relation GPP − R = NPP – ½ mark · NPP = 14,400 kJ m^{-2} $year^{-1}$ – ½ mark · 40% – ½ mark · Importance of NPP – ½ mark

Examiner tip: Write the unit with the answer; NPP is always less than GPP.

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

Q.15 The water of a tender coconut is a liquid, while the white kernel lining the shell is solid. (a) Name the type of endosperm development seen in coconut and explain how it takes place. (b) How does cellular endosperm differ from it? Give one example. (c) Describe helobial endosperm with an example.

Answer (3 marks)

(a) Nuclear type (the most common type). The triploid primary endosperm nucleus divides repeatedly by mitosis without wall formation, producing a large number of free nuclei. A big central vacuole pushes the nuclei to the periphery; later walls develop between the nuclei. In several cases wall formation remains incomplete – coconut has multicellular endosperm in the outer part (white kernel) and free-nuclear, vacuolated endosperm in the centre (coconut water).

(b) Cellular type: each division of the primary endosperm nucleus is immediately followed by wall formation, so the endosperm is cellular right from the beginning. Example: *Balsam*, *Petunia* or *Adoxa*.

(c) Helobial type (order Helobiales of monocots): the first division of the PEN is followed by a transverse wall that divides the cell unequally into a small chalazal cell and a large micropylar cell; the nuclei in each then divide by free nuclear divisions, and walls develop between the nuclei in the micropylar chamber. It is intermediate between the cellular and nuclear types. Example: *Asphodelus*.

Marking: Nuclear type explained with coconut – 1 mark · Cellular type with example – 1 mark · Helobial type with example – 1 mark

Examiner tip: Coconut water is free-nuclear endosperm, not 'fruit juice'; relate both parts of the coconut to the nuclear type.

Q.16 Explain the process of oogenesis in the human female. Why is the egg released at ovulation called a secondary oocyte? How many functional ova are formed from 100 primary oocytes, and how many sperms from 100 primary spermatocytes?

Answer (3 marks)

Oogenesis (formation of the haploid ovum from the diploid germinal epithelium of the ovary):

1. Multiplication phase – primordial germ cells (2n) divide repeatedly by mitosis to form

oogonia (2n); this is completed in the embryonic stage.
2. Growth phase – some oogonia stop dividing and grow into primary oocytes (2n).
3. Maturation phase – the primary oocyte undergoes meiosis I with unequal division of cytoplasm, forming a large secondary oocyte (n) and a small first polar body (n). The secondary oocyte proceeds with meiosis II only up to metaphase II and is arrested there. Meiosis II is completed only when a sperm enters (in the ampulla of the fallopian tube), giving a large ovum (n) and a small second polar body (n).
The egg released at ovulation is called a secondary oocyte because its meiosis II is not complete – it is arrested at metaphase II.
100 primary oocytes → 100 ova (each gives 1 ovum + polar bodies). 100 primary spermatocytes → 400 sperms (each gives 4 spermatids).

Marking: Three phases with ploidy – 1½ marks · Reason for 'secondary oocyte' (arrested at metaphase II) – ½ mark · 100 ova and 400 sperms – ½ mark each

Examiner tip: Show the unequal division and the polar bodies; that is why one primary oocyte gives only one ovum.

Q.17 A woman with normal blood clotting, whose father was haemophilic, marries a haemophilic man. Using a checkerboard, work out the genotypes and phenotypes of their children. What is the chance that (a) a son of this couple is haemophilic, and (b) a child of this couple is a haemophilic daughter?

Answer (3 marks)

The woman received an X^h from her haemophilic father, so she is a carrier: X^HX^h. Husband: X^hY.
Gametes: woman – X^H, X^h; man – X^h, Y

♀ \ ♂	X^h	Y
X^H	X^HX^h carrier daughter	X^HY normal son
X^h	X^hX^h haemophilic daughter	X^hY haemophilic son

Children: carrier daughter : haemophilic daughter : normal son : haemophilic son = 1 : 1 : 1 : 1 (25% each).
(a) Among sons, 1 of 2 is haemophilic – 50%.
(b) Chance of a child being a haemophilic daughter = 1/4 – 25%.

Marking: Genotypes of parents (woman is a carrier) – ½ mark · Checkerboard with phenotypes – 1½ marks · 50% and 25% – ½ mark each

Examiner tip: Work out first that the woman must be a carrier; a daughter can be haemophilic only when she receives X^h from both parents.

Q.18 *E. coli* cells grown for many generations in a medium containing ^{15}N were transferred to a medium containing ^{14}N. The bacteria divide once every 20 minutes. Samples were taken at 20, 40 and 60 minutes after transfer and their DNA was separated by density gradient centrifugation. (a) Name the technique and the medium used. (b) What type(s) of DNA band will be seen at 20 minutes and at 40 minutes? (c) What proportion of the DNA molecules will be hybrid at 60 minutes? What does the experiment prove?

Answer (3 marks)

(a) Equilibrium density gradient centrifugation in 6 M caesium chloride (CsCl) (Meselson and Stahl, 1958).

(b) At 20 minutes (generation I): a single hybrid band (^{15}N–^{14}N DNA) of intermediate density.

At 40 minutes (generation II): two bands – hybrid (^{15}N–^{14}N) and light (^{14}N–^{14}N) – in equal amounts (50% each).

(c) At 60 minutes (generation III), 8 DNA molecules are formed from each original molecule; only 2 still carry an original ^{15}N strand. So hybrid DNA = 2/8 = 25% (and light DNA = 75%). The experiment proves that DNA replication is semiconservative – each new DNA molecule has one parental (old) strand and one newly synthesised strand.

Marking: Technique and CsCl – ½ mark · 20 min: one hybrid band – ½ mark · 40 min: hybrid and light bands, 1 : 1 – ½ mark · 60 min: 25% hybrid – 1 mark · Semiconservative replication – ½ mark

Examiner tip: A heavy (^{15}N–^{15}N) band never appears after the transfer; the two original heavy strands stay in hybrid molecules.

Q.19 Identify the mode of speciation in each case and explain it. (a) A river changes its course and divides a population of land snails into two groups that can no longer meet; after many generations they cannot interbreed. (b) Within a single lake, a new species of fish arises without any geographical barrier, because of reproductive isolation. (c) Two different species of plants cross, and doubling of chromosomes in the hybrid gives a new fertile species.

Answer (3 marks)

(a) Allopatric speciation – formation of a new species due to separation of a segment of a population from its original population by distance or by a geographical barrier (here a river). The separated groups change independently and become reproductively isolated. (Other barriers: creeping glaciers, mountains.)

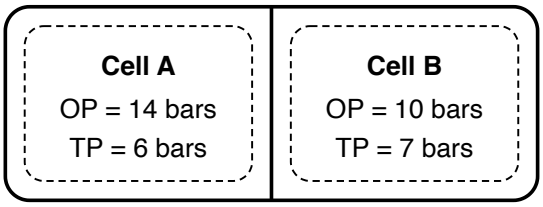
(b) Sympatric speciation – formation of a species within a single population without geographical isolation; new species are formed due to reproductive isolation, and mutations help in it (e.g. cichlid fishes of Lake Victoria).

(c) Interspecific speciation by hybridisation – two different species cross to give a hybrid, which on doubling of chromosomes forms a new species, e.g. *Triticum aestivum* (hexaploid wheat) and *Gossypium herbaceum* (tetraploid cotton).

Marking: Allopatric with explanation – 1 mark · Sympatric with explanation – 1 mark · Hybridisation with explanation – 1 mark

Examiner tip: Allopatric = 'other place' (barrier); sympatric = 'same place' (no barrier). Do not mix them up.

Q.20 The figure shows two adjacent plant cells A and B with their osmotic pressure (OP) and turgor pressure (TP). (a) Calculate the diffusion pressure deficit (DPD) of each cell. (b) In which direction will water move between them? Give a reason. (c) Express the water potential of each cell and state the DPD of cell A when it becomes fully turgid.



Two adjacent parenchyma cells (common wall in the middle)

Answer (3 marks)

(a) DPD = OP − TP

Cell A: DPD = 14 − 6 = 8 bars

Cell B: DPD = 10 − 7 = 3 bars

(b) Water moves from cell B to cell A, because cell A has the higher DPD (greater suction pressure – it is 'thirstier').

(c) Water potential is equal to DPD but opposite in sign: ψ of A = −8 bars, ψ of B = −3 bars. Water flows from the less negative (higher) water potential (B) to the more negative (lower) water

potential (A) – the same answer.
When cell A becomes fully turgid, TP = OP, so its DPD = 0.

Marking: DPD formula and both values – 1 mark · Direction B → A with reason – 1 mark · Water potentials −8 and −3 bars – ½ mark · DPD of fully turgid cell = 0 – ½ mark

Examiner tip: Water moves towards higher DPD, i.e. towards more negative water potential; check that both ways give the same direction.

Q.21 A doctor asks a patient to breathe in deeply and then breathe out. Explain the roles of the diaphragm, the external intercostal muscles and the pressure changes in the thorax during (a) inspiration and (b) expiration.

Answer (3 marks)

(a) Inspiration (an active process): the diaphragm contracts, becomes flat and moves downward; the external intercostal muscles contract, so the ribs and sternum move upward and outward. The volume of the thorax increases and the pressure in the thorax and lungs decreases below atmospheric pressure. To equalise the low pressure, air from the atmosphere rushes into the lungs.
(b) Expiration: the diaphragm relaxes and is pushed upward, becoming dome-shaped; the intercostal muscles relax, pulling the rib cage inward and downward. The volume of the thorax decreases and the pressure in the thorax and lungs becomes higher than atmospheric pressure, so air from the lungs rushes out.
(One inspiration and one expiration make one breath.)

Marking: Inspiration: diaphragm and external intercostals – 1 mark · Inspiration: volume ↑, pressure ↓, air enters – ½ mark · Expiration: muscles relax, diaphragm dome-shaped – 1 mark · Expiration: volume ↓, pressure ↑, air leaves – ½ mark

Examiner tip: Air moves because of the pressure gradient; always link the volume change to the pressure change.

Q.22 A post-menopausal woman complains of soft, bending bones that fracture easily. Her report shows hypersecretion of a hormone that removes calcium from the bones. (a) Name the hormone, its gland and the condition. How does this hormone raise the blood calcium level? (b) Name the hormone that acts antagonistically to it and give its source. (c) What happens when the first hormone is secreted in too small an amount?

Answer (3 marks)

(a) Parathormone (PTH, Collip's hormone) from the parathyroid glands. Hypersecretion causes demineralisation of bones – softening, bending and fracture – called osteoporosis (common in women after menopause).
PTH raises blood calcium by (i) taking calcium from the bones, (ii) increasing calcium absorption in the digestive tract and (iii) reducing the loss of calcium in the urine.
(b) Calcitonin, secreted by the parafollicular (C) cells of the thyroid gland. It lowers blood calcium and phosphorus by decreasing their release from bones and accelerating their uptake by bones. PTH and calcitonin form an antagonistic pair.
(c) Hyposecretion of PTH lowers blood calcium; this increases the excitability of nerves and muscles, causing muscle twitches and spasms – parathyroid (hypocalcaemic) tetany.

Marking: PTH, parathyroid, osteoporosis – ½ mark · Three ways PTH raises blood Ca^{2+} – 1 mark · Calcitonin from parafollicular cells – ½ mark · Hyposecretion → tetany – 1 mark

Examiner tip: Remember the pair: parathormone raises and calcitonin lowers blood calcium.

Q.23 An Rh-negative woman married to an Rh-positive man has her first baby, which is Rh-positive and healthy. The doctor warns her about her next pregnancy if the foetus is again Rh-positive. (a) Name the disease that the second baby may suffer from. (b) Explain why the first baby was safe but the second may be affected. (c) How can this be prevented?

Answer (3 marks)

(a) Haemolytic disease of the newborn (HDN), called erythroblastosis foetalis (destruction of the erythrocytes of the foetus).

(b) The Rh factor (D antigen) is an antigenic protein on the RBCs. During the birth of the first Rh-positive child, Rh-positive RBCs of the foetus may enter the mother's circulation. The Rh (D) antigen induces a strong immune response in the Rh-negative mother, who starts producing anti-Rh antibodies. The first baby is already born, so it is not affected. In the next pregnancy with an Rh-positive foetus, the mother's anti-Rh antibodies reach the foetus and destroy its RBCs, causing HDN.

(c) The Rh-negative mother is injected with anti-Rh antibody during all pregnancies carrying an Rh-positive foetus.

Marking: Erythroblastosis foetalis / HDN – ½ mark · Sensitisation of mother at first birth – 1 mark · Antibodies destroy RBCs of second foetus – 1 mark · Prevention with anti-Rh antibody – ½ mark

Examiner tip: The problem arises only with an Rh-negative mother and an Rh-positive foetus; the reverse combination does not cause HDN.

Q.24 A start-up plans to grow microorganisms on sugarcane molasses and agricultural waste to produce protein-rich feed for poultry and fish. (a) What is single cell protein (SCP)? (b) Name one alga and one yeast used for producing SCP. (c) Give any two advantages of SCP.

Answer (3 marks)

(a) Single cell protein is the crude or refined edible protein extracted from pure microbial cultures or from dead or dried microbial cell biomass (algae, fungi, yeast, bacteria).

(b) Alga: *Spirulina* or *Chlorella pyrenoidosa*. Yeast: *Saccharomyces cerevisiae* or *Candida utilis*. (Fungi: *Aspergillus niger*, *Trichoderma viride*; bacteria: *Methylophilus methylotrophus*, *Bacillus megasterium*.)

(c) Any two:

1. Microorganisms multiply at a high rate, so a large quantity of biomass is produced in a short time.
2. Microbes have a high protein content (43% to 85% w/w) and can be genetically modified to vary the amino acid composition.
3. A broad variety of raw materials, including waste materials, can be used as substrate; this also helps to decrease pollutants.
4. SCP is a good source of vitamins (vitamin B complex), amino acids, minerals and crude fibres.

Marking: Definition – 1 mark · One alga and one yeast – ½ mark each · Two advantages – ½ mark each

Examiner tip: Give names with genus and species; 'algae and yeast' alone earns nothing in part (b).

Q.25 Bt cotton is grown by many farmers in Maharashtra. (a) What does 'Bt' stand for, and which gene has been introduced into this plant? (b) Explain how the protein made by Bt cotton kills a susceptible insect that feeds on it. (c) Why are Bt plants preferred to spraying the bacterium on crops?

Answer (3 marks)

(a) Bt stands for the bacterium *Bacillus thuringiensis*. The cry gene of this bacterium has been introduced into cotton.

(b) The cry gene produces a protein that forms crystalline inclusions (in the bacterial spores). When the insect (e.g. bollworm) feeds on the plant and ingests the protein, the combination of

high pH and the enzyme proteinase in the insect's midgut processes the protein hydrolytically, releasing the core toxic fragments, which kill the insect.
(c) The use of *B. thuringiensis* sprays is limited because of the low stability of the protein in the field. A Bt plant makes the protein itself, so the crop is protected continuously; this reduces the use of chemical pesticides and the cost of producing food.

Marking: Bacillus thuringiensis and cry gene – 1 mark · Activation in alkaline midgut by proteinase → toxic fragments – 1 mark · Advantage over sprays – 1 mark

Examiner tip: Mention that the toxin is released only in the insect's alkaline midgut; that is the key step.

Q.26 A lake surrounded by farms receives run-off water carrying fertilizers, and sewage from nearby homes. After some years the water turns green and smelly, and fish begin to die. (a) Name this phenomenon and give its two types. (b) Explain the sequence of events that leads to the death of fish. (c) What is BOD and what does a high BOD indicate?

Answer (3 marks)

(a) Eutrophication (nutrient enrichment of water). Natural eutrophication is the slow ageing of a lake over thousands of years; when the process is accelerated by human activities (effluents from farms, industries and homes) it is called cultural or accelerated eutrophication – as in this lake.
(b) Nutrient enrichment → excessive growth of free-floating planktonic algae, especially blue-green algae (algal bloom), which colours the water → submerged plants die due to reduced light → organic load increases → microorganisms decomposing this matter consume a lot of dissolved oxygen → dissolved oxygen falls sharply; algal blooms also release toxins → fish and other aquatic animals die, and species diversity is lost.
(c) BOD (Biochemical Oxygen Demand) is the amount of dissolved oxygen required by microorganisms for decomposing the organic matter present in water (expressed in mg of O_2 per litre). A high BOD indicates an intense level of microbial (organic) pollution.

Marking: Eutrophication with natural and cultural types – 1 mark · Sequence: algal bloom → decomposition → O_2 depletion / toxins → fish death – 1 mark · BOD definition and meaning of high BOD – 1 mark

Examiner tip: Fish die mainly because of loss of dissolved oxygen; write the steps in the correct order.

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

Q.27 In maize, the gene for coloured grain (C) is dominant over colourless (c) and full grain (S) is dominant over shrunken (s). A plant heterozygous for both genes (CS/cs, obtained from a cross of coloured full × colourless shrunken) was test-crossed with a colourless shrunken (cs/cs) plant. The offspring were:

Class of offspring	Number
Coloured, full	482
Colourless, shrunken	478
Coloured, shrunken	22
Colourless, full	18
Total	1000

(a) What ratio would be expected if the two genes assorted independently? Do these results agree with it? (b) Name the phenomenon shown and identify the parental and recombinant types. (c) Calculate the percentage of recombination and state whether the genes are strongly or loosely linked. (d) Explain how the recombinant types arise and at which stage of meiosis this happens.

Answer (4 marks)

(a) With independent assortment, the dihybrid test cross (CcSs × ccss) would give the four classes in the ratio 1 : 1 : 1 : 1, i.e. about 250 each. The results (482 : 478 : 22 : 18) do not agree – the parental combinations are far more frequent.

(b) Linkage – the genes C and S lie on the same chromosome and tend to be inherited together. Since a few recombinants do appear, the linkage is not complete (the textbook gives colour and shape of grain in *Zea mays* as its example of incomplete linkage).

Parental types: coloured full (482) and colourless shrunken (478) – 960.

Recombinant (new) types: coloured shrunken (22) and colourless full (18) – 40.

(c) Percentage of recombination = (recombinants / total) × 100 = (22 + 18) / 1000 × 100 = 4%. The genes are strongly (closely) linked, because they show very few recombinations – like Morgan's strongly linked yellow-body and white-eye genes (1.3%), and unlike his loosely linked white-eye and miniature-wing genes (37.2%).

(d) Recombinant types arise by crossing over – the exchange of segments between non-sister chromatids of homologous chromosomes. It occurs during the pachytene stage of prophase I of meiosis, through synapsis, tetrad formation, crossing over and terminalization. Because C and S lie close together, crossing over between them is rare, so parental combinations occur more (due to linkage) and new combinations less (due to crossing over).

Marking: (a) 1 : 1 : 1 : 1 expected; results do not agree – ½ mark · (b) Linkage named; parental and recombinant classes identified – 1 mark · (c) 4% recombination, strongly linked – 1 mark · (d) Crossing over between non-sister chromatids at pachytene of prophase I – 1½ marks

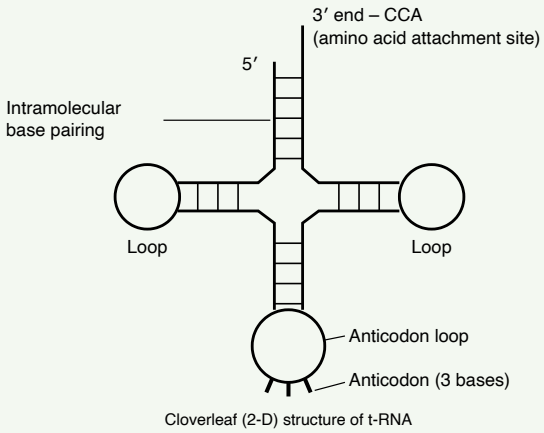
Examiner tip: Recombination % = recombinants ÷ total × 100; use only the two smaller classes as recombinants. 'Strongly linked' refers to the low recombination value; the genes are still not completely linked, because recombinants appear.

Q.28 Draw a neat labelled diagram of the cloverleaf structure of t-RNA. Explain why t-RNA is described as an adapter molecule. Write the anticodon of the t-RNA that pairs with the codon 5′-UGG-3′. A ribosome has three binding sites for t-RNA – name them and state which site the initiator charged t-RNA occupies.

Answer (4 marks)

Diagram: cloverleaf (two-dimensional) t-RNA showing the 5′ end, the 3′ end with unpaired CCA bases (amino acid attachment site), regions of intramolecular base pairing, loops, and the

anticodon loop with the anticodon. (In the actual three-dimensional structure t-RNA looks like an inverted L.)
Adapter molecule: t-RNA reads the code on m-RNA through its anticodon (complementary to the codon) and at the same time carries the specific amino acid at its 3′ end; thus it links (adapts) the language of nucleotides to that of amino acids and brings the correct amino acid to the ribosome. For every amino acid there is a specific t-RNA.
Anticodon for codon 5′-UGG-3′: 3′-ACC-5′ (antiparallel and complementary: U–A, G–C, G–C).
t-RNA binding sites of the ribosome: P site (peptidyl t-RNA site), A site (aminoacyl t-RNA site) and E site (exit site).
The initiator charged t-RNA (carrying activated methionine) directly enters and occupies the P site; the A site remains vacant to receive the next charged t-RNA.



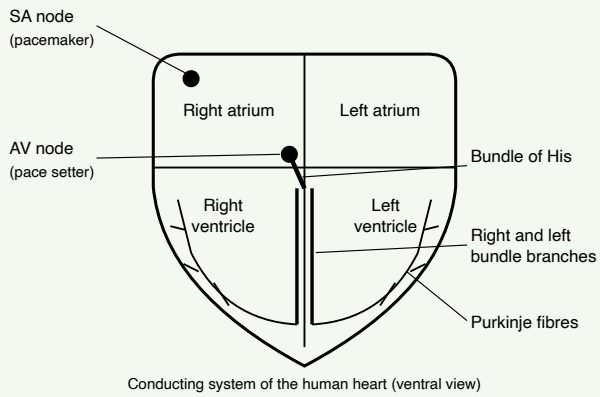
Cloverleaf (2-D) structure of t-RNA

Marking: Labelled cloverleaf diagram (5′ end, CCA 3′ end, anticodon loop, base pairing) – 1½ marks · Adapter role explained – 1 mark · Anticodon 3′-ACC-5′ – ½ mark · P, A and E sites named – ½ mark · Initiator t-RNA in the P site – ½ mark

Examiner tip: Write the anticodon antiparallel to the codon and mark its 3′ and 5′ ends.

Q.29 A heart that is transplanted into a patient continues to beat rhythmically even though its nerves have been cut. Draw a neat labelled diagram of the conducting system of the human heart. Trace the path of the cardiac impulse through it. Why is the SA node called the pacemaker, and how do both ventricles come to contract at the same time?

Answer (4 marks)
Diagram: conducting (nodal) tissue – SA node in the upper right corner of the right atrium (at the base of the opening of the superior vena cava), AV node in the right atrial wall near the base of the interatrial septum, bundle of His passing into the interventricular septum, right and left bundle branches, and Purkinje fibres in the ventricular walls.
The heart is myogenic – it generates its own contraction through this nodal tissue, independent of nervous input; hence a transplanted heart keeps beating.
Path of impulse: SA node → atrial walls (atria contract – atrial systole) → AV node → bundle of His → right and left bundle branches → Purkinje fibres → ventricular muscles (ventricular systole).
SA node is called the pacemaker because it has the power of generating a new wave of contraction and sets the pace (rate) of the heart beat. (The AV node is called the pace setter.)
The bundle of His and the Purkinje fibres spread the impulse quickly through the walls of both ventricles, so both ventricles contract simultaneously.



Conducting system of the human heart (ventral view)

Marking: Labelled diagram (SA node, AV node, bundle of His, bundle branches, Purkinje fibres) – 1½ marks · Correct sequence of the impulse – 1 mark · Myogenic / pacemaker explained – 1 mark · Simultaneous contraction of ventricles – ½ mark

Examiner tip: Place the SA node near the opening of the superior vena cava and the AV node near the interatrial septum; both are in the right atrium.

Q.30 A newly dug village pond is left undisturbed for several hundred years and is finally covered by a forest. (a) Name the type of succession. (b) Describe the sequence of stages, naming one plant typical of each stage. (c) Define 'pioneer species' and 'climax community'. (d) Why would a burnt forest return to its climax much faster than this pond?

Answer (4 marks)

(a) Primary succession in water – hydrarch succession (hydrosere); the series progresses from hydric to mesic conditions.

(b) Stages:

1. Phytoplankton stage (pioneers – small phytoplankton)
2. Rooted submerged plants – *Hydrilla*
3. Rooted floating angiosperms – lotus
4. Free-floating plants – *Pistia*
5. Reed swamp – *Typha*
6. Marsh meadow – *Cyperus*
7. Scrub – *Alnus*
8. Climax forest – *Quercus*

With time the water body is converted into land.

(c) Pioneer species: the species that first invade a bare area (here phytoplankton). Climax community: the final stable community of a sere, which remains stable as long as the environment remains unchanged; all successions proceed to a similar (mesic) climax.

(d) A burnt forest undergoes secondary succession. Since soil (with seeds and other propagules) is already present, succession is much faster and the climax is reached more quickly; primary succession needs thousands of years because soil must first be formed.

Marking: Hydrarch / primary succession – ½ mark · Sequence of stages with examples – 1½ marks · Pioneer and climax defined – 1 mark · Secondary succession faster (soil present) – 1 mark

Examiner tip: Write the stages in the correct order from water to forest; examples must match the stages.

Q.31 (a) Name the four major causes of loss of biodiversity known as the 'Evil Quartet' and give one example of each. (b) In a coastal creek polluted by an industry, the mercury content measured (hypothetical values) was: water 0.00001 ppm, zooplankton 0.05 ppm, small fish 0.6 ppm, large fish 3 ppm and fish-eating birds 20 ppm. Name this phenomenon and explain why the concentration is highest in the birds. Name one other substance that behaves in the same way.

Answer (4 marks)

(a) The Evil Quartet:

1. Habitat loss and fragmentation – e.g. loss of tropical rain forests; the Great Indian Bustard (Maldhok) was lost from Maharashtra by habitat loss and hunting.
2. Over-exploitation – e.g. extinction of the Dodo, Steller's sea cow and passenger pigeon.
3. Alien species invasion – e.g. Nile perch introduced in Lake Victoria harmed about 200 local cichlid species; carrot grass (*Parthenium*), *Lantana*, water hyacinth; African catfish *Clarias gariepinus* in India.
4. Co-extinctions – when organisms are associated in an obligatory way, extinction of one leads to loss of the associate, e.g. extinction of a host fish causes extinction of its unique parasites; co-evolved plants and pollinators face the same threat.

(b) Biological magnification (biomagnification): certain pollutants get accumulated in tissues in increasing concentration along the food chain (successive trophic levels).

Such pollutants are non-degradable – they are neither metabolised nor excreted, so they accumulate in the tissues and are passed on to the next trophic level. Each higher consumer eats many organisms of the lower level, so the concentration rises at every step and is highest in the top consumers – the fish-eating birds (20 ppm, i.e. 2 million times the level in water).

Other substance: DDT.

Marking: Four causes – ½ mark each with example (2 marks) · Biomagnification named – ½ mark · Reason: non-degradable, not metabolised or excreted, passed up the food chain – 1 mark · DDT – ½ mark

Examiner tip: Give an example for each cause; just listing the four names earns only half the marks of part (a).

All the best for your exam!