Biology (044)

CBSE Class 12 Board Examination 2027 – Practice Paper No. 1

Model Answer Paper

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

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

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

1 The cells in the leaf of a flowering plant contain 18 chromosomes each. How many chromosomes will be present in (i) a synergid of its embryo sac and (ii) a cell of the endosperm of its seed?

(A) 9 and 18 (B) 18 and 27

(C) 9 and 27 (D) 18 and 36

Answer (1 mark)
(C) 9 and 27
Leaf cells are diploid (2n = 18), so n = 9. The synergid is a cell of the haploid female gametophyte (n = 9); the endosperm develops from the triploid primary endosperm nucleus (3n = 27).

2 An ultrasound scan on day 14 of a regular 28-day menstrual cycle shows that the Graafian follicle of a woman has just ruptured and released the ovum. This rupture was induced by a rapid rise, a little earlier, in the level of

(A) progesterone secreted by the corpus luteum (B) luteinising hormone (LH)

(C) hCG secreted by the placenta (D) relaxin

Answer (1 mark)
(B) luteinising hormone (LH)
The rapid secretion of LH reaching its maximum in the middle of the cycle (LH surge) induces rupture of the Graafian follicle and thereby ovulation.

3 At an IVF clinic, an embryo that had already reached the 16-celled stage in the laboratory was transferred into the mother's body to complete its development. Identify the technique and the site of transfer.

(A) ZIFT – fallopian tube (B) GIFT – fallopian tube

(C) IUI – uterus (D) IUT – uterus

Answer (1 mark)
(D) IUT – uterus
Zygotes or early embryos with up to 8 blastomeres are transferred into the fallopian tube (ZIFT); embryos with more than 8 blastomeres are transferred into the uterus (intra-uterine transfer, IUT).

4 A man with blood group AB marries a woman with blood group O. Which blood groups are possible among their children?

(A) A and B only
(B) AB and O only
(C) A, B and AB only
(D) A, B, AB and O

Answer (1 mark)
(A) A and B only
Man I^AI^B gives gametes I^A or I^B; woman ii gives only i. Children are I^Ai (group A) or I^Bi (group B).

5 A double-stranded DNA segment is 1500 base pairs long and 30 per cent of its bases are thymine. What is the total number of hydrogen bonds holding its two strands together?

(A) 3000
(B) 3600
(C) 3900
(D) 4500

Answer (1 mark)
(B) 3600
Total bases = 3000; T = A = 30% = 900 each, so there are 900 A=T pairs. G = C = 20% = 600 each, so there are 600 G≡C pairs.
H-bonds = 900 × 2 + 600 × 3 = 1800 + 1800 = 3600.

6 In a mutant strain of *E. coli*, the repressor protein made by the *i* gene can still bind to the operator but can no longer bind to the inducer. If this strain is grown in a medium containing lactose as the only sugar,

(A) the repressor will be inactivated by lactose and the lac operon will be switched on.
(B) RNA polymerase will bind to the operator and transcribe the *z*, *y* and *a* genes.
(C) the repressor will remain bound to the operator, so the *z*, *y* and *a* genes will not be transcribed.
(D) the operon will be switched on but only the *a* gene will be expressed.

Answer (1 mark)
(C) the repressor will remain bound to the operator, so the *z*, *y* and *a* genes will not be transcribed.
The operon is switched on only when the inducer binds the repressor and inactivates it. Since this repressor cannot bind the inducer, it keeps blocking the operator and RNA polymerase cannot transcribe the structural genes.

7 In a population that is in Hardy–Weinberg equilibrium for a gene with two alleles, the frequency of homozygous recessive individuals is 0.16. What is the frequency of heterozygous individuals?

(A) 0.16
(B) 0.24
(C) 0.48
(D) 0.36

Answer (1 mark)
(C) 0.48
$q^2 = 0.16$, so q = 0.4 and p = 1 − 0.4 = 0.6. Frequency of heterozygotes = 2pq = 2 × 0.6 × 0.4 = 0.48.

8 A health worker explains to villagers how malaria spreads. Which of the following statements is correct?

(A) *Plasmodium* enters the human body as sporozoites through the bite of an infected female *Anopheles* mosquito.

(B) *Plasmodium* enters the human body as gametocytes through the bite of an infected female *Anopheles* mosquito.

(C) *Plasmodium* enters the human body as sporozoites through the bite of an infected male *Anopheles* mosquito.

(D) *Plasmodium* enters the human body as merozoites through contaminated drinking water.

Answer (1 mark)
(A) *Plasmodium* enters as sporozoites (the infectious form) through the bite of an infected female *Anopheles* mosquito. Gametocytes develop in human RBCs and are taken up by the mosquito, not injected into humans.

9 A farm worker bitten by a cobra is given an injection of anti-venom at the hospital. This injection provides

(A) active immunity, because the body makes antibodies against the venom

(B) passive immunity, because it contains preformed antibodies against the venom

(C) active immunity, because it contains preformed antibodies against the venom

(D) passive immunity, because it stimulates the formation of memory cells

Answer (1 mark)
(B) passive immunity, because it contains preformed antibodies against the venom. A quick response is needed for a snakebite, so ready-made antibodies are injected (passive immunisation).

10 Match the microbes in Column I with their products in Column II and select the correct option.

Column I (Microbe)	Column II (Product)
P. *Monascus purpureus*	(i) Cyclosporin A
Q. *Streptococcus*	(ii) Streptokinase
R. *Trichoderma polysporum*	(iii) Statins
S. *Propionibacterium sharmanii*	(iv) Swiss cheese

(A) P-(i), Q-(ii), R-(iii), S-(iv)

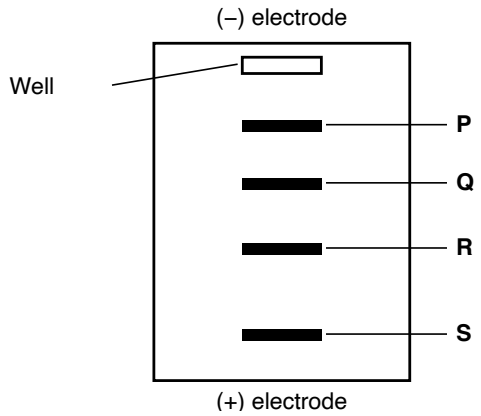
(B) P-(iii), Q-(i), R-(ii), S-(iv)

(C) P-(ii), Q-(iii), R-(i), S-(iv)

(D) P-(iii), Q-(ii), R-(i), S-(iv)

Answer (1 mark)
(D) P-(iii), Q-(ii), R-(i), S-(iv)
Statins (blood-cholesterol lowering) – yeast *Monascus purpureus*; streptokinase (clot buster) – *Streptococcus*; cyclosporin A (immunosuppressant) – fungus *Trichoderma polysporum*; the large holes of Swiss cheese – CO_2 from *Propionibacterium sharmanii*.

11 The figure given below shows an agarose gel after electrophoresis of a DNA sample cut with a restriction enzyme. Which band (P, Q, R or S) contains the smallest DNA fragments?



(A) P
(B) Q
(C) R
(D) S

For visually impaired candidates (in lieu of the above):
In agarose gel electrophoresis, DNA fragments move towards the _____ and the smaller fragments move _____.
(A) cathode; farther
(B) anode; farther
(C) anode; a shorter distance
(D) cathode; a shorter distance

Answer (1 mark)
(D) S
DNA fragments are negatively charged and move from the well (near the negative electrode) towards the anode; the smaller the fragment, the farther it moves through the gel matrix. S is farthest from the well.
Visually impaired alternative: (B) anode; farther.

12 A wetland near Bhigwan had a population of 500 painted storks at the beginning of a year. During that year, 45 of these storks died. What was the death rate of this population for that year?
(A) 0.09 individuals per stork per year
(B) 0.45 individuals per stork per year
(C) 11.1 individuals per stork per year
(D) 0.9 individuals per stork per year

Answer (1 mark)
(A) 0.09 individuals per stork per year
Death rate is a per capita rate = number of deaths ÷ population = 45 ÷ 500 = 0.09.

13 **Assertion (A):** Seeds produced by apomixis in a hybrid variety show segregation of the hybrid characters in the next generation.
Reason (R): In apomixis, an embryo develops in the seed without fertilisation.
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

Answer (1 mark)
(D) A is false but R is true.
Apomixis produces seeds without fertilisation, so there is no segregation of characters in the hybrid progeny – this is why apomictic hybrid seeds could be used by farmers year after year.

14 **Assertion (A):** The wings of a butterfly and the wings of a bird are analogous structures.
Reason (R): Analogous structures have the same anatomical structure but perform different functions.

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

Answer (1 mark)
(C) A is true but R is false.
Analogous structures are anatomically different but perform similar functions (convergent evolution). Same structure with different functions describes homologous organs.

15 **Assertion (A):** Bt cotton reduces the need to spray insecticides for controlling cotton bollworms.
Reason (R): Bt cotton carries the genes *cryIAc* and *cryIIAb*, whose protein products are toxic to cotton bollworms.

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

Answer (1 mark)
(A) Both A and R are true and R is the correct explanation of A.
The Cry proteins coded by *cryIAc* and *cryIIAb* kill bollworms that feed on the plant, so the crop protects itself and fewer insecticide sprays are needed.

16 **Assertion (A):** The pyramid of energy in an ecosystem is always upright.
Reason (R): In the sea, the pyramid of biomass is generally inverted.

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

Answer (1 mark)
(B) Both A and R are true but R is not the correct explanation of A.
The energy pyramid is always upright because some energy is lost as heat at every transfer to the next trophic level. The inverted biomass pyramid of the sea (fish biomass exceeds phytoplankton biomass) is a true fact but does not explain A.

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

17 Attempt either option A or B.

A. In a botanical garden, pollen grains of a sunflower plant and of a hibiscus plant both land on the stigma of a hibiscus flower. Only the hibiscus pollen grains germinate and produce pollen tubes. (i) What ability of the pistil does this show? (ii) How is the acceptance of one type of pollen and the rejection of the other brought about?

OR

B. Pollen grains recovered from lake sediments thousands of years old can still be identified by palynologists. (i) Name the substance responsible for this and give two of its properties. (ii) At which places on the pollen wall is this substance absent, and why is this important for the pollen grain?

Answer (2 marks)
A. (i) The pistil can recognise whether the pollen is of the right type (compatible – here hibiscus pollen of the same species) or of the wrong type (incompatible – sunflower pollen of another

species). Compatible pollen is accepted and post-pollination events leading to fertilisation are promoted; incompatible pollen is rejected by preventing pollen germination on the stigma or pollen-tube growth in the style.
(ii) Acceptance or rejection is the result of a continuous dialogue between the pollen grain and the pistil, mediated by chemical components of the pollen interacting with those of the pistil.
OR
B. (i) Sporopollenin, present in the exine. Properties (any two): one of the most resistant organic materials known; withstands high temperatures; withstands strong acids and alkalis; no enzyme that degrades it is known so far.
(ii) It is absent at the germ pores. During germination on the stigma, the pollen tube comes out through a germ pore, so these thin regions are essential for germination.

Marking: A: (i) Recognition of compatible/incompatible pollen with acceptance/rejection – 1 mark; (ii) chemical dialogue between pollen and pistil – 1 mark · OR B: (i) Sporopollenin – ½ mark, two properties – ½ mark; (ii) germ pores – ½ mark, pollen tube emerges through them – ½ mark

Examiner tip: In B, write 'exine' and 'germ pores' – vague answers like 'outer coat' or 'holes' lose the ½ mark.

18 The genetic material of a few viruses, such as the tobacco mosaic virus, is RNA, while most organisms use DNA. (i) Give two reasons, based on chemical structure, why DNA is a more stable genetic material than RNA. (ii) State one advantage that an RNA genome gives to such viruses.

Answer (2 marks)
(i) Any two: (a) every nucleotide of RNA has a 2'-OH group on the ribose, which makes RNA reactive, labile and easily degradable; DNA (deoxyribose) lacks it. (b) DNA has thymine (5-methyl uracil) in place of uracil, which gives additional stability. (c) DNA is double-stranded with complementary strands; even if the strands separate (e.g. on heating), they come together again under appropriate conditions.
(ii) RNA mutates at a faster rate, so viruses with RNA genomes and short life spans mutate and evolve faster (helping them adapt quickly).

Marking: Two structural reasons – ½ + ½ mark · Faster mutation/evolution of RNA viruses – 1 mark

Examiner tip: 'DNA is double-stranded' alone is not enough – mention the 2'-OH group of ribose; it is the most important reason.

19 The table below gives hypothetical antibody levels (arbitrary units) in the blood of a child after the first dose of a vaccine and after a booster dose of the same vaccine given some weeks later.

Days after the injection	0	7	14	21	28
After first dose	0	2	10	6	3
After booster dose	3	40	120	110	90

(i) Compare the two responses and name each. (ii) Explain why the response to the booster dose is different.

Answer (2 marks)
(i) After the first dose, antibody production is slow and of low intensity (peak only 10 units, falling quickly) – the primary immune response. After the booster, antibodies rise quickly to a much higher level (peak 120 units) and stay high – the secondary or anamnestic response.
(ii) The first dose (antigens of the pathogen) generates memory B-cells and T-cells. On the next exposure (booster), these memory cells recognise the antigen quickly and the body produces a highly intensified response with large amounts of antibodies – the body 'remembers' the first encounter.

Marking: Comparison with names primary and secondary/anamnestic – 1 mark · Memory B and T cells explanation – 1 mark

Examiner tip: Use figures from the table (10 vs 120 units) when comparing; 'booster is stronger' alone is too general.

20 Attempt either option A or B.

A. A crop-research laboratory wants to protect a vegetable crop from the root-knot nematode *Meloidogyne incognita*, using the strategy already used successfully in tobacco. (i) Name the strategy. (ii) Explain how it makes the transgenic plant resistant to the nematode.

OR

B. A doctor suspects HIV infection in a patient at a stage when the symptoms have not yet appeared. (i) Why are conventional methods such as serum and urine analysis not useful at this stage? (ii) Name two techniques used for early diagnosis and state the principle of any one of them.

Answer (2 marks)

A. (i) RNA interference (RNAi).

(ii) Using *Agrobacterium* vectors, nematode-specific genes were introduced into the host plant in such a way that the host cells produce both sense and anti-sense RNA. These two complementary RNAs form double-stranded RNA (dsRNA), which starts RNAi and silences the specific mRNA of the nematode. The parasite therefore cannot survive in the transgenic host, which is protected.

OR

B. (i) Conventional methods detect a disease only after the pathogen has multiplied and symptoms appear; when the pathogen (bacteria/virus) is present in very low concentration, early detection is not possible.

(ii) Recombinant DNA technology-based tests, Polymerase Chain Reaction (PCR) and ELISA (any two). Principle: PCR amplifies even very small amounts of the pathogen's nucleic acid so that it can be detected; ELISA is based on the principle of antigen–antibody interaction (detecting the pathogen's antigens or the antibodies made against it).

Marking: A: (i) RNAi – ½ mark; (ii) sense + anti-sense RNA → dsRNA – 1 mark, silencing of nematode mRNA so parasite cannot survive – ½ mark · OR B: (i) Low concentration/no symptoms – ½ mark; (ii) two techniques – ½ mark, principle of one – 1 mark

Examiner tip: In A, mention that the silenced mRNA is the nematode's, not the plant's.

21 Attempt either option A or B.

A. Hypothetical results of collecting peppered moths from tree trunks in two areas of England in the year 1920 are given below.

Area	White-winged moths (%)	Dark-winged moths (%)
X – rural, unpolluted woodland	85	15
Y – woodland near factories	15	85

(i) Explain why dark-winged moths outnumber white-winged moths in area Y. (ii) Why would lichens be almost absent from tree trunks in area Y?

OR

B. A storm carried a few seeds of a wild plant species to an isolated island, where they grew into a new population. After many generations, the frequency of one allele in the island population was found to be very different from that in the original mainland population. (i) Name this effect and explain how it arises. (ii) Name any two other factors that disturb Hardy–Weinberg equilibrium.

Answer (2 marks)

A. (i) In area Y, smoke and soot from industries darkened the tree trunks and the white lichens did not grow. White-winged moths were easily seen against the dark bark and were picked off by predators (birds), while dark-winged moths were camouflaged and survived to reproduce.

Thus natural selection favoured the dark (melanised) form.
(ii) Lichens cannot grow in polluted areas; they are sensitive to industrial pollution and are used as pollution indicators.
OR
B. (i) Founder effect. When a small sample of a population moves to a new place, the allele frequencies in the new population may change by chance (genetic drift); the original drifted population becomes the founders, and if the change is large they may even become a different species.
(ii) Any two: gene migration (gene flow), mutation, genetic recombination, natural selection.

Marking: A: (i) Soot-darkened bark + predation of conspicuous white moths/ survival of camouflaged dark moths – 1 mark; (ii) lichens as pollution indicators – 1 mark · OR B: (i) Founder effect – ½ mark, explanation by chance/genetic drift – ½ mark; (ii) two factors – ½ + ½ mark

Examiner tip: Industrial melanism is selection of an existing variation – never write that moths 'turned dark' to hide.

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

22 (a) How many sperms will be formed from 30 primary spermatocytes, and how many ova from 30 primary oocytes? Give the reason for the difference.
(b) In a man, the Leydig cells are not functional. How would spermatogenesis be affected? Which cells of the testis, acted upon by FSH, help in spermiogenesis?

Answer (3 marks)
(a) Each primary spermatocyte completes meiosis to form four haploid spermatids, which change into four sperms: 30 × 4 = 120 sperms.
Each primary oocyte forms only one ovum: 30 primary oocytes give 30 ova.
Reason: in oogenesis the meiotic divisions are unequal – the first division gives a large haploid secondary oocyte and a tiny first polar body, and the second division gives the ovum (ootid) and a second polar body. Polar bodies do not form gametes, whereas all four products of a primary spermatocyte become sperms.
(b) LH acts on the Leydig cells and stimulates the synthesis and secretion of androgens, which stimulate spermatogenesis. If Leydig cells do not function, androgens will not be secreted and spermatogenesis will be hindered.
FSH acts on the Sertoli cells, which secrete factors that help in spermiogenesis.

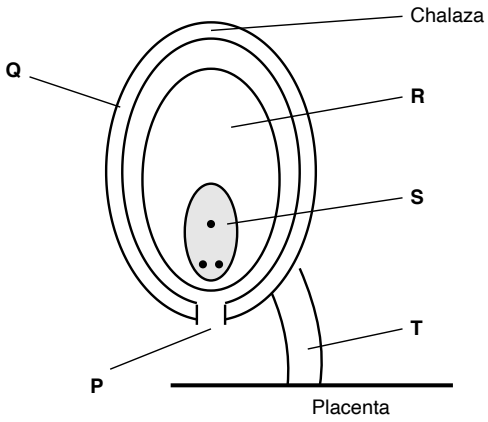
Marking: 120 sperms – ½ mark · 30 ova – ½ mark · Reason (unequal division/polar bodies) – 1 mark · No androgens → spermatogenesis affected – ½ mark · Sertoli cells – ½ mark

Examiner tip: Say why: 'polar bodies' must appear in the reason, not just 'one ovum is formed'.

23 Study the diagram of an anatropous ovule given below.

(a) Name the parts labelled P, R, S and T.

(b) After fertilisation, what do the structure Q and the whole ovule develop into?



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

(a) Name the following parts of an anatropous ovule: (i) the opening through which the pollen tube usually enters; (ii) the mass of cells enclosed within the integuments; (iii) the female gametophyte located in the nucellus; (iv) the stalk that attaches the ovule to the placenta.

(b) After fertilisation, what do the integuments and the whole ovule develop into?

Answer (3 marks)

(a) P – micropyle; R – nucellus; S – embryo sac (female gametophyte); T – funicle.

(b) Q is the outer integument; the integuments harden to form the tough protective seed coat(s) (the micropyle remains as a small pore in the seed coat). The ovule develops into the seed.

Visually impaired alternative: (a) (i) micropyle; (ii) nucellus; (iii) embryo sac; (iv) funicle. (b) Integuments → seed coat; ovule → seed.

Marking: Four correct names – ½ mark each (2 marks) · Integument → seed coat – ½ mark · Ovule → seed – ½ mark

Examiner tip: Ovary forms the fruit, ovule forms the seed – mixing these up is the most common error.

24 Seema has normal colour vision, but her father was colour blind. She marries Ramesh, who has normal colour vision.

(a) Write the genotypes of Seema and Ramesh and work out the cross to show the genotypes of their children.

(b) What percentage of their sons and of their daughters are expected to be colour blind?

(c) Why is colour blindness much more common in men than in women?

Answer (3 marks)

(a) Colour blindness is a sex-linked recessive trait. Seema received an X^c from her colour-blind father, so she is a carrier: X^cX. Ramesh: XY.

Cross: $X^cX \times XY$

Gametes	X (from Ramesh)	Y (from Ramesh)
X^c (from Seema)	X^cX – carrier daughter	X^cY – colour-blind son
X (from Seema)	XX – normal daughter	XY – normal son

(b) Sons: 50% colour blind. Daughters: 0% colour blind (50% are carriers with normal vision).

(c) Males have only one X chromosome, so a single recessive allele (X^cY) causes the disorder. A female is colour blind only if both her X chromosomes carry the allele, i.e. her mother is at least a carrier and her father is colour blind, which is rare.

Marking: Correct parental genotypes – ½ mark · Cross with correct offspring genotypes – 1 mark · Percentages for sons and daughters – ½ + ½ mark · Reason – ½ mark

Examiner tip: Show X and Y in every genotype; writing 'Cc' as for an autosomal gene gets no credit.

25 A part of the template strand of a transcription unit in a eukaryote is: 3'–TACCGTAAGCTT–5'
(a) Write the sequence of the mRNA transcribed from it and of the coding strand, showing polarity.
(b) When the mature mRNA of this gene was isolated from the cytoplasm, three differences from the gene were noticed: (i) some internal stretches present in the gene were missing in the mRNA; (ii) an unusual nucleotide was present at its 5'-end; (iii) it ended in a long stretch of adenylate residues that is not coded by the gene. Name and explain the process responsible for each observation.

Answer (3 marks)
(a) mRNA: 5'–AUGGCAUUCGAA–3'
Coding strand: 5'–ATGGCATTCGAA–3' (same as mRNA except T in place of U; it has the same polarity as the mRNA).
(b) The primary transcript (hnRNA) is processed in the nucleus:
(i) Splicing: the hnRNA contains both exons and introns; the introns are removed and the exons are joined together in a defined order.
(ii) Capping: an unusual nucleotide, methyl guanosine triphosphate, is added to the 5'-end of the hnRNA.
(iii) Tailing: adenylate residues (200–300) are added at the 3'-end in a template-independent manner (so they are not coded by the gene).
The fully processed hnRNA is now mRNA and is transported out of the nucleus for translation.

Marking: mRNA with polarity – ½ mark · Coding strand with polarity – ½ mark · Splicing – 1 mark · Capping – ½ mark · Tailing – ½ mark

Examiner tip: The mRNA is complementary to the template, written 5'→3'; reversing the polarity costs the ½ mark.

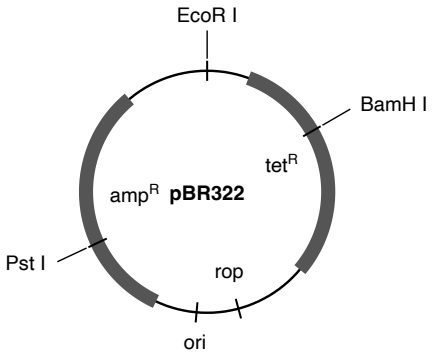
26 Three patients from a village visit a primary health centre.
Patient P: sustained high fever (39 °C to 40 °C), weakness, stomach pain, constipation and loss of appetite; the Widal test is positive.
Patient Q: internal bleeding, muscular pain, fever, anaemia and blockage of the intestinal passage; eggs of a roundworm are seen in the stool.
Patient R: dry, scaly, intensely itching lesions in the skin folds of the groin and between the toes.
For each patient, name the disease and its causative organism, and state how the infection is acquired.

Answer (3 marks)
P – Typhoid, caused by the bacterium *Salmonella typhi*. It enters the small intestine through food and water contaminated with the pathogen (spreads from infected persons/carriers).
Q – Ascariasis, caused by the intestinal roundworm *Ascaris*. Its eggs are passed out with the faeces of infected persons and contaminate soil, water and plants; a healthy person gets infected through contaminated water, vegetables and fruits.
R – Ringworm, caused by fungi of the genera *Microsporum*, *Trichophyton* or *Epidermophyton*. It is acquired from soil or by using towels, clothes or the comb of an infected person; heat and moisture help the fungi grow in skin folds.

Marking: For each patient: disease and pathogen – ½ mark, mode of infection – ½ mark (3 × 1 = 3 marks)

Examiner tip: Name the pathogen at genus level at least (*Salmonella typhi*, *Ascaris*); 'bacteria' or 'worm' alone gets no credit.

27 The figure shows the *E. coli* cloning vector pBR322. A scientist ligates a foreign gene into the Pst I site of this vector and uses the ligation mixture to transform *E. coli* cells.
(a) Which antibiotic resistance will the recombinant plasmids lose, and which will they keep? Why?
(b) Explain how the scientist can separate recombinants from non-recombinants using ampicillin and tetracycline.
(c) Why is this method of selection considered cumbersome? Name the alternative selectable marker based on colour production.

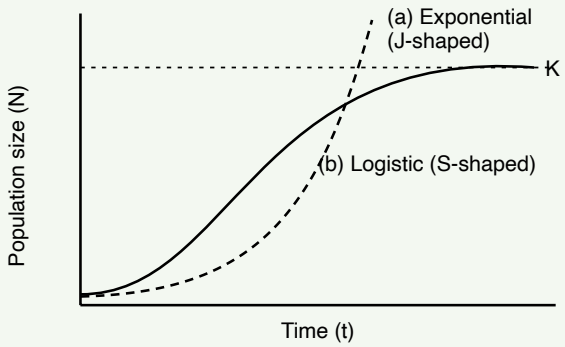


Answer (3 marks)
(a) The Pst I site lies within the ampicillin resistance gene (amp^R). Insertion of the foreign DNA inactivates this gene (insertional inactivation), so recombinant plasmids lose ampicillin resistance; the tetracycline resistance gene (tet^R) is intact, so they keep tetracycline resistance.
(b) The transformants are first plated on a medium containing tetracycline – all cells carrying the plasmid (recombinant or not) grow, because tet^R is intact. These colonies are then transferred (replica plated) to a medium containing ampicillin. Recombinants grow on tetracycline but not on ampicillin; non-recombinants grow on both antibiotics.
(c) It requires simultaneous plating on two plates having different antibiotics. Alternative: inserting the DNA within the coding sequence of the enzyme β-galactosidase; in the presence of a chromogenic substrate, non-recombinant colonies are blue, while recombinant colonies (β-galactosidase gene inactivated) produce no colour.
Marking: (a) Loss of amp resistance due to insertional inactivation, tet resistance kept – 1 mark · (b) Correct plating logic (tetracycline first, then ampicillin) – 1 mark · (c) Reason – ½ mark, β-galactosidase/blue-white selection – ½ mark
Examiner tip: Recombinants are the colonies that grow on tetracycline but NOT on ampicillin here – the inactivated gene decides which antibiotic kills them.

28 A herd of spotted deer was introduced into a forest reserve where the carrying capacity (K) for this species is 800 deer. The intrinsic rate of natural increase (r) is 0.3 per year.
(a) Write the Verhulst–Pearl logistic growth equation.
(b) Calculate the rate of population growth (dN/dt) when the population (N) is 400 and when it is 600. At which of these two sizes is the population growing faster?
(c) What will be the growth rate when N reaches 800? Why is the logistic model considered more realistic than the exponential model?

Answer (3 marks)
(a) $dN/dt = rN\,(K - N)/K$, where N = population density at time t, r = intrinsic rate of natural increase, K = carrying capacity.
(b) N = 400: $dN/dt = 0.3 \times 400 \times (800 - 400)/800 = 120 \times 0.5 = 60$ deer per year.
N = 600: $dN/dt = 0.3 \times 600 \times (800 - 600)/800 = 180 \times 0.25 = 45$ deer per year.
The population grows faster at N = 400.

(c) At N = K = 800, (K − N)/K = 0, so dN/dt = 0 – the population stops growing (asymptote). Resources for growth of most animal populations are finite and become limiting sooner or later, so no population can grow exponentially for long; hence the logistic (sigmoid) model is more realistic.



Marking: Equation – ½ mark · dN/dt at 400 – ½ mark, at 600 – ½ mark, faster at 400 – ½ mark · dN/dt = 0 at K – ½ mark · Reason (finite resources) – ½ mark

Examiner tip: Use (K − N)/K as a fraction; many students multiply by (K − N) and get absurd numbers.

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

29 Read the passage and answer the questions that follow.

An ASHA worker conducts an awareness session for women and couples at a primary health centre in a village. Rekha, whose first child is one year old, wants to space her next pregnancy by about three years with an effective, reversible method that she need not remember every day. A couple, Mohan and his wife Kavita, have completed their family and want to know about permanent methods of birth control. The worker also explains that sexually transmitted infections (STIs) should be detected early, and that in India pregnancy can be medically terminated only under conditions laid down by law.

A. Suggest a suitable method for Rekha and state how it prevents conception. (1)

B. Name the permanent method available to Mohan and to Kavita, and briefly describe what is done in each. (2)

Attempt either subpart C or D.

C. According to the MTP (Amendment) Act, 2017, who must give the opinion for terminating a pregnancy (i) within the first 12 weeks and (ii) after 12 weeks but before 24 weeks? (1)

OR

D. Name any two STIs that are completely curable if detected early and treated properly. (1)

Answer (4 marks)

A. An intra-uterine device (IUD) – ideal for women who want to delay pregnancy and/or space children – e.g. a copper-releasing IUD such as Copper-T (CuT), inserted by a doctor or trained nurse into the uterus. Cu ions released suppress sperm motility and the fertilising capacity of sperms (IUDs also increase phagocytosis of sperms within the uterus).

B. Mohan (male) – vasectomy: a small part of the vas deferens is removed or tied up through a small incision on the scrotum, so sperms cannot be transported.

Kavita (female) – tubectomy: a small part of the fallopian tube is removed or tied up through a small incision in the abdomen or through the vagina, so the ovum cannot meet sperms.

C. (i) Within the first 12 weeks – the opinion of one registered medical practitioner. (ii) After 12 weeks but before 24 weeks – two registered medical practitioners must be of the opinion, formed in good faith, that the required grounds exist.

OR

D. Any two: gonorrhoea, syphilis, chlamydiasis, genital warts, trichomoniasis. (Hepatitis-B, genital herpes and HIV infections are not completely curable.)

Marking: A: IUD/Copper-T – ½ mark, action of Cu ions – ½ mark · B: vasectomy with description – 1 mark; tubectomy with description – 1 mark · C: one RMP / two RMPs – ½ + ½ mark OR D: two curable STIs – ½ + ½ mark

Examiner tip: Sterilisation does not stop gamete formation; it only blocks gamete transport – write it that way.

30 Read the passage and answer the questions that follow.

A sewage treatment plant of a city treats the waste water of a large residential area. A student recorded the following hypothetical BOD values of water samples taken at different stages of the plant.

Sample	BOD (mg/L)
Raw sewage entering the plant	350
After primary treatment	230
Effluent after secondary treatment, from the settling tank	20

The student also noticed that a part of the sludge from the settling tank was pumped back into the aeration tank, and the rest was sent to large closed tanks that produced a gas used to run the plant's generator.

A. Calculate the percentage reduction in BOD brought about by secondary treatment, and name the organisms responsible for it. (1)

B. What are 'flocs'? Explain why a part of the activated sludge is returned to the aeration tank and what happens to the remaining sludge. (2)

Attempt either subpart C or D.

C. What does BOD measure, and what does a high BOD of the raw sewage indicate? (1)

OR

D. Name the group of bacteria that produce methane in the closed tanks, give one example, and name one other natural habitat where they are found. (1)

Answer (4 marks)

A. Reduction = (230 − 20)/230 × 100 = 210/230 × 100 ≈ 91.3%. It is brought about by aerobic microbes (bacteria with fungal filaments forming flocs): in the aeration tanks, the primary effluent is constantly agitated and air is pumped in, allowing vigorous growth of useful aerobic microbes into flocs. While growing, these microbes consume the major part of the organic matter in the effluent, which significantly reduces the BOD (from 230 to 20 mg/L).

B. Flocs are masses of bacteria associated with fungal filaments forming mesh-like structures. Once BOD is reduced, the effluent is passed into a settling tank where the flocs sediment as activated sludge. A small part of this sludge is pumped back into the aeration tank to serve as the inoculum (to seed fresh sewage with microbes). The remaining major part is pumped into large tanks called anaerobic sludge digesters, where other kinds of bacteria, growing anaerobically, digest the bacteria and fungi in the sludge and produce a mixture of gases such as methane, hydrogen sulphide and carbon dioxide – biogas.

C. BOD (biochemical oxygen demand) is the amount of oxygen that would be consumed if all the organic matter in one litre of water were oxidised by bacteria; it is a measure of the organic matter present. A high BOD means the raw sewage has a large amount of organic matter and is highly polluting.

OR

D. Methanogens, e.g. *Methanobacterium*. They are also found in the rumen of cattle (and in anaerobic sludge).

Marking: A: ≈ 91% with working – ½ mark; aerobic microbes/flocs consuming organic matter – ½ mark · B: definition of flocs – ½ mark; sludge returned as inoculum – ½ mark; anaerobic sludge digesters → biogas – 1 mark · C: definition of BOD – ½ mark, high organic matter/polluting – ½ mark OR D: methanogens + example – ½ mark, rumen of cattle – ½ mark

Examiner tip: Secondary treatment is biological (aerobic, then anaerobic for sludge); do not call the aeration tank 'anaerobic'.

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

31 Attempt either option A or B.

A. (i) A pea plant producing round, yellow seeds was crossed with a plant producing wrinkled, green seeds. The progeny had round yellow, round green, wrinkled yellow and wrinkled green seeds in the ratio 1 : 1 : 1 : 1. Name this type of cross, give the genotype of the round, yellow-seeded parent and show the cross with gametes. (2)

(ii) In *Drosophila*, a female heterozygous for two genes, which received the dominant alleles A and B from one parent and the recessive alleles a and b from the other, was crossed with an aabb male. The progeny obtained were:

Phenotype of progeny	Number
Dominant for both genes (A, B)	418
Recessive for both genes (a, b)	402
Dominant A, recessive b	92
Recessive a, dominant B	88

Calculate the recombination frequency between the two genes. Why does this result differ from the 1 : 1 : 1 : 1 ratio in (i)? How is the recombination frequency used by geneticists? (3)

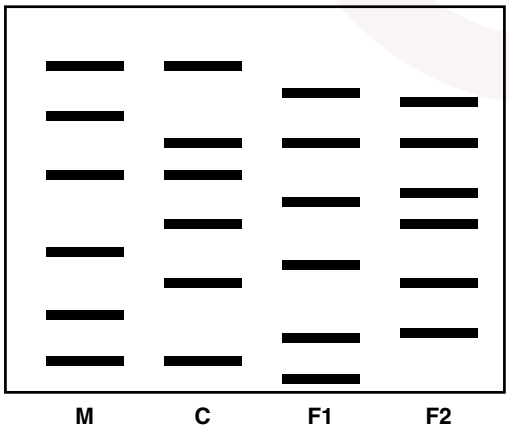
OR

B. In a disputed parentage case, DNA fingerprints of the mother (M), the child (C) and two men (F1 and F2) were prepared. The bands obtained are shown in the figure given below.

(i) What is the basis of DNA fingerprinting? Name the type of DNA sequence used as a probe. (1)

(ii) List the steps of the DNA fingerprinting technique (Southern blot hybridisation). (2)

(iii) Which man is the biological father of the child? Justify your answer using the bands. (2)



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

In place of (iii): The child's DNA fingerprint has six bands. Three of them match bands of the mother. The other three bands are all present in the fingerprint of man F2, while only one of them is present in that of man F1. Which man is the biological father? Justify. (2)

Answer (5 marks)

A. (i) Test cross (a dihybrid test cross with the double recessive parent). Let R/r = round/wrinkled and Y/y = yellow/green. The 1 : 1 : 1 : 1 ratio shows that the round, yellow parent is heterozygous for both genes: RrYy.

RrYy (round yellow) × rryy (wrinkled green)
Gametes: RY, Ry, rY, ry × ry
Progeny: RrYy (round yellow) : Rryy (round green) : rrYy (wrinkled yellow) : rryy (wrinkled green) = 1 : 1 : 1 : 1.
(ii) Total progeny = 418 + 402 + 92 + 88 = 1000. Recombinants (new combinations) = 92 + 88 = 180.
Recombination frequency = 180/1000 × 100 = 18%.
The two genes in *Drosophila* are located on the same chromosome (linked), so parental combinations (418 + 402 = 82%) are far more frequent than recombinants; recombinants arise only by crossing over between them. In pea (i), the two genes assort independently (on different chromosomes), so all four types are equal.
Use: the frequency of recombination between gene pairs on the same chromosome is a measure of the distance between them; Sturtevant used it to map the positions of genes on the chromosome (genetic maps). Tightly linked genes show low recombination, loosely linked genes show higher recombination.
OR
B. (i) DNA fingerprinting identifies differences in specific regions of repetitive DNA (satellite DNA) which show a high degree of polymorphism; the copy number of the repeats varies from person to person and is inherited from the parents. The probe used is VNTR (Variable Number of Tandem Repeats, a mini-satellite).
(ii) Steps: (1) isolation of DNA; (2) digestion of DNA by restriction endonucleases; (3) separation of DNA fragments by gel electrophoresis; (4) transferring (blotting) the separated fragments to synthetic membranes such as nitrocellulose or nylon; (5) hybridisation using a labelled VNTR probe; (6) detection of hybridised fragments by autoradiography.
(iii) F2 is the biological father. A child inherits half of its bands from the mother and half from the father. Three of the child's bands are shared with the mother (M); the remaining three bands of the child are all present in F2, while F1 has only one of them. So F1 cannot have contributed the paternal bands.

Marking: A (i): test cross – ½ mark; genotype RrYy – ½ mark; cross with gametes and ratio – 1 mark · A (ii): RF = 18% with working – 1 mark; linkage/crossing over explanation – 1 mark; use for gene mapping (distance) – 1 mark · OR B (i): polymorphism of repetitive/satellite DNA – ½ mark; VNTR probe – ½ mark · B (ii): six steps in order – 2 marks (any four correct steps – ½ mark each) · B (iii): F2 identified – 1 mark; justification from bands – 1 mark

Examiner tip: In A, recombinants are the NEW combinations (A with b, a with B), not the larger classes. In B, compare only the child's non-maternal bands.

32 Attempt either option A or B.

A. A biotechnology laboratory has to amplify a gene of interest and then introduce it into *E. coli*.

(i) Name the three steps of each cycle of the polymerase chain reaction (PCR). Why is the DNA polymerase used in PCR isolated from *Thermus aquaticus*? (2)

(ii) If the reaction starts with 5 copies of the target DNA, how many copies will be present after 10 cycles (assuming every cycle doubles the DNA)? (1)

(iii) *E. coli* cells cannot normally take up DNA. Explain how they are made competent and how recombinant DNA is then forced into them. (2)

OR

B. (i) Describe the structure of human insulin and how its pro-hormone is processed in the body. (1½)

(ii) Explain how Eli Lilly produced human insulin using recombinant DNA technology in 1983. (1½)

(iii) Why was insulin from the pancreas of slaughtered cattle and pigs not ideal for diabetic patients? (1)

(iv) What is biopiracy? Give one example related to India. (1)

Answer (5 marks)

A. (i) Each PCR cycle has three steps: (1) denaturation of double-stranded DNA at high temperature; (2) primer annealing – two sets of primers (small, chemically synthesised oligonucleotides complementary to the regions of DNA) bind to the template; (3) extension of primers by DNA polymerase using the nucleotides provided.

The DNA polymerase from the bacterium *Thermus aquaticus* (Taq polymerase) is thermostable – it remains active during the high temperature used for denaturation in every cycle, so repeated amplification is possible.

(ii) Copies after n cycles = initial copies × 2^n = 5 × 2^{10} = 5 × 1024 = 5120 copies.

(iii) DNA is a hydrophilic molecule and cannot pass through cell membranes. The bacterial cells are treated with a specific concentration of a divalent cation such as calcium, which increases the efficiency with which DNA enters the bacterium through pores in its cell wall. The cells are then incubated with the recombinant DNA on ice, placed briefly at 42 °C (heat shock), and put back on ice; this enables the bacteria to take up the recombinant DNA.

OR

B. (i) Insulin consists of two short polypeptide chains, chain A and chain B, linked together by disulphide bridges. In mammals, including humans, it is synthesised as a pro-hormone (pro-insulin) that contains an extra stretch called the C peptide; the C peptide is removed during maturation, so it is not present in mature insulin.

(ii) Eli Lilly prepared two DNA sequences corresponding to the A and B chains of human insulin and introduced them into plasmids of *E. coli* to produce the insulin chains. Chains A and B were produced separately, extracted and combined by creating disulphide bonds to form human insulin.

(iii) Insulin from an animal source caused some patients to develop allergy or other types of reactions to the foreign protein (and the supply from slaughtered animals was limited).

(iv) Biopiracy is the use of bio-resources (and related traditional knowledge) by multinational companies and other organisations without proper authorisation from the countries and people concerned and without compensatory payment. Example: in 1997 an American company got patent rights on Basmati rice (a 'new' variety derived from Indian farmers' varieties) through the US Patent and Trademark Office; attempts have also been made to patent uses of turmeric and neem.

Marking: A (i): three steps – 1½ marks (½ each); thermostable Taq polymerase – ½ mark · A (ii): $5 \times 2^{10} = 5120$ – 1 mark · A (iii): divalent cation (Ca^{2+}) treatment – 1 mark; ice – 42 °C heat shock – ice – 1 mark · OR B (i): A and B chains with disulphide bridges – ½ mark; pro-hormone with C peptide removed – 1 mark · B (ii): separate DNA sequences for A and B in E. coli plasmids – 1 mark; chains combined by disulphide bonds – ½ mark · B (iii): allergy/reaction to foreign protein – 1 mark · B (iv): definition – ½ mark; example – ½ mark

Examiner tip: In A(ii), the number of copies doubles every cycle – use 2^n, not 2n. In B(ii), the A and B chains were made separately, not as pro-insulin.

33 Attempt either option A or B.

A. A group of college students in Pune visited (P) a *devrai* (sacred grove) in the Western Ghats region of Maharashtra, (Q) a zoological park and (R) a facility storing seeds of different strains of crop plants.

(i) Classify P, Q and R as *in situ* or *ex situ* conservation and justify your classification. (1½)

(ii) Give one advantage of protecting species in P over keeping them in Q, and one situation in which conservation in Q or R becomes necessary. (1)

(iii) What is a biodiversity hotspot? Name the hotspot to which the Western Ghats belong and the other two hotspots that cover India's exceptionally rich biodiversity regions. (1½)

(iv) Name the technique by which gametes of threatened species can be preserved in a viable and fertile condition for long periods. (1)

OR

B. In a grassland ecosystem, the producers fix 30,000 kJ m^{-2} yr^{-1} of energy as gross primary productivity (GPP), and 40 per cent of the GPP is used up in their respiration.

(i) Calculate the net primary productivity (NPP). (1)

(ii) Assuming the 10 per cent law applies from the NPP of producers upward, calculate the energy available at the level of secondary carnivores in the food chain: grass → grasshopper → frog → snake. (1)

(iii) Draw a labelled pyramid of energy for this food chain showing the values. (1)

(iv) State any two limitations of ecological pyramids. (2)

Answer (5 marks)

A. (i) P (sacred grove) – in situ conservation: the species are protected in their natural habitat. Q (zoological park) and R (seed bank) – ex situ conservation: threatened animals and plants (or their seeds) are taken out of their natural habitat and placed in special settings where they are protected and given special care.

(ii) Advantage: in P the whole ecosystem is protected, so biodiversity at all levels – the species together with its habitat and its interactions with other species – is conserved (in Q only individual animals are kept). Ex situ conservation in Q or R becomes necessary when a plant or animal is endangered or threatened and needs urgent measures to save it from extinction (e.g. its natural habitat is being lost).

(iii) A biodiversity hotspot is a region with very high levels of species richness and a high degree of endemism (species confined to that region and not found anywhere else); such regions are also regions of accelerated habitat loss. The Western Ghats belong to the 'Western Ghats and Sri Lanka' hotspot. The other two hotspots covering India are Indo-Burma and the Himalaya.

(iv) Cryopreservation.

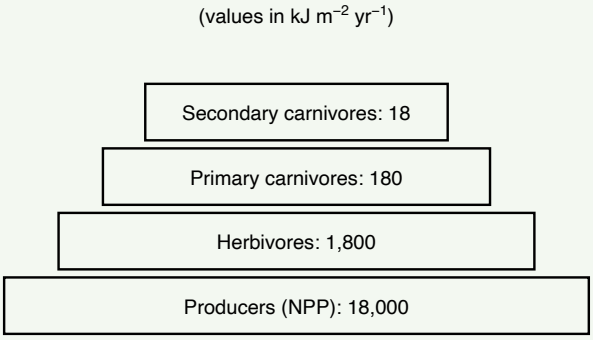
OR

B. (i) Respiration = 40% of 30,000 = 12,000 kJ m^{-2} yr^{-1}.

NPP = GPP − R = 30,000 − 12,000 = 18,000 kJ m^{-2} yr^{-1}.

(ii) Herbivores (grasshopper) = 10% of 18,000 = 1,800; primary carnivores (frog) = 180; secondary carnivores (snake) = 18 kJ m^{-2} yr^{-1}.

(iii) Pyramid of energy (upright) – see figure: producers 18,000 at the base, then 1,800, 180 and 18 kJ m^{-2} yr^{-1} at the top.
(iv) Any two: the pyramids do not take into account the same species belonging to two or more trophic levels; they assume a simple food chain, which almost never exists in nature, and do not accommodate a food web; saprophytes (decomposers) are not given any place in ecological pyramids even though they play a vital role in the ecosystem.



Marking: A (i): P in situ, Q and R ex situ – ½ mark each with justification (1½) · A (ii): whole ecosystem/habitat protected – ½ mark; urgent rescue of endangered/threatened species – ½ mark · A (iii): definition (richness + endemism) – ½ mark; Western Ghats and Sri Lanka – ½ mark; Indo-Burma and Himalaya – ½ mark · A (iv): cryopreservation – 1 mark · OR B (i): NPP = 18,000 with working – 1 mark · B (ii): 18 kJ m^{-2} yr^{-1} with steps – 1 mark · B (iii): correctly labelled upright pyramid with values – 1 mark · B (iv): two limitations – 1 + 1 mark

Examiner tip: In B, apply the 10 per cent law to NPP (energy available to the next level), not to GPP, and always write the unit.

All the best for your exam!