2024 H2 Biology Prelim Paper 2 Answer

1 Amoeba is a single-celled organism of the kingdom Protista. Amoeba gets its nutrients in a heterotrophic manner, taking in food from its surroundings.

Fig. 1.1 shows the electron micrograph of an amoeba.

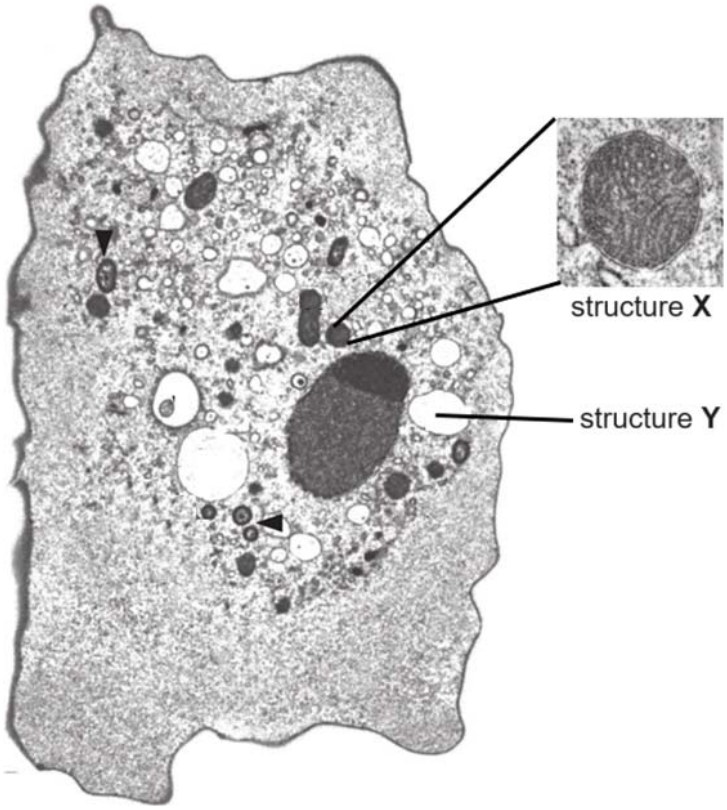


Fig. 1.1

(a) With reference to Fig. 1.1 and the information provided,

(i) identify structure **X** and **Y** and state a structural difference between them. [2]

Identify
- X: mitochondrion, Y: vesicle / phagocytic vesicle / food vacuole;

Structural difference
- X is double membrane bound / presence of cristae while Y is single membrane bound / no infolding of membranes;

(ii) explain the importance of structure **X** to the amoeba. [3]

- Mitochondrion (X) allows for respiration to take place to produce ATP;
- ATP is required for important metabolic processes within amoeba;
- ATP is also important for phagocytosis / endocytosis process to occur for amoeba to take in food from surrounding;

(b) Marseillevirus is a virus that infects amoeba. It is taken up by amoeba via phagocytosis. Upon membrane fusion, new progeny viruses are formed through DNA replication and protein synthesis. The progeny viruses are then released as the amoeba is lysed.

Fig. 1.2 shows the structure of Marseillevirus.

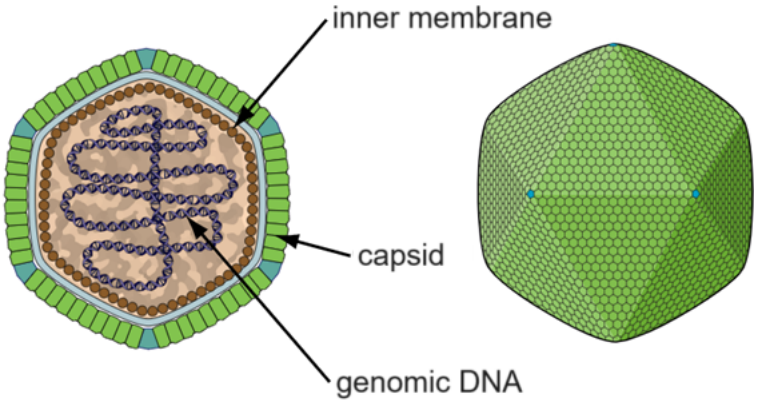


Fig. 1.2

With reference to Fig. 1.2 and the information provided, explain how Marseillevirus challenges the cell theory. [3]

- Identify why *Marseillevirus* is not considered as a cell making reference to figure 1.2;
- Identify how *Marseillevirus* exhibits living characteristics with reference to the context;
- Identify one tenet of the cell theory that it challenges (cells are the basic unit of life / all living things are made from cells and all cells come from pre existing cells);

2 Some structural features of phospholipids are listed in Table 2.1.

Table 2.1

features	affect role in cell surface membrane
synthesised by condensation	
hydrophobic fatty acid chains	√
unsaturated fatty acid chains	√
saturated fatty acid chains	√

(a) (i) Indicate, with the use of a tick (√), which of the structural features in Table 2.1 affect the role of phospholipids in the cell surface membrane. [1]

(ii) Outline how a property of phospholipids allows them to form an effective barrier as the cell surface membrane. [1]

- Amphipathic nature of the phospholipid, having both hydrophilic and hydrophobic regions allow the formation of effective lipid bilayer as barrier;

(b) Many multicellular organisms produce antimicrobial polypeptides (APs) that protect them against prokaryotes.

Fig. 2.1 shows one type of AP that acts on the cell surface membrane of prokaryotes.

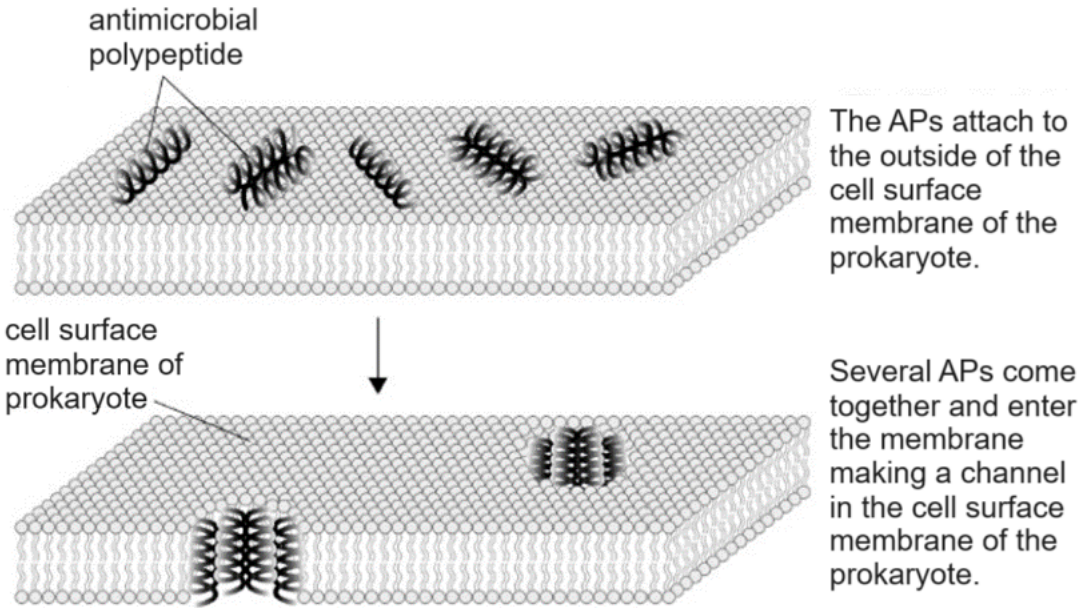


Fig. 2.1

Fig. 2.2 shows further information about a channel formed in the cell surface membrane by the APs.

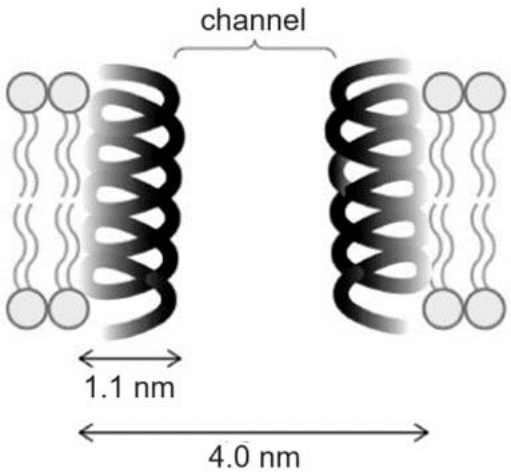


Fig. 2.2

Using Fig. 2.2, calculate the cross-sectional area of the channel through which ions can pass.

Use π = 3.14 in your calculation. Give your answer in nm^2 and to 1 decimal place. [2]

- Diameter of channel = 4.0-(1.1+1.1) = 1.8nm
- Cross sectional area = ¶r^2 = 3.14 x $(1.8/2)^2$ = 2.54 = 2.5nm (1 dp)

(c) Prokaryotic membranes do not contain cholesterol.

APs damage prokaryotic cells but do not damage eukaryotic cells in the organisms that produce them.

Explain how that is possible. [2]

- Presence of cholesterol in eukaryotic membranes allow them to be more stable and less fluid, hence restricting the ability of the APs to form channels through them;
- Presence of higher composition of saturated fatty acids in the phospholipid tails of eukaryotic membranes make them more rigid and hence difficult for APs to form channels;
- APs are unable to attach securely to the surface membrane of eukaryotic cells due to lack of specificity to the glycocalyx layer;

(d) To observe the action of APs on prokaryotes, scientists made use of a microscope that detects fluorescence, as well as monoclonal antibodies.

Suggest how the action of APs on prokaryotes can be observed. [2]

- Monoclonal antibodies have an epitope / antigen binding regions that are specific to the Aps;
- Upon binding, can be detected by the microscope due to the fluorescence they emit;

3 Collagen is the most abundant protein found in the human body.

Glycine is a common amino acid found in collagen and plays an important role in contributing to the high tensile strength of collagen.

(a) Explain how glycine contributes to the high tensile strength of collagen. [3]

- **Small size** / **Small R group** / **Hydrogen atom as R group** of glycine results in the formation of a **kinked helix**;
- This allows the **3 polypeptides** to be packed / wound **more closely** / **tightly**, (forming tropocollagen);
- (The –NH group of) Glycine on one chain forms **inter-chain hydrogen bonds** with (the –C=O groups of peptide bonds) one of the other two polypeptide chains;
- [Idea of increase the tensile strength of collagen] Greater force is required to break the tropocollagen / collagen;
- Strand-like / Fibrous structure (of kinked helices) leads to large surface area exposed for more hydrogen bond formation;

(b) In the human skin, the enzyme collagenase is synthesised and secreted by the fibroblast cells to break down collagen in damaged tissues and help in the growth of healthy tissues.

Describe **one** structural difference between collagenase and collagen and explain the significance of this difference to the function of the respective proteins. [3]

Structural difference:
- Collagenase is globular protein whereas collagen is a fibrous protein;

OR

Collagenase – hydrophobic groups are kept within the globular structure and only hydrophilic groups are exposed on the surface of the molecule vs collagen consists of many hydrophobic amino acids;

Relate significance of difference to function of protein
- Thus, collagenase is soluble in water, allows it to carry out its enzymatic function in aqueous medium/be transported in aqueous medium;
- vs collagen insoluble in water, and can remain stable to perform its structural function in solution [idea of maintaining function without dissolving];

(c) Collagenase has an optimal pH around pH 7. The pH of the extracellular matrix and tissue microenvironment can influence collagenase activity and collagen turnover. For example, inflammation or infection can alter the local pH and impact collagen degradation processes.

Explain how alterations in pH can affect the activity of collagenase. [3]

- As pH deviates from the optimum (whether higher or lower), the **concentration of hydrogen ions would be changed**;
- This disrupts the **ionic bonds** and **hydrogen bonds** between R groups of amino acids in the enzyme collagenase;
- **denaturing** the enzyme molecule, causing it to **lose** its specific 3D conformation and **shape of the active site** such that its **no longer complementary to the substrate** collagen;
- The change in concentration of hydrogen ions may also **affect the charges of the active site and the substrate** such that they may **no longer have opposite electrostatic charges**;
- **preventing effective collisions** between enzyme and substrate molecules and the enzyme is **unable to form enzyme-substrate complex** with substrate molecules;

(d) Under natural conditions, healthy skin tissues grow under strict regulation. Explain why this is significant. [2]

Any one
- Ensure skin cells only allowed to proceed to the next phase of the cell cycle if it has properly completed the previous phase;
  OR
  Halting the cell cycle when the cell has not completed the previous phase properly;
- Cells with damaged DNA/ mutated DNA not allowed to divide so that DNA repair can take place or cells undergo apoptosis when the DNA damage is too severe;
- ref check for DNA replication, DNA damage and chromosome-to-spindle attachments;

Any one
- This helps to prevent the accumulation of mutations in daughter cells;
- [Idea of prohibiting cancer progression] If mutations allowed to accumulate, can lead to uncontrolled cell division / idea of tumor formation;

OR
- Skin cells divide only when necessary e.g. receive the appropriate signals for growth or repair of skin tissues;
- Idea of keeping the number of cells in skin tissue constant;

4 Fig. 4.1 shows an electron micrograph of protein synthesis in a eukaryotic cell.

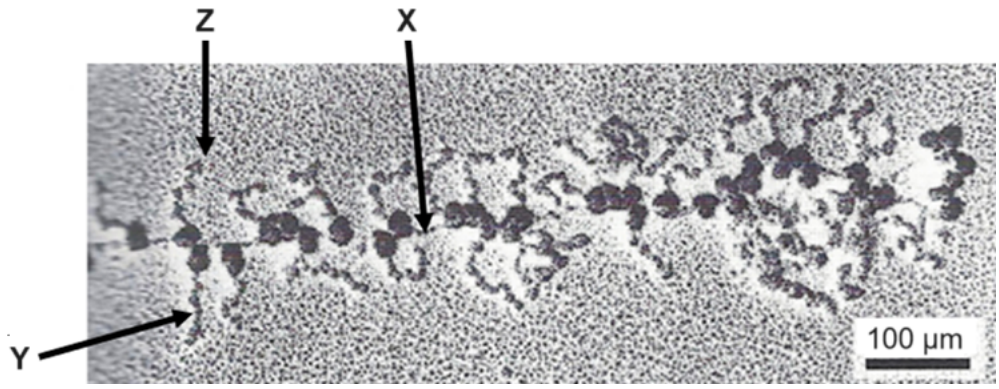


Fig. 4.1

(a) (i) Identify structure **X** and **Y** and describe **two** structural differences between them. [3]

- X: mRNA, Y: polypeptide;

Features	mRNA	Polypeptide
Monomer	RNA nucleotides	Amino acids
Bond	Phosphodiester bond	Peptide bond

(ii) Arrow **Z** points to the end of a molecule.

State the directionality of the end of the molecule indicated by arrow **Z**. [1]

- N-terminus;

(b) The structure in Fig. 4.1 is sometimes described as beads on a thread.

Briefly describe how this structure is formed. [3]

- Ribosome binding to the ribosomal binding side of mRNA to initiate translation;
- As ribosome translocate along the mRNA to synthesis polypeptide;
- The ribosomal binding site is available for the ribosome to bind and initiate translation. The process repeats again;

(c) In prokaryotic cells, protein synthesis can be inhibited by antibiotics, leading to bactericidal effects.

Fig. 4.2 below shows the effect of two different antibiotics on protein synthesis.

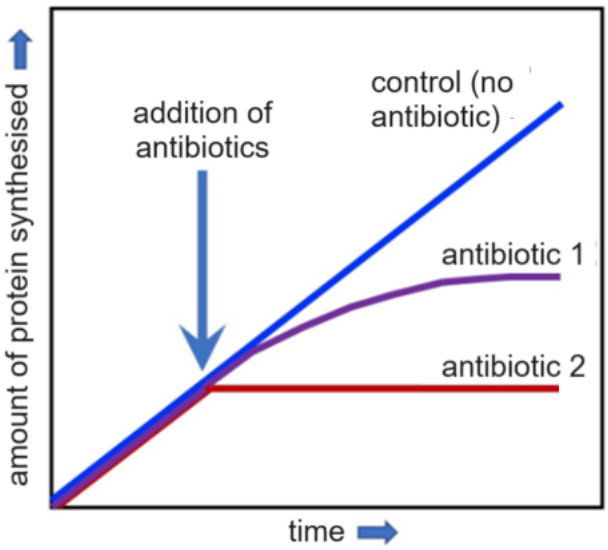


Fig. 4.2

With reference to Fig. 4.2, suggest which specific steps of translation each antibiotic inhibits and explain your answer. [4]

- [Describe] Antibiotic 2 results in **immediate** stopping of protein synthesis while antibiotic 1 has **a delayed** effect / OWTTE;
- Antibiotic 2 inhibits the **elongation of translation** polypeptide chain;
- Antibiotic 1 inhibits the **initiation of translation** / **transcription** step of protein synthesis;
- With the use of antibiotic 1, **existing mRNA** is still able to be translated to form proteins **until it gets degraded** and thus resulting in the delayed effect in the halting of protein synthesis;
- With antibiotic 2, since elongation is inhibited, there is an immediate effect that polypeptide will **stop its synthesis immediately** and will not go on to form more proteins;

5 A karyotype shows the complete set of chromosomes found in the genome of an individual. The chromosomes are obtained by freezing dividing cells in prophase, stained, pictured and arranged.

Fig. 5.1 shows a karyotype of an individual suffering from a chromosomal aberration.

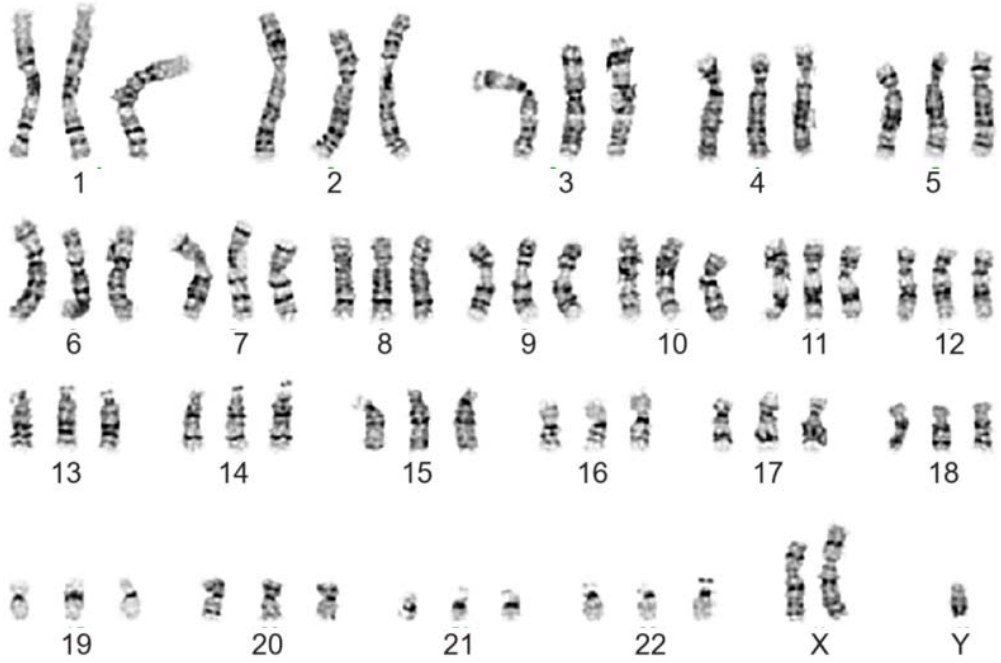


Fig. 5.1

(a) With reference to Fig. 5.1, state

(i) the gender of the individual and the type of chromosomal aberration the individual suffers from. [1]

- Gender: male, Chromosomal aberration: triploidy / polyploidy;

(ii) the number of DNA molecules present in Fig. 5.1. [1]

- 138 DNA molecules;

(b) Describe how DNA is packaged into each chromosome found in Fig. 5.1. [4]

- **Ionic attraction** between **positively-charged histones** and **negatively-charged DNA**;
- **DNA winds around 8 histone proteins** to form **nucleosomes**, stabilised by **H1 histone**;
- A **chain of nucleosomes joined by linker DNA** coils to form **30 nm chromatin** / **solenoid fibre**, which is further coiled into **300 nm chromatin** / **solenoid fibre**;
- 300nm chromatin coils into **looped domains** associated with **central nuclear matrix**, which **further coil and fold** to form a **condensed chromosome**;

(c) Proteins that are no longer needed by the cell are broken down and the raw materials recycled for synthesis of other proteins.

Fig. 5.2 shows a mechanism how proteins may be broken down in the cytoplasm. E1, E2 and E3 are enzymes involved in the process.

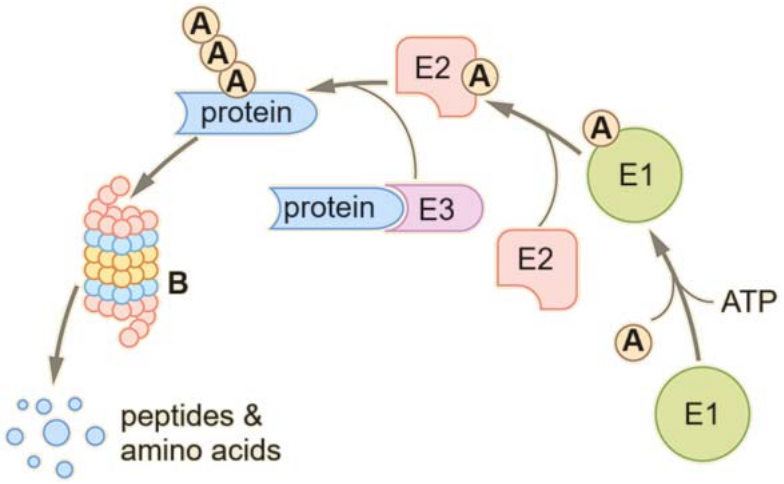


Fig. 5.2

Explain the roles of structure **A** and **B** in the process shown in Fig. 5.2. [3]

- Ref. to structure A as **ubiquitin** and structure B as **proteasome**;
- **E1**, **E2 and E3** adds A covalently to the **N-terminus of the protein** to be degraded;
- This **marks the protein** to be **degraded** / **hydrolysed** / **broken down by proteasome** into **peptides and amino acids**;

6 The Jacob-Monod hypothesis describes lactose metabolism in the bacterium *Escherichia coli*. An investigation of this reaction in *E. coli* at 25 °C was carried out as described below.

- 100 cm^3 of gel beads coated with *E. coli* were placed into each of seven identical funnels fitted with outlet taps.
- 100 cm^3 of solution containing two grams of lactose was poured into each funnel at 0 min.
- At regular time interval, the solution from the respective funnel was released and collected.
- The mass of lactose in each solution was measured.

Fig. 6.1 shows the experimental set-up of one of the seven funnels used.

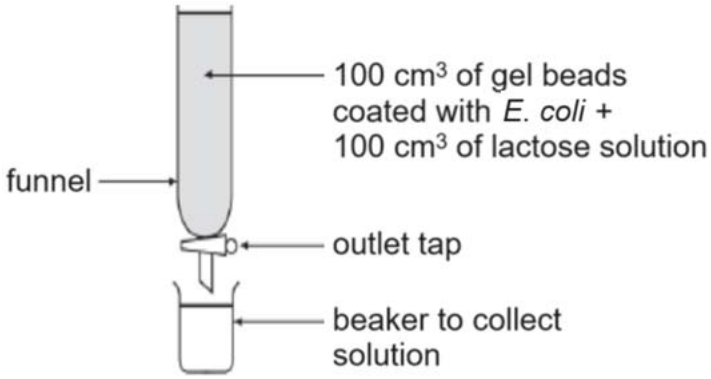


Fig. 6.1

The results are shown in Table 6.1.

Table 6.1

funnel	time (min)	mass of lactose collected in the solution (g)
1	0	2.00
2	10	2.00
3	20	1.48
4	30	0.92
5	40	0.40
6	50	0.12
7	60	0.04

(a) With reference to Table 6.1,

(i) explain the results from funnels 3 to 7. [4]

Describe the results
- (must have) As incubation time increased from **20 to 60 min**, the mass of lactose collected **decreased in decreasing rate from 1.48 to 0.04 g**;

Explanation
- (must have) Longer incubation time allows more **lactose to be hydrolysed** / **broken down** into glucose and galactose, catalysed by **β-galactosidase**;

- Lactose is taken into the bacteria by lactose permease and **converted to allolactose**;
- Allolactose binds to the *lac* repressor, causes a **conformation change** to **inactivate the *lac* repressor**;
- Inactive lac repressor is **unable to bind to the operator** of the *lac* operon, RNA polymerase is able to move downstream of the *lac* operon to **transcribe the *lacZ* gene**;

(ii) suggest a reason for the results from funnels 1 and 2.

Describe the results
- As incubation time increased from **0 to 10 min** / In the **first 10 min**, the mass of lactose collected **remained constant at 2.00 g**;

Explanation
- Time is needed for the bacteria to switch on expression of the *lac* operon / to transcribe the *lacZ* gene and synthesise β-galactosidase in order to hydrolyse / break down lactose;

(b) The monomers of lactose are β-galactose and β-glucose, arranged as shown in Fig. 6.2.

Fig. 6.2

Fig. 6.3 shows the structure of a β-galactose.

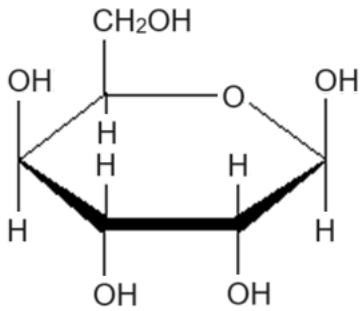
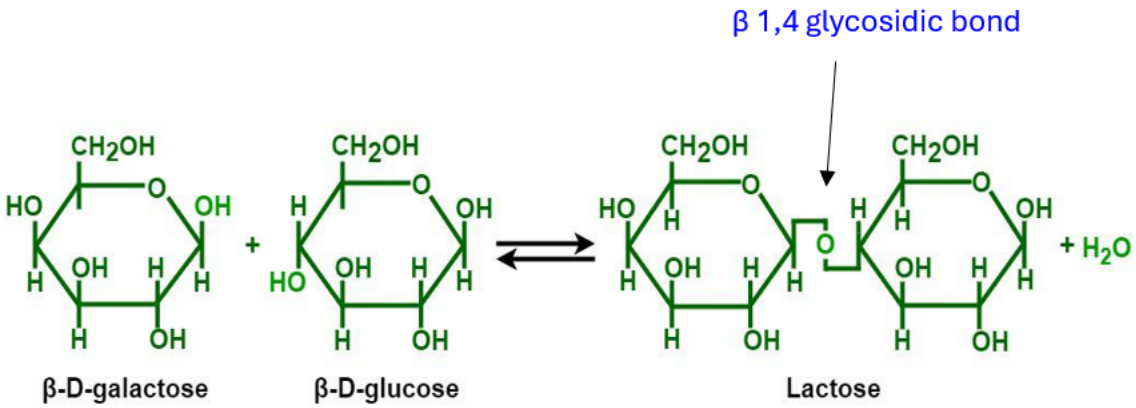


Fig. 6.3

With reference to Fig. 6.2 and 6.3, illustrate, with a labelled diagram, how a lactose disaccharide can be formed from its monomers. [3]



- Correct drawing of β-galactose and β-glucose;
- Correct drawing of lactose, with water formed / condensation reaction indicated;
- Labelling of monomers, product and bond formed;

(c) The *lac* operon codes for inducible enzymes. Repressible operons code for repressible enzymes.

Suggest and explain why it is advantageous for a prokaryote to have a repressible operon. [3]

- Enzymes can be made continuously;
- Enzymes are available whenever necessary;
- End product inhibition allow product concentrations to be regulated;

7 **(a)** Define the following terms:

(i) recessive allele. [2]

- Allele that is **masked** in expression / in the phenotype by a **dominant allele** in a **heterozygous** individual;
- Allele that is **only expressed** in the phenotype in **homozygous** (recessive) individuals;

(ii) autosomal linkage. [2]

- **Two or more genes** are found in different gene loci on the **same autosomal chromosome**;
- The alleles of the genes **do not assort independently** and tend to be inherited together;

(b) In a certain type of plant, the gene for fruit colour has three alleles. Allele **R** coding for red fruits is dominant over allele $\mathbf{R^O}$ coding for orange fruits, which is dominant over allele **r** coding for yellow fruits.

The appearance of leaves in this plant is controlled by a separate gene. Allele **B** of this gene codes for leaves with dark spots, while allele **b** codes for leaves with no spots.

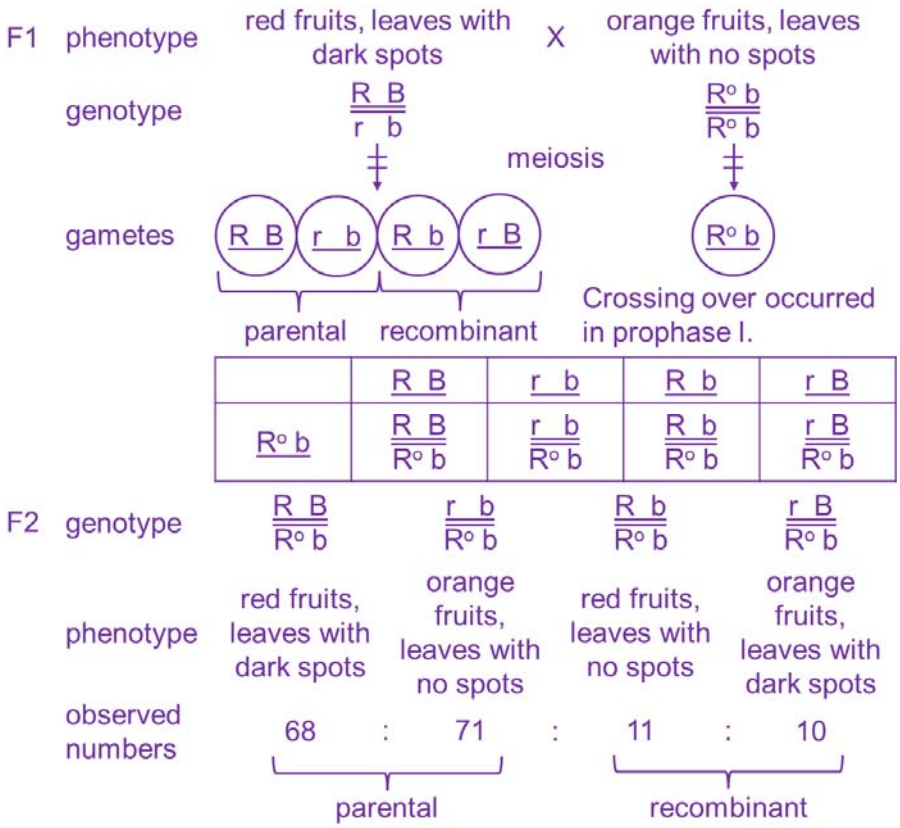
A pure-breeding plant with red fruits and leaves with dark spots was crossed with a plant with yellow fruits and leaves with no spots. One of the F1 plant was then crossed with another pure-breeding plant with orange fruits and leaves with no spots. The following F2 plants were obtained:

plants with red fruits and leaves with dark spots	68
plants with orange fruits and leaves with no spots	71
plants with red fruits and leaves with no spots	11
plants with orange fruits and leaves with dark spots	10

(i) State the type of variation shown in the fruit colour. [1]

- Discontinuous variation;

(ii) Draw a genetic diagram to show how the F2 plants were obtained. [4]



8 An investigation into the effect of carbon dioxide concentration on the rate of photosynthesis was carried out using different concentrations of sodium hydrogencarbonate solution.

All other conditions were kept constant.

Fig. 8.1 shows the experimental set-up used in the investigation.

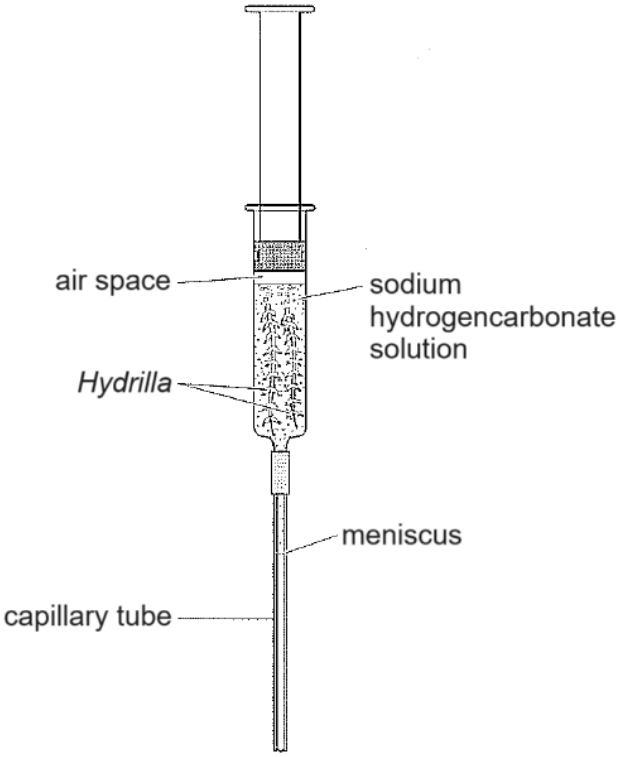


Fig. 8.1

For each concentration of sodium hydrogencarbonate solution, the distance moved by the meniscus in 10 minutes was measured. The results are shown in Table 8.1.

Table 8.1

concentration of sodium hydrogencarbonate solution / mol dm^{-3}	distance moved by meniscus after 10 minutes / cm
0.02	9.0
0.04	11.0
0.06	13.5
0.08	11.2
0.10	10.0

(a) State the reason why the meniscus moved. [1]

- **Oxygen was produced by photosynthesis**, which **increased the volume of air space**, thus pushing the meniscus further down the capillary tube / away from the syringe;

(b) Predict, with reasons, the result that would be obtained

(i) if 0.15 mol dm^{-3} of sodium hydrogencarbonate solution was used. [2]

- Less than 10.0 cm;
- Enzymes in photosynthesis / Calvin cycle / light-independent reactions denatured by low pH due to high carbon dioxide concentration;

(ii) if light intensity was increased when 0.04 mol dm^{-3} of sodium hydrogencarbonate solution was used. [2]

- Around 11.0 cm;
- Carbon dioxide concentration is the limiting factor, increasing light intensity does not increase rate of photosynthesis;

(c) Describe the light independent stage of photosynthesis. [4]

- Occurs in the **stroma**;

Carbon fixation
- **Carbon dioxide** (CO_2) is **added to ribulose bisphosphate** (RuBP) to form an unstable 6-carbon intermediate, catalysed by **RuBP carboxylase**;
- The 6-carbon intermediate splits into 2 molecules of **3-phosphoglycerate** (PGA) / **glycerate-3-phosphate** (GP);

PGA reduction
- **PGA is reduced to triose phosphate** (TP) / **glyceraldehyde 3-phosphate** (G3P) with the use of **reduced NADP and ATP**;
- 2 molecules of TP link together to form **glucose**;

RuBP regeneration
- Remaining TP are used to **regenerate RuBP** for the light independent stage / Calvin cycle to continue, with the use of **ATP**;

9 There are many different species of *Drosophila* fruit fly.

Three of these species, *D. pseudoobscura*, *D. persimilis* and *D. miranda*, are thought to be closely related. Samples of these three species were collected from the western United States of America. The base sequences of four regions of DNA of each species were sequenced.

The divergence of these base sequences in *D. pseudoobscura* and *D. persimilis* from the sequences in *D. miranda* was calculated. The results are shown in Table 9.1 below.

Table 9.1

DNA region	*Drosophila* species	divergence of base sequence from that of *D. miranda* / %
non-coding region 1	*pseudoobscura*	2.8
	persimilis	2.4
non-coding region 2	*pseudoobscura*	8.1
	persimilis	7.3
coding region 1	*pseudoobscura*	2.1
	persimilis	2.0
coding region 2	*pseudoobscura*	1.9
	persimilis	1.7

(a) (i) State which species of fruit fly shares a more recent common ancestor with *D. miranda*. [1]

- *D. persimilis*;

(ii) Other than the four DNA regions that were used in this study, a high proportion of non-coding DNA sequences were often used for further evolutionary studies.

Suggest why it would be more advantageous to use the non-coding DNA to construct phylogenetic relationships. [2]

1. Higher Mutation Rates: Non-coding regions often have higher mutation rates compared to coding regions; which can provide more variation to distinguish between closely related species or populations;
2. Non-coding DNA is not expressed / neutral variation / mutations in non-coding DNA may not affect gene expression / may not confer selective advantage or disadvantage; hence, mutations in non-coding regions are less likely to be eliminated by natural selection, preserving more evolutionary changes that can be informative for phylogenetic analysis;
3. Non-coding regions make up a large portion of the genome; Using these regions allows for a more comprehensive representation of genetic variation across the genome, providing a more complete picture of evolutionary relationships;

(b) Fig. 9.1 shows the features of *D. pseudoobscura* and *D. persimilis*.

Fig. 9.1

Based on Table 9.1 and Fig. 9.1, outline two species concepts that may be applicable to *D. pseudoobscura* and *D. persimilis*. [2]

1. Morphological Species Concept: Based on physical characteristics. Both species can be distinguished by subtle differences in morphology;
2. Genetic Species Concept: Based on genetic divergence. *D. pseudoobscura* and *D. persimilis* have distinct genetic differences that contribute to their classification as separate species;

(c) Fig. 9.2 shows the distribution of *D. pseudoobscura* and *D. persimilis* in the American continent.

Both species can be found in the darkened region indicated by the bracket. Yet, they do not interbreed to produce viable, fertile offspring.

It was also observed that female *Drosophila* respond differently to the frequency in pulses in the mating sounds of the male *Drosophila*.

Fig. 9.2

(i) With reference to Fig. 9.2, explain how biogeography supports Darwin's theory of evolution. [3]

1. Biogeography / Study of biographic distributions have shown that closely related species / share a recent common ancestor tend to be found in the same geographic region;
2. *D. pseudoobscura* and *D. persimilis* are closely related as they belong to the same genus, and they are found in the same geographic region;
3. This supports Darwin's theory: All organisms are related through descent from common ancestors and descendants have accumulated modifications or adaptations that fit them into their environment;

(ii) Explain how the two species, *D. pseudoobscura* and *D. persimilis* were formed. [4]

1. Ref. to sympatric speciation;
2. Females were attracted to certain males and not others based on their frequency in pulses in mating sounds – sexual selection / behavioral isolation;
3. No/restricted gene flow between populations – reproductive isolation;
4. Via natural selection – different populations accumulate different mutations / adaptations (such that they no longer interbreed to produce viable, fertile offspring, as stated in the qn);

10 (a) (i) Suggest one feature of a naïve B cell that differentiates it from a plasma cell.

- Naïve B cell produces IgM and IgD while a plasma cell produces only one type of Ig e.g. IgG / does not produce IgD;
- Naïve B cells express membrane-bound antibodies while a plasma cell secretes antibodies;

(ii) A medical researcher proclaimed that 'when it comes to B cells, the human body is capable of fighting any foreign invader'.

Name a process responsible for his claim. [1]

- Somatic recombination;

(b) Fig. 10.1 below shows the activation of B cells in an immune response.

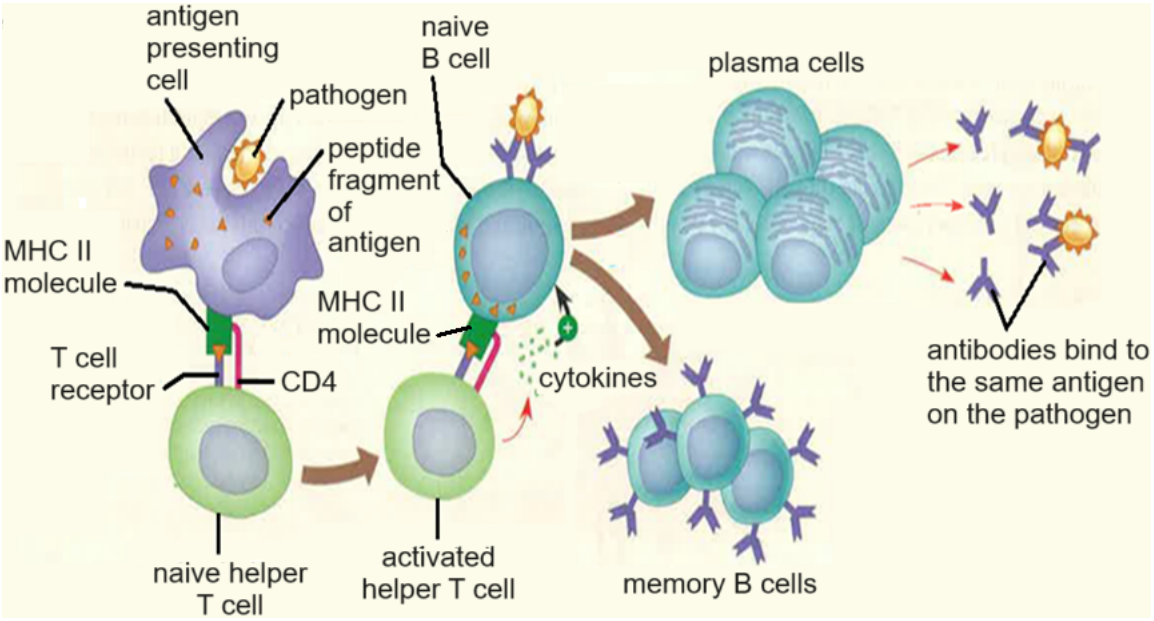


Fig. 10.1

(i) Name one antigen presenting cell in the body. [1]

- Dendritic cells / Macrophages / Monocytes;

(ii) B cells can also play the role of antigen presentation.

With reference to Fig. 10.1, explain how the features of B cells make them useful as professional antigen presenting cells in an immune response. [3]

- B cells are antigen presenting cells because they can capture and digest foreign organisms like macrophages and dendritic cells and present the digested antigens to CD4+ T cells via the **MHC II** receptors;
- Each mature B cell expresses its unique IgD antibodies on the surface. These antibodies can specifically recognise antigens complementary to them. As a result, B cells can recognize antigens via their subtle differences from human antigens (such as viral envelope glycoproteins);
- Macrophages and dendritic cells present antigens to CD4+ T cells to activate them, while B cells present antigens to be activated for clonal expansion and memory cell formation;
- B cell activation involves two steps: the recognition of native antigens by B cell receptors and the recognition of processed antigens by T cells;

11 The frog populations have been on a decline in Costa Rica and Panama since the early 1980s. This is due to the arrival of a fungus, *Batrachochytrium dendrobatidis*. The fungus causes a deadly infectious disease, known as chytridiomycosis, in the amphibian populations.

As an inhabitant of lowland wet areas in tropical forests, the decline in frog population is further exacerbated by climate change.

(a) Explain how climate change exacerbated the decline in frog population. [2]

- Global warming results in rise in sea level / extreme weather events like flooding / altered precipitation patterns resulting in drying of lowland wet areas;
- Destroy the habitat / breeding ground of the frog;

(b) Following the decline in amphibian populations, researchers investigated the correlation between the decline and the number of malaria case.

The results are shown in Fig. 11.1.

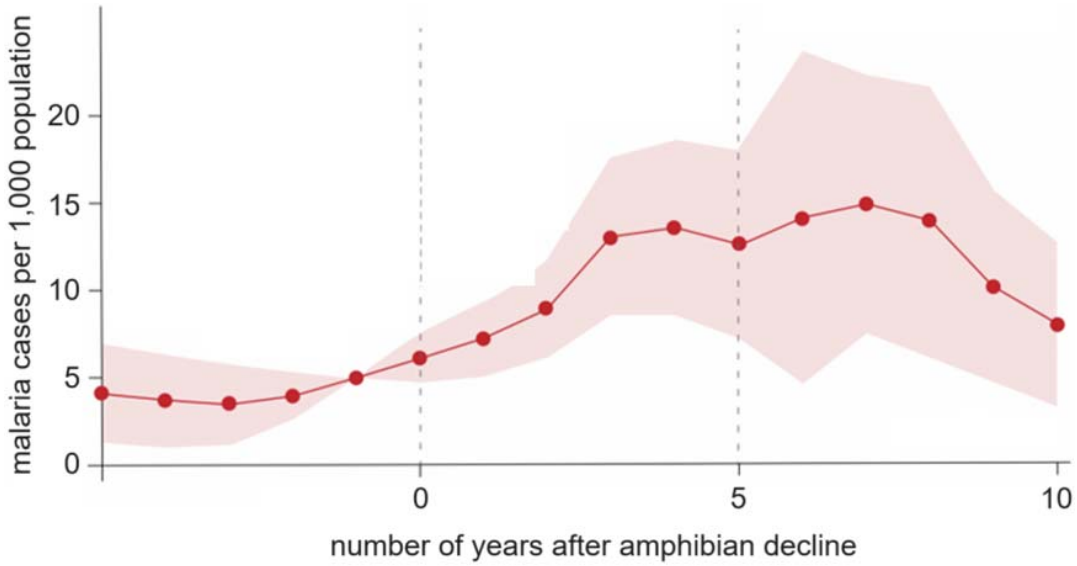


Fig. 11.1

(i) With reference to Fig. 11.1, suggest a reason for the change in the number of malaria cases from 0 to 5 years after the amphibian decline. [3]

- After the amphibian population decline between 0-5 years, there is an increase in malaria cases from 6 cases per 1000 population to 12.5 cases per 1000 population;
- Increase in anopheles mosquitoes population because if decline in predators which cause more malaria as;
- Anopheles is a vector for malaria;

(ii) Suggest why the number of malaria cases decreases beyond 5 years after amphibian decline. [1]

- Government intervention / Drugs to control malarial introduced / AVP;