VCEweb

BIOLOGY QUESTION BOOK

VOLUME 1: STUDY DESIGN QUESTIONS

- OVER 300 PRACTICE QUESTIONS
- HAND-WRITTEN ANNOTATED SOLUTIONS
- WRITTEN FOR THE NEW STUDY DESIGN
- WRITTEN BY THREE MEDICAL STUDENTS
- STUDYING AND WRITING TIPS
- COMMAND TERM LIST
- EXTENSION NOTES WITH COMMON TRICKS

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Book and Legal Information

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PREFACE: ABOUT THE AUTHORS

My interest in Biology is a significant reason why I applied for medicine in university, and VCE Biology was genuinely one of my favourite subjects at school!. A narrative around VCE Biology that is all too common is that you are required to relentlessly rote learn and memorise facts. While it's true that there is quite a large breadth of content to cover, I do believe that there is a way to go through the subject exploring the content and finding the parts of biology and the world around us that fascinate you and keep you engaged, without losing yourself to boredom and hundreds of cue cards. I get that for most of us VCE is about marks, and there are absolutely tips and tricks that enable you to score highly - some of which are as simple as using a particular keyword anytime you come across a certain topic. However, I think that the ability to maintain motivation throughout the year and into the exam period really comes from striking the right balance between 'playing the VCE game', and making the effort to find the passion and interest that made you choose the subject in the first place - that's what I would really encourage you to do!

- Gaia Charan (99.85, 49 Study Score, Medical Student)

After completing VCE biology, for the first time I was able to directly apply the what I had learnt into everyday life. Yes atoms are cool, but have you ever looked down at your skin and just taken a moment to appreciate what a great first line of defence it is and how well its 'intactness' prevents the entry of pathogens! Sure, you could say that 'any science in VCE can be applied to every day life', but there's a reason you're reading these words now and hopefully, it's because you find the science of life interesting enough to add into your top 4 VCE subjects! Good luck with your VCE biology journey!

- Rachel Chen (99.85, 49 Study Score, Medical Student)

Back when my sisters were in kindergarten, my mum would drag me along to pick them up. She'd speak with my sisters' teachers for ages and I was left behind to stare at a wall of neatly organised pockets, stacked full with medical brochures displaying big words like 'Bacterial Meningitis', 'Immunisations' and 'Chickenpox'. Naturally, curiosity got the best of me and I'd read them, taking one or two brochures home each time (sorry to the kindergarten staff - don't think I was the intended audience). And that's how I wrote my first ever 'research paper' on meningitis, which I then proceeded to "diagnose" everyone on the playground with. When asked what kicked off my interest in biology and medicine, I will always refer to these moments of genuine curiosity and interest. Over a decade later, my passion for medicine and biology are still as strong as ever; what I've come to understand is that the more you learn, the more you realise you don't know. Biology is practical: it's the study of life. You might not cure cancer with VCE Biology, but every piece of knowledge brings you one step closer!

- Cindy Zeng (99.65, 42 Study Score, Medical Student)

SAC AND EXAM TIPS

1. STUDYING TIPS

MAKE NOTES BASED OFF THE STUDY DESIGN	Some VCE Biology books in the market contain irrelevant pieces of information or concepts from old study designs that make it confusing for students to understand what they need to know. The study design provides the **exact curriculum** which students need to know for SACs and Exams. Since Biology examiners can only test you on content from the study design, you should create notes on what will be **examined**!
ERROR BOOK	An 'error book' is simply **a book with all your mistakes**! Throughout the year you will complete many practice assessments for Biology and are bound to make at least a few mistakes. A book like this is useful in: a) understanding why you made the specific error and b) identifying all your common errors so that, in subsequent practice tasks, you are less likely to make the same mistake. This means you can maximise the amount of marks earned!
WORK AHEAD OF CLASS	This one is quite logical — if you learn a concept before you cover it in class then you won't be learning anything new in that next lesson! This means you will instead **be revising** and so, you can ask questions to **consolidate** your understanding rather than learn the content from scratch.
FLASHCARDS	Flashcards are a useful **active recall** revision technique that can be used to learn definitions, concepts, theories or examples for Biology. You can make your own flashcards through purchasing them from the local store or via an online mean (such as Quizlet!).
READ/WATCH THE NEWS	The exam will not only test your knowledge of concepts but also your ability to apply that to contemporary Biology examples. So, reading or watching the news will be of benefit to you in becoming a Biology student with a holistic understanding of the scientific community.
EXAMINATION REPORTS	The Examination Reports for Biology are useful for three reasons: a) it provides information on how students performed in specific questions, b) there are examples of high scoring responses and c) general feedback is provided for student performance across the state. Knowledge of how students have performed is useful in **predicting questions** for future years (as I have done in this book!) — if students perform poorly in a question that targets a specific concept, it is highly likely that it will be tested the following year. Additionally, reading through the high scoring example responses allows you to know how you can improve the **structure and quality** of your own writing (so that you too can tailor your response to be a 'high scoring' answer).
UNDERSTAND THE RELATIONSHIP BETWEEN DIFFERENT TOPICS OF THE COURSE	The concepts taught in Biology are not separated but rather, are **interrelated**. For example, the processes of transcription and translation (AOS 1 topic) leads to the synthesis of photosynthetic enzymes like Rubisco (AOS 2 topic). Knowing how different parts of the study design relate can help you develop a deeper understanding of the Biology course, which is useful for answering the **harder questions** in the exam!

2. WRITING TIPS

SIGNPOSTING	Signposting can be useful in giving your response **structure** and directly 'showing' the examiner where to **allocate** marks. Examples of signposting include: • "One application of the polymerase chain reaction is..." • "The difference between CAM and C4 plants is..." • "One international strategy to prevent pandemics is..."
UNDERLINE KEY TERMS	Underlining key terms can, again, 'show' the examiners where to allocate marks for your response — this is particularly important for **extended response questions** where large quantities of information must be processed by the examiner. Examples of responses where key terms are underlined can be found in the solutions section of this book.
USE BRACKETS	Brackets can be used to **define key terms** in the response and also explain your **thought process** regarding specific concepts! So, instead of wasting writing space and time by writing out a new sentence to explain your thoughts, you can instead use brackets.
HAVE A CHECKLIST AFTER ANSWERING A QUESTION	A 'checklist' can just be a **series of questions** you ask yourself after responding to the question to ensure that you have adequately responded to all parts of the question. This can include: • Have I used the task word properly? • Have I underlined key terms? • Have I linked to the case study? • Have I justified my response using sound biological principles?
EXPAND YOUR VOCABULARY	This can almost be seen as a way to **'subtly flex'** on your examiner. Similar to VCE English, using complex words can elevate your responses by providing it with a new level of sophistication. You can expand your vocabulary by creating a list of unique words (separated by AOS). For example, when you learn immunity, you would potentially learn medical jargon which may be useful if a medical-oriented immunity question appeared in your exam!

COMMAND TERM LIST

COMMAND TERM	DEFINITION	EXAMPLE
DEFINE	Present the **meaning** of a specific term.	"Define the term speciation."
DISCUSS	Present the **advantages** and **disadvantages**.	"Discuss the biological implications of genetic modification of crops."
COMPARE	Present the **similarities** and **differences**.	"Compare the cell-mediated immune response with the humoral immune response."
EVALUATE	Present the **advantages** and **disadvantages** along with a **final opinion**.	"Evaluate the effectiveness of CRISPR-Cas9 as a gene replacement technology."
EXPLAIN	Present the **features** along with **reasoning** or **implications.**	"Explain how global travel influences the spread of disease."
OUTLINE	Present the **specific features** of a concept.	"Outline one method to measure the rate of photosynthesis."
DISTINGUISH	Present how two concepts **differ** by a **specific feature**.	"Distinguish between anaerobic and aerobic respiration in terms of ATP yield."
DESCRIBE	Present an overview of the **features** of a concept.	"Describe the role of mast cells in the allergic response."
IDENTIFY	Present from **alternative options**.	"Identify, from the electron microscope diagram, where photosynthesis occurs."
JUSTIFY	Present the **advantages** and **significance** of a specific concept.	"Justify the use of face masks as a public health measure for reducing the spread of COVID-19."
STATE	Present in a **simple** manner.	"State one reason why the average brain size of hominins increased over time."

PRACTICE QUESTIONS

Questions: Unit 3 AOS 1

1. ***Nucleic acids as information molecules that encode instructions for the synthesis of proteins: the structure of DNA, the three main forms of RNA (mRNA, rRNA and tRNA) and a comparison of their respective nucleotides.*** **VCE BIOLOGY SD, p. 29**

1.1 Define the term 'nucleic acid'. [1 mark]

1.2 Draw a labelled diagram of a nucleotide from a DNA molecule. [3 marks]

22% of a specific DNA molecules' bases are adenine.

1.3 What percentage of this DNA molecule is composed of cytosine bases? [1 mark]

1.4 Use the table below to describe the cellular role played by the three forms of RNA in protein synthesis. [3 marks]

Form of RNA	**Function**
mRNA	
tRNA	
rRNA	

1.5 Outline three structural differences between DNA and RNA molecules. [3 marks]

2. ***The genetic code as a universal triplet code that is degenerate and the steps in gene expression, including transcription, RNA processing in eukaryotic cells and translation by ribosomes.*** **VCE BIOLOGY SD, p. 29**

2.1 Identify the two main stages of protein synthesis. [1 mark]

2.2 Define the terms 'transcription', 'post-transcriptional modifications' and 'translation'. In your response, identify where these processes occur within a cell. [5 marks]

2.3 Outline the difference between introns and exons. [2 marks]

Hypoproteinemia is a medical condition in which diagnosed patients have low levels of protein in their blood. This means that the concentration of essential proteins such as membrane-transport proteins would be low.

2.4.1 Other than a lower rate of protein synthesis, suggest one reason why this patient may be diagnosed with hypoproteinemia. [1 mark]

2.4.2 Explain the consequence of a patient having a low concentration of membrane-transport proteins. [2 marks]

2.4.3 Describe the main steps of the first stage of synthesis of a membrane-transport protein. [3 marks]

2.4.4 Explain the purpose of adding a poly-A tail and methyl cap to a pre-mRNA molecule. [2 marks]

2.4.5 Describe the main steps of the second stage of synthesis of a membrane-transport protein. [3 marks]

Explain the roles of the following in transcription:

2.5.1 RNA polymerase. [2 marks]
2.5.2 DNA template strand. [2 marks]

Explain the roles of the following in translation:

2.6.1 Ribosome. [2 marks]
2.6.2 tRNA. [2 marks]

A section of a DNA template strand that codes for amino acids has the following sequence:

3' CAGCTATATAACGCG 5'

2.7.1 Explain why this sequence of DNA codes for 5 amino acids rather than 15 amino acids. [2 marks]

2.7.2 Outline the purpose of DNA having a 3' and 5' end. [1 mark]

3. The structure of genes: exons, introns and promoter and operator regions. **VCE BIOLOGY SD, p. 29**

3.1 Define the term 'gene'. [1 mark]

3.2 Distinguish between the terms 'introns' and 'exons'. [2 marks]

3.3 Outline the function of the 'promoter' region of a gene. [2 marks]

3.4 Outline the function of the 'operator' region of a gene. [2 marks]

4. The basic elements of gene regulation: prokaryotic trp operon as a simplified example of a regulatory process. **VCE BIOLOGY SD, p. 29**

4.1 Describe the purpose of gene regulation. [1 mark]

4.2 Outline the purpose of the trp operon. [1 mark]

4.3 Explain how the trp operon operates when there is a low concentration of tryptophan present. [3 marks]

4.4 Explain how the trp operon operates when there is a high concentration of tryptophan present. [3 marks]

Explain the role of the following components of the trp operon:

4.5.1 RNA Polymerase. [2 marks]
4.5.2 Operator. [2 marks]
4.5.3 Inhibitory Transcription Factor. [2 marks]

5. Amino acids as the monomers of a polypeptide chain and the resultant hierarchical levels of structure that give rise to a functional protein. **VCE BIOLOGY SD, p. 29**

5.1 Define the term 'condensation polymerisation'. [1 mark]

5.2 Complete the following equation:

Alanine + Glycine Dipeptide + _____. [1 mark]

A specific section of RNA is extracted and it is found to contain 540 monomers. However, it is known that a polypeptide chain containing only 25 amino acids is translated from this section.

5.3 Explain how this may be the case. [2 marks]

5.4 Explain the main steps involved in the process of condensation polymerisation. [3 marks]

6. Proteins as a diverse group of molecules that collectively make an organism's proteome, including enzymes as catalysts in biochemical pathways. **VCE BIOLOGY SD, p. 29**

6.1 Define the term 'proteome'. [1 mark]

6.2 Distinguish between the genome and the proteome of a cell. [3 marks]

6.3 Explain why proteins are generally studied collectively rather than in isolation. [1 mark]

6.4 Identify whether the proteome or human genome is larger. Explain your choice. [3 marks]

6.5 Use the spaces provided to define each level of protein structure and outline the bonding present. [4 marks]

Level of Protein Structure	**Definition**	**Bonding Present**
Primary		
Secondary		
Tertiary		
Quaternary		

7. The role of rough endoplasmic reticulum, Golgi apparatus and associated vesicles in the export of proteins from a cell via the protein secretory pathway. **VCE BIOLOGY SD, p. 29**

7.1 Complete the table below, explaining the function of the following organelles involved in protein exportation. [4 marks]

Organelle	**Organelle Function**
Ribosomes	
Rough Endoplasmic Reticulum	
Golgi Body	
Secretory Vesicle	

7.2 Outline the functional difference between free cellular ribosomes and ribosomes studded on the rough endoplasmic reticulum. [2 marks]

8. The use of enzymes to manipulate DNA, including polymerase to synthesise DNA, ligase to join DNA and endonucleases to cut DNA. **VCE BIOLOGY SD, p. 29**

8.1 Outline the general function of endonucleases. [1 mark]

8.2 Describe the general function of ligases. [2 marks]

8.3 Describe the general function of polymerases. [2 marks]

9. The function of CRISPR-Cas9 in bacteria and the application of this function in editing an organism's genome. **VCE BIOLOGY SD, p. 29**

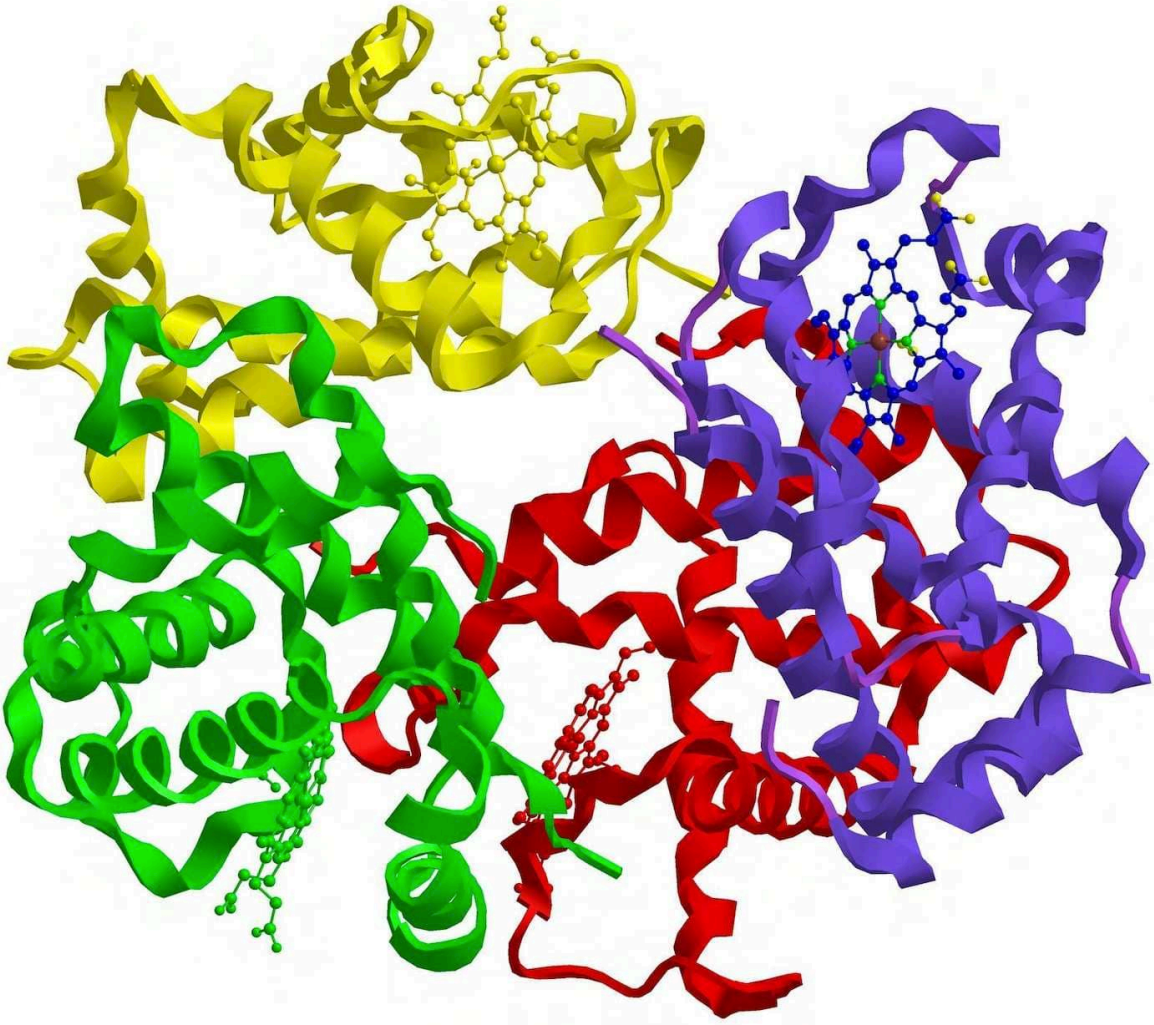
9.1 What does the term 'CRISPR' in CRISPR-Cas9 stand for? [1 mark]

9.2 Explain the function of the CRISPR-Cas9 system in bacteria. [2 marks]

9.3 Explain how the CRISPR-Cas9 system in bacteria acts to develop immunological memory and respond to viruses that they have been previously exposed to. [5 marks]

Sickle cell anaemia is an autosomal recessive disorder that causes the breakdown of premature red blood cells. A mutation in haemoglobin, a protein in red blood cells that is responsible for delivering oxygen to cells throughout the body, results in the disease. Research is currently taking place to determine if genetic editing technologies can treat sickle cell anaemia patients.

Below is a diagram of haemoglobin.



9.4.1 Identify and define the level of protein structure of haemoglobin. [1 mark]

β-globin is a protein subunit of haemoglobin and is necessary for carrying oxygen in red blood cells. The gene that codes for this particular protein, when mutated, results in sickle cell anaemia. CRISPR-Cas9, a gene editing tool, is proposed to be a potential solution to replacing this mutated gene. Hematopoietic stem cells, a type of cell that can differentiate into red blood cells, would be first collected from affected patients. CRISPR-Cas9 technology would then be used to replace the defective gene with a functional β-globin gene in these cells.

9.4.2 Using your own understanding and the information above, explain how CRISPR-Cas9 technology can be used to replace the defective β-globin gene. [4 marks]

9.4.3 Explain one advantage and one disadvantage of using CRISPR-Cas9 technology to treat sickle cell anaemia. [4 marks]

10. Amplification of DNA using polymerase chain reaction and the use of gel electrophoresis in sorting DNA fragments, including the interpretation of gel runs for DNA profiling.*VCE BIOLOGY SD, p. 29**

10.1.1 Describe the purpose of the polymerase chain reaction. [1 mark]

10.1.2 Describe the steps of the polymerase chain reaction. [4 marks]

10.1.3 State two applications where the polymerase chain reaction can be used. [2 marks]

The polymerase chain reaction process can be described as 'sensitive'.

10.2 Explain the above statement. [2 marks]

10.3 Complete the table below, explaining the function of the following components involved in the polymerase chain reaction. [4 marks]

Components	**Function**
Nucleotides	
Taq Polymerase	
Primers	
DNA Sample	

10.4.1 Describe the purpose of gel electrophoresis. [1 mark]

10.4.2 Identify one molecule, other than DNA fragments, that can be separated through gel electrophoresis. [1 mark]

10.5 Explain why DNA molecules are negatively charged. [2 marks]

10.6 Explain the main steps of the process of gel electrophoresis. [4 marks]

10.7 Complete the table below, describing the function of the following features involved in the process of gel electrophoresis. [6 marks]

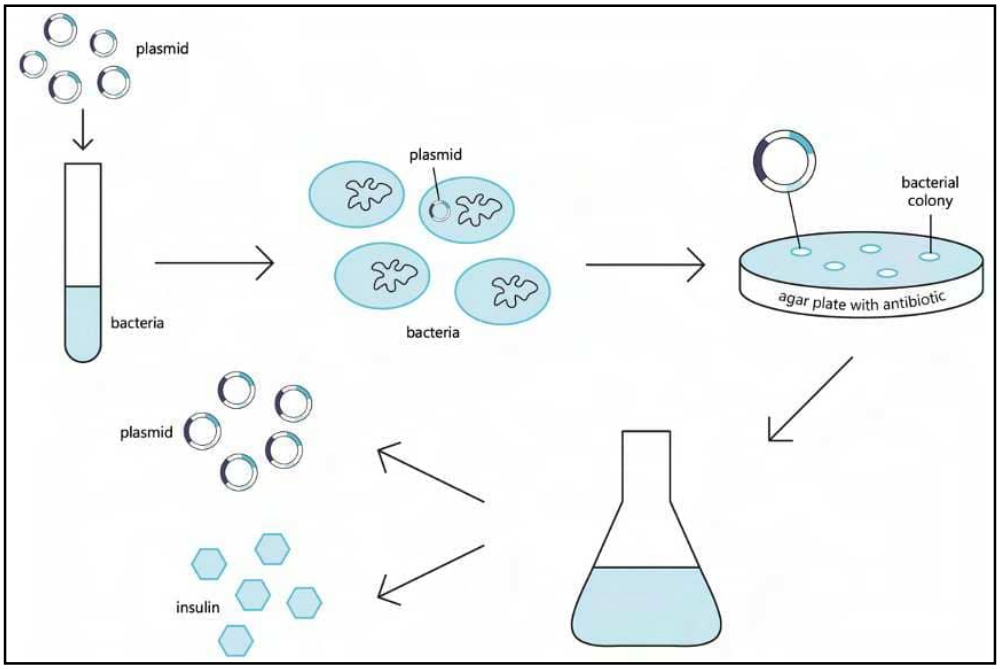
Feature	**Function**
Buffer Solution	
Wells	
Terminals	
Dye	
Current (power)	
DNA Ladder	
Restriction Enzymes	

11. The use of recombinant plasmids as vectors to transform bacterial cells as demonstrated by the production of human insulin. **VCE BIOLOGY SD, p. 29**

11.1 Define the term 'gene cloning'. [1 mark]

11.2 Describe the structure and function of plasmids. [2 marks]

The diagram below displays the process of bacterial transformation.



11.3 Describe the process of bacterial transformation and outline how transformed bacteria are identified. [4 marks]

12. The use of genetically modified and transgenic organisms in agriculture to increase crop productivity and to provide resistance to disease. **VCE BIOLOGY SD, p. 29**

12.1 Distinguish between 'genetically modified organisms' and 'transgenic organisms'. [3 marks]

12.2 Explain two benefits, one agricultural and one immunological, of the genetic modification of organisms. [4 marks]

12.3 Complete the table below, explaining the social implications of the use of genetically modified organisms. [6 marks]

Implication	**Explanation**
Social inequality is created.	
Malnutrition can be solved.	
Human self-interest is prioritised over the ethical treatment of organisms.	

12.4 Complete the table below, explaining the biological implications of the use of genetically modified organisms. [6 marks]

Implication	**Explanation**
Cross pollination between genetically modified crops and non-genetically modified crops can occur.	
Loss of biodiversity.	
Genetically modified animals may compete with natural populations.	

12.5 Complete the table below, explaining the ethical implications of the use of genetically modified organisms. [6 marks]

Implication	**Explanation**
Violation of animal rights.	
Inappropriate intervening of evolution.	
Costs for farmers increases.	

Questions: Unit 3 AOS 2

1. ***The general structure of the biochemical pathways in photosynthesis and cellular respiration from initial reactant to final product .*** **VCE BIOLOGY SD, p. 30**

1.1.1 Define the term photosynthesis. [1 mark]

1.1.2 Explain the importance of photosynthesis. [3 marks]

1.1.3 Write the chemical equation for photosynthesis. [1 mark]

1.1.4 Write the worded equation for photosynthesis. [1 mark]

1.2.1 Define the term cellular respiration. [1 mark]

1.2.2 Explain the importance of cellular respiration. [3 marks]

1.2.3 Write the chemical equation for cellular respiration. [1 mark]

1.2.4 Write the worded equation for cellular respiration. [1 mark]

2. ***The general role of enzymes and coenzymes in facilitating steps in photosynthesis and cellular respiration.*** **VCE BIOLOGY SD, p. 30**

2.1 Define the term 'enzyme'. [2 marks]

Enzymes are referred to as biological catalysts.

2.2 Outline what is meant by the terms 'biological' and 'catalyst' in the term biological catalyst. [2 marks]

2.3 Define the term 'activation energy'. [1 mark]

2.4 Identify two enzymes in the human body and outline their purpose. [3 marks]

2.5 Outline how the structure of an enzyme's active site suits its function. [2 marks]

Yeasts metabolise different sugars to varying extents.

2.6 Suggest two reasons for this. [2 marks]

Catalase is an enzyme that catalyses the breakdown of hydrogen peroxide. Below is a chemical reaction that demonstrates this:

$$2H_2O_2 \xrightarrow{\text{Catalase}} 2H_2O + O_2$$

2.7.1 Draw a labelled diagram of the action of catalase using the lock and key model of enzyme action. [3 marks]

2.7.2 Draw a labelled diagram of the action of catalase using the induced fit model of enzyme action. [3 marks]

2.8 Explain the difference between coenzymes and cofactors. [3 marks]

2.9 Distinguish between the 'unloaded' and 'loaded' form of a coenzyme. [2 marks]

2.10.1 Explain the function of the coenzyme ATP. [2 marks]

2.10.2 Explain the function of the coenzyme NADH. [2 marks]

2.10.3 Explain the function of the coenzyme NADPH. [2 marks]

2.11 Outline one similarity and one difference between NADPH and NADH. [2 marks]

3. The general factors that impact on enzyme function in relation to photosynthesis and cellular respiration: changes in temperature, pH, concentration, competitive and non-competitive enzyme inhibitors. **VCE BIOLOGY SD, p. 30**

3.1 Explain the importance of kinetic energy in enzyme-catalysed reactions. [2 marks]

3.2.1 Define the term 'inhibitor'. [1 mark]

3.2.2 Explain the mode of action of competitive inhibitors. Draw a labelled diagram to support your response. [4 marks]

3.2.3 Explain the mode of action of non-competitive inhibitors. Draw a labelled diagram to support your response. [4 marks]

A student accidentally mislabels an inhibitor solution and is unsure whether it contains a 2% solution of a competitive inhibitor, X, or a 2% solution of a non-competitive inhibitor, Y. Both these inhibitors inhibit the action of enzyme Z.

3.3 Design an experiment to determine if the inhibitor in the solution is X or Y. [5 marks]

3.4 Identify three factors, other than the action of inhibitors, that can have an effect on enzyme activity. [1 mark]

To determine the effect of increasing temperature on the rate of lipid breakdown, five separate test tube solutions of lipase are subject to varying temperatures. The individual test tubes are then added to separate solutions of milk. Lipase acts to break down lipids in the milk into glycerol and fatty acids. The rate of enzyme activity is determined by recording the concentration of glycerol before and 5 minutes after adding the lipase solution. This data is presented below.

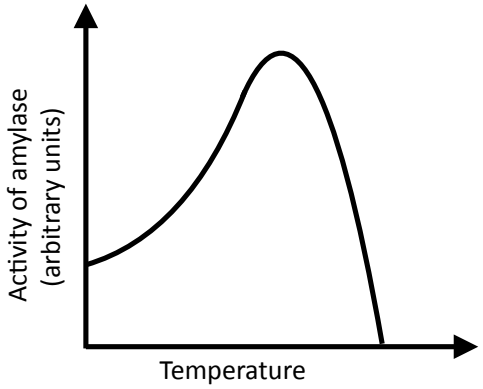
Temperature (ºC)	**Concentration of glycerol in milk before lipase is added (M)**	**Concentration of glycerol in milk after lipase is added (M)**
10ºC	0.1M	0.15M
20ºC	0.1M	0.25M
30ºC	0.1M	0.4M
40ºC	0.1M	0.28M
50ºC	0.1M	0.13M

3.5.1 Identify the temperature at which lipase activity was most optimal. Explain your choice using data from the above table. [3 marks]

3.5.2 Using your understanding of enzyme structure and function, explain the data obtained at 50ºC. [3 marks]

3.5.3 Explain how recording the pH of the milk solution before and after adding the lipase solution can be used to determine the rate of lipase activity in this experiment. [3 marks]

Below is a line graph displaying the effect of varying temperature on the activity of amylase.

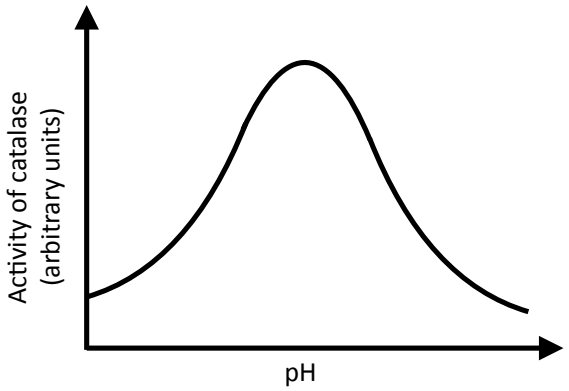


3.6.1 Explain what the ascending and descending portions of the graph above reflects in terms of amylase activity. [4 marks]

3.6.2 Describe the term 'denaturation' with reference to enzyme structure. [2 marks]

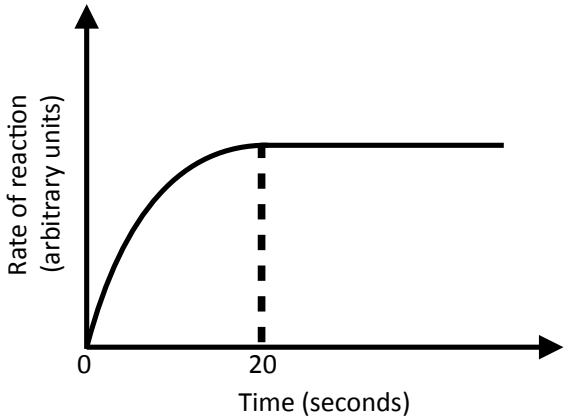
3.6.3 Explain why the primary structure of amylase is unaffected by denaturation whereas the tertiary structure is. [3 marks]

Below is a line graph displaying the effect of varying pH on the activity of catalase.



3.7 Explain what the ascending and descending portions of the graph above reflects in terms of catalase activity. [3 marks]

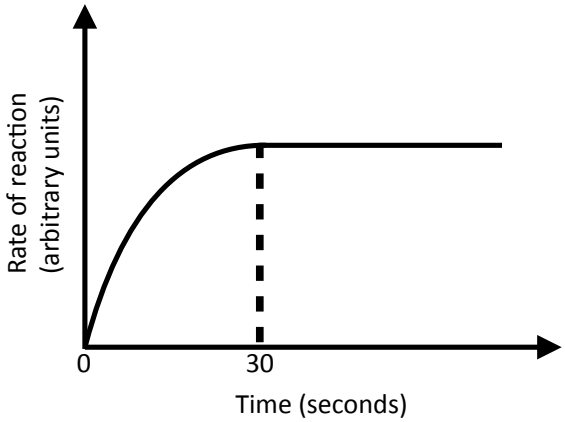
Below is a line graph displaying the rate of reaction between lipase and lipids. In this particular experiment, the concentration of lipids is increasing and the concentration of lipase is fixed.



3.8.1 Explain the results of the graph from 0-20 seconds. [3 marks]

3.8.2 Explain the results of the graph from 20 seconds onwards. [3 marks]

Below is a line graph displaying the rate of reaction for an experiment whereby trypsin, an enzyme that catalyses the breakdown of proteins, is increasing in concentration.



3.9.1 Explain the results of the graph from 0-30 seconds. [3 marks]

3.9.2 Explain the results of the graph from 30 seconds onwards. [3 marks]

4. Inputs, outputs and locations of the light dependent and light independent stages of photosynthesis in C_3 plants (details of biochemical pathway mechanisms are not required). **VCE BIOLOGY SD, p. 30**

4.1 Identify the two stages of photosynthesis and where each stage occurs. [2 marks]

4.2 Explain the steps of the light-dependent stage of photosynthesis. [3 marks]

4.3 Explain the steps of the light-independent stage of photosynthesis. [3 marks]

5. The role of Rubisco in photosynthesis, including adaptations of C_3, C_4 and CAM plants to maximise the efficiency of photosynthesis required). **VCE BIOLOGY SD, p. 30**

Rubisco is one of the most abundant enzymes in the world and is a key enzyme in photosynthesis. Below is an incomplete chemical equation that demonstrates the action of rubisco.

$$\_\_\_\_\_{}_{(g)} + RuBP \longrightarrow 3GP_{(aq)}$$

5.1.1 Complete the above chemical equation by writing the correct input in the empty space. [1 mark]

5.1.2 Explain the function of Rubisco in photosynthesis. [2 marks]

5.1.3 Identify whether Rubisco is involved in the light-dependent or light-independent stage of photosynthesis. [1 mark]

5.1.4 Identify where Rubisco is found in a cell. [1 mark]

5.1.5 Describe the main steps of the first stage of Rubisco synthesis. [3 marks]

Scientists have hypothesised that two different types of plants, C4 and CAM, arrived from natural selection. Their primary purpose is to minimise the chance of engaging in photorespiration.

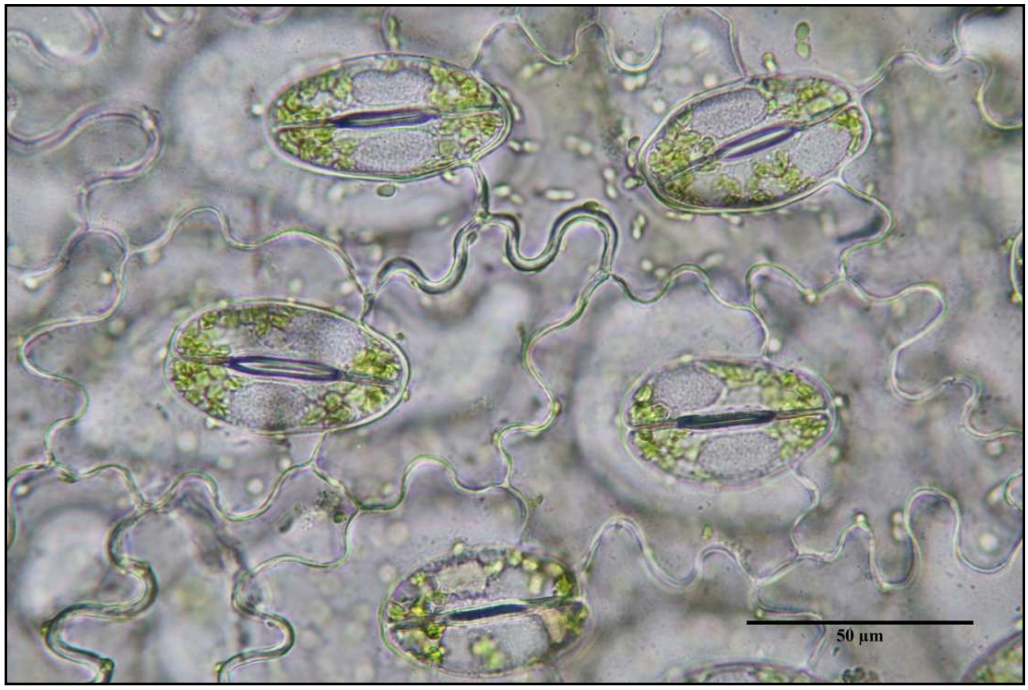
5.2.1 Define the term 'photorespiration'. [1 mark]

5.2.2 Describe two consequences of a C3 plant engaging in photorespiration. [2 marks]

5.2.3 Explain how C4 plants avoid engaging in photorespiration. [3 marks]

5.2.4 Explain how CAM plants avoid engaging in photorespiration. [3 marks]

A section of a C3 plant leaf is prepared and viewed under a light microscope. Below is what is viewed.



5.3.1 Outline why the stomata of a C3 plant remains closed during hot conditions and explain the consequences of this on the efficiency of photosynthesis. [4 marks]

Although the stomata of CAM pants remain closed during the day, they are still able to photosynthesise.

5.3.2 Explain how this is the case. [3 marks]

Euphorbia balsamifera is a flowering plant that grows in the hot and dry conditions of the Sahara desert. Due to these conditions, *E. balsamifera* separates the light-dependent and light-independent stages of photosynthesis. However both these stages occur in the mesophyll cells of the plant.

5.4 Identify whether *E. balsamifera* is a C3, C4 or CAM plant and outline how these two stages of photosynthesis are 'separated'. [2 marks]

Corn is a C4 plant that has developed adaptations to minimise the chance of undergoing photorespiration.

5.5.1 Identify one example of a C4 plant, other than corn. [1 mark]

5.5.2 Explain one physical feature of C4 plants that distinguish them from C3 plants. [2 marks]

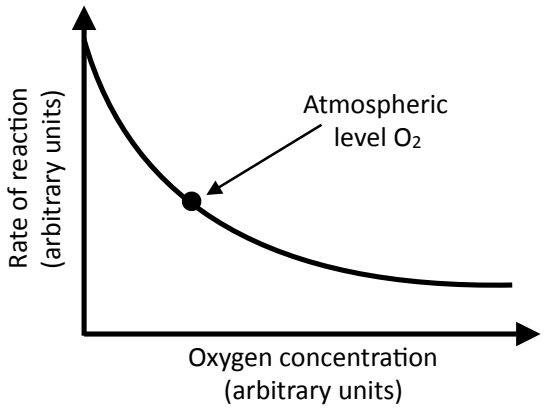
5.5.3 In regards to corn, identify which cell type the light-dependent stage occurs and in which cell type the light-independent stage occurs. [2 marks]

5.5.4 Explain the purpose of separating the light-dependent and light-independent stage by cellular location as seen in C4 plants. [3 marks]

Oxygen is a competitive inhibitor of Rubisco. This is because oxygen has a high affinity for the active site of Rubisco. The binding of oxygen to Rubisco can lead to photorespiration.

5.6.1 Draw a labelled diagram explaining the mode of action of oxygen as a competitive inhibitor of Rubisco. [3 marks]

Below is a graph displaying the effect of increasing the concentration of oxygen in a closed system on the rate of photosynthesis.

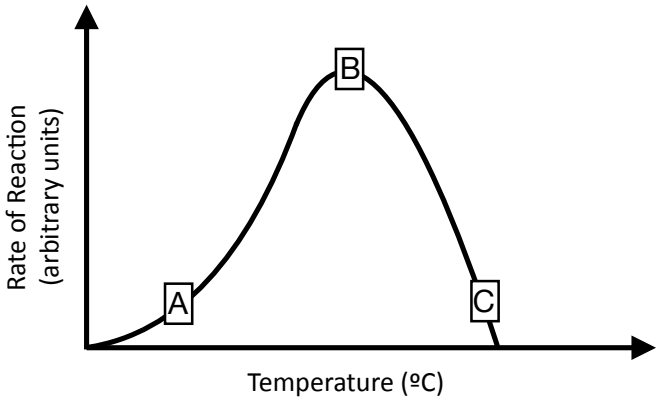


5.7 Explain the results of the data above. [3 marks]

6. The factors that affect the rate of photosynthesis: light availability, water availability, temperature and carbon dioxide concentration). **VCE BIOLOGY SD, p. 30**

6.1 Define the term 'limiting factor. [1 mark]

An experiment was conducted to determine the effect of varying temperature on the rate of photosynthesis. The results of this experiment are graphed below.



6.2.1 Explain the results of the experiment at point A of the above graph. [3 marks]

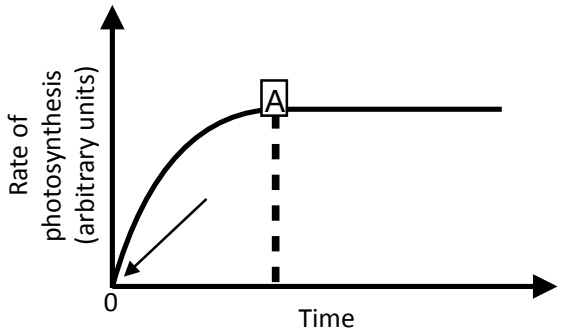
6.2.2 Explain the results of the experiment at point B of the above graph. [3 marks]

6.2.3 Explain the results of the experiment at point C of the above graph. [3 marks]

Two separate experiments were conducted in the classroom to prove that CO2 is required for photosynthesis. Two enclosed test tubes with two halves of a leaf are prepared in the same conditions except test tube 1 contains potassium hydroxide and test tube 2 does not contain potassium hydroxide. The function of potassium hydroxide is to absorb CO2. The exposed parts of each leaf are then tested for starch.

6.3 Identify whether the leaf in test tube 1 or test tube 2 will test positive for starch. Justify your choice. [3 marks]

An experiment was conducted to determine the effect of increasing the concentration of carbon dioxide on the rate of photosynthesis. The results of this experiment are graphed below.



6.4.1 Explain the results from of the experiment from point A onwards. [3 marks]

The arrow on the above graph indicates where the rate of photosynthesis is zero.

6.4.2 Explain why the rate of photosynthesis is zero when there is no carbon dioxide available. [2 marks]

6.5 Explain the relationship between water availability and the rate of photosynthesis. [3 marks]

6.6 Explain the relationship between light intensity and the rate of photosynthesis. [3 marks]

7. The main inputs, outputs and locations of glycolysis, Krebs Cycle and electron transport chain including ATP yield (details of biochemical pathway mechanisms are not required). **VCE BIOLOGY SD, p. 30**

7.1 Define the term 'glycolysis'. [1 mark]

7.2 Identify the inputs and outputs of glycolysis. [2 marks]

7.3 Explain why glucose is broken down via a series of reactions rather than a single-step reaction. [3 marks]

7.4 Identify the inputs and outputs of the Krebs Cycle. [2 marks]

7.5.1 Identify the inputs and outputs of the Electron Transport Chain. [2 marks]

7.5.2 Describe the main steps of the Electron Transport Chain. [3 marks]

8. The location, inputs and the difference in outputs of anaerobic fermentation in animals and yeasts). **VCE BIOLOGY SD, p. 30**

8.1 Define the term 'anaerobic fermentation'. [1 mark]

8.2 Explain two reasons why anaerobic respiration is a less efficient process than aerobic respiration. [2 marks]

8.3 Identify the cellular location of anaerobic fermentation in animals and yeasts. [2 marks]

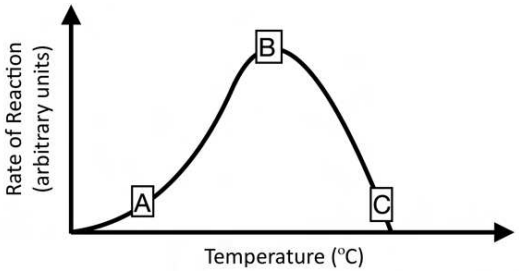
8.4 Identify the inputs and outputs of anaerobic fermentation in animals. [2 marks]

8.5 Identify the inputs and outputs of anaerobic fermentation in yeasts. [2 marks]

8.6 Describe two applications of anaerobic fermentation. [2 marks]

9. The factors that affect the rate of cellular respiration: temperature, glucose availability and oxygen concentration). **VCE BIOLOGY SD, p. 30**

An experiment was conducted to determine the effect of varying temperature on the rate of photosynthesis. The results of this experiment are graphed below.



9.1.1 Explain the results of the experiment at point A of the above graph. [3 marks]

9.1.2 Explain the results of the experiment at point B of the above graph. [3 marks]

9.1.3 Explain the results of the experiment at point C of the above graph. [3 marks]

9.2 Explain the relationship between glucose availability and the rate of cellular respiration. [3 marks]

9.3 Explain the relationship between oxygen availability and the rate of cellular respiration. [3 marks]

10. Potential uses and applications of CRISPR-Cas9 technologies to improve photosynthetic efficiencies and crop yields. **VCE BIOLOGY SD, p. 31**

10.1 Outline one biotic and one abiotic stressor which plants can possess tolerance against if CRISPR-Cas9 technology is used to modify the plant genome. [2 marks]

Cucumis sativus L., commonly referred to as cucumbers, was the subject of genetic testing in January 2016. Scientists used CRISPR-Cas9 technology to target a gene eIF4E, which is associated with increased viral pathogenesis. Disruption of this gene can lead to viral resistance in cucumbers. Consumption of virally-infected cucumbers do not cause negative health effects for humans - only the plant will be harmed if infected by a plant-specific virus.

10.2 Explain one advantage of using CRISPR-Cas9 technology to produce virally-resistant plants. [2 marks]

10.3 Based on the above information and using your own knowledge, outline two way in which CRISPR-Cas9 technology can be used to control plant viruses. [2 marks]

11. Uses and applications of anaerobic fermentation of biomass for biofuel production. **VCE BIOLOGY SD, p. 31**

11.1 Define the term 'biomass'. [1 mark]

11.2 Define the term ‘biofuel’. [1 mark]

11.3 Explain whether biofuels are renewable or non-renewable sources. [3 marks]

11.4 Identify one type of biofuel. Explain how it is produced and its environmental benefits. [3 marks]

Questions: Unit 4 AOS 1

1. ***Physical, chemical and microbiota barriers as preventative mechanisms of pathogenic infection in animals and plants.*** **VCE BIOLOGY SD, p. 34**

1.1 Define the term 'pathogen'. [1 mark]

1.2 Explain how pathogens cause disease. [3 marks]

1.3 Outline two differences between plant and animal immune systems to prevent pathogenic infection.

1.4.1 Describe two physical barriers that would protect the human body from an invading pathogen. [2 marks]

1.4.2 Describe two chemical barriers that would protect the human body from an invading pathogen. [2 marks]

1.4.3 Describe two microbiological barriers that would protect the human body from an invading pathogen. [2 marks]

1.5.1 Describe two physical barriers that could be present in a plant that would protect itself from an invading pathogen. [2 marks]

1.5.2 Describe two chemical barriers that could be present in a plant that would protect itself from an invading pathogen. [2 marks]

1.5.3 Describe two microbiological barriers that could be present in a plant that would protect itself from an invading pathogen. [2 marks]

2. ***The innate immune response including the steps in an inflammatory response and the characteristics and roles of macrophages, neutrophils, dendritic cells, eosinophils, natural killer cells, mast cells, complement proteins and interferons.*** **VCE BIOLOGY SD, p. 34**

2.1 Identify two antigen presenting cells. [2 marks]

2.2 Draw a labelled diagram of the steps involved in phagocytosis. [3 marks]

Sam was recently diagnosed with the common cold as a result of infection by the Influenza virus.

2.3.1 Identify whether the Influenza virus is a cellular or non-cellular pathogen. Explain your choice. [2 marks]

2.3.1 Describe how natural killer cells would protect Sam once the Influenza virus has gained entry to the internal environment. [2 marks]

2.3.2 Describe how complement proteins would protect Sam once the Influenza virus has gained entry to the internal environment. [2 marks]

2.3.3 Describe how neutrophils would protect Sam once the Influenza virus has gained entry to the internal environment. [2 marks]

2.3.4 Describe how interferons would protect Sam once the Influenza virus has gained entry to the internal environment. [2 marks]

2.3.5 Explain why Sam is more susceptible to being infected by other invading pathogens now that he has been diagnosed with the cold. [3 marks]

2.3.6 Explain the importance of a fever in reducing the spread of the Influenza virus and describe how a fever is brought on. [4 marks]

Rachel is a keen biology student who is studying for her end of year examinations. Whilst completing a practice examination, she cuts her finger with the edge of the paper.

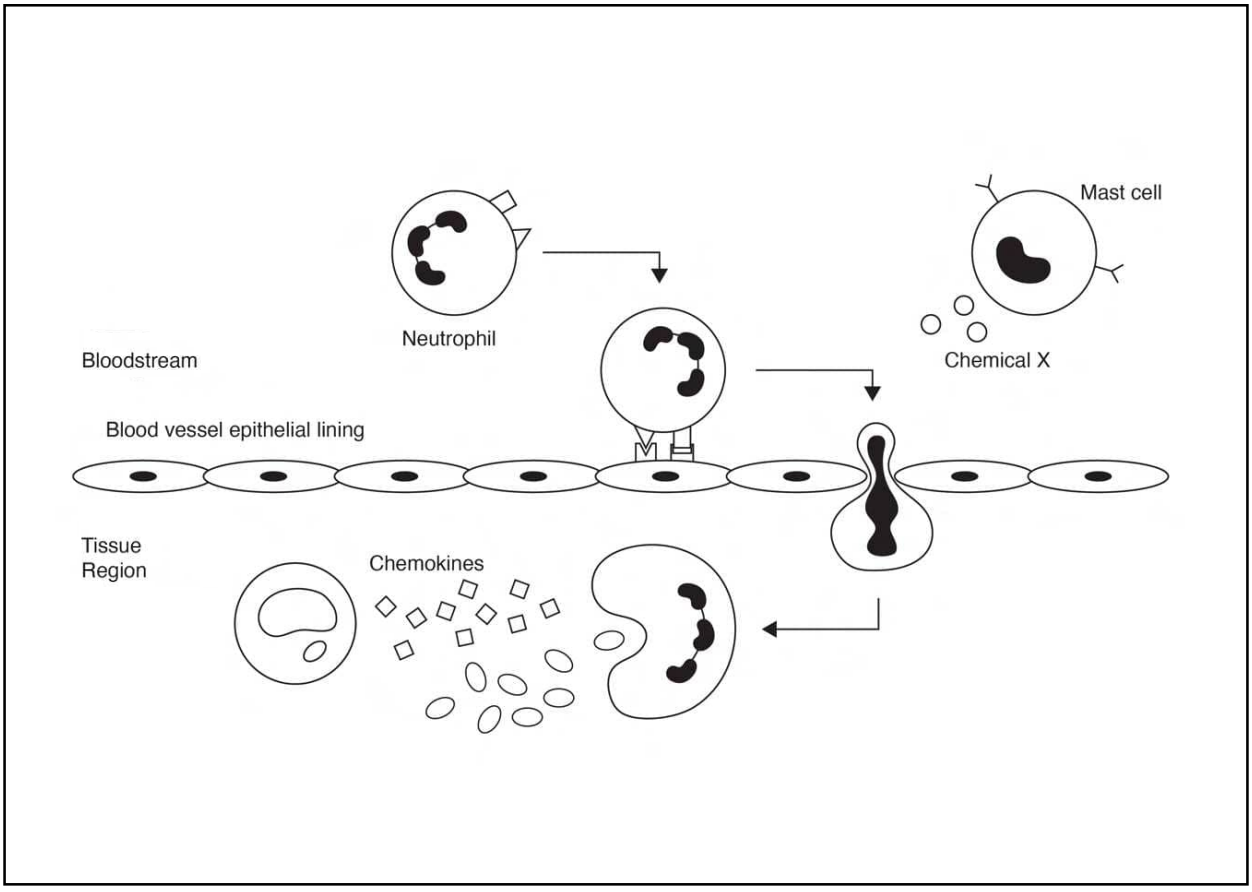
2.4.1 Explain the inflammatory response that will occur at a cellular level. [5 marks]

2.4.2 Explain the purpose of the inflammatory response. [3 marks]

During spring, James develops watery eyes, a runny nose and congestion as symptoms of hay fever. This is brought on when he plays outside, particularly on windy days. These symptoms are due to an allergic reaction to pollen.

2.5 Explain, at a cellular level, the steps leading to an allergic reaction in James. [4 marks]

Neutrophils are located in the bloodstream. When a pathogen gains entry into the internal environment, neutrophils migrate to the site of invasion by a process called extravasation. Below is a labelled diagram displaying this process.



2.6.1 Describe the role of mast cells in the migration of leukocytes. In your response, identify what chemical X is. [3 marks]

2.6.2 Explain why the epithelial lining is impermeable when there are no invading pathogens. [2 marks]

2.6.3 Describe how the neutrophil will respond when in the presence of the invading pathogens. [2 marks]

3. Initiation of an immune response, including antigen presentation, the distinction between self-antigens and non-self antigens, cellular and non-cellular pathogens and allergens.*VCE BIOLOGY SD, p. 34**

3.1 Define the term 'antigen'. [1 mark]

3.2 Explain why it is important for immune cells to be able to recognise the difference between self and non-self antigens. [3 marks]

3.3 Describe the role of mast cells in an allergic response. [2 marks]

3.4 Outline how sensitisation to an allergen first occurs. [2 marks]

3.5 Identify the key difference between MHC-I and MHC-II. [1 mark]

3.6 Give an example of one cellular and one non-cellular pathogen, and describe how the body responds differently to each. [3 marks]

4. The role of the lymphatic system in the immune response as a transport network and the role of lymph nodes as sites for antigen recognition by T and B lymphocytes.*VCE BIOLOGY SD, p. 34**

4.1 Define the term 'lymphatic system'. [1 mark]

4.2 Describe two functions of the lymphatic system in humans. [2 marks]

4.3 Describe how lymph fluid moves in the lymphatic system. [2 marks]

4.4 Name one body system that is closely connected to the lymphatic system. [1 mark]

4.5 State one example of a primary and secondary lymph organ. [2 marks]

4.6 State the location of B and T lymphocyte formation and maturation. [2 marks]

4.7 Describe how the lymph system assists in antigen recognition. [2 marks]

4.8 Describe one structural feature of the lymphatic system and explain how it assists in its function. [2 marks]

After infection with a virus, Jane notices that the lymph nodes underneath her chin are hard and swollen.

4.9 Explain why this has occurred. [2 marks]

Weil's disease is a severe form of infection caused by the *Leptopspira* bacteria. It is generally not spread from person to person but instead passed from the urine of infected animals. The bacteria can easily pass through skin abrasions, or through the consumption of contaminated food and water.

4.10 Describe how the lymph system assists in antigen recognition of the *Leptopspira* bacteria. [3 marks]

5. The characteristics and roles of the components of the adaptive immune response against both extracellular and intracellular threats, including the actions of B lymphocytes and their antibodies, helper T and cytotoxic T cells. **VCE BIOLOGY SD, p. 34**

5.1 Explain how clonal selection and expansion contribute to the adaptive immune response. [2 marks]

Cancer occurs when mutated DNA in cells produce uncontrolled cellular growth. A normal body cell differentiates and produces proteins specific to its function, whereas cancer cells do not require differentiation to produce proteins required for proliferation. Cancer cells do not require the same growth factors as normal cells, in addition to other factors, this enables them to grow at a faster rate. Not all cancerous cells result in the formation of a tumour. In many instances, the cancerous cells are detected by the immune system and subsequently removed.

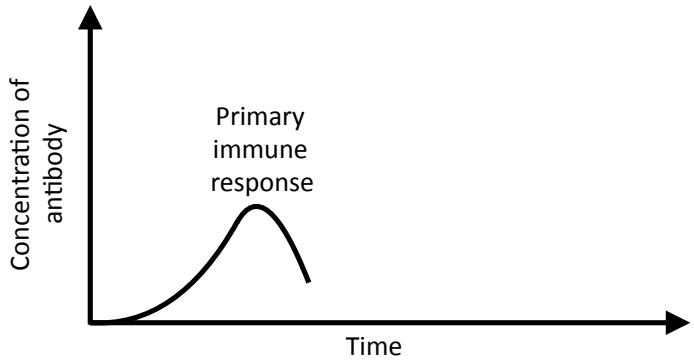
The immune system contains multiple methods for removing cancer cells.

5.2.1 Name and describe one adaptive pathway that can reduce cancer cells. [4 marks]

5.2.2 Name and describe another adaptive pathway that can impair cancer cells. [4 marks]

5.2.3 Explain how both pathways can prevent the same type of cancer cells from growing. [2 marks]

5.3 Graph the concentration of antibody that occurs during a secondary immune response and label key points on the graph below. [3 marks]



6. The difference between natural and artificial immunity and active and passive strategies for acquiring immunity. **VCE BIOLOGY SD, p. 34**

6.1 Distinguish between natural and artificial immunity. [2 marks]

6.2 Distinguish between active immunity and passive immunity. [2 marks]

6.3 Complete the following table, classifying examples of active and passive immunity. [4 marks]

Method of acquiring immunity	**Active or Passive and Natural or Artificial?**
Vaccination	
Catching a cold	
Injection of antibodies	
Consuming breast milk	

6.4 Describe one advantage and one disadvantage of active immunity. [2 marks]

6.5 Describe one advantage and one disadvantage of passive immunity. [2 marks]

7. The emergence of new pathogens and re-emergence of known pathogens in a globally connected world, including the impact of European arrival on Aboriginal and Torres Strait Islander peoples.*VCE BIOLOGY SD, p. 34**

7.1 Explain how global travel increases the risk of infectious diseases emerging in a population. [3 marks]

7.2 Identify two factors that increase the likelihood of a pathogen spreading in a population. [2 marks]

7.3 Explain why people previously unexposed to particular microbes are more susceptible to becoming ill after exposure. [2 marks]

7.4 Outline two ways in which Aboriginal and Torres Strait Islander people's health may have been negatively impacted by colonisation beyond the introduction of new pathogens into the environment. [2 marks]

Measles was declared to be eradicated from Australia in February 2009. However in 2019, 57 confirmed cases of measles was reported in Victoria.

7.5 Explain two reasons for why there are still cases in Australia, 10 years after endemic measles was eradicated. [2 marks]

Severe acute respiratory syndrome (SARS) is a viral respiratory illness caused by a coronavirus, called SARS-associated coronavirus (SARS-CoV). Following the outbreak in February 2003, the illness spread to more than two dozen countries in North America, South America, Europe, and Asia in a matter of months.

7.6.1 Would the spread of this disease be more correctly referred to as an epidemic or a pandemic? Provide a reason to support your answer. [2 marks]

Some scientists tried to put samples from the affected individuals onto agar in Petri dishes and incubating them.

7.6.2 Explain why this approach was unsuccessful in isolating the SARS-CoV virus. [2 marks]

7.7 Identify two factors which may have contributed to the rapid spread of disease. [2 marks]

Within fourteen months of the arrival of the First Fleet, it was reported that over half the Indigenous people in Sydney had succumbed to epidemic diseases brought over by the Europeans, such as smallpox, influenza and measles. However, the European settlers were only minimally affected by this disease due to previous exposure in Europe.

7.8 Explain why previous exposure to a pathogen minimises the effect of the pathogen. [3 marks]

7.9 Explain why a pandemic is more likely to occur when a new pathogen emerges. [3 marks]

8. Scientific and social strategies employed to identify and control the spread of pathogens, including identification of the pathogen and host, modes of transmission and measures to control transmission.*VCE BIOLOGY SD, p. 34**

In the food industry, many methods are employed to identify pathogens in foods being sold to consumers.

8.1.1 Explain how culturing of pathogens on agar plates can be used to identify specific pathogens. [3 marks]

8.1.2 Briefly explain the steps of polymerase chain reaction and how this technique can be use to identify pathogens. [3 marks]

8.1.3 Why might a company choose to use polymerase chain reaction techniques over culturing for pathogen identification. [2 marks]

8.2 Explain two adaptations of bacteria that enable it to evade host defences. [2 marks]

8.3 How does the mode of transmission of a pathogen influence the spread of disease? [2 marks]

COVID-19 is transmitted from person to person through direct contact with respiratory droplets of an infected person, generated through coughing and sneezing. Individuals can be infected from touching surfaces contaminated with the virus and then touching their face (via World Health Organisation).

8.4.1 Outline two public health measures that could control the spread of COVID-19 and explain how they would be effective. [2 marks]

Protective gowns and masks are a preventative measure used against AIDS, a disease that spreads via infected body fluids.

8.4.2 Describe another effective method for preventing the transmission of diseases that spread through infected body fluids. [2 marks]

8.4.3 Explain why wearing protective gowns and masks is not completely effective when preventing the spread of COVID-19. [2 marks]

Explain how the following three strategies can limit the impact of new emerging diseases:

8.5.1 Carrying out research. [2 marks]
8.5.2 Improving international relationships. [2 marks]
8.5.3 Developing training programs. [2 marks]

9. Vaccination programs and their role in maintaining herd immunity for a specific disease in a human population. **VCE BIOLOGY SD, p. 34**

9.1 Define the term ‘vaccine’. [1 marks]

9.2 Describe the purpose of vaccines. [2 marks]

9.3 Explain how vaccinations generate immunological memory to specific pathogens. [4 marks]

Vaccinations serve to develop an individual’s primary immune response to a particular pathogen.

9.4 Identify two reasons why a mother may choose not to vaccinate her child. [2 marks]

In some circumstances, a booster vaccination may be required years after an initial vaccination against a pathogen.

9.5 Explain why this may be the case. [2 marks]

9.6 Explain two health-related impacts of implementing vaccination programs. [3 marks]

9.7 Define the term ‘herd immunity’. [1 mark]

9.8 Explain how vaccines can be used to achieve herd immunity. [3 marks]

9.9 Describe two features of an effective vaccination program? [2 marks]

9.10 Explain how opposition to vaccination programs poses a challenge to the development of herd immunity in a population. [3 marks]

10. The development of immunotherapy strategies, including the use of monoclonal antibodies for the treatment of autoimmune diseases and cancer. **VCE BIOLOGY SD, p. 34**

10.1 Define the term 'monoclonal antibody'. [1 mark]

10.2 Describe one advantage and one challenge with the use of monoclonal antibody treatment. [2 marks]

10.3 Assuming that antibodies created are derived from a mouse, explain how monoclonal antibodies can be developed for the treatment of cancer. [4 marks]

10.4 Describe two ethical associated with using animals to create monoclonal antibodies. [2 marks]

10.5.1 Define the term 'autoimmune disease'. [1 mark]

10.5.2 Explain why autoimmune diseases occur, with reference to self and non-self cells. [2 marks]

10.5.3 Explain why it is difficult to diagnose and treat autoimmune diseases. [3 marks]

10.6 Explain why immunotherapy is considered a type of biological treatment. [2 marks]

In a lab, a sample of lung cancer tissue has been used to cultivate monoclonal antibodies to treat adenocarcinoma. After purification, the monoclonal antibodies are read to be used.

10.7.1 Describe how monoclonal antibodies are administered to patients. [1 mark]

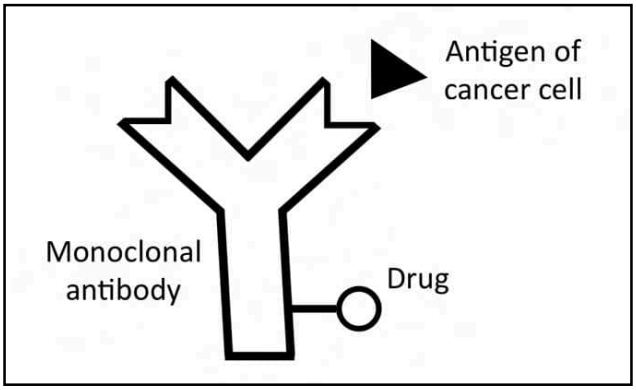
During transportation, the monoclonal antibodies produced were mistakenly labelled under another name, and given to a patient with leukaemia, which refers to cancers of blood cells.

10.7.2 How will the cellular effects of the monoclonal antibody change as a result? [2 marks]

Largely used in the treatment of cancer, chemotherapy causes many unwanted side effects such as nausea, hair loss and fatigue. A new therapy is being trialled that involves delivering a chemotherapy drug conjugated to a monoclonal antibody specific to an antigen on the cancer cell.

10.8.1 Explain why this may help to minimise the side effects of chemotherapy drug. [1 marks]

A diagram of the proposed setup is shown below.



The chemotherapy drug that is attached to the antibody unfortunately breaks down before it is able to attach to the antigen of the cancer cell.

10.8.2 Determine what actions the now naked monoclonal antibody may perform. [1 mark]

Cancer cells are generally quite difficult to detect by the immune system as they contain many similar antigens to other healthy cells in your body.

10.8.3 Explain why this is the case. [1 marks]

A radioactive tag may be bound in place of the drug.

10.8.4 Explain why this tag may be useful in the detection and treatment of cancer. [2 marks]

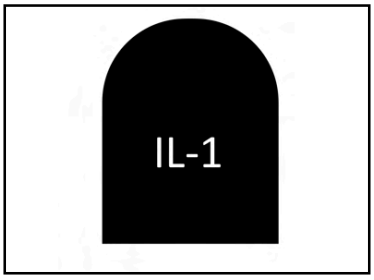
Rheumatoid arthritis (RA) is an autoimmune disease that presents with joint pain and arthritis as the immune system attacks the joint linings. Blood tests of patients with rheumatoid arthritis present with elevated levels of interleukin-6 (IL-6), a cytokine that promotes inflammation and leads to joint pain. Recent developments of monoclonal antibodies known as IL-6 inhibitors have shown promising results in relieving the pain associated with rheumatoid arthritis.

10.9.1 Explain why IL-6 inhibitors may relieve the pain and inflammation associated with rheumatoid arthritis. [2 marks]

An adult RA patient receiving treatment from IL-6 inhibitors is infected with a virus that is typically self-limiting, causing fever and cough for a maximum of five days in most adults. However, this patient does not develop a fever and their cough persists for over two weeks.

10.9.2 Explain why this may be the case. [1 mark]

Interleukin-1 (IL-1) is another cytokine that is involved in the inflammatory response and is over-expressed in patients with RA. A diagram of a IL-1 molecule is depicted below.



10.9.3 Draw a labelled diagram of a monoclonal antibody that could be used to minimise the action of IL-1. [2 marks]

Questions: Unit 4 AOS 2

1. ***Causes of changing allele frequencies in a population's gene pool, including environmental selection pressures, genetic drift and gene flow; and mutations as the source of new alleles.*** **VCE BIOLOGY SD, p. 35**

1.1.1 Define the term 'gene pool'. [1 mark]

1.1.2 Define the term 'genetic drift'. [1 mark]

1.1.3 Distinguish between the terms 'gene flow' and 'genetic drift'. [2 marks]

1.2.1 Explain how the 'founder effect' can reduce genetic variation in a population. [2 marks]

1.2.2 Explain why the frequency of a specific mutation would be higher in the founding population compared to a parent population. [2 marks]

1.3.1 Explain how the 'bottleneck effect' can reduce genetic variation in a population. [3 marks]

1.4 Explain why genetic drift has a greater impact on small populations compared to larger ones. [2 marks]

The sable antelope species possess horns that arch backwards, with males having larger horns than females. However, the larger horns make it difficult for these antelopes to move, catch prey and eat. There are more male sable antelopes with larger horns compared to smaller horns.

1.5 Explain how the larger horns in the males of this species could have evolved despite the difficulties stated above. [3 marks]

Phytophthora infestans is a fungus that causes a disease in potatoes and tomatoes termed 'late blight'. It is considered to be the catalyst for the Irish potato famine. The organism originated in Mexico and it is theorised that a single microorganism was transported into Europe, and Ireland specifically, due to global trade.

1.6.1 Identify the phenomenon that best describes the movement of *P. infestans* from Mexico to Europe. [1 mark]

1.6.2 Compare the likely genetic diversity of the *P. infestans* populations in Mexico and Europe, and explain why this would be the case. [3 marks]

1.6.3 Identify and describe two consequences of lowered genetic diversity. [2 marks]

1.6.4 Outline one method to increase the genetic diversity of a population. [2 marks]

The New Zealand black robin suffered a severe bottleneck when cats and rats depleted the population to only five individuals, of which only one was a mature female.

1.7.1 Explain the bottleneck effect and its impact on the genetic diversity of a population. [4 marks]

1.7.2 Describe one benefit and one risk of human intervention to encourage breeding and population growth after a bottleneck like that of the New Zealand black robin. [2 marks]

In the event of a fixed gene pool, determine whether the following statements are true or false:

1.8.1 The population must be small. [1 mark]
1.8.2 There must be no mutations occurring at all. [1 mark]
1.8.3 Natural selection must not be operating on the population. [1 mark]
1.8.4 There can be immigration but not emigration. [1 mark]

1.9.1 Define the term 'mutation' and outline one cause of mutations. [2 marks]

1.9.2 Explain how point mutations are sources of new alleles. [2 marks]

A section of DNA was found to have the following sequence:

3'... CCAAGCCAA ...5'

1.10.1 Using a codon table, write down the amino acid sequence coded for by this DNA sequence. [1 mark]

A mutation occurs, causing the first adenine nucleotide to be replaced with a thymine.

New strand: 3'... CCTAGCCAA ...5'

1.10.2 Name the type of mutation and outline the potential effect on the resultant protein produced. [2 marks]

A mutation occurs, causing the first guanine nucleotide to be replaced with a thymine.

New strand: 3'... CCAATCCAA ...5'

1.10.3 Name the type of mutation and describe the potential effect on the resultant protein produced. [3marks]

A section of DNA was found to have the following sequence:

3'… TACCCAAGTCAT … 5'

1.11.1 Using a codon table, write down the amino acid sequence coded for by this DNA sequence. [1 mark]

A mutation occurs in which the 7th base in the DNA sequence, adenine, was replaced by a guanine base.

3'… TACCCAGGTCAT … 5'

1.11.2 What type of mutation has occurred in this example? [1 mark]

1.11.3 Explain the effect that this mutation will have on the structure and function of the polypeptide. [3 mark]

1.11.4 Assuming that the protein produced as a result of the mutation is functional, describe the effect that the mutation will have on the genetic diversity of the population. [2 marks]

1.12 Explain how evolution by natural selection brings about phenotypic differences between species. [3 marks]

2. Biological consequences of changing allele frequencies in terms of increased and decreased genetic diversity. **VCE BIOLOGY SD, p. 35**

"Populations tend to produce more offspring than the environment can support."

2.1 Explain the consequences of the above statement. [2 marks]

2.2 Complete the table below, identifying whether or not the below factors increase or decrease genetic variation. [4 marks]

Factor	**Increase or decrease in genetic variation?**
Artificial selection	
Migration	
Genetic drift	
Mutation	

2.3 Explain why offspring are not genetically identical to their parents. [2 marks]

2.4 Explain how inbreeding lowers the fitness levels of populations. [2 marks]

Northern elephant seals have reduced genetic variation because of a population bottleneck that humans inflicted on them in the 1890s. Hunting reduced their population size to as few as 20 seals by the end of the 19th century.

2.5.1 Describe how the bottleneck effect has impacted the variation of the northern elephant seals. [3 marks]

2.5.2 Identify two strategies that can help to increase genetic diversity in critically endangered species like the northern elephant seals. [2 marks]

There is a higher incidence of fumarase deficiency in a population of members of a fundamentalist church. The enzyme, fumarase, plays an important role in energy production. Some people who experience this condition are severely disabled, with both developmental abnormalities and mental retardation. Practices of the church include endogamy, marrying within the religion, and polygyny or the practice of taking several wives. The population that practices this religion is isolated from surrounding populations and experience a much higher incidence of this specific genetic condition.

2.6.1 What evolutionary mechanism has caused a higher incidence of fumarase deficiency to occur within this population? [1 mark]

2.6.2 Describe how this mechanism has caused this to occur. [3 marks]

2.6.3 Which organelle does this genetic condition most likely affect? [1 mark]

3. Manipulation of gene pools through selective breeding programs. **VCE BIOLOGY SD, p. 35**

3.1 Explain the purpose of 'selective breeding programs'. [2 marks]

3.2 Identify the selective pressure in selective breeding programs. [1 mark]

3.3 Describe one similarity and one difference between natural and artificial selection. [2 marks]

3.4.1 Explain how domestic dogs can be selectively bred. [3 marks]

3.4.2 Describe the effect that the selective breeding of dogs has on the gene pool of the domestic dog population. [2 marks]

3.4.3 Explain one advantage and one disadvantage of the selective breeding of dogs. [2 marks]

3.4.4 Explain two ethical issues associated with the selective breeding of dogs. [2 marks]

3.4.5 Explain two reasons, except for aesthetic value, why individuals want to selectively breed dogs. [2 marks]

3.5 Explain how drought-resistant crop plants can be produced by selective breeding. [3 marks]

3.6 Describe how phenotypic differences in two unrelated species would prevent them from producing offspring. [2 marks]

4. Consequences of bacterial resistance and viral antigenic drift and shift in terms of ongoing challenges for treatment strategies and vaccination against pathogens. **VCE BIOLOGY SD, p. 35**

SARS-CoV-2, known by the common name COVID-19, was declared a pandemic in March 2020 by the World Health Organisation. In countries where it was highly prevalent among the population, new strains emerged.

4.1.1 Describe the process for the emergence of these new viral strains. [4 marks]

4.1.2 Explain why these new strains soon infected a larger proportion of the population, compared to the old strains. [2 marks]

In order to control the spread of the disease, many countries implemented vaccine programs.

4.1.3 Explain how the appearance of new strains potentially affect the vaccine program. Describe one method to manage this effect. [3 marks]

4.2 Explain why new strains of bacteria spread rapidly in populations. [2 marks]

4.3.1 Define the term 'antigenic shift' and explain the consequence of viruses undergoing antigenic shift. [3 marks]

4.3.2 Define the term 'antigenic drift' and explain the consequence of viruses undergoing antigenic drift. [3 marks]

Methicillin-resistant Staphylococcus aureus (MRSA) is a 'superbug' that is capable of causing infection in different parts of the body. MRSA arises as a result of S. aureus, a bacteria, being resistant to common antibiotics. MRSA infections typically occur in hospital environments.

4.4.1 With reference to Darwin's theory of evolution by natural selection, explain how MRSA bacteria have evolved to become resistant to antibiotics. [3 marks]

4.4.2 Outline two methods to reduce the development of antibiotic-resistant strains of bacteria. [2 marks]

4.4.3 Explain why it would be infeasible to create new antibiotics to reduce the spread of MRSA. [2 marks]

Haemagglutinin (HA) and neuraminidase (NA) are the two main antigens found on the influenza virus.

4.5.1 Draw and annotate a diagram that shows how antigenic shift may occur in influenza virus particles. [3 marks]

4.5.2 Identify whether antigenic shift or antigenic drift is a greater challenge against treatment and immunity, and explain why this is the case. [3 marks]

5. Changes in species over geological time as evidenced from the fossil record: faunal (fossil) succession, index and transitional fossils, relative and absolute dating of fossils. **VCE BIOLOGY SD, p. 35**

5.1 Define the term 'palaeontology'. [1 mark]

5.2.1 Define the term 'fossil'. [1 mark]

5.2.2 Explain what is meant by the term 'fossil record' and what it provides evidence of. [3 marks]

5.3 Explain why the fossil record is incomplete. [2 marks]

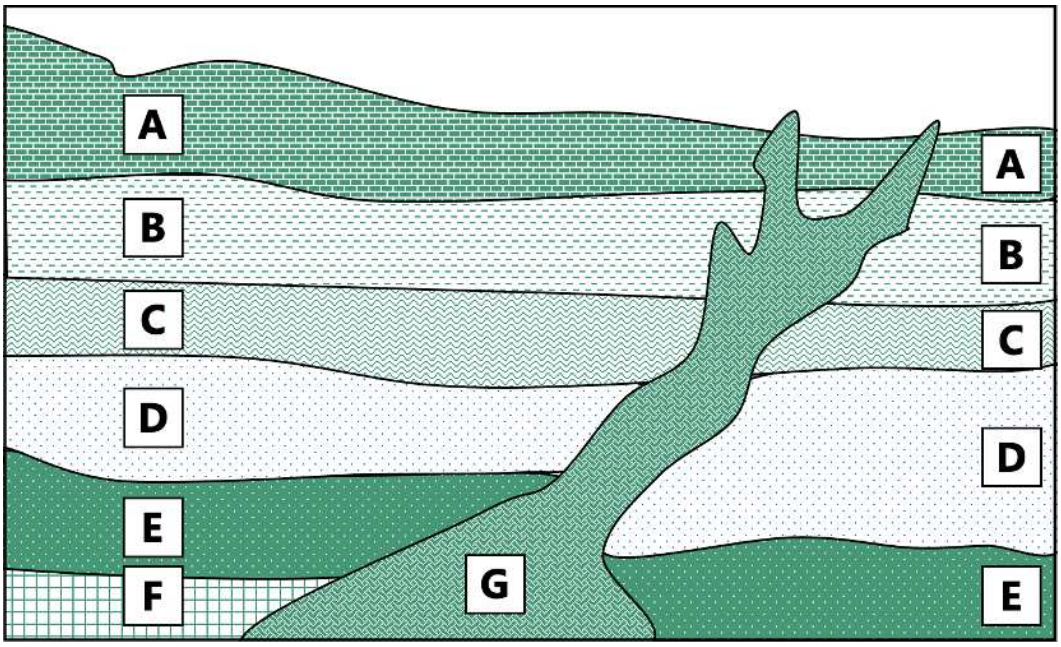
5.4 What is the term used to describe dating methods that make use of radioisotopes such as carbon-14?

A fossil was located which was believed to be approximately 8 million years old.

5.5.1 Determine whether it is possible to establish the age of the fossil using carbon-14 dating. [2 mark]

5.5.2 Determine what other methods can be used to determine the absolute age of this fossil. [1 mark]

An alternative method of dating involves the use of stratigraphy, such as in the diagram shown below - different strata and formations are indicated with different letters.



5.5.3 Given that there are fossils in each section, which section would have the oldest fossil? Provide a reason to support your answer. [2 marks]

Human artefacts, such as old pottery pieces and rudimentary cooking supplies are found in layers B and C only.

5.5.4 What information can you infer on the settlement of humans in the area? [2 marks]

5.6 Explain what is meant by the term 'transitional fossils' and how they can be used to determine relatedness between species. [3 marks]

5.7.1 Explain what is meant by the term 'index fossils' and how they can be used to determine relatedness between species. [3 marks]

5.7.2 List two criteria that a fossil must satisfy in order to be classified an 'index fossil'. [2 marks]

Explain the importance of the following conditions for fossilisation:

5.8.1 Low oxygen levels. [2 marks]
5.8.2 Lack of scavengers. [2 marks]

5.9 Explain why the most common fossils found are shelled invertebrates that existed in an aquatic environment. [2 marks]

5.10 Describe the specific conditions that would have to occur in order for a terrestrial animal to become fossilised. [3 marks]

5.11.1 Explain how ‘relative dating’ can be used to establish the age of a fossil. [3 marks]

5.11.2 Outline one advantage and one disadvantage of relative dating. [2 marks]

5.11.3 Explain how ‘absolute dating’ can be used to establish the age of a fossil. [3 marks]

5.11.4 Outline one advantage and one disadvantage of absolute dating. [2 marks]

5.11.5 Identify two differences between relative and absolute dating. [2 marks]

In 1977, the fossil of a baby wooly mammoth was discovered. It dates back approximately 40,000 years ago and was found frozen in an ice tomb in Siberia.

5.12.1 Explain why the wooly mammoth was found in a well-preserved state with little evidence of decaying. [3 marks]

Wooly mammoths are said to be descendants of modern elephants.

5.12.2 Describe two methods that can be taken to determine if this is true. [2 marks]

5.12.3 Suggest two reasons why wooly mammoths are extinct. [2 marks]

6. Evidence of speciation as a consequence of isolation and genetic divergence, including Galapagos finches as an example of allopatric speciation and Howea palms on Lord Howe Island as an example of sympatric speciation. **VCE BIOLOGY SD, p. 35**

6.1 Define the term ‘master regulatory gene’. [1 mark]

6.2 Define the term ‘novel phenotype’. [1 mark]

6.3 Define the term ‘speciation’. [1 mark]

6.4 Define the term ‘adaptive radiation’. [1 mark]

A river separates members of a rabbit population that used to occupy the same geographical area. After many generations, the rabbits on the left side of the river are significantly smaller and more athletic than the rabbits on the right side of the river. Scientists observed that it may be because of the population of foxes on the left side of the river.

6.5.1 Explain what happened to the rabbit population on the left side of the river. [4 marks]

Scientists discovered that these two rabbit populations were no longer of the same species.

6.5.2 Define the term 'species'. [1 mark]

6.5.3 Describe the process of allopatric speciation with relation to these rabbit populations. [3 marks]

It was found that finches on the island of Galapagos expressed a variety of beaks that differed in shape and size. After analysis, it was found that these differences were caused by mutations in the BMP4 gene.

6.6.1 State the function of the BMP4 gene. [1 mark]

6.6.2 Explain why mutations occurring in the BMP4 gene can quickly create a variety of phenotypes with regards to beak shapes in Galapagos finches. [3 marks]

6.6.3 What name is given to structures that have the same common evolutionary origin? [1 mark]

6.6.4 Using the diagram above, explain the conditions that are suitable for the finches to undergo speciation. [3 marks]

6.6.5 Explain how one species of finch can be found on different islands in Galapagos. [1 mark]

6.6.6 Name the process that allows for the accumulation of differences between populations of finches. [1 mark]

A longer, more pointed beak is better equipped to eat the food available to finches in a certain environment. A population of finches includes those with beaks of various lengths.

6.6.7 Explain how this population is likely to evolve. [4 marks]

There are two species of Howea plants (*H. belmoreana* and *H. forsteriana*) on Lord Howe Island that appear to have a common ancestor and accumulated enough differences to be considered different species.

Experiments were conducted to test the effect of soil pH and height above sea level on the growth of the two species of Howea plants after one month. In the first experiment, the Howea plant species were planted in soils of varying pH. In the second experiment, they were planted in soils at different heights above sea level. All other factors were controlled.

Data for these two experiments can be found below.

Figure 1

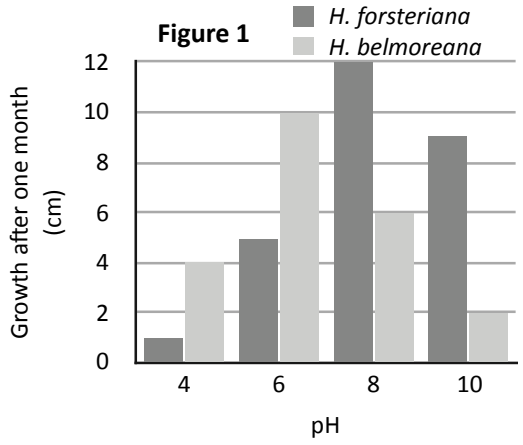
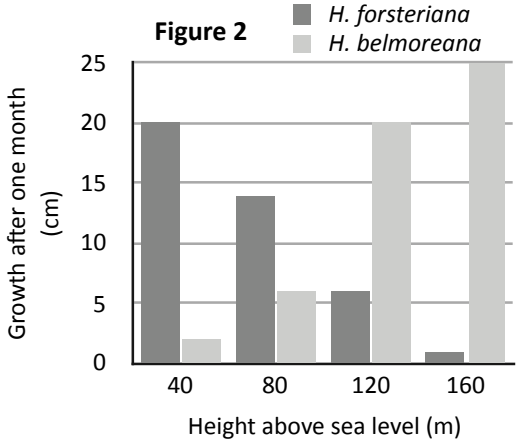


Figure 2



6.7.1 Explain what key features result in two populations being considered different species. [1 mark]

6.7.2 Identify the process through which the two species of Howe plants would have developed from their common ancestor. [1 mark]

6.7.3 Explain why the process identified in 6.7.2 is less likely to occur then the type of speciation in which populations are geographically isolated and name the process that occurs when different species develop from geographically isolated populations. [3 marks]

6.7.4 Using the data from Figure 1, explain how the two species of Howea plants developed. [3 marks]

6.7.5 Using the data from Figure 2, explain how the two species of Howea plants developed. [3 marks]

7. Evidence of relatedness between species: structural morphology – homologous and vestigial structures; and molecular homology – DNA and amino acid sequences. **VCE BIOLOGY SD, p. 35**

7.1 Define the terms 'analogous structures' and 'homologous structures'. [2 marks]

7.2 Explain how DNA sequencing provides evidence of relatedness between species. [3 marks]

A section of an intron from four species: A, B, C and D, was taken and analysed. The results are as shown below:

A	*…GCACTTCGATAGGC…*
B	*…GCACTTCGATAAGC…*
C	*…GAACTCCGATACGC…*
D	*…GGACTACGATACGC…*

7.3.1 Based on the sequences of DNA listed above, draw a cladogram showing the relative genetic relationship between the four species. [2 marks]

A study of the four species' ancestry indicates that individuals B and D were the most closely related.

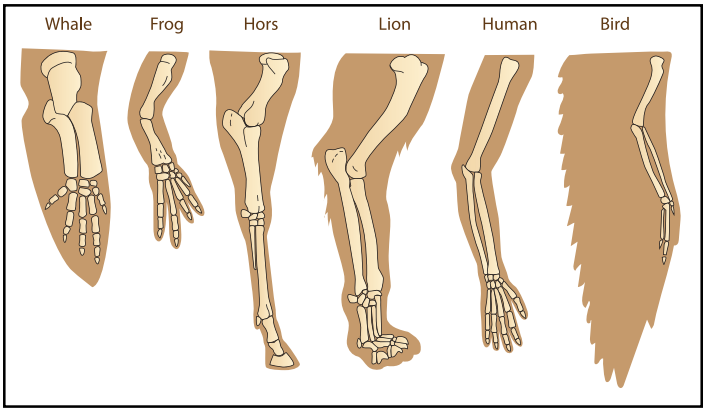
7.3.2 Explain why this result might differ from that provided by the DNA sequences above. [2]

7.3.3 Why can studying mutations within introns be more useful than studying mutations that occur within exons? [3 marks]

We can also use amino acid sequences to determine relatedness between species.

7.3.4 Why is DNA generally more preferable than amino acid sequences in molecular homology? [2 marks]

7.4 Explain how amino acid sequencing of a protein can provide evidence of relatedness between organisms. [3 marks]



7.5 State whether or not the above diagram suggests that the six organisms evolved from a common ancestor. Explain your choice. [3 marks]

7.6 Explain why using multiple different types of data can improve the reliability of estimated evolutionary relationships. [2 marks]

Sharks and dolphins are distantly related species, with their most recent common ancestor having existed over 290 million years ago. As such, sharks are classified as fish and dolphins as mammals. However, these two species have similar structures such as the streamlined body and fins optimised for swimming rapidly through water.

7.7.1 What term is used to describe these structures? [1 mark]

7.7.2 Name the type of evolution that occurred between sharks and dolphins from their respective ancestors, explained how it occurred. [2 marks]

8. The use and interpretation of phylogenetic trees as evidence for the relatedness between species. **VCE BIOLOGY SD, p. 35**

8.1 Outline what information is obtained from analysing phylogenetic trees. [1 mark]

8.2 Explain the relationship between branch length and species relatedness. [2 marks]

9. The shared characteristics that define mammals, primates, hominoids and hominins. **VCE BIOLOGY SD, p. 36**

9.1 Define the term ‘primates’. [1 mark]

9.2 Define the term ‘hominoids’. [1 mark]

9.3 Define the term ‘hominins’. [1 mark]

9.4 State two characteristics of primates that differentiates them from other mammals. [2 marks]

9.5 Identify a characteristic of hominoids that differentiate them from primates? [1 mark]

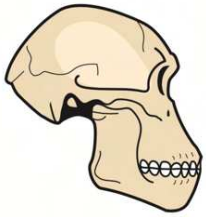
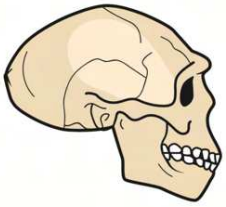
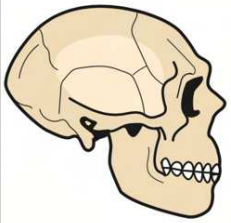
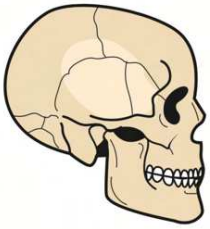
Explain the purpose of the following primate characteristics:

9.6.1 Pentadactylism. [2 marks]
9.6.2 Mobile arms. [2 marks]
9.6.3 Prehensile toe. [2 marks]
9.6.4 Being able to live in social groups. [2 marks]

Outline the purpose of the following hominin characteristics:

9.7.1 Having less body hair. [2 marks]
9.7.2 Being bipedal. [2 marks]
9.7.3 Central foramen magnum. [2 marks]

10. Evidence for major trends in hominin evolution from the genus Australopithecus to the genus Homo: changes in brain size and limb structure. **VCE BIOLOGY SD, p. 36**

	Austalopithecus afarensis	***Homo erectus***	***Homo neanderthalensis***	***Homo sapiens***
				
Average adult height (metres)	1.51	1.56	1.64	1.78
Average brain size (cm^3)	450	900	1500	1350

Using data from the above table, explain the reason for the following trends:

10.1.1 Average brain size increasing. [3 marks]

10.1.2 Average adult height increasing. [3 marks]

Approximately 40% of a skeleton of *Australopithecus afarensis*, commonly known as Lucy, was discovered in 1974. It has been dated back 3.2 million years. The skeletal structure indicates that Lucy walked upright.

10.2 Explain the changes in limb structure that have facilitated an upright walking position in early hominins. [3 marks]

Explain how the following aspects of hominin cultural evolution provide supporting evidence of an increasing brain size:

10.3.1 Domestication of plants and animals. [2 marks]

10.3.2 Construction of containers. [2 marks]

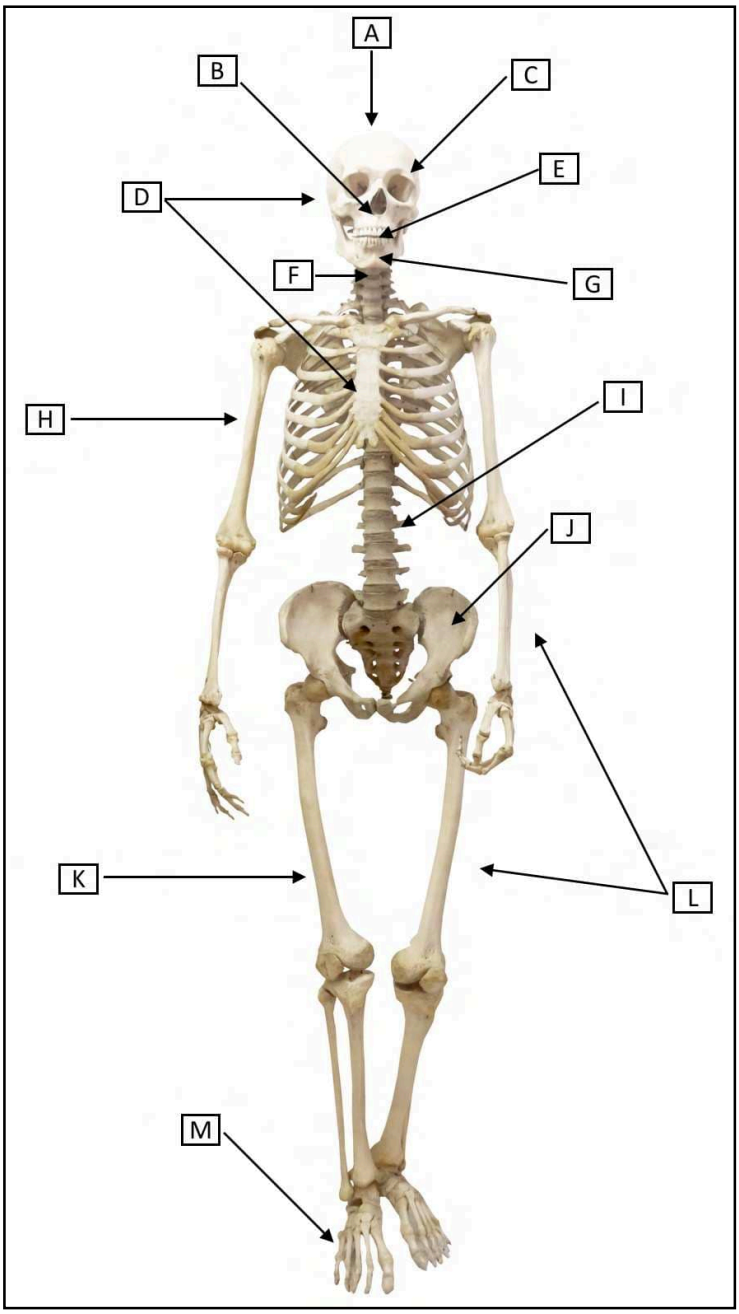
10.3.3 Production of tools. [2 marks]

10.3.4 Painting in caves. [2 marks]

10.3.5 A greater number of animals animals being hunted and killed. [2 marks]

10.4 Describe one product of the cultural evolution of hominins that has led to increased genetic evolution and one product that has led to decreased genetic evolution. [3 marks]

10.5 Identify two differences that would be expected to be observed between a skull of *Homo erectus* and a skull of *Homo sapiens*. [2 marks]



The above diagram is a complete skeleton of a modern day human. Over millions of years, many changes have occurred to hominins. The specific features that have changed are indicated by the letters above.

Explain the reason for the changes in the labelled hominin features:

10.6.1 (A): The cranial capacity has increased. [3 marks]
10.6.2 (B): The face has become flatter. [2 marks]
10.6.3 (C): The supraorbital brow ridges have reduced in size. [2 marks]
10.6.4 (D): The size of the cranial capacity compared to body size has increased. [2 marks]
10.6.5 (E): The size of teeth has reduced. [2 marks]
10.6.6 (F): The foramen magnum has become more centrally located. [2 marks]
10.6.7 (G): The jaw has decreased in size. [2 marks]
10.6.8 (H): The strength of bones has reduced. [2 marks]
10.6.9 (I): The shape of the spine has become more 'S-shaped' and less 'C-shaped'. [3 marks]
10.6.10 (J): The pelvis has become shorter and more bowl shaped. [3 marks]
10.6.11 (K): The carrying angle has increased. [2 marks]
10.6.12 (L): The leg length has increased relative to the arm length. [2 marks]
10.6.13 (M): The toes of the feet point more outwards. [3 marks]

11. The human fossil record as an example of a classification scheme that is open to differing interpretations that are contested, refined or replaced when challenged by new evidence, including evidence for interbreeding between Homo sapiens and Homo neanderthalensis and evidence of new putative Homo species. **VCE BIOLOGY SD, p. 36**

Some modern humans of European or Asian background carry about one to two percent of Neanderthal DNA.

11.1 What does this indicate about the two species of *H. neanderthalensis* and *H. sapiens*? [1 mark]

11.2 State one reason for the extinction of *H. neanderthalensis*. [1 mark]

Consider the below three statements regarding hominin migration:

1. Modern Europeans and Asians have between one and two percent of Neanderthal DNA.
2. Modern Africans have close to zero Neanderthal DNA.
3. Modern humans have no evidence of Neanderthal mtDNA.

11.3.1 Explain how both statements 1 and 3 can be true. [3 marks]

11.3.2 Explain the reasons for statement 2. [3 marks]

New anthropomorphic (meaning human-like) skeletons were discovered under volcanic rock on the island of Indonesia. These skeletons are thought to belong to a separate species from the homo genus and are given a new species name: *Homo florensiensis*.

11.4.1 What criteria must be satisfied in order to determine that *Homo florensiensis* is a new undiscovered species? [2 marks]

11.4.2 How does the evidence of *Homo neaderthalensis* and *Homo sapiens* interbreeding challenge this criteria? [2 marks]

12. Ways of using fossil and DNA evidence (mtDNA and whole genomes) to explain the migration of modern human populations around the world, including the migration of Aboriginal and Torres Strait Islander populations and their connection to Country and Place. **VCE BIOLOGY SD, p. 36**

12.1.1 Identify one strength and one weakness of using fossil evidence to track migration of human populations around the world. [2 marks]

12.1.2 Identify one strength and one weakness of using mtDNA to track migration of human populations around the world. [2 marks]

The 'Out of Africa' theory is a proposed explanation of how modern homo sapiens have evolved.

12.2.1 Explain the main principles of the ‘Out of Africa’ theory of modern human migration. [2 marks]

A scientist claimed that “the greatest variation in mitochondrial DNA is found in African people compared to populations in other continents.”

12.2.2 Explain whether or not the above claim supports or opposes the ‘Out of Africa’ theory. In your response, refer to genetic drift. [4 marks]

12.3 Explain the main principles of the ‘Multiregional’ theory of modern human migration. [2 marks]

12.4 Outline one similarity and one difference between the ‘Out of Africa’ theory and the ‘Multiregional’ theory. [2 marks]

Two fossils of Aboriginal and Torres Strait Islanders were discovered - one on the coast of Sydney and one in Northern Territory. There are visible phenotypic differences between the skull shapes of both individuals discovered. Scientists would like to determine the extent of relatedness between the two individuals as this may help to determine migration patterns.

12.5 Explain why extracting mtDNA from both fossils would be more useful in determining relatedness than extracting nuclear DNA. [3 marks]

Studies suggest that *Homo denisovans* are more closely related to *Homo neanderthalensis* than *Homo Sapiens*.

12.6.1 Using the above information, draw a phylogenetic tree, including *H. denisovans*, *H. neanderthalensis* and *H. sapiens*. [2 marks]

12.6.2 Suggest why Neanderthals and Denisovans are believed to have more features in common with each other than either species have in common with modern humans. [1 mark]

There was evidence that Neanderthals created art in the form of etchings onto cave walls.

12.7 Describe the significance of this finding with regards to cultural evolution. [1 mark]

Solutions: Unit 3 AOS 1

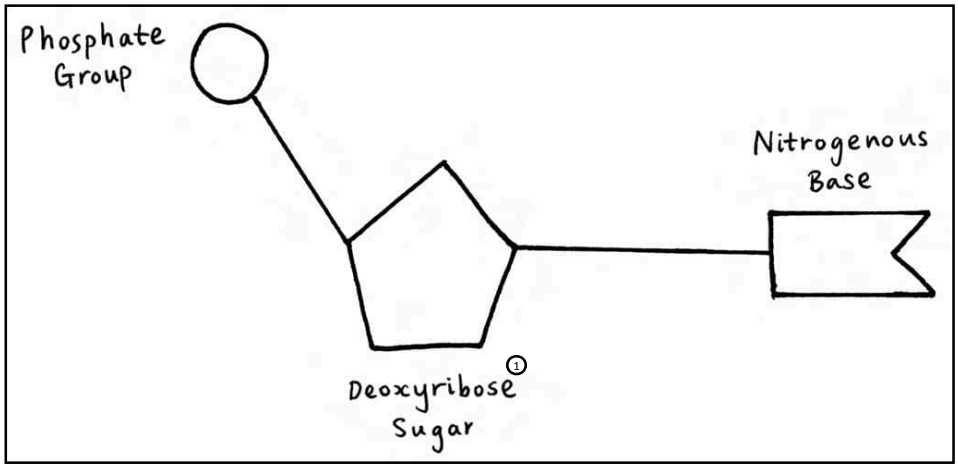
1.1 Define the term 'nucleic acid'. [1 mark]

Nucleic acids① are information molecules which encode instructions for the synthesis of specific proteins in cells.

Extension notes:

① There are two types of nucleic acids you are required to know for the VCE Biology course - **DNA** (deoxyribonucleic acid) and **RNA** (ribonucleic acid).

1.2 Draw a labelled diagram of a nucleotide from a DNA② molecule. [3 marks]



Extension notes:

① It is important to note whether the nucleotide needs to be drawn for a DNA or RNA molecule! If the question specifies a **RNA molecule**, then the sugar molecule in the nucleotide needs to be labelled as a **'ribose sugar'** (as opposed to a 'deoxyribose sugar').

② A **phosphodiester bond** is formed **between** two adjacent **nucleotides** in DNA, while **hydrogen bonds** are formed between **nitrogenous bases** of DNA; do not confuse these! The weaker hydrogen bonds allow DNA to be unwinded for replication or transcription, while the stronger phosphodiester bonds ensure that the DNA does not degrade or fall apart during these processes.

1.3 What percentage of this DNA molecule is composed of cytosine bases?

28%①

Extension notes:

① If 22% of the nitrogenous bases in a DNA molecule are adenine bases then, by complementary base pairing, 22% of the nitrogenous bases in this DNA molecule must be thymine bases. Remember that DNA is compromised of adenine, thymine, guanine and cytosine. The rest of the DNA molecule must be made up of guanine and cytosine bases! Therefore, we perform some calculations:

22% + 22% = 44% <— this is the percentage of the DNA molecule comprised of adenine and thymine!

100% - 44% = 56% <— this is the percentage of the DNA molecule compromised of guanine and cytosine!

This question asks specifically about **cytosine bases** within this DNA molecule; therefore, to calculate the percentage of this DNA molecule composed of cytosine bases, we perform the calculation:

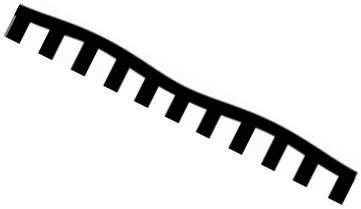
56% ÷ 2 = **28%**

1.4 Use the table below to describe the cellular role played by the three forms of RNA in protein synthesis. [3 marks]

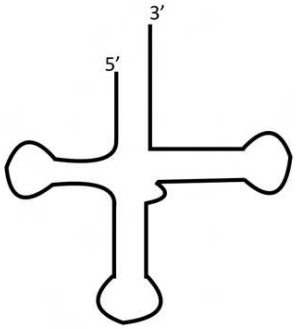
Form of RNA	Function
mRNA	mRNA carries information from the nucleus to the ribosomes for protein synthesis.
tRNA	tRNA carries specific amino acids to the ribosomes, releasing it to form a growing polypeptide chain.
rRNA	rRNA is a structural component of the ribosome that is responsible for carrying out the process of translation.

Extension notes

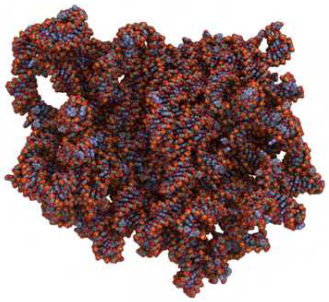
ⓘ It is important to **distinguish** between the three forms of RNA in **pictorial form**. See below:



mRNA



tRNA



rRNA

1.5 Outline three structural differences between DNA and RNA molecules. [3 marks]

① DNA is a double-stranded molecule; whereas, RNA is a single-stranded molecule.

② DNA nucleotides contain a deoxyribose sugar; whereas, RNA nucleotides contain a ribose sugar.

③ Thymine is a nitrogenous base in DNA molecules; whereas, uracil (and not thymine) is a nitrogenous base found in RNA molecules.

2.1 Identify the two main stages of protein synthesis. [1 mark]

The two main stages of protein synthesis are transcription and translation.

2.2 Define the terms 'transcription', 'post-transcriptional modifications' and 'translation'. In your response, identify where these processes occur within a cell. [5 marks]

Transcription refers to the synthesis of pre-mRNA using a DNA strand within a gene as a template by RNA polymerase. Transcription occurs in the nucleus.

Post-transcriptional modifications refers to the process where pre-mRNA undergoes specific modifications after transcription. Post-transcriptional modifications occur in the nucleus.

Translation refers to the synthesis of a polypeptide chain using information carried by mRNA. Translation occurs in ribosomes.

2.3 Outline the difference① between introns and exons. [2 marks]

Introns refer to the non-coding region of RNA which are spliced out during post-transcriptional modifications and do not code for amino acids. Whereas, exons refer to the coding region of RNA which contributes to the overall structure and arrangement of amino acids in a polypeptide chain.

Extension notes:

① An alternative explanation is that **introns** are transcribed but **not** translated whereas **exons** are transcribed **and** translated!

2.4.1 Other than a lower rate of protein synthesis, suggest one reason why this patient may be diagnosed with hypoproteinemia. [1 mark]

The patient may have a severely insufficient intake of protein in the diet.

2.4.2 Explain the consequence of a patient having a low concentration of membrane-transport proteins. [2 marks]

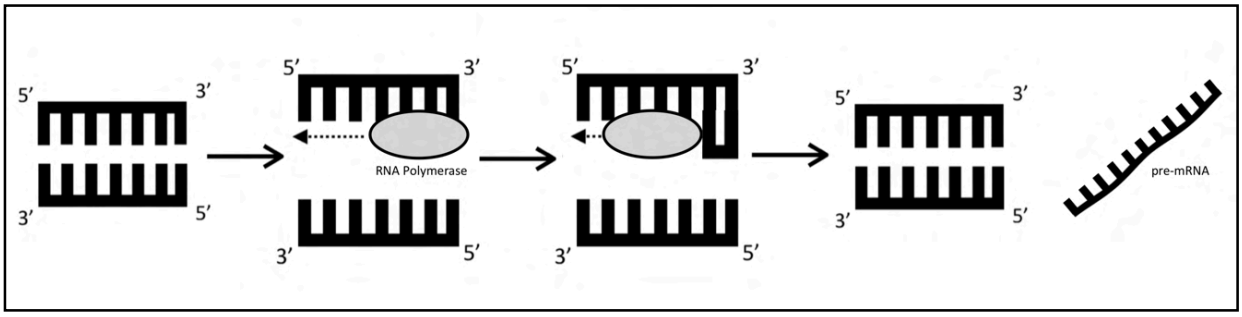
The movement of substances required by the cell and transported via facilitated diffusion would be slowed down, as well as the expulsion of waste products that may be toxic to the cell if not removed via the membrane-transport proteins. This could result in cellular death.

2.4.3 Describe the main steps of the first stage of synthesis of a membrane-transport protein. [3 marks]

① RNA polymerase separates the DNA strand by breaking hydrogen bonds between complementary nitrogenous bases. ② A DNA template strand is then copied by RNA polymerase ③ through the enzyme moving along the template strand. ③ A molecule of pre-mRNA ④ is produced by complementary base pairing.

Extension notes:

① Below is a **labelled diagram** of the steps of transcription - it is important to visualise this process as this will help to improve your understanding of the content.



② For questions that require a **step-by-step** outline of a specific process, consider using **numbers** like this in order to present the information more succinctly.

③ Note that RNA polymerase will **"read"** the DNA template strand in a 3' to 5' direction and synthesise a complementary pre-mRNA strand in a 5' to 3' direction. RNA polymerase **reads up (3' to 5') and makes down (5' to 3')**!

④ The product of transcription is **pre-mRNA** and NOT mRNA!

2.4.4 Explain the purpose of adding a poly-A tail and methyl cap to a pre-mRNA molecule. [2 marks]

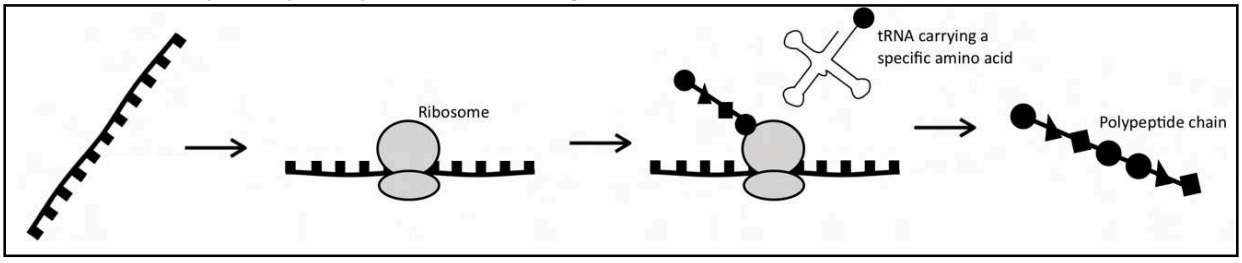
The addition of a poly-A tail and methyl cap is important for maintaining the stability of the mRNA molecule. This protects the mRNA molecule from degradation as it exits the nucleus, allowing it to be used during translation.

2.4.5 Describe the main steps① of the second stage of synthesis of a membrane-transport protein. [3 marks]

① mRNA carries information to the ribosome (where its codons are read) leading to mRNA-ribosomal complex formation. ② tRNA carries specific amino acids to the ribosome - the mRNA codon binds temporarily with its complementary anticodon. ③ tRNA joins specific amino acids to the growing polypeptide chain through peptide bonds in a process called condensation polymerisation. ④ This process continues until the stop codon is reached and translation is terminated. ⑤ All components dissociate, resulting in a polypeptide chain being produced.

Extension notes:

① The **labelled diagram** below presents the steps of translation - it is important to visualise this process as this will help to improve your understanding of the content.



2.5.1 RNA polymerase. [2 marks]

RNA polymerase is an enzyme that catalyses the formation of and copying of a DNA template strand by breaking hydrogen bonds between complementary nitrogenous bases.

2.5.2 DNA template strand. [2 marks]

The DNA template strand functions as a template for the synthesis of a complementary mRNA transcript by RNA polymerase.

2.6.1 Ribosome. [2 marks]

Ribosomes are responsible for reading the mRNA code and is the site of protein synthesis.

2.6.2 tRNA. [2 marks]

tRNA molecules contain an anticodon that is complementary to each mRNA codon - tRNA binds to the ribosome, carrying a specific amino acid to add to the growing polypeptide chain.

2.7.1 Explain why this sequence of DNA codes for 5 amino acids rather than 15 amino acids. [2 marks]

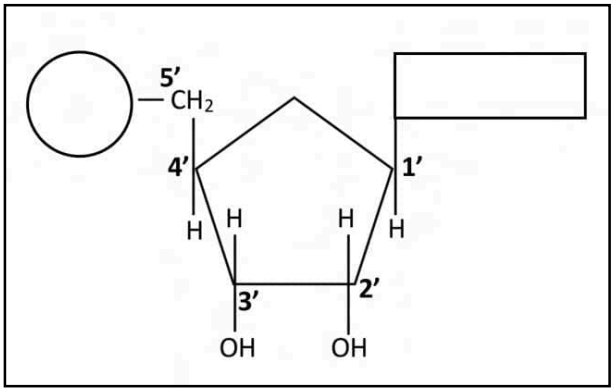
Each DNA triplet codes for one specific amino acid. A triplet includes three nucleotides, which is why 15 nucleotides will code for 5 amino acids.

2.7.2 Outline the purpose of DNA having a 3' and 5' end. [1 mark]

The different ends of the DNA molecule (3' and 5' end) enable directionality① such that transcription only starts from the 3' end of a DNA strand.

Extension notes:

① The 3' and 5' ends refer to the 3rd and 5th carbon of the pentose sugar respectively (see diagram below). Enzymes can only catalyse reactions in **one specific orientation**; RNA polymerase can only **'read'** DNA in a **3' to 5'** direction and **'synthesise'** DNA in a **5' to 3'** direction.



3.1 Define the term 'gene'. [1 mark]

A gene is a section of DNA which codes for a specific protein or multiple proteins.

3.2 Distinguish between the term 'introns' and 'exons'. [2 marks]

Introns refer to the non-coding region of RNA which are spliced out during post-transcriptional modifications and do not code for amino acids. Whereas, exons refer to the coding region of RNA which contributes to the overall structure and arrangement of amino acids in a polypeptide chain.

3.3 Outline the function of the 'promoter region' of a gene. [1 mark]

The promoter region is a DNA segment where RNA polymerase binds to begin transcription.

3.4 Outline the function of the 'operator region' of a gene. [1 mark]

The operator region is a DNA segment which provides a binding site for a repressor protein.

4.1 Describe the purpose① of gene regulation. [1 mark]

Gene regulation allows the body to conserve its resources (energy and time) by only synthesising proteins when necessary - this allows structural genes to only be expressed when required.

Extension notes:

① Note that gene regulation has two purposes:

1. to prevent **excessive** gene expression —> this is to converse energy and time
2. to prevent **reduced** gene expression —> this is to ensure there is a sufficient proteins available for cellular processes

4.2 Outline the purpose of the trp operon. [1 mark]

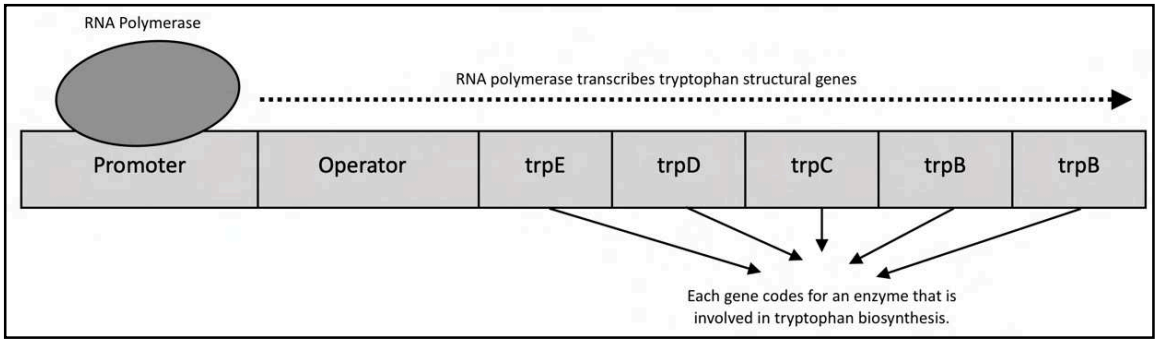
The trp operon regulates the production of tryptophan such that it is only produced by the cell if tryptophan is absent in the environment.

4.3 Explain how the trp operon operates when there is a low concentration of tryptophan present. [3 marks] ①

At low concentrations, there is insufficient tryptophan to bind to the repressor and activate it. The repressor does not bind to the operator region and hence RNA polymerase is not blocked and can conduct transcription of structural trp genes. The structural trp genes are expressed and tryptophan is synthesised.

Extension notes:

① Below is a labelled diagram displaying how the trp operon operates when there is a low concentration of tryptophan present:

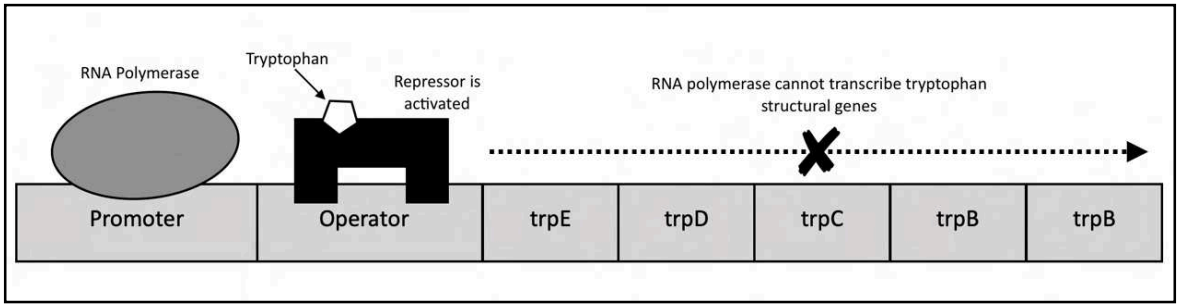


4.4 Explain how the trp operon operates when there is a high concentration of tryptophan present. [3 marks] ①

A regulatory gene (trpR) produces a transcription factor, known as a repressor, that is inactive at low concentrations of tryptophan so that structural trp genes can be transcribed. When there is a high concentration of tryptophan, it binds to the repressor causing a conformational change in shape which activates it. The repressor then binds to the operator region, preventing RNA polymerase from transcribing structural trp genes.

Extension notes:

① Below is a labelled diagram displaying how the trp operon operates when there is a high concentration of tryptophan present:



4.5.1 RNA Polymerase. [2 marks]

RNA polymerase binds to the promoter region of the trp operon and catalyses the synthesis of structural genes (trpE, trpD, trpC, trpB, trpA) by transcribing DNA into pre-mRNA.

4.5.2 Operator. [2 marks]

The operator region is a short DNA segment that acts as a binding site for a repressor protein to prevent RNA polymerase binding to the promoter region and transcribing structural genes. In the trp operon, tryptophan binds to and activates a repressor protein - the tryptophan-repressor complex binds to the operator and prevents expression of the trp operon.

4.5.3 Inhibitory Transcription Factor. [2 marks]

The inhibitory transcription factor binds to the operator region and prevents the trp operon from expressing its structural genes (trpE, trpD, trpC, trpB, trpA). Tryptophan acts as an inhibitory transcription factor at high concentrations of tryptophan, preventing further biosynthesis of tryptophan.

5.1 Define the term 'condensation polymerisation'. [1 mark]

Condensation polymerisation is a reaction in which two monomers join together to form a larger molecule, which releases a water molecule at the site of bonding.

Extension notes:

ⓘ Please note that condensation polymerisation does not just apply to polypeptide chain formation but other polymers such as:

- **Nucleic acids**
- **Carbohydrates**
- **Lipids**

5.2 Complete the following worded equation:

Alanine + Glycine —> Dipeptide + Water. [1 mark]

Extension notes:

① Remember that, when monomers are joined together to form a larger molecule (polymer), **water** is released at **the site of bonding**.

5.3 Explain how this may be the case. [2 marks]

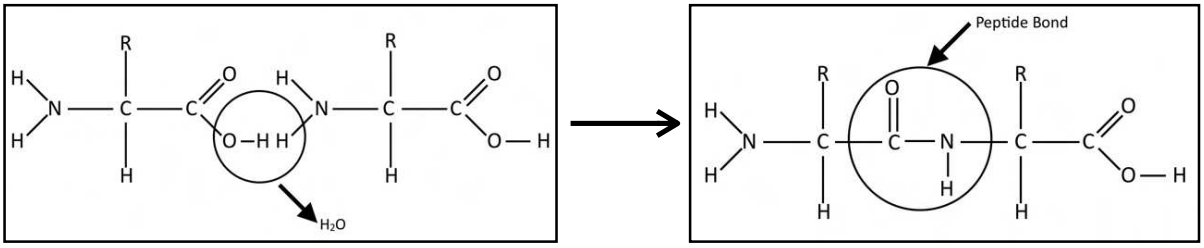
Many monomers contribute to the non-coding region of RNA (introns) which are spliced out (removed) during post-transcriptional modifications and do not code for amino acids. Additionally, each amino acid is coded for by three monomers.

5.4 Explain the main steps involved in the formation of a dipeptide by condensation polymerisation. [3 marks]

① Two amino acids join together to form a dipeptide. ② A peptide linkage is formed from the carboxyl group of one amino acid and an amine group of an adjascent amino acid. ③ A molecule of water is released at the site of bonding.

Extension notes:

① Below is a **labelled diagram** of how dipeptides are formed by condensation polymerisation:



6.1 Define the term 'proteome'. [1 mark]

The complete set of proteins expressed by a cell's genome at a given time period.

6.2 Distinguish between the genome and the proteome of a cell. [3 marks]

The genome describes the complete set of genes in a cell; whereas, the proteome describes the complete set of proteins expressed by a cell's genome at a given time period. While a cell's genome remains stable during its life, the proteome can change depending on various environmental factors.

6.3 Explain why proteins are generally studied collectively rather than in isolation. [2 marks]

Many proteins interact and rely on each other to carry out specific cellular processes① – therefore, proteins are studied collectively because studying them separately would lead to incomplete data and information being obtained.

Extension notes:

① For example, **proteins** in the **electron transport chain**, called **cytochromes**, rely on each other to transfer hydrogen ions across the cristae.

6.4 Identify whether the proteome or human genome is larger. Explain your choice. [3 marks]

The proteome is larger than the human genome. This is because of the different post-transcriptional modifications that pre-mRNA can undergo, such as the removal of introns and splicing of exons together in different arrangements (alternative splicing①). This means that different mRNA sequences can code for different proteins from a single gene. Post-translational changes to the final protein product can also occur, such as alternative folding. This, ultimately, makes the proteome (the complete set of proteins expressed by a cell's genome at a given time period) more diverse②.

Extension notes:

① From an evolutionary perspective, **alternative splicing** can **increase** the **phenotypic variation** within a species over time.

② Increasing the **proteome diversity** helps to overcome the lack of proportionality between genome size and cell complexity —> put more simply, a cell is very is complex and requires many complex processes and the diversity of the promote allows it to **compensate** for the **proportionally small genome size**.

6.5 Use the spaces provided to define each level of protein structure and outline the bonding present. [4 marks]

Level of Protein Structure	Definition	Bonding Present
Primary	The linear sequence of amino acids in a polypeptide chain.	Peptide
Secondary	The regular foiling, pleating or localised coiling of the polypeptide chain (forming alpha helices, beta-pleated sheets and random coils).	Hydrogen
Tertiary	The overall three-dimensional functional shape of a single polypeptide chain.	Hydrogen Dipole-Dipole Ionic
Quaternary	The joining of two or more polypeptide chains to form a fully functional protein.	Hydrogen Dipole-Dipole Ionic

7.1 Complete the table below, explaining the function of the following organelles involved in protein exportation. [4 marks]

Organelle	Organelle Function
Ribosomes	Ribosomes are responsible for reading the mRNA code and is the site of protein synthesis.
Rough ① Endoplasmic Reticulum	The site of protein synthesis and polypeptide chain folding for export out of the cell.
Golgi Body	The site of protein modification, processing and packaging (into secretory vesicles) for export out of the cell.
Secretory Vesicle	Secretory vesicles protect and transport (carry) protein material from the golgi body and fuses with the plasma membrane - the contents of the vesicle are then expelled (released) into the extracellular environment.

Extension notes:

① It is important to be able to distinguish between smooth endoplasmic reticulum and rough endoplasmic reticulum - smooth endoplasmic reticulum is responsible for the synthesis of lipids whereas, the rough endoplasmic reticulum is responsible for protein synthesis (including the subsequent folding and transport of the polypeptide chain to the golgi body).

7.2 Outline the functional difference between free cellular ribosomes and ribosomes studded on the rough endoplasmic reticulum. [2 marks] ②

Free cellular ribosomes are involved in the synthesis of proteins for the cell in which they are found; whereas, ribosomes studded on the rough endoplasmic reticulum synthesise proteins for export outside the cell.

8.1 Outline the general function of endonucleases. [1 mark]

Endonucleases are restriction enzymes that are used to cut around specific genes at specific recognition sites. ①

8.2 Outline the general function of ligases. [1 mark]

Ligases are enzymes that facilitate (catalyse) the formation of hydrogen bonds between the exposed complementary bases of two DNA fragments.

8.3 Outline the general function of polymerases. [1 mark]

Polymerases are enzymes that facilitate the formation of double-stranded DNA from single-stranded DNA.

9.1 What does the term 'CRISPR' in CRISPR-Cas9 stand for? [1 mark]

Clustered Regularly-Interspaced Short Palindromic Repeats ②

9.2 Explain the function of the CRISPR-Cas9 system in bacteria. [2 marks]

The CRISPR-Cas9 system in bacteria ① acts as an adaptive immune system against bacteriophages (viruses). This is through integrating short viral DNA sequences into CRISPR arrays, which allows the bacteria to develop immunological memory to viruses such that it can respond faster and more effectively to future invasions by the same virus. ③

Extension notes:

① The CRISPR-Cas9 **naturally exists** in specific **bacteria**, but is continually being adapted to treat conditions in humans, such as cancer and heart disease.

② Scientists **exploit the specificity** of the **CRISPR-Cas9 system** to **edit 'faulty' genes** within humans.

③ Note that the use of CRISPR-Cas9 technology in humans bear many intrinsic ethical issues because it involves **permanently editing** the **human genome**.

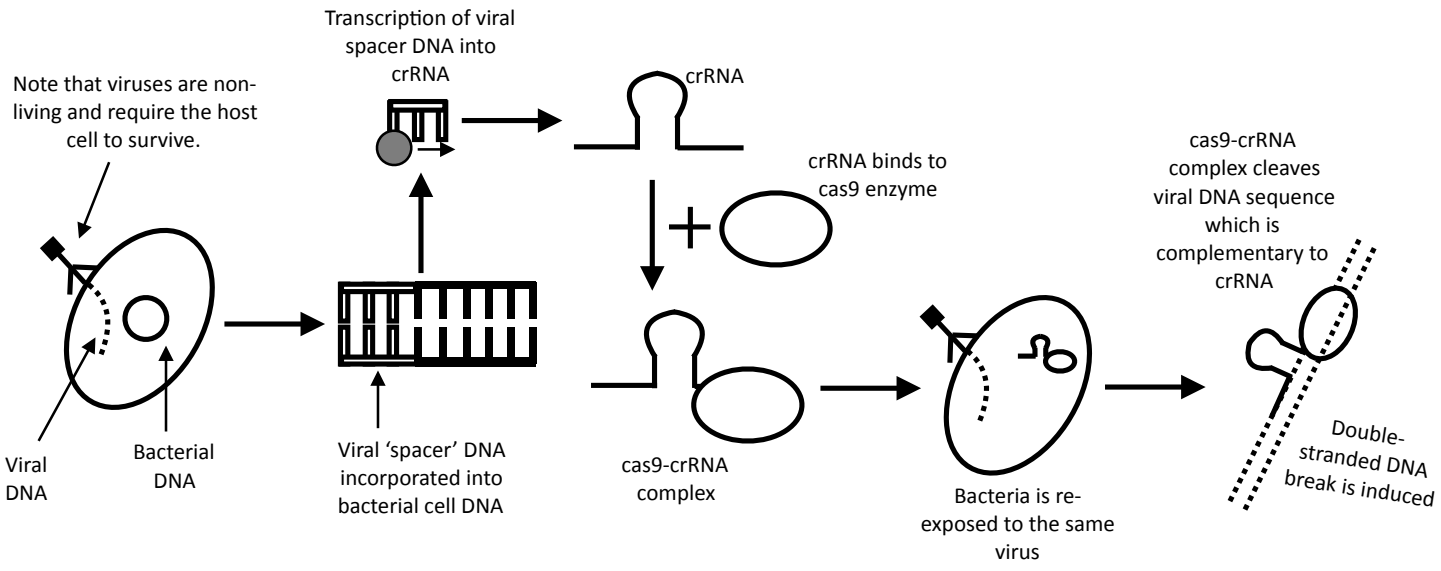
9.3 Explain how the CRISPR-Cas9 system in bacteria acts to develop immunological memory and respond to viruses that they have been previously exposed to. [5 marks]

① A virus invades a bacterial cell. ② Viral DNA from the invading virus is incorporated into the bacterial cell CRISPR locus as 'spacers'. This allows for immunological memory formation to this specific invading virus. ③ crRNA (RNA sequence of the spacer viral DNA) is formed by transcription of the viral DNA spacer (the crRNA is complementary to the specific viral DNA sequence). ④ crRNA binds to the cas9 enzyme, forming a cas9-crRNA complex. ⑤ The bacteria is re-exposed to the same virus. ⑥ cas9-crRNA complex travels along the viral DNA and crRNA binds to its specific and complementary target viral DNA sequence. ⑦ The cas9 enzyme then cleaves the viral DNA at a specific target sequence which the crRNA is complementary to. ⑧ This induces a double-stranded DNA break which breaks down (inactivates) the viral DNA and hence, prevents further viral replication.

Extension notes:

① It is important to mention that, when the bacteria is exposed to a virus (such as a bacteriophage) for the first time, it has **no immunological memory** to it. It is only **AFTER** exposure to this virus the first time that it will **develop** immunological memory! This is why it is important to mention that the bacteria is **re-exposed** to the same virus to answer the **second part** of this question (which refers to how the bacteria will respond to the virus)!

② Below is a **labelled diagram** of this process:



9.4.1 Identify and define the level of protein structure of haemoglobin. [2 marks]

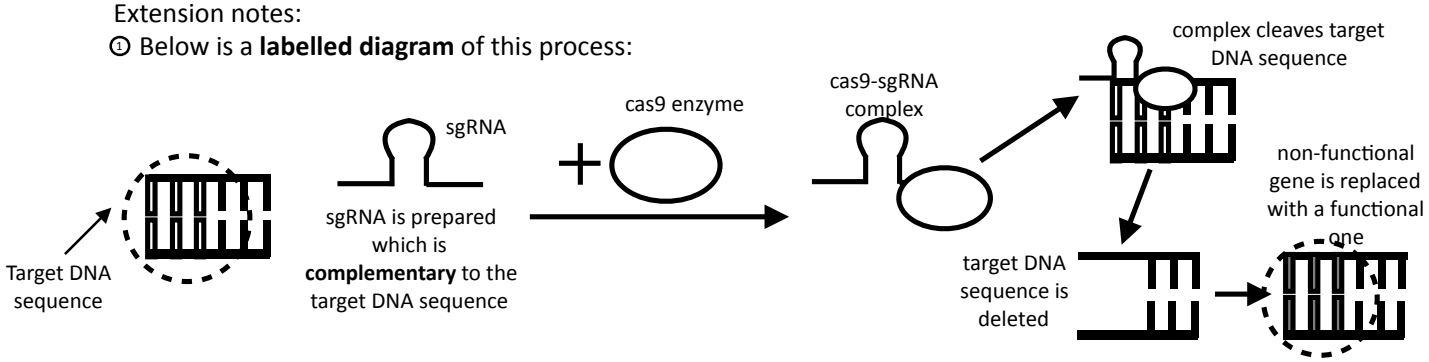
Quaternary structure. This refers to the joining of two or more polypeptide chains to form a fully functional protein.

9.4.2 Using your own understanding and the information above, explain how CRISPR-Cas9 technology can be used to replace the defective β-globin gene. [4 marks]

① sgRNA (single guide RNA) is prepared which is complementary to a specific target DNA sequence (the defective β-globin gene sequence). ② sgRNA binds to the cas9 enzyme, forming a cas9-sgRNA complex which travels along DNA. ③ sgRNA binds to its specific and complementary target DNA sequence (mutated β-globin gene). ④ The cas9 enzyme then cleaves the DNA at the specific target sequence which the sgRNA is complementary to. ⑤ This induces a double-stranded DNA break - a functional β-globin gene can then be inserted into the place of excision to replace the removed mutated DNA segment (sequence).

Extension notes:

① Below is a **labelled diagram** of this process:



9.4.3 Explain one advantage and one disadvantage of using CRISPR-Cas9 technology to treat sickle cell anaemia. [4 marks]

One advantage of using CRISPR-Cas9 technology is that the replacement of a mutated β-globin gene with a functional one reduces the chance of red blood cells being prematurely broken down (reduces symptoms of and potentially treats sickle cell anemia). However, one disadvantage of CRISPR-Cas9 is the potential for unwanted off-target DNA breaks - this means that a different gene to the mutated β-globin would be cleaved, which potentially further compromises patient health.

10.1.1 Describe the purpose of the polymerase chain reaction. [1 mark]

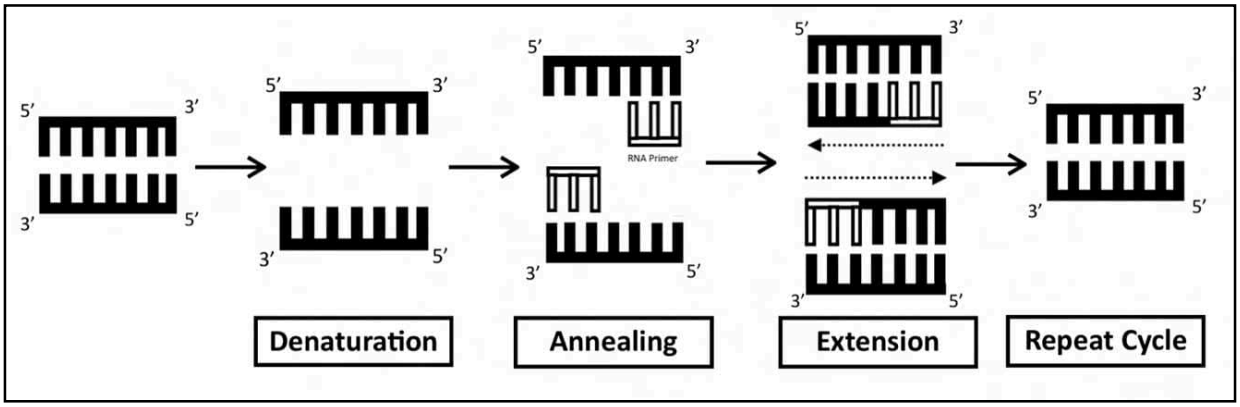
The purpose of the polymerase chain reaction is to amplify (make a large number of copies) DNA.

10.1.2 Describe the steps① of the polymerase chain reaction. [4 marks]

① Denaturation: the temperature is increased to 92°C, which allows the section of double-stranded DNA to be separated into two template strands by breaking hydrogen bonds between complementary bases.
② Annealing: the temperature is reduced to 55°C, which allows primers to bind to template strands and act as an attachment site for Taq Polymerase.
③ Extension: the temperature is increased to 72°C, which allows Taq Polymerase③ to read the template strands and assemble complementary daughter strands, producing two double-stranded copies of the original DNA segment.
④ The cycle is repeated②.

Extension notes:

① The diagram below demonstrates the process of polymerase chain reaction:



② Many students often forget the fourth step and that is that the polymerase chain reaction process is **repeated**! To calculate the **total number of DNA molecules** produced by undergoing the polymerase chain reaction process, use the formula $\mathbf{2^n}$ where **n** is the number of cycles repeated. For example, if the cycle is repeated 3 times, then we will have a total of 2^3 DNA molecules (which is 8 DNA molecules).

③ Recall that **Taq polymerase** is **naturally synthesised in bacteria** and is **resistant to heat** (thermostable). Thereby, it is able to assemble complementary daughter strands despite the **high temperature of 72°C.**

10.1.3 State two applications where the polymerase chain reaction can be used. [2 marks]

① PCR can be used to amplify trace amounts of DNA from crime scenes to aid in the identification of criminals.

② PCR can be used for personalised genome testing in order to determine and demonstrate familial relationships.

10.2 Explain the above statement. [2 marks]

The PCR process mimics the biological process of DNA replication by using a semi-conservative replication method to significantly amplify DNA (as each cycle doubles the amount of DNA) - this means that only a single molecule of DNA is enough for PCR amplification. The consequence of being a sensitive process is that any contamination or mutation in the original DNA sample will be copied over and over again. This means that extreme care is required in sample preparation and the process needs to be controlled.

10.3 Complete the table below, explaining the function of the following components involved in the polymerase chain reaction. [4 marks]

Components	**Function**
Nucleotides	Nucleotides are the monomers of DNA. These monomers can be used to assemble a new complementary strand of DNA using a template DNA strand.
Taq Polymerase	Taq Polymerase is an enzyme responsible for reading template DNA strands and assembling complementary strands.
Primers	Primers proride an attachment site for Taq Polymerase to bind to - they are small pieces of DNA that are complementary to the DNA segment that amplification starts from.
DNA Sample	The DNA sample is the original piece of DNA that is being copied.

10.4.1 Describe the purpose of gel electrophoresis. [1 mark]

The purpose of gel electrophoresis is to separate and sort DNA fragments in a sample based on their size by forcing them to migrate through a gel under the influence of an electric current.

10.4.2 Identify one molecule, other than DNA fragments, that can be separated through gel electrophoresis. [1 mark]

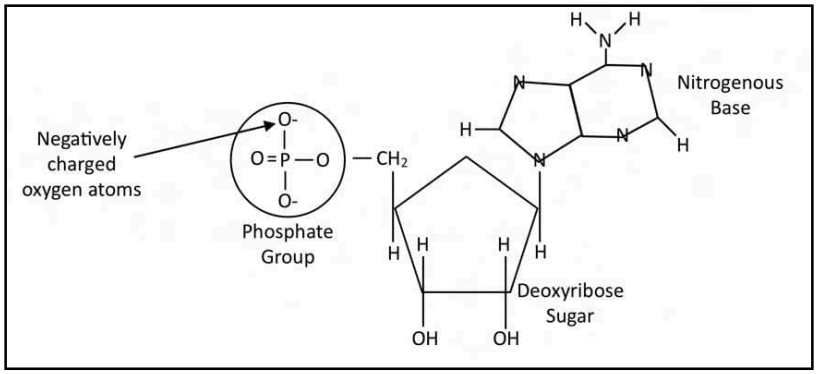
Proteins

10.5 Explain why DNA molecules are negatively charged. [2 marks]

The phosphate groups in each nucleotide are negatively charged① due to the negative charge of oxygen atoms. Hence, DNA is a negatively charged molecule.

Extension notes:

① Below is a diagram of a nucleotide with an annotated phosphate group:



10.6 Explain the main steps of the process of gel electrophoresis. [5 marks]

① DNA samples[1] are cleaved (cut) using restriction enzymes. ② An electrophoresis chamber is set up, along with agarose gel, electrodes (terminals) and a buffer solution. ③ DNA samples (along with dye) are loaded into the wells located at the negative terminal. A DNA ladder is added to one of the wells for reference (to estimate the size of the unknown DNA fragments). ④ A current is supplied (with the negative terminal aligned with the DNA wells and the positive terminal on the opposite end). Consequently, negatively charged[2] DNA migrates through the gel to the positive terminal. ⑤ The gel acts as a molecular mesh, whereby smaller fragments move through the gel more easily and thus, travel further than larger fragments do in the same period of time; this separates[3] DNA by size and creates a banding pattern. ⑥ DNA fragments are detected by adding fluorescent stains which bind to DNA.

Extension notes:

① The aim of gel electrophoresis is to separate macromolecules, specifically DNA, based on their rate of movement through a gel under the influence of electric charge.

② DNA is negatively charged due to the presence of phosphate groups; therefore, the DNA fragments migrate towards the positive end (anode).

③ Components in gel electrophoresis are separated based on the number of DNA nucleotides in the fragment (equivalent to the size of the DNA fragment) - larger fragments are slowed by resistance and move slower through the gel.

10.7 Complete the table below, describing the function of the following features involved in the process of gel electrophoresis. [6 marks]

Feature	Function
Buffer Solution	A buffer solution is used to provide ions that carry a current. The buffer solution is also present to maintain the pH of the gel.
Wells	Wells are indentations in the gel that samples of DNA are loaded into.
Terminals	Terminals are used to separate DNA fragments. This is because DNA is negatively charged and so will be repelled by the negative pole (terminal) and attracted towards the positive pole (terminal).
Dye	The dye adds mass so that DNA fragments settle into the wells during loading. The dye increases the visibility of the DNA fragments as they migrate through the gel (the purpose of this is to prevent the DNA fragments falling off the end of the gel during the electrophoresis process).
Current (power)	The purpose of the current is to separate DNA fragments by size as these negatively charged molecules move through the gel when an electric current is passed through.
DNA Ladder	The DNA ladder refers to a solution that contains DNA fragments of a known size. The position of an unknown DNA fragment can be compared to the size of a specific marker fragment on the ladder, allowing the size of the unknown fragment to be estimated.
Restriction Enzymes	Restriction enzymes are used to recognise, bind to and cut (cleave) DNA at specific sequences, producing sticky ends.

11.1 Define the term 'gene cloning'. [1 mark]

Gene cloning refers to the formation of multiple copies of a specific section of DNA.

11.2 Describe the structure and function of plasmids. [2 marks]

Plasmids refer to small circular structures of extra chromosomal DNA. Plasmids function as vectors to transfer foreign DNA into cells.

①

11.3 Describe the process of bacterial transformation and outline how transformed bacteria are identified. [4 marks]

① Treat bacterial plasmids and the specific gene of interest with the same specific restriction enzyme (that produces sticky ends). ② DNA ligase anneals the plasmid and gene of interest together - a recombinant plasmid is formed. ③ Allow bacteria to take up plasmid by subjecting it to heat-shock therapy or electroporation. ④ The plasmid also contains an antibiotic resistance gene - antibiotic selection is used to determine which bacteria have taken up the plasmid. This is because basteria that survive antibiotic selection will have the plasmid containing both the antibiotic resistance gene and the gene of interest. ⑤ Bacteria that have taken up the plasmid are 'transformed'

Extension notes:

① One **application** of this process is the **production of human insulin** for patients with **type 1 diabetes**. Type 1 diabetes is a condition in which patients are **unable** to produce insulin, which is responsible for the **uptake of glucose** into cells. The absence of insulin means that **blood glucose levels** will **rise**, leading to symptoms like **increased thirst**!

Bacterial transformation can be used to **produce insulin**, which can then be **regularly injected** into patients with type 1 diabetes **to treat symptoms**.

12.1 Distinguish between 'genetically modified organisms' and 'transgenic organisms'. [3 marks]

Genetically modified organisms have altered genomes through genetic engineering technology; whereas, transgenic① organisms are a specific type of genetically modified organism that are altered through the transfer of genetic material from one organism of a different species.②

Extension notes:

① All transgenic organisms are also genetically modified organisms, as the insertion of genetic material is an example of altering the genome.

② It is important to distinguish between artificially selected organisms and genetically modified organisms. Artificial selection selects phenotypes by encouraging promotion of an organism that already exists with the phenotype, whereas genetic modification selects phenotypes by altering the genome of the organism that would otherwise not express the desired phenotype.

12.2 Explain two benefits, one agricultural and one immunological, of the genetic modification of organisms. [4 marks]

One agricultural① benefit is that food security can increase. This is through increasing the crop yield with improved quality and nutritions produce to provide greater reassurance to communities where food is harder to grow.

One immunological② benefit is that there will be reduced outbreak of zoonotic diseases (diseases caused by pathogens transmitted from animals to humans). This is because farm animals can be genetically modified to become disease-resistant and so are less likely to fall ill. This limits the spread of zoonotic diseases.

Extension notes:

① Alternative **agricultural** benefits include:

- **Increased crop yield:** genetically modified organisms are able to select for qualities that tolerate specific conditions better.
- **Reduced costs for crop production:** less money is required to be spent to use pesticides for plants.
- **Reduced need for pesticides:** this reduces any damage caused by harmful pesticides that are released into the environment.
- **Higher food security:** increased crop yield with better quality and nutrition can provide more reassurance to communities where food is harder to grow.

② Alternative **immunological** benefits include:

- **Reduced costs for healthcare:** edible vaccines will create a more accessible method of being vaccinated that does not require the production of expensive equipment.
- **Reduced rates of malaria:** genetically modified mosquitoes contain proteins which disrupt the life cycle of plasmodium, the malaria parasite and can ease the healthcare burden caused by malaria.

12.3 Complete the table below, explaining the social implications of the use of genetically modified organisms. [6 marks]

Implication	Explanation
Social inequality is created.	Genetic engineering technology may only be accessible to certain members of the population, providing them with benefits not available to others.
Malnutrition can be solved.	Staple and cheaper foods, like rice, can be genetically modified to contain a greater amount of nutrients than usual, enhancing their nutritional benefit.
Human self-interest is prioritised over the ethical treatment of organisms.	Genetic modification may be implemented in such a way that maximising benefit to humans endangers or is detrimental to the organisms being modified.

12.4 Complete the table below, explaining the biological implications of the use of genetically modified organisms. [6 marks]

Implication	Explanation
Pesticides may affect food webs.	In the case of pesticides, insects other than the intended target may be affected. If a large number of non-target organisms die, then the food web of the specific environment may be impacted.
Loss of biodiversity.	As farmers choose to use genetically modified crops, there will be fewer crops grown that differ from each other. Thereby, reducing the genetic pool (this is detrimental if a genetic bottleneck occurs).
Genetically modified animals may compete with natural populations.	Genetically modified organisms may outcompete natural populations, resulting in the widespread eradication of populations and damage to food webs.

12.5 Complete the table below, explaining the ethical implications of the use of genetically modified organisms. [6 marks]

Implication	**Explanation**
Violation of animal rights.	Animals are unable to consent to being genetically modified.
Inappropriate intervening of evolution.	If traits in germline cells are passed down to offspring, it will disrupt the natural course of evolution, which can have detrimental effects to the ecosystem.
Costs for farmers increases.	If farmers choose to grow unmodified organisms, they may lose market share because consumers may opt to purchase genetically modified organisms.

Solutions: Unit 3 AOS 2

1.1.1 Define the term photosynthesis. [1 mark]

Photosynthesis is a biochemical process where green plants and other photosynthetic organisms transform light energy from sunlight into chemical energy stored as glucose.

1.1.2 Explain the importance of photosynthesis. [3 marks]

Photosynthesis is necessary for plants and other photosynthetic organisms to synthesise glucose as a form of chemical energy. This glucose is an input① for cellular respiration to synthesise ATP - a usable form of energy required for all metabolic reactions to occur. Glucose synthesis is necessary both② for the autotrophic organism undergoing photosynthesis and heterotrophs (like human beings) which consume chemical energy in the form of glucose and transform (convert) it into ATP in the body.③

Extension notes:

① Photosynthesis produces glucose, which functions as a fuel source in plants, just as it functions as a fuel source in animals.

② The primary purpose of photosynthesis is to produce glucose for the plant - oxygen is just a by-product that is released in the process.

③ Photosynthesis should occur at a faster rate than cellular respiration - this is so that the plants have reserves of stored energy in case of high-demand metabolic activities —> this can be likened to humans having a greater income stream compared to expenses, with a financial reserve in case of emergency situations (like a pandemic!).

1.1.3 Write the chemical equation for photosynthesis. [1 mark]

$$6CO_{2(g)} + 6H_2O_{(aq)} \longrightarrow C_6H_{12}O_{6(aq)} + 6O_{2(g)}$$

1.1.4 Write the worded equation for photosynthesis. [1 mark]

Carbon Dioxide + Water ⟶ Glucose + Oxygen

1.2.1 Define the term cellular respiration. [1 mark]

Cellular respiration is a catabolic process where energy in the form of ATP is produced through a combination of biochemical pathways using glucose as a fuel.

1.2.2 Explain the importance of cellular respiration. [2 marks]

Cellular respiration allows the cell to transform stored chemical energy (glucose) into a usable energy form (ATP). This provides the cell with sufficient energy to carry out all energy-requiring processes to sustain life.

1.2.3 Write the chemical equation for cellular respiration. [1 mark]

$C_6H_{12}O_{6(aq)} + 6O_{2(g)} \longrightarrow 6H_2O_{(aq)} + 6CO_{2(g)} + 36ATP$

1.2.4 Write the worded equation for cellular respiration. [1 mark]

Glucose + Oxygen ⟶ Carbon Dioxide + Water + ATP

2.1 Define the term 'enzyme'. [2 marks]①

Enzymes are protein-based biological catalysts that increase the rate of chemical reactions by providing an alternative route with a lower activation energy (Ea).

Extension notes:

① Two points must be made in your response in order to receive full marks:

- that enzymes **increase** the **rate** of chemical reactions
- that enzymes act to **lower** the **activation energy** of reactions

2.2 Outline what is meant by the terms 'biological' and 'catalyst' in the term biological catalyst. [2 marks]

① Biological is used in reference to living things.

② A catalyst is a substance that increases the rate of a chemical reaction (without being consumed in the reaction itself) by lowering the activation energy required for the reaction to occur.

2.3 Define the term 'activation energy'. [1 mark]

The activation energy (Ea) refers to the minimum amount of energy required for a reaction to occur.

2.4 Identify two enzymes in the human body and outline their purpose. [3 marks]

Lactase is an enzyme found in the small intestines that breaks down lactose into glucose and galactose. Amylase is an enzyme found in mucus that breaks down carbohydrates for digestion.

2.5 Outline how the structure of an enzyme's active site suits its function. [2 marks]

The active site① of an enzyme has a complementary shape to a specific substrate, enabling the substrate to bind and form an enzyme-substrate complex. Since the active site's shape is specific to a particular substrate, other molecules are unable to bind to it - this means that enzymes can only catalyse specific reactions.

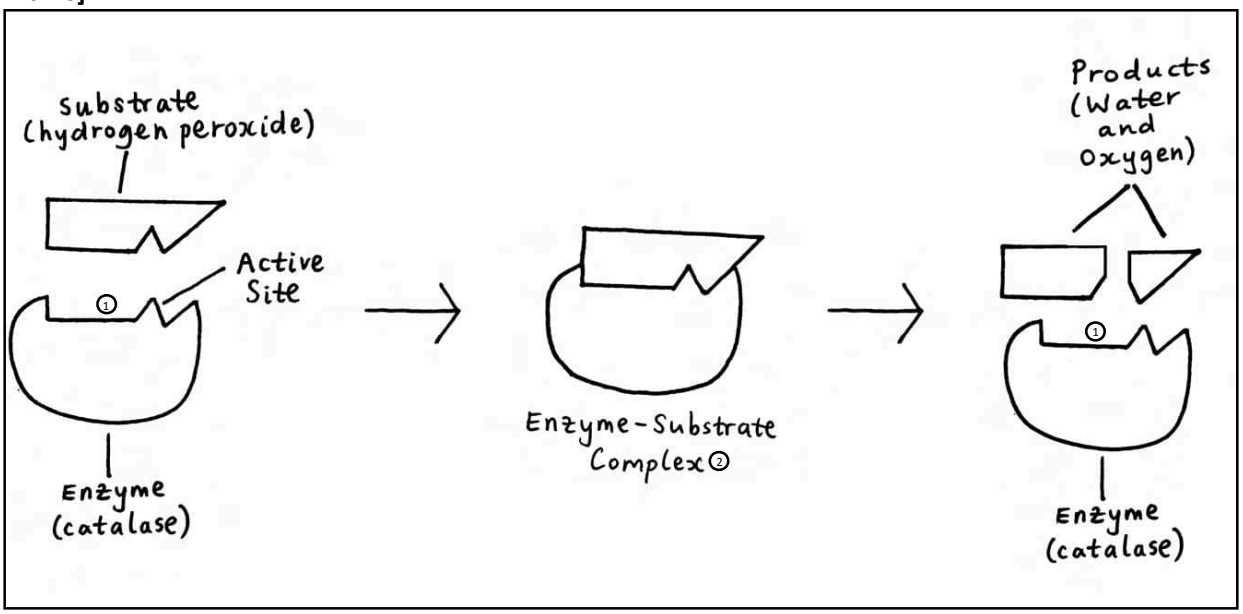
Extension notes:

① The **active site** of an enzyme is part of its **tertiary structure** and allows the polypeptide chain to be a **functioning protein**. Anything that disrupts the bonds in the tertiary structure can cause the active site to undergo a change in shape and consequently, lose its biological function.

2.6 Suggest two reasons for this. [2 marks]

One reason may be because yeasts lack specific membrane-bound transport proteins that are complementary in shape to specific sugar molecules (which prevents the sugar from travelling into the cell). Another reason may be because yeasts have varying concentrations of enzymes that break down specific sugar molecules (this means that different sugars will be metabolised to different extents).

2.7.1 Draw a labelled diagram of the action of catalase using the lock and key model of enzyme action. [3 marks]

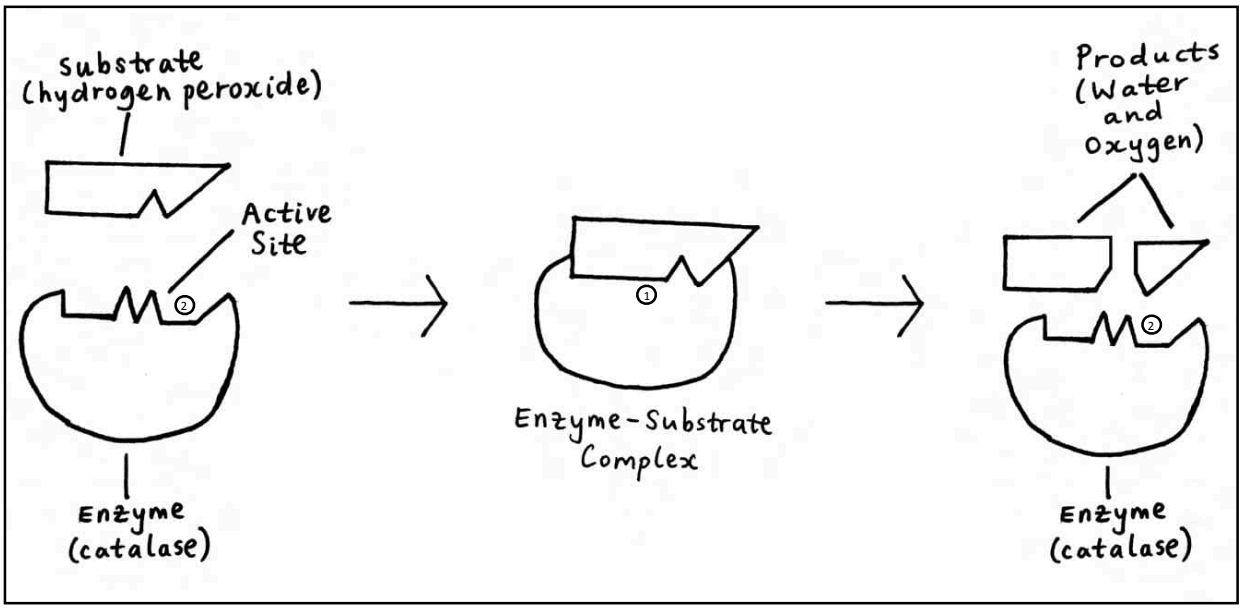


Extension notes:

① Note that the active site shape remains unchanged before and after catalysis occurs.

② The binding of the substrate to the enzyme causes temporary bonds to form between the enzyme-substrate complex, which acts to 'loosen' and weaken the bonds within the substrate. Thereby, reducing the activation energy of the reaction.

2.7.2 Draw a labelled diagram of the action of catalase using the induced fit model of enzyme action. [3 marks]



Extension notes:

① The change in shape of the active site is a conformational change, caused by the substrate binding to the active site. This change in shape serves to improve binding to the substrate molecule.

② Note that the active site reverts back to its original shape despite initially changing shape to accommodate the shape of the substrate.

2.8 Explain the difference between coenzymes and cofactors. [3 marks]

A cofactor is a molecule that is necessary for the activation (functioning) of an enzyme; whereas, a coenzyme is a specific subset of cofactors that are organic molecules. Cofactors bind to enzymes and enable them to catalyse a reaction whilst coenzymes work with an enzyme to aid its function (by acting as a carrier of protons and electrons between reactions). Examples of cofactors include Mg^{2+} and Zn^{2+} ions and examples of coenzymes include NADH and ATP.

2.9 Distinguish between the 'unloaded' and 'loaded' form of a coenzyme.① [2 marks]

The unloaded form of a coenzyme is free to accept protons, high-energy electrons and chemical groups (phosphates); whereas, the loaded form of a coenzyme has already accepted protons, electrons or a chemical group.

Extension notes:
① Examples of loaded forms of coenzymes include: NADH, NADPH and ATP

Examples of unloaded forms of coenzymes include: NAD+, NADP+, ADP

2.10.1 Explain the function of the coenzyme ATP. [2 marks]

ATP is a coenzyme which provides chemical energy for endergonic (energy requiring) reactions and processes. It acts as a carrier of energy to cellular reactions.

2.10.2 Explain the function of the coenzyme NADH. [2 marks]

The function of the coenzyme NADH is to carry high-energy electrons and hydrogen ions (from glycolysis in the cytosol and the krebs cyle in the mitochondrial matrix) to the Electron Transport Chain in the mitochondrial cristae.

2.10.3 Explain the function of the coenzyme NADPH. [2 marks]

NADPH is a coenzyme that carries hydrogen ions and high-energy electrons from the light-dependent stage in the grana to the light-independent stage in the stroma (where hydrogen ions will be combined with atoms in CO_2 to produce glucose).

2.11 Outline one similarity and one difference between NADPH and NADH. [2 marks]

One similarity is that both NADH and NADPH act as carriers of hydrogen ions and high-energy electrons between reactions (both are coenzymes). One difference is that NADH carries protons and electrons between organelles (from the cytosol to mitochondria); whereas, NADPH carries protons and electrons within the same organelle (as all photosynthetic reactions occur in chloroplasts).

3.1 Explain the importance of kinetic energy in enzyme-catalysed reactions. [2 marks]

Kinetic energy is energy due to motion①. It is important in enzyme-catalysed reactions because the amount of kinetic energy determines the speed at which enzyme and substrate molecules collide and bind (thus, determining reaction rate).

Extension notes:

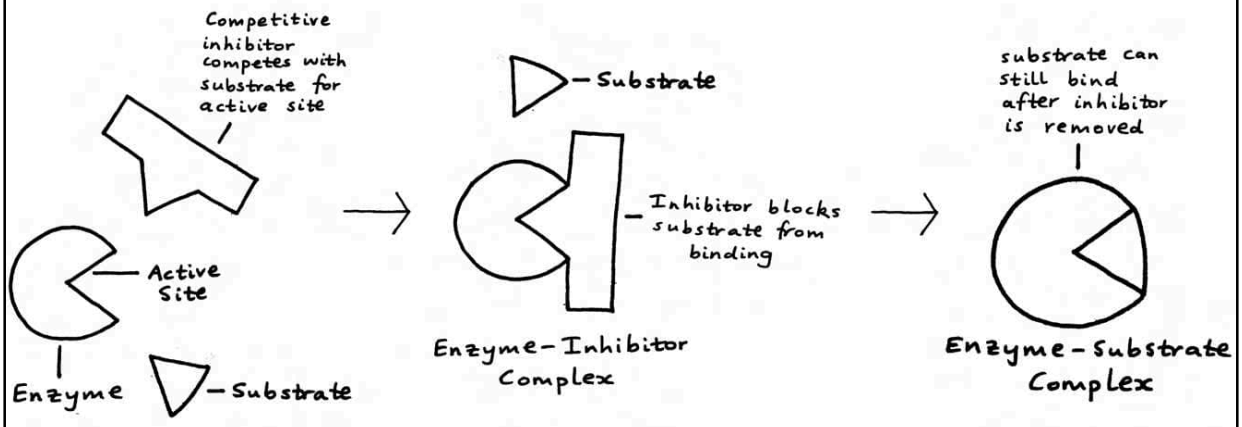
① Temperature is **proportional** to kinetic energy. This means that an increase in temperature will increase the kinetic energy acquired by particles.

3.2.1 Define the term 'inhibitor'. [1 mark]

Inhibitors are chemicals which reduce the rate of enzyme-catalysed reactions by binding to the enzyme.

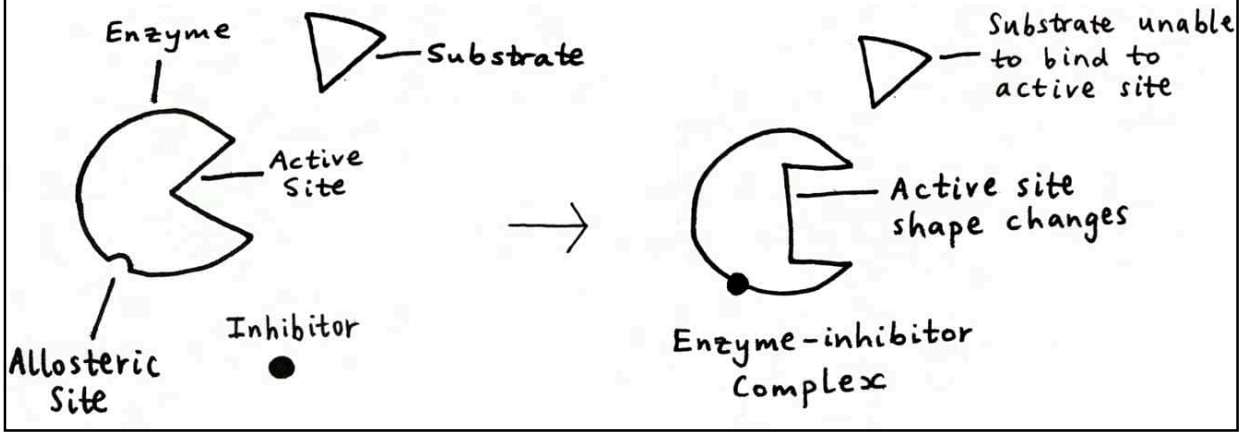
3.2.2 Explain the mode of action of competitive inhibitors. Draw a labelled diagram to support your response. [4 marks]

A competitive inhibitor is a compound that competes with a structurally similar substrate for the active site of a specific enzyme. The inhibitor will bind to the active site of the enzyme and prevent (block) the substrate from binding; this reduces the frequency of enzyme-substrate complex formation and prevents the reaction from occuring. This process is reversible because the inhibitor does not change the conformation (shape) of the active site and thus, the substrate can still bind if the inhibitor is removed.



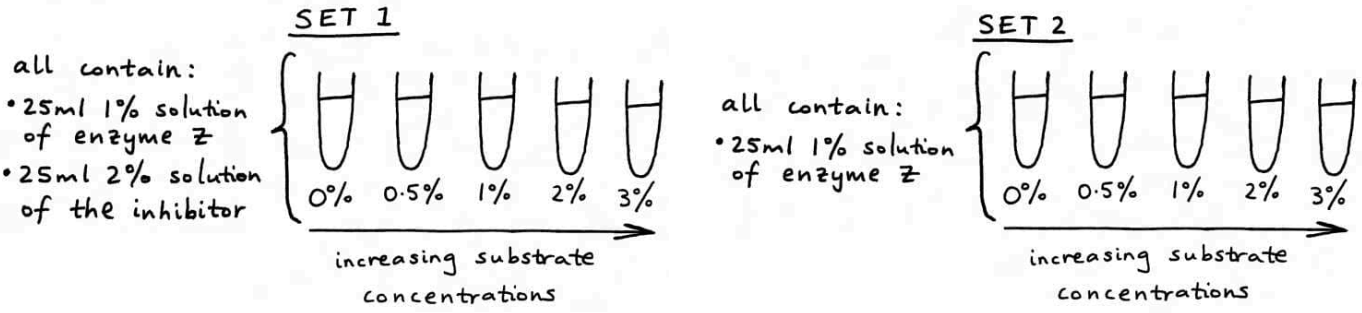
3.2.3 Explain the mode of action of non-competitive inhibitors. Draw a labelled diagram to support your response. [4 marks]

A non-competitive inhibitor is a compound that binds to a regulatory region (allosteric site) on an enzyme. This results in a conformational change to the shape of the active site which affects the binding of the substrate to the active site (prevents enzyme-substrate complex formation). Thus, preventing the reaction from occuring.



3.3 Design an experiment to determine if the inhibitor in the solution is X or Y. [5 marks]

An experiment can be conducted where 2 sets of 5 test tubes are prepared. One set of test tubes, Set 1, will all contain 25ml of a 2% solution of the mislabelled inhibitor and another set of test tubes, Set 2, will contain no inhibitor solution - both sets of test tubes will also contain 25ml of a 1% solution of enzyme Z. Increasing concentrations (0%, 0·5%, 1%, 2%, 3%) of a substrate solution (at a fixed volume of 25ml) will then be separately added to the 5 test tubes in each set. See a visual representation below:



The concentration of product produced after 5 minutes is then measured in each test tube and the rate of reaction can be numerically calculated. If the rate of reaction for Set 1 of the experiment approaches the rate of reaction that occurs without the inhibitor (as substrate concentration increases) then the mislabelled inhibitor is chemical X (the competitive inhibitor). If the rate of reaction for Set 1 of the experiment does not approach the rate of reaction that occurs without the inhibitor (as substrate concentration increases) then the mislabelled inhibitor is Chemical Y (the non-competitive inhibitor).

3.4 Identify three factors, other than the action of inhibitors, that can have an effect on enzyme activity. [1 mark]

Temperature, pH and enzyme concentration.

3.5.1 Identify the temperature at which lipase activity was most optimal. Explain your choice using data from the above table. [3 marks] ①

Lipase activity was most optimal at 30°C ②. This is because, at 30°C, the glycerol concentration increased from 0·1M (before adding lipase) to 0·4M (after adding lipase) – a difference of 0·3M which is the highest out of all temperatures. This means that lipase was able to catalyse the breakdown of milk lipids into glycerol and fatty acids most optimally at 30°C compared to other temperatures

Extension notes:

① This is a **two-part question** - you should first **identify** the temperature and then give an **explanation**!

② Note that this question doesn't require you to give a biological explanation, but rather a **justification** of what temperature is the most optimal for lipase activity **based on the data**.

3.5.2 Using your understanding of enzyme structure and function, explain the data obtained at 50ºC. [3 marks]

At 50°C, the final concentration of glycerol is the lowest (compared to every temperature tested) which suggests that most of the lipase molecules have denatured and are no longer functional. At temperatures above the optimum, hydrogen bonds in the tertiary structure break – consequently, the active site ① is permanently distorted (conformational change in shape) and is no longer complementary to the specific substrate. Thus, lipase can no longer bind to the lipid substrate (loss of specificity) to produce glycerol, resulting in the low concentration of glycerol (0·13M) seen in the experiment.

Extension notes:

① Reference to the **shape** of the enzyme **active site** must be made when explaining denaturation.

3.5.3 Explain how recording the pH of the milk solution before and after adding the lipase solution can be used to determine the rate of lipase activity in this experiment. [3 marks]

Lipase breaks down lipids into glycerol and fatty acids.① As such, the pH of the solution is expected to decrease due to the production of fatty acids. The change in pH (from before to after adding the lipase solution) can be used to determine the amount of fatty acid produced and thus, determine the rate of lipase activity.

Extension notes:

① Fatty **acids** have a **high concentration of H+ ions** (they are **acidic**). So, if the concentration of fatty acids in the solution increases, then the concentration of H+ ions will also increase and the **pH will decrease** as a result. Note that a decrease in the concentration of H+ ions leads to the pH increasing (becoming more alkaline).

3.6.1 Explain what the ascending and descending portions of the graph above reflects in terms of amylase activity. [4 marks]

Before the temperature reaches 40°C, the graph is shown to be ascending which indicates an increase in the catalytic activity of amylase. This is because, as the temperature increases, enzyme (amylase) and substrate molecules acquire more kinetic energy and collide (at the active site)① more frequently. Thus, the rate of this reaction increases. However, as the temperature increases above 40°C (the optimum) the graph is descending② which indicates a decrease in amylase activity. This is due to progressive denaturation of amylase molecules whereby hydrogen bonds in the tertiary structure break. Consequently, the shape of amylase's active site changes and its ability to catalyse reactions reduces (loss of specificity).

Extension notes:

① When explaining the enzyme activity-temperature graph, it is important to make the link between temperature and its effect on the structure of the enzyme - this can be accomplished by making reference to key enzyme concepts such as the enzyme 'active site'.

② It is important to remember that low temperatures do not result in enzyme denaturation - low temperatures only act to slow down the molecules (enzyme and substrate particles) involved in the reaction. This will result in a decrease in enzyme activity due to the lack of kinetic energy acquired by particles.

3.6.2 Describe the term 'denaturation' with reference to enzyme structure. [2 marks]

Denaturation refers to the breaking① of hydrogen bonds in the tertiary structure of an enzyme. This changes the shape of the enzyme's active site such that it is no longer complementary to its substrate (loss of specificity); thereby, permanently② preventing the formation of enzyme-substrate complexes (decreased enzyme activity).

Extension notes:

① Often, after denaturation, coagulation occurs as the remaining forces in the polypeptide chain still attract each other.

② A visible example of denaturation is cooking an egg. As an egg is subject to high temperatures, it is cooked, causing denaturation of the protein inside the egg. The egg goes from translucent to opaque as it denatures and coagulates, forming the spongy and relatively hard texture. An egg cannot be uncooked once it is cooked, a testament to the irreversibility of denaturation.

3.6.3 Explain why the primary structure of amylase is unaffected by denaturation whereas the tertiary structure is. [3 marks]

The primary structure is unaffected during denaturation due to the presence of peptide bonds between amino acids - a type of strong covalent bond which is difficult to break with increasing temperatures. However, at temperatures above optimal, hydrogen bonds in the tertiary structure are too weak to maintain the enzyme's shape against the increased random molecular motion of atoms in the enzyme. This causes a conformational change to the active site shape of the enzyme - and so, the tertiary structure is affected by denaturation.

Extension notes:

① Covalent bonds are strong because…

3.7 Explain what the ascending and descending portions of the graph above reflects in terms of catalase activity. [3 marks]

Catalase has the highest (greatest) rate of activity at the optimum pH① (pH 7) as represented by the peak on the graph. Either side of the optimum pH the enzyme may still function but at a reduced rate which is represented by the ascending and descending portions of the graph. Too far either side of the optimum pH catalase molecules denature which is indicated by the steadily decreasing slope. This is because significant changes in pH disrupt hydrogen bonds in the tertiary structure of catalase and affect protein folding - thereby, resulting in a change to the shape of catalase's active site and loss of specificity (reduced enzyme activity).

Extension notes:
① Not only do extreme changes in temperature affect enzyme activity, but changes in pH too.

3.8.1 Explain the results of the graph from 0-20① seconds. [3 marks]

As substrate (lipid) concentration increases, the rate of reaction increases. This is due to increased frequency of random successful collisions between lipase and lipid molecules (greater formation of enzyme-substrate complexes). Consequently, the amount of product (glycerol and fatty acids) produced per unit time increases which leads to an increased rate of reaction.

Extension notes:
① For questions where you are asked to explain the results for a specific time frame (eg. 0-20 seconds), make sure to double-check that you are writing about the correct time frame!

3.8.2 Explain the results of the graph from 20 seconds. [3 marks]

From 20 seconds onwards, the active sites of lipase molecules become saturated ① (due to the high concentration of substrate molecules compared to enzyme molecules). Consequently, the rate of reaction plateaus (the rate is constant) because all active sites for enzyme are engaged in catalysis ② after 20 ③ seconds; the concentration of substrate (lipid) has become a limiting factor. Thus, substrate (lipid) molecules will have to wait until there are free active sites available to be broken down.

Extension notes:

① The **saturation** of enzyme active sites is a key point that must be made in your response!

② This means that **all enzyme active sites** are **bound** to **substrate** molecules (**none are available**)!

③ Note that, from 20 seconds onwards, the rate of reaction is at its **maximum** and is **constant**.

3.9.1 Explain the results of the graph from 0-30 seconds. [3 marks]

The amount of substrate (protein) ① exceeds the amount of enzyme (trypsin) ① molecules until 30 seconds. Thus, as the concentration of trypsin increases, there are more available active sites for proteins to bind to. This leads to more frequent enzyme-substrate complex formation and, consequently, the amount of product (amino acids) produced per unit time increases. Thus, the rate of reaction increases.

Extension notes:

① You should use brackets to indirectly identify what the enzyme and substrate is for this reaction!

3.9.2 Explain the results of the graph from 30 seconds onwards. [3 marks]

From 30 seconds onwards, the rate of reaction plateaus. This is because a saturation point has been reached whereby the substrate concentration has become a limiting factor. This is a result of the maximum number of trypsin-protein (enzyme-substrate) complexes being formed and hence, all substrate molecules are consumed - the maximum rate of reaction is achieved.

4.1 Identify the two stages of photosynthesis and where each stage occurs. [2 marks]

The first stage of photosynthesis is the light-dependent stage - this occurs in the thylakoid membranes. The second stage of photosynthesis is the light-independent stage - this occurs in the stroma.

4.2 Explain the steps of the light-dependent[1] stage of photosynthesis. [3 marks]

① Light energy is absorbed by chlorophyll. ② Water is photolysed using photons (wavelengths) of light to split water molecules into hydrogen ions (H^+), oxygen gas (O_2) and high-energy electrons (e^-). ③ The high-energy electrons and hydrogen ions will get accepted by the coenzyme $NADP^+$ to form NADPH. ④ ATP is consequently formed (from ADP and Pi).

Extension notes:

[1] The inputs of the light-dependent stage include: water, NADP+, ADP and Pi. The outputs of the light-dependent stage include: oxygen, NADPH and ATP.

4.3 Explain the steps of the light-independent[1] stage of photosynthesis. [3 marks]

① Carbon dioxide gas enters a cycle of reactions (the calvin cycle) in the stroma of chloroplasts. ② The energy from ATP and hydrogen ions from NADPH is used to form glucose from carbon dioxide. ③ $NADP^+$ and ADP + Pi are produced.

Extension notes:

[1] The inputs of the light-independent stage include: carbon dioxide, NADPH and ATP. The outputs of the light-independent stage include: glucose, NADP+, ADP and Pi.

4.1.1 Complete the above chemical equation by writing the correct input in the empty space. [1 mark]

$$CO_{2\,(g)} + \text{RuBP} \xrightarrow{\text{Rubisco}} 3GP_{(aq)}$$

4.1.2 Explain the function of Rubisco in photosynthesis. [2 marks]

Rubisco is a photosynthetic enzyme that is involved in carbon fixation (the first stage of the light-independent stage of photosynthesis). Rubisco acts by catalysing the attachment of inorganic carbon dioxide gas to organic RuBP.

4.1.3 Identify whether Rubisco is involved in the light-dependent or light-independent stage of photosynthesis. [1 mark]

Rubisco is involved in the light-independent stage of photosynthesis.

4.1.4 Identify where Rubisco is found in a cell. [1 mark]

The stroma of chloroplasts.

4.1.5 Describe the main steps of the first stage of Rubisco synthesis. [3 marks] ①

① RNA polymerase separates the DNA strand by breaking hydrogen bonds between complementary nitrogenous bases. ② A DNA template strand is then copied by RNA polymerase through the enzyme moving along the template strand. ③ A molecule of pre-mRNA is produced by complementary base pairing.

Extension notes:

① Remember that Rubisco is a protein and therefore, will be synthesised via the processes of transcription and translation.

4.2.1 Define the term 'photorespiration'. [1 mark]

Photorespiration is a process that reduces the rate of photosynthesis through Rubisco catalysing the attachment of oxygen (and not carbon dioxide) to RuBP.

4.2.2 Describe one consequence of a C3 plant engaging in photorespiration. [2 marks]

One consequence of a C3 plant engaging in photorespiration① is that the efficiency of photosynthesis is reduced. Thereby, reducing energy yield in C3 plants.

Extension notes:

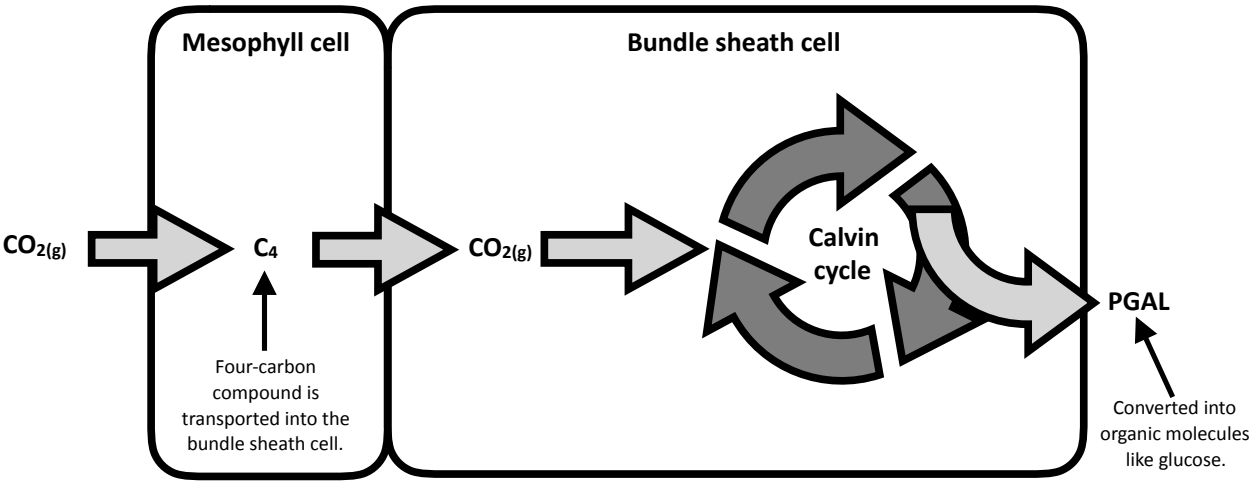
① It is important to understand, at a biological level, why this occurs. If the weather is hot and dry, the stomatal openings of plants will close in order to reduce water loss (conserve water). However, the closure of these stomates results in the concentration of $CO_{2(g)}$ decreasing in the leaves, as this gas normally enters the plants via these surface openings. Consequently, the concentration of $O_{2(g)}$ (which is a by-product of the light-dependent reaction) inside the plant increases. Thereby, increasing the rate of photorespiration.

4.2.3 Explain how C4 plants avoid engaging in photorespiration.① [3 marks]

C4 plants avoid photorespiration by physically separating the light-independent and light-dependent reactions of photosynthesis. The purpose of this is to separate carbon dioxide and oxygen such that Rubisco catalyses the attachment of carbon dioxide (and not oxygen gas) to RuBP. Carbon dioxide gas is fixed into an organic four-carbon compound in mesophyll cells and then transported to bundle sheaths - this compound is then broken down, which releases carbon dioxide gas. Carbon dioxide gas can then be fixed by Rubisco in the Calvin Cycle (without oxygen competing for Rubisco's binding site); thereby, avoiding photorespiration.

Extension notes:

① Below is a diagram representing the fixation of carbon dioxide in C4 plants:

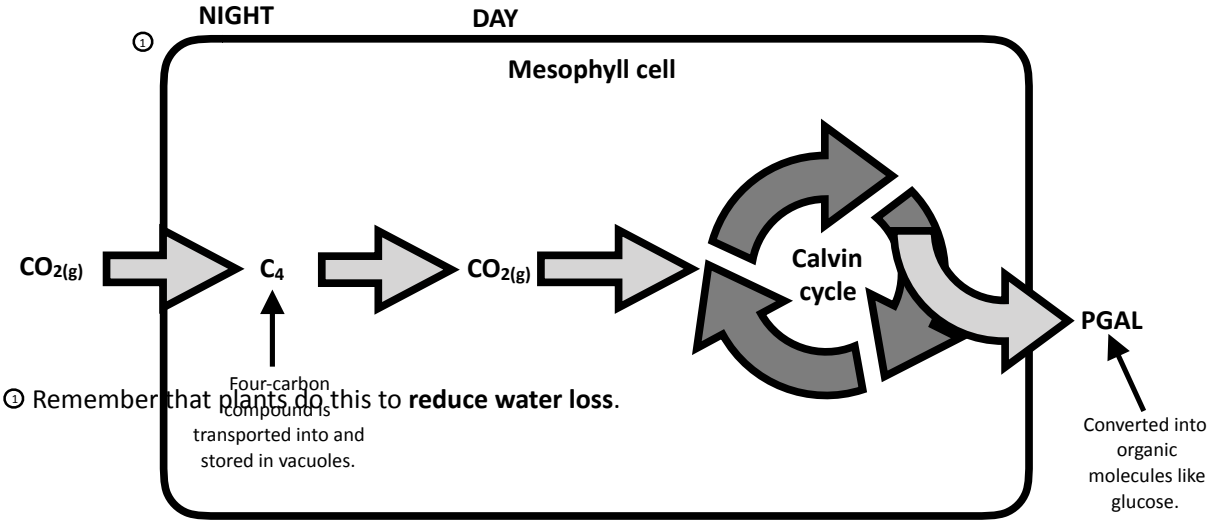


4.2.4 Explain how CAM plants avoid engaging in photorespiration. [3 marks]

CAM plants separate③ the two stages of photosynthesis by the time of day: night and morning. CAM plants open their stomata in the night, which allows carbon dioxide gas① to diffuse into the mesophyll cells. Carbon dioxide gas is then fixed into an organic four-carbon compound, which allows reserves of carbon dioxide to be created (as the four-carbon compound will be stored in vacuoles). During the day, whilst the stomata are closed, the organic four-carbon compound is transported out of the vacuole and broken down into carbon dioxide to be fixed by Rubisco via the Calvin Cycle in the mesophyll cell. Thereby, avoiding photorespiration by ensuring there is a high concentration of carbon dioxide for Rubisco to fix.②

Extension notes:

① Below is a diagram representing the fixation of carbon dioxide in CAM plants:



① Remember that plants do this to **reduce water loss**.

② The difference between C4 and CAM plants is that, whilst C4 plants partition photosynthetic reactions by cellular location (between mesophyll cells and bundle sheath cells), CAM plants partition photosynthetic reactions by the time of day (day and night).

③ The primary reason why the light-dependent and light-independent stage is separated is to conserve water. This adaptation allows CAM plants to live in hot, dry and arid regions of the world.

4.3.1 Outline why the stomata of a C3 plant remains closed during hot conditions and explain the consequences of this on the efficiency of photosynthesis. [3 marks]

The stomata of C3 plants close in hot conditions in order to reduce water loss (water retention). However, as a consequence, less $CO_{2(g)}$ enters these photosynthetic cells via the stomata. The reduction in the concentration of $CO_{2(g)}$ increases the rate of photorespiration because Rubisco will catalyse the fixation of $O_{2(g)}$ as opposed to $CO_{2(g)}$. Thereby, decreasing the rate of photosynthetic reactions and reducing the efficiency of photosynthesis.

4.3.2 Explain how this is the case. [3 marks]

CAM plants separate the two stages of photosynthesis by the time of day: night and morning. CAM plants open their stomata in the night, which allows carbon dioxide to diffuse into the mesophyll cells. Reserves of carbon dioxide are then created in the vacuoles (by fixing carbon dioxide into a four-carbon compound); thus, when the stomata are closed during the day, this organic compound is then broken down into carbon dioxide to be fixed by Rubisco in the Calvin Cycle. Thereby, CAM plants can still undergo photosynthesis even when the stomata remain closed during the day.

Extension notes:

5.4 Identify whether E. balsamifera is a C3, C4 or CAM plant and outline how these two stages of photosynthesis are 'separated'. [2 marks]

E. balsamifera is a CAM plant. It separates the two stages of photosynthesis by the time of day: night and day. The light-dependent stage occurs during the day and the light-independent stage occurs at night.

5.5.1 Identify one example of a C4 plant, other than corn. [1 mark]

Sugarcane

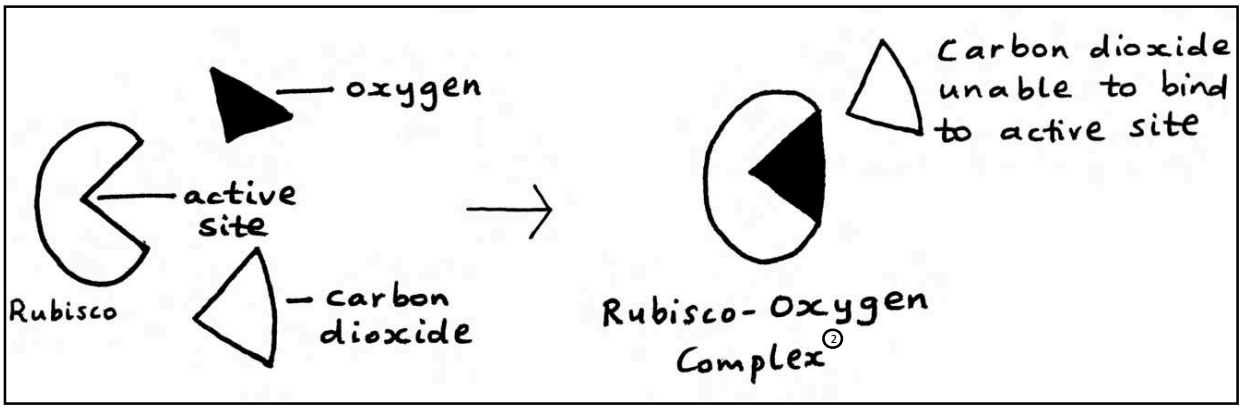
5.5.3 In regards to corn, identify which cell type the light-dependent stage occurs and in which cell type the light-independent stage occurs. [2 marks]

The light-dependent stage occurs in the mesophyll cells and the light-independent stage occurs in the bundle-sheath cells.

5.5.4 Explain the purpose of separating the light-dependent and light-independent stage by cellular location as seen in C4 plants. [3 marks]

The purpose of physically separating the light-independent and light-dependent reactions of photosynthesis is to avoid engaging in photo-respiration. This is because oxygen and carbon dioxide can be separated such that Rubisco catalyses the attachment of carbon dioxide (and not oxygen gas) to RuBP. Carbon dioxide is fixed into an organic four-carbon compound in mesophyll cells and then transported to bundle sheaths - this compound is then broken down, which releases carbon dioxide gas. Carbon dioxide gas can then be fixed by Rubisco in the Calvin Cycle (without oxygen competing for Rubiscos binding site).

5.6.1 Draw a labelled diagram explaining the mode of action of oxygen as a competitive inhibitor of Rubisco. [3 marks]①



Extension notes:

① Please see question 3.2.2 for revision on the action and effect of competitive inhibitors.

② This can lead to photorespiration, whereby the rate of photosynthesis is reduced (as carbon fixation does not occur).

5.7 Explain the results of the data above. [2 marks]

As the concentration of oxygen① increases, the rate of photosynthesis decreases. This is because as the concentration of oxygen increases, Rubisco will catalyse the attachment of oxygen (and not carbon dioxide) to RuBP. Consequently, the Calvin Cycle is disrupted because Rubisco will not catalyse the fixation of carbon dioxide, leading to the rate of photosynthesis reducing.

Extension notes:

① Remember that this **oxygen gas** is a product of the **light-dependent** reaction.

6.1 Define the term 'limiting factor. [1 mark]

A limiting factor is a variable whose availability precludes an increase in reaction rate despite increasing availability of other rate-impacting factors.

6.2.1 Explain the results of the experiment at point A of the above graph. [3 marks]

At point A, the temperature is lower than the optimal temperature which results in a low rate of photosynthesis. This is because the kinetic energy acquired by substrate and enzyme molecules (such as carbon dioxide and rubisco) is too low for successful collisions to occur. Thereby, substrates in photosynthesis collide ① at the active site of photosynthetic enzymes less frequently (enzyme activity is lower). Thus, resulting in a low rate of reaction.

Extension notes:
① Remember that a **successful collision** requires molecules to **collide** at the **correct orientation** with a **sufficient amount of energy** to **break chemical bonds** in the reactants.

6.2.2 Explain the results of the experiment at point B of the above graph. [3 marks]

At point B, the temperature has reached the optimal temperature for enzymes facilitating photosynthesis. Thereby, substrate molecules and enzymes involved in photosynthesis have acquired the optimal amount of kinetic energy required for fruitful collisions to occur - the enzymes are functioning at their most effective rate. Thereby, reaching the maximum rate of enzyme-substrate complex formation - which is why 'point B' is the maximum rate of reaction.

6.2.3 Explain the results of the experiment at point C of the above graph. [3 marks]

At point C, the rate of photosynthesis is decreasing. This is because as the temperature of the reaction increases past the optimal (40°), enzymes which control photosynthesis (such as Rubisco) denature (due to the breaking of hydrogen bonds in the tertiary structure of these enzymes and consequent change to the active site shape). Thus, the rate of photosynthesis will also reduce as a result of decreased catalysis①.

Extension notes:

① This means that there will be **reduced successful collisions** between enzyme and substrate molecules (decreased enzyme-substrate complex formation).

6.3 Identify whether the leaf in test tube 1 or test tube 2 will test positive for starch. Justify your choice. [3 marks]①

Test tube 1 will test negative for starch, whereas test tube 2 will test positive for starch. CO_2 is an input of photosynthesis and is required for the production of glucose; therefore, glucose will be produced in test tube 2 but not test tube 1 (which is where KOH has absorbed the CO_2). Over time, the leaf in test tube 2 will begin to store glucose as starch, resulting in a positive test.

Extension notes:

① Remember that **carbon dioxide gas** is an **input** of the **light-independent stage** of photosynthesis. Hence, if CO2 is absorbed (as is the case in test tube 1), the Calvin Cycle will not occur - this results in glucose being absent.

6.4.1 Explain the results from of the experiment from point A onwards. [3 marks]

From point A onwards, increasing the concentration of CO_2 will have no further effect on the rate of photosynthesis. This is because the enzyme responsible for carbon fixation, Rubisco, will be saturated. Hence, Rubisco becomes the limiting factor (at any given point in time all active sites are occupied) – the rate of reaction becomes constant (the graph plateaus) as the rate of photosynthesis is at its maximum.

6.4.2 Explain why the rate of photosynthesis is zero when there is no carbon dioxide available. [2 marks]

When there is no① carbon dioxide available, the light-independent reaction of photosynthesis (which involves Rubisco catalysing the attachment of carbon dioxide to RuBP) does not occur. Since the Calvin Cycle does not occur, carbon dioxide does not undergo fixation and glucose will not be produced. Thus, the rate of reaction will be zero (as the dependent variable is glucose concentration).

Extension notes:

① **Carbon dioxide gas** is an **input** of the **light-independent stage** of photosynthesis. Therefore, when no carbon dioxide is available, the light-independent stage will not occur.

6.5 Explain the relationship between water availability and the rate of photosynthesis. [3 marks]

The relationship① between water availability and photosynthesis is that as water availability reduces②, the rate of photosynthesis will also reduce. Water is an input of the light-dependent stage for photosynthesis; when a plant suffers from water stress (due to being in arid conditions), stomates will close which reduces the availability of carbon dioxide. Thereby, less carbon dioxide will be fixed by Rubisco in the Calvin Cycle, reducing the production of glucose and, therefore, decreasing the rate of photosynthesis. When there is more② water available, the light-dependent stage occurs to a greater extent (resulting in increased production of ATP and NADPH for the light-independent reaction) and stomates open (resulting in increased carbon dioxide availability).

Extension notes:

① For all **relationship** questions, you must first state **WHAT** the relationship is before **EXPLAINING** why and how the relationships exists!

② To **explain** the relationship, you could outline the **effect** on photosynthesis when **water is present and absent**.

6.6 Explain the relationship between light intensity and the rate of photosynthesis. [3 marks]

The relationship① between light intensity and the rate of photosynthesis is that as light intensity increases, the rate of photosynthesis also increases. This is because the amount of light energy absorbed by chlorophyll increases - there is more light to excite electrons during the light-dependent stage of photosynthesis. Furthermore, there will be more efficient photolysis of water. However, this occurs up until the rate of photosynthesis becomes constant due to saturation of chlorophyll molecules (further increases to light intensity will have no further effect on photosynthesis and so the rate plateaus).

Extension notes:

① For all **relationship** questions, you must first state **WHAT** the relationship is before **EXPLAINING** why and how the relationships exists!

7.1 Define the term 'glycolysis'. [1 mark]

Glycolysis refers to the breakdown of glucose into two molecules of pyruvate in the cytosol.

7.2 Identify the inputs and outputs of glycolysis. [2 marks]

Inputs: Glucose, NAD^+, ADP and P_i

Outputs: Pyruvate, NADH, ATP

7.3 Explain why glucose is broken down via a series of reactions rather than a single-step reaction. [3 marks]

Glucose is an energy-rich① molecule that contains stored chemical energy. If glucose was broken down (hydrolysed) in one step, the majority of this energy would be lost as metabolic heat (and very little will be used to make ATP molecules). By breaking down glucose in a series of reactions, energy can be more efficiently stored in ATP molecules.

Extension notes:

① Glucose is composed of **6 carbon atoms**. Breaking down glucose in a **single step** will result in energy being lost (**inefficient** harnessing of energy). Therefore, breaking down glucose in a series of reactions (such as one **carbon** at a time) will result in more **efficient** harnessing of energy!

7.4 Identify the inputs and outputs of the Krebs Cycle. [2 marks]

Inputs: Pyruvate, NAD^+, FAD^+, ADP and Pi
Outputs: CO_2, NADH, $FADH_2$, ATP

7.5.1 Identify the inputs and outputs of the Electron Transport Chain. [2 marks]

Inputs: O_2, NADH, $FADH_2$, ADP and Pi
Outputs: H_2O, NAD^+, FAD^+, ATP

7.5.2 Describe the main steps of the Electron Transport Chain. [3 marks]

① High-energy electrons are passed along a series of electron acceptors (cytochromes). ② Hydrogen ions are transferred across the cristae from NADH and $FADH_2$① to create a H^+ concentration gradient. ③ Hydrogen ions are accepted by oxygen to produce water as a final product. ④ Energy derived from the movement of these protons through ATP synthase is used to phosphorylate ADP to produce 32 ATP molecules.

Extension notes:

① Recall that the coenzymes NADH and FADH2 are loaded from NAD and FAD at the Krebs Cycle for use in the electron transport chain, where they are unloaded and returned to the Krebs Cycle for recycling.

8.1 Define the term 'anaerobic fermentation'. [1 mark]

Anaerobic fermentation involves the breakdown of glucose in the absence of oxygen in the cytosol.

8.2 Explain two reasons why anaerobic respiration is a less efficient process than aerobic respiration. [2 marks]

① A considerable amount of energy remains trapped in the products (ethanol in plants and lactic acid in animals.
② The regeneration of NAD^+ does not yield ATP as the electrons are not transported to the Electron Transport Chain.

8.3 Identify the cellular location of anaerobic fermentation in animals and yeasts. [2 marks]

Cytosol

8.4 Identify the inputs and outputs of anaerobic fermentation in animals. [2 marks]

Inputs: glucose
Outputs: Lactic acid + 2 ATP molecules

8.5 Identify the inputs and outputs of anaerobic fermentation in yeasts. [2 marks]

Inputs: glucose
Outputs: ethanol, carbon dioxide + 2 ATP molecules

8.6 Describe one application of anaerobic fermentation. [2 marks]

Anaerobic fermentation by yeast is used in food processing. For example, when producing bread carbon dioxide causes dough to rise and ethanol evaporates during baking.

9.1.1 Explain the results of the experiment at point A of the above graph. [3 marks] ①

At point A, the temperature is lower than the optimal temperature which results in a low rate of cellular respiration. This is because the kinetic energy acquired substrate and enzyme molecules (such as glucose and glycolytic enzymes) is too low for successful collisions to occur. Thereby, substrates in cellular respiration collide at the active site of enzymes less frequently (enzyme activity is lower). Thereby, resulting in a low rate of cell respiration.

Extension notes:

① Note that the explanation of results is largely the same for photosynthetic and cellular respiration experiments. Most **independent variables** in these experiments (such as temperature) will affect **enzyme structure** and hence, **function**.

9.1.2 Explain the results of the experiment at point B of the above graph. [3 marks]

At point B, the temperature has reached the optimal temperature for enzymes facilitating cellular respiration. Thereby, substrate molecules and enzymes (such as glucose and glycolytic enzymes ①) involved in cell respiration have acquired the optimal amount of kinetic energy required for fruitful collisions to occur - the enzymes are functioning at their most effective rate. Thereby, reaching the maximum rate of enzyme-substrate complex formation - which is why 'Point B' is the maximum rate of reaction for cellular respiration processes.

Extension notes:

① Specific **examples** of substrates and enzymes have been included by us to elevate our response.

9.1.3 Explain the results of the experiment at point C of the above graph. [3 marks]

At point C, the rate of cellular respiration is decreasing. This is because as the temperature of the reaction increases past the optimal, enzymes which control cellular respiration (such as glycolytic enzymes) denature. This is because hydrogen bonds in the tertiary structure of these enzymes break. Consequently, the shape of the active site changes, resulting in reduced enzyme activity (decreased enzyme-substrate complex formation). Thus, the rate of cell respiration decreases.

9.2 Explain the relationship between glucose availability and the rate of cellular respiration. [3 marks]

The relationship between glucose availability and the rate of cellular respiration is that as glucose availability increases, the rate of cellular respiration will also increase. Glucose is an input of glycolysis; therefore, increasing① the concentration of glucose available will increase the frequency of successful collisions between glucose and glycolytic enzymes - thereby, increasing the amount of pyruvate required for the Krebs Cycle. Thereby, leading to an increased rate of cellular respiration. If glucose was absent①, glycolysis will fail to occur and as a consequence, cellular respiration will not occur.

Extension notes:
① You should explain the effect of glucose being both **present and absent**!

9.3 Explain the relationship between oxygen availability and the rate of aerobic respiration. [3 marks]

The relationship between oxygen availability and the rate of aerobic respiration is that as oxygen availability increases, the rate of aerobic cell respiration will also increase. Oxygen is an input of the Electron Transport Chain - oxygen will act as the final electron acceptor and binds with protons to form water. The purpose of this is to maintain the hydrogen gradient by removing H^+ ions from the mitochondrial matrix (create a difference in proton concentration). Thereby, increasing the concentration of oxygen available ensures this concentration difference can be maintained. If oxygen was not available, electron flow along the Electron Transport Chain will stop and NADH will not be converted back to NAD^+. Consequently, the supply of NAD^+ for the Krebs Cycle is reduced and the rate of aerobic respiration decreases.

10.1 Outline one biotic and one abiotic stressor which plants can possess tolerance against if CRISPR-Cas9 technology is used to modify the plant genome. [2 marks]

Biotic factor: bacterial pathogens
Abiotic factor: drought.

10.2 Explain one advantage① of using CRISPR-Cas9 technology to produce virally-resistant plants. [2 marks]

One advantage of the production of virally-infected plants is that it limits the chance of viral infection② of plants. Thereby, there is reduced chance of plant malformation or growth stunting, which means the quality of the plants improves.

Extension notes:

① Another **advantage** is that this technology can reduce expenses for farmers associated with discarding of poor quality crops. This is an **economic advantage**.

② Interestingly, plant viruses can **disrupt** the **synthesis of gibberellin**: a plant hormone that regulates plant growth. Infection by a plant virus can lead to reduced expression of gibberellin, which can lead to plant dwarfing.

10.3 Based on the above information and using your own knowledge, outline two way in which CRISPR-Cas9 technology can be used to control plant viruses. [2 marks]

① Manipulate the host cell's susceptibility factors required for viral infection in order to improve plant immunity. ② Target the plant viruses genome and destroy it in order to inhibit viral replication.

11.1 Define the term 'biomass'. [1 mark]

Biomass refers to any organic material, living or dead, that is derived from living things.

11.2 Define the term 'biofuel'. [1 mark]

Biofuels are fuels that have been derived from living things such as plants and animals.

11.3 Explain whether biofuels are renewable or non-renewable resources. [2 marks]

Biofuels are renewable resources. When biofuels are made, there is a very short time frame between the gathering of the organic plant or animal material and the production of the fuel - since they are derived from biomass, they can be replenished by natural processes within a relatively short period of time.

11.4 Identify one type of biofuel. Explain how it is produced and its environmental benefits.[1] [3 marks]

One biofuel is biogas, which is a gas that is released in the breakdown (decomposition) of organic waste by anaerobic bacteria. In the absence of oxygen, this bacteria will decompose complex molecules into simple molecular compounds like methane (CH_4) and carbon dioxide (CO_2). Biogas (specifically methane) can be combusted to produce energy for specific purposes (such as heating homes). Biogas is "carbon neutral" which is environmentally advantageous because its combustion releases recently extracted CO_2 (which was absorbed by the living organisms during its growth) back into the atmosphere.

Extension notes:

[1] Note that, although biofuels have their advantages, they are **disadvantageous** in two primary ways:

1. They have a relatively low energy content.

2. The production of biofuels often requires habitat clearly (which can potentially strain the production of crops for food)

Solutions: Unit 4 AOS 1

1.1 Define the term 'pathogen'. [1 mark]

A pathogen is an agent, either cellular or non-cellular, that is capable of causing disease.

1.2 Explain how pathogens cause disease. [2 marks]

Pathogens must first breach the first line of defence of their host to cause disease. There are a variety of ways they can then harm the host, including the direct damage① of body cells or the release of toxins.

Extension notes:
① Damage to the body cells can result in disease due to disruption of homeostasis.

1.3 Outline two differences between plant and animal immune systems to prevent pathogenic infection.

One difference is that plants do not have mobile immune cells; whereas, humans do have mobile immune cells which are able to migrate to sites of infection to neutralise and engulf invading pathogens. Another difference is that humans have the ability to acquire and form immunological① memory to specific pathogens encountered; whereas, plants are unable to form immunological memory.

Extension notes:
① The absence of immune cells means that immunological memory cannot be developed in response to specific pathogens.

1.4.1 Describe two physical barriers that would protect the human body from an invading pathogen. [2 marks]

One physical barrier is intact skin①, which prevents the entry of pathogens into the internal environment. Another physical barrier is ear wax, which prevents the mobilisation of foreign substances by trapping them until they can be removed.

Extension notes:
① Ensure that when mentioning skin as part of the innate immune system in humans that you write **"intact skin"** as opposed to only "skin" - this is because broken skin does not protect the body from invading pathogens.

1.4.2 Describe two chemical barriers that would protect the human body from an invading pathogen. [2 marks]

One chemical barrier① is fatty acids on skin - fatty acids create an acid environment which makes it unfavourable for microorganisms to grow and reproduce. Another chemical barrier is lysozymes in tears - an enzyme that catalyses the lysis of bacterial cell walls.

Extension notes:
① Another chemical barrier is the production of toxic chemicals by **phytoalexins** that inhibit pathogenic growth.

1.4.3 Describe two microbiological barriers that would protect the human body from an invading pathogen. [2 marks]

One microbiological barrier is natural flora. This refers to harmless populations of bacteria that exist on the surface of intact skin; their presence inhibits the ability of pathogens to colonise these surfaces. Another microbiological barrier is the mucosal lining - the sticky mucus traps foreign substances (immobilises them) until they can be removed.

1.5.1 Describe two physical barriers that could be present in a plant that would protect itself from an invading pathogen. [2 marks]

One physical barrier is the presence of a thick waxy cuticle that is smooth and water-resistant; pathogens cannot adhere and are blown off by wind before they can germinate. Another physical barrier is a thick bark layer which prevents pathogens from penetrating into the plant (even if the pathogen germinates on the surface of the bark).

1.5.2 Describe two chemical barriers that could be present in a plant that would protect itself from an invading pathogen. [2 marks]

One chemical barrier is increased production of abscisic acid that allows the plant to shed infected leaves. Another chemical barrier is the production of galls that seal off infected areas to isolate the pathogen and prevent its spread.

1.5.3 Describe two microbiological barriers that could be present in a plant that would protect itself from an invading pathogen. [2 marks]

① Microbiota occupy space and use nutrients, competing with pathogens and thus reducing the accessibility of resources needed for the pathogen to proliferate.
② Microbiota release antimicrobial compounds that inhibit pathogen growth.

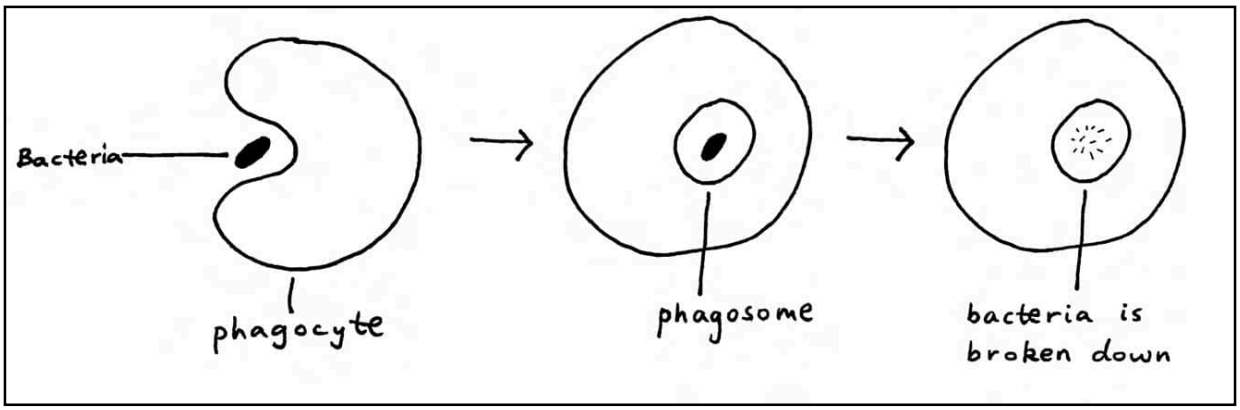
2.1 Identify two antigen presenting cells. [2 marks]

Two antigen presenting cells① are macrophages and dendritic cells.

Extension notes:

① Another antigen presenting cell is **B cells**. Note that antigen presenting cells will display fragments of a pathogen's antigens on their MHC 2 markers and present these to specific naive B cells - these cells have B cell receptors that will be specific to the antigenic fragments being presented.

2.2 Draw a labelled diagram② of the steps① involved in phagocytosis. [3 marks]



Extension notes:

① Note that exocytosis of the bacterial debris is not required to be drawn!

② For all diagram-related questions, make sure to keep the following tips in mind:

1. Make sure your diagrams are **big**!
2. Double check the question to see if you are required to **label** a specific feature in your diagram!
3. Draw your diagrams in **pencil** in case you make an error!

2.3.1 Identify whether the Influenza virus is a cellular or non-cellular pathogen. Explain your choice. [2 marks]

Viruses are non-cellular pathogens. The influenza virus is unable to replicate outside a living host cell and, hence, is considered non-cellular.

2.3.1 Describe how natural killer cells would protect Sam once the Influenza virus has gained entry to the internal environment. [2 marks]

Natural killer (NK) cells identify abnormal or missing MHC1 complexes on virally-infected cells①. NK cells release toxic molecules that trigger apoptosis of the infected cells in a process called degranulation.

Extension notes:
① NK cell action prevents **further replication of viruses** through by lysing virally-infecting cells. Thereby, containing its spread throughout the body.

2.3.2 Describe how complement proteins would protect Sam once the Influenza virus has gained entry to the internal environment. [2 marks]

Complement proteins assist phagocytes in recognising the presence of pathogens by attaching to the pathogen and acting as a marker①. This serves to attract more phagocytes to the site of invasion and hence, promote phagocytosis.

Extension notes:
① The human body has approximately 20 complement proteins! Anther mode of action is causing lysis of pathogens by **membrane attack complexes**.

2.3.3 Describe how neutrophils would protect Sam once the Influenza virus has gained entry to the internal environment. [2 marks]

Neutrophils are leukocytes (white blood cells) which travel① to areas of infection via the circulatory system. Neutrophils engulf pathogens and break them down using digestive enzymes.

Extension notes:
① Neutrophils can be found surrounding blood vessels. They have a **flexible cell membrane** which allows them to squeeze through the cells lining these blood vessels!

2.3.4 Describe how interferons would protect Sam once the Influenza virus has gained entry to the internal environment. [2 marks]

Interferons are antiviral chemicals that are released from virally-infected host cells after being colonised by a virus. Interferons spread to neighbouring cells, which take it up and produce antiviral enzymes; these enzymes degrade (break down) viral DNA, preventing the host nucleus from making more copies of the viral DNA (prevents viral replication).

2.3.5 Explain why Sam is more susceptible to being infected by other invading pathogens now that he has been diagnosed with the cold. [3 marks]

Sam has a compromised immune system that is currently treating an infection by another pathogen. While the immune cells of the body are focused on combatting one specific pathogen, other pathogens are able to evade the defence mechanisms (innate barriers) more easily. This results in in Sam becoming more susceptible to infection by other pathogens (increasing the chance of being subject to an opportunistic infection).

2.3.6 Explain the importance of a fever in reducing the spread of the Influenza virus. [3 marks]

A fever is an increase in body temperature above normal to reduce the growth of pathogens. This serves to slow the replication of pathogens by shifting the temperature away from their optimal functional range. This allows time for defence mechanisms to intervene (helps to mobilise defences) and also increases the metabolic activity of phagocytic cells, making them move quicker and react faster. Thereby, limiting the spread of the Influenza virus.

2.4.1 Explain the inflammatory response that will occur at a cellular level. [5 marks]

Platelets first reach the damaged tissue to form a blood clot and prevent further blood loss. Mast cells degranulate and release histamine and prostaglandins that attract phagocytes to the area of infection. Blood vessels nearby dilate and increase in permeability to allow for increased blood flow to the infection site to maximise the number of phagocytes present, contributing to the swollen and red appearance of Rachel's finger. Any dead cells, body fluid or damaged tissue may be released in the form of pus.

2.4.2 Explain the purpose of the inflammatory response. [3 marks]

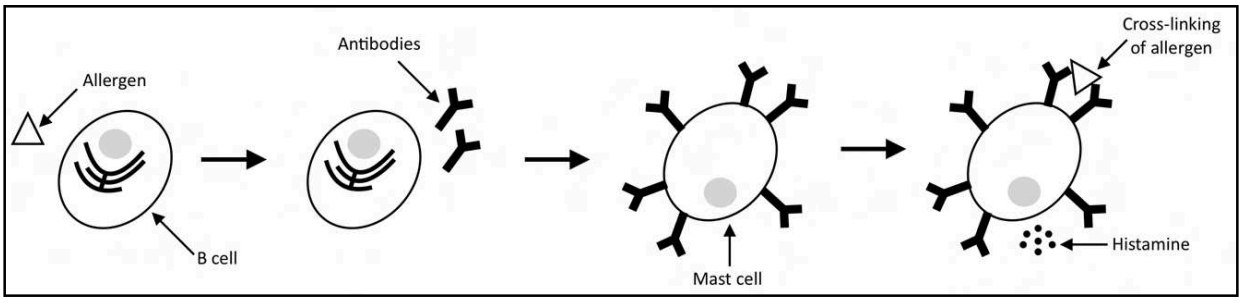
The inflammatory response helps the body halt the spread of infection and accomplishes this through sectioning off the damaged tissue using fibrinogen clots, away from the healthy, uninfected tissue. It also begins the healing process by recruiting greater numbers of monocytes and granulocytes (in particular neutrophils and macrophages) that migrate to the area of infection and break down the pathogen.

2.5 Explain, at a cellular level, the steps① leading to an allergic reaction in James. [4 marks]

① At first exposure to an allergen, antigen presenting cells present the allergens on their surface markers and travel to lymph nodes. ② A specific naive B-cell encounters the allergen and a specific T-helper cell secretes cytokines to stimulate the naive B-cell to undergo clonal expansion - this yields memory-B cells and plasma-B cells that produce antibodies specific to the allergen. ③ The IgE antibody binds to the surface of mast cells. ④ The allergen may cross-link② antibodies on the surface of mast cells, which stimulates the mast cell to degranulate and release histamine. ⑤ Histamine causes the allergic response by: increasing blood vessel permeability, promoting vasodilation, inflammation and swelling.

Extension notes:

① Below is a diagram of the steps of an allergic reaction:



② **Cross-linking** causes **gross exaggeration** of the immune system, leading to an even more exaggerated response that can commonly progress into anaphylactic shock.

2.6.1 Describe the role of mast cells in the migration of leukocytes. In your response, identify what chemical X is. [3 marks]

Mast cells release histamine, chemical X, which causes vasodilation of blood vessels. Consequently, the blood vessels (epithelial lining) becomes more permeable, allowing neutrophils to squeeze through into the bloodstream (where the site of invasion is).

2.6.2 Explain why the epithelial lining is impermeable when there are no invading pathogens. [2 marks]

Impermeability prevents toxic substances from entering the blood, as well as maintaining and containing the appropriate balance of substances within the blood.

2.6.3 Describe how the neutrophil will respond when in the presence of the invading pathogens. [2 marks]

As a phagocytic cell, the neutrophil will recognise the pathogen as foreign and then engulf it via phagocytosis and destroy it using digestive enzymes.

3.1 Define the term 'antigen'. [1 mark]

An antigen is a unique molecule or part of a molecule that initiates an immune response.

3.2 Explain why it is important for immune cells to be able to recognise the difference between self and non-self antigens. [3 marks]

In order for the immune system to provide effective defence against pathogens, it is necessary for immune cells to be able to recognise tissues that belong to the body so that these tissues are not recognised as non-self. Misidentification of self-cells as non-self by an individual's own immune system can lead to immune cells mounting an attack① towards self cells.

Extension notes:

① This is referred to as an **autoimmune disease**. An example of an autoimmune disease is **multiple sclerosis**, whereby immune cells of the body attack and break down neurons (specifically the myelin sheath, which is a protective coating surrounding neurons)! This means that communication between neutrons and muscles is impaired, which can lead to muscle weakness and fatigue.

3.3 Describe the role of mast cells in an allergic response. [2 marks]

IgE antibodies bind to the mast cell surface and, when an allergen cross-links these antibodies, the mast cell is stimulated to release histamine. Histamine causes the allergic response by: increasing blood vessel permeability, promoting vasodilation, inflammation and swelling.

3.4 Outline how sensitisation to an allergen first occurs. [2 marks]

Upon first introduction to the allergen, the body undergoes an immune response that creates IgE antibodies specific to the allergen. These antibodies then bind to the mast cells and are dormant until the allergen is reintroduced.

3.5 Identify the key difference between MHC-I and MHC-II. [1 mark]

MHC 1 markers are found on all nucleated① cells of the body, whereas MHC 2 markers are only found on antigen-presenting cells.

Extension notes:
① Note that red blood cells lack a nucleus and hence, will not contain MHC 1 markers.

3.6 Give an example① of one cellular and one non-cellular pathogen, and describe how the body responds differently to each. [3 marks]

One cellular pathogen is E. coli and one non-cellular pathogen is the Influenza virus. For cellular pathogens, the body initiates the humoral response which is facilitated by B-lymphocytes; whereas, non-cellular pathogens are primarily responded to by the cell-mediated response, facilitated by T-lymphocytes.

Extension notes:
① Other examples of **cellular pathogens** include S*taph aureus* and S*trep viridans*.
Other examples of **non-cellular pathogens** include *SARS-CoV-2* and *HIV.*

4.1 Define the term 'lymphatic system'. [1 mark]

The lymphatic system is a network of tubes throughout the body that drains lymph (a fluid) from tissues and empties it back into the bloodstream.

4.2 Describe two functions of the lymphatic system in humans. [2 marks]

One function of the lymphatic system is to act as a transport system for antigen presenting cells (such as dendritic cells). Another function of the lymphatic system is to drain lymph (containing pathogens and other foreign substances) from tissues and empty it back into the bloodstream.

4.3 Describe how lymph fluid moves in the lymphatic system. [2 marks]

Lymph travels around the body through small vessels that contain valves to allow unidirectional flow. As lymph does not have a pumping system (unlike the cardiovascular system) it instead relies on muscle movement to move lymph fluid around the body.

4.4 Name one body system that is closely connected to the lymphatic system. [1 mark]

Cardiovascular System

4.5 State one example of a primary and secondary lymph organ. [2 marks]

One example of a primary lymphoid organ is the thymus. One example of a secondary lymphoid organ is the spleen.

4.6 State the location of B and T lymphocyte formation and maturation. [2 marks]

B lymphocytes are formed and mature in the bone marrow; T lymphocytes are formed in the bone marrow and mature in the thymus.

4.7 Describe how the lymph system assists in antigen recognition. [3 marks]

Infections are localised to specific tissues; the immune system requires a way to alert the adaptive immune system to the presence of pathogens. Antigen presenting cells locate pathogens and, upon engulfing them, will display antigenic fragments on their MHC 2 markers. They then travel through the lymph system to the nearest lymph node① in order to activate a T-helper cell that can then begin clonal expansion (such that an immune response can be mounted against the pathogen).

Extension notes:
① Humans have **over 500** lymph nodes that are distributed throughout the body - these lymph nodes help to filter excess body tissue and are the site of specific immune cell production.

4.8 Describe one structural feature of the lymphatic system and explain how it assists in its function. [2 marks]①

The presence of valves within large lymphatic vessels prevents the backflow of lymph (enables unidirectional flow).

Extension notes:
① Cancers tend to **metastasise** (spread) from tissues to lymph nodes. Interestingly, cancerous lymph nodes are non-painful.

4.9 Explain why this has occurred. [2 marks]

The swelling① is due to the proliferation of lymphocytes in the lymph nodes that are specific to Janés infection, as well as the increase flow of lymph through the area underneath her chin as the body fights infection.

Extension notes:
① The swelling is due to the increased migration of immune cells to the lymph node as well as the build up of cellular and harmful waste.

4.10 Describe how the lymph system assists in antigen recognition of the *Leptopspira* bacteria. [3 marks]

The Leptopspira bacteria is phagocytosed in the tissue by a macrophage. Antigenic fragments from the Leptopspira bacteria are displayed on the macrophagés MHC 2 markers. The macrophage then travels via the lymph fluid of the lymph system to the nearest lymph node where the antigen is presented to a T-helper cell (in order to activate it).

5.1 Explain how clonal selection and expansion contribute to the adaptive immune response. [2 marks]

Clonal selection occurs when a lymphocyte specific to the antigen of the pathogen is identified and activated. Clonal expansion is the proliferation of this specific activated lymphocyte such that there are many copies of it available to attack the invading pathogen.

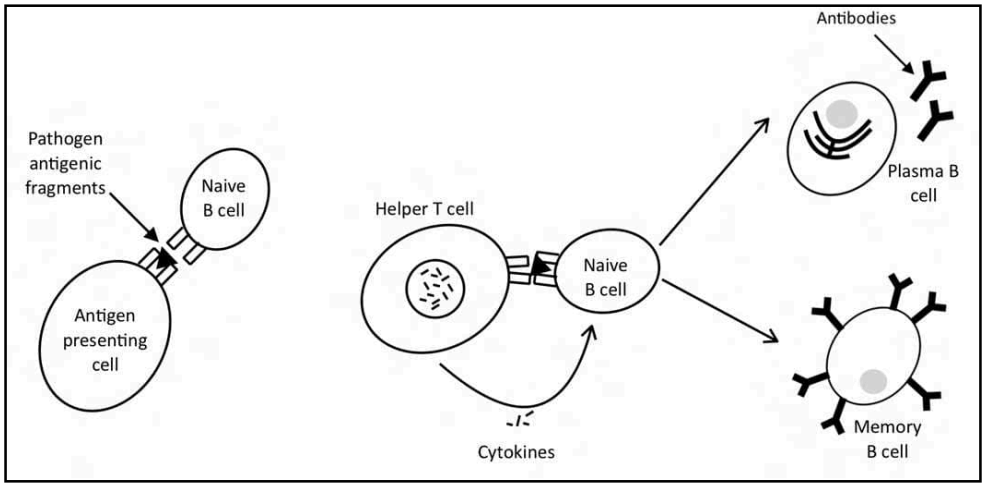
5.2.1 Name and describe one adaptive pathway that can remove cancer cells. [4 marks]

The humoral response:

① A specific naive B-cell encounters the specific cancer cell antigen. ② A specific helper T-cell produces cytokines to stimulate the naive B-cell to undergo clonal expansion - proliferation and differentiation occurs to give rise to plasma B-cells and memory B-cells. ③ Plasma B-cells produces specific antibodies with a complementary binding site to the specific cancer cell antigen - these specific antibodies will bind to the cancer cell antigen and neutralise it. ④ Memory ② B cells remain after the cancerous cells have been eliminated to provide immunological memory and yield a faster and stronger response if the specific cancer re-emerges.

Extension notes:

① The diagram below displays the **humoral response** to general pathogens:



② Memory B cells proliferate into **plasma B cells** that will produce **specific antibodies** - these antibodies will bind to the same antigen that once triggered the immune response.

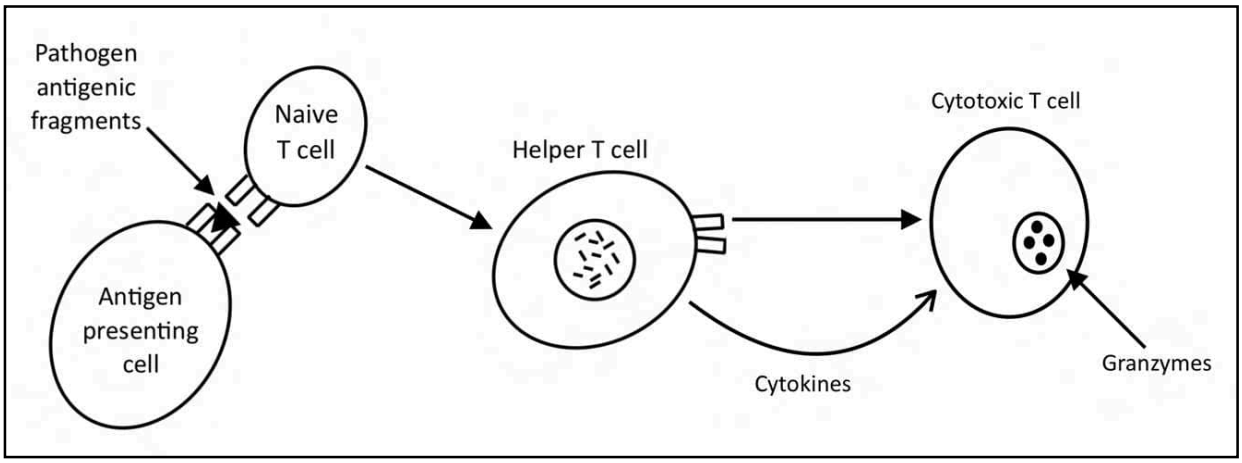
5.2.2 Name and describe another adaptive pathway that can remove cancer cells. [4 marks]

The cell-mediated response:①

① An antigen presenting cell engulfs and destroys a cancer cell and displays the cancer cell antigen on its MHC2 marker to a specific immature T-cell.
② The T-cell undergoes clonal expansion, proliferating and differentiating to produce specific helper T-cells.
③ The helper T-cells release cytokines to promote the proliferation and activation of other T-cells; such as cytotoxic T-cells (Tc), T-suppressor cells (Ts) and memory T-cells. ④ Cytotoxic T cells migrate to the site of infection and detect cancerous cells - they secrete toxins to lyse the cell or initiate apoptosis. to remove (destroy) the cancer cell.② ⑤ Memory T cells remain after the infection to provide immunological memory.

Extension notes:

① The diagram below displays the cell-mediated response to general pathogens:

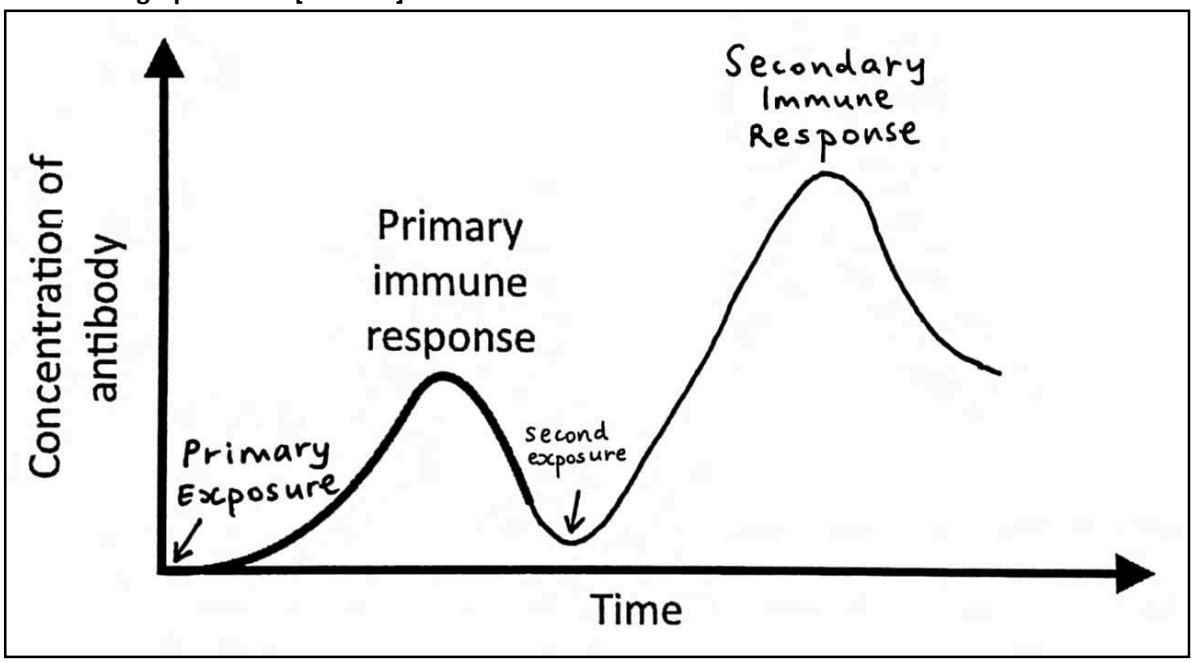


② Note that the same general pathway of cell-mediated immunity applies to cancer cells as well as virally-infected cells!

5.2.3 Explain how both pathways can prevent the same type of cancer cells from growing. [2 marks]

Immunological memory helps to prevent the same types of infection from occurring repeatedly. Once the adaptive immune system has created B-memory and T-memory cells, when it next detects the cancer cell antigens, it will launch a faster and more magnified response against these cancer cells, preventing their growth.

5.3 Graph the concentration of antibody that occurs during a secondary immune response and label key points on the graph below. [3 marks] ①



Extension notes:

① When completing the graph, you should ensure the following:

- that the shape of the primary and secondary immune response is almost identical
- the secondary immune response has a steeper gradient and larger response
- the concentration of antibody at the end of the secondary immune response never falls below the level at the beginning of the response.

6.1 Distinguish between natural and artificial immunity. [2 marks]

Natural immunity occurs through non-deliberate contact with a disease-causing agent, whereas artificial immunity refers to immunity acquired through deliberate actions of exposure.

6.2 Distinguish between active immunity and passive immunity. [2 marks]

Active immunity is where the body produces its own antibodies against an antigen, such as through being exposed to a pathogen. Whereas, passive immunity involves the acquiring of specific antibodies from an external source, such as a vaccine.

6.3 Complete the following table, classifying examples of active and passive immunity. [4 marks]

Method of acquiring immunity	Active or Passive and Natural or Artificial?
Vaccination	Artificial Active
Catching a cold	Natural Active
Injection of antibodies	Artificial Passive
Consuming breast milk	Natural Passive

6.4 Describe one advantage and one disadvantage of active immunity. [2 marks]

One advantage of active immunity is that immunological memory to specific pathogens can be formed (which is important if future exposure to the same pathogen occurs). One disadvantage is that the development of active immunity is a slow process.

6.5 Describe one advantage and one disadvantage of passive immunity. [2 marks]

One advantage of passive immunity is that individuals with compromised immune systems who may not be able to create antibodies against a pathogen can still receive the antibodies passively so that the pathogen is eliminated from the body. One disadvantage of passive immunity is that immunological memory is not generated - hence, if exposed to the pathogen again, they will not have memory cells that will quickly eliminate the pathogen and prevent disease.

7.1 Explain how global travel increases the risk of infectious diseases emerging in a population. [2 marks]

Global travel increases the chance of the gene pool interacting, particularly between populations from different environments where immunity to specific pathogens may not be present. Consequently, non-immune individuals may travel to infected areas and contract a specific disease or infected travellers may introduce a new pathogen to a previously unexposed population (person to person transmission). Thereby, increasing the risk of infectious diseases emerging by improving the ease at which a disease can spread.

①②

7.2 Identify two factors that increase the likelihood of a pathogen spreading in a population. [2 marks]

① Population has no previous immunity to the pathogen.
② The pathogen is less virulent and hence damaging to the host - this allows infected people to come into contact with other potential hosts.

Extension notes:

① Alternative factors that increase the likelihood of the spread of pathogens include: long-distance travel and increased population density.

② This question can also be answered with reference to:

- behavioural factors: level of education, personal hygiene
- environmental factors: swampy ground, temperature, sanitation and sewage treatment

7.3 Explain why people previously unexposed to particular microbes are more susceptible to becoming ill after exposure. [2 marks]

Individuals who have not been exposed to certain microbes do not have memory cells for those microbes. Upon exposure, their adaptive immune system will take longer to be activated compared to those who have been previously exposed, increasing their susceptibility to illness.

7.4 Outline two ways in which Aboriginal and Torres Strait Islander people's health may have been negatively impacted by colonisation beyond the introduction of new pathogens into the environment. [2 marks]

① The financial gap created by colonisation decreases the accessibility of healthcare for Aboriginal and Torres Strait Islander people. ② Intergenerational trauma has increased the prevalence of mental health issues and disparities. ①

Extension notes:

① Another point is that the **introduction of new food groups** and diets may have increased the risk of development of chronic diseases.

7.5 Explain two reasons for why there are still cases in Australia, 10 years after endemic measles was eradicated. [2 marks]

① Global travel allows for measle cases to re-enter Australia from other countries where measles is prevalent (as measles has not been globally eradicated). ② Individuals may not have natural immunity against measles if they have not been vaccinated (this allows for easy transfer from infected to non-infected individuals).

7.6.1 Would the spread of this disease be more correctly referred to as an epidemic or a pandemic? Provide a reason to support your answer. [2 marks]

A pandemic; this is because the disease is distributed worldwide and affects many countries.

7.6.2 Explain why this approach was unsuccessful in isolating the SARS-CoV virus. [2 marks]

The SARS-CoV virus is a non-cellular pathogen and thus cannot reproduce outide a living host organism. Agar in a petri dish is not living and hence does not have the required conditions to isolate a virus.

7.7 Identify two factors which may have contributed to the rapid spread of disease. [2 marks]

① Urban expansion continues to occur, displacing wild animals and increasing the likelihood of people coming into contact with these animals; thus, increasing the chance of zoonotic diseases transmitting.
② An increased number of people travelling overseas on a more frequent basis increases the transmission of diseases between countries.

7.8 Explain why previous exposure to a pathogen minimises the effect of the pathogen. [3 marks]

The initial response to a pathogen will create memory T cells and memory B cells, which are stored in the lymph nodes for future exposure to the same specific pathogen (antigen). The second response is faster, stronger and lasts longer. This is because there are specific memory cells that will proliferate and differentiate quickly into plasma B cells, helper T cells and cytotoxic T cells when exposed to the same specific antigen.

7.9 Explain why a pandemic[1] is more likely to occur when a new pathogen emerges. [3 marks]

If the population has never been exposed to the pathogen, they are much less likely to already have immune defences against the pathogen, meaning individuals are more susceptible to infection. The modes of transmission and virulence of the pathogen would need to be investigated and before these were determined, it would be much easier for the pathogen to spread as there is less public health knowledge. The high frequency of global travel would also make it easy for the pathogen to spread internationally rapidly before there is global awareness of the danger of the disease.

Extension notes:

[1] When a new pathogen emerges, there is no pre-existing immunological memory (no immediate immune defences) against this pathogen. This means that every individual is more likely to be susceptible to infection as they have do not have an immunological memory against this new pathogen. With a greater number of people being infected, the pathogen can spread more easily and infect enough people across multiple continents to be classified as a pandemic.

8.1.1 Explain how culturing of pathogens① on agar plates can be used to identify specific pathogens. [2 marks]

Different pathogens are able to proliferate and multiply under different conditions. Therefore, a pathogen can be cultured② on different types of agar plates (such as blood agar plates and nutrient agar plates) to observe the growth (or lack of growth) of the pathogen and determine the identity of the pathogen.

Extension notes:

① Pathogens can be attained by **mouth swabs**!

② Note that this process can be quite lengthy and cheap before results are obtained compared to PCR which is more expensive, but faster!

8.1.2 Briefly explain the steps of polymerase chain reaction and how this technique can be use to identify pathogens. [3 marks]

Polymerase chain reaction① (PCR) allows for fast replication of a DNA sequence, regardless of size. A sample of DNA from a pathogen is denatured by heating it to 95°C to create two single-stranded DNA molecules. The sample is then cooled to 55°C to allow the primers to anneal at their complementary site on the template DNA strand. At 72°C, Taq Polymerase catalyses the formation of a new DNA strand using a template strand. The cycle is then repeated many times, generating multiple copies of the pathogen DNA. Testing and sequencing of the amplified DNA can be done in order to identify the pathogen.

Extension notes:

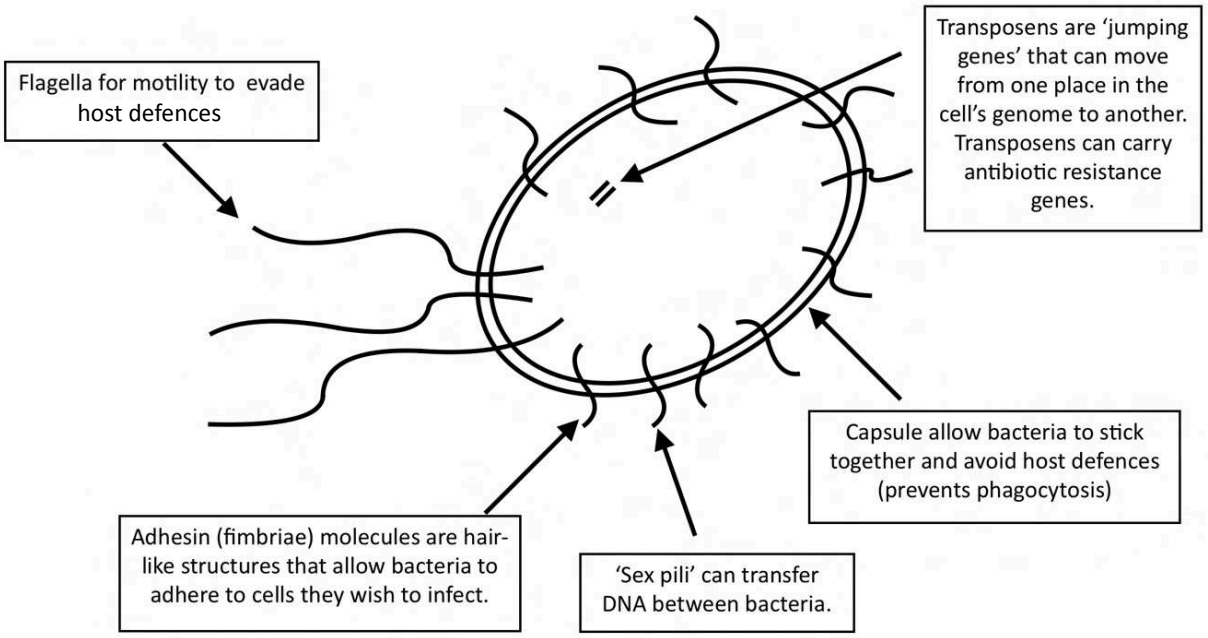
① See question 10.1.2 from AOS1 for an explanation of the steps of the polymerase chain reaction.

8.2 Explain two adaptations of bacteria that enable it to evade host defences. [2 marks] ①

① Adhesin molecules are appendages on bacterial cells that enable their attachment onto host cells. ② Capsules that surround bacteria prevent their phagocytosis when they enter the host.

Extension notes:

① The diagram below displays the adaptations that bacteria possess to enable host defence evasion:



8.3 How does the mode of transmission of a pathogen influence the spread of disease? [2 marks]

The spread of a disease can occur through 4 main methods: direct contact, droplets, airborne or via vectors. The mode of transmission of a pathogen can impact the speed and reach of the pathogen. For example, pathogens that spread via direct contact are limited to the immediate surroundings of the infected person; whereas pathogens that are aireborne can spread much further. ①

Extension notes:

① This increases the chance of a disease spreading from person to person.

8.4.1 Outline two public health measures ① that could control the spread of COVID-19 and explain how they would be effective. [2 marks]

① Education around hand hygiene techniques prevent the spread of COVID-19 through direct contact and infected surfaces.
② Wearing face masks when with other people prevents the airborne transmission of the virus from exhaled particles.

Extension notes:

① **QR codes** for **contact tracing** is also a suitable strategy that can be outlined here - the location of an infected person at specific points in time can be mapped out to determine infection sites and individuals near the site of infection can accordingly quarantine.

8.4.2 Describe another effective method for preventing the transmission of diseases that spread through infected body fluids. [2 marks]

Practising safe sex : using condoms for duration of every sex practice in order to avoid contact with semen and vaginal fluids that could be infected.

8.4.3 Explain why wearing protective gowns and masks is not completely effective when preventing the spread of COVID-19. [2 marks]

COVID-19 is spread through infected water droplets; a patient who is infected with COVID-19 commonly has a dry cough as a symptom. Coughing allows infected water droplets to travel a greater distance and land on unprotected surfaces (once an object is touched, the virus then may spread to uninfected indiriduals).

8.5.1 Carrying out research. [2 marks]

Researching emerging diseases can assist in developing strategies to limit their impact on population health. For example, targeting the mode of transmission can help inform educational programs and prevent the spread of the disease.

8.5.2 Improving international relationships. [2 marks]

Improving international relationships will increase the number of government and non-government bodies that are aware of new emerging pathogens. Furthermore, co-operation should improve the speed of a global response towards an emerging disease.

8.5.3 Developing training programs. [2 marks]

Training programs can provide relevant and up-to-date information for the general public on how to best keep themselves and other individuals safe from emerging pathogens, allowing the spread of disease to be limited or contained.

9.1 Define the term 'vaccine'. [1 marks]

A vaccine is a solution that contains an antigenic substance specific to the pathogen or pathogenic agent an individual is being vaccinated against.

9.2 Describe the purpose of vaccines. [2 marks]①

The purpose of vaccines is to produce immunity to a disease by stimulating the production of antibodies against specific pathogens or pathogenic agents. Thereby, if an individual is exposed to the same specific antigen again, their immune system will mount a secondary response that is faster and more effective (immunological memory). Thus, generating long-term immunity.

Extension notes:

① Fun facts:

- There are vaccines available that can prevent the onset of **certain types of cancers**! For example, there is the **Gardasil vaccine** which prevents cervical cancer in women (generates immunity against the **HPV vaccine**).
- The **hepatitis B vaccine** is given to children **immediately after birth** (**within 24 hours** for the greatest benefit)!

9.3 Explain how vaccinations generate immunological memory to specific pathogens. [4 marks]

① An attenuated② form of the pathogen and its antigen (or part of it) are introduced via the vaccine. ② A specific naive B cell encounters the specific antigen. ③ A specific helper T cell produces cytokines to stimulate the naive B cell to undergo clonal expansion - proliferation and differentiation gives rise to plasma B cells and memory B cells. ④ Plasma B cells produce specific antibodies with a complementary binding site to the specific antigen - these specific antibodies bind to the pathogen's antigens and neutralise the pathogen. ⑤ Memory B cells remain after infection to provide immunological memory and yield a stronger, faster and longer antibody-mediated response if re-exposure to the same pathogen occurs.

Extension notes:

① Note that the response of a patient to the antigen in the vaccine is the humoral immune response! For a refresher on this topic, please visit question 5.3.1 in this AOS!

② The reason why the pathogen is attenuated is to prevent disease from occurring in the vaccinated patient.

9.4 Identify two reasons why a mother may choose not to vaccinate her child. [2 marks]

① The short-term discomfort of being injected with a needle (syringe). ② Vaccinations may be against one's religious beliefs.

9.5 Explain why this may be the case. [2 marks]

Memory cells from the initial exposure may die off or decrease in number. A booster vaccination serves to increase the number of memory cells against a specific pathogen and thus increase the magnitude and speed of the response upon re-exposure.

9.6 Explain two health-related impacts of implementing vaccination programs. [3 marks]

① Reduction in morbidity and mortality of infectious diseases: more of the population will be encouraged to obtain vaccinations, increasing the proportion that is immune to a specific disease; thereby, reducing the morbidities and mortalities caused by the disease.

② The development of herd immunity: vaccination programs encourage more people to obtain vaccinations due to the ease of access. Once a significant portion of the population is immune, those who are unable to be vaccinated due to immunocompromised state are indirectly protected from contracting the disease.

Extension notes:

① Another **advantage** is that it reduces bacterials and viruses developing antibiotic and antiviral resistance respectively. This is because there is **reduced overprescription** of these **medications**!

② Note that vaccination programs targets **communicable** (infectious) diseases rather than non-communicable (non-infectious diseases) such as obesity and diabetes.

9.7 Define the term 'herd immunity'. [1 mark]

Herd immunity is a form of immunity that occurs when a significant portion of a population has been vaccinated against a specific pathogen and, consequently, provides a measure of protection for individuals who have not developed immunity against the same specific pathogen.

9.8 Explain how vaccines can be used to achieve herd immunity. [3 marks]

Vaccines enable a significant enough percentage of the population to become immune to a disease such that transmission through the population becomes difficult, which is much less likely to be achieved if natural exposure to the pathogen is relied on to develop immunity in the population. Thereby, individuals that are unable to be vaccinated safely are protected from contracting the disease and facing more severe consequences of infection.

9.9 Describe two features of an effective vaccination program.① [2 marks]

One feature of an effective vaccination program is that the specific vaccine is accessible to everyone (all communities). This increases the chance of herd immunity being achieved because there will be a greater uptake of the vaccine in the community. Another feature of an effective vaccination program is that minimal repeat vaccinations are required to achieve immunity (immunological memory). This helps to prevent people from dropping out of vaccination programs before they have finished by requiring minimal effort.

Extension notes:

① Interestingly, **polyvalent vaccines** combine multiple antigens from different pathogens into a single injection! This **reduces the costs** of **extra healthcare visits** and reduces the costs of **stocking and administering separate vaccines**.

9.10 Explain how opposition to vaccination programs poses a challenge to the development of herd immunity in a population. [3 marks]

For herd immunity to be effective, at least 90% of the population needs to be immune to a specific pathogen or pathogenic agent. Opposition to vaccinations pose a challenge to herd immunity development by allowing preventable diseases to persist in or reappear in communities. This is because a decline in vaccination rates mean that a disease cannot be effectively contained, which increases the chance of the pathogen spreading from infected to healthy individuals. (increasing the incidence of specific diseases). Thereby, herd immunity cannot be achieved because less than 90% of a population will be immune to immune to the specific pathogen.

10.1 Define the term 'monoclonal antibody'. [1 mark]

Monoclonal antibodies are antibodies that have been produced by cells that are clones of a single parent B cell.

10.2 Describe one advantage and one challenge with the use of monoclonal antibody treatment. [2 marks]

One advantage is that monoclonal antibodies can be indefinitely produced from a single hybridoma. One challenge is that the efficacy of monoclonal antibodies has not been sufficiently explored in humans thus far.

10.3 Assuming that antibodies created are derived from a mouse, explain how monoclonal antibodies can be developed for the treatment of cancer. [4 marks][1]

① Mouse is injected with cancer cell antigens from a patient with cancer. ② Mice's B-lymphocytes recognise the specific antigen as foreign and are activated to undergo clonal expansion, proliferating and differentiating into plasma B cells that produce specific antibodies to the cancer cell antigen. ③ The plasma B cells specific for the cancer cell antigen are isolated from the mouse spleen. ④ The plasma B cell is fused with a myeloma to form a hybridoma. ⑤ The hybridoma is grown and then screened for the production of specific antibodies - the hybridoma that produces the optimum level of antibodies is selected and cloned. ⑥ The monoclonal antibodies are isolated and purified (using centrifugation). ⑦ These monoclonal antibodies[2] are then administered to the patient with cancer.

Extension notes:

① Below is a diagram displaying the process of creating monoclonal antibodies from a mouse:

② This treatment exploits the **specificity of antibodies**.

10.4 Describe two ethical issues associated with using animals to create monoclonal antibodies.

① The risks of the process of creating monoclonal antibodies are often not known before testing on animals (therefore, the animals may be harmed).
② The long-term implications of monoclonal antibody immunotherapy may include the breeding of animals solely for the purpose of antibody synthesis.

10.5.1 Define the term 'autoimmune disease'. [1 mark]

An autoimmune disease is a disease in which the immune system misidentifies self cells as non-self (foreign) and mounts an attack towards these self cells.

10.5.2 Explain why autoimmune diseases occur, with reference to self and non-self cells. [2 marks]

Autoimmune diseases occur due to a failure of self-tolerance. This means that self cells of the body are misidentified as non-self by an individual's own immune system and immune cells mount an attack towards these misidentified self cells.

10.5.3 Explain why it is difficult to diagnose and treat autoimmune diseases. [3 marks]

It is difficult to diagnose autoimmune diseases because a number of conditions may cause similar symptoms. Furthermore, it is difficult to treat autoimmune diseases because they occur due to misidentification of self-cells as non-self. Therefore, any treatment developed may affect an individual's healthy cells rather than the compromised (affected) tissues.

10.6 Explain why immunotherapy is considered a type of biological treatment. [2 marks]

Immunotherapy involves stimulating parts of the immune system to allow it to recognise and attack specific antigens better. By utilising the body's own immune cells (or another product of a living organism, immunotherapy is hence classified as a biological treatment.

10.7.1 Describe how monoclonal antibodies are administered to patients. [1 mark]

Monoclonal antibodies are injected into patients using a syringe as a delivery system.

10.7.2 How will the cellular effects of the monoclonal antibody change as a result? [2 marks]

As the monoclonal antibodies are primed to treat adenocarcinoma, it only has specific antigen-binding sites that will bind to antigens found on lung cancer cells. However, the patient does not have lung cancer; their leukemia will not be treated as a result (the patient will not feel the positive effects expected from monoclonal antibody therapy).

10.8.1 Explain why this may help to minimise the side effects of chemotherapy drug. [1 marks]

The monoclonal antibody is specific to the antigen on cancer cells; thefore, it will only act on cancer cells and not other cells in the body, minimising adverse effects on other cells.

10.8.2 Determine what actions the now naked monoclonal antibody may perform. [1 mark]

The monoclonal antibody will flag the cancer cell for phagocytosis (opsonisation).

10.8.3 Explain why this is the case. [2 marks]

Cancer cells are mutated versions of original, once-healthy cells. Some of the antigens may not have mutated through cancer progression, meaning that the cancer cells will have the same markers (antigens) as self cells. Thus, the cancer cells will not be recognised as foreign (non-self) due to self-tolerance.

10.8.4 Explain why this tag may be useful in the detection and treatment of cancer. [2 marks]

The monoclonal antibody will bind to a specific and complementary cancer cell antigen – where the cancer cells are located can be determined by indentifying the location of the radioactive tag. Thus, a tumour can be located for removal by surgery or targeting by drugs.

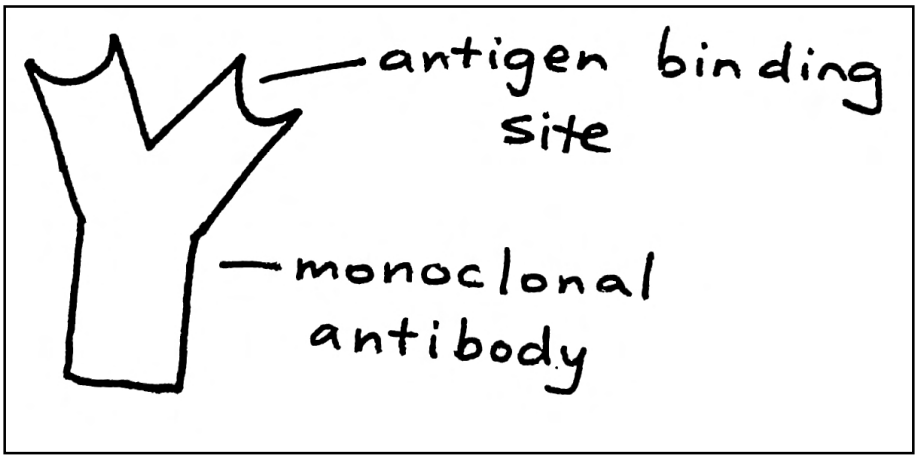
10.9.1 Explain why IL-6 inhibitors may relieve the pain and inflammation associated with rheumatoid arthritis. [2 marks]

IL-6 inhibitors prevent cytokine IL-6 from promoting inflammation, preventing unnecessary information and reducing joint pain.

10.9.2 Explain why this may be the case. [1 mark]

IL-6 is associated with inflammation and fever by extension. The IL-6 inhibitors minimise the action of IL-6, reducing inflammation, which is beneficial in the recovery process of infection.

10.9.3 Draw a labelled diagram of a monoclonal antibody that could be used to minimise the action of IL-1. [1 marks]



Solutions: Unit 4 AOS 2

1.1.1 Define the term 'gene pool'. [1 mark]

The gene pool refers to the sum total of all the genes and their alleles in a population.

1.1.2 Define the term 'genetic drift'. [1 mark]

Genetic drift refers to random changes in the allele frequency of a gene pool over time, causing the phenotype of the species to develop in a particular direction.

1.1.3 Distinguish between the terms 'gene flow' and 'genetic drift'. [2 marks]

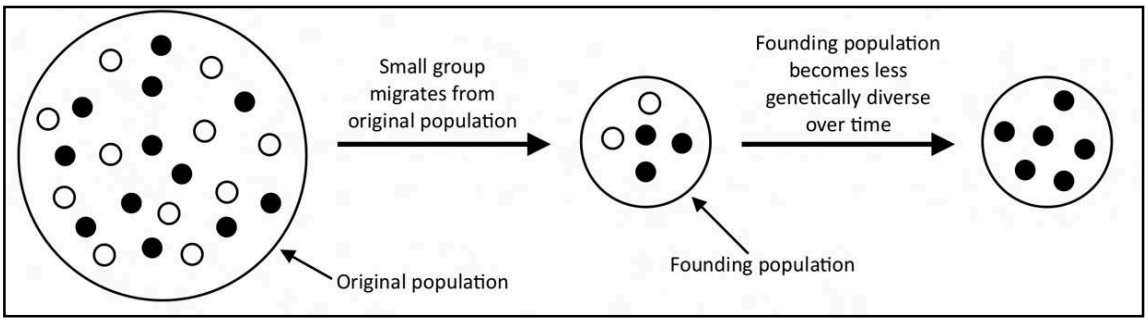
Gene flow refers to the movement of alleles in and out of the gene pool; whereas, genetic drift refers to a random change caused by a random chance event that can lead to changes in the allele frequency.

1.2.1 Explain how the 'founder effect'[1] can reduce genetic variation in a population. [3 marks]

The founder effect can reduce genetic variation because the genetic diversity and allele frequency of the founding population (a small group of a population that leaves a larger population and colonises another area) is comparatively lower to the parent population. Consequently, the variation in the descendents of the founding population will be similarly limited.

Extension notes:

[1] Below is a diagram explaining the founder effect:



1.2.2 Explain why the frequency of a specific mutation would be higher in the founding population compared to a parent population. [2 marks]

A smaller number of individual organisms in the founding population results in a smaller and less diverse gene pool. Organisms with the mutation reproducing will pass on the mutation in their alleles, and this will contribute to a greater proportion of the gene pool.

1.3.1 Explain how the 'bottleneck effect' can reduce genetic variation in a population. [3 marks]

The bottleneck effect is when a population's size is drastically reduced due to a specific event (such as a natural disaster) and the survivors are unrepresentative of the original population. The bottleneck effect can reduce genetic variation because the allele frequencies in the surviving population are not reflective of the gene pool of the original population (which makes them more vulnerable to the effects of genetic drift). Consequently, the variation in the descendents of the surviving population will be limited.

1.4 Explain why genetic drift has a greater impact on small populations compared to larger ones. [2

Smaller populations have a limited genetic diversity compared to larger populations and in small populations, the contribution of specific individuals to the gene pool is comparatively large. Thus, genetic drift has a greater impact on smaller populations because their ability to adapt to changing conditions① reduces.

Extension notes:

① These changing conditions are called **selective pressures**.

1.5 Explain how the larger horns in the males of this species could have evolved despite the difficulties stated above. [3 marks]

The larger horns perhaps evolved by sexual selection①. This could have been because the female sable antelopes preferred to mate with males that had larger horns - consequently, males with larger horns are more likely to produce fertile offspring compared to males with smaller horns. Thus, the frequency of alleles for large horns will increase over time despite the difficulties in being able to move and catch prey.

Extension notes:

① This question is **quite tricky!** One would think that those that find it difficult to move, catch prey and eat would be less likely to pass on their alleles to the next generation. However, you must remember that **sexual selection** (irrespective of the favourability of a trait) plays a role in determining the frequency of a specific allele.

1.6.1 Identify the phenomenon that best describes the movement of *P. infestans* from Mexico to Europe. [1 mark]

Founder effect

1.6.2 Compare① the likely genetic diversity of the *P. infestans* populations in Mexico and Europe, and explain why this would be the case. [3 marks]

The European population will be less genetically diverse than the Mexican population. All the organisms in the European population will only have alleles from the gene pool brought to Europe, which was the genome of just a single microorganism. In comparison, the Mexican population will have a significantly larger gene pool due to the presence of a greater number of organisms with different alleles.

Extension notes:

① Note that if you are asked to **compare** the genetic diversity of two populations, you should first state which population is **less or more genetically diverse** before explaining the **reasons** for this!

1.6.3 Identify and describe two consequences of lowered genetic diversity. [2 marks]

① If a selection pressure targets a certain characteristic that is shared by organisms with specific gene sequences, more organisms will be negatively impacted in a population with lower genetic diversity.
② If the environment changes, it is less likely that there will be the genetic variation needed to adapt to the change, increasing the likelihood of extinction.

1.6.4 Outline one method to increase the genetic diversity of a population. [2 marks]

One method is human intervention to introduce genetically variant organisms of the same species into the population and encourage breeding between the old and new populations to increase gene flow. Thereby, increasing genetic diversity.

1.7.1 Explain the bottleneck effect and its impact on the genetic diversity of the population of black robins. [4 marks]

The bottleneck effect occurs when a chance event, like a natural disaster① or influx in predation, dramatically reduces the size of a population, lowering the genetic diversity of the population. Smaller populations will be more drastically impacted because there is an increased likelihood of entire allele groups being wiped out from the population, decreasing the gene pool. In the black robin population, genetic diversity would be minimised to just the combination of the mature males remaining interbreeding with the only mature female.

Extension notes:
① The 'natural disaster' here is the introduction of a new species that perhaps competes with the black robins for resources or preys on the black robins as a food source.

1.7.2 Describe one benefit and one risk of human intervention to encourage breeding and population growth after a bottleneck like that of the New Zealand black robin. [2 marks]

Benefit: breeding the black robins with those from a different population would encourage gene flow and increase genetic diversity.

Risk: any harmful mutations in the remaining population will be passed onto offspring, potentially causing needless suffering to a growing population.

1.8.1 The population must be small. [1 mark]

False

1.8.2 There must be no mutations occurring at all. [1 mark]

False

1.8.3 Natural selection must not be operating on the population. [1 mark]

True

1.8.4 There can be immigration but not emigration. [1 mark]

False

1.9.1 Define the term 'mutation' and outline one cause of mutations. [2 marks]

A mutation is a change in the sequences of nucleotides in DNA that contributes to genetic variation within a population by giving rise to new alleles. One cause of mutuations is exposure to mutagenic agents (such as radiation).

1.9.2 Explain how point mutations are sources of new alleles. [2 marks]

Point mutations involve a single DNA base change and can potentially code for a different amino acid, compared to the original sequence. The gene may still fulfil the same function; however, the new amino acid sequence results in the formation of a new allele①.

Extension notes:

① This new allele can either be **advantageous** (favourable) or **disadvantageous** (unfavourable) for the particular organism's **survivability and reproducibility**.

1.10.1 Using a codon table, write down the amino acid sequence coded for by this DNA sequence. [1 mark]

gly-ser-val

1.10.2 Name the type of mutation and outline the potential effect on the resultant protein produced. [2 marks]

A silent mutation - there will be no effect on the protein produced.

1.10.3 Name the type of mutation and describe the potential effect on the resultant protein produced. [3 marks]

The type of mutation is a nonsense mutation. The codon coding for serine is replaced with a stop codon (which codes for a release factor). The resulting polypeptide chain would be shorter than normal, resulting in a protein that is likely to be non-functional.

1.11.1 Using a codon table, write down the amino acid sequence coded for by this DNA sequence. [1 mark]

met-gly-ser-val

1.11.2 What type of mutation has occurred in this example? [1 mark]

A missense mutation.

1.11.3 Explain the effect that this mutation will have on the structure and function of the polypeptide. [3 mark]

The change to the codon has caused the production of proline (pro) instead of serine (ser). As a result, the primary structure① of the polypeptide has been slightly altered, which will cause a slight alteration to the tertiary structure of the protein. As the function of a protein is largely determined by the three-dimensional tertiary structure, an alteration will mean the protein will be less likely to carry out its function.

Extension notes:
① Remember that the **primary structure** refers to the **linear sequence** of **amino acids** that make up a polypeptide chain. The primary structure is largely responsible for the shape of the tertiary structure.

1.11.4 Assuming that the protein produced as a result of the mutation is functional, describe the effect that the mutation will have on the genetic diversity of the population. [2 marks]

If the protein is functional then it means that a new allele has been produced which may be selected for or retained in the population. The presence of an additional allele will increase the genetic diversity of the population because there is now an additional allele in the gene pool.

1.12 Explain how evolution by natural selection ① brings about phenotypic differences between species. [3 marks]

Different species are exposed to different selection pressures depending on their environment. As a result, certain phenotypes in these populations will have a selective advantage and be more likely to survive and pass on their favourable alleles to the next generation. Over time, the advantaged phenotypes for each species will become frequent in each population and these differences are likely to accumulate for two species that are subjected to different environments and have differing behaviours.

Extension notes:

① For all natural selection questions you should use the following template:

1. Phenotypic variation in relation to [insert phenotype] exists within a population of [insert species].
2. [Insert environmental change or selection pressure] acts as a selection pressure on [insert species].
3. Organisms possessing [insert phenotype] trait are at a selective advantage - these organisms have a greater chance of surviving [insert selection pressure] and passing on their favourable alleles to the next generation (offspring).
4. Over time, the allele frequency of [insert phenotype] increases such that more individuals possess the advantaged trait.

2.1 Explain the consequences of the above statement. [2 marks] ①

When a population number exceeds the carrying capacity of an environment, there is a lack of resources to be used in the population. Without enough resources to sustain a population, the population numbers will decrease as life cannot be sustained.

Extension notes:

① The **carrying capacity** refers to the **number of organisms** for a particular species that the **environment** can **sustain** (‘carry').

2.2 Complete the table below, identifying whether or not the below factors increase or decrease genetic variation. [4 marks]

Factor	Increase or decrease in genetic variation?
Artifical Selection	Decrease
Migration	Increase
Genetic drift	Decrease
Mutation	Increase

2.3 Explain why offspring are not genetically identical to their parents. [2 marks]

Offspring of sexual reproduction are produced from haploid gametes① of their parents, thus retaining half the allele set from each of their parents. These alleles are then crossed over and independently assorted to result in new gene sequences in the chromosomes of the offspring as well as potentially being subjected to mutation.

Extension notes:

① Haploid gametes refer to sex cells that contain half the number of usual chromosomes, that combine with another haploid gamete to form the normal number of chromosomes expected in a body cell.

2.4 Explain how inbreeding lowers the fitness levels of populations. [2 marks]

Inbreeding① decreases genetic diversity due to the limited gene pool available for the new offspring. By limiting the gene pool, populations have less traits to naturally select against, creating weaker odds for their survival. This, in turn, lowers the level of fitness in these inbred populations.

Extension notes:

① Inbreeding not only limits the number of useful traits to naturally select against, but can also amplify harmful and unwanted traits in the population. Inbreeding was common for certain royal families and a prime example of a harmful trait is the 'hasburg jaw', which was characterised by a bottom jaw that jutted out, and prevented the user from chewing properly.

2.5.1 Describe how the bottleneck effect has impacted the variation of the northern elephant seals. [3 marks]

A random chance event (hunting) occurs that caused pockets of the original population of northern elephant seals to die. Consequently, the allele frequency of the surviving population does not reflect that of the original population. The surviving population continues to reproduce - the resulting offspring will only contain the surviving populations alleles, thus reducing genetic variation.

2.5.2 Identify two strategies that can help to increase genetic diversity in critically endangered species like the northern elephant seals. [2 marks]

① Create laws to ban hunting of the northern elephant seals.

② Establish captive breeding programs for the northern elephant seals.

2.6.1 What evolutionary mechanism has caused a higher incidence of fumarase deficiency to occur within this population? [1 mark]

The Founder Effect.

2.6.2 Describe how this mechanism has caused this to occur. [3 marks]①

A small founder group (members of the fundamentalist church) colonise a new area. The offspring of the founding population can only inherit alleles from the founders (due to a lack of gene flow between the original and founding population). If the allele frequency for fumarase deficiency is high in the founding population, then it will increase in frequency over time in subsequent generations (which is amplified by "marrying within the religion" and "taking several wives").

Extension notes:

① Below is a simplistic **step-by-step approach** to explain the response:

- A founder group is formed from the original population
- Members of the founder group reproduce
- The frequency of specific alleles will increase

2.6.3 Which organelle does this genetic condition most likely affect? [1 mark]

The mitochondria

3.1 Explain the purpose of 'selective breeding programs'. [2 marks]

The purpose of selective breeding programs is to carry out artificial selection. This is where organisms with particular phenotypes (traits) that are desirable or favourable to a breeder are allowed to reproduce to a greater capacity than other organisms of the same population.

3.2 Identify the selective pressure in selective breeding programs. [1 mark]

In selective breeding programs, the breeder (human) acts as the selective pressure.

3.3 Describe one similarity and one difference between natural and artificial selection. [2 marks]

One similarity is that differential reproduction occurs, such that organisms with certain favoured alleles are more likely to reproduce than others. One difference is that, in artificial selection, the traits that are selected for appeal to human needs and values; whereas in natural selection the phenotypes that are selected for provide the organism with greater biological fitness.

3.4.1 Explain how domestic dogs can be selectively bred. [3 marks]

① Initially, phenotypic variation exists in the population of domestic dogs such that some are more aesthetically appealing than others. ② Aesthetically appealing domestic dogs are identified and bred with each other, such that their favourable alleles are passed onto the next generation of domestic dogs. ③ Over time, the population of domestic dogs has a much higher proportion of the alleles that make them more aesthetically appealing.

3.4.2 Describe the effect that the selective breeding of dogs has on the gene pool of the domestic dog population. [2 marks]

The gene pool will decrease as, over time, alleles that are not favourable and thus not included in the selective breeding process will diminish from the population. ①

Extension notes:
① All the dogs will become **genetically similar** (less genetically variable).

3.4.3 Explain two ethical issues associated with the selective breeding of dogs. [2 marks]

① Selective breeding can result in phenotypes that are disadvantageous to the dogs despite serving human interest. For example, selectively bred dogs that have difficulty breathing.

② Selective breeding may be considered to interfere with the natural process of evolution within the species.

3.4.4 Explain two reasons, except for aesthetic value, why individuals want to selectively breed dogs. [2 marks]

One reason individuals may want to selectively breed dogs is because individuals have allergies to dogs. Another reason individuals may want to selectively breed dogs is to produce non-aggressive (docile) dogs to prevent biting.

3.5 Explain how drought-resistant crop plants can be produced by selective breeding. [3 marks]

① Initially phenotypic variation exists in the crop plants, such that some are more resistant to drought than others. ② More drought-resistant crops are identified and bred with each other, such that their alleles are passed onto the next generation of crop plants more than the alleles of other plants.[1] ③ Over time, the population of crop plants has a much higher proportion of alleles that make them resistant to drought.

Extension notes:
[1] Plants with the desired traits are then interbred again.

3.6 Describe how phenotypic differences in two unrelated species would prevent them from producing offspring. [2 marks]

Two organisms of unrelated species may have different mating calls, which may no longer be recognised by the two organisms. Additionally, the genitalia of the organisms may be incompatible. Consequently, this may prevent the two organisms from being able to successfully interbreed and produce offspring.

4.1.1 Describe the process for the emergence of these new viral strains. [4 marks]

The process of natural selection① occurs.

① As SARS-CoV-2 infects more host cells, it may undergo mutations in its viral RNA which results in the emergence of new strains and variation in the population. ② These new strains are selected against for a particular trait such as virulence (the ability to infect cells). ③ Viruses that are more virulent are selected for and are able to infect more host cells and reproduce more viruses that carry this mutated RNA, making a greater contribution to the gene pool for the next generation of viruses. ④ Viruses that are less virulent are selected against, which means they are less likely to pass on their genes to the next generation.

Extension notes:

① For all natural selection questions you should use the following template:

1. Phenotypic variation in relation to [insert phenotype] exists within a population of [insert species].
2. [Insert environmental change or selection pressure] acts as a selection pressure on [insert species].
3. Organisms possessing [insert phenotype] trait are at a selective advantage - these organisms have a greater chance of surviving [insert selection pressure] and passing on their favourable alleles to the next generation (offspring).
4. Over time, the allele frequency of [insert phenotype] increases such that more individuals possess the advantaged trait.

4.1.2 Explain why these new strains soon infected a larger proportion of the population, compared to the old strains. [2 marks]

Natural selection tends to select for strains with greater virulences. Viruses that are more virulent are able to infect more cells, allowing them to outcompete the old strain and thereby infect a larger proportion of the population.

4.1.3 Explain how the appearance of new strains potentially affect the vaccine program. Describe one method to manage this effect. [3 marks]

The appearance of new viral strains would render previous vaccination programs as ineffective. New viral strains have mutated① nucleic acid that may result in changing proteins. Hence, B memory cells produced in response to the viral particles in the vaccine would not provide protection against new strains. This is because B memory cells would be unable to recognise the new viral antigens and hence would not mount an immune response.

Extension notes:
① A **link** between **altered nucleic acid** and **viral antigens** must be made!

4.2 Explain why new strains of bacteria spread rapidly in populations. [2 marks]

Individuals in the population are less likely to have developed immunological memory to a new strain of bacteria than to one they have been previously exposed to, so are more likely to be infected for a longer period of time. Strategies for preventing spread and treatment of the disease will also be unknown for a new strain.

4.3.1 Define the term 'antigenic shift' and explain the consequence of viruses undergoing antigenic shift. [2 marks]

Antigenic shift is the process through which different strains of a virus exchange their surface antigens. The viruses are then unrecognisable by memory cells for the initial strains of the virus, enabling them to replicate rapidly without being immediately eliminated by the immune system.

4.3.2 Define the term 'antigenic drift' and explain the consequence of viruses undergoing antigenic drift. [2 marks]

Antigenic drift refers to the gradual accumulation of mutations in viral genes that code for the surface antigens of the virus. When antigenic drift occurs, the body will not be immune to the 'new' virus strains (as there has been no previous exposure) - thereby, the individual becomes susceptible to infection.

4.4.1 With reference to Darwin's theory of evolution by natural selection, explain how MRSA bacteria have evolved to become resistant to antibiotics. [3 marks]

① The extent of antibiotic resistance in a population of S. aureus bacteria varies. ② The bacteria is exposed to a specific antibiotic. ③ Bacteria which are sensitive to the specific antibiotic (unable to grow and survive) will be killed. ④ Bacteria which are resistant to the antibiotic are more biologically fit and thus, survived, reproduced and passed on their favourable alleles to the next generation. ⑤ There is a change in the gene pool as the incidence of antibiotic-resistant (MRSA) bacteria will increase in subsequent generations.

4.4.2 Outline one method to reduce the development of antibiotic-resistant strains of bacteria. [2 marks]

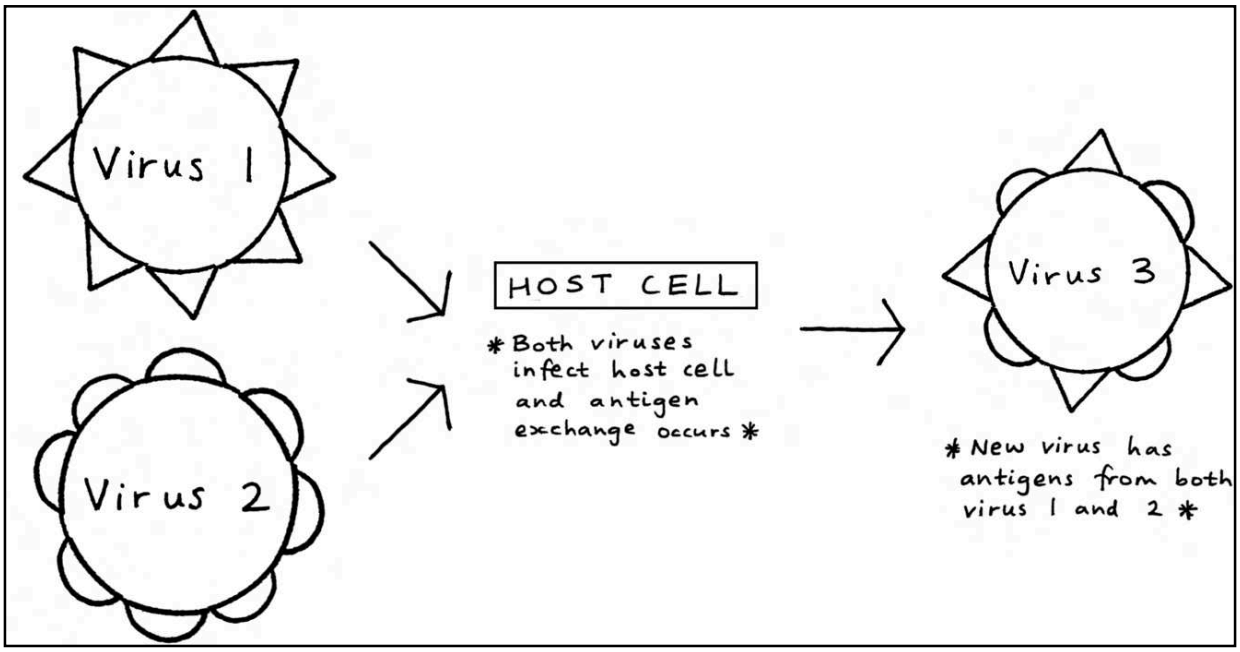
One method can be to avoid prescribing antibiotics to people who do not need them (for example, for those with a viral infection). This is because bacteria unnecessarily exposed to the antibiotic will develop mechanisms of resistance that can then spread to other bacteria - this can reduce the efficacy① of the antibiotic.

Extension notes:
① **Efficacy** refers to the ability to produce a **desired result**.

4.4.3 Explain why it would be infeasible to create new antibiotics to reduce the spread of MRSA. [2 marks]

The research and development of antibiotics that are sufficiently different from the antibiotics to which MRSA is already resistant would be an extremely timely and expensive process. The benefits of creating new antibiotics may not outweigh the disadvantages if alternative forms of treatment already exist.

4.5.1 Draw and annotate a diagram that shows how antigenic shift may occur in virus particles. [3 marks]



4.5.2 Identify whether antigenic shift or antigenic drift is a greater challenge against treatment and immunity, and explain why this is the case. [3 marks]

Antigenic shift poses a greater challenge. Antigenic shift refers to the mixing of genes from different strains of the virus, resulting in a more rapid change in the genetic makeup of the pathogen than antigenic drift, which is a more gradual accumulation of mutations which change the antigens of the virus. Consequently, viruses undergoing antigenic shift will radically change much faster and be more difficult to reproduce treatment and immunity for than the process of antigenic drift, in which the treatment may still be effective for a certain period of time and the changes can be more easily tracked.

5.1 Define the term 'palaeontology'. [1 mark]

Paleontology refers to the identification, interpretation and dating of fossils.

5.2.1 Define the term 'fossil'. [1 mark]

Fossils are preserved remains or impressions of an organism of the past.

5.2.2 Explain what is meant by the term 'fossil record' and what it provides evidence of. [3 marks]

The fossil record refers to the totality of fossils, both discovered and undiscovered. The fossil record provides evidence that, over time, changes have occurred to the features of living organisms. Different fossil types provide different information - for example, trace fossils provide information about how an organism lived and body fossils provide information about the structure of an organism.

5.3 Explain why the fossil record is incomplete. [2 marks]

The fossil record is incomplete① because not all fossils have been found yet. Furthermore, some fossils have been destroyed (by human activity or natural disasters such as earthquakes).

Extension notes:

① The conditions required for fossilisation are quite specific and also rarely occur successfully, which contributes to the incompleteness of the fossil record.

5.4 What is the term used to describe dating methods that make use of radioisotopes such as carbon-14?

Absolute dating.

5.5.1 Determine whether it is possible to establish the age of the fossil using carbon-14 dating. [2 mark]

It would not be possible to use radioactive carbon dating to establish the age of a fossil if it were approximately 8 million years old. The half-life of carbon-14 is approximately 5730 years and the majority of the carbon-14 has decayed by 28,500 years. There would be insufficient carbon-14 remaining in the fossil to provide a reliable means of dating it.

5.5.2 Determine what other methods can be used to determine the absolute age of this fossil. [1 mark]

Potassium-Argon dating

5.5.3 Given that there are fossils in each section, which section would have the oldest fossil? Provide a reason to support your answer. [2 marks]

Section G would have the oldest fossil. The lowest areas were deposited first and should contain the oldest fossils. Section G is the lowest portion (it extends through section F which is more recent).

5.5.4 What information can you infer on the settlement of humans in the area? [2 marks]

Humans must have arrived while Layer C was forming and then left while Layer B was forming. As there are no remains found in the deeper strata, humans would be unlikely to have existed then; and, as there are no remains found in the newest strata (A) humans must have migrated from the area.

5.6 Explain what is meant by the term 'transitional fossils' and what they are used for. [2 marks]

Transitional fossils are fossils that are intermediates between ancient and modern forms. They are useful because they provide evidence of an organisms evolutionary pathway - allow observations about the transition from one species to another.

5.7.1 Explain what is meant by the term 'index fossils' and how they can be used to determine relatedness between species. [3 marks]

Index fossils are fossilised remains of an organism that lived for a short time and are used to date or identify the strata in which they are found and to define the boundary of a particular geological period. They can be used to determine the age of a fossil because a strata with an index fossil is close in age to another strata with the same index fossil in it. Thus, different strata of the same age can be matched in order to determine the relative ages of strata in a series of outcrops.

5.7.2 List two criteria that a fossil must satisfy in order to be classified an 'index fossil'. [2 marks]

① They must be abundant.
② They must be easily recognisable.

5.8.1 Low oxygen levels. [2 marks]

Low oxygen levels① save the organic matter from decay in order to produce remnants that withstand the long period of time required for fossilisation.

Extension notes:
① **High oxygen levels** may increase the **decomposition** (decay) due to the presence of **aerobic bacteria** that will decompose the organism. Aerobic bacteria will not be present in aerobic environments.

5.8.2 Lack of scavengers. [2 marks]

Scavengers① destroy and disturb the remains of animals, causing them to decay more easily or become digested. Hence, scavengers prevent the remains from undergoing fossilisation.

Extension notes:
① Scavengers, such as vultures, are **attracted to the smell** of decomposing organisms (these organisms **release specific chemicals** when decaying).

5.9 Explain why the most common fossils found are shelled invertebrates that existed in an aquatic environment. [2 marks]

Shelled invertebrates are more likely to fossilise due to their hard outer shell, as hard body parts are more likely to turn into fossilised rocks. The aquatic environment provides a low oxygen environment that saves the shelled invertebrates from decay. These two favourable conditions contribute to the increased chance of shelled invertebrates being fossilised.

5.10 Describe the specific conditions that would have to occur in order for a terrestrial animal to become fossilised. [3 marks]

① The terrestrial animal has died and is quickly buried with sediment in order to minimise decay and scavengers.
② Over millions of years, more layers build and increase the pressure on the remains, preserving the organism's hard body parts as minerals.
③ Erosion then occurs to allow exposure of the remains of the animal.

5.11.1 Explain how 'relative dating' can be used to establish the age of a fossil. [3 marks]

Relative dating is a technique used by scientists to estimate the age of a fossil by comparing the position of the rock strata that the fossil was located in to other strata. Layers of sedimentary rock are arranged in the order in which they were deposited, with the most recent layers near the surface. Therefore, the deeper the layer in which a fossil is found, the older the fossil.

5.11.2 Outline one advantage and one disadvantage of relative dating. [2 marks]

Advantage: can determine temporal relationships between different populations.
Disadvantage: cannot determine the actual time period in which the fossil was alive with great accuracy.

5.11.3 Explain how 'absolute dating' can be used to establish the age of a fossil. [2 marks]

Absolute dating involves using the radioactive decay of some elements to establish the age of a fossil. By knowing the half-life of these specific elements, the ratio of the original element to the decayed version can be compared to gain an absolute age.

5.11.4 Outline one advantage and one disadvantage of absolute dating. [2 marks]

Advantage: can determine the actual time period in which the fossil was alive with good accuracy.
Disadvantage: limited by how long the half-life of the element being used is (for example, Carbon-12 dating is only useful within a 50,000 year time period).

5.11.5 Identify two differences between relative and absolute dating. [2 marks]

① Absolute dating provides a precise age for the fossil, whereas relative dating gives no indication of an actual time period. ② Relative dating is possible for fossils regardless of age, whereas absolute dating is limited by the half-life of the radioisotope being used.

5.12.1 Explain why the wooly mammoth was found in a well-preserved state with little evidence of decaying. [3 marks]

The conditions for decay of the woolly mammoth were absent as a result of being frozen. The woolly mammoth was unlikely to be decomposed by scavengers because the environment would have been too cold for them to live in. Furthermore, if any bacteria or microorganisms were present, the rate at which they decomposed 'soft parts' of the woolly mammoth would have been slow.

5.12.2 Describe one method that can be taken to determine if this is true. [2 marks]

DNA analysis of woolly mammoths compared to modern elephants can be employed. Related species will have significant similarities in their DNA as they will have arisen from a recent common ancestor.

5.12.3 Suggest two reasons why wooly mammoths are extinct. [2 marks]

① Woolly mammoths were hunted to extinction by humans.
② Woolly mammoths may have been unable to adapt to a warming climate (global warming).

6.1 Define the term 'master regulatory gene'. [1 mark]

A master regulatory gene is a gene that regulates or coordinates the expression of genes (regulatory and structural genes) that lead to the development of specific tissues or organs.

6.2 Define the term 'novel phenotype'. [1 mark]

A novel phenotype refers to the formation of new phenotypes as a result of the impact of environmental factors on the existing phenotypes of organisms.

6.3 Define the term 'speciation'. [1 mark]

Speciation refers to the formation of a new species from a pre-existing one.

6.4 Define the term 'adaptive radiation'. [1 mark]

Adaptive radiation refers to the rapid diversification of a single (common) ancestor into multiple different species that inhabit various environments and that vary in phenotypes used to exploit those environments.

6.5.1 Explain what happened to the rabbit population on the left side of the river. [4 marks]

There is variation within the population with respect to the size and athleticism of the rabbits. A selection pressure is applied in the form of predation by foxes. Rabbits that were smaller and more athletic have a selective advantage - they are more likely to survive, reproduce and pass on their favourable alleles to the next generation. Thereby, making a greater contribution to the gene pool of the next generation (on the left side of the river). Rabbits that were larger and not as athletic are less likely to reproduce and will be less likely to pass on their genes onto the next generation, making a smaller contribution to the gene pool. Thereby, increasing the incidence of smaller and athletic rabbits on the left side of the river.

6.5.2 Define the term 'species'. [1 mark]

A species refers to a group of organisms that are capable of successfully interbreeding to produce fertile and viable offspring.

6.5.3 Describe the process of allopatric speciation with relation to these rabbit populations. [3 marks]

The river acts as a geographical barrier①, separating the original population of rabbits into two populations and preventing gene flow. The two populations were subjected to different selection pressures, causing them to adapt independently via natural selection. Over time, the cumulative differences between the two rabbit populations led to the two populations being unable to reproduce together to produce viable and fertile offspring.

Extension notes:
① Examples of geographical barriers include: shifting mountains, rivers and changing environments.

6.6.1 State the function of the BMP4 gene. [1 mark]

The BMP4 gene is involved in regulating bone growth (by coding for the production of a bone growing protein).

6.6.2 Identify the correlation between BMP4 activity and beak size in finches and explain the significance of this correlation. [3 marks]

The greater the BMP4 activity, the more BMP4 protein is made (and hence, the greater the beak size). This is significant because variable expression of the BMP4 gene allows for phenotypic variation of beak size and shape in finches. This variation in beak shape and size allowed ancestral finches to take advantage of different niches. (adaptive radiation).

6.6.2 Explain why mutations occurring in the BMP4 gene can quickly create a variety of phenotypes with regards to beak shapes in Galapagos finches. [3 marks]

As a master regulatory gene, the BMP4 gene is able to control the expression of many other genes. Mutations in the BMP4 gene may lead to a selective advantage, which will cause finches with this particular phenotype to contribute their favourable alleles to the gene pool of the next generation. Thus, quickly creating beak variation within the Galapagos finches in order to inhabit different niches (adaptive radiation).

6.6.3 What name is given to structures that have the same common evolutionary origin? [1 mark]

Homologous structures

6.6.4 Explain the conditions that are suitable for the finches to undergo speciation. [2 marks]

The sea between the islands acts as a geographical barrier and hence, prevents gene flow. Different islands will have different selection pressures (due to there being different habitats) - this facilitates speciation.

6.6.5 Explain how one species of finch can be found on different islands in Galapagos. [1 mark]

Different islands may have similar environments with similar food availability and other similar selective pressures.

6.6.6 Name the process that allows for the accumulation of differences between populations of finches. [1 mark]

Natural selection

6.6.7 Explain how this population is likely to evolve. [4 marks]

① Originally, phenotypic variation① exists in the population of finches such that there are beaks of different lengths. ② The type of food available acts as a selection pressure (with a longer and more pointed beak being favoured). ③ Differential reproduction occurs where finches with longer and more pointed beaks are more likely to survive and pass on their favourable alleles to the next generation (offspring). ④ Over time, the allele frequency of longer and more pointed beaks increases such that the majority of the population has this phenotype.

Extension notes:

① For all natural selection questions you should use the following template:

1. Phenotypic variation in relation to [insert phenotype] exists within a population of [insert species].
2. [Insert environmental change or selection pressure] acts as a selection pressure on [insert species].
3. Organisms possessing [insert phenotype] trait are at a selective advantage - these organisms have a greater chance of surviving [insert selection pressure] and passing on their favourable alleles to the next generation (offspring).
4. Over time, the allele frequency of [insert phenotype] increases such that more individuals possess the advantaged trait.

6.7.1 Explain what key features result in two populations being considered different species. [1 mark]

They cannot interbreed to produce viable and fertile offspring.

6.7.2 Identify the process through which the two species of Howe plants would have developed from their common ancestor. [1 mark]

Sympatric speciation

6.7.3 Explain why the process identified in 6.8.2 is less likely to occur then the type of speciation in which populations are geographically isolated and name the process that occurs when different species develop from geographically isolated populations. [3 marks]

Sympatric speciation occurs when populations are not geographically isolated. The likelihood of populations being subjected to different selective pressures is far lower in the same geographical region. This process is less likely to occur than the process which involves geographical isolation①: allopatric speciation.

Extension notes:

① Note that **geographical isolation** results in a greater chance of encountering **different selection pressures**.

6.7.4 Using the data① from Figure 1, explain how the two species of Howea plants developed. [4 marks]

Soils of varying pHs exist and variation in relation to the ability to grow optimally at different pHs (selective pressure) exists between Howea plants in the original population. The ecological isolating mechanism of different soil pHs prevents Howea plants that grow at different pHs from mating with each other - this is through preventing gene flow② between different populations of Howea plants.

Over time, mutations accumulate between the different populations of Howea plants. that grow at different pHs to the point where they become different species (process of speciation). Consequently (according to Figure 1) producing two species of Howea plants that optimally grow under different pH's - H. forsteriana optimally grows at a pH of 8 and H. belmoreana optimally grows at a pH of 6.

Extension notes:

① Ensure that you use **data** in your response!

② An important point that must be made is that **gene flow** is **prevented** from occurring.

6.7.5 Using the data from Figure 2, explain how the two species of Howea plants developed. [4 marks]

Growth of Howea plants occurs at different heights above sea level and variation in relation to the ability to grow optimally at these different heights above sea level exists between Howea plants in the original population. The ecological isolating mechanism of different heights above sea level prevents Howea plants that grow optimally at different heights above sea level from mating with each other - this is through preventing gene flow between different populations of Howea plants.

Over time, mutations accumulate between the different populations of Howea plants that grow at different heights above sea level to the point where they become different species (process of speciation). Consequently, as per Figure 2, H. forsteriana is able to optimally grow at heights below 80m and H. belmoreana is able to optimally grow at heights greater than 120m above sea level.

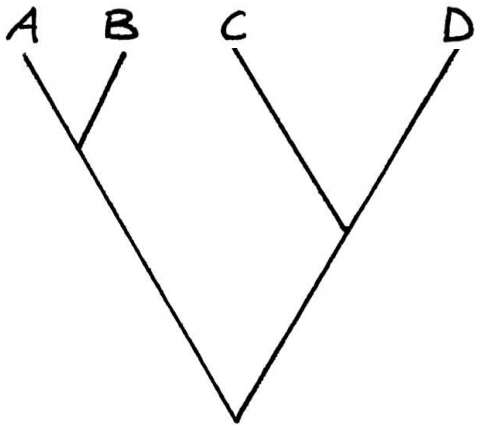
7.1 Define the terms 'analogous structures' and 'homologous structures'. [2 marks]

Analogous structures are features that are similar in function, but not in structure; homologous structures are features that are similar in structure, but have different functions.

7.2 Explain how DNA sequencing provides evidence of relatedness between species. [3 marks]

The sequences of DNA nucleotides in related genes in different species can be determined. Over time, mutations in a gene can accumulate. The number of differences in base sequences of the same gene in different species can give an indication of the relatedness of the species - for example, the more similar the nucleotide sequences are, the more closely related the two organisms are.

7.3.1 Based on the sequences of DNA listed above, draw a cladogram showing the relative genetic relationship between the four species. [2 marks]



7.3.2 Explain why this result might differ from that provided by the DNA sequences above. [2]

Only a small section of DNA is being examined, so it may be less accurate compared to if the study was performed on a larger sample. Multiple mutations may have altered the nucleotides so that they appear unchanged (silent mutations).

7.3.3 Why can studying mutations within introns be more useful than studying mutations that occur within exons? [3 marks] ①

Introns are non-coding regions of DNA whereas exons are coding regions of DNA (and thus, are responsible for inheritable characteristics). Mutations within exons may alter the genes' function and the consequence of this change could become an issue for survival. Introns can mutate without altering gene function and therefore be passed on through the generations without any adverse effects.

Extension notes:

① Organisms that have had exon mutations may be unable to survive to pass on their mutation. However since mutations in the intron sections of organisms are not expressed these organisms may survive to pass on their alleles to the next generation.

7.4 Explain how amino acid sequencing of a protein can provide evidence of relatedness between organisms. [3 marks]

The amino acid sequence of protein molecules can be determined. Over time, mutations accumulate that may change the sequence of amino acids. The more time that has passed since the two species diverged from a common ancestor, the more differences there will be in the amino acid sequences. ① Species that are more closely related have less differences in the amino acid sequence of specific proteins. This is because the longer the time period since the two species diverged from a common ancestor, the more time there has been for changes to occur in a specific protein present in both species.

Extension notes:

① This means that **less time has passed** to **accumulate mutations!**

7.5 State whether or not the above diagram suggests that the six organisms evolved from a common ancestor. Explain your choice. [3 marks]

Organisms that originated from a recent common ancestor may look phenotypically different; however, they often share similar bone structure. This is due to features slowly evolving to adapt to each species' specific environment (niche). These are referred to as homologous features and suggest a recent common ancestry due to similar bone arrangement. Thus, the six organisms evolved (divergent evolution) from a recent common ancestor as per the diagram.

7.6 Explain why using multiple different types of data can improve the reliability of estimated evolutionary relationships. [2 marks]

Having multiple sources of data allows for any inconsistent data or sources to be identified by cross-referencing the information collected. It can also provide new information to supplement gaps in the estimated evolutionary relationships.

7.7.1 What term is used to describe these structures? [1 mark]

Analogous structures

7.7.2 Name the type of evolution that occurred between sharks and dolphins from their respective ancestors, explained how it occurred. [2 marks]

Convergent evolution has occured, leading to similar structures between sharks and dolphins. This occurred due to similar selection pressures causing similar adaptations in these two species.

8.1 Outline what information is obtained from analysing phylogenetic trees. [1 mark]

Phylogenetic trees show how long ago species diverged from each other and the order in which they diverged from a recent common ancestor.

8.2 Explain the relationship between branch length and species relatedness. [2 marks]

As branch length increases, the degree of relatedness between species decreases because they have moved further along their evolutionary path.

9.1 Define the term 'primates'. [1 mark]

Primates are a group of mammals, including humans, great apes and monkeys.

9.2 Define the term 'hominoids'. [1 mark]

Hominoids are a group consisting of all extinct and modern great apes.

9.3 Define the term 'hominins'. [1 mark]

Hominins are a group consisting of extinct and modern humans as well as immediate ancestors.

9.4 State two characteristics of primates that differentiates them from other mammals. [2 marks]

Primates, in comparison to other mammals, have:

① Forward-facing eyes
② Opposable thumbs.

9.5 Identify a characteristic of hominoids that differentiate them from primates? [1 mark]

Hominoids do not have tails.

9.6.1 Pentadactylism. [2 marks]

Pentadactylism in primates has evolved to produce 4 digits and an opposable thumb for their upper and lower limbs. The 5 digits work together to allow primates to grasp objects with their hands and feet, such as tools or branches.

9.6.2 Mobile arms. [2 marks]

Mobile arms occur because the shoulder joints allow movement to occur in three dimensions. This adaptation facilitates tree climbing.

9.6.3 Prehensile toe. [2 marks]

A prehensile toe refers to a big toe that is widely separated from the other toes. This allows the organism to be able to climb better as they have better grip with their feet.

9.6.4 Being able to live in social groups. [2 marks]

Groups increase the efficiency of finding food and shelter for the population, as tasks can be divided between organisms. Cultural and technological evolution is also facilitated through collaboration.

9.7.1 Having less body hair. [2 marks]

Having less body hair allowed for efficient thermoregulation (increased heat loss by radiation). Thereby, allowing hominins to hunt during the day in the hot grasslands without overheating.

9.7.2 Being bipedal. [2 marks]

Bipedalism increases eye level such that things being sought after like food sources can be more easily seen and danger can be easily avoided. The upper limbs can then be used for tasks other than walking, like using tools or grasping other objects.

9.7.3 Central foramen magnum. [2 marks]

A central foramen magnum allows the skull to be balanced on the spine, enabling an upright posture. This facilitates bipedalism.

10.1.1 Average brain size increasing. [3 marks]

The average brain size increased from 450cm^3 in A. Aferensis to 1350cm^3 in H. sapiens - this increase has produced a highly developed brain. As hominins evolved, they underwent biological and cultural evolution. Cultural evolution has allowed them to manipulate their environments such as through the controlled use of fire to cook food and coordinate hunting in packs, which means that a greater amount of meat can be consumed. Thereby, there are additional nutrients necessary for brain growth and development, leading to an increased brain size. Even though Homo neanderthalensis had a larger brain size (1500cm^3) than Homo sapiens, there is still an overall increasing trend that demonstrates greater use of the brain in later hominins.

10.1.2 Average adult height increasing. [2 marks] ①

The average height increasing from 1.51m in A. afarensis to 1.78m in H. sapiens is due to an increase in relative leg length compared to arm length. The shift to bipedalism emphasises the need for longer legs that can travel greater distances and can support the rest of the body, whereas beforehand the support was shared between all four limbs.

Extension notes:

① A case could also be made that **increased consumption of meat** (due to controlled used of fire) could have lead to height increasing due to increased nutrients for **bone development**! Thereby, leading to greater heights!

10.2 Explain the changes in limb structure that have facilitated an upright walking position in early hominins. [3 marks]

① The legs have increased in length to support the rest of the body in an upright position, rather than on all four limbs.
② An increased carrying angle places the foot closer to the midline and enables balance in bipedalism.
③ An arched foot evolved to increase endurance and propel mobility.

10.3.1 Domestication of plants and animals. [1 mark]

The domestication of plants and animals indicates increased cognitive ability because less effort is required to find sources of food - the shift to a more settled lifestyle.

10.3.2 Construction of containers. [1 mark]

The production of containers indicates increased cognitive ability due to the understanding that food can be stored for later use - a shift to a more settled lifestyle.

10.3.3 Production of tools. [1 mark]

The production of tools indicates cognitive ability necessary to develop tools used to solve a specific problem.

10.3.4 Painting in caves. [1 mark]

Painting in caves indicates cognitive ability necessary to pass on information by non-biological means - the desire to document experiences through art.

10.3.5 A greater number of animals being hunted and killed. [1 mark]

A greater number of animals being killed indicates increased cognitive ability to hunt 'game' - this is because an understanding is required of physical laws to use weapons and the behaviour of prey.

10.4 Describe one product of the cultural evolution of hominins that has led to increased genetic evolution and decreased genetic variation. [3 marks]

The use of tools by hominins has both increased and decreased their genetic evolution. Through the use of tools, hominins have increased their survivability in the wild, allowing more of them to survive to produce fertile offspring. By improving the chance for individuals to produce offspring, the gene pool increases and genetic variation is more likely to occur. However, through the use of tools hominins were able to harm each other more easily. By killing other hominins, the gene pool reduces and genetic variation decreases.

10.5 Identify two differences that would be expected to be observed between a skull of[1] *Homo erectus* and a skull of *Homo sapiens*. [2 marks]

Compared to Homo sapiens, Homo erectus:
① Would have a foramen magnum positioned to the rear of the skull.
② Would have more prominent brow ridges.

Extension notes:
[1] If the question mentions a specific body part (such as a skull) ensure that you refer to features of that body part - for example, do not mention the cranial capacity if the fossil found is of a finger!

10.6.1 (A): The cranial capacity has increased. [3 marks]

The cranial capacity has increased because the controlled use of fire to cook food means that a greater amount of meat can be consumed. Consequently, there are additional nutrients necessary for brain growth and development, leading to an increased brain size and cranial capacity.

10.6.2 (B): The face has become flatter. [2 marks]

The face has become flatter to accomodate for an increasing brain size - specifically the development of the frontal lobe①.

Extension notes:
① The **frontal lobe** of the brain is responsible for **motor functions** of the body!

10.6.3 (C): The supraorbital brow ridges have reduced in size. [2 marks]

The purpose of the prominent supraorbital brow ridges was to support the weaker bones of the face. The brow ridges have become less prominent over time to support a growing brain (frontal lobe).

10.6.4 (D): The size of the cranial capacity compared to body size has increased. [2 marks]

An increased cranial capacity facilitates technological and cultural evolution, while body size does not increase concurrently as a smaller body size facilitates greater mobility and fine motor skills.

10.6.5 (E): The size of teeth has reduced. [2 marks]

The teeth (canines and molars) has reduced in size. This is because the controlled use of fire to cook food means that food eaten by humans is less fibrous and tough (making it easier to eat).

10.6.6 (F): The foramen magnum has become more centrally located. [2 marks]

The foramen magnum has become centrally placed so that the skull is balanced on the spine - this enables an upright position and hence facilitates bipedalism. If the foramen magnum is located to the rear of the skull, then a more bent stance would need to be adopted.

10.6.7 (G): The jaw has decreased in size. [2 marks]

The jaw decreased in size over time due to a change in dietary habits - the food eaten became less fibrous and tough due to the controlled use of fire to cook food.

10.6.8 (H): The strength of bones has reduced. [2 marks]

The strength of bones has reduced because there is less reliance on humans to possess strength to catch prey and physically compete for resources (which has instead been aided by tool use and social organisation respectively).

10.6.9 (I): The shape of the spine has become more 'S-shaped' and less 'C-shaped'. [3 marks]

The human spine is S-shaped to allow the weight of the chest to sit above the spine and the pelvis rather than forward. This allows for more efficient upright walking because a S-shaped spine can act as a spring to facilitate bipedalism. Furthermore, the spine has become less C-shaped as bipedalism involves upright walking as opposed to quadrapedal locomotion (knuckle walking).

10.6.10 (J): The pelvis has become shorter and more bowl shaped. [2 marks]

The pelvis has become shorter and more bowl shaped. to provide support to internal organs. This allows greater stability for running and walking, facilitating bipedal movement.

10.6.11 (K): The carrying angle has increased. [2 marks]

The carrying angle (valgus angle) has increased which means the thigh bone (femur) angles outwards rather than being straight. This brings the feet closer to the centre of gravity and ensures the knees are underneath the body when walking. Thereby, enabling an upright posture and facilitating bipedalism.

10.6.12 (L): The leg length has increased relative to the arm length. [2 marks]

The leg length has increased because the shift to bipedalism emphasises the need for longer legs that can travel greater distances and can suppert the rest of the body. Whereas beforehand the support was shared between all four limbs (knuckle walking).

10.6.13 (M): The toes of the feet point more outwards. [2 marks]

The toes point outwards as this enables the weight of the human to be transferred in a forward direction - this facilitates bipedal movement. This is in contrast to toes that point sideways that enable the organism to grip better.

11.1 What does this indicate about the two species of *H. neanderthalensis* and *H. sapiens*? [1 mark]

This implies that interbreeding occurred between Homo sapiens and Homo neanderthalensis, suggesting that they may be of the same species as they were able to interbreed to produce viable and fertile offspring.

11.2 State one reason for the extinction of *H. neanderthalensis*. [1 mark]

Neanderthal females did not interbreed, contributing to the extinction of H. neanderthalensis.

11.3.1 Explain how both statements 1 and 3 can be true. [3 marks]

Statement 1 and 3 can be explained by the fact that interbreeding① occurred between Neanderthal males and female ancestors of Homo sapiens, but not Neanderthal females and male ancestors of Homo sapiens. Since Neanderthal mtDNA is only passed down the maternal line, Neanderthal females may not have contributed to the modern human genome, which is why there is no evidence of Neanderthal mtDNA in Homo sapiens. However, Neanderthal males may have contributed to the modern human genome in European and Asian countries, which is why modern European and Asians have between one and two percent of Neanderthal DNA.

Extension notes:

① A key point that must be made in your response is that **interbreeding** occurred between **Neanderthal males and female ancestors of Homo sapiens** and that **no interbreeding** occurred between **Neanderthal females and male ancestors of Homo sapiens**.

11.3.2 Explain the reasons for statement 2. [3 marks]

Statement 2 can be explained by the 'Out of Africa' theory which proposes that populations of Homo erectus migrated out of Africa and dispersed across the world and diverged into Homo neanderthalensis (Neanderthals). If Neanderthals interbred with the ancestors of modern humans, then this would be done so outside of Africa. Hence, any Homo sapiens with ancestors that did not migrate out of Africa will have no Neanderthal DNA (which explains why modern Africans would have close to zero Neanderthal DNA.

11.4.1 What testing can be performed to determine that *Homo florensiensis* is a new undiscovered species? [2 marks]

mtDNA analysis can be performed, whereby the number of mtDNA mutations accumulated can be compared between the fossil found and known fossils (such as Homo erectus).

11.4.2 How does the evidence of *Homo neaderthalensis* and *Homo sapiens* interbreeding challenge this criteria? [2 marks]

If Homo neanderthalensis and Homo sapiens were able to interbreed to produce fertile offspring, then they should be classified under the same species. The biological definition of a species states that organisms are considered to belong to the same species if they are able to interbreed to produce viable and fertile offspring.

12.1.1 Identify one strength and one weakness of using fossil evidence to track migration of human populations around the world. [2 marks]

Strength: fossils proride evidence of morphological changes that have occurred in populations.
Weakness: may be difficult to determine the chronlogy of migration if absolute dating is not possible.

12.1.2 Identify one strength and one weakness of using mtDNA to track migration of human populations around the world. [2 marks]

Strength: The high volume of mtDNA in cells make it easy to isolate and analyse.
Weakness: The rapid mutation of mtDNA may make it difficult to identify and follow the pathway of the same population through migration.

12.2.1 Explain the main principles of the 'Out of Africa' theory of modern human migration. [2 marks]

Homo sapiens evolved in Africa (from Homo erectus) and migrated out of Africa, replacing and outcompeting the existing hominin populations (such as Homo erectus and Homo neanderthalensis).

12.2.2 Explain whether or not the above claim supports or opposes the 'Out of Africa' theory. In your response, refer to genetic drift. [4 marks]

The claim supports the 'Out of Africa' theory as the greatest genetic variation would be expected in the original population. If migration out of Africa occurred through the founder effect, then smaller populations would move to other continents with a smaller initial gene pool. As a result, when the population size of the founder group increases, there would be a lower genetic diversity. Thus, if African people have the greatest genetic variation, it supports the theory that they are the original population and not a founder group.

12.3 Explain the main principles of the 'Multiregional' theory of modern human migration. [2 marks]

The multiregional theory states that Homo erectus first migrated out of Africa and established multiple populations around the world. These populations interbred (encouraging gene flow) and evolved to form Homo sapiens around the same time at each population.

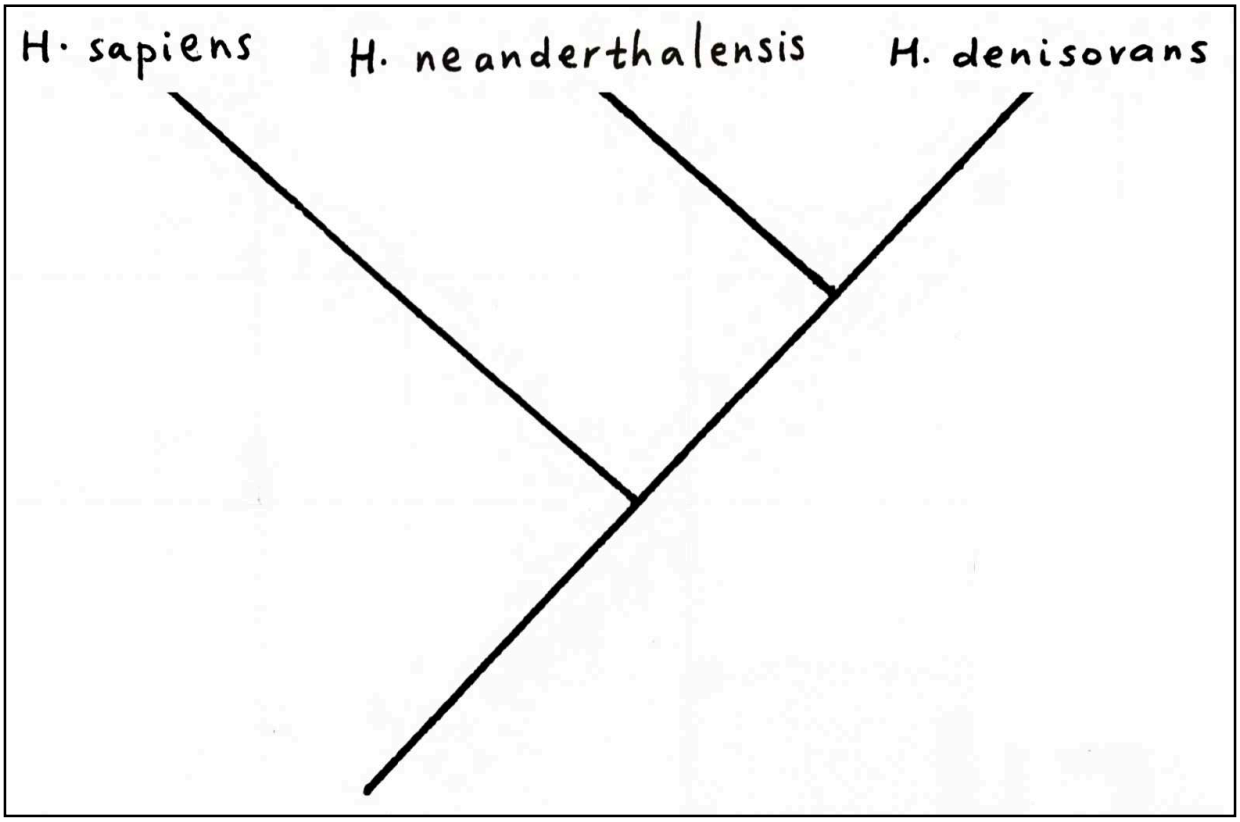
12.4 Outline one similarity and one difference between the 'Out of Africa' theory and the 'Multiregional' theory. [2 marks]

One similarity is that both theories support the claim that Homo sapiens emerged (evolved) from Homo erectus. One difference is that the 'Out of Africa' theory states that Homo sapiens evolved in Africa whereas the 'Multiregional' theory states that Homo sapiens evolved from different populations around the world at the same time.

12.5 Explain why extracting mtDNA from both fossils would be more useful in determining relatedness than extracting nuclear DNA. [3 marks]

There are more copies of mtDNA in a cell compared to nuclear DNA, meaning there is a higher chance of it being extracted from a dead organism. Nuclear DNA shows variation due to both mutations and the crossing over of chromosomes in meiosis (genetic recombination); whereas, mtDNA only showcases variation due to mutation. Furthermore, due to the rapid mutation rate of mtDNA, there would be more differences in mtDNA compared to nuclear DNA, giving a more reliable indicator of time of divergence. Thus, a more accurate measure of species relatedness can be obtained by using mtDNA.

12.6.1 Using the above information, draw a phylogenetic tree, including *H. denisovans*, *H. neanderthalensis* and *H. sapiens*. [2 marks]



12.6.2 Suggest why Neanderthals and Denisovans are believed to have more features in common with each other than either species have in common with modern humans. [1 mark]

Homo neanderthalensis and Homo denisovans shared a more recent common ancestor with each other than either did with Homo sapiens, leading to these two hominins having a greater degree of similarity than either did with Homo sapiens. ①

Extension notes:

① This means that there will be **less chance** for **mutations** to accumulate. Thereby, leading to less genetic diversity and hence, **phenotypic variation**.

12.7 Describe the significance of this finding with regards to cultural evolution. [1 mark]

The cave art indicates cultural evolution ① in Neanderthals as this art was not directly associated with survival.

Extension notes:

① **Survival** is associated with **biological evolution**.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