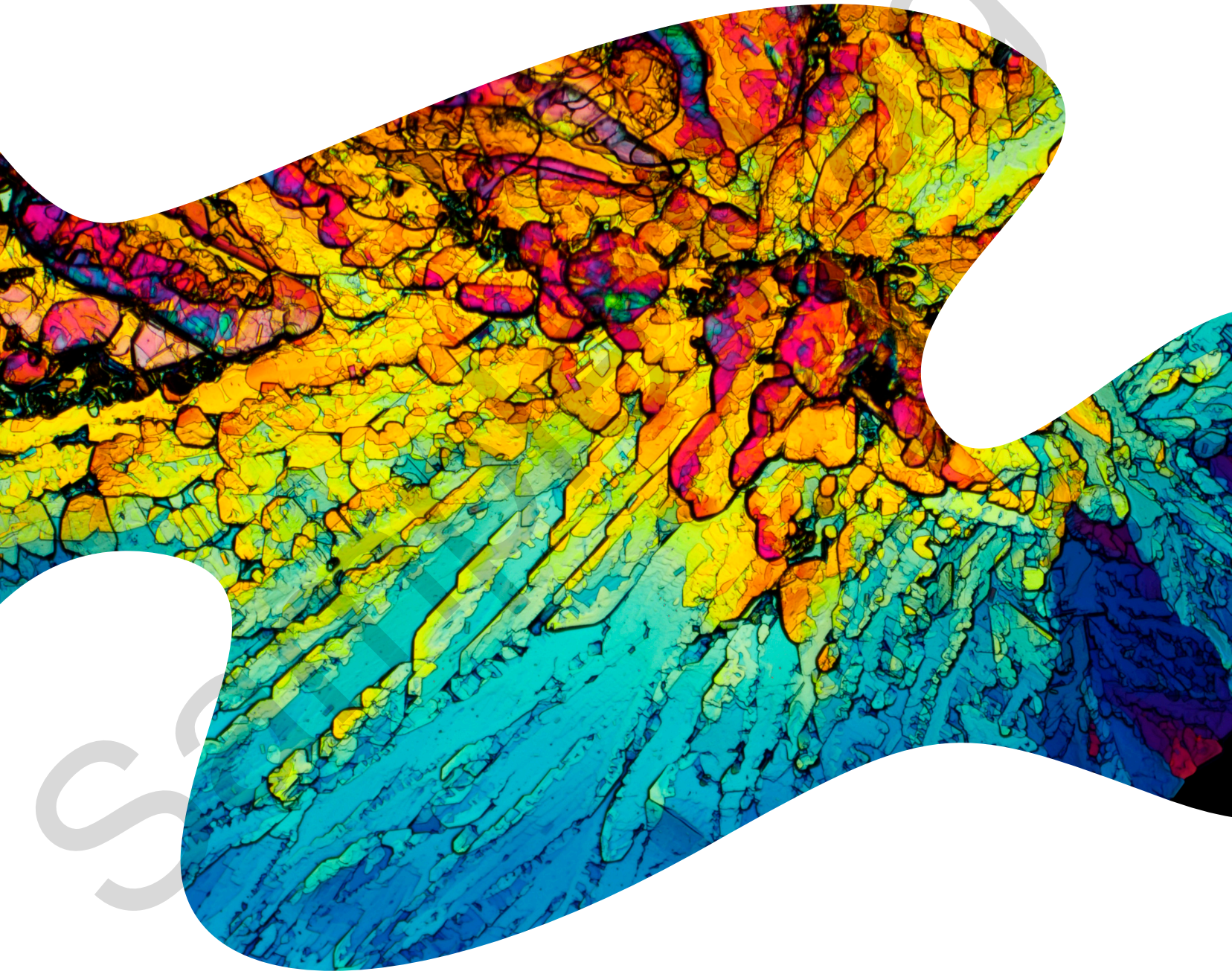
HEINEMANN

BIOLOGY 2

6TH EDITION



VCE UNITS 3 AND 4 • 2022-2026

Contents

Unit 4 How does life change and respond to challenges?

AREA OF STUDY 1

How do organisms respond to pathogens?

AREA OF STUDY 2

How are species related over time?

AREA OF STUDY 3

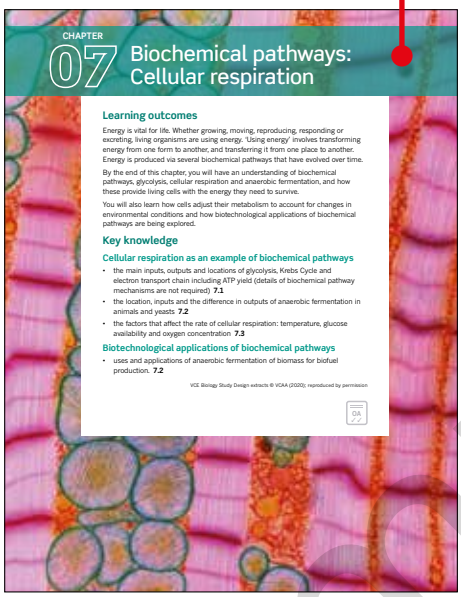
Heinemann Biology 2 6th edition includes a comprehensive set of resources to support Area of Study 3 via your Pearson Places bookshelf.

How to use this book Heinemann Biology 2 6th edition

Heinemann Biology 2 6th edition has been written to the new VCE Biology Study Design 2022–2026. The book covers Units 3 and 4. Explore how to use this book below.

Chapter opener

Chapter opening pages link the study design to the chapter content. Key knowledge addressed in the chapter is clearly listed. To help you find where each outcome is covered in the chapter, the relevant section numbers are written in bold.


CHAPTER 07 Biochemical pathways: Cellular respiration

Learning outcomes

Energy is vital for life. Whether growing, moving, reproducing, responding or excreting, living organisms are using energy. 'Using energy' involves transforming energy from one form to another, and transferring it from one place to another. Energy is produced via several biochemical pathways that have evolved over time.

By the end of this chapter, you will have an understanding of biochemical pathways, glycolysis, cellular respiration and anaerobic fermentation, and how these provide living cells with the energy they need to survive.

You will also learn how cells adjust their metabolism to account for changes in environmental conditions and how biotechnological applications of biochemical pathways are being explored.

Key knowledge

Cellular respiration as an example of biochemical pathways

- 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) **7.1**
- the location, inputs and the difference in outputs of anaerobic fermentation in animals and yeasts **7.2**
- the factors that affect the rate of cellular respiration: temperature, glucose availability and oxygen concentration **7.3**

Biotechnological applications of biochemical pathways

- uses and applications of anaerobic fermentation of biomass for biofuel production. **7.2**

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Highlight

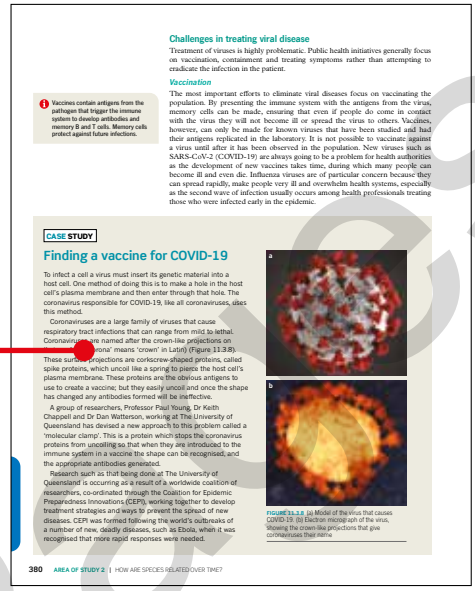
Focus on important information such as key definitions and summary points.

BioFile

BioFiles include interesting information and real world examples.

Case study

Case studies place biology in an applied situation or relevant context. Text and artwork refer to the nature and practice of biology, applications of biology and associated issues, and the historical development of biological concepts and ideas.


Challenges in treating viral disease

Treatment of viruses is highly problematic. Public health initiatives generally focus on vaccination, containment and treating symptoms rather than attempting to eradicate the infection in the patient.

Vaccination

The most important efforts to eliminate viral diseases focus on vaccinating the population. By presenting the immune system with the antigens from the virus, memory cells can be made, ensuring that even if people do come in contact with the virus they will not become ill or spread the virus to others. Vaccines, however, can only be made for known viruses that have been studied and had their antigens replicated in the laboratory. It is not possible to vaccinate against a virus until after it has been observed in the population. New viruses such as SARS-CoV-2 (COVID-19) are always going to be a problem for health authorities as the development of new vaccines takes time, during which many people can become ill and even die. Influenza viruses are of particular concern because they can spread rapidly, make people very ill and overwhelm health systems, especially as the second wave of infection usually occurs among health professionals treating those who were infected early in the epidemic.

Vaccines contain antigens from the pathogen that trigger the immune system to develop antibodies and memory B and T cells. Memory cells protect against future infections.

CASE STUDY

Finding a vaccine for COVID-19

To infect a cell a virus must insert its genetic material into a host cell. One method of doing this is to make a hole in the host cell's plasma membrane and then enter through that hole. The coronavirus responsible for COVID-19, like all coronaviruses, uses this method.

Coronaviruses are a large family of viruses that cause respiratory tract infections that can range from mild to lethal. Coronaviruses are named after the crown-like projections on their surface. 'Corona' means 'crown' in Latin (Figure 11.3.8).

These surface projections are corkscrew-shaped proteins, called spike proteins, which uncoil like a spring to pierce the host cell's plasma membrane. These proteins are the obvious antigens to use to create a vaccine; but they easily uncoil and once the shape has changed any antibodies formed will be ineffective.

A group of researchers, Professor Paul Young, Dr Keith Chappell and Dr Dan Watterson, working at The University of Queensland has devised a new approach to this problem called a 'molecular clamp'. This is a protein which stops the coronavirus proteins from uncoiling so that when they are introduced to the immune system in a vaccine the shape can be recognised, and the appropriate antibodies generated.

Research such as that being done at The University of Queensland is occurring as a result of a worldwide coalition of researchers, co-ordinated through the Coalition for Epidemic Preparedness Innovations (CEPI), working together to develop treatment strategies and ways to prevent the spread of new diseases. CEPI was formed following the world's outbreaks of a number of new, deadly diseases, such as Ebola, when it was recognised that more rapid responses were needed.

a

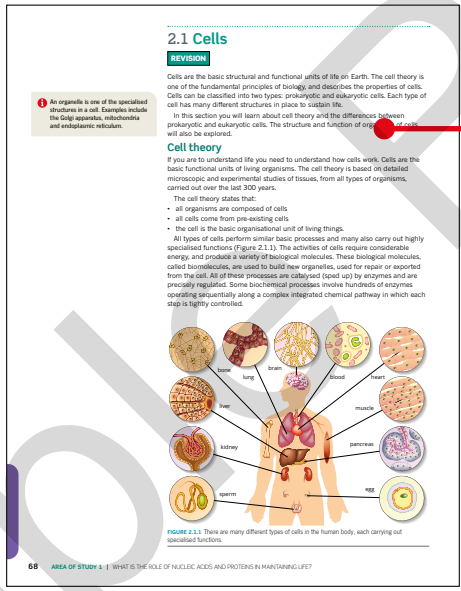
b

FIGURE 11.3.8 (a) Model of the virus that causes COVID-19. (b) Electron micrograph of the virus, showing the crown-like projections that give coronaviruses their name

380 AREA OF STUDY 2 | HOW ARE SPECIES RELATED OVER TIME?

Revision

Revision sections contain vital information from Year 11.


2.1 Cells

REVISION

Cells are the basic structural and functional units of life on Earth. The cell theory is one of the fundamental principles of biology, and describes the properties of cells. Cells can be classified into two types: prokaryotic and eukaryotic cells. Each type of cell has many different structures in place to sustain life.

In this section you will learn about cell theory and the differences between prokaryotic and eukaryotic cells. The structure and function of organelles in eukaryotic cells will also be explored.

Cell theory

If you are to understand life you need to understand how cells work. Cells are the basic functional units of living organisms. The cell theory is based on detailed microscopic and experimental studies of tissues, from all types of organisms, carried out over the last 300 years.

The cell theory states that:

- all organisms are composed of cells
- all cells come from pre-existing cells
- the cell is the basic organisational unit of living things.

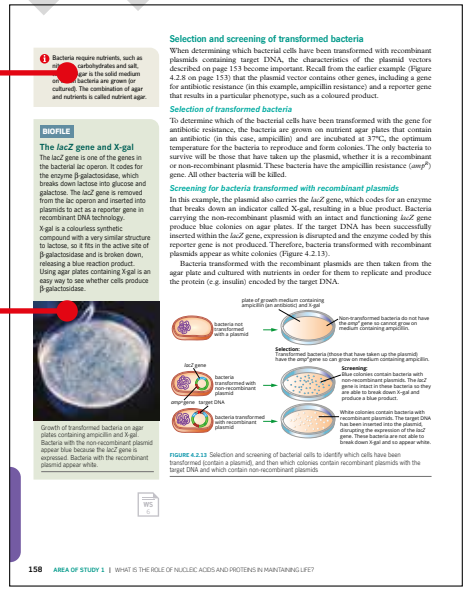
All types of cells perform similar basic processes and many also carry out highly specialised functions (Figure 2.1.1). The activities of cells require considerable energy, and produce a variety of biological molecules. These biological molecules, called biomolecules, are used to build new organelles, used for repair or exported from the cell. All of these processes are catalysed (sped up) by enzymes and are precisely regulated. Some biochemical processes involve hundreds of enzymes operating sequentially along a complex integrated chemical pathway in which each step is tightly controlled.

An organelle is one of the specialised structures in a cell. Examples include the Golgi apparatus, mitochondria and endoplasmic reticulum.

bone, lung, brain, blood, heart, liver, muscle, kidney, pancreas, sperm, egg

FIGURE 2.1.1 There are many different types of cells in the human body, each carrying out specialised functions.

68 AREA OF STUDY 1 | WHAT IS THE ROLE OF NUCLEIC ACIDS AND PROTEINS IN MAINTAINING LIFE?


Bacteria require nutrients, such as sugars, carbohydrates and salt, and agar is the solid medium on which bacteria are grown (or cultured). The combination of agar and nutrients is called nutrient agar.

BIOFILE

The *lacZ* gene and X-gal

The *lacZ* gene is one of the genes in the bacterial *lac* operon. It codes for the enzyme β-galactosidase, which breaks down lactose into glucose and galactose. The *lacZ* gene is removed from the *lac* operon and inserted into plasmids to act as a reporter gene in recombinant DNA technology.

X-gal is a colourless synthetic compound with a very similar structure to lactose, so it fits in the active site of β-galactosidase and is broken down, releasing a blue reaction product. Using agar plates containing X-gal is an easy way to see whether cells produce β-galactosidase.

Growth of transformed bacteria on agar plates containing ampicillin and X-gal. Bacteria with the non-recombinant plasmid appear blue because the *lacZ* gene is expressed. Bacteria with the recombinant plasmid appear white.

Selection and screening of transformed bacteria

When determining which bacterial cells have been transformed with recombinant plasmids containing target DNA, the characteristics of the plasmid vectors described on page 153 become important. Recall from the earlier example (Figure 4.2.8 on page 153) that the plasmid vector contains other genes, including a gene for antibiotic resistance (in this example, ampicillin resistance) and a reporter gene that results in a particular phenotype, such as a coloured product.

Selection of transformed bacteria

To determine which of the bacterial cells have been transformed with the gene for antibiotic resistance, the bacteria are grown on nutrient agar plates that contain an antibiotic (in this case, ampicillin) and are incubated at 37°C, the optimum temperature for the bacteria to reproduce and form colonies. The only bacteria to survive will be those that have taken up the plasmid, whether it is a recombinant or non-recombinant plasmid. These bacteria have the ampicillin resistance (amp^R) gene. All other bacteria will be killed.

Screening for bacteria transformed with recombinant plasmids

In this example, the plasmid also carries the *lacZ* gene, which codes for an enzyme that breaks down an indicator called X-gal, resulting in a blue product. Bacteria carrying the non-recombinant plasmid with an intact and functioning *lacZ* gene produce blue colonies on agar plates. If the target DNA has been successfully inserted within the *lacZ* gene, expression is disrupted and the enzyme coded by this reporter gene is not produced. Therefore, bacteria transformed with recombinant plasmids appear as white colonies (Figure 4.2.13).

Bacteria transformed with the recombinant plasmids are then taken from the agar plate and cultured with nutrients in order for them to replicate and produce the protein (e.g. insulin) encoded by the target DNA.

plate of growth medium containing ampicillin (an antibiotic) and X-gal

bacteria not transformed with a plasmid

Non-transformed bacteria do not have the *amp*^{R} gene so cannot grow on medium containing ampicillin.

Selection: Transformed bacteria (those that have taken up the plasmid) have the *amp*^{R} gene so can grow on medium containing ampicillin.

lacZ gene

bacteria transformed with non-recombinant plasmid

Screening: Blue colonies contain bacteria with non-recombinant plasmids. The *lacZ* gene is intact in these bacteria so they are able to break down X-gal and produce a blue product.

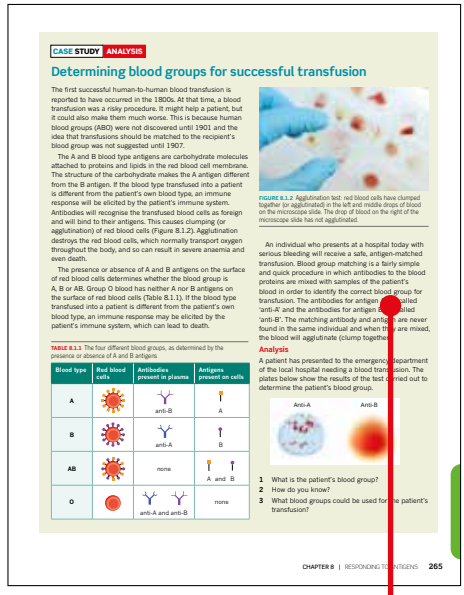
amp^R gene target DNA

bacteria transformed with recombinant plasmid

White colonies contain bacteria with recombinant plasmids. The target DNA has been inserted into the plasmid, disrupting the expression of the *lacZ* gene. These bacteria are not able to break down X-gal and so appear white.

FIGURE 4.2.13 Selection and screening of bacterial cells to identify which cells have been transformed (contain a plasmid), and then which colonies contain recombinant plasmids with the target DNA and which contain non-recombinant plasmids

158 AREA OF STUDY 1 | WHAT IS THE ROLE OF NUCLEIC ACIDS AND PROTEINS IN MAINTAINING LIFE?


CASE STUDY ANALYSIS

Determining blood groups for successful transfusion

The first successful human-to-human blood transfusion is reported to have occurred in the 1800s. At that time, a blood transfusion was a risky procedure. It might help a patient, but it could also make them much worse. This is because human blood groups (ABO) were not discovered until 1901 and the idea that transfusions should be matched to the recipient's blood group was not suggested until 1907.

The A and B blood type antigens are carbohydrate molecules attached to proteins and lipids in the red blood cell membrane. The structure of the carbohydrate makes the A antigen different from the B antigen. If the blood type transfused into a patient is different from the patient's own blood type, an immune response will be elicited by the patient's immune system. Antibodies will recognise the transfused blood cells as foreign and will bind to their antigens. This causes clumping (or agglutination) of red blood cells (Figure 8.1.2). Agglutination destroys the red blood cells, which normally transport oxygen throughout the body, and so can result in severe anaemia and even death.

The presence or absence of A and B antigens on the surface of red blood cells determines whether the blood group is A, B or AB. Group O blood has neither A nor B antigens on the surface of red blood cells (Table 8.1.1). If the blood type transfused into a patient is different from the patient's own blood type, an immune response may be elicited by the patient's immune system, which can lead to death.

FIGURE 8.1.2 Agglutination test: red blood cells have clumped together (or agglutinated) in the left and middle drops of blood on the microscope slide. The drop of blood on the right of the microscope slide has not agglutinated.

An individual who presents at a hospital today with serious bleeding will receive a safe, antigen-matched transfusion. Blood group matching is a fairly simple and quick procedure in which antibodies to the blood proteins are mixed with samples of the patient's blood in order to identify the correct blood group for transfusion. The antibodies for antigen A are called 'anti-A' and the antibodies for antigen B are called 'anti-B'. The matching antibody and antigen are never found in the same individual and when they are mixed, the blood will agglutinate (clump together).

TABLE 8.1.1 The four different blood groups, as determined by the presence or absence of A and B antigens

Blood type	Red blood cells	Antibodies present in plasma	Antigens present on cells
A		anti-B	A
B		anti-A	B
AB		none	A and B
O		anti-A and anti-B	none

Analysis

A patient has presented to the emergency department of the local hospital needing a blood transfusion. The plates below show the results of the test carried out to determine the patient's blood group.

Anti-A Anti-B

1 What is the patient's blood group?
2 How do you know?
3 What blood groups could be used for the patient's transfusion?

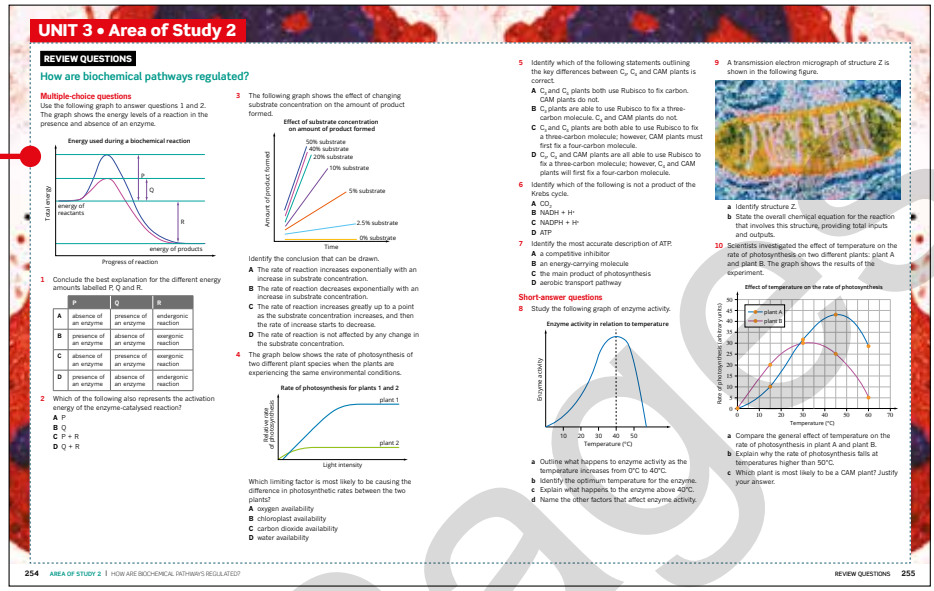
CHAPTER 8 | RESPONDING TO ANTIGENS 265

Case study: Analysis

These case studies include real-world data that can be analysed and evaluated.

Area of Study review

Each area of study concludes with a comprehensive set of exam-style questions, including multiple choice and short answer, to support you in your exam preparation.



UNIT 3 • Area of Study 2

REVIEW QUESTIONS

How are biochemical pathways regulated?

Multiple-choice questions

Use the following graph to answer questions 1 and 2. The graph shows the energy levels of a reaction in the presence and absence of an enzyme.

Energy used during a biochemical reaction

Total energy

energy of reactants

P

Q

R

energy of products

Progress of reaction

1 Conclude the best explanation for the different energy amounts labelled P, Q and R.

	P	Q	R
A	absence of an enzyme	presence of an enzyme	endergonic reaction
B	presence of an enzyme	absence of an enzyme	exergonic reaction
C	absence of an enzyme	presence of an enzyme	exergonic reaction
D	presence of an enzyme	absence of an enzyme	endergonic reaction

2 Which of the following also represents the activation energy of the enzyme-catalysed reaction?

A P
B Q
C P + R
D Q + R

3 The following graph shows the effect of changing substrate concentration on the amount of product formed.

Effect of substrate concentration on amount of product formed

Amount of product formed

50% substrate
40% substrate
20% substrate
10% substrate
5% substrate
2.5% substrate
0% substrate

Time

Identify the conclusion that can be drawn.

A The rate of reaction increases exponentially with an increase in substrate concentration.
B The rate of reaction decreases exponentially with an increase in substrate concentration.
C The rate of reaction increases greatly up to a point as the substrate concentration increases, and then the rate of increase starts to decrease.
D The rate of reaction is not affected by any change in the substrate concentration.

4 The graph below shows the rate of photosynthesis of two different plant species when the plants are experiencing the same environmental conditions.

Rate of photosynthesis for plants 1 and 2

Relative rate of photosynthesis

plant 1

plant 2

Light intensity

Which limiting factor is most likely to be causing the difference in photosynthetic rates between the two plants?

A oxygen availability
B chloroplast availability
C carbon dioxide availability
D water availability

5 Identify which of the following statements outlining the key differences between C_3, C_4 and CAM plants is correct.

A C_4 and C_3 plants both use Rubisco to fix carbon. CAM plants do not.
B C_3 plants are able to use Rubisco to fix a three-carbon molecule. C_4 and CAM plants do not.
C C_3 and C_4 plants are both able to use Rubisco to fix a three-carbon molecule; however, CAM plants must first fix a four-carbon molecule.
D C_3, C_4 and CAM plants are all able to use Rubisco to fix a three-carbon molecule; however, C_4 and CAM plants will first fix a four-carbon molecule.

6 Identify which of the following is not a product of the Krebs cycle.

A CO_2
B $NADH + H^+$
C $NADPH + H^+$
D ATP

7 Identify the most accurate description of ATP.

A a competitive inhibitor
B an energy-carrying molecule
C the main product of photosynthesis
D aerobic transport pathway

Short-answer questions

8 Study the following graph of enzyme activity.

Enzyme activity in relation to temperature

Enzyme activity

Temperature (°C)

a Outline what happens to enzyme activity as the temperature increases from 0°C to 40°C.
b Identify the optimum temperature for the enzyme.
c Explain what happens to the enzyme above 40°C.
d Name the other factors that affect enzyme activity.

9 A transmission electron micrograph of structure Z is shown in the following figure.

a Identify structure Z.
b State the overall chemical equation for the reaction that involves this structure, providing total inputs and outputs.

10 Scientists investigated the effect of temperature on the rate of photosynthesis on two different plants: plant A and plant B. The graph shows the results of the experiment.

Effect of temperature on the rate of photosynthesis

plant A
plant B

Rate of photosynthesis (arbitrary units)

Temperature (°C)

a Compare the general effect of temperature on the rate of photosynthesis in plant A and plant B.
b Explain why the rate of photosynthesis falls at temperatures higher than 50°C.
c Which plant is most likely to be a CAM plant? Justify your answer.

254 AREA OF STUDY 2 | HOW ARE BIOCHEMICAL PATHWAYS REGULATED?

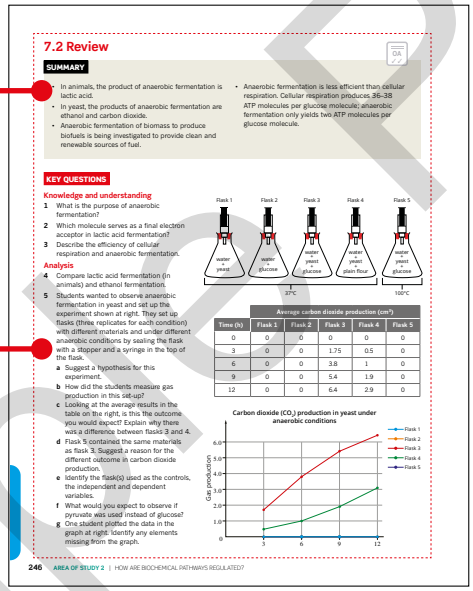
REVIEW QUESTIONS 255

Section summary

Each section includes a summary to help you consolidate key points and concepts.

Section review

Each section concludes with questions that test your ability to recall, explain and apply key concepts.



7.2 Review

SUMMARY

- In animals, the product of anaerobic fermentation is lactic acid.
- In yeast, the products of anaerobic fermentation are ethanol and carbon dioxide.
- Anaerobic fermentation of biomass to produce biofuels is being investigated to provide clean and renewable sources of fuel.
- Anaerobic fermentation is less efficient than cellular respiration. Cellular respiration produces 36–38 ATP molecules per glucose molecule; anaerobic fermentation only yields two ATP molecules per glucose molecule.

KEY QUESTIONS

Knowledge and understanding

1 What is the purpose of anaerobic fermentation?
2 Which molecule serves as a final electron acceptor in lactic acid fermentation?
3 Describe the efficiency of cellular respiration and anaerobic fermentation.

Analysis

4 Compare lactic acid fermentation (in animals) and ethanol fermentation.
5 Students wanted to observe anaerobic fermentation in yeast and set up the experiment shown at right. They set up flasks (three replicates for each condition) with different materials and under different anaerobic conditions by sealing the flask with a stopper and a syringe in the top of the flask.
a Suggest a hypothesis for this experiment.
b How did the students measure gas production in this set-up?
c Looking at the average results in the table on the right, is this the outcome you would expect? Explain why there was a difference between flasks 3 and 4.
d Flask 5 contained the same materials as flask 3. Suggest a reason for the different outcome in carbon dioxide production.
e Identify the flask(s) used as the controls, the independent and dependent variables.
f What would you expect to observe if pyruvate was used instead of glucose?
g One student plotted the data in the graph at right. Identify any elements missing from the graph.

Flask 1: water + yeast
Flask 2: water + glucose
Flask 3: water + yeast + glucose
Flask 4: water + yeast + plain flour
Flask 5: water + yeast + glucose

37°C
100°C

Time (h)	Average carbon dioxide production (cm³)				
	Flask 1	Flask 2	Flask 3	Flask 4	Flask 5
0	0	0	0	0	0
3	0	0	1.75	0.5	0
6	0	0	3.8	1	0
9	0	0	5.4	1.9	0
12	0	0	6.4	2.9	0

Carbon dioxide (CO_2) production in yeast under anaerobic conditions

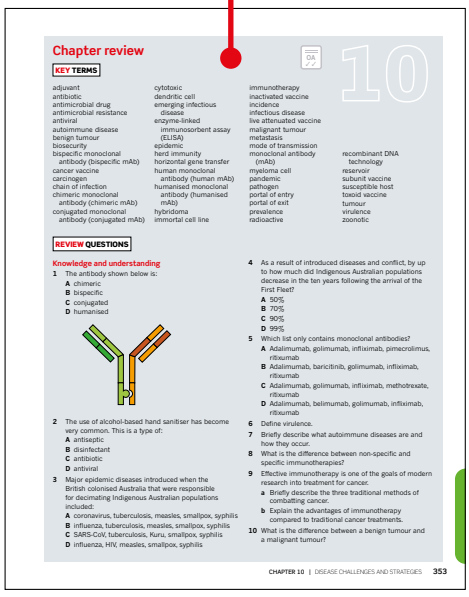
CO_2 production

Flask 1
Flask 2
Flask 3
Flask 4
Flask 5

246 AREA OF STUDY 2 | HOW ARE BIOCHEMICAL PATHWAYS REGULATED?

Chapter review

Each chapter concludes with a list of key terms and questions that test your understanding of the key knowledge covered in the chapter.



Chapter review

10

KEY TERMS

adjuvant
antibiotic
antimicrobial drug
antimicrobial resistance
antiviral
autoimmune disease
benign tumour
biosecurity
bispecific monoclonal antibody (bispecific mAb)
cancer vaccine
carcinogen
chain of infection
chimeric monoclonal antibody (chimeric mAb)
conjugated monoclonal antibody (conjugated mAb)
cytotoxic
dendritic cell
emerging infectious disease
enzyme-linked immunosorbent assay (ELISA)
epidemic
herd immunity
horizontal gene transfer
human monoclonal antibody (human mAb)
humanised monoclonal antibody (humanised mAb)
hybridoma
immortal cell line
immunotherapy
inactivated vaccine
incidence
infectious disease
live attenuated vaccine
malignant tumour
metastasis
mode of transmission
monoclonal antibody (mAb)
myeloma cell
pandemic
pathogen
portal of entry
portal of exit
prevalence
radioactive
recombinant DNA technology
reservoir
subunit vaccine
susceptible host
toxoid vaccine
tumour
virulence
zoonotic

REVIEW QUESTIONS

Knowledge and understanding

1 The antibody shown below is:
A chimeric
B bispecific
C conjugated
D humanised

2 The use of alcohol-based hand sanitiser has become very common. This is a type of:
A antiseptic
B disinfectant
C antibiotic
D antiviral

3 Major epidemic diseases introduced when the British colonised Australia that were responsible for decimating Indigenous Australian populations included:
A coronavirus, tuberculosis, measles, smallpox, syphilis
B influenza, tuberculosis, measles, smallpox, syphilis
C SARS-CoV, tuberculosis, Kuru, smallpox, syphilis
D influenza, HIV, measles, smallpox, syphilis

4 As a result of introduced diseases and conflict, by up to how much did Indigenous Australian populations decrease in the ten years following the arrival of the First Fleet?
A 50%
B 70%
C 90%
D 99%

5 Which list only contains monoclonal antibodies?
A Adalimumab, golimumab, infliximab, pimecrolimus, rituximab
B Adalimumab, baricitinib, golimumab, infliximab, rituximab
C Adalimumab, golimumab, infliximab, methotrexate, rituximab
D Adalimumab, belimumab, golimumab, infliximab, rituximab

6 Define virulence.
7 Briefly describe what autoimmune diseases are and how they occur.
8 What is the difference between non-specific and specific immunotherapies?
9 Effective immunotherapy is one of the goals of modern research into treatment for cancer.
a Briefly describe the three traditional methods of combatting cancer.
b Explain the advantages of immunotherapy compared to traditional cancer treatments.
10 What is the difference between a benign tumour and a malignant tumour?

CHAPTER 10 | DISEASE CHALLENGES AND STRATEGIES 353

Icons

This icon is used to alert you to engage with auto-corrected questions through Pearson Places.

These icons indicate when it is the best time to engage with a worksheet (WS), a practical activity (PA) or exam questions (EQ) in *Heinemann Biology 2 Skills and Assessment* book.

Glossary

Key terms are shown in **bold** throughout, and listed at the end of each chapter. A comprehensive glossary at the end of the book defines all key terms.

Answers

Comprehensive answers for all section review, chapter review and Area of Study review questions are provided via *Heinemann Biology 2 Reader+* 6th edition.