SACE ONE - AUSTRALIAN CURRICULUM

BIOLOGY

WORKBOOK
SECOND EDITION

ALAN CRIERIE
DAVID GREIG
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Essentials education
ADELAIDE TUITION CENTRE

PUBLISHING INFORMATION

This Workbook is part of the Essentials series, designed to support the teaching of SACE Stage 1 and 2 subjects in South Australia. It is specially designed to meet the requirements of the SACE Stage 1 Australian Curriculum Biology Subject Outline.

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To the Reader,

This 'Essentials Education' Biology Workbook has been written by a team of South Australian senior Biology teachers with many decades of experience writing books and many more decades teaching in the classroom. It is part of a series of Workbooks that have been written for both SACE Stages 1 and 2 Biology, Chemistry and Physics courses. The following three pages outline some of the key features of this book so that teachers and students can make the best possible use of it.

Book structure

The book contains a diverse array of information, illustrations, online resources, questions, assignments and investigations which provide a rich resource and will suit a wide variety of learning styles within a classroom and possibly between different schools.

Each Topic is divided into a number of Chapters and each Chapter follows a standard layout which will soon become apparent to the reader. The main body of each Chapter consists of written information, illustrations and online resources to support particular Science Understanding.

What have you learned?

At the end of each Chapter there are questions and questions for students to do, as directed by their teacher:

Key Terms

Throughout each Chapter can be found words that are semi-bold, these are listed at the end of the chapter as 'Key Terms' to be defined by the student. These terms are also included in the *Glossary* near the back of the book for reference, and also in the Index at the back of the book.

Knowledge and Understanding

Application, Analysis and Evaluation

The exercises and questions at the end of each Chapter are classified as above (i.e. K&U, A,A&E), no doubt your teacher will suggest which of these questions you should do.

Chapter Answers and Laboratory Notes

At the end of each Topic, suggested answers to the Chapter Exercises and Laboratory Notes for the Science Inquiry Skills (SIS) Practicals are provided for reference as required.

Test Yourself

At the end of each Topic a comprehensive 'Test Yourself' consisting of Exam-style questions, is provided for student use. It is recommended that students should do this under test conditions as revision before a summative Topic Test in the classroom. Again, suggested marks and answers are provided, immediately following the Test questions. All of these questions have been written and classified according to the SACE Assessment Design Criteria as shown in the 'Assessment Key' on the last page of the Test.

Within each Chapter are a number of different types of 'Boxes'

Helpful Online RESOURCES and Videos

Within each chapter can be found 'Helpful Online Resources' including Videos that can be accessed using a QR code for which an App on a mobile phone, computer or tablet will be required. Some of these resources include:

- Helpful websites, including *YouTube videos*, that are recommended by the authors
- *Essentials Video Animations* (EVA) which illustrate important biological processes that are part of this course

The EVAs can also be accessed directly from our website using:

<https://essentialseducation.com.au/online-resources/>, or by scanning this QRC.

Information Boxes

These Boxes provide illustrative material and examples to support the Science Understanding in the *SACE Subject Outline*. Often helpful online resources will also be suggested and QR codes provided.

C 'Capabilities' Boxes

An important aspect of this course is the opportunity to develop various ***Capabilities*** which are identified in the *SACE Subject Outline*. The authors have done so, both implicitly as part of the text or other activities and explicitly (i.e. maroon pages like this) with additional information and examples, usually with an opportunity for student response.

Your teacher will decide which of these you need to do and if and how they are to be assessed. These are summarised on the following page and more detail is in the Appendix.

? 'Science Inquiry Skills' Boxes

The *SACE Subject Outline* specifies certain *Science Inquiry Skills (SIS)* and knowledge that are an integral part of this course. Many of the chapters include activities (i.e. orange pages like this) that can be done in class to develop these skills. Comprehensive Laboratory Notes are provided at the end of each Topic, they are intended mainly for reference by staff.

Again your teacher will decide which of these you do and how they are to be assessed. These are summarised on the following page and more detail is in the Appendix.

'Science as a Human Endeavour' Boxes

The *SACE Subject Outline* also specifies certain key concepts within *Science as a Human Endeavour (SHE)* and how they are related to this course. The authors have developed a number of activities (i.e blue pages like this) to help students develop and understand these concepts; these are highlighted as a heading in each Box.

Again, your teacher will decide which of these you do and if and how they are to be assessed. These are summarised on the following page and more detail is in the Appendix.

You will also notice that there are symbols in the margin to indicate where these various 'Boxes' are related to the text in each Chapter. A summary page is provided opposite and more details can be found in the Appendix at the end of this Workbook.

Appendix

This section can be found towards the back of the book and contains a variety of resources that will be useful for teachers, laboratory staff and students. This includes summary tables for the various knowledge and skills, support materials for 'Science Inquiry Skills', 'Science as a Human Endeavour' and 'Capabilities' and a comprehensive Glossary with all Key Terms and Practical Terms and an Index.

As you can appreciate, many hundreds of hours have been spent writing and collating this Biology Workbook for your use and we have enjoyed doing it.

We trust that you will find it useful in your learning and we welcome any comments that you may have for future editions; these can be forwarded to us via the website <www.adelaidetuition.com.au> or directly using <reception@adelaidetuition.com.au> or calling us on 08 8241 5568.

Kindest regards,

Alan Crierie, David Greig, Simon Ruthven

(The Authors)

September 2019

Capabilities

L= Literacy, N = Numeracy, ICT = Information and communication technology capability, CCT = Critical and creative thinking, PS = Personal and social capability, EU = Ethical understanding, IU = Intercultural understanding

Science Inquiry Skills

IAE1 = Deconstruction of a problem and design of a biological investigation.

IAE2 = Obtaining, recording, and representation of data, using appropriate conventions and formats.

IAE3 = Analysis and interpretation of data and other evidence to formulate and justify conclusions.

IAE4 = Evaluation of procedures and their effect on data.

KA4 = Communication of knowledge and understanding of biological concepts and information.

Science as a Human Endeavour

CC = Communication and Collaboration, D = Development, I = Influence, AL = Application and Limitation

Chapter	Capabilities							Science Inquiry Skills					Human Endeavour			
	L	N	ICT	CCT	PS	EU	IU	IAE1	IAE2	IAE3	IAE4	KA4	CC	D	I	AL
Topic 1																
1.1	●	●							●	●		●		●		
1.2		●			●				●	●			●			
1.3			●						●	●		●		●		
1.4																●
1.5	●	●			●				●	●	●					
1.6	●			●	●											
1.7	●				●		●	●				●	●			
Topic 2																
2.1										●						
2.2	●	●			●				●	●		●			●	
2.3		●				●			●	●						●
2.4	●			●	●							●				●
2.5																
2.6	●								●							
2.7			●										●			
2.8		●			●		●	●							●	
Topic 3																
3.1	●												●			
3.2						●			●	●		●				●
3.3	●	●			●				●	●	●			●		
3.4		●							●							●
3.5			●		●					●		●		●		
3.6		●					●		●			●			●	
3.7	●			●	●				●	●		●		●		
3.8		●			●			●								
Topic 4																
4.1					●				●	●		●				●
4.2	●		●													
4.3																
4.4	●	●			●				●	●	●	●				
4.5												●				●
4.6		●							●							●
4.7	●	●								●		●				●
4.8	●	●			●	●		●								

Further details are provided in the General Appendix on pages 466-482.

Table of Contents

Author Profiles

Alan Crierie (B.Sc., Dip.Ed.)

Alan has been involved with the Adelaide Tuition Centre for over 30 years as both an author and tutor. He has worked as an author of many Textbooks, Workbooks and Practical manuals, supporting Science and Biology students in South Australia. He is also a past Chairperson of the Biology Subject Advisory Committee at SSABSA (now SACE). He has experience teaching Biology in both State and Independent schools for 40 years and currently is at St Michael's College where he has taught senior Biology for the last 12 years.

David Greig (B.Sc., Dip. Ed., Dip. T., G.C.S.E.)

David has taught mainly Junior Science and Senior Biology in South Australian Secondary schools for nearly 40 years. For the past 25 years or so, he has worked as an author, editor, publisher and consultant on a variety of Science and Biology publishing projects at state, national and international level. In particular, he has been involved with the writing and publication of the Stage 2 Biology Practical Manual (1995-2016) and various editions of Stage 1 and 2 Essentials Biology and Psychology Textbooks and Workbooks in South Australia.

Simon Ruthven (B.Sc., Dip.Ed.)

Simon graduated from the University of Adelaide in 1985 with a B.Sc., in Zoology and Botany and obtained his Dip.Ed. there in 1988. He has 30 years of experience teaching Biology and Science in independent schools, including five years in Victoria and nearly ten years in London in the UK. Simon has taught SACE Stage 1 and 2 Biology, as well as Biology for the IB Diploma, and is author and co-author of six books including this one. His interests include developing in students Capabilities to equip them for life in a changing world and providing opportunities for them to experience Science as a Human Endeavour. Simon has been Head of Science at Immanuel College since 2013 and lives in the Adelaide Hills.

All of the authors trust that these materials will assist and even inspire, in some small ways, the next generation of biology students and biologists.

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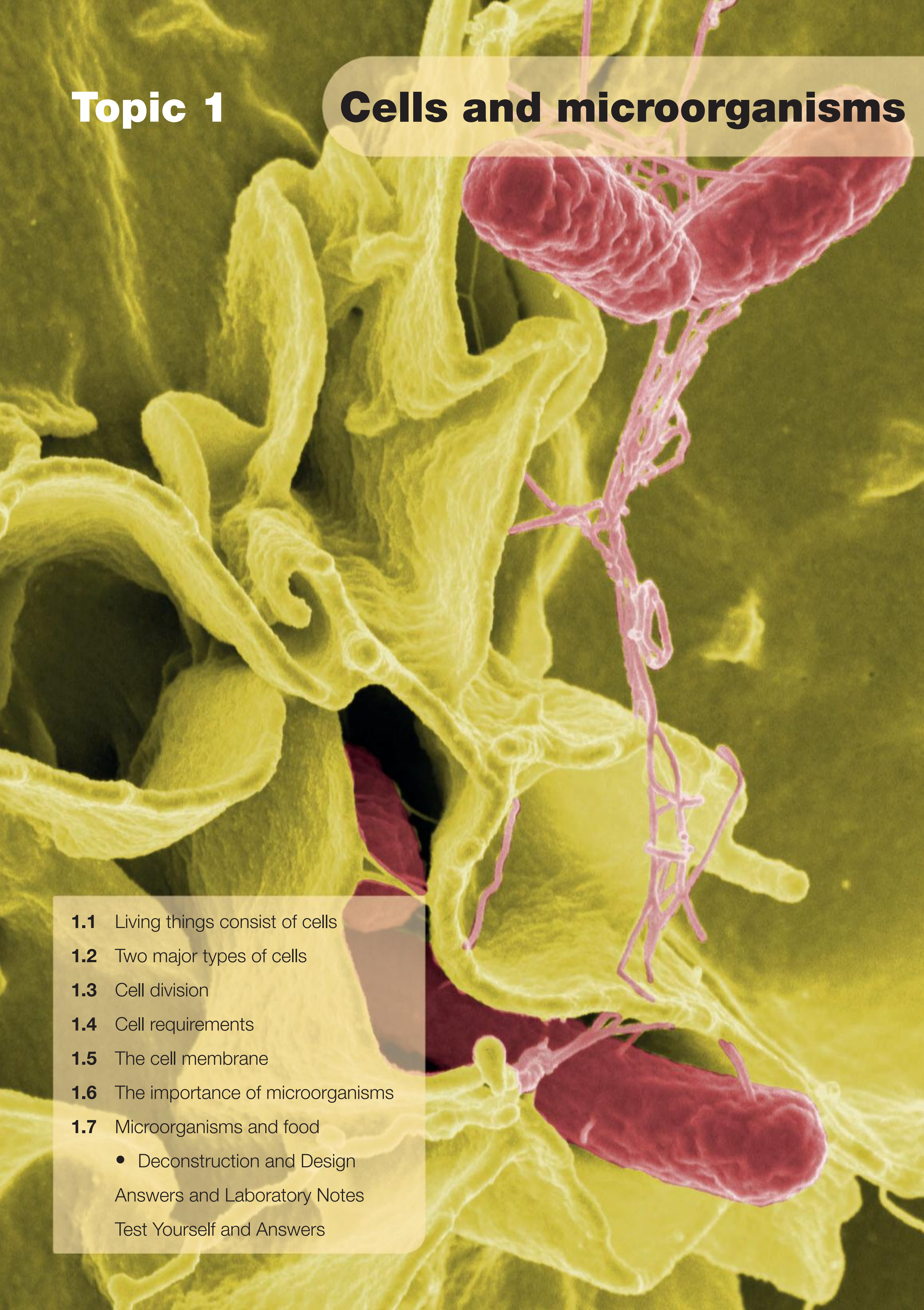
SACE for permission to use extracts and adaptations of the Biology Course Outline

'Science Photo Library' in London for their assistance with images (*refer Figure Credits*)

Our friends and families for their patience and support



Topic 1 Cells and microorganisms

Chapter 1.1 Living things consist of cells

Science Understanding

Living things are distinguishable from non-living things.

The cell theory unifies all living things.

Living things are made up of one or more cells.

Cells:

- are the structural and functional units of life
- come from pre-existing cells
- contain hereditary material.

The cell is the smallest independent unit of life.

The cell membrane defines a cell; it separates the cell from its surroundings.

Living things

The Earth is the only place known to sustain life. The term 'life' refers to the vast diversity of living things that inhabit the planet. The scientific study of living things is called biology. Scientists who study living things are called biologists.

But what exactly is a living thing?

One way to define living things is to ask what makes living things alive. To most biologists, something is alive if it carries out fundamental processes associated with life called life processes. All living things carry out these same fundamental life processes. The main processes, together with examples are shown in the following table.

Life Process	Example
Maintaining a stable internal environment	Humans sweating on a hot day
Controlled exchange of materials	Plants taking in carbon dioxide and giving out oxygen in daylight hours
Response to **stimuli**	Birds migrating for the winter
Obtaining energy and chemical elements	Reptiles catching, killing and consuming prey
Transport of materials	Blood in fish carrying oxygen to muscle cells
Removal of waste	Human kidneys producing urine
Cell division	A fertilised ovum dividing many times to form an embryo
Growth and development	A caterpillar gradually changing into a butterfly
Independent movement	A koala climbing a tree
Reproduction	A bacterium dividing to produce two daughter cells

An **organism** is the name given to a living thing. Organisms can be **unicellular** (made up of one **cell**) or **multicellular** (made up of many cells), sometimes many billions, even trillions of cells. It has been estimated that there are about 35 trillion cells in an adult human being.

The cell is the fundamental or basic unit of life. It is often stated that the cell is the unit of structure and function of organisms. As such, the cell is the smallest independent unit of life that can carry out life's processes.

Cell types

Multicellular organisms consist of large numbers, sometimes trillions, of cells of different types. The different cells are structured differently, some types of animal and plant cells are shown in *Figure 111* below. *Please note that the cells and structures are not drawn to the same scale. Figure 112* illustrates how the human body is made up of many different cell types including red blood cells, nerve cells and muscle cells.

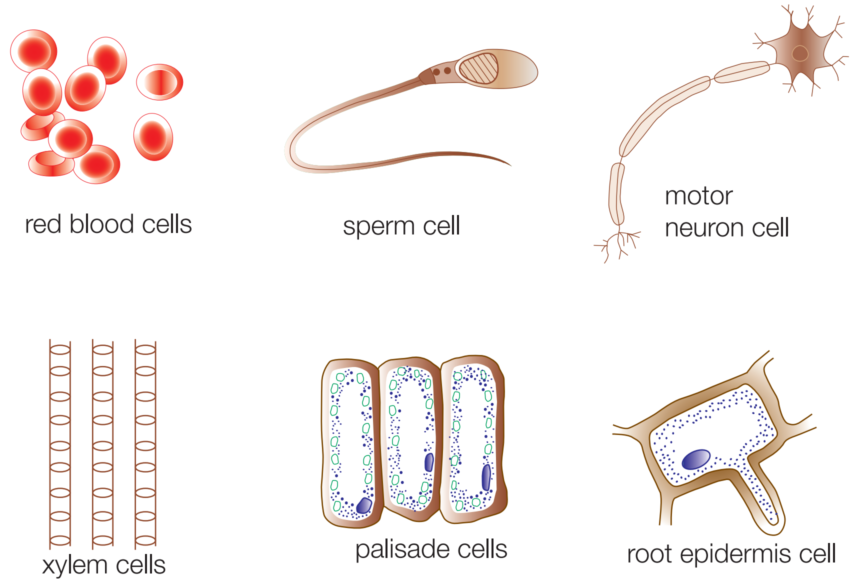


Figure 111(a),(b),(c) Some animal cells & Figure 111(d),(e),(f) Some plant cells *Figure 112 Some human cells*

The Cell Theory

The cell theory states that:

- all organisms consist of cells or the products of cells.
- all cells come from pre-existing cells by the process of **cell division**.
- cells are the building blocks of life.

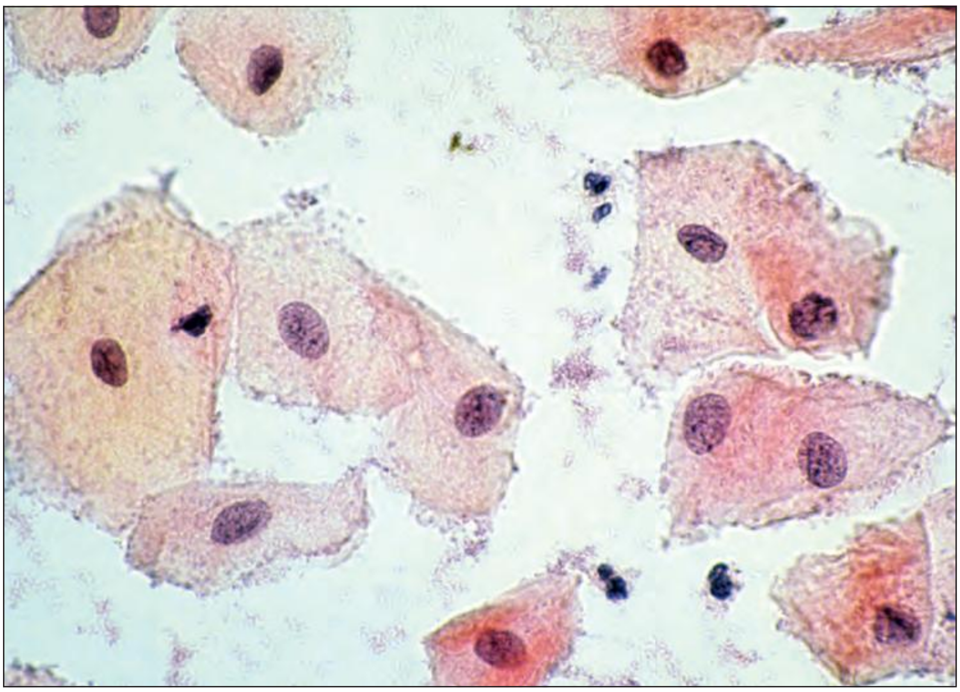


Figure 113 Human cheek cells

Cells

Cells consist of a volume of fluid enclosed by a membrane. The membrane is called the cell membrane and the enclosed fluid is called the **cytoplasm**. The cytoplasm is mostly made up of water in which substances are dissolved and some insoluble proteins. In animal and plant cells the cytoplasm also has structures in it called membrane-enclosed **organelles** that have specific functions; for example a **nucleus** that controls the overall function of the cell. Example of cheek cells are shown in *Figure 113 (light microscope ~x800)*.

Unicellular organisms

Living things that consist of one cell only are called unicellular organisms; for example, bacteria (singular bacterium), fungi like yeasts, protists like amoeba, and algae (singular alga); for example, phytoplankton. *Figures 114(a),(b),(c)* and *(d)* show images of some common unicellular organisms, no uniform scale is used.

Figure 114 (a) Amoeba, (b) Bacteria, (c) Paramecium, (d) Euglena

Multicellular organisms

Living things that consist of large numbers of cells are called multicellular organisms; for example, mushrooms, animals and plants. *Figure 115 (a)-(h)* shows some images of a variety of multicellular organisms, no uniform scale is used.

Figure 115 (a)-(h) A variety of multicellular organisms

Helpful Online RESOURCE to learn more about the location

These organisms, photographed by an associate of one of the authors, all live together somewhere in the world, can you work out where?

If you wish, scan this QR code to learn more.

Cells and DNA

All cells contain the chemical **DNA** (deoxyribonucleic acid) found in special structures called **chromosomes**. This is a very special chemical that enable cells to:

- make important molecules like proteins for cellular function.
- divide and produce new cells.

Heredity is defined as the passing on of characteristics genetically from one generation to the next. It is the chemical DNA (found in the nucleus of cells in multicellular organisms) that is responsible for passing on this **genetic material** from parent to offspring.

Chromosomes in cells of multicellular organisms

DNA is found in the nucleus of cells of multicellular organisms. DNA is a very long macromolecule; molecules called histones are usually associated with DNA. A human cell may contain about 2 metres of DNA and the total length of DNA in a human body is hundreds of thousands of kilometres. Such a long molecule can fit into a space as small as a nucleus by being packed into structures called chromosomes. *Figure 116* illustrates how these various components are organised. This matter will be more thoroughly discussed in Topic 3.

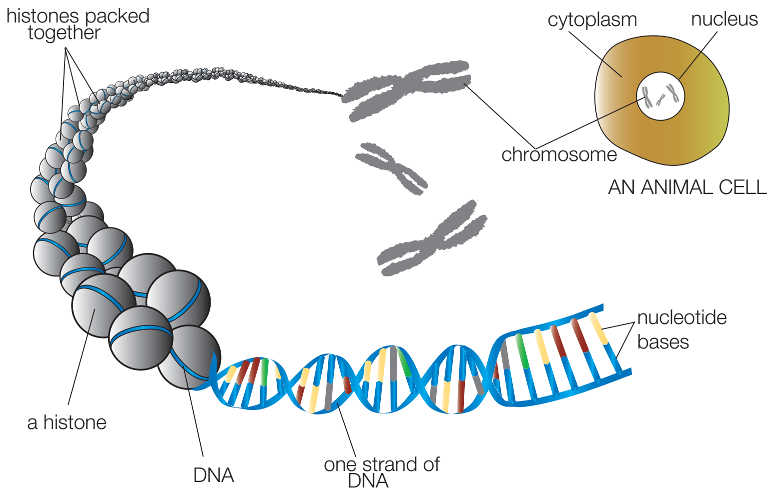


Figure 116 Chromosomes and DNA

The Cell Membrane

The **cell membrane** is a structure found in all cells; it defines a cell and separates the cell from its surroundings. The cell membrane is found in all living cells and controls the entry and exit of materials in and out of the cell. The membrane is a thin layer (0.01µm) consisting of two layers of **phospholipid** molecules with embedded proteins. Refer to *Figure 117* which a computer graphic illustrating the cell membrane. The dual phospholipid bilayer is clearly visible.

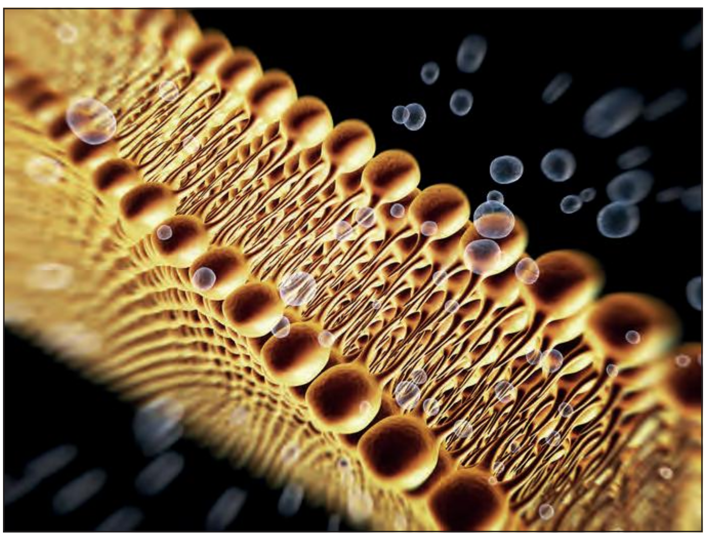


Figure 117 A model of a cell membrane

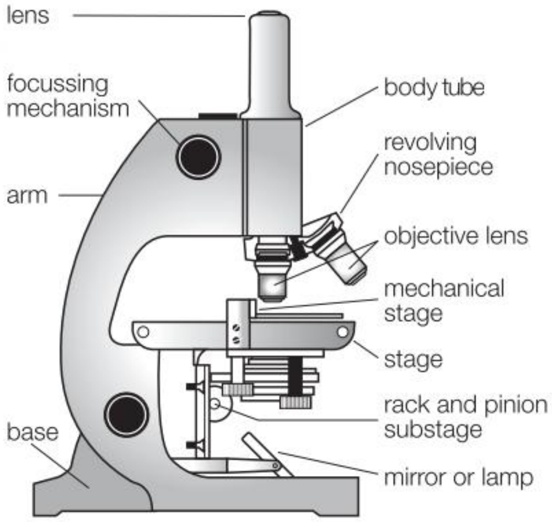
The model used to describe the structure and function of the cell membrane is now known as the '**Fluid-mosaic' model**.

Fluid: This part of the terminology refers to the ability of both the lipids and proteins to move sideways within the membrane structure. The membrane relies on the fluid nature to carry out its functions.

Mosaic: The term mosaic refers to the pattern of **protein molecules** that are either embedded into or attached to the phospholipid bi-layer. It is these proteins that mainly determine the function of the cell membrane.

The light microscope

An instrument that is used to produce a much bigger (or magnified) image of what is viewed is called a microscope. The type of microscope students use in school laboratories is called a light microscope. What is viewed using a light microscope is called the specimen. Light microscopes are able to magnify up to about 1500×. A photograph (*Figure 118(a)*) and a diagram (*Figure 118(b)*) of a light microscope are shown below and you will probably have the opportunity to use one of these in the laboratory to examine cells and other structures.



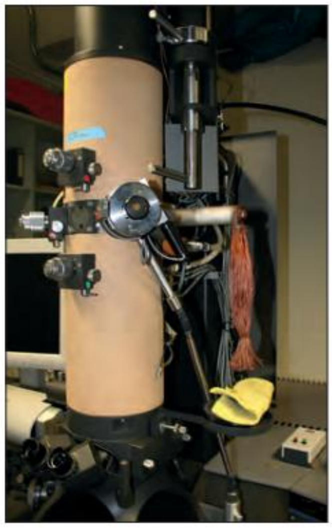


Figure 118(a) A photograph of a microscope

Figure 118(b) A labelled drawing of a microscope

Figure 119 An electron microscope

The electron microscope

This is a very specialised microscope that uses a beam of electrons to provide images with a high degree of resolution enabling the user to see inside the workings of a cell.

Using an electron microscope it is possible to see images of structures magnified tens or even hundreds of thousands of times. A photograph of an electron microscope is shown in *Figure 119*. A scanning electron microscope (SEM) can produce 3D images whereas an transmission electron microscope (TEM) can not.

Key Concepts

1. All life forms have a number of distinguishing processes that identify them from nonliving things.
2. Cell theory states that all living organisms are made up of cells and the products of cells and that cells come from pre-existing cells.
3. Cells are the unit of structure and function in all living organisms.
4. Cells contain DNA which is the molecule of heredity.
5. All organisms are either unicellular or multicellular.
6. All cells have a cell membrane which defines them.

What have you learned?

Key Terms

cell
cell membrane
Fluid-mosaic model
organism
heredity
DNA
protein molecules
genetic material
chromosome
stimuli
cell division
cytoplasm
nucleus
unicellular
multicellular
organelle
micrometre
phospholipid

Knowledge and Understanding

1. Describe three life processes performed by all forms of life.
2. Explain, giving examples the difference between a unicellular and multicellular organism.
3. State three features of the cell theory.
4. Cells vary in size, give an example of:
   a) very small cell in the human
   b) a large cell in the human
5. "Most cells are microscopic", explain the meaning of this statement.

6. State 2 functions of the cell membrane.

7. State why specimens observed using a light microscope must be very thin.

8. State two properties of the molecule DNA that explain why it is found in virtually all forms of life.

1. Explain why the cell is described as the unit of structure and function in a multicellular organism.

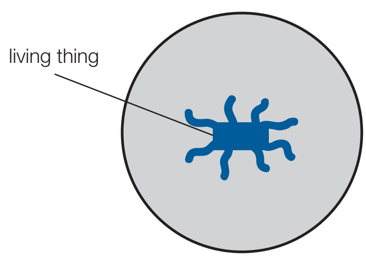
Application, Analysis and Evaluation

10. A student found a scaly leafy type structure growing on a rock surface. Describe two pieces of evidence they could collect or observe to enable them to determine if this was a living organism.

11. An indoor plant near a window has all of its leaves facing the window. Suggest why.

12. A student was examining two sets of photographs one taken with a light microscope and the other with an electron microscope. Explain the evidence to the student that would enable them to determine which one was which.

13. If the diameter of the field of view is 1200μm, estimate the length of the 'living thing' shown in this diagram. (N.B. 1000μm = 1mm)



14. Refer to the table below of some typical sizes of cells to answer the questions that follow:

Cell	Human skin cell	Bacteria	Human ovum	amoeba
Approx size	50 µm	2 µm	0.12 mm	50 µm

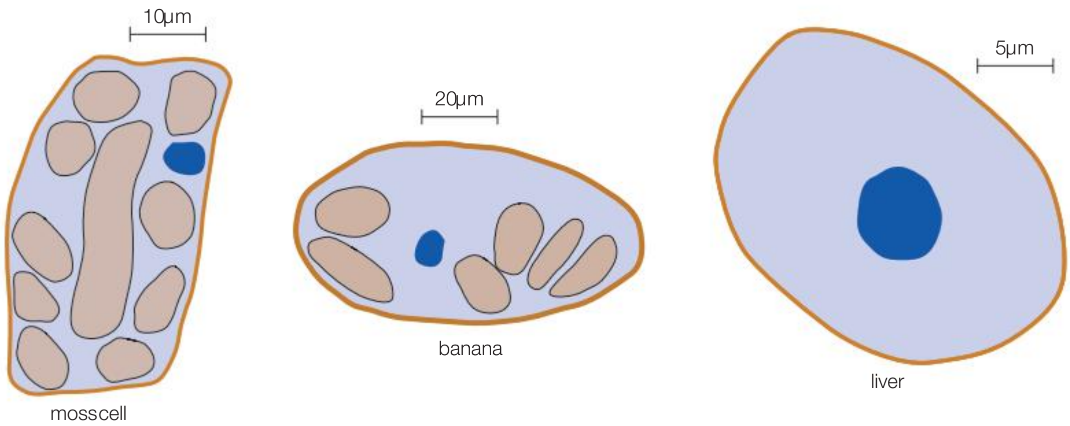
HINT: A length of one millimetre is equal to 1000 µm (or 1µm = 1/1000 mm = 0.001 mm).

a) Which is bigger? An amoeba or an ovum? Approximately how many times bigger?

b) How many times bigger is an ovum than a skin cell?

c) Approximately how many *E. coli* bacteria would fit across a human skin cell?

15. The diagrams below show three types of cells. Use the scale bars to select the longest cell and explain your reasoning.



Helpful Online RESOURCE about cell sizes

To learn more about cell size use this QR code to visit:
<http://sciencenetlinks.com/tools/cell-size-and-scale/>

Science Inquiry Skills 1.1 - Using a microscope

Introduction

All organisms are made up of cells and the products of cells. In this investigation students need to learn or revise some basic skills using a light microscope that can then enable them to make slides from tissue and observed cells and their basic cellular structures. This activity involves using a light microscope to estimate the field of view and observe cells.

Materials

Light microscope

Mini grid

Clean microscope slide

Sharp pencil

Pair of sharp scissors

Clear sticky tape

Method

Part A: Estimating the diameter of the field of view

1. Obtain a microscope and transport it carefully to a bench – ensure one hand supports the base.
2. Turn on the light and adjust the iris diaphragm to form a clear 'circle of light'.
3. Put a mini grid in the centre of the stage and secure it with the stage clips.
4. Adjust the coarse focus until the 4× lens and stage are brought as close together as possible.
5. Look through the eyepiece and adjust the coarse focus until the mini grid comes into view.
6. Adjust the fine focus slowly until the large squares with 1mm sides come into sharp focus.
7. Use the mini grid to estimate the diameter of field of view at this magnification (i.e. 40×).
8. Establish a magnification of 100× and estimate the diameter of field of view at 100×.
9. Establish a magnification of 400× and estimate the diameter of field of view.
10. Draw a table to record the diameter of field of view at 40×, 100× and 400× magnification.

Part B: Viewing a specimen

1. Obtain a microscope slide.
2. Pluck a single hair from your head.
3. Use the scissors to carefully cut a section of the hair about 1cm from the root end.
4. Cut another section of the hair about 1cm from the tip.
5. Place the two sections of hair onto the microscope slide and fix in place with a piece of sticky tape. Ensure the tape used is not marked with fingerprints, and that any 'excess tape' is trimmed not wrapped round the slide.
6. Use the microscope to view the pieces of hair at 40× magnification.
7. Adjust the microscope to view the pieces of hair at 100× magnification, and then 400×.

Science Inquiry Skills 1.1 - Using a microscope (continued)

8. Draw a diagram of one of the pieces of hair. Include the magnification and a title for the drawing.

Analysis

1. Why are both coarse and fine focus needed to bring a specimen into full focus?

2. What happens to the diameter of the field of view as the magnification increases?

3. Does the structure of the hair near the root differ from the structure near the tip? If so, in what way?

4. Compare the structure of your hair with that of two other students (and possibly your teacher (?)) in the class

Helpful Online RESOURCE about using a microscope

To learn more about using a microscope you can view a video, although this microscope may be different to the one you use in class.

<https://www.udel.edu/biology/ketcham/microscope>

Science as a Human Endeavour 1.1 - The cell theory

Development

New technologies ... can reveal new evidence that ...

A theory is a collection of ideas used to explain something. The theory used to explain the existence of cells and living matter consisting of them is called the cell theory.

Before the mid-17th century, living matter was thought to arise spontaneously from non-living matter (refer to the drawing which shows spontaneous generation of bees from a dead cow). The discoveries by ***Robert Hooke*** in 1665 (cork is made up of units he termed 'cells') and A***ntony van Leeuwenhoek*** in 1676 (pond water was full of moving cells or 'animalcules') initially did little to displace this theory. Cells and microscopic life developed spontaneously as well. According to this 'free cell formation' idea, cells simply crystallised into existence.

This included bacteria (probably first observed by *van Leeuwenhoek* in 1683).

By the 1830s, microscopic instruments and techniques had improved sufficiently to provide evidence that cells were tiny bags of fluid, each one a separate unit. Observations by *Robert Burn* in 1831 showed that cells of plant leaves also contained a concentration of material, soon to be called the nucleus. After viewing tissues of many plant species, *Mathias Schleiden* then published work in 1838 stating that all plants are made up of cells. This was followed a year later by Theodore Schwann whose own microscopic studies of animal tissue showed that all animals consist of cells. This prompted the idea that all life consisted or one or more cells.

In 1852, the work done by *Robert Remak* led to him making his now famous statement 'Omnis cellula e cellula' (all cells come from other cells). This and the 1858 book by *Rudolf Virchow* 'Die Cellular-pathologie' provided the final pieces of evidence that living matter did not arise from non-living matter. Nor did cells arise from a free cell formation process. Thereafter, and to this day, the existence of cells and living matter is understood to be a product of cell division, as explained by the cell theory.

Science as a Human Endeavour 1.1- The cell theory (continued)

You may need to refer to the online resources below to answer the questions that follow:

1. New technologies can reveal new evidence that may led to the replacement of theories. What piece of technology provided evidence that ultimately yielded the cell theory, and what were some of those pieces of evidence?

2. Walther Flemming's work improved understanding of the nucleus and what happens in the nucleus in mitotic cell division. What structures in the nucleus did he discover in 1879, and what was he first to conclude in 1882 happens to the nucleus of a dividing cell?

3. What technologies in the 20th century further advanced our understanding of cells?

N.B. In this and all other Activities and Assignments your teacher will advise you how to present your answers, whether in these spaces or separate paper or on screen.

Helpful Online RESOURCE about the development of the cell theory

To learn more about the development of the cell theory view the clip below:

<https://www.youtube.com/watch?v=4OpBylwH9DU>

Helpful Online RESOURCE about German scientist *Walther Flemming*

To learn more about the work of Walther Flemming view the clip below:

<https://en.wikipedia.org/wiki/Walther_Flemming>

Chapter 1.2 Two major types of cells

Science Understanding

The major cell types are:

- prokaryotic
- eukaryotic.

Prokaryotic and eukaryotic cells have many features in common (a reflection of their common evolutionary past). These features include:

- cell membrane
- nucleic acids
- proteins
- ribosomes.

Prokaryotic cells lack internal membrane-bound organelles, do not have a nucleus, are significantly smaller than eukaryotic cells, and usually have a single circular chromosome.

- Compare the structure of prokaryotes and eukaryotes.

Prokaryotes

The first organisms to inhabit the earth were most probably the prokaryotes. The cells of all bacteria are **prokaryotic** and come in a variety of shapes; spheres (cocci), rods (bacilli) and spirals (spirilli). Virtually all prokaryotes are unicellular and small, approximately 0.5-5 micrometres *(N.B. 1000 micrometres=1 mm*). *Refer to Chapter 1.7 for more details.*

Prokaryotic cells have existed for millions of years, they are relatively unspecialised and are defined by the fact that they do not have a nucleus.

Despite the fact that they are small and relatively unspecialised they are well organised and possess all of the necessary chemicals and processes that enable them to carry out all of life's processes.

Prokaryotes have the ability to adapt to a vast range of habitats, their collective mass is considered to be many times that of all of the eukaryotes.

Prokaryotic cells

The cells of all bacteria are called prokaryotic cells. Prokaryotic cells usually:

- Have a cell wall that surrounds the cell membrane.
- Carry DNA in the cytoplasm where it is organised into a single circular chromosome.
- Contain simple sub-cellular components that lack a membrane; for example, ribosomes.
- Exist as single cells, or are unicellular.

The structure of a bacterium as a typical example of a generalised prokaryotic cell is shown in *Figure 121*.

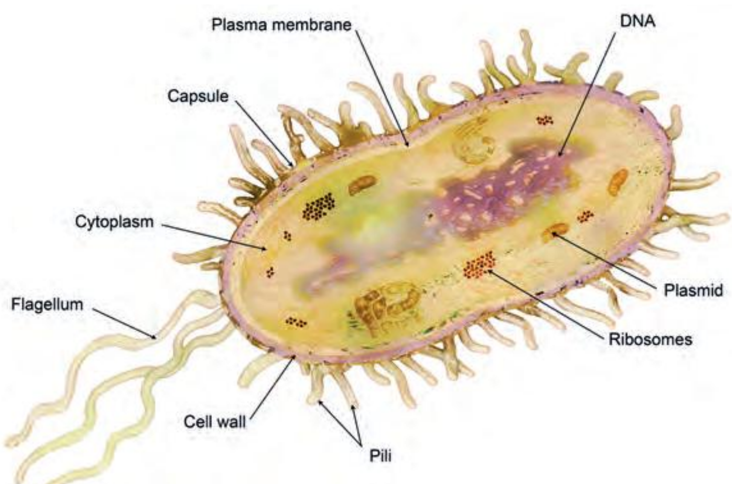


FIgure 121 The structure of a generalized prokaryotic cell

Some bacteria have structures in addition to the ones shown in *Figure 121*. These may include:

- A layer of sticky material that covers the cell wall called a capsule
- Hair-like structures that project from the cell wall called pili (singular pilus)
- Filaments attached to the cell wall called flagella (singular flagellum)
- Small loops of DNA in the cytoplasm that are separate from the chromosome called plasmids.

The shape of prokaryote cells varies considerably. The most common shapes of prokaryote cells are:

- Rods
- Spheres
- Spirals.

The different shapes of prokaryote cells occur singly, in pairs or in chains of many cells. Chains of prokaryote cells may be straight or coiled.

Figure 122 shows a single rod-shaped prokaryote cell with pili and flagella (left) and some spherical and spiral-shaped prokaryote cells without them (right). The contents of the spiral prokaryotes are not shown.

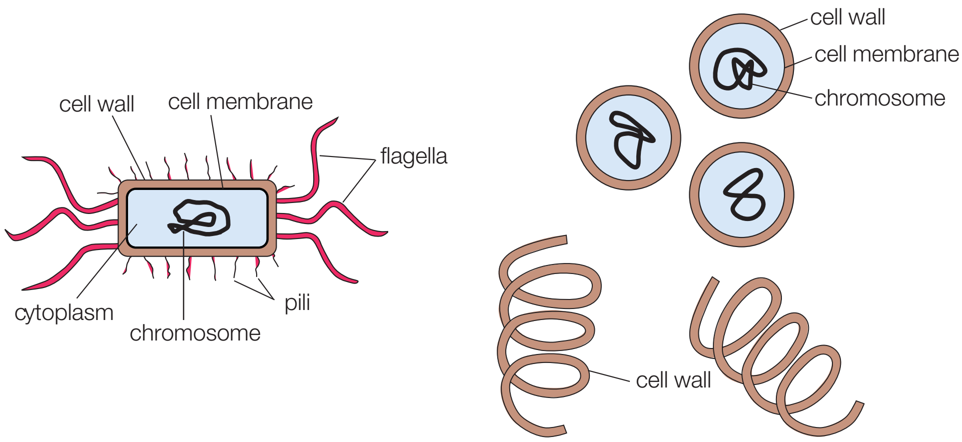
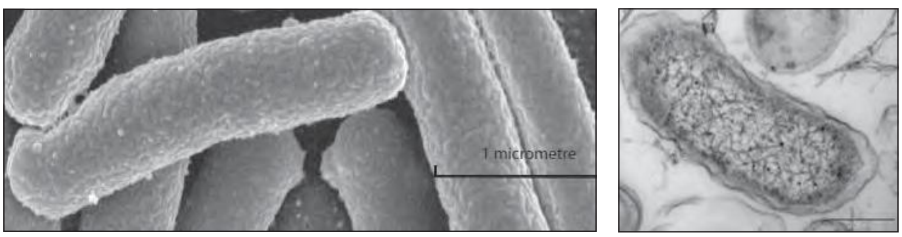


Figure 122 Some single rod-shaped prokaryotic cells

The different parts of a prokaryote cell have different functions as shown in the following table:

The part	**Function**
Cell wall	To strengthen the cell and to help maintain its shape
Cell (plasma) membrane	To control the exchange of materials between a cell and its external environment
Cytoplasm	To provide a medium suitable for biochemical reactions to take place
Ribosome	To synthesise proteins for the cell
Chromosome	To carry genetic instructions for the cell
Capsule and pilus	To allow the cell to stick to a surface or to other prokaryotes
Flagellum	To allow the cell to move

Figures 123(a) and (b) show electron micrographs of several prokaryotic cells with a scale bar.



Figures 123(a) and (b) Electron micrographs of several prokaryotic cells

Eukaryotes

Eukaryotes are all of the organisms that have cells with a nucleus and well-defined organelles. Protists, fungi, and all plants and animals are eukaryotes.

Eukaryotic cells

Eukaryotic cells usually:

- Carry DNA in a nucleus where it is organised into a set of linear chromosomes.
- Contain a variety of sub-cellular components called membrane-enclosed organelles.
- Exist with large numbers of similar cells (in animals/plants) but may exist as single cells (in protists).
- Are significantly larger than prokaryote cells.

Figure 124 shows the structure of a typical eukaryote cell from an animal. Typical cellular structures and organelles are labelled.

Although animal and plant cells are both eukaryote cells, their structure differs in several ways. These include:

- Plant cells have a cell membrane surrounded by a cell wall; animal cells do not.
- Plant cells have a small number of large, permanent vacuoles; animal cells do not.
- Plant cells may carry membrane-enclosed organelles called **chloroplasts**; animal cells do not.

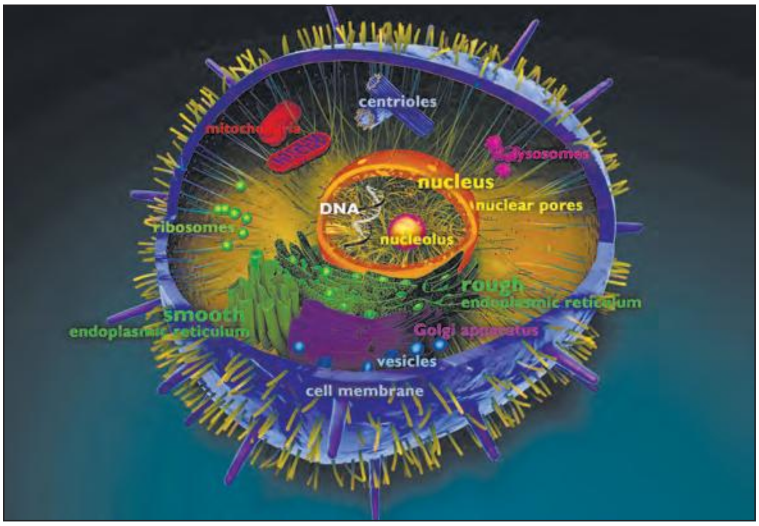


Figure 124 The structure of a typical animal cell

Figure 125 shows the structure of a typical eukaryote cell from a plant. Typical cellular structures and organelles are labelled.

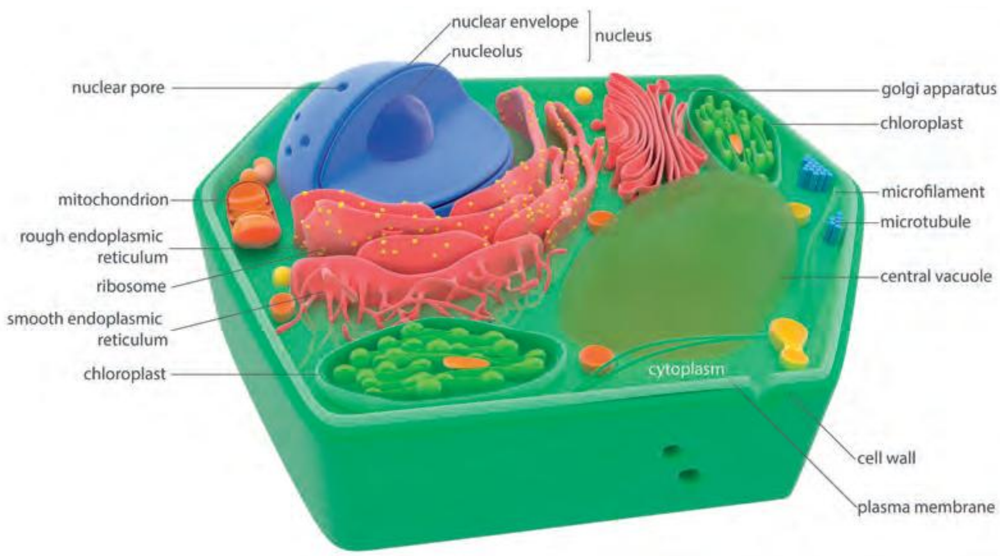


Figure 125 The structure of a general plant cell

The membrane-enclosed organelles in eukaryote cells have a variety of functions. These include:

- Making important biological molecules; for example, proteins.
- Performing biochemical reactions; for example, aerobic cell respiration and photosynthesis.
- Secretion (or release) of substances made by the cell; for example, proteins.
- Removal of wastes; for example, carbon dioxide.

The following table shows the functions of the different parts of eukaryote cells and some membrane-enclosed organelles.

The part	**Membrane-enclosed?**	**Function**
Cell wall	No	To strengthen the cell and to help maintain its shape
Cell membrane	No	To control the exchange of materials between the cell and its external environment. To facilitate inter-cellular communication between cells
Cytoplasm	No	To provide a medium suitable for biochemical reactions to take place
Ribosome	No	To synthesise proteins for the cell or for secretion from the cell
Nucleus (pl. nuclei)	Yes	To store the genetic information/DNA (deoxyribo **nucleic acid**). To control (or coordinate) its overall function
Rough endoplasmic reticulum	Yes	To package proteins made by ribosomes into small vacuoles for transport to a Golgi body (with ribosomes attached to it).
Smooth endoplasmic reticulum	Yes	To package proteins made by ribosomes into small vacuoles for transport to a Golgi body (i.e. no ribosomes attached)
Golgi body **(or apparatus)**	Yes	To package proteins sent to them into small vacuoles for transport to the cell membrane for secretion from the cell
Mitochondrion (pl. mitochondria)	Yes	To carry out aerobic respiration to produce an energy-carrying molecule called ATP which cells use for energy-requiring processes
Vacuole	Yes	To maintain cell shape and to store water and ions (large permanent ones) To transport substances within cells (small temporary ones)
Chloroplast	Yes	To carry out photosynthesis to produce organic molecules using simple inorganic ones

Images and drawings of some organelles found in eukaryotic cells are shown in *Figures 126*, *127* and *128*.

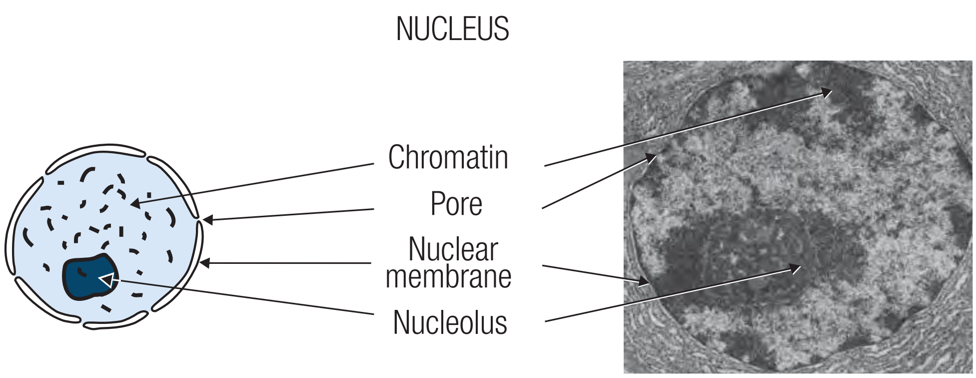


Figure 126 Diagram and electron micrograph of a nucleus

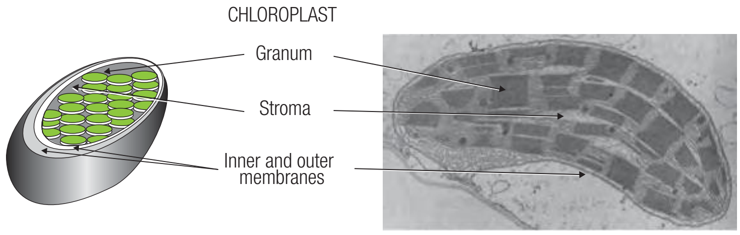


Figure 127 Diagram and electron micrograph of a chloroplast

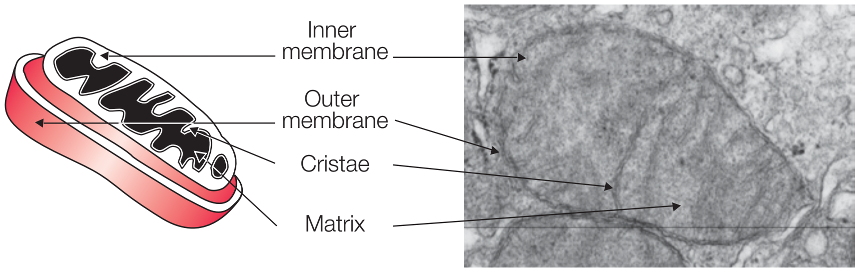


Figure 128 Diagram and electron micrograph of a mitochondrion

Key Concepts

1. There are two major categories of cell types, eukaryotic and prokaryotic.
2. Prokaryotic cells are smaller and less specialised than eukaryotic cells.
3. Prokaryotic cells do not contain membrane-bound organelles.
4. It is thought that eukaryotic cells evolve from prokaryotic cells and thus they share common features such as cell membrane, nucleic acids, proteins and ribosomes.

What have you learned?

Key Terms

prokaryotic
eukaryotic
nucleic acids
ribosomes
Golgi body
vacuole
mitochondrion
rough endoplasmic reticulum
smooth endoplasmic reticulum
chloroplast
plasmid

1.2

Knowledge and Understanding

1. Complete this table for a prokaryotic cell in as much detail as possible.

Organelle	Structural feature(s)	Special function(s)
Ribosome		
Cell wall		
Cell membrane		
Chromosomes		

2. Complete this table for organelles found in plant and animal cells.

Organelle	In plant/animal?	Structural features	Special functions
Nucleus			
Golgi bodies			
Mitochondria			
Chloroplasts			
Vacuoles			
Endoplasmic reticulum (smooth)			

3. Name the features that eukaryotic and prokaryotic cells have in common.

4. Describe two differences between prokaryotic and eukaryotic cells.

5. Identify the parts of a eukaryotic cell listed below that are not membrane-enclosed organelles:
Golgi body, nucleus, cell membrane, mitochondrion, ribosome

Application, Analysis and Evaluation

6. Prokaryotic cells do not contain membrane-enclosed organelles. How is it possible for them to grow, divide and make energy available?

....

....

....

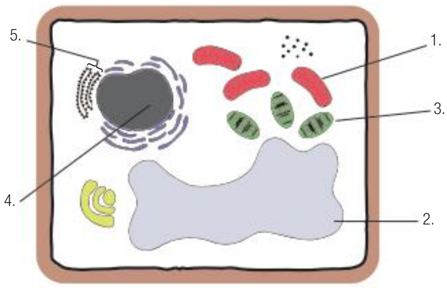
7. Not all cells, as we have seen, have the same structures or functions. Likewise, they do not necessarily have similar numbers of particular organelles. Suggest where types of cells containing large numbers of the following organelles would be found:

   a) mitochondria ....

   b) chloroplasts ....

   c) Golgi bodies ....

8. The adjacent diagram shows the structure of a palisade cell in a leaf. Some of its organelles are labelled 1, 2, 3, 4, 5.



   a) Which of the organelles are also found in animal cells?

....

....

   b) In which organelle is aerobic respiration performed?

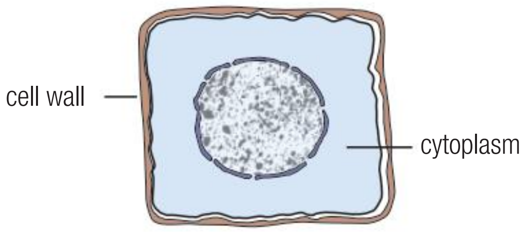
....

   c) What is the function of organelle 3?

....

....

9. The adjacent diagram shows a student's partly labelled drawing of a cell.



   a) Is the cell a prokaryotic cell or a eukaryotic cell?

....

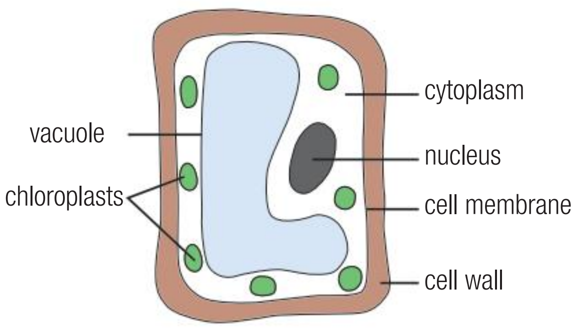
....

   b) Justify your decision.

....

....

10. The adjacent diagram shows a cell that is common in flowering plants. Gemma suggested the cell would be found in leaves. Discuss the evidence for this.



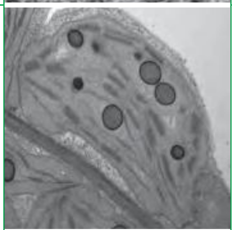
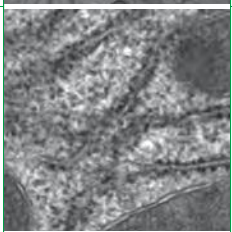
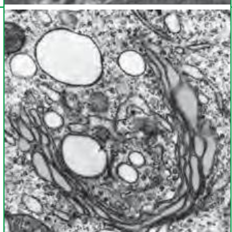
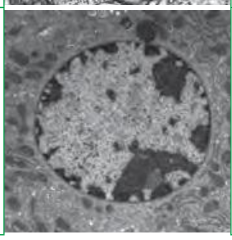
....

....

....

....

11. Complete the table below:

	Electron micrograph **(sizes not shown)**	**Name of organelle**	**Location in a plant or animal cell or both**	**Important structural features**	**Function**
A					
B					
C					
D					
E					

Science Inquiry Skills 1.2 - Observing cells

Introduction

Cells are the structural and functional units of living things. It is sometimes possible to use living materials and at other times it is better to use 'prepared' slides. From your observations of these and some electron micrographs, you will make some inferences about the structural organisation of some typical eukaryotic cells.

PART A OBSERVING CELLS

1. Use a light microscope to observe:
   a) plant and animal cells
   b) internal cellular structure

2. Compare the size of eukaryotic and prokaryotic cells and some typical organelles.
3. Recognise a range of organelles from electron micrographs: mitochondria, chloroplast, nucleus, endoplasmic reticulum and Golgi body.

Materials

Light microscope, Slides/cover slips, Teat pipette, Forceps, Tooth picks

Fresh materials, e.g.

- Geranium leaves or similar
- onion epidermis
- filamentous algae (*Spirogyra*)
- Stain – Methylene blue (see Lab Notes)

Prepared slides, e.g.

- leaf epidermis
- blood smears
- other mammalian tissue
- Stain – Iodine (see Lab Notes)

Method

1 Plant cells

Select 1 or 2 specimens from the following list of prepared or fresh slides.

- Geranium leaves or similar, Filamentous algae, Onion epidermis

Draw 1 or 2 cells and label structures/region of cells including: cell wall, cell membrane, cytoplasm, chloroplasts, and nucleus.

2 Animal cells

Select 1 or 2 specimens from the following list.

- Prepared blood slides
- Cheek cells stained with Methylene blue (see Lab Notes)
- Other animal cells from prepared slides

Draw 1 or 2 cells below and label structures regions including: cell membrane, cytoplasm, nucleus.

? Science Inquiry Skills 1.2 - Observing cells (continued)

Introduction

Eukaryotic cells are found in all animals, plants and protists and are typically quite specialised cells containing membrane bound organelles including the nucleus, mitochondria and chloroplast (plant cells only).

Prokaryotic cells, on the other hand, are typically smaller, less specialised cells without membrane bound organelles and are represented by unicellular organisms such as bacteria.

PART B ESTIMATING SIZES OF CELLS

To draw scale diagrams to represent relative differences in size between eukaryotic and prokaryotic cells and some typical organelles.

Typically cells are measured in units termed micrometres (μm)

1 mm = 1,000 μm.

Some average sizes of cells and organelles are listed below.

Cell / Organelle / Structure	Average size (μm)
Human red blood cell	7.5
Human cheek cell	60
Mesophyll cell	80-100
E. coli bacterium	2
Chloroplast	5
Mitochondria	1.5
Nucleus	5

In the space below draw rough shapes, drawn to scale size, to represent each of the structures from the table. Use the approximate scale: 1μm represents 1mm.

E. coli bacterium

Chloroplast

Mitochondria

Nucleus

Human red blood cell

Human cheek cell

Mesophyll cell

Science as a Human Endeavour 1.2 - *Antonie van Leeuwenhoek*

Communication and collaboration

Science is a global enterprise that relies on clear communication...

"My work which I've done for a long time, was not pursued in order to gain the praise I now enjoy, but chiefly from a craving after knowledge, which I notice resides in me more than in most other men. And therewith all, whenever I found out anything remarkable, I have thought it my duty to put down my discovery on paper, so that all ingenious people might be informed of thereof."

Antonie van Leeuwenhoek

Do some research on his work and answer the question in the spaces below or as required by your teacher.

1. Antonie van Leeuwenhoek was a pioneering scientist in microscopy and the discovery of the microscopic world. Briefly describe some advances in scientific knowledge that came about as a result of his work.

2. Explain, using the quotation above, that it was clear that van Leeuwenhoek was aware that collaboration and communication are essential in scientific discovery and progress.

Helpful Online RESOURCE about *Antonie van Leeuwenhoek*

This website will provide some useful information for this assignment:

<https://en.wikipedia.org/wiki/Antonie_van_Leeuwenhoek>

Chapter 1.3 Cell division

Science Understanding

In order to reproduce, cells need to copy their genetic material, and then divide to form two new (daughter) cells.

- Describe and represent binary fission in prokaryotic cells.
- Describe and represent mitosis.
- Compare binary fission with mitotic cell division in eukaryotic cells.

The purpose of cell division

New cells are formed by a process called cell division. The division of cells is fundamental to the continued life of all living things. This is because cell division:

- Permits genetic information (encoded in DNA) to be transmitted from generation to generation.
- Provides a way for multicellular organisms to grow and develop from a fertilised ovum.
- Makes new cells available in multicellular organisms to replace dead or damaged cells.
- Allows unicellular organisms to reproduce; for example, bacteria and *Amoeba*.

Figure 131 illustrates the way an *Amoeba* reproduces. Each new cell is a new fully functional *Amoeba*.

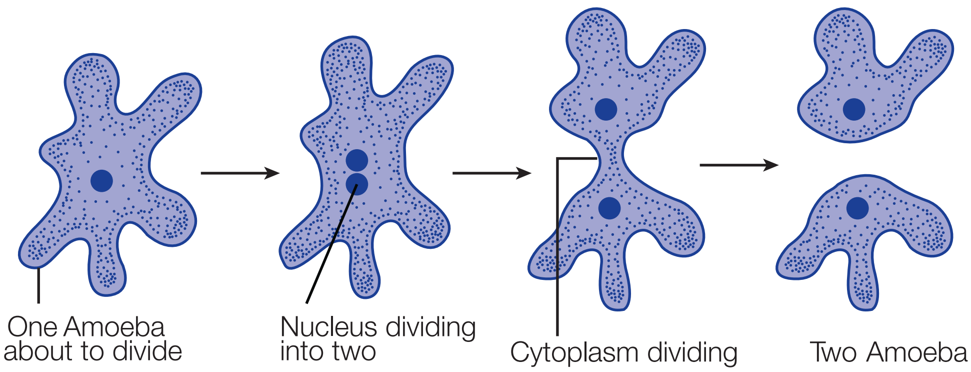


Figure 131 The method of reproduction of an Amoeba

Passing DNA from one generation of cells to the next

A cell that divides is called a parent cell. For a cell to divide to form two new functional cells of the same type, one copy of the parent cell's DNA must be passed to both new cells. To achieve this, three events need to take place.

These are:

- Copying of the parent cell's DNA. The copying of DNA is called **DNA replication**.
- The two copies of the DNA need to be moved to opposite ends of the parent cell.
- The parent cell must divide into two cells. These new cells are called daughter cells.
- Cells produced by this kind of cell division are genetically identical to their parent cell, and to each other.

Binary fission

Most unicellular organisms that are prokaryotes (or consist of a single prokaryotic cell) reproduce by a type of cell division called binary fission.

Prior to binary fission, the parent cell's DNA is replicated so that two copies of it exist. Thereafter, the events in **binary fission** include:

- The parent cell's DNA coils to form two identical circular chromosomes. This process is called condensation.
- Each chromosome attaches to the inside of the parent cell membrane.
- The two chromosomes are moved to opposite ends of the parent cell as it grows lengthways.
- The cell membrane of the parent cell grows inwards, and new cell wall is formed over the outside of it; both processes cause the parent cell to divide in two.
- The division of the parent cell is completed, resulting in two daughter cells.

Binary fission is illustrated in *Figures 132 (a) and (b).*

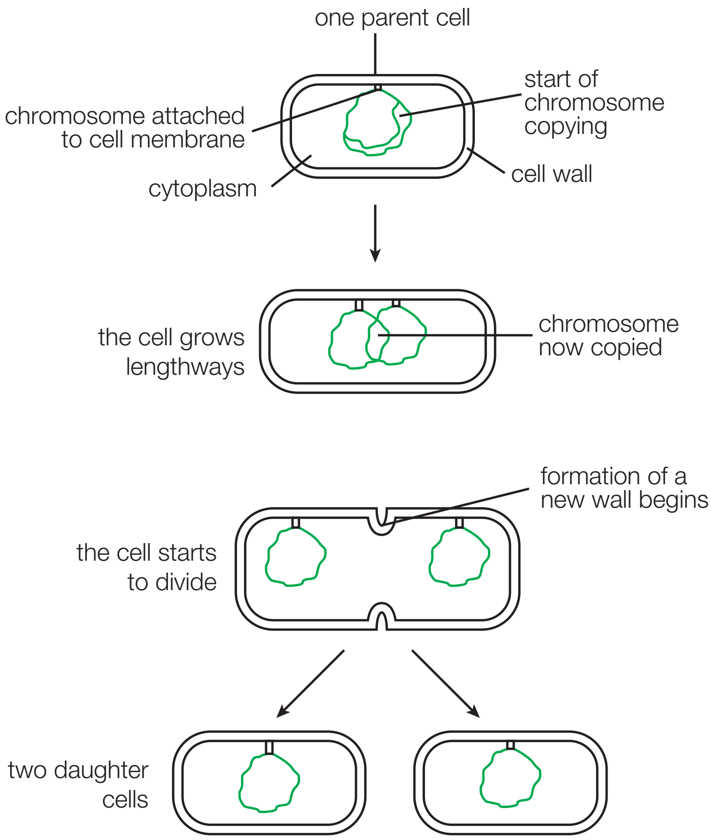


Fig 132 (a) Binary fission occurs in prokaryotic cells

Fig 132 (b) Binary fission occurs in prokaryotic cells (approx. 10000×)

Mitotic division

Most eukaryotic cells divide by a type of cell division called **mitotic division**.

This type of cell division is used by:

- Unicellular eukaryotes (or organisms consisting of a one eukaryote cell) to reproduce; for example, *Amoeba*.
- Multicellular organisms to grow and develop from a fertilised ovum, and to produce new cells to replace dead or damaged ones.

Prior to mitotic division, during **Interphase**, the parent cell's DNA is replicated so that two copies of it exist. Sometimes various stages of this process are identified as G1, S and G2 but the details are not needed here. Mitotic division ensues and is characterised by two distinct stages. These are:

- The two copies of the parent cell's DNA/chromosomes are separated and the nucleus divides in two to form two genetically identical nuclei. This stage is called **mitosis**.
- The cytoplasm divides in two to form two genetically identical cells. This stage is called **cytokinesis**.

Mitosis

Mitosis actually refers to the division of the nucleus in a eukaryotic cell. The process of mitosis consists of four distinct phases. These are:

- **Prophase**, during which the nuclear membrane of the parent cell breaks down and the already copied chromosomes condense and become visible under a microscope. Each chromosome consists of a pair of identical **chromatids** joined by a structure called a centromere. Also, long protein filaments called **spindle fibres** are assembled to form a structure called the spindle.
- **Metaphase**, during which the pairs of chromatids are gradually moved to the equator of the spindle by the spindle fibres.
- **Anaphase**, during which chromatid pairs are separated to form two identical sets of daughter chromosomes. Each daughter chromosome set is then moved to the poles of the spindle by the spindle fibres.
- **Telophase**, during which the spindle breaks down and the set of chromosomes at each pole of the spindle de-condense and become enclosed by a nuclear membrane.

Figures 133(a) and (b) illustrates mitosis in plant cells showing the 4 phases from left to right.

Interphase ***Prophase*** ***Metaphase*** ***Anaphase*** ***Telophase*** ***Cytokinesis***

Figure 133(a) A photo micrograph of the process of mitosis

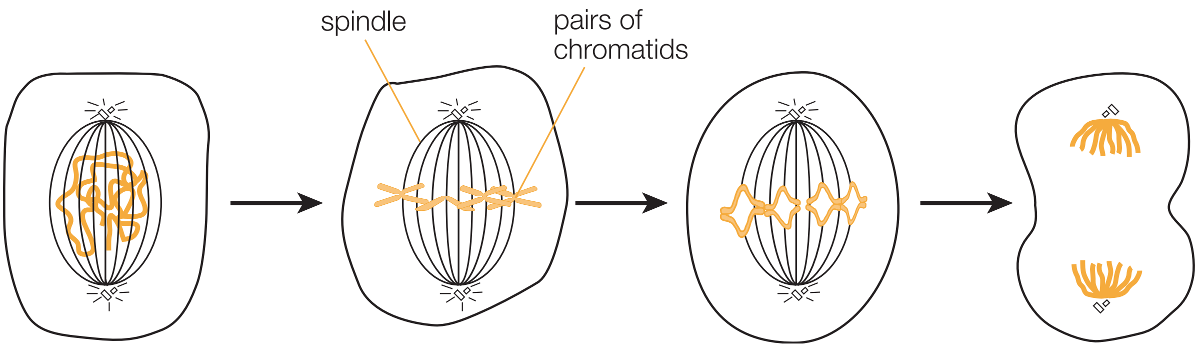


Figure 133(b) A diagram of the process of mitosis

Helpful Online RESOURCE about mitosis

To view an animation of mitosis, use this QR code to visit the website below. *You do not need to know all of the terms mentioned.*

<https://www.youtube.com/watch?v=AEt8V53oddA>

Helpful Online RESOURCE to view an EVA of mitosis

To view an Essentials Video Animation (EVA) on this topic use this QR code to visit:

<http://essentialseducation.com.au/resources/sace-1/biology/mitosis/>

Cytokinesis

The cytokinesis stage begins near the end of telophase in mitosis. In animal cells protein fibres in the cell membrane constrict to form an infolding called a cleavage furrow. Further constriction leads to the production of two genetically identical daughter cells. *Figure 134* illustrates the process of cytokinesis.

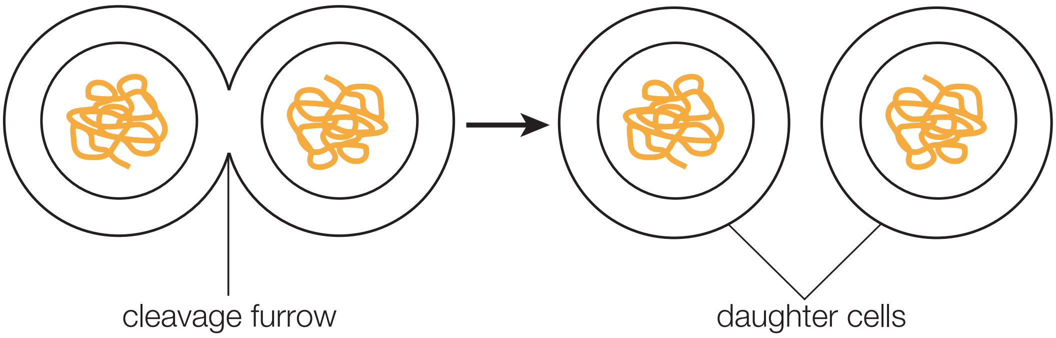


Figure 134 The process of cytokinesis

Diploid cells

The products of mitotic division (the daughter cells) and the cell they arose from (the parent cell) are called **diploid** cells. This is because they contain a full set of chromosomes. With the exceptions of sperm and ova, all human cells are diploid cells. In diploid cells, the chromosomes are in pairs. Each chromosome in the pair is the same in size and general structure. One chromosome originated from the mother, and is called the **maternal chromosome**; the other originated from the father, and is called the **paternal chromosome**. The two chromosomes that form the pair are called **homologous chromosomes.** This is shown in *Figure 135*

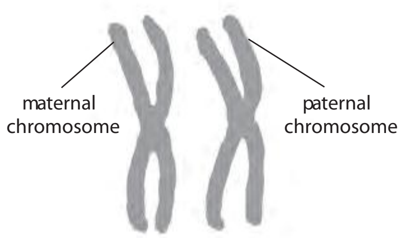


Figure 135 One pair of homologous chromosomes

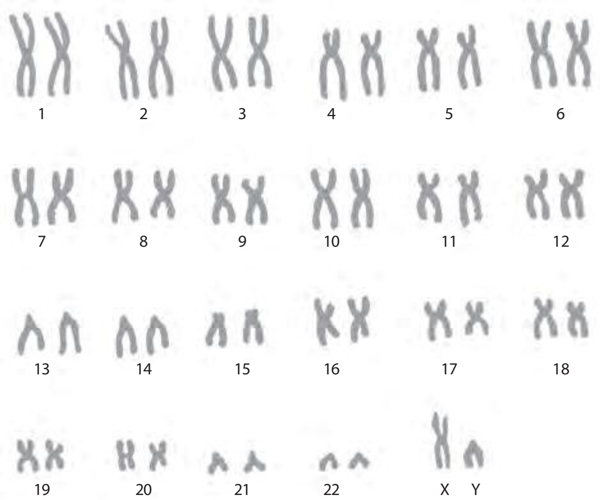


Figure 136 The karyotype of a human cell

Cancer

In the bodies of multicellular organisms there is a constant cycle of cells undergoing mitosis, then cytokinesis, to form new cells; for example, in the human body, inside bones, skin and major organs like the liver and kidneys. Sometimes the cycle of cell division can be disturbed; cells may divide in an uncontrolled way forming tumours, the general name for this disease is **cancer**. There are a number of factors that can increase the likelihood of cancer and there are also different treatments available.

Karyotyping

Diploid cells in humans carry 23 pairs of chromosomes; 22 pairs of homologous chromosomes, and one pair of sex chromosomes. This is called the **karyotype**. In females, the pair of sex chromosomes consists of two X chromosomes. In males, the pair of sex chromosomes consists of one X chromosome, and one Y chromosome. Photographing the different chromosomes and arranging them in numbered homologous pairs is called karyotyping. An example of karyotyping is shown in *Figure 136*, the cell has been obtained from a male because one X chromosome and one Y chromosome are present.

Haploid cells

Sperm and ova do not carry a full set of chromosomes. Instead, these cells have one chromosome from each homologous pair, which means they carry 23 chromosomes instead of 23 pairs of them. Cells that carry one set of chromosomes are called **haploid** cells. Haploid sperm and ova are also called gametes or sex cells.

Key Concepts

1. Cells use the process of DNA replication prior to cell division to make an identical copy of their DNA. Each daughter cell formed receives a full complement of DNA which is identical to the parent cell.
2. Prokaryotic cells divide by binary fission.
3. In prokaryotic cells a circular chromosome replicates and attaches to the cell membrane prior to the cell dividing into two new cells. Mitosis involves division of the nucleus to form two identical daughter cells.
4. Eukaryotic cells divide by mitotic division which involves division of the nucleus (mitosis) and division of the cytoplasm (cytokinesis).
5. Mitosis has four phases: Prophase, Metaphase, Anaphase and Telophase.
6. During anaphase in mitosis pairs of chromatids are separated and are moved by the spindle to opposite poles of the cell.
7. Chromosomes in eukaryotic cells are linear.

C ICT: *'My Skin Track UV'*

Regular exposure to sunlight is vital for good health. Ultraviolet radiation (UVR) in sunshine absorbed by bare skin enables skin cells to make vitamin D. Although obtained through eating certain foods (eggs, chicken, tuna, mushrooms), vitamin D production by the skin ensures blood levels remain at healthy levels. Vitamin D is essential for calcium absorption from the digestive system, and therefore bone, tooth and muscle growth, as well as proper functioning of the immune system and the nervous system.

Too much exposure to sunlight, however, is harmful. In the first instance, it causes reddening of the skin or 'sunburn'. Absorption of UVR by skin cells may damage their DNA that can lead to cancer-causing mutations. One of the body's safeguards against this is a response that involves DNA-damaged skin cells 'killing themselves' so as to prevent cancer developing. Blood vessels in the skin dilate (widen) to allow more blood to be moved into the region (making the skin look red) to transport white blood cells to breakdown the cells that died.

Long-term overexposure to UVR increases the risk of DNA damage occurring in genes that control mitotic division. This is very dangerous if these mutations occur in melanocytes, skin cells that produce a pigment called melanin that otherwise causes skin to darken or 'tan'. Melanocytes do not have a 'cell-death' response to UVR-caused DNA mutations, so if the mutation occurs in a mitotic division control gene, a melanocyte will begin to divide uncontrollably, eventually producing a 'mole' on the surface of the skin (*refer to the photo showing a melanoma approximately 1cm in diameter).* Although most moles are harmless, changes in the size, shape or colour of one can suggest melanoma is developing (skin cancer).

You may need to refer to the online resources below to answer the questions that follow.

1. A variety of environmental factors affect how much UVR is absorbed by a person's skin. List five of them, and identify the ones an individual can control on a daily basis.

2. A number of wearable technologies have been developed to inform a wearer about exposure to UVR. One is a clip-on gadget called *My Skin Track UV*. Describe how a person wearing this product may use it to reduce the risk of skin cancer.

Helpful Online RESOURCE about UV radiation

To learn more about UV radiation and cancer view the clip below:

<https://www.cancer.org.au/preventing-cancer/workplace-cancer/uv-radiation.html>

Helpful Online RESOURCE about *My Skin Track UV*

To learn more about My Skin Track UV view the clip below:

<https://www.youtube.com/watch?v=INmiVAQ7iko>

What have you learned?

Key Terms

binary fission

mitotic division

DNA replication

interphase

mitosis

chromatid

prophase

metaphase

anaphase

telophase

spindle fibres

cytokinesis

homologous chromosomes

maternal chromosome

paternal chromosome

cancer

karyotype

diploid

haploid

Knowledge and Understanding

1. Explain why the daughter cells produced by binary fission and mitosis are identical to the parent cell.

2. Describe in a short sentence and possibly a simple diagram for each phase what happens to the chromosomes in mitosis.

   a) Prophase

   b) Metaphase

   c) Anaphase

   d) Telophase

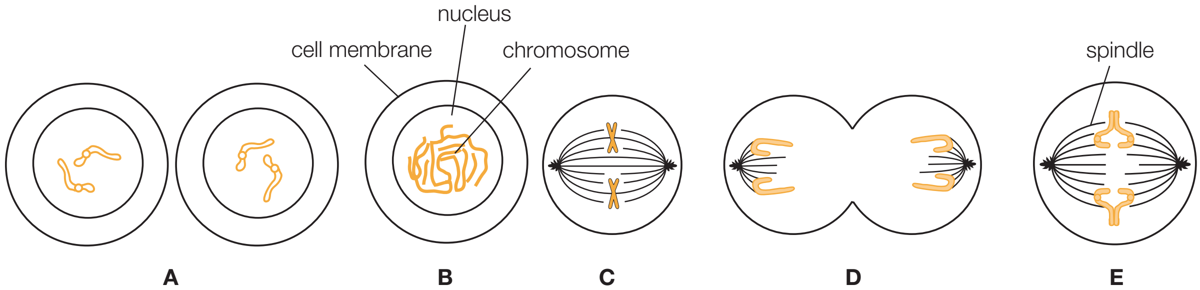
3. Distinguish between mitosis and cytokinesis.

4. Complete the table below comparing binary fission with mitosis.

Type of division	**Type of organism**	**Type of chromosome**	**Number of cells formed**	**Spindle fibres Yes/No**	**DNA replication Yes/No**
Binary fission					
Mitotic division					

Application, Analysis and Evaluation

5. The diagram below shows events that occur in mitosis.



a) How many chromatids can be seen at C? ....

b) Which process involving the cytoplasm has started at D? ....

c) Put the events in the correct sequence, starting with B. ....

6. A student wrote the following to compare mitotic division with binary fission:

'Binary fission is how all unicellular organisms reproduce. Mitotic division does not take place in cells that have a cell wall. In binary fission the chromosomes are separated without a spindle.'

Judge the accuracy of the student's summary. Justify your decision.

....

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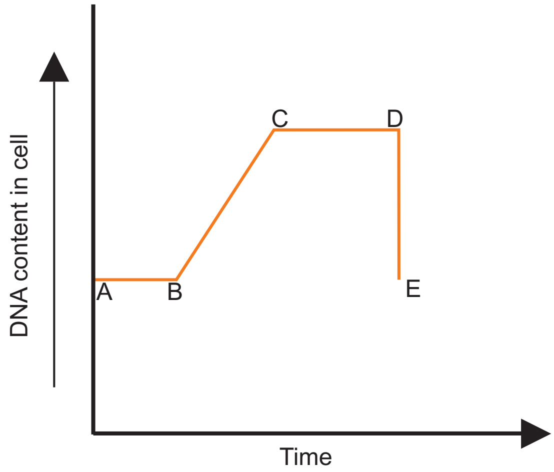
7. Below is a graph of one division of mitosis.



a) Which stage A-B, B-C, C-D or D-E indicates DNA replication? Explain why.

b) Does the actual number of types of chromosomes change in the process of DNA replication? Explain your answer.

c) Explain what is happening in the section D-E.

8. DNA replication is termed 'semi-conservative'.

a) Find out what this term means and explain it in your own words, possibly using a diagram.

b) Do some research to explain how the use of radioactive bases has provided evidence for this term.

Science Inquiry Skills 1.3 - Observing Mitosis

Introduction

This activity involves observing mitosis in onion tissue.

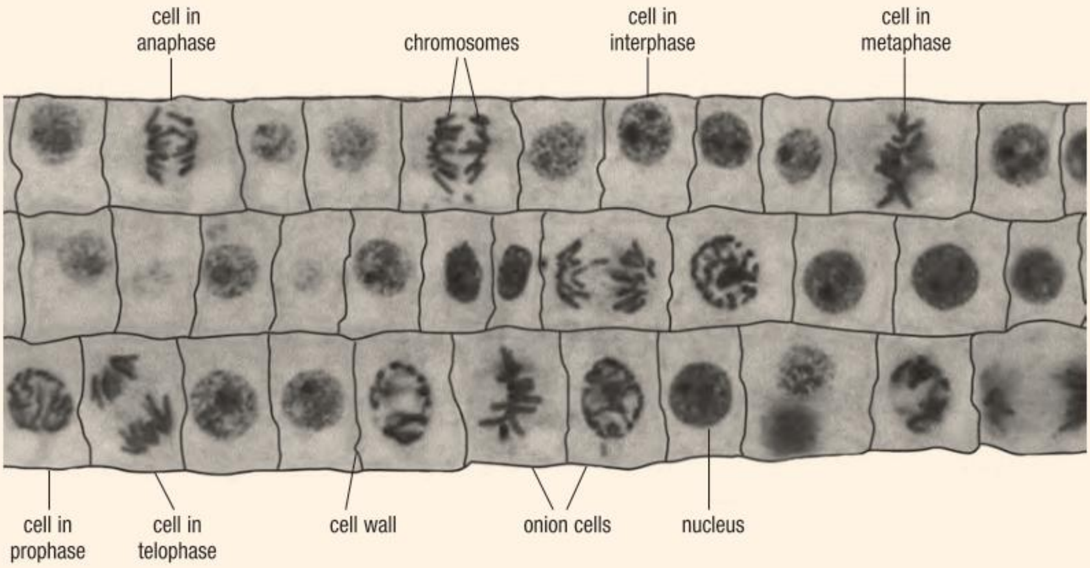
Materials

- Light microscope
- Prepared slides of an onion root tip stained to show chromosomes in the nucleus.

PART A OBSERVING CELLS

1. Set the microscope up for viewing and put the slide on the stage.
2. Examine the specimen just behind the root tip.
3. Examine carefully the nucleus of some of the onion cells.
4. Look for cells that are in interphase and cells that are in the mitotic division (or M) phase.

Use the photograph below to help you.



PART B COUNTING CELLS

1. Draw a table to record the number of cells viewed that are in interphase, prophase, metaphase, anaphase and telophase.
2. Survey carefully 200 cells in the same region of the root tip.
3. Calculate the percentage of cells viewed that are:
   a) Undergoing mitotic division..
   b) In prophase, metaphase, anaphase and telophase.........................

Science Inquiry Skills 1.3 - Observing Mitosis (continued)

Analysis

1. Mitotic division is rapid just behind a root tip. Which life processes does this illustrate?

2. The end of a root tip is protected by a layer of cells called the root cap. Protected from what?

3. Cells further away from the root tip are larger and more fully developed. Suggest why.

The following online resource boxes are relevant to the Science as a Human Endeavour Activity on the following page.

Helpful Online RESOURCE about cancer

To learn more about causes and treatment of cancer view the clip below:

<https://www.youtube.com/watch?v=3qv8DTrRAoQ>

Helpful Online RESOURCE about Australian scientist Ian Frazer

To learn more about the work of Ian Frazer view the clip below:

<https://www.youtube.com/watch?v=aAb5Ib9rMWs>

Science as a Human Endeavour 1.3 - Viruses can cause cancer

Development

Development of complex theories often requires a wide range of evidence...

Most theories about the onset of cancer concern mitotic division. Normally, mitotic division is tightly controlled by the body to ensure that cells only divide a certain number of times. If this control process breaks down in a tissue or organ, cells there divide many, many times to produce a mass of cells called a tumour.

By the 1960s, theories to explain cancer had developed to the point where they included risk factors (aspects of the environment or behaviour that increased the likelihood of cancer). These included smoking, drinking too much alcohol, exposure to radiation (nuclear and UVR), and exposure to mutagenic (cancer causing) chemicals like asbestos. Work done in the 1980s eventually led to the discovery that risk factors have the potential to disrupt the structure of genes in DNA (mutations) that regulate mitotic division, leading to loss of control of it.

Peyton Rous, however, had discovered in 1911 that a virus causes cancer in chickens. Furthermore, Richard Shope had shown in 1933 that a virus causes a cancer in rabbits, the first time this had been determined in a mammal. Then in 1964, a virus called the Epstein-Barr virus was discovered to cause a cancer in humans. By the early 1980s, the list of cancer-causing viruses or 'oncoviruses' included two strains of the human papilloma virus (HPV) called HPV16 and HPV18 that cause cancer of the cervix (lower part of the uterus). Rather than cause mutations, it became clear that oncoviruses cause cancer by inserting DNA into the DNA of the host cell in such a way that it causes the infected cell to make proteins that stop genes it has to control mitotic division from working.

Today, cancer theories include exposure to oncoviruses as a risk factor. It is also now known that viruses play a role in about 15% of the cases of human cancer and the possible association of other viruses with human cancers is the subject of ongoing research.

You may need to refer to the online resources on the previous page to answer the questions that follow:

1. List the types of evidence which have led to the latest theories about cancer.

2. The discovery of oncoviruses suggested that vaccines for them could be produced. An early example of a cancer vaccine involved the work of Professor *Ian Frazer* at the University of Queensland ***(refer to the photo above)***. Briefly discuss the impact this discovery has had and could have in the developing world.

Chapter 1.4 Cell requirements

Science Understanding

Cells require energy.

The source(s) of energy are light (most autotrophs) and chemical (heterotrophs).

Photosynthesis, respiration, and fermentation are important energy processes for cells.

- Write word equations for photosynthesis, respiration, and fermentation (in plant and animal cells).

Cells require materials and the removal of wastes:

- Compare the sources of materials for autotrophs and heterotrophs.
- Explain the need for removal of wastes.

1.4

Energy requirements of cells

Living cells require energy for movement, synthesis and maintenance of a stable intracellular environment (or homeostasis). In all living cells there is a continual transformation of energy from one type into another. 'Energy cannot be created or destroyed but simply changed from one form to another.' The statement is sometimes known as the 'Law of Conservation of Energy' or the 'First Law of Thermodynamics'. Energy may be present in different forms. These include light, heat, chemical and kinetic energy. Generally, living cells must be able to convert chemical energy into other forms of energy which are more useful to the cell. This is shown in *Figure 141*.

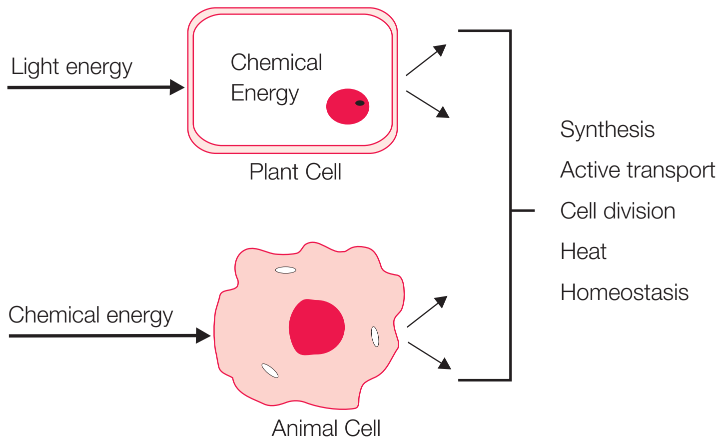


Figure 141 Energy changes in cells

Movement

Most cells are able to move about or change their shape. Good examples are sperm cells that can move for several days and the contraction of muscle cells in larger organisms. Other examples of movement include the movement of chromosomes during mitosis, packaging and secretion of substances by cells and the movement of the plasma membrane during the taking in or removing of large molecules like proteins. Some molecules can be moved across a membrane because they will not diffuse across and this is called active transport.

Synthesis

All cells need to conduct **synthesis reactions** to produce a variety of molecules that involves a conversion of one type of chemical energy to another. Good examples include endocrine cells, which produce hormones and all cells when they undergo DNA replication and manufacture proteins. Cells constantly require energy to break down and build up molecules.

Stable internal environment

Cells also need to maintain a constant internal environment. This will mean they need to actively regulate the concentration of various substances in the cell. The cells of the body need to maintain a temperature of around 37^{0}C and when the temperature varies from this, energy is required for a range of mechanisms that can restore the correct temperature. Concentrations of salts, ions and useful molecules like glucose, as well as **metabolic waste** products like **urea** also need to be maintained within relatively narrow limits.

Autotrophs and heterotrophs

Generally, most organisms have either an autotrophic or heterotrophic form, or mode, of nutrition.

Autotrophs are organisms that use light energy to synthesise **organic molecules** (e.g. carbohydrates) from inorganic substances (e.g. carbon dioxide and water). These organisms generally use light energy in a process called photosynthesis to manufacture glucose molecules. These organisms include all types of plants and certain types of protists; for example, algae.

Chemo-autotrophs are organisms that use energy from the breakdown of inorganic substances (e.g. hydrogen sulphide) to synthesise organic molecules. These organisms are certain types of prokaryotes. Some of these organisms live around volcanic cracks at the bottom of the Earth's oceans called hydrothermal vents.

Heterotrophs obtain organic molecules from other organisms, generally by feeding on them. These organic molecules are both a source of energy and provide the materials that heterotrophs use to make essential molecules in their own bodies. Most heterotrophs are animals, but some types of plants and protists are heterotrophs as well.

Photosynthesis

During photosynthesis carbon dioxide and water are chemically combined together in **chloroplasts** which contain the pigment **chlorophyll.** Two products are formed; oxygen and an organic molecule called glucose. *Figure 142* shows this process in which sunlight is converted to chemical energy in the form of glucose. Light is absorbed by chlorophyll in the chloroplasts found in the leaves of plants.

Photosynthesis may be summarised in the following word equation:

carbon dioxide + water → glucose + oxygen

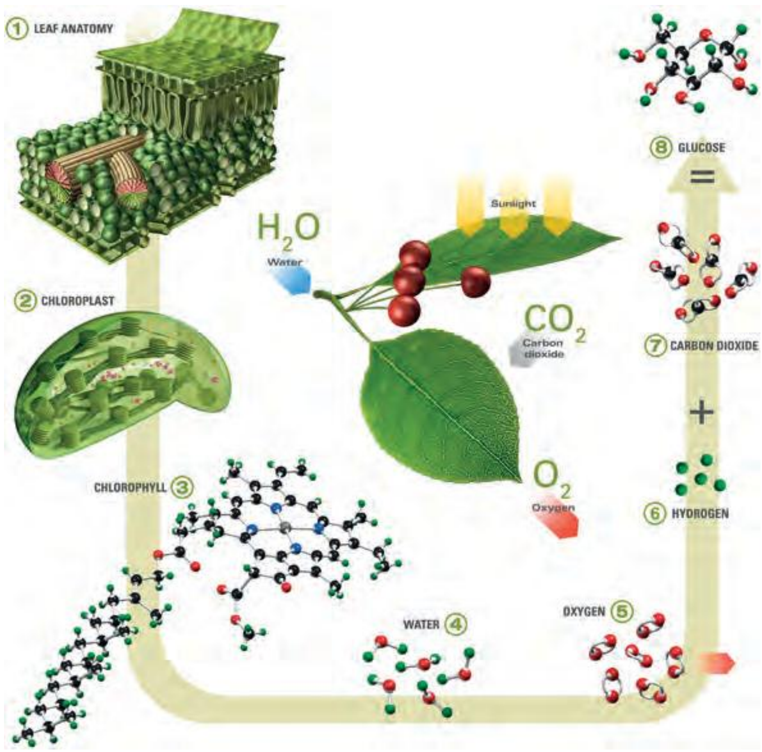


Figure 142 Plants conduct photosynthesis

Cell Respiration

Cell **respiration** is a biochemical process that takes place in mitochondria and the cytoplasm. It is the main energy pathway cells use to make energy (carried by ATP) available for use.

Cell respiration requires glucose and oxygen. Glucose is made available for the process through the metabolism (or breakdown) of an energy-storage complex carbohydrate (or polysaccharide). In the case of animal cells this is usually glycogen and in plant cells starch is used. The production of ATP using energy released by breaking down glucose with oxygen (or aerobically) is called aerobic cell respiration. Two waste products are formed; carbon dioxide and water.

The process of aerobic respiration can be summarised using the following word equation:

glucose + oxygen → carbon dioxide + water

Fermentation

ATP production using energy released by breaking down glucose without oxygen (or anaerobically) is called **fermentation**. Like aerobic cell respiration, fermentation begins with a process called **glycolysis**. A small amount of energy is released, which results in a small yield of ATP. In fermentation, however, pyruvate produced by glycolysis remains in the cytoplasm, where it is converted into one or more waste products. No further energy is released, which explains why fermentation results in a small yield of ATP.

There are two kinds of fermentation: **alcohol fermentation** and **lactic acid fermentation**.

Alcohol fermentation may be summarised in the following word equation:

glucose → ethanol + carbon dioxide

Lactic acid fermentation occurs in animal cells when there are insufficient quantities of oxygen to carry out aerobic respiration any faster; for example, in muscle cells during strenuous exercise and in some bacteria. There is one waste product called lactic acid. Lactic acid fermentation may be summarised in a word equation as follows:

glucose → lactic acid

Figure 143 illustrates products of fermentation; alcohol from yeast fermentation and yoghurts and cheese from bacterial fermentation.

Figure 143 Products of fermentation

Material requirements of cells

As well as energy requirements, cells also need very specific nutrients and materials for their survival. As already mentioned, autotrophs and heterotrophs differ in their initial input of energy. In addition to a source of light, **photo-autotrophs** also need carbon dioxide and water. To assist plants in the manufacture of many different organic molecules they also require a range of inorganic nutrients necessary to supply a source of such elements as nitrogen, phosphorus, magnesium, sodium, cobalt and many other **trace elements**. These materials are dissolved in solution in the soil and absorbed by root hairs of plant cells.

Heterotrophs cannot convert **inorganic materials** into organic molecules and therefore a range of elements need to be provided by the organic molecules they feed on. A typical heterotrophic diet will contain proteins, carbohydrates, fats and oils, nucleic acids as well as water and some mineral ions and vitamins.

Waste production and removal

Some metabolic reactions in cells produce harmful substances. These substances are called waste products and need to be removed from cells/the bodies of multicellular organisms because they can be toxic.

Metabolism refers to all of the chemical reactions that occur in a living organism. The removal of the wastes of metabolism is called **excretion**. Two examples of wastes that are excreted are carbon dioxide and a nitrogen-containing substance called urea. Faeces is not a metabolic waste because it is not produced by biochemical reactions that take place in cells; it is mostly indigestible food material and bacteria.

Carbon dioxide is produced by all cells in aerobic respiration. It is transported from cells in the blood to the respiratory system by the circulatory system, where it is excreted by simple diffusion into alveoli in the lungs. The excreted carbon dioxide is then removed from the body in exhaled air.

Urea is produced by a biochemical reaction called deamination which takes place in liver cells. It is transported from liver cells in blood plasma to the excretory system by the circulatory system, where it is excreted into nephrons in the kidneys by a process called filtration. The excreted urea is then removed from the body in urine.

Key Concepts

1. All cells require a form of energy for life's processes such as movement, synthesis and maintaining a stable internal environment.
2. Autotrophs can convert inorganic materials into organic molecules using light energy in the process called photosynthesis.
3. Heterotrophs need to feed on matter containing organic molecules to provide energy and essential materials for growth and life's processes.
4. Three important chemical reactions are involved in energy changes in organisms, they are:
   - photosynthesis
   - aerobic respiration
   - fermentation (in both plants and animals)
5. There are other material requirements for both heterotrophs and autotrophs, including substances that are gases and minerals.
6. Metabolic wastes are a by-product of biochemical reactions in cells. They need to be excreted from cells and from the body of multicellular organisms to avoid poisoning other cells.

What have you learned?

Key Terms

autotroph ....

heterotroph ....

photosynthesis ....

respiration ....

fermentation ....

metabolic waste ....

excretion ....

urea ....

organic molecule ....

inorganic material ....

chemo- autotroph ....

photo-autotroph ....

synthesis reaction ....

chlorophyll ....

glycolysis ....

chloroplast ....

alcohol fermentation ....

lactic acid fermentation ....

trace elements ....

Knowledge and Understanding

1. Give an example for each of the following to illustrate how a cell would require energy.
   a) Movement of chromosomes during cell division ....

   ....

   b) Making a protein molecule ....

   ....

   c) Maintaining a stable temperature ....

   ....

2. Complete the table below comparing autotrophs and heterotrophs.

Organism	Type of nutrition	Example of organism	How carbon is obtained	Initial energy input
Autotroph				
Heterotroph				

3. Write word equations for each of the following processes:
   a) photosynthesis
   b) aerobic respiration
   c) lactic acid fermentation
   d) alcohol fermentation

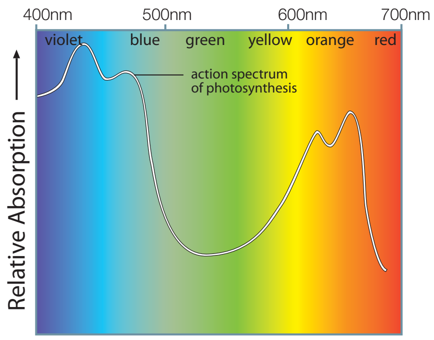
4. Name two metabolic waste products produced by cells

5. Explain why CO_2 can be considered a metabolic waste product from human cells but not from plant cells.

6. Name three factors that may alter the rate of photosynthesis, giving a short explanation for each factor.

Application, Analysis and Evaluation

7. Visible light is part of a continuum of radiations with different wavelengths called the electromagnetic spectrum. These wavelengths are measured in nanometres (nm). A graph that shows, as a percentage, the different wavelengths of visible light used for photosynthesis, is termed the action spectrum. *Refer to the graph below that shows the action spectrum for a typical flowering plant.*

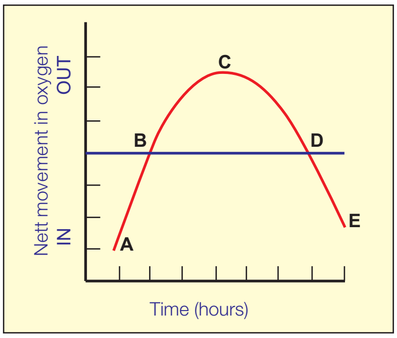


   a) Which wavelengths, and colours, are mainly used for photosynthesis?

   b) Growing a plant under blue light may increase its growth rate. Suggest why.

   c) Use data in the graph to suggest why leaves tend to be green.

8. The nett movement of oxygen into and out of a leaf was measured over a six hour period and the results are shown graphically.



a) At what point of the graph is the light intensity likely to be greatest? Give reasons for your answer

b) Write down and name the two biochemical reactions likely to be causing fluctuations in the oxygen levels in the leaf.

c) At what points on the graph is the rate of photosynthesis equal to the rate of respiration?

d) Explain why a plant needs aerobic respiration to provide energy when it can use photosynthesis.

9. *Euglena (see pic) i*s an example of an organism that can obtain nutrients as an autotroph and also as a heterotroph. (*Approx. 100*×)

Research how and when Euglena does this, giving a brief description below.

Science Inquiry Skills 1.4 - Observing Photosynthesis

Introduction

It is possible to estimate the rate of photosynthesis by measuring the rate of oxygen production from leaves. Oxygen is a by-product of photosynthesis as indicated in the word equation below:

carbon dioxide + water → oxygen + glucose

An aquatic plant such as ‘pond weed’ (***Hydrilla or Spirogyra***) can be used for this process as, when exposed to the right conditions aquatic plants will release small bubbles of oxygen into the water and these can be counted. The number of oxygen bubbles per minute is a reasonable estimation of the relative rate of photosynthesis.

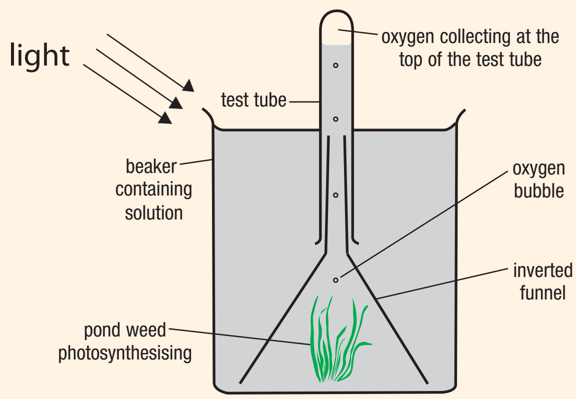
The purpose of this activity is to observe photosynthesis in a species of water plant to validate a reliable technique.

If time permits, you may be able to Design Your Own (DYO) practical. To do this you can vary a factor such as light intensity, temperature or carbon dioxide concentration and investigate the effect on the rate of photosynthesis.

Materials

large test-tube, glass funnel, 500 ML beaker, thermometer, light source, razor blade os scalpel, sodium hydrogen carbonate (6% solution), pond weed (e.g. ***Hydrilla or Spirogyra***), stopwatch.

Method



1. Set up the apparatus as shown in the diagram above.
2. Take a healthy sprig of pond weed and using the razor blade or scalpel, cut off about a 5 cm piece.
3. Observe carefully for 5 minutes and count the number of oxygen bubbles released by the plant.
4. It would be good practice to do this several times and calculate an average rate.

Results

In the space below, prepare a table to record this data as the rate of photosynthesis in ‘bubbles per minute’.

Science as a Human Endeavour 1.4 - Bionic leaf

Application and limitation

Science understanding/inquiry enables scientists to make discoveries

The application of how living organisms 'work' to the design of new technologies is known as biologically inspired engineering or 'bionics'. Examples include the front of bullet trains (kingfisher head), sonar (animal echolocation) and ultra-low drag hulls for ships (shark skin). For several years, a team of scientists led by *Daniel Nocera* at Harvard University has been developing a bionic leaf. Their goal is to engineer a system that harnesses the principles of photosynthesis to produce fuel, including liquid fuel, to use to meet everyday energy needs.

In natural photosynthesis, carbon dioxide and water with light energy enable chloroplasts in leaves to produce glucose (used as a fuel by plants) and oxygen. Light energy is used to split water (H_2O) into hydrogen and oxygen (the source of oxygen is water, not carbon dioxide). The hydrogen is combined with carbon dioxide to form glucose. This 'natural leaf process' though is poorly efficient – only about 1% of the energy associated with light ends up being stored (as chemical energy) in the glucose formed.

In 2016, Nocera and his team managed to discover a 'bionic leaf process' that boosts the efficiency of conversion of light energy to chemical energy to 10%, or ten times better than real plants. The system they invented uses water, carbon dioxide and sunlight that is used to split water just like photosynthesis in natural leaves. However, it also uses a chemical called a light absorbing catalyst, which greatly reduces the amount of light needed to split water. Although the hydrogen produced can be used as a fuel directly (e.g. to power electric cars), the real breakthrough was being able to use it to make liquid fuel. This was done by supplying the hydrogen to a genetically modified (altered DNA) species of 'hydrogen-eating' bacteria called *Raistonia eutrophia* that can combine hydrogen with carbon dioxide to form liquid alcohol. This can be purified and used as a liquid fuel.

You may need to refer to the online resources below to answer the questions that follow:

1. *Daniel Nocera (refer to photo)* has led a team that has discovered how to produce a bionic leaf. Outline the science understanding used by Nocera and his team that enabled them to put together a bionic leaf.

2. Describe 2 possible limitations with the use of this technology in meeting everyday energy needs.

Helpful Online RESOURCE about the bionic leaf

To learn more about the bionic leaf system view the clip below:

<https://www.youtube.com/watch?v=A2iEBPwOgzg>

Helpful Online RESOURCE about turning sunlight into liquid fuel

To learn more about using a bionic leaf to make liquid fuel view the clip below:

<https://www.youtube.com/watch?v=2KRIRhNbxKg>

Chapter 1.5 The cell membrane

Science Understanding

Material requirements move in and wastes and some cell products move out of cells.

The cell membrane separates cellular activity from the external environment.

- Describe the structure of the semi-permeable cell membrane.

The selectively permeable nature of the cell membrane maintains relatively constant internal conditions.

- Explain how the cell membrane controls the exchange of materials between the cell and its environment.
- Describe how some substances move passively across the cell membrane with the concentration gradient (i.e. by diffusion and osmosis).
- Compare active and passive transport with regard to:
  - concentration gradient
  - energy requirement

The surface area-to-volume ratio of cells is critical to their survival.

1.5

The structure of the cell membrane

The cell membrane is vital in controlling the exchange of materials between the internal and external environment of the cell.

The cell membrane separates the internal environment of the cell from its surroundings. The cell membrane mostly consists of two kinds of molecules – **phospholipids** (and other lipids such as cholesterol) and membrane proteins. According to the fluid-mosaic model for membrane structure, the structure of a cell membrane includes:

A bilayer (or two layer) framework of phospholipids (blue colour) with membrane proteins (green) embedded in it.

- Phospholipid 'heads' positioned on the outer and inner edges of the bilayer - **hydrophilic** (water-loving).
- Phospholipid 'tails' positioned in the centre of the bilayer - **hydrophobic** (water-hating).
- Membrane proteins (green colour) that either span the width of the membrane or sit in the bilayer.
- Glycoproteins which are membrane proteins with carbohydrate chains (pink colour) attached to them.
- Glycolipids (pink) which are phospholipids with carbohydrates chains attached to them.

The structure of a cell membrane is illustrated below in *Figure 151*.

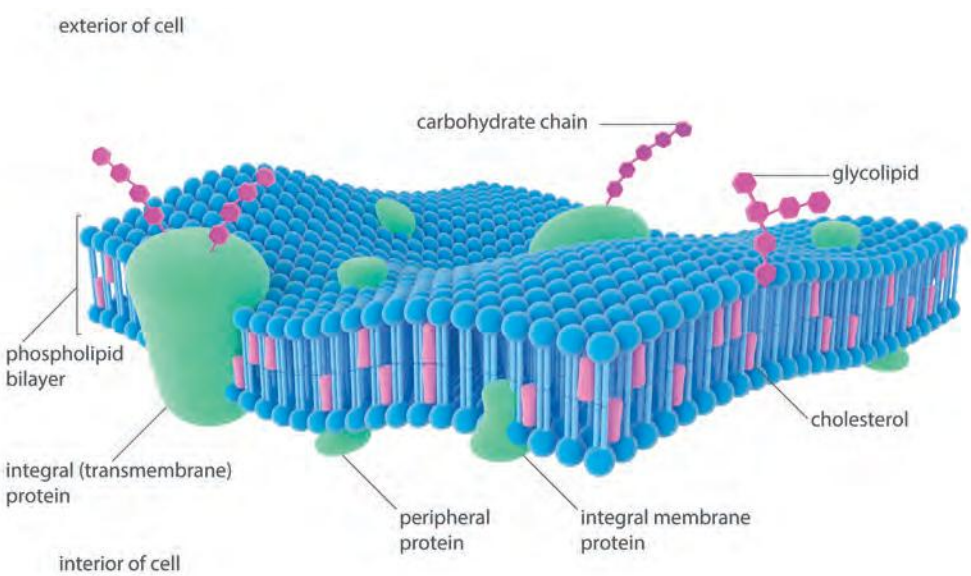


Figure 151 The internal structure of a membrane

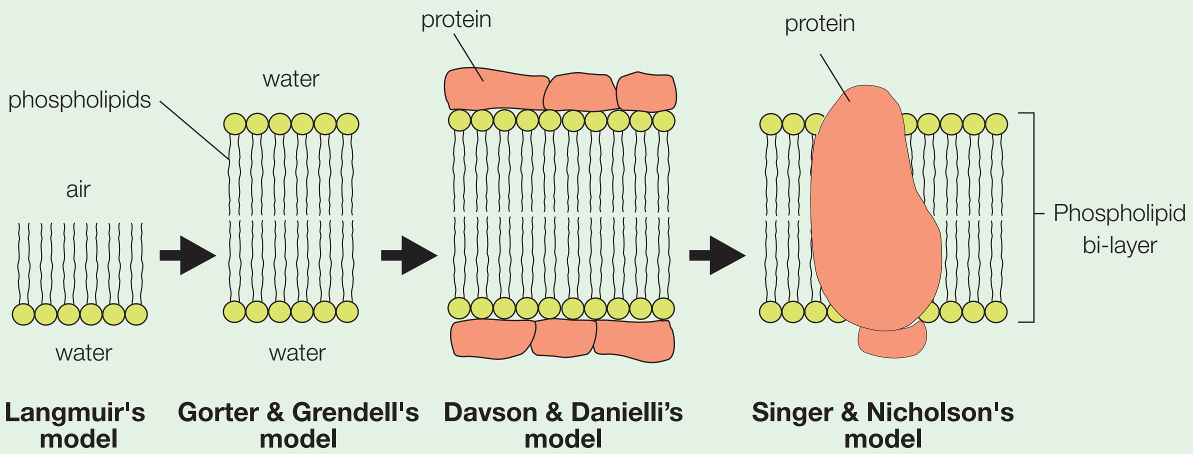
As already mentioned, one important function of the cell membrane is to keep the cell's contents separate from the external environment. In order to achieve this function, the membrane must be able to control which substances enter and leave the cell.

The changing model of the structure of the cell membrane

The scientific study of membranes by various scientists over the last 100 years or so is interesting and a very good example of how human endeavour and the use of models helps the understanding of biological structures.

- In 1917 *Langmuir* made an artificial membrane using phospholipids.
- In 1925 *Gorter* and *Grendell* suggested that cell membranes consisted of two layers of phospholipids which were attracted to water on the outside (hydrophilic) but repelled water on the inside (hydrophobic).
- In 1935 *Davson* and *Danielli* developed a model consisting of a phospholipid bilayer between two layers of protein.
- With the development of electron microscopy, scientists were able to confirm that *Davson* and *Danielli's* model helped to explain the structure of all membranes.
- In the 1960s further experiments showed that not all membranes were the same and also that the protein was not evenly distributed throughout the membrane.
- In 1972 *Singer* and *Nicholson* suggested that the proteins are inserted in the phospholipid layers and go right through the membrane. This finding can be used to explain receptor sites on membranes, cell adhesion and transport proteins.

These stages are illustrated in the *Figures* below:



Controlled exchange of materials

Cells must exchange materials with their external environment; for example, glucose and oxygen are obtained from the external environment and carbon dioxide is released into the external environment. All materials exchanged must pass across the cell membrane.

Materials exchanged across the cell membrane include:

- gases
- nutrients
- waste products

The structure of the cell membrane permits it to control the exchange of materials between the cell's internal environment (its cytoplasm) and the external environment. This is because the structure of the cell membrane permits it to select what passes across it–some materials may pass across it, but not others. The cell membrane is therefore described as being selectively (or semi) permeable.

Factors that influence whether a substance will pass across the cell membrane or not include its:

- **Size** – only very small molecules are freely exchanged; for example, gases like oxygen and carbon dioxide. Larger molecules are not; for example, many proteins.
- **Charge** – **ions** (or atoms/molecules with a charge) can only be exchanged if specific membrane proteins called membrane transport proteins are used.
- **Solubility in water** – water and hydrophilic molecules (or molecules that are soluble in water) can only be exchanged if specific membrane transport proteins are used as well.

Two characteristics of the membrane are largely responsible for the selective nature of the exchange:

- the lipid nature of the membrane
- the proteins embedded in the lipid bilayer

The proportions of chemicals in the intracellular environment of cells is different from those in the extracellular environment of cells. The cells need the correct pH, glucose concentrations and the correct water and solute balance to ensure that cell reactions can occur. The levels of waste products like carbon dioxide and urea need to be kept low inside the cell.

Passive and Active transport across the cell membrane

Passive transport

According to the kinetic model for matter, atoms and molecules are in a state of constant, random motion. In gases and liquids, this causes them to collide so often that there is a gradual net movement away from where the atoms or molecules are most concentrated to where they are least concentrated. The movement of atoms and molecules in this way is called **passive transport** because it does not involve the expenditure of energy.

Diffusion and osmosis

?

The passive transport of a substance from a region of high concentration to a region of lower concentration until an overall even concentration is reached is called simple **diffusion**. Small, uncharged molecules are continuously exchanged across membranes by simple diffusion; for example, oxygen and carbon dioxide.

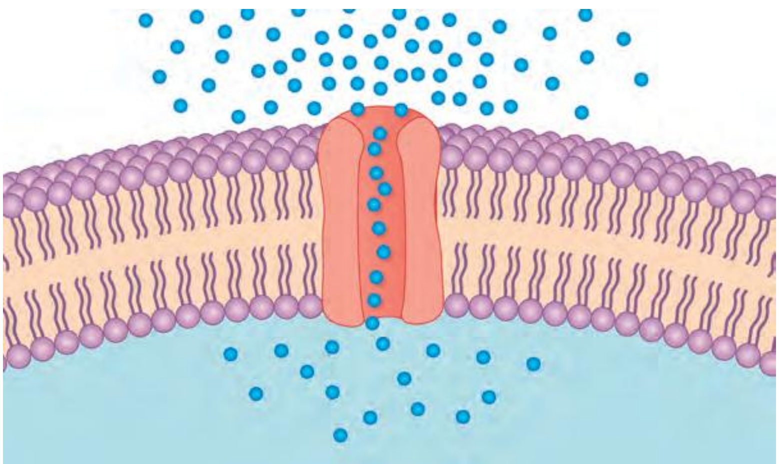


Figure 153 Passive diffusion of molecules across a cell membrane

Figure 153 shows diffusion of molecules from a region of high concentration (outside) to a region of low concentration (inside) through a transmembrane protein channel. The membrane is **selectively permeable** allowing some molecules to move across the membrane but not others.

The passive transport of a substance across a membrane through a membrane transport protein is called facilitated diffusion. Substances continuously exchanged by facilitated diffusion include hydrophilic molecules; for example, glucose and some **ions**.

The movement of water across membranes between regions that have different solute concentrations is another example of passive transport. The term 'solute concentration' refers to how much solute there is in a solution relative to 'free' water (or water not bound to a solute). A solution with a high solute concentration is defined as one that has fewer 'free' water molecules than one with a low solute concentration.

The passive transport of water from a region of low solute concentration to a region of higher solute concentration across a selectively permeable membrane is called **osmosis**.

Figure 154 shows how water moves into a red blood cell placed in a beaker of distilled water by osmosis because the solute concentration of distilled water is less than the solute concentration inside the cell.

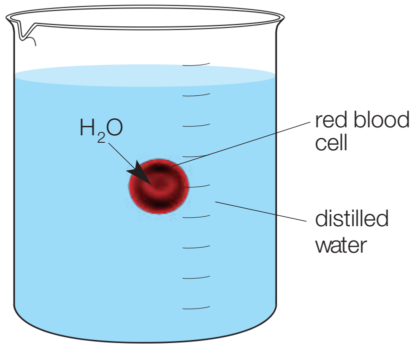


Figure 154 Water will move into cells by osmosis (not drawn to scale!)

The rate of exchange of materials at the cell membrane

How quickly materials are exchanged across the cell membrane depends on factors including the:

- **Surface area** to **volume** ratio of the cell
- **Concentration gradient** (or, in the case of water, the solute concentration gradient)
- Nature of the material being exchanged; for example, its size, charge and solubility in water
- Temperature

Active transport

The movement of substances from a region of low concentration to a region of high concentration is called **active transport**. The movement of substances in this way is termed 'active' because it involves the expenditure of energy. Ions are continuously exchanged across membranes by active transport; for example, sodium and potassium ions.

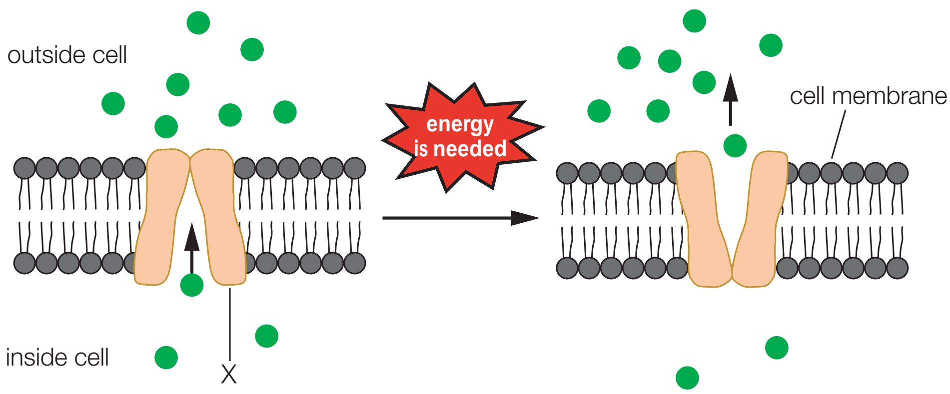


Figure 155 Active transport across a membrane

Figure 155 shows molecules (represented by green circles) that may be actively transported from a region of low concentration (inside the cell) to a region of higher concentration (outside the cell) by binding to a special membrane protein called a protein pump (shown labelled as X). Energy is used by the cell to change the shape of the membrane protein, which causes the molecule to be pumped out of the cell against its concentration gradient.

Helpful Online RESOURCE for an EVA on active transport

To view an Essentials Video Animation (EVA) on this topic use this QR code to visit:

<http://essentialseducation.com.au/resources/sace-1/biology/active-transport/>

The role of the membrane in endocytosis and exocytosis

Generally, if materials in solution are to pass through the membrane they must pass through either the lipid layers or through the protein molecules that span the membrane. However, if larger molecules such as proteins or polysaccharides or even tiny solid particles or liquid droplets cross the membrane, they do so by a different mechanism. The release of a substance from a cell by **exocytosis** is called **secretion**. Examples of substances that move in this manner are molecules that are packaged into vesicles by organelles such as **Golgi bodies** and **endoplasmic reticulum**. Examples of such substances are hormones, extracellular enzymes and materials that are used to make cell walls in plants. See *Figure 156*.

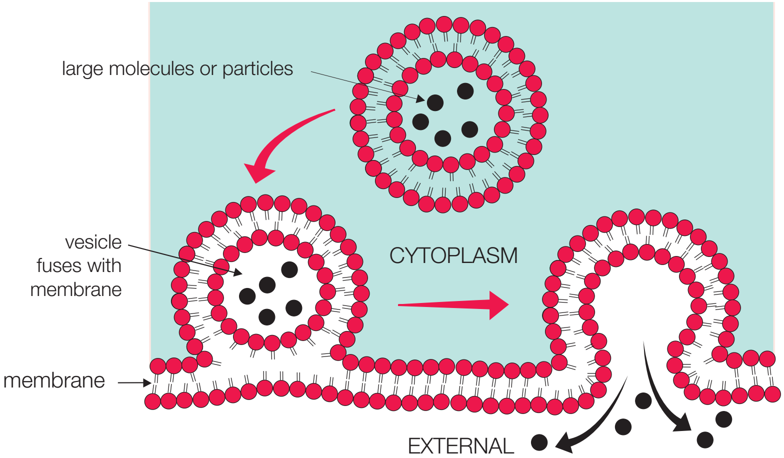
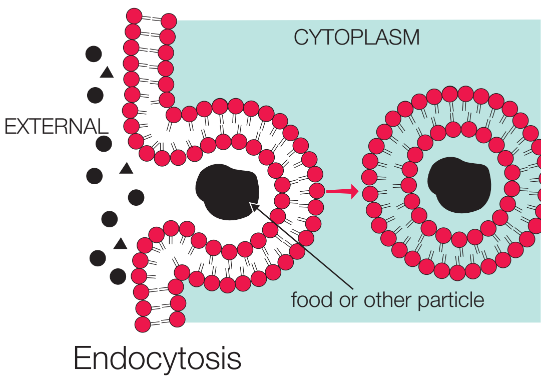


Fig 156 The process of exocytosis

On the other hand, if large particles or molecules are being taken into the cell, the process is called **endocytosis**. Both of these processes involve a change in the shape of the cell membrane to form a vesicle. *Figure 157*(a) illustrates endocytosis where larger solids or liquids are enclosed ina vesicle and taken into a cell. *Figure 157*(b) illustrates a type of white blood cell (macrophage) engulfing bacteria by endocytosis in a mammalian lung.



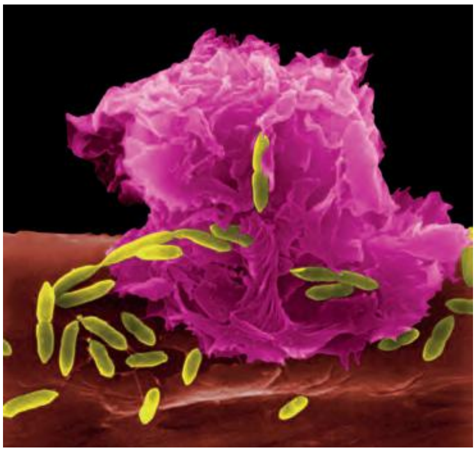


Fig 157(a) and (b) The process of endocytosis

Helpful Online RESOURCE for an EVA about passive transport

To view an Essentials Video Animation (EVA) on this topic use this QR code to visit:
<http://essentialseducation.com.au/resources/sace-1/biology/passive-transport/>

Helpful Online RESOURCE for an EVA on endocytosis and exocytosis

To view an Essentials Video Animation (EVA) on this topic use this QR code to visit:
<http://essentialseducation.com.au/resources/sace-1/biology/endocytosis-exocytosis/>

Surface area to volume ratio

The surface area to volume ratio (SA:V) is an important concept for cells in explaining the efficiency of the exchange of materials between the external and internal environment. The ratio is a numerical value that represents the relationship between the amount of external surface area of the cell membrane and volume of the cytoplasm. Virtually all cells are microscopic for a reason. By being incredibly small they are able to have a very large surface area to volume ratio. This is critical to their survival because it means they can exchange materials with the external environment very efficiently.

No cells are the size of a seed, let alone a tennis ball because to be that large would mean having a very small surface area to volume ratio. Cells that big could not survive because the efficiency of exchange of materials with the external environment would far too low to carry out life processes. As a cell grows larger it will have relatively less membrane area compared to its volume and it is thought that this is a stimulus for the cell to divide.

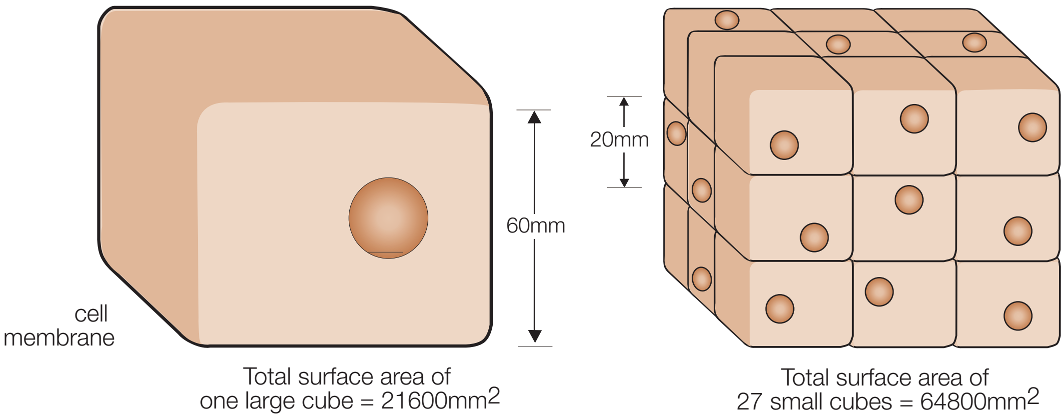


Figure 158 The effect of reducing the size of an object on the surface area to volume ratio

Figure 158 shows that if the larger cube is cut into smaller cubes its surface area is multiplied by three times, whereas the volume remains the same. The total volume of the larger cube and the total volume of the smaller cubes is 21,600mm^3. The SA:V ratio of the lager cube is therefore 1:1 whereas the SA:V ratio of the smaller cubes is 3:1. This means that the ratio of surface area to volume (SA:V) is three times greater with the smaller cubes. Cells that are smaller which have a larger ratio of surface area to volume are able to obtain their nutrients and dispose of their wastes much more efficiently than larger cells.

Key Concepts

1. The cell membrane separates the internal environment of the cell from the external environment.
2. The cell membrane is a phospholipid bilayer with embedded proteins. It provides a selectively permeable layer that surrounds and defines the cell.
3. The cell membrane controls the exchange of materials that move in and out of cells by processes such as diffusion, osmosis, active transport, endocytosis and exocytosis. For osmosis, the movement is from a low solute concentration to a high solute concentration.
4. Passive transport occurs via diffusion and osmosis. Molecules move from high concentrations to low and no input of energy is required.
5. Active transport requires energy and processes include active transport, endocytosis and exocytosis. In active transport, molecules move from low concentration to high concentration against the gradient.
6. Cells are usually very small and this maximises their surface area to volume (SA:V) ratio and optimises rates of diffusion and exchange of materials.

What have you learned?

Key Terms

phospholipid

hydrophobic

hydrophilic

concentration gradient

surface area

volume

selectively permeable

passive transport

active transport

diffusion

Golgi bodies

endoplasmic reticulum

osmosis

endocytosis

exocytosis

secretion

ions

Knowledge and Understanding

1. Name three useful substances that move into a cell from the external environment and state why each substance is required by the cell.

2. Name two metabolic waste products made by cells that move from cell to outside of the cell.

3. Name two useful products that are secreted from cells

4. Draw a labelled diagram to illustrate the process of active transport occurring across a cell membrane.

5. Outline three differences between active and passive transport.

6. Describe two properties of cell membranes that determine why the membrane is selectively permeable.

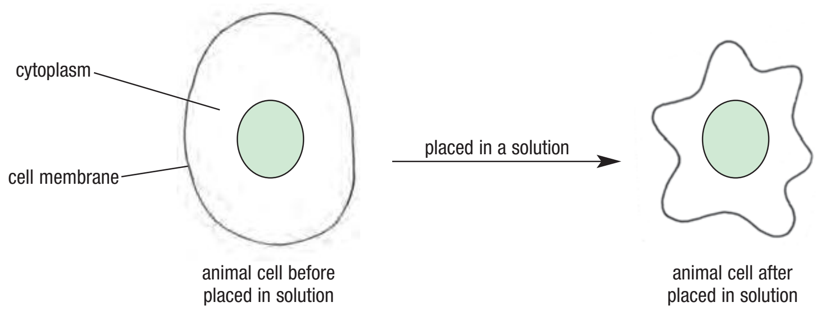
Application, Analysis and Evaluation

7. Calculate the Surface Area to Volume (SA:V) ratio of a 2 cm cube. Then imagine that the 2 cm cube is cut into 1 cm cubes and again calculate the total surface area to volume ratio. What do you notice?

8. Following cell division, daughter cells are about half the size of the parent cell. As the cells grow, what happens to their ability to exchange materials with the external environment. Suggest why.

9. Describe the property of the cell membrane that enables it to perform the following processes:
   a) diffusion
   b) active transport
   c) endocytosis

10. The diagram below shows what happens to an animal cell before and after it is placed in a solution that has a different solute concentration to the cytoplasm.



   a) How has the volume of the cytoplasm changed?
   b) Describe the direction of movement of water that has resulted in this change and name the process by which it moved.
   c) Does the solution outside the cell have a lower or higher solute concentration than the cytoplasm?
   d) Infer why it is important for cells to maintain a relatively constant internal environment.

11. Infer how each of the following materials may be transported across a cell membrane:

a) water going from wet soil into a plant root

b) mineral ions (low concentration) going from soil into a plant root

c) epithelial cells absorbing small droplets of lipid from the gut

d) a white blood cell engulfing a bacterium

e) oxygen gas going from the lungs into your blood

12. Use your knowledge of transport across membranes to assess and explain the following observations:

a) Plants become droopy or wilt if the weather is hot and they do not have sufficient water.

b) The same plant will recover its shape if watered.

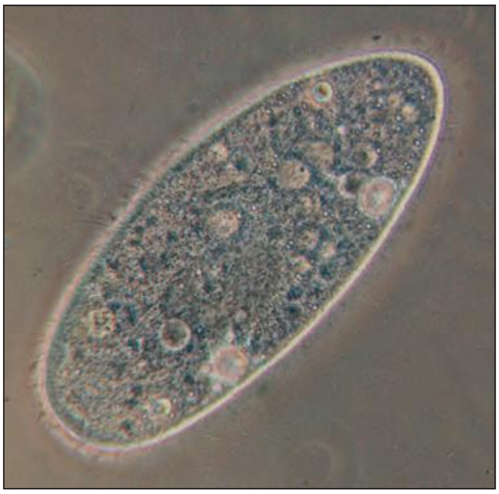
c) If animal cells, such as blood cells, are placed in distilled water they will swell and burst, whereas in slightly salty water they will not do so.

d) Assess and explain which process temporarily makes the cell membrane smaller: endocytosis or exocytosis.

13. *Refer to the information below to answer the questions that follow (overpage).*

Paramecium is a unicellular organism that lives in fresh-water and possesses a structure known as a contractile vacuole. This vacuole fills with fresh water and periodically contracts to expel water from the cell.

Refer to photograph below (400x)



A researcher conducted an investigation to observe the effect of changing the external solute (dissolved substances) concentration on the rate of contraction of the vacuole. The data is shown below. Refer to this data to answer the questions that follow.

External Solute concentration (arbitrary units)	Number of contractions per minute
0	7.1
0.02	7.0
0.04	5.3
0.06	5.2
1.0	4.9

a) Draw a graph of the data in the table above. Include a title, plot the external solute concentration on the X axis and the number of contractions on the y-axis.

b) Describe the relationship between the external solute concentration and the number of contractions per minute.

c) Using your knowledge of the cell membrane and the above data, do you think that the cell membrane is permeable to water. Explain your reasons.

d) When analysing the data, suggest a possible reason why the number of contractions changes as the solute concentration changes.

e) What limitations would you apply to your conclusions?

Science Inquiry Skills 1.5 - Osmosis in potato tissue

Introduction

All living organisms consist of cells and all cells are surrounded by a membrane. One of the major functions of the cell membrane is to regulate the passage of materials into and out of the cell. These materials include dissolved gases, sugars, salts and water. Cell membranes are 'semi-permeable' which means that some substances can easily pass through them, whereas others can not. Most materials move by simple diffusion from high concentration on one side of the membrane to a lower concentration on the other. Some substances may be actively transported, which requires the provision of energy.

Water is the most abundant and one of the most important substances in cells. The diffusion of water across a partially-permeable membrane is called osmosis.

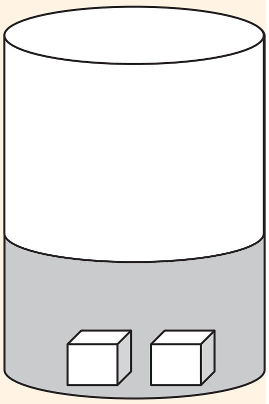
Vegetables are storage organs of plants which consist of cells and the products of cells. The cells are surrounded by a cell wall and, inside that, a plasma membrane. Vegetable tissue provides an excellent model to assist the understanding of the structure and function of cell membranes.

Materials (per group)

1 large fresh potato	knife
spoon	paper towelling
ruler	100 mL 10% NaCl solution
100mL distilled water	2 × 250 mL beakers

accurate triple arm or electronic balance

Method



1. Read right through this method and prepare a suitable data table in the space provided to record the masses.
2. Obtain a large fresh potato, peel it and use a ruler to measure and a knife to cut four 2 cm × 2 cm cubes, split them into 2 pairs and use a balance to determine the mass of the pairs as accurately as possible.
3. Place one pair of the cubes in one of the beakers and add the 10% salt solution so that the cubes are fully covered and leave for 20 minutes, remove excess water and weigh and record the mass again. Calculate the change in mass and calculate % loss or gain and enter this in the table. Record any other observations.
4. Place the other two cubes in the other beaker and cover them with distilled water and leave for 20 minutes, remove excess water and weigh and record the mass again. Calculate the change in mass and calculate % loss or gain and also enter this in the table. Also record any other observations.
5. When you have finished with your potato cubes dispose of them as instructed.

Results

In the space below, represent your findings in a table with relevant column headings and units as appropriate. Ensure that the number of significant figures is appropriate.

Science Inquiry Skills 1.5 - Osmosis in potato tissue (continued)

Discussion

1. Describe and account for any differences in the % loss or gain in mass of the potato in the distilled water and 10% salt solution.

2. Identify and discuss any factors that you planned to keep constant and also any factors that could not be controlled.

3. Identify possible sources of random or systematic error which might have affected the data. Describe the significance of these errors on the accuracy and reliability of the data.

4. Outline the possible significance of any observed effects in this experiment on organisms living in fresh water (e.g. The River Murray).

5. Outline the possible significance of any observed effects in this experiment on organisms living in saturated (i.e. very highly concentrated) salt water (e.g. Lake Eyre).

Chapter 1.6 The importance of microorganisms

Science Understanding

Microorganisms are important living things.

Microorganisms include bacteria, fungi and protists.

In ideal conditions bacteria grow exponentially.

Different bacteria require specific conditions for growth.

Discuss the effects of factors such as:

- temperature
- nutrient availability
- moisture
- pH
- the removal of wastes.

Microorganisms act as decomposers, which enables recycling of essential nutrients.

Bacteria reproduce by binary fission (asexual).

Microorganisms are important to humans.

Discuss the role of microorganisms in:

- the digestive system
- oxygen production by phytoplankton
- recycling nutrients through the non-living environment by decomposing dead and waste materials
- recombinant DNA technology.

Humans have cultured and used microorganisms for about 10,000 years.

Types of microorganisms

Microorganisms (or microbes) are organisms that are tiny, to see them a microscope is needed. They can be unicellular or multicellular; prokaryotic or eukaryotic, animal or plant.

The major groups are: **Bacteria**, **Fungi**, **Protista, Algae** and **Archaea**. More information about each group follows.

Bacteria

Bacteria are unicellular and consist of a prokaryotic cell that lacks a nucleus and other membrane-bound organelles, they exist in different shapes, namely:

- Bacillus (rod shaped)
- Coccus (spherical)
- Spirilli (spiral)
- Vibrio (curved)

Figure 161 (a),(b),(c) and (d) shows photomicrographs of a variety of bacterial cells at different magnifications. Bacteria have cell walls and as seen earlier in Chapter 1.3, divide by a process called binary fission.

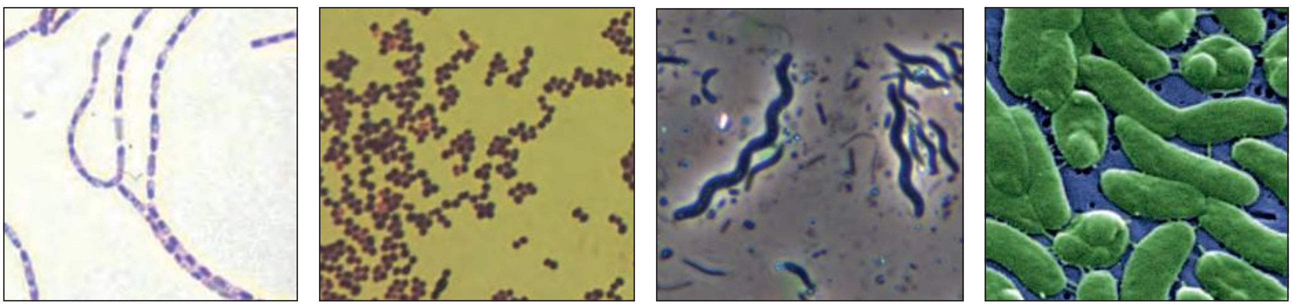


Figure 161 (a) Bacilli, (b) Cocci, (c) Spirilli and (d) Vibrio

Some bacteria use heterotrophic nutrition and others are autotrophic. Again, recall from Chapter 1.4, that autotrophs can convert inorganic material into organic material using light or obtaining energy from inorganic compounds, and heterotrophs need to consume or ingest food materials containing organic molecules.

Bacteria that obtain their organic molecules by consuming decaying or dead matter are termed **decomposers** (or saprophytes).

Fungi

Many fungi are microscopic and even though they are multicellular, they are eukaryotic and possess cell walls. Examples of microscopic fungi include certain moulds and yeast. Examples of fungi that are easy to see include other types of mould and mushrooms and toadstools.

Fungi do not possess chlorophyll and are heterotrophs, this method of obtaining nutrients is used to classify them as follows:

- **decomposers** - decay organic matter
- **parasites** - feed on a host organism.

Fungi reproduce by releasing spores which are then able to grow into new organisms in suitable environments. *Figure 162 (a) and (b)* shows some examples of fungi.

Figure 162(a) Mushrooms

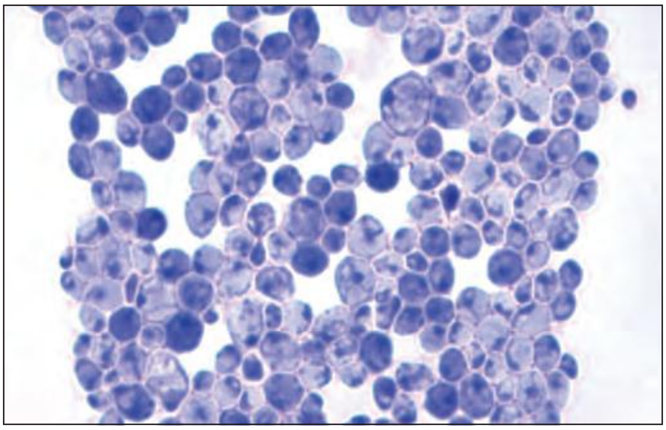


Figure 162(b) Yeast cells

Protista

Protista literally means, 'the first animal' reflecting the original discoveries and thoughts concerning this most diverse and large group of unicellular organisms. This is no longer considered to be accurate due to such a broadly diverse group of unicellular eukaryotes.

They make up the largest group of organisms on earth with some 32,000 living species. **Protists** are eukaryotic as they have a nucleus and membrane-bound organelles inside their cells. Many protists are not protozoans so the terms do not mean the same thing.

There are four groups: Amoeba, Flagellates, Ciliates and Spirozoa, as shown in *Figure 163 (a),(b),(c)* and *(d).*

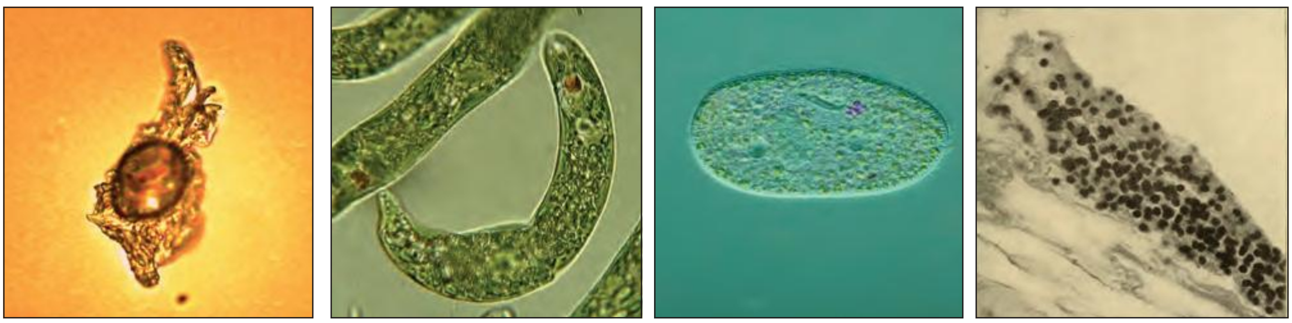


Figure 163 (a) Amoeba, (b) Flagellate, (c) Ciliate and (d) Spirozoa

Algae

Algae are autotrophic; they carry out the process of photosynthesis. They tend to lack many of the structures associated with typical plants and can vary in size from unicellular and microscopic to the extremely large multicellular kelps and seaweeds. They inhabit both marine and freshwater environments.

One of their most important contributions to life on Earth is as the producers in aquatic foodwebs, trapping the sun's energy for other organisms. They also produce about half of all the oxygen produced on Earth. *Figure 164* shows a microscopic filamentous alga called *Spirogyra*.

The classification of these organisms is not universally agreed amongst scientists and sometimes, some types of algae are classified as protists (i.e. protista).

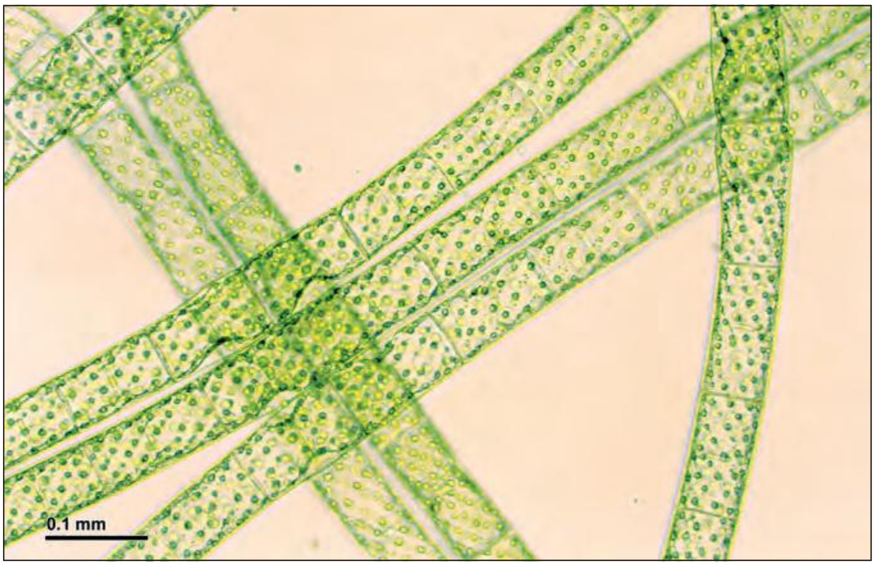


Figure 164 A filamentous alga Spirogyra

Archaea

The archaea or archaebacteria are a very interesting but not well-known group of microorganisms. They tend to inhabit extreme habitats from high to low temperatures or highly saline environments. They can use inorganic molecules, like hydrogen sulphide, which is made using hydrogen and sulfur gas, as a source of energy. Like bacteria, archaea are prokaryotes. *Figure 165* shows a NASA satellite photo of a flooded Lake Eyre in South Australia, the pink colour is due mainly to archaea.

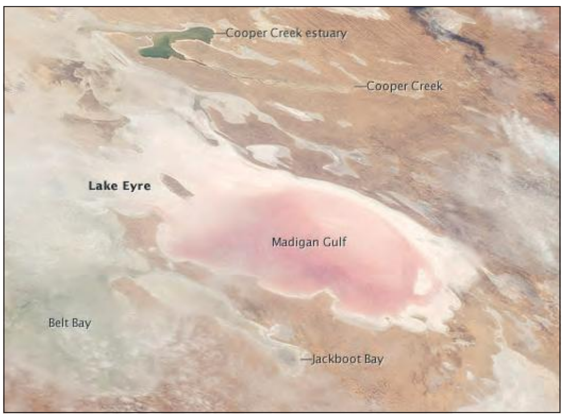


Figure 165 Lake Eyre showing archaea *Figure 166 an image of the Ebola virus*

Viruses

Some scientists classify **viruses** as microorganisms but strictly speaking they are not alive as they cannot carry out life's processes, as discussed in Chapter 1.1. They are also non-cellular but do contain nucleic acids (DNA or RNA). They can only reproduce inside the cell of a host organism (animals, humans, plants and bacteria) and often cause disease as a result. *Figure 166* shows an image of an *Ebola* virus particle from a patient.

Conditions for growth of bacteria

Under ideal conditions bacteria can produce enormous numbers of daughter cells through binary fission in a very short time. As was explained in Chapter 1.3, bacteria are prokaryotes that divide by binary fission; many species have a generation time of around only 20 minutes. Refer to the table and graph in *Figure 167* which illustrate very rapid or **exponential growth** (i.e. doubling every 20 minutes or so).

Time (mins)	No. of bacteria
20	2
40	4
60	8
80	16
100	32
120 (2 hours)	64
240 (4 hours)	4096
480 (8 hrs)	16,777,216

Figure 167 (a) The data

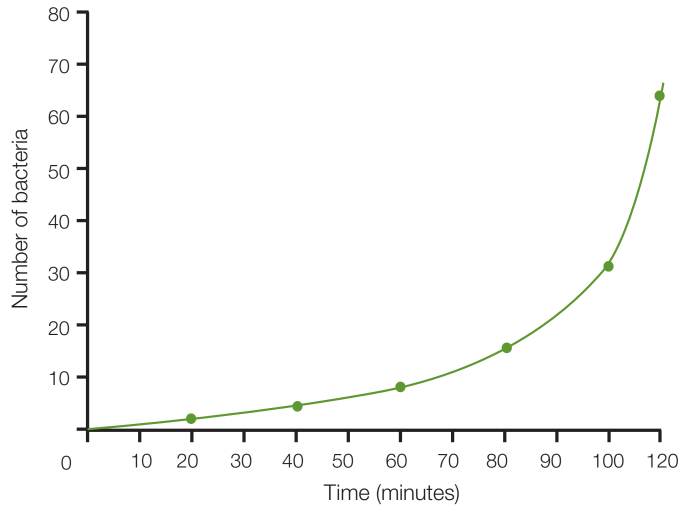


Figure 167 (b) The graph

Fortunately, such exponential growth rarely occurs because resources are a limiting factor and waste production is toxic.

To provide optimal conditions for growth, bacteria need both suitable environmental factors and a source of energy. Different types of bacteria are very diverse in their structure and also their set of requirements for life. Nonetheless there are a range of essential requirements that most bacteria need to grow.

Nutrients

Bacteria need essential matter to provide them with the required elements such as carbon, nitrogen, sulphur, and phosphorus. As has been explained in Chapter 1.4, there are two distinct types of nutrition; heterotrophic and autotrophic. Bacteria can also have different forms of nutrition and this determines in what form, whether **inorganic** or **organic**, they take in the various essential nutrients. Note that inorganic nutrients lack carbon and organic nutrients contain carbon.

Temperature

As bacteria are such a diverse group, it comes as no surprise that they can live in a vast range of temperatures from very cold (beneath ice) to extremely hot (in hot springs). Those that live in high temperatures are called **thermophiles**. Nonetheless many disease-causing bacteria flourish from about 30°C to 40°C.

Acidity/alkalinity (pH)

Some bacteria can live in very alkaline or very acidic conditions but most have optimal growth with a pH of 7.2-7.4.

Oxygen

Most bacteria require oxygen for life (aerobic) whilst others do not require oxygen (anaerobic).

Water

All bacteria need moisture to survive; there needs to be the correct water/solute balance.

Energy requirements

One of the absolute fundamentals of all life forms is the ability to source and make energy available for life's processes. The reactions studied in Chapter 1.4, i.e. fermentation, aerobic respiration and photosynthesis, can be found in different species of bacteria.

Microorganisms are important to humans

Digestive system

Human Intestines have two major functions: nutrition and defence.

Nutrition functions include digestion, **absorption** of nutrients, **excretion** of waste and removal of non-digested food (faeces). Enzymes released by bacteria in the gut help digests sugars that can be used by cells in the gut and elsewhere in the body.

Intestinal bacteria are known to produce a variety of substances that can inhibit or destroy potentially dangerous or pathogenic bacteria. Some strains can also produce enzymes capable of destroying bacterial toxins. Microorganisms in our intestines are an important component of a robust, balanced immune system.

Refer to *Figure 168* showing four species of bacteria commonly found in the human intestine.

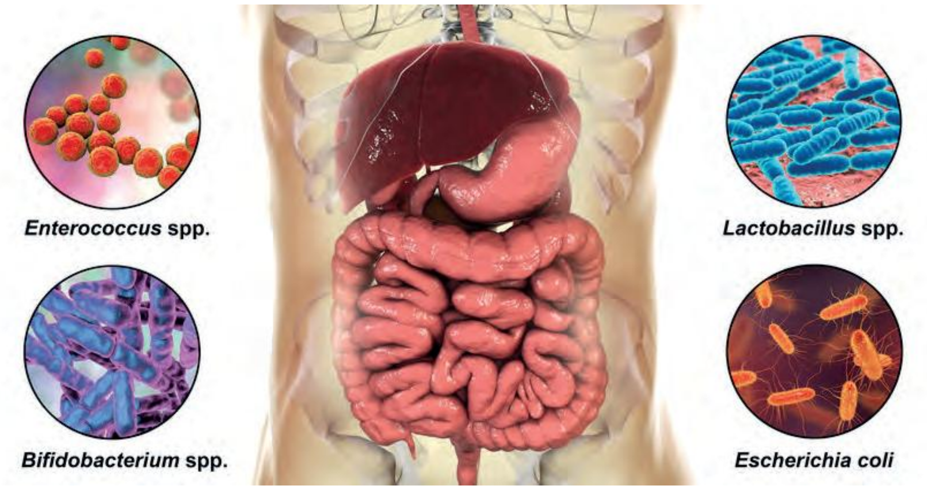


Figure 168 Bacteria in human intestines

Recycling of essential nutrients

All organisms need energy and matter to build up their tissues. The main elements that make up living tissue are carbon, oxygen, nitrogen, sulfur, phosphorous, potassium and calcium. Large animals, in fact, require around 40 essential nutrients to sustain life processes. As matter is neither created nor destroyed in the ecosystem, it is important to recycle matter from the **abiotic** environment through living organisms and back to the abiotic environment.

This process of recycling is due in part to the action of the decomposers, like bacteria and fungi. By feeding on dead and decaying material, the metabolic action of decomposers breaks down the organic material like carbohydrates, proteins, nucleic acids and lipids into inorganic substances. These are returned to the environment to be taken up by producers and incorporated back into new plant material and, in turn, the consumers. This is perhaps the most important role of soil microorganisms; to decompose organic matter and allow the recycling of important elements. Among such important elements are carbon, nitrogen, sulphur and phosphorus. *These matters are discussed in more detail in Topic 4 of this course.*

The carbon cycle

Carbon is an important element that comprises much of the structure of the organic molecules previously mentioned. Carbon dioxide (CO_2) in the atmosphere is incorporated into the tissues of plants as they use the process of photosynthesis to build up carbohydrate. This carbohydrate may be incorporated into other organic molecules, or respired by the plant to release energy that is used for life processes, and carbon dioxide, which is released back to the atmosphere. *Figure 169* shows a diagram of the carbon cycle.

When consumers feed on plants, they are consuming the plant organic material and ultimately incorporating this as their tissue. As this process continues at the different trophic levels, the element carbon is either passed on or released as carbon dioxide. When organisms die, their tissues are broken down by the action of decomposers, which releases further carbon dioxide to the atmosphere. The carbon cycle depends on both photosynthesis and respiration, and these processes generally balance each other.

There are large stores of carbon in fossil fuels like coal and oil that are the remains of organisms that lived many millions of years ago. As humans have used large amounts of fossil fuels this century, there has been a steady increase in the atmospheric carbon dioxide. Most scientists are very concerned about this increase and the effects it is having in causing global heating.

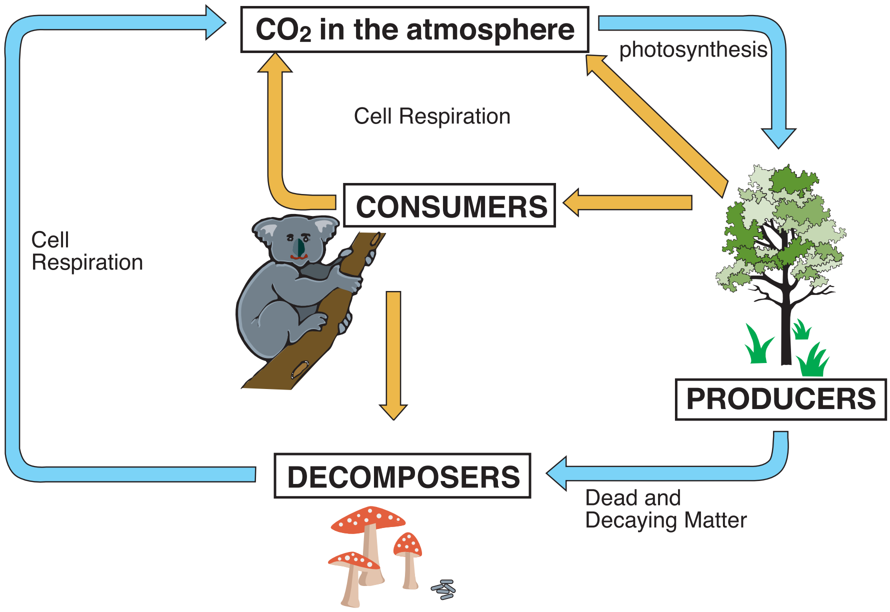


Figure 169 The carbon cycle

Helpful Online RESOURCE for an EVA about the carbon cycle

To view an Essentials Video Animation (EVA) on this topic use this QR code to visit:
<http://essentialseducation.com.au/resources/sace-1/biology/carbon-cycle/>

Oxygen production by phytoplankton

The ocean has a relatively high solute concentration and is low in nutrients and as such, not a huge number of organisms can survive in such an environment. One type however does thrive; the **phytoplankton**. These microorganisms are photosynthetic algae; they are autotrophic and use the sun's energy and atmospheric carbon dioxide to produce organic molecules (e.g. sugars) and oxygen. It has been estimated that some 50% of the world's production of oxygen comes from the ocean's phytoplankton. *Figure 1610* shows an example of a phytoplankton and *Figure 1611* an example of an 'algal bloom' in the *Bay of Biscay* which is off the Spanish coast.

Figure 1610 An example of phytoplankton (diatom)

Figure 1611 An algal bloom

Recombinant DNA technology

Bacteria are frequently used in 'genetic modification' or 'genetic engineering'. Features such as a short generation time, small size, simple DNA and less ethical concerns make bacteria the ideal organism to use in this technology and they have been used extensively since the mid 1970s.

Microorganisms have been used in a range of different technologies and applications including the production of human insulin, blood clotting factors in the treatment of haemophilia, human growth hormone (HGH) and the production of vaccines. Using **recombinant DNA** technology, bacteria have been genetically modified to fight tumour growth, treat Crohn's disease and clean up pollution in the environment. When genetic material is moved from one species to another it is called '**trangenesis**' and the modified organisms are called transgenic organisms.

Gene cloning

One example of recombinant DNA technology is called gene **cloning**. This is a technique for producing identical copies of a gene. One technique for cloning a gene involves using species of bacteria that has small loops of DNA in their cytoplasm called **plasmids**.

The cloning of a gene using bacterial plasmids includes:

- Removing a bacterial plasmid from a suitable species of bacterium
- 'Cutting' the plasmid with a type of enzyme called a restriction enzyme
- Obtaining a cell from the organism that carries the gene to be cloned and removing its DNA
- 'Cutting' the cell's DNA with the same restriction enzyme used to cut the plasmid DNA
- 'Pasting' the gene to be cloned into the plasmid DNA using an enzyme called a ligase
- Putting the genetically modified plasmid back into the original bacterium
- Allowing the genetically modified bacterium to divide by binary fission many times. Since the daughter cells are all genetically identical, they all carry a copy of the gene.

1.6

Figure 1612 (a) shows how a gene in one species can be cloned using a plasmid carried by a bacterium.

The gene cloning technique has many applications. These include:

- Inserting into bacteria a human gene that carries the information the body needs to make a protein vital for its proper functioning. The protein is made by the bacteria and is then extracted and purified, for use in medicine; e.g. the production of insulin in the treatment of diabetes.
- Inserting into bacteria artificially constructed genes that provide bacteria with information they can then use to make fuels or synthetic materials. This new area of biotechnology is called synthetic biology.

Figure 1612(b) is a coloured transmission electron micrograph (TEM) of genetically engineered DNA plasmids from bacteria. The original plasmids (yellow coat) have had the coloured gene sequences spliced into them.

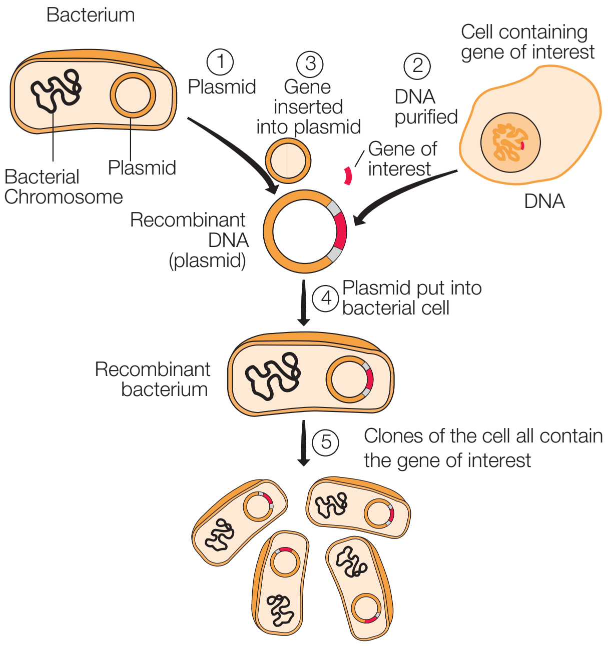


Figure 1612(a) How a gene can be cloned

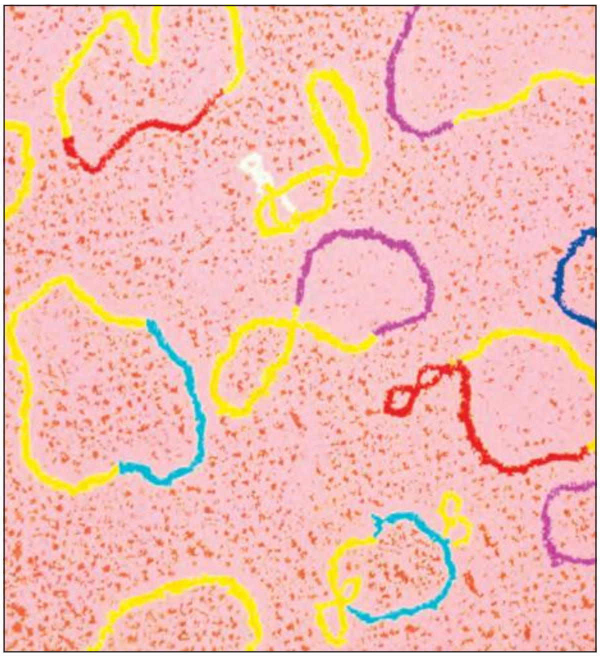


Figure 1612(b) A TEM of recombinant plasmids

Helpful Online RESOURCE for an EVA about gene cloning

To view an Essentials Video Animation (EVA) on this topic use this QR code to visit:

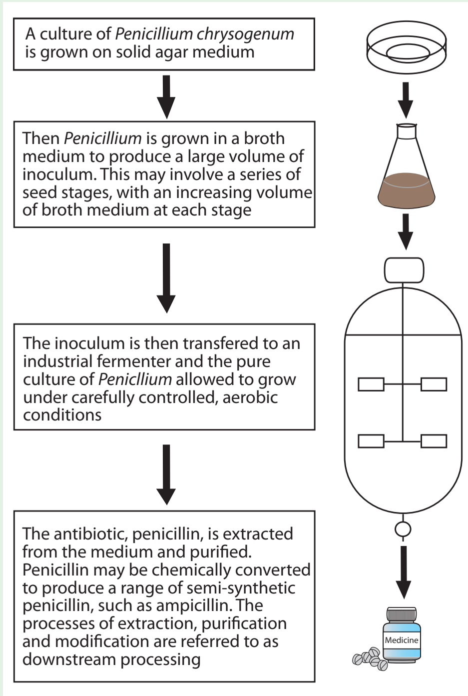
<http://essentialseducation.com.au/resources/sace-1/biology/cloning-genes/>

A commercial application: Production of penicillin

The production of penicillin requires the presence of oxygen and lactose. Glucose inhibits penicillin production. The pH and the levels of amino acids, phosphate and oxygen of the batches must be carefully controlled.

The penicillium cells are grown using a technique called fed-batch culture, in which the fungal cells are constantly subjected to stress which is required for penicillin production. Penicillin is excreted into the medium and dissolves in the solution with many other chemicals.

The process of extraction, purification and chemical modification of penicillin is referred to as down stream processing (*see Figure*). The penicillin is extracted by evaporation, which separates the insoluble fungal material from the medium. Solvent extraction (using an organic solvent then a buffered aqueous solution) is then used to isolate and then crystallize the penicillin.



Uses of microorganisms by humans

C Humans have cultured microorganisms such as yeast and bacteria for about 10,000 years to make products that are useful including alcoholic beverages, bread and dairy products, such as yoghurt and cheese.

Like 'artificial selection', making products using unicellular organisms has been practiced for thousands of years. A good example of this has been the use in winemaking of a unicellular fungus called yeast. When added to grape juice yeast converts the sugar glucose it contains into the gas carbon dioxide and an alcohol called ethanol. Alcohol fermentation of glucose may be summarised using the following word equation:

$$\text{glucose} \rightarrow \text{ethanol} + \text{carbon dioxide}$$

A diagram of a commercial fermenter is show in *Figure 1613*.

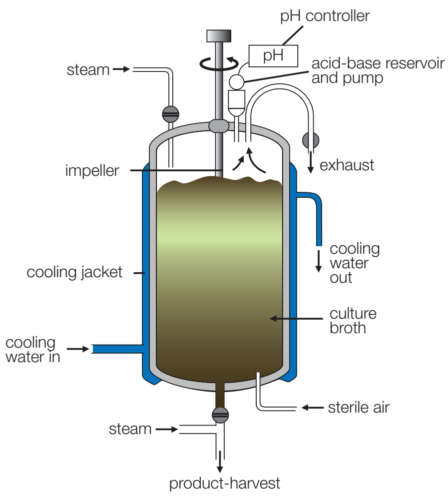


Figure 1613 A commercial fermenter

Another example of the use of unicellular organisms to make useful products is the use of bacteria to make cheese. When added to milk bacteria convert the sugar lactose it contains into an acid called lactic acid. This process is an example of lactic acid fermentation. *Figure 1614* shows a variety of hard cheeses.

Lactic acid fermentation of lactose may be summarised using the following word equation:

lactose → glucose + galactose → lactic acid

The method used to make a hard cheese:

1. Adding a starter population of bacteria to ferment the lactose in the milk into lactic acid
2. Adding a coagulant; for example the enzyme called rennet
3. Allowing the mixture to form into a solid called curd and a watery liquid called the whey
4. Separating the curd from the whey and pressing it into the desired shape
5. Salting the cheese to help prevent unwanted growth of bacteria and to enhance its flavour
6. Ageing the cheese in an environment where temperature and humidity can be carefully controlled
7. Packaging the cheese, sealing and labelling it, and sending it to distributors.

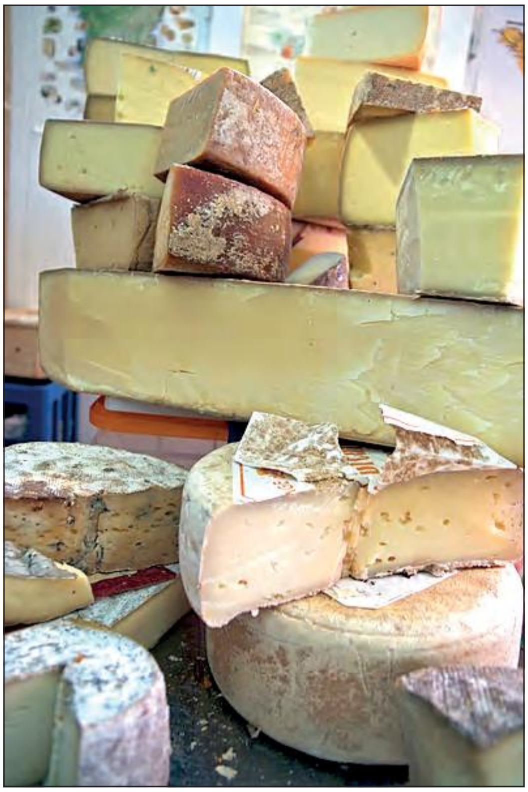


Figure 1614 A variety of hard cheeses

1.6

Key Concepts

1. The main groups of microorganisms are bacteria, archaea, fungi, protists and algae
2. Generally bacteria grow best in the following conditions:
   - 30-40°C
   - organic and inorganic materials to provide essential elements like carbon, nitrogen, sulphur and phosphorus
   - pH of around 7.2-7.4
   - suitable water/solute balance.
3. Microorganisms are important to humans:
   - as decomposers, recycling matter to make elements available for organisms
   - oxygen production by phytoplankton accounts for approximately 50% of the total oxygen produced on earth
   - recombinant DNA technology e.g. insulin production
   - culturing microorganisms in industry to produce bread, wine, cheese, beer and yoghurts.

What have you learned?

Key Terms

decomposer

parasite

bacteria

protists

fungi

algae

archaea

viruses

exponential growth

organic

inorganic

thermophile

digestion

absorption

excretion

phytoplankton

recombinant DNA

trangenesis

cloning

plasmid

abiotic

Knowledge and Understanding

1. Name the 5 main types of microorganisms and for each write one sentence that describes one important feature of the group.

2. Describe three differences between autotrophic and heterotrophic bacteria.

3. Bacteria can grow exponentially.

   a) Explain what this statement means.

   b) Give two reasons why this growth rate is not sustained for long periods.

4. Give an example of a microorganism that uses:
   a) photosynthesis
   b) fermentation
   c) aerobic respiration
5. Describe the role of bacteria in the recycling of carbon.

6. Name three features of bacteria that make them highly suitable to use in 'genetic engineering'.

7. Wine making is an important industry in our State of South Australia.
   a) Write a word equation to represent the production of alcohol in the winemaking process.

   b) What type of microorganism is used in winemaking?
8. List the main steps involved in producing a 'transgenic' bacterium.

Application, Analysis and Evaluation

9. Recombinant DNA techniques have been used to engineer bacteria and produce useful proteins.
   a) Name such a protein and say why it is useful.

   b) Briefly explain how it is possible for the transgenic bacteria to produce a human protein.

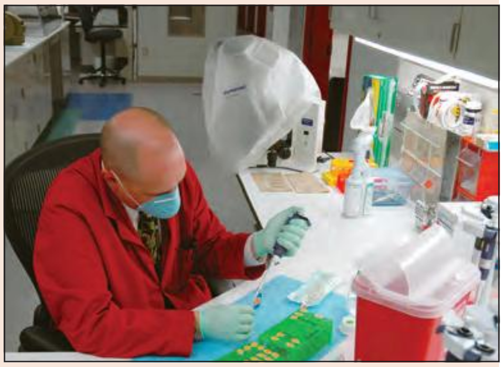
10. A carbon atom that was once part of an organic molecule in another person's body could now be incorporated into your tissue. Using your knowledge of the carbon cycle, describe a possible metabolic pathway of the carbon atom to explain how this is possible.

11. At the bottom of deep oceans, scientists have discovered isolated communities of organisms concentrated around hydrothermal (volcanic) vents. No light can penetrate to this depth.
   a) Name the group of likely microorganisms that could survive in this environment.

   b) Suggest the energy input enabling the microbes to survive.

C Critical and creative thinking: Microbial fingerprinting

The invention of fingerprinting techniques in the early 20th century enabled police to place a person at a crime scene without anyone seeing them. DNA fingerprinting (first used in a criminal case in 1986) and the use of DNA profiling today greatly enhance the power of police agencies to convict criminals.



The use of gloves makes it possible for criminals to leave no fingerprints and using DNA fingerprinting and DNA profiling depends on the collection of cells that carry DNA which can breakdown before it can be analysed.

Scientists have been searching for other methods to use in a forensic investigation to solve this problem. One imaginative solution concerns the human microbiome, or all the microscopic organisms that live in and on us. Although it has been known for some time that everyone hosts billions of bacteria and microscopic fungi in the digestive system and on skin, it has only just been discovered that the mix of species in an individual's microbiome is unique to them. Not only that, people constantly shed millions of microorganisms per hour into the air and onto surfaces they touch that is not blocked by gloves or clothing. This means collecting them at a crime scene and using DNA sequencing to determine the species present could be used to identify the person who was there.

There are, however, obstacles to using 'microbial fingerprinting' in criminal investigations. Unlike a fingerprint, a criminal's microbial fingerprint will start to decay 30-60 minutes after they leave. The microbiome also changes over time as it is influenced by diet and lifestyle choices including medications being taken. This means a suspect's microbiome at some point in the future will not match exactly the microbial fingerprint collected from the crime scene. However, according to leading scientists in the field like *Jack Gilbert* at the *Argonne National Laboratory in Chicago in America*, the technology is set to become an incredibly useful tool.

You may need to refer to the online resources below to answer the questions that follow.

1. Criminals who know that microorganisms they carry could be used to put them at the scene of a crime might try taking steps to hide their 'microbiotic fingerprint'. Briefly discuss some ways they might try to achieve this.

2. Problems with microbial fingerprinting simply require some creative solutions. What novel solutions can you suggest that will bring the use of microbial fingerprinting in forensic science a step closer?

Helpful Online RESOURCE about the microbiome around a person

formation of a microbiome around a person view the clip below:

<https://www.youtube.com/watch?v=cUjWapxvvsc>

Helpful Online RESOURCE about how the microbiome identifies criminals

To learn more about the use of the microbiome to catch criminals view the clip below:

<https://www.youtube.com/watch?v=jUANHQRUCdA>

Chapter 1.7 Microorganisms and food

Microorganisms can cause food spoilage and by controlling the growth of microorganisms, food can be preserved.

- Describe the causes of food spoilage, and explain the importance of hygienic practices.
- Describe techniques for preserving food, including the use of heat/cold, the addition of acids, sugars, or salt, and the removal of water. Relate each technique to growth requirements of microorganisms and/or diffusion.

Science Understanding

Food spoilage

One of the main agents leading to the spoilage of food are microorganisms, in particular members of the bacteria, yeasts and moulds. Such organisms that give rise to disease from this are termed **pathogenic** (or pathogens) and their actions can be caused by the host either ingesting live microorganisms (or microbes) which then grow in the host or by food-borne intoxication. The study of widespread diseases is called **epidemiology**.

Food borne intoxication is where the microbe releases **toxic** waste products as a result of their action in growing on or in the food. Poisoning occurs when the host ingests these toxins.

1.7

Food stored or left at room temperature for any length of time provides an ideal set of conditions for pathogenic organisms to flourish. Such conditions include a temperature from 10°C - 40°C, adequate moisture, optimum pH and a rich supply of nutrients. A very common cause of food poisoning is caused by the toxin produced by *Staphylococcus aureus*. These bacteria are quite resistant to a range of harsh conditions, able to survive temperatures of 60°C for 30 minutes, resistant to some **radiation** and high solute concentrations. *Figures 171* and *172* shows decomposing fruit.

Figures 171 and 172 Decomposing fruit

Hygienic practices

In Australia, many steps have been put in place to ensure that human health is not adversely affected by food spoilage or contaminated food. These steps include hygienic practices and the development of best practices in preserving food so that it can be stored and kept with minimum spoilage.

Helpful Online RESOURCE about SA food regulations

Scan this QR code to learn more about the regulations in South Australia:

<http://www.sahealth.sa.gov.au/wps/wcm/connect/public+content/sa+health+internet/health+topics/health+conditions+prevention+and+treatment/food+safety>

Hygienic practices are taken very seriously in the food industry with people working in these areas subject to strict training, necessary qualifications and associated government guidelines and regulations. These practices relate to an understanding of microbes and can be placed into the following categories:

Sanitisation

- keeping workbenches clean and **sanitised** by using **disinfectants**
- ensuring all areas where food is prepared is free from vermin (e.g. rats), insects, dirt etc. which may harbour or transmit microbes

Personal hygiene

- washing hands frequently (see *Figure 173*)
- avoiding coughing and sneezing near food
- wearing proper clothing and paying attention to good personal hygiene with hair tied back or the use of a hair net (see *Figure 174*)

Figure 173 Hand washing

Figure 174 Use of hair nets

Cleaning equipment

- ensuring all cooking utensils are cleaned thoroughly and regularly
- cleaning all knives, plates and surfaces regularly
- using high temperature and pressure apparatus to clean surfaces and utensils

Storing food

- correctly using refrigeration
- adhering to use-by dates
- ensuring adequate cooking

Figure 175 shows the effect of temperature on bacterial growth.

The four core practices for **hygienic** food management are:

CLEAN: wash hands and surfaces often

SEPARATE: don't cross- contaminate

COOK: cook at proper temperature

CHILL: refrigerate promptly

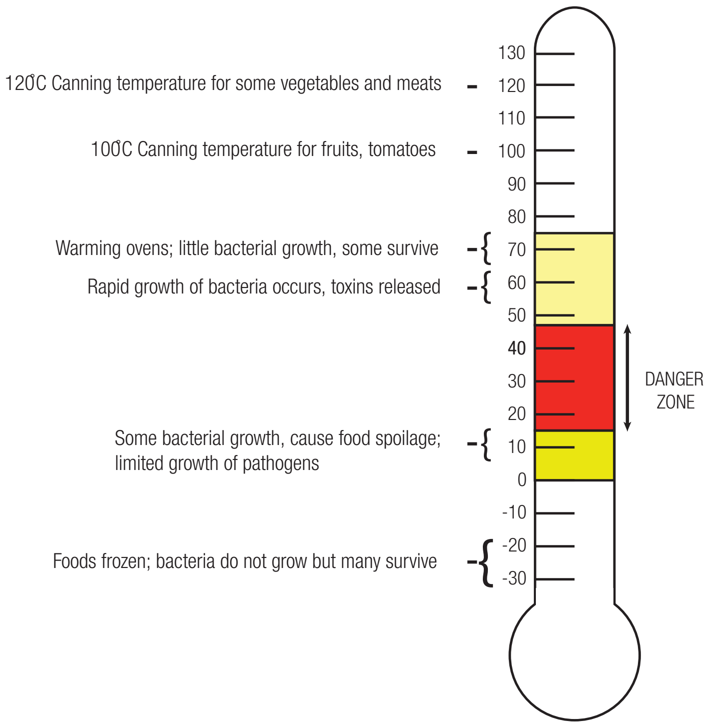


Figure 175 Food storage temperatures

Preserving food

C Some preservation methods date back thousands of years and a very important aspect of modern civilisation has been the discovery of better methods of preserving food in attempting to reduce food spoilage. As has been explained, food spoilage is caused primarily by the action of bacteria, yeasts and moulds and so any processes or techniques that inhibit microbial growth in food, whilst still maintaining the taste and texture, quality and appeal, will help to prolong food life.

Sometimes older, more traditional methods are used (see *Figure 176(a) and (b)*) to preserve food whilst sometimes more modern methods are used (see *Figure 177*).

Figures 176 (a),(b) Some more traditional methods

Figure 177 Some more modern methods

Throughout time many discoveries about food preservation were probably discovered by chance but now we can link these to our knowledge of the essential conditions for the optimal growth of microbes. Sometimes more than one method of preservation is used e.g. preserving fruit by cooking, adding sugar and sealing.

Refer to the table below that summarises a range of preservation methods.

Method of preserving food	Main mode of action
Heat sterilisation/boiling/steam	kills bacteria and fungi in 10 minutes
Pasteurisation	heat treatment for milk at 72°C for 15 seconds kills most bacteria
Refrigeration	slows cell metabolism and bacterial growth at approximately 5°C
Deep freezing	freezing makes liquid water unavailable to microbes which greatly slows their growth and reproduction
Drying	removes moisture from microbes and the food itself and kills most pathogens since they lose water.
Radiation	destroys DNA and kills pathogens
Chemical **preservatives**	e.g. acids, sugars, sodium nitrite, salt and smoke destroy pathogens
Commercial sterilisation	this process kills pathogens and the food is then stored in a sealed container until use

Key Concepts

1. Human food is a perfect source of nutrients for microbes such as bacteria , moulds and yeast.
2. When microbes grow on food they increase in number and release waste products and toxins that cause the food to be unsuitable for human consumption.
3. Food can be preserved and kept for longer periods by preventing the growth of these microbes.
4. Hygienic practices such as washing hands, cleaning food preparation surfaces and washing kitchen utensils are important in avoiding the spread of disease.
5. There are a range of techniques used to preserve food including:
   - Heating/ freezing
   - Addition of acids, sugars, salt or other preservatives
   - Removal of water – e.g. dehydration.

C Intercultural understanding: The world's first bread

Today bread is part of the diet of many human cultures. However, for how long? For many a study published by the late British archaeologist *Gordon Hillman* (died 2018) in 1989 provides the answer - bread making first took place in ancient Egypt about 17,000 years ago.

In July 2018, work published in the science journal Proceedings of the National Academy of Sciences of the United States (PNAS) presented evidence obtained from the Black Desert in the Middle Eastern country of Jordan that the oldest actual bread dates from 14,500 years ago. Remains of two buildings unearthed at the site were each discovered to contain a large circular stone fireplace within which charred breadcrumbs were found. When these were viewed under a microscope, the bread samples (from a flatbread) showed signs of grinding. It is likely that ground barley or oats (flour) was mixed with water to form a dough, which was baked on hot stones around the fire, or in the ashes. The work suggests humans learned to bake before farming (that started more recently in the Middle East, about 11,000 years ago).

There is, however, evidence that bread making dates back even further. Fragments of grindstones recovered from the Cuddie Springs area in central Northern New South Wales have been found to be at least 30,000 years old (*refer to photo*). *Richard Fullager* (Australian Museum) and *Judith Field* (University of Sydney) published a scientific paper in 1997 that concluded these grindstones were used to produce a flour from seeds. According to the Australian Museum in 2018, the flour was mixed with water and eaten as a paste or baked (on stones or in coals) and eaten as 'seed cakes' or 'bush bread'.

Baking cakes and bread had many benefits. As a good source of carbohydrates that was compact and portable, they could be taken and consumed on journeys. As a baked product, the cakes or bread were devoid of water, and thus provided a way to preserve food. In a landmark 2014 book Dark Emu, *Bruce Pascoe* states this means that it was actually Aboriginal people who were the first to bake bread, not the ancient people of the Middle East.

You may need to refer to the online resources below to answer the questions that follow.

1. Describe 3 cultural factors that may have influenced the types of breads that are currently available in Australia.

2. New information has come to light that suggests this 'out-of-the-Middle-East' hypothesis for the origin of bread making is incorrect. Briefly describe this evidence.

Helpful Online RESOURCE about the discovery of 14000-year-old bread

To learn more about the discovery of 14000-year-old bread in Jordan view the clip below:

<https://www.youtube.com/watch?v=6Y0hIo-u9_A>

Helpful Online RESOURCE about Australian Aboriginal baking

To learn more about Aboriginal Australians being first to bake bread view the article below:

<https://renew.org.au/renew-magazine/community/the-worlds-first-baker-australian-indigenous-innovation/>

What have you learned?

Key Terms

toxic

hygienic

pathogenic

epidemiology

sanitisation

disinfectant

pasteurisation

radiation

preservatives

Knowledge and Understanding

1. Name the main groups of microbes that cause food spoilage and for each give a typical example to illustrate the spoilage.

2. Explain two reasons why eating spoiled food can lead to serious disease.

3. State three hygienic practices and for each explain why the practice helps prevent pathogenic microbes from causing disease.

4. Staff working in chemotherapy wards in hospitals are required to place a hand print on an agar plate prior to working with patients. Explain the reason for this practice.

Application, Analysis and Evaluation

5. Below is a list of a few common foods that might be found in a supermarket. Complete this table to indicate the likely method of food preservation used to reduce or prevent food spoilage.

Food	Method of preservation
Pickled onions	
Vacuum-sealed salmon	
Frozen vegetables	
Ham	
Dried fruit	
Canned tomatoes	

6. Choose a method of food preservation that works predominantly by:
   a) greatly slowing the growth of microbes.
   b) destroying microbes.
   c) preventing the entry of microbes.
7. Explain the concept of the 'use-by-date' on foods, linking this to food spoilage.

8. Using your work from Chapter 1.5 on osmosis, explain why most microbes cannot grow in food that has been stored or preserved in salt and/or sugar.

Science as a Human Endeavour 1.7 - Food contamination

Communication and collaboration

Collaboration ... is often required in scientific investigation...

Hepatitis A and frozen berries (a case study)

Epidemiology

By the end of March 2015 some 28 cases of hepatitis A were reported in Victoria, New South Wales, Queensland, Western Australia, ACT and South Australia.

In all cases individuals had consumed frozen mixed berries during the period of 15 to 50 days prior to the onset of symptoms. The particular product containing raspberries, strawberries and blackberries was packaged in China, under the one brand name.

The virus

Hepatitis A is a food or water born viral disease that infects the liver. The virus that causes it can contaminate food by contact with faeces, poor personal hygiene, contaminated food from an infected food handler or contaminated water.

The disease may not present symptoms until 50 days. The symptoms include fever, jaundice, nausea, vomiting, and dark urine.

The response

- recalling all suspected products
- screening all frozen berry consignments from China
- mandatory *E. coli* and hepatitis A testing of the product sourced from the facilities in China

Helpful Online RESOURCE about frozen berry contamination

To read an original news report use the QR code to follow this link:

<http://www.abc.net.au/news/2015-02-17/fourth-frozen-berry-product-recalled-in-hepatitis-a-scare/6126272>

Science as a Human Endeavour 1.7 - Food contamination (continued)

Do some further research on this incident and write a report under the following headings:

1. Describe how collaboration is required to address and resolve this issue, and others like it.

2. Describe one way that new technologies have improved the efficiency of detection of these viruses.

3. Outline how science has informed public debate and resolution of this issue.

(Your teacher may provide more instructions for your report.)

Deconstruction and Design - Factors affecting the rate of osmosis

Introduction

All living organisms consist of cells and all cells are surrounded by a membrane. One of the major functions of the membrane is to regulate the passage of materials into and out of the cell. The diffusion of water across a partially-permeable membrane is called osmosis.

Possible factors for investigation

There are many factors that affect the rate of osmosis in living organisms.

Several possible problems might arise including:

- What is osmosis and why is it necessary in organisms?
- Does a change in temperature affect the rate of osmosis?
- Does the pH of the solution affect the rate of osmosis?
- Does the concentration gradient affect the rate of osmosis?
- Do different tissues have different rates of osmosis?
- Do saline soils affect the impact on the rate of osmosis with plant tissue?
- Does the SA:V ratio affect the rate of osmosis (i.e. the size and shape of the tissue used)?

With the direction of your teacher you will then you will Deconstruct the problem and then Design and conduct an experiment to determine the effect of one factor on the rate of osmosis.

A Deconstructing the problem *(Refer to the Guidelines on page 470 in the Appendix.)*

1. Research the process of osmosis and its relevance to organisms, focussing particularly on the factor you are interested in investigating.
2. Explore factors that impact on the rate of osmosis such as those mentioned above.
3. Make informed decisions about determining experimentally how one factor that might affect the rate of osmosis could be measured.
4. Explore and address the health and safety risk factors involved.
5. Select the one factor and develop a method to test the effect of changing this on the rate of osmosis.

B Designing your own investigation *(Refer to the Guidelines on pages 471, 472 in the Appendix.)*

Use the guidelines from the General Appendix of this Workbook and/or the SACE Subject Outline to help you Design your own investigation.

Justify the decisions you have made about such factors as:

- the type of tissue you have chosen
- the independent and dependent variables
- how the independent variable will be changed
- how the dependent variable will be measured (a blank data table should be included)
- what variables will be held constant and why
- the variable factors that may not be able to be held constant or controlled and consider their potential impact.

C Conducting the investigation

Your teacher will set out guidelines, including health and safety considerations, about how this is to be achieved.

D Writing a report *(Refer to the Guidelines on page 473 in the Appendix.)*

The requirements of the practical report are to be found in either the SACE Subject Outline or in the Appendix of this book. In particular, the word count for the Introduction, Analysis of results, Evaluation of method/procedure and Conclusion should not exceed 1000 words in Stage 1 (and 1500 words in Stage 2). The Deconstruction and Design, including the method chosen and the justification of the plan of action must be a maximum of four sides of an A4 page and needs to be attached to the practical report.

Introduction

These Answers have been suggested by the authors, they are not intended to be either comprehensive or exclusive. In some cases no answer is suggested because it relies on research or an individual response from students.

Chapter 1.1 Answers

1. Suggestions are:
   - reproduction
   - respond to stimuli
   - utilise energy
2. Unicellular organisms consist of only one cell e.g. *Euglena*, whereas multicellular organisms are made up of many cells e.g. yourself
3. Features include:
   - all life consists of cells and the products of cells
   - a cell is the smallest unit of life
   - cells are the units of structure and function in all organisms
4. Examples are:
   a) red blood cell
   b) nerve cell
5. Cells are tiny, in most cases a microscope is needed to see them.
6. A cell membrane defines the boundary of a cell, encloses its contents and controls the entry and exit of materials.
7. Sections need to be very thin so as to allow light to pass through the specimen and then through the lenses of the microscope to your eye.
8. Properties include:
   - it possesses a code that carries information to make protein molecules.
   - It possesses the ability to self replicate i.e. to make other copies of itself
9. Reasons include:
   - Structure: all cells consist of cells and the products of cells
   - Function: cells carry out all vital functions of organisms
10. Evidence would include:
    - look for evidence of cells
    - observe whether the structure responds to stimuli
11. Responding to light as a stimulus for photosynthesis.
12. With a light microscope the internal details such as smaller cell organelles like mitochondria, Golgi bodies and endoplasmic reticulum can not be seen.
13. The living thing is approximately half of the diameter of the field of view = ½ x 1200 μm = 600 μm
14. Suggestions are:
    a) an ovum is 120 μm which is about twice as big as an amoeba
    b) an ovum is about 2.4 times bigger than a skin cell
    c) approximately 25 E. coli cells would fit across a cheek cell
15. Estimates are:
    - moss cell approximately 45 μm
    - banana cell approx 90 μm
    - liver cell approx 25 μm
    - a banana cell is the largest

Chapter 1.2 Answers

1. Suggestions are shown:

Organelle	Structural feature(s)	Special function(s)
Ribosome	Tiny non-membrane bound organelle	Site of protein synthesis
Cell wall	Wall outside of cell membrane, made up of sugars and amino acids	Provide support and structure for the unicellular organism
Cell membrane	Phospholipids and membrane proteins	Controls entry and exit of materials
Chromosomes	Consists of one circular chromosome	Genetic information of bacteria

2. Suggestions are shown:

Organelle	In plant/animal?	Structural features	Special functions
Nucleus	Both	Membrane bound, contains pores	Contains DNA, chromosomes, genetic material
Golgi bodies	Both	Stacks of flattened structures	Packaging and secretion of molecules
Mitochondria	Both	Double membrane contains many enzymes	Site of aerobic respiration
Chloroplasts	Some plant cells only	Contains the pigment chlorophyll	Site of photosynthesis
Vacuoles	Both	Larger and more central in plants	Storage of water and ions in plants
Endoplasmic reticulum	Both	Network of membranous structures in cytoplasm	Internal transport of molecules

3. Common features include: cell membranes, contain DNA, transform energy and carry out chemical reactions.
4. Differences include: eukaryotic cells are bigger, there are non-membrane-bound organelles in prokaryotic cells, chromosomes are circular in prokaryotic cells and are linear in eukaryotic cells.
5. The organelles that are not membrane enclosed are: cell membrane and ribosomes.
6. They can do so because:
   - prokaryotic cells contain DNA but not in a nucleus
   - they have chemicals for metabolism and transformation of energy
   - they are simpler cells with less internal organisation
7. Suggestions include:
   a) active muscle cells e.g. heart, sperm cells
   b) in the leaves of plants
   c) in the respiratory tract (lungs and trachea) where they secrete mucus.

8. As follows:
   a) Organelles 1, 2, 4, and 5
   b) Organelle 1 (mitochondrion)
   c) Photosynthesis (chloroplast)
9. As follows:
   a) it is a eukaryotic cell
   b) because it has a nucleus and possibly a cell wall
10. The cell contains chloroplasts which contain chlorophyll and are able to conduct photosynthesis. Animal cells cannot carry out photosynthesis.
11. Answers as follows:

Name of organelle	Location plant or animal cell or both	Important structural features	Function
Mitochondria	Both	Double membrane contains many enzymes	Site of aerobic respiration
Chloroplast	Plant	Contains the pigment chlorophyll	Site of photosynthesis
Endoplasmic re-ticulum	Both	Network of membranous structures in cytoplasm	Internal transport of molecules
Golgi bodies	Both	Stacks of flattened structures	Packaging and secretion of molecules
Nucleus	Both	Membrane bound, contains pores	Contains DNA, chromosomes and genetic material

Chapter 1.3 Answers

1. DNA replication occurs prior to both forms of cell division when equal amounts of identical DNA is passed on to each daughter cell.
2. In brief:
   c) Prophase; chromosomes shorten and thicken becoming visible
   d) Metaphase; chromosomes are attached to the spindle apparatus at the equator of the cell.
   e) Anaphase; chromosomes separate so that one identical chromatid for each chromosome moves to each pole.
   f) Telophase; chromosomes begin to elongate and a nucleus begins to form in each daughter cell.
3. Mitosis is defined as division of the nucleus, four phases occur as described above. Cytokinesis is the actual process of one cell splitting into two identical new daughter cells.
4. As follows:

Type of division	**Type of organism**	**Type of chromosome**	**Number of cells formed**	**Spindle fibres Yes/No**	**DNA replication Yes/No**
Binary fission	Prokaryote	Circular	2	No	Yes
Mitotic division	Eukaryote	Linear	2	Yes	Yes

5. As follows:
   a) 4
   b) cytokinesis
   c) B, C, E, D, A
6. Binary fission is used by prokaryotic cells; some unicellular organisms are eukaryotic and have a nucleus. Mitotic division can occur in cells that have a cell wall if they possess a nucleus e.g. plant cells. It is true that spindle fibres are not involved in binary fission.
7. With reference to the graph:
   a) DNA replication occurs in the section B-C because during this time the amount of DNA per cell doubles.
   b) No. Single-stranded chromosomes become double-stranded and consist of two chromatids.
   c) Chromatids are being pulled to the poles in Anaphase. The double-stranded chromosomes are becoming single strands in each new daughter cell. Note that each chromatid is still composed of a double helical molecule of DNA.
8. Suggested answers:
   a) The term is used to describe the fact that when double-stranded DNA makes another copy of itself, it unravels and each original strand is used as a template to make a new strand. When the copied DNA separates, each molecule of DNA contains one old and one new strand; hence replication is said to be ‘semi-conservative’.
   b) Using radioactive bases enable scientists to track where the new strands are. After the replication of a radioactive DNA molecule it is found that each new chromosome contains one strand with radioactive bases and one strand without any radioactivity.

Chapter 1.4 Answers

1. Examples are:
   a) During mitosis, chromatids move on spindle fibres to the poles of the cell.
   b) Amino acids are joined or synthesised at ribosomes into polypeptides (and/or proteins).
   c) A range of homeostatic processes are involved in temperature control; e.g. sweating, shivering
2. Suggested answers:

Organism	**Type of nutrition**	**Example of organism**	**How carbon is obtained**	**Initial energy input**
Autotroph	Autotrophic	Plant	From carbon dioxide	Light
Heterotroph	Heterotrophic	Animal	From organic molecules	Chemical energy

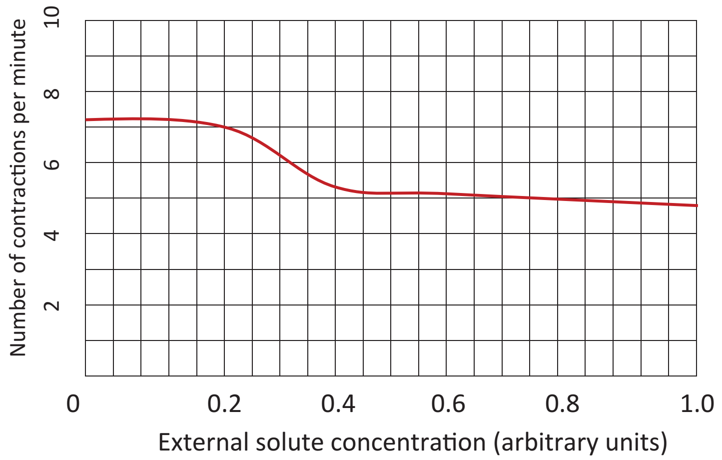
3. The word equations are:
   - carbon dioxide + water → glucose + oxygen
   - glucose + oxygen → carbon dioxide + water
   - glucose → lactic acid
   - glucose → ethanol + carbon dioxide
4. Suggested answers: carbon dioxide, urea, water
5. Carbon dioxide is a by-product from aerobic respiration. Carbon dioxide in plants is a raw material for photosynthesis.
6. Factors which may affect the rate of photosynthesis:
   a) Temperature will affect the rate of chemical reactions (photosynthesis) within the cells.
   b) Light intensity is important because light provides energy for photosynthesis.
   c) Carbon dioxide level is important since it is a raw material for the process.
7. Referring to the graph:
   a) The colours mainly used are violet and blue and yellow and orange.
   b) Blue light is absorbed by the leaf providing energy for photosynthesis and more glucose will be produced.
   c) Green light is not absorbed, therefore reflected which explains why most leaves are green in colour.
8. Referring to the graph:
   a) At point C. The nett movement of oxygen out is greatest. Oxygen is a product of photosynthesis which requires light.
   b) Photosynthesis: carbon dioxide + water → glucose plus oxygen

      Aerobic respiration: glucose + oxygen → carbon dioxide plus water
   c) Points B and D
   d) Photosynthesis only provides glucose. Glucose needs to be broken down in aerobic respiration to release energy for use by cells/organisms.
9. Euglena can photosynthesise where light is available, hence autotrophic nutrition. When light intensity is lower it can absorb nutrients across a cell membrane and use organic materials for respiration to provide energy, hence heterotrophic nutrition.

Chapter 1.5 Answers

1. Useful substances include:
    - glucose; substrate for aerobic respiration and a source of energy
    - oxygen; needed for aerobic respiration to break down glucose
    - amino acids; building blocks for polypeptides and protein molecules
2. Metabolic waste products include:
    - carbon dioxide (produced by aerobic respiration)
    - urea (produced by the breakdown of proteins)
3. Useful products include
    - hormones; e.g. insulin is involved in the control of blood sugar concentration
    - mucus; used in the body defences by trapping pathogens
4. Refer to *Figure 155*.
5. Differences Include:
    - active transport requires energy whereas passive transport does not
    - active transport move substances from low to high concentration whereas passive does not
    - active transport will move substances that do not normally diffuse
6. Properties include:
    - they are made of phospholipid bilayer and tends to accept lipid-soluble molecules
    - the channels or membrane proteins do not allow large molecules to pass through
7. Calculations are:
    - for the 2 cm cube: SA = 24 cm^2, V = 8 cm^3, SA:V = 3:1
    - for the 1 cm cube: SA = 6 cm^3, V = 1 cm^3, SA:V = 6:1
8. As the cell grows and becomes larger its SA:V ratio decreases. This means that a bigger cell has more volume compared to its surface area than a smaller cell. This means that its ability to exchange materials with the external environment is decreased.
9. The relevant properties are:
    a) semi-permeable which means it will allow some molecules to diffuse across it and not others
    b) contains protein pump molecules that can move molecules actively against a concentration gradient
    c) a flexible, fluid-like membrane that can surround and engulf particles
10. Referring to the diagram:
    a) the volume has decreased (shrunk)
    b) water moves out of the cell by osmosis
    c) outside the cell is a higher solute concentration
    d) cell metabolism requires specific conditions e.g. temperature and other conditions for reactions to proceed
11. Sensible inferences are:
    a) osmosis
    b) mineral ions move by active transport
    c) epithelial cells absorb droplets by endocytosis (pinocytosis)
    d) endocytosis (phagocyctosis)
    e) oxygen moves by diffusion

12. Possible explanations:
    a) water moves out of the plant by osmosis making leaves and the stem less firm
    b) water moves into plant cells by osmosis from low solute to high solute concentration making leaves and the stem more firm.
    c) In distilled water there is a low solute concentration outside and water moves in by osmosis. If the solution is slightly salty and there are equal concentrations outside and inside there will be no nett movement.
    d) Endocytosis: a section of membrane pinches off and moves into the cell and the membrane becomes smaller.
13. Referring to the data:
    a) Your graph should look like this.



    b) The smooth line graph will start higher on the left and slope down to the right.
    c) As the external solute concentration increases the rate of contractions per minute slowly decreases.
    d) It is very likely that the cell membrane is permeable to water because at lower solute concentration more water moves in to the cell and has to be pumped out by faster contractions of the contractile vacuole.
    e) As the solute concentration increases outside less water moves in by osmosis so less rapid contractions of the vacuole are needed to pump out water. Data is not reliable, there is no replication of the measurements and only one Paramecium was used; reducing rates of contraction of the vacuole may be due to another factor e.g. fatigue

Chapter 1.6 Answers

1. The main groups are:
   - Bacteria; unicellular, prokaryotic organisms, very small and simple
   - Fungi; eukaryotic with cell walls, heterotrophic and involved in decomposition
   - Protists; one of the largest groups on earth, unicellular eukaryotic and very diverse
   - Archaea; similar to bacteria, they are unicellular, prokaryotic and a different group that often live in hostile environments
   - Algae; autotrophs and vary from unicellular to large multicellular organisms
2. Three differences are:
   - autotrophs can convert inorganic matter to organic matter
   - heterotrophs need to feed on organic matter to survive
   - autotrophic bacteria need an external energy source e.g. light or chemicals to synthesise organic materials
3. Regarding exponential growth:
   a) growth is very rapid, progressing geometrically rather than arithmetically e.g. 1, 2, 4, 8, 16, 32 etc.
   b) resources will eventually run out and the waste materials produced by the bacteria may be toxic to them
4. Examples include:
   a) Algae
   b) Bacteria in an anaerobic environment e.g. mud
   c) Protist
5. Their main role is as decomposers, they are consuming/feeding on dead/decaying organic matter. As an outcome, the carbon in the organic molecules is changed into different molecules e.g. carbon dioxide that plants can use for photosynthesis.
6. Three features are:
   - very few ethical issues
   - very small, containing little genetic material that is relatively easy to manipulate
   - very short life-cycle and produce products quickly
7. With regards to winemaking:
   a) glucose → ethanol + carbon dioxide
   b) yeast (a type of fungus)
8. The main steps are:
   - identify a gene of interest in a host organism
   - remove the gene of interest from the host and the plasmid from a bacterium
   - join the gene of interest into the plasmid
   - place the genetically modified plasmid back into the bacterium
9. Regarding DNA technologies:
   a) Insulin; useful because it can be injected into diabetic patients to control their blood sugar levels.
   b) As the transgenic bacteria contain a human gene, when activated it produces human protein.
10. A possible pathway is:
    - Organic molecules in food may be broken down in the body and released as carbon dioxide.
    - This carbon dioxide could then be absorbed by a plant e.g. a cereal crop and converted into an organic molecule.
    - You could then eat some cereal from this crop and synthesise an organic molecule that becomes part of your tissue.
11. Around these hydrothermal vents:
    a) bacteria, archaea, chemo-autotrophs
    b) In the absence of light, energy will probably be obtained from other chemicals that are present e.g. hydrogen sulphide.

Chapter 1.7 Answers

1. Regarding food spoilage:
   - Bacteria; S.aureus causes food spoilage in chicken meat that is not cooked fully
   - Yeasts; in high acid foods e.g. tomatoes, some fruits and jams
   - Mould; e.g. growing on fruit as shown in *Figure 172*
2. Foods may contain micro-organisms that:
   - may be ingested and grow inside the host causing disease
   - may release toxins that cause serious health issues
3. Three hygienic practices include:
   - Sanitisation; cleaning and disinfecting work areas to remove microbes
   - Personal hygiene; washing hands and wearing gloves to avoid contaminating food
   - Storing food; using accepted protocols, cooling and freezing to reduce microbial growth
4. Chemotherapy patients often have weakened immune systems and are unable to fight off infection. A handprint on an agar plate will reveal microbes on the hand indicating the level of cleanliness of staff e.g. hand washing, which may affect the health of the patient.
5. See table below:

Food	Method of preservation
Pickled onions	Sugar, salt, vinegar - all kill microbes
Vacuum-sealed salmon	No oxygen is available for (aerobic) microbial growth
Frozen vegetables	Liquid water is unavailable, microbes are unable to grow, although they are not all killed
Ham	Salting, smoking extracts moisture and will inactivate or destroy microbes
Dried fruit	Removes moisture that is necessary for the growth of microbes
Canned tomatoes	Boiling kills microbes and sealing prevents any re-entry

6. Common methods are:
   a) Freezing
   b) Pasteurisation, radiation
   c) Canning or bottling
7. Suppliers of food products need to have ‘use-by’ (or 'best-by') dates on their products. This is particularly important since since micro-organisms can increase in numbers over time reaching levels where toxins they produce and the numbers of them become poisonous to consumers. It is wise to check these dates when food is purchased.
8. Salt and sugar are solutes and when dissolved in water have a high solute concentration. When microbes are exposed to such high solute concentrations water moves from inside the microbe (low solute concentration) to outside thereby killing the microbe due to water loss and shrinking cells.

Introduction

The Laboratory Notes are suggested, particularly for use by Teachers and Laboratory technicians, and again are advisory and not intended to be either comprehensive or exclusive.

SIS 1.1 Laboratory Notes

No doubt all students will have done some microscopy in their Junior Science courses. However, they will need reminders about handling, setting up and using senior microscopes. A very important skill is focussing on Low Power (40X) first before rotating the nosepiece and then it is strongly recommended that students use the **fine focus only** to focus on High Power (100X, 400X). This will save breaking many glass slides!

Part A: Estimating the field of view

Stress frequently the importance of carrying and setting up a microscope correctly and focussing it properly.

If possible it is a good idea to demonstrate the whole activity using a flex cam and monitor, or equivalent, so students know what they are looking for, before they undertake the task.

Part B: Viewing the specimen

Individual prepared stained onion root tip slides are available from:

- Southern Biological <www.southernbiological.com>
- Omega Scientific Pty Ltd <www.omegascientific.com.au>

Prepared onion bulb epidermis slides are available from:

- Serrata Pty Ltd <www.serrata.com.au>
- Microscopes and More <www.microscopesandmore.com.au>

Stress the fact that a microscope drawing is a form of communication and so needs to be done carefully. In particular it should be done using a sharp pencil.

Although slightly time-consuming, an alternative is to make the slides 'in-house'.

This can be done, following these instructions:

- Prepare onion epidermis slides following the method in Science Inquiry Skills 1.2 Laboratory Notes
- Remove as much of the stain as possible by soaking it up with a piece of tissue
- Add a drop or two of Depex mounting medium (which is available from Southern Biological), cover with a coverslip and allow to set overnight. Note however, that *Depex* is classified as a hazardous substance and should be stored and handled appropriately, as per SDS

SIS 1.2 - Laboratory Notes

This activity is an excellent opportunity for students to learn how to make wet mount slides and to consolidate how to use a light microscope effectively.

Onion epidermal cells

- Store the onion in the fridge prior to the activity to reduce the volatility of the irritants it contains.
- If it is difficult to get one layer of onion tissue, put a drop of water on the slide and use the brush to roll the specimen off it and onto the slide.
- Make the onion cells more visible by staining them; for example, add a drop of iodine solution instead of a drop of water. Can use Iodine antiseptic drops e.g. Betadine, or Laboratory prepared. To prepare, add 1g of Iodine and 5g Potassium Iodide to 20mL distilled or de-ionised water, dissolve, then make up to 250mL. Store in a brown glass bottle to protect from light.
- One 'less mess' method for iodine-staining involves putting a drop of iodine solution on the slide next to the coverslip instead of on the specimen. If a piece of tissue is put on the opposite side of the coverslip, the tissue will draw the iodine stain under the coverslip and across the specimen.

Human cheek cells

- To reduce clumping of cheek cells, smear the cotton bud onto the slide and then use a tooth-pick to stir the cheek cells in a drop of (methylene blue) stain before placing the coverslip.
- Use a 0.01% solution of Methylene blue stain. To prepare, dissolve 0.1g of Methylene blue powder in 100mL of distilled or de-ionised water.
- Reduce methylene blue staining of the skin by instructing students to hold the slide at one end with thumb and forefinger..
- After the Activity has been completed laboratory staff should use gloves to handle and the wash slides to protect against body fluids and staining of the skin by methylene blue.

Slides/coverslips can be cleaned using an acid/alcohol solution; for example, to 100 mL of 70 % ethanol add 1 mL of 1 % hydrochloric acid. Soak them in this for an hour and then rinse in water.

SIS 1.3 Laboratory Notes

No doubt all students will have done some microscopy in their Junior Science courses. However, they will need reminders about handling, setting up and using senior microscopes.

A very important skill is focussing on Low Power (40X) first before rotating the nosepiece and then it is strongly recommended that students use the **fine focus only** to focus on High Power (100X, 400X). This will save breaking many glass slides!

SIS 1.4 - Laboratory Notes

Insist that razor blades or scalpels are always used to cut down onto a cutting mat and that the equipment is labelled, placed well away from the edge of the bench, and stored safely between lessons, preferably placed together on a tray in the storeroom.

SIS 1.5 Laboratory Notes

In other practical manuals there are many interesting activities that use tissues like blood, rhubarb, algae and beetroot to demonstrate the movement of water across the cell membrane. There are also a variety of activities using dialysis tubing which many schools may use regularly. What really appeals to us about using cubes of potato is that it is very cheap, clean and safe to use.

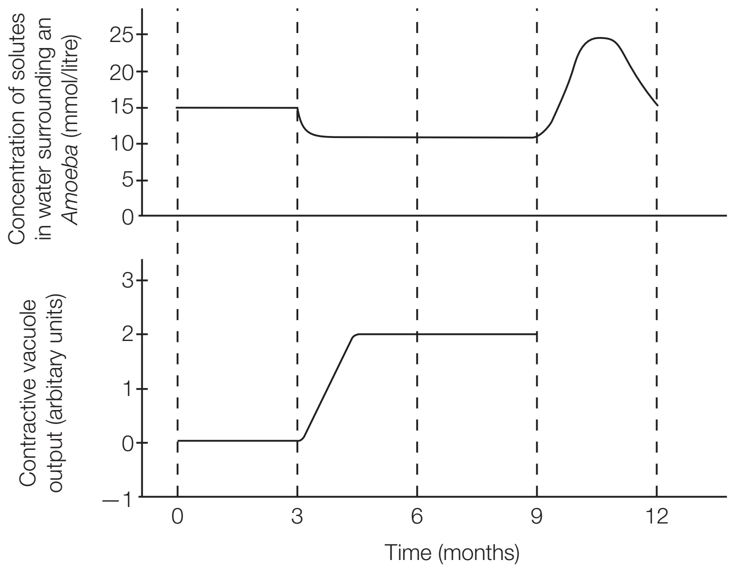
TOPIC 1 Test Yourself

Answer all of the questions in the spaces provided. The number of marks for each question is shown in brackets. Answers are suggested for all questions at the end of the test. Note that they are not intended to be the only possible answer. Read these carefully after the test and use them as part of an assessment for learning activity.

1. A prokaryotic cell can be distinguished from a eukaryotic cell by the:
   - J presence of a cell membrane
   - K absence of membrane-bound organelles
   - L absence of a nucleus
   - M presence of a cell wall

2. In mitosis, a parent cell usually produces:
   - J two daughter cells, each of which has the same number of chromosomes as the parent cell.
   - K four daughter cells, each of which has the same number of chromosomes as the parent cell.
   - L two daughter cells, each of which has half the number of chromosomes as the parent cell.
   - M four daughter cells each of which has half the number of chromosomes as the parent cell.

3. Amoeba, a single-cell freshwater organism lives in water where the solute concentration varies with the seasons. Amoeba have evolved an internal structure called a contractile vacuole which has the ability to expel water from the cell if too much water accumulates inside of the organism. Refer to the graph below which shows the solute concentration of the water in which the amoeba lives and its contractile vacuole activity at different times of the year.

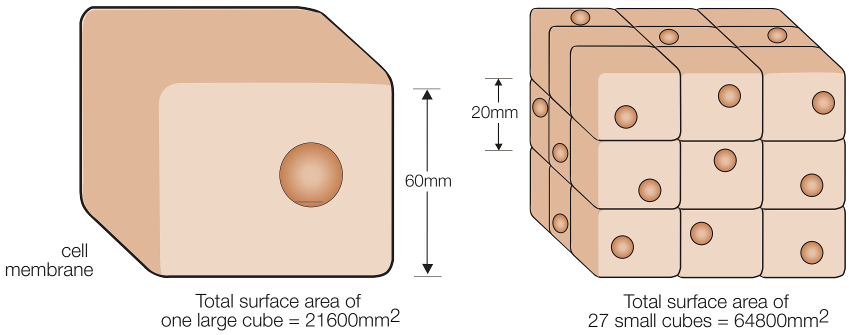


Which one of the following changes in the Amoeba's environment is most likely to explain the increase in activity of the contractile vacuole between 3-4 months?
   - J An increase in the solute concentration.
   - K An increase in temperature.
   - L A decrease in temperature.
   - M An influx of fresh water.

4. If liver cells growing in a solution with required nutrients had the oxygen removed from the solution they would most likely:
   - J produce alcohol
   - K produce lactic acid
   - L fail to break down glucose
   - M die from a lack of energy for cellular requirements.

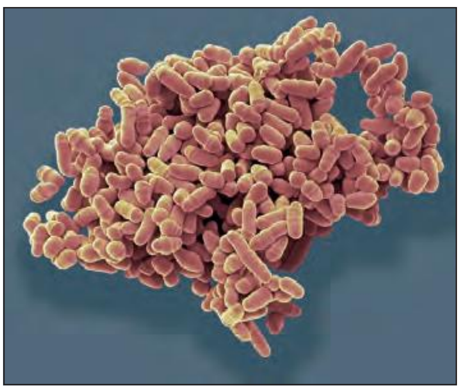
5. Autotrophs can be distinguished from heterotrophs by:
   - J their ability to carry out photosynthesis.
   - K the presence of chloroplasts in their cells.
   - L the ability to make organic molecules from simple inorganic ones.
   - M their ability to carry out the process of fermentation.

6. Refer to the following diagram to select the true statement that follows:



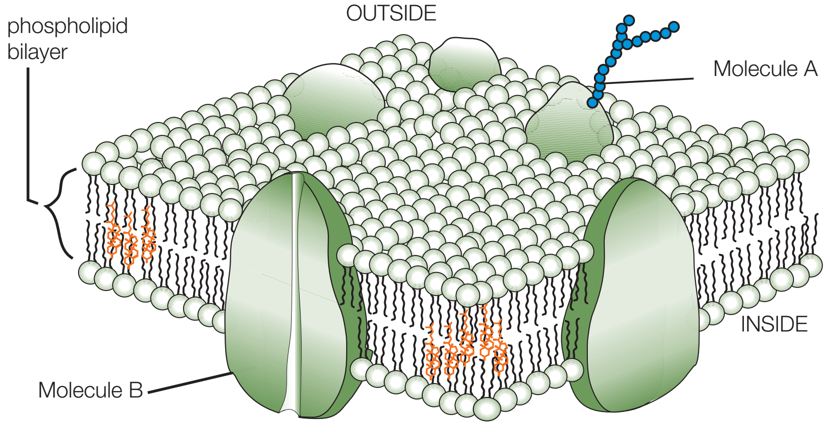
   - J Cells need to have a small surface area to help speed up the rate of diffusion.
   - K Cells need to have a small surface area to volume ratio to maximise their exchange of materials.
   - L Cells need to have a large surface area to volume ratio and therefore tend to grow as large as possible.
   - M Cells need to remain small to maximise their exchange of materials.

7. Which one of the following best explains why the diagram below is an image of a fungus and NOT bacteria:



   - J The cells are eukaryotic.
   - K The cells are microscopic.
   - L The cells do not possess chlorophyll.
   - M The cells have a cell wall

8. *Refer to the diagram below and answer the questions that follow:*



a) Name two ways in which this membrane controls the entry and exit of materials between the cell and its external environment.

(2 marks)

b) Name molecule B

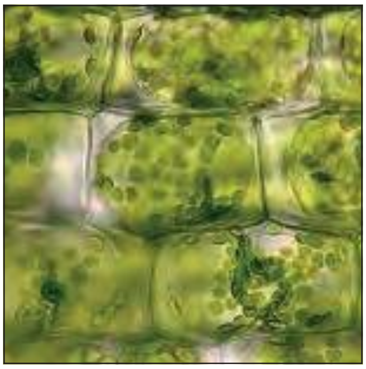
(1 mark)

c) Explain how molecule B could be involved in the process of active transport.

(2 marks)

9. *Refer to the pictures below to answer the questions that follow.* (*Source: Google images*)

Cell A (~5000x)



Cell B (~250x)

Cell C (~500x)

a) Explain the meaning of the phrase ‘ the cell is the unit of structure and function in all organisms.

(2 marks)

b) Name one organelle that you would expect to find in all three types of cells.

(1 mark)

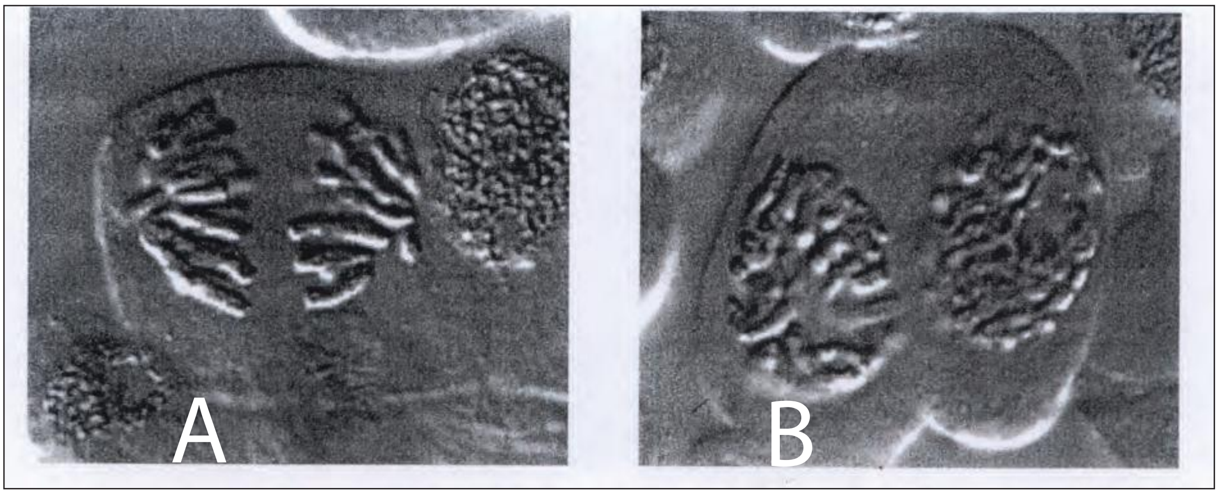
c) State one difference between DNA in cell A compared to cells B and C.

(1 mark)

d) Explain why cell A cannot be part of a tissue.

(2 marks)

10. *Refer to the following photographs A and B which show two stages in mitosis.*



a) State what is happening to the chromosomes in stage A.

(1 mark)

b) State what is happening to the chromosomes in stage B.

(1 mark)

c) Explain how it is possible that cells produced from mitosis are clones of the original cell.

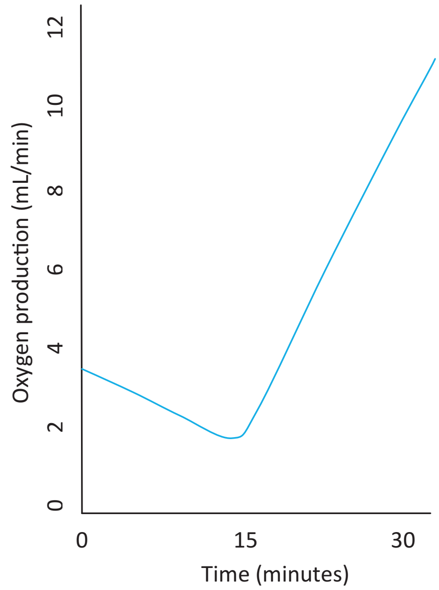
(2 marks)

d) Explain one difference between mitotic division and binary fission.

(2 marks)

11. In an investigation into the effects of light on the rate of photosynthesis, a scientist enclosed a group of plants in the dark for a period of 15 minutes and they were then exposed to light. The researcher continually measured and recorded the volume of oxygen produced in the air surrounding the plants.

Refer to the graph below to answer the following questions.



a) Write a possible investigable question that the researcher might have used in this investigation.

(2 marks)

b) Write a word equation for the process of photosynthesis.

(2 marks)

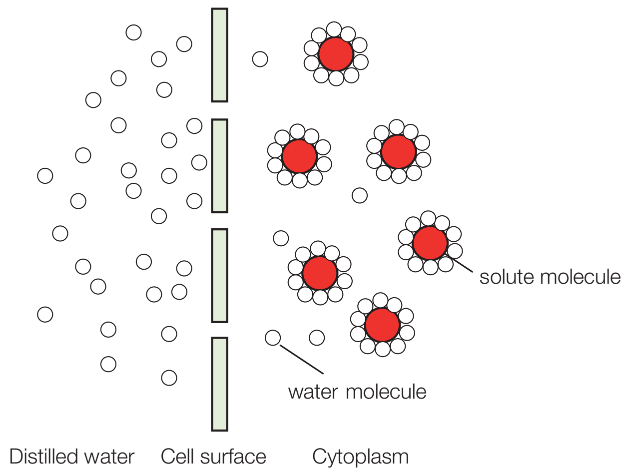
c) Write a possible conclusion based on the data.

(2 marks)

d) State the reason that the concentration of oxygen can be used as a measure of the rate of photosynthesis.

(1 mark)

12. *Refer to the diagram below to answer the questions that follow*



a) Explain why the nett movement of water molecules would be from left to right, i.e. from the distilled water into the cell.

(2 marks)

b) Explain why the impact of this movement is usually more significant for animal cells when compared to plant cells.

(2 marks)

13. *Refer to the diagram below of two potato cubes* that were placed in 5% solution of glucose; the smaller cube measures 1x1x1 cm and the larger is 2x2x2 cm.

It was noted that both cubes shrunk and became soft when left in the solution for one hour. Use this information to help you answer the questions that follow.

a) State the reason the cubes became soft.

(1 mark)

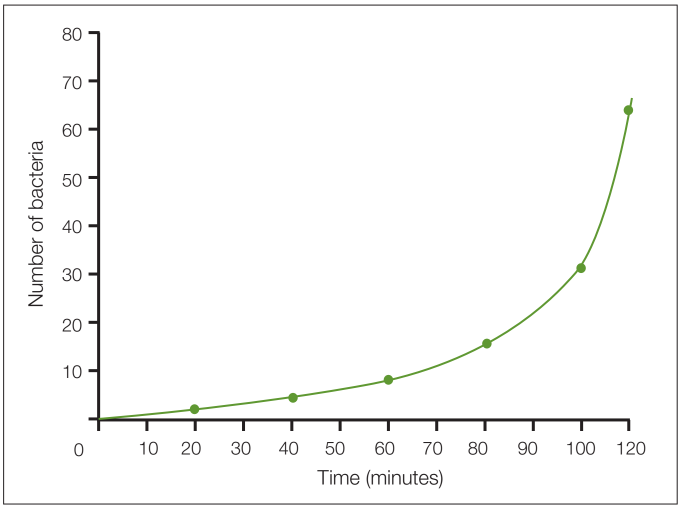
b) Calculate the surface area to volume ratio for each cube.

(2 marks)

c) The student who conducted this investigation predicted that the 1 cm cube would lose a greater percentage of its mass when compared to the 2 cm cube. Explain the likely reason that they made this prediction.

(2 marks)

14. *Refer to the graph of exponential bacterial growth under ideal conditions.* Fortunately this rarely occurs as resources become a limiting factor.



a) Name two such resources required by bacteria that could become limiting factors and outline the importance of each for bacterial growth.

Resource 1

(2 marks)

Resource 2

(2 marks)

b) Briefly name and describe the process that enables the bacteria to divide so rapidly.

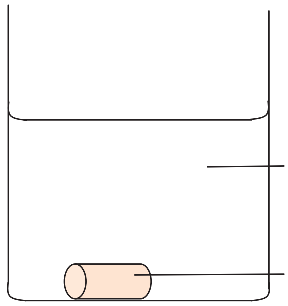
(3 marks

c) Bacteria are one useful group of microbes for humans. Name one other group of microbes that are also useful and outline how this group is important.

(3 marks)

Science Inquiry Skills

15. Potato cylinders of equal mass were placed in 5 separate beakers, one of which is shown below:



The 5 beakers contained salt solutions of 0.2%, 0.7%, 1.2%, 1.7%, 2.2%

After 3 hours the change of mass of each cylinder was measured.

Refer to the table below to answer the questions that follow.

Beaker	**Salt solution (%)**	**Change in mass (g)**
A	0.2	+ 0.3
B	0.7	+ 0.1
C	1.2	- 0.1
D	1.7	- 0.4
E	2.2	- 0.5

a) Describe the pattern of results as shown in the table.

(2 marks)

b) Predict 2 variables that would have been controlled in the experiment to ensure that this was a 'fair test'.

(2 marks)

c) Explain the change in mass observed in the potato cylinder in Beaker A

(2 marks)

d) Predict the salt concentration at which there would be no change in the mass of the potato cylinder.

(1 mark)

e) Describe how a scientist might have tried to ensure that these results were valid and reliable.

(2 marks)

Science as a Human Endeavour

16. *The following is adapted from an article in the Advertiser August 8, 2016. Read it carefully and then answer the question that follows to show your understanding of various aspects of Science as a Human Endeavour*:

Medical triumph in war on cancer

Written by reporter Rose Brennan

Australian scientists have achieved a world-first breakthrough in the battle against the deadliest cancer. Nano-medicine technology can now deliver 'gene silencing' drugs to pancreatic cancer tumours that are notoriously difficult to treat. Pancreatic cancer is the most chemotherapy resistant and therefore deadly cancer in Australia, claiming five lives a day. Most people diagnosed with pancreatic cancer are dead within six months.

Scar tissue, which can make up to 90% of a tumour, poses the greatest challenge for doctors as it blocks drugs from reaching the tumour, while also increasing its resistance to chemotherapy. New South Wales University pancreatic cancer translational research group head Dr Phoebe Phillips said her team developed a powerful new drug and an effective way of delivering it to tumours.

"We chemically engineered tiny particles that can get past that scar tissue barrier and actually reach the tumour cells, so that to me is a fairly significant breakthrough" Dr Phillips said.

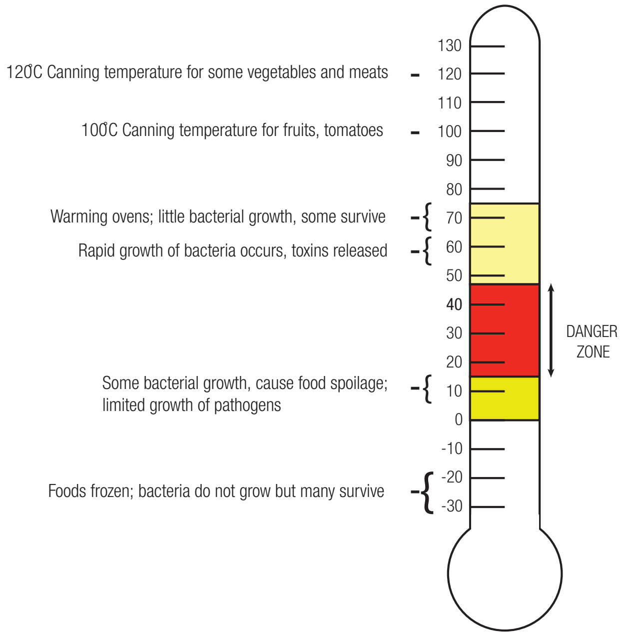
The particles are used as a vessel to deliver the drug to the tumours. "It can make the development of a tumour and its ability to metastasise and spread throughout the body switch off" Dr Phillips said. The results were achieved in mice which had extensive scar tissue that mimicked human tumours.

"Obesity is a risk factor for pancreatic cancer, which Dr Phillips said by 2030 was expected to be the second biggest killer of all cancers. As obesity and diabetes are on the rise because of the way we live, more and more we are seeing younger patients with pancreatic cancer" Dr Phillips said...

Discuss how this example demonstrates one or more Key Concepts of Science as a Human Endeavour.

(6 marks)

17. *Refer to the figure below regarding food temperature and storage to answer the questions that follow:*



a) Outline a reason for the red or danger zone being labelled as such.

(2 marks)

b) Imagine you are a visiting Health Inspector giving advice to a bakery about storing hot pastries before sale. What advice would you suggest to help ensure the safety of customers regarding bacterial growth?

(2 marks)

Assessment Key

Assessment Design Criteria	Questions where this could be assessed
IAE1	11a, 16b
IAE2	13b
IAE3	11c, d, 13c, 16a
IAE4	16e
KA1	1, 2, 4, 5, 6, 8a-c, 9a, b, 10c, d, 11b, 12a, b, 13a, 14a-c, 17a, 17b
KA2	3, 7, 9c, d, 10a, 10b, 17b, 16c, 16d
KA3	15
KA4	15

Topic 1 Test Yourself - Suggested answers

The answers for each part of each question provided here are suggestions. They are not intended to be the only answer. Read and use them carefully to self-assess your performance in the test. Consider asking someone in your class to peer-assess them as well, then discuss. Make notes of errors for future reference and seek the assistance of your teacher as required.

Multiple Choice

1. L 2. J 3. M 4. K 5. L 6. M 7. J

8. Regarding the membrane:
   a) It is lipid in nature and therefore tends to repel a range of molecules that are not lipid soluble. Also it is semi--permeable and restricts the movement of larger molecules. Proteins-both pumps and channels facilitate movement of particular molecules.
   b) A protein channel or pump.
   c) Active transport involves the movement of molecules against the concentration gradient. A protein pump can use energy to pump or move molecules from a low concentration to a high concentration.
9. With reference to the photographs:
   a) All organisms are made up of cells or the products of cells. The cell is the basic unit of life, it is the smallest unit that is considered to be alive. As such, it is the building block of all life and the unit of function in carrying out life's processes.
   b) A ribosome
   c) A being a prokaryotic cell has DNA in the cytoplasm. B and C are eukaryotic cells with the DNA contained in a nucleus.
   d) Cell A is a prokaryotic, unicellular organism consisting of a single cell. Tissues consist of many cells combined that have similar structures and functions.
10. With reference to the photographs:
   a) Each chromosome consists of two chromatids which are being pulled towards the poles of the cell.
   b) In stage B, the chromosomes are condensing-pulling together.
   c) Prior to mitosis, the DNA in the cell replicates i.e. DNA is doubled making two identical copies. In mitosis, the DNA separates so that each new cell contains the same DNA and genes as the original cell.
   d) Mitotic division occurs in eukaryotic cells, it is a division of the nucleus. Binary fission occurs in prokaryotic cells, as no nuclei are present the circular chromosome replicates and then divides into two.
11. With regard to this investigation:
   a) Is light necessary for the process of photosynthesis to occur?
   b) Water + carbon dioxide → oxygen + glucose
   c) Light is required for photosynthesis to occur in plants producing oxygen gas.
   d) Oxygen is a by-product of photosynthesis, the greater the rate of photosynthesis, the more oxygen is produced.
12. With regard to the diagram:
   a) Osmosis is the nett movement of water molecules from low solute concentration to high solute concentration. This is a naturally occurring process and as the left side has a low solute concentration and the right side has a high solute concentration water will move from left through the cell surface to the cytoplasm on the right.
   b) Plant cells have a cell wall which can resist movement of water into the cell and out of the cell enabling the cell to maintain its structure and shape. Animal cells only have a cell membrane which is more flexible and can breach or break with too much water moving into the cell.

13. With reference to the potato cubes:
   a) The cubes become soft as water moves out of the cell by osmosis.
   b) For 1 cm^3 cube: SA = (1x1)x6 = 6 cm^2 `V = 1x1x1 = 1cm^3 SA:V = 6:1
      For 2 cm^3 cube: SA = (2x2)x6 = 24 cm^2 `V = 2x2x2 = 8cm^3 SA:V = 3:1
   c) The 1 cm cube has an SA:V of 6:1 compared to the 2 cm^3 with a SA:V of 3:1. The cube with the greater SA:V will exchange materials faster because there is a greater rate of diffusion and therefore it will lose a greater percentage of its mass as water moves out by osmosis.
   d) Cells that are smaller have a higher SA:V ratio and are therefore more efficient at exchanging materials. Cells therefore do not usually grow too large as they will not be able to obtain their requirements as efficiently.
14. With reference to the graph:
   a) Two such resources include:
   Water; all organisms need water to survive. It maintains the structure and integrity of cells and it is the solvent for the chemicals of life. If water is in short supply, bacterial growth will be limited.
   A source of energy e.g. glucose. All organisms including bacteria, require energy for synthesis reactions and a range of other processes. Breaking down glucose releases energy for cellular activities.
   b) Binary fission. The bacterial cells replicate their DNA and then divide forming two new, identical cells.
   c) Yeast; yeasts are used in the production of a range of household foods and beverages including bread, wine and beer making.
15. With regards to this data:
   a) When the cylinder is placed in salt solutions from 0.2%-0.7%, there is a nett gain in mass. At concentrations greater than 1-2% there is a nett loss of water.
   b) The temperature of the solution is another important variable, temperature influences the rate of diffusion and osmosis. The SA:V ratios of the potato cylinders is another variable, they should be the same size, mass and SA:V ratio.
   c) The cylinder in beaker A has increased in mass due to the gain of water. Water has moved into the cylinder by osmosis; from a low solute concentration (0.2%) to a higher solute concentration inside the potato.
   d) Approximately 0.9%; about halfway between 0.7% and 1.2%.
   e) The scientist would need to ensure that a reasonable sample size was included. Repeating the experiment with fresh solutions and new equipment enables the scientist to identify any systematic errors and be more confident about the validity of the experiment.
16. Possibilities include:

- The nano-medicine technology would have been developed across disciplines e.g. physics and chemistry.
- The technology now transferred to medicine has direct links to society and human health.
- Science has developed solutions based on reliable predictions as to how this technology might save lives.
- Use of this technology has enormous potential advantages but would require monitoring and evaluating risks in the transition of the application from animals to humans.
- Science is informing us of the potential links between lifestyle choices and long-term health e.g. diet and obesity.

17. With reference to the diagram:
   a) The red zone from around 15°C-47°C is an ideal temperature for the rapid growth of bacteria. If allowed to grow unchecked at these temperatures, bacteria will multiply rapidly in food causing spoilage.
   b) Fruits, including tomatoes often have higher concentrations of sugars and acids which also inhibit bacterial growth.
   c) From the data above, it would appear that the pastries need to be kept in the temperature range 65°C-75°C. At these temperatures, many bacteria die, there is little growth and the food is able to be kept for a reasonably long time.

P.S. Although the answer here is given in note form, the student answer should be written in sentences and paragraphs.

Topic 2 Infectious Disease

Chapter 2.1 Different types of disease

Science Understanding

Infectious disease differs from other diseases.

- Distinguish between infectious and non-infectious disease.
- Determine the characteristics of a pathogen.

Disease

A disease is characterised by any change to an organism that negatively impacts on the functioning of that organism. Diseases can be categorised into two groups; **infectious** and **non-infectious**.

Non-infectious disease

Disease that cannot be transmitted from one organism to another is called non-infectious disease.

Non-infectious disease is caused by a wide variety of factors including:

- Carcinogens (or cancer-causing chemicals); e.g. lung and bowel cancer.
- Exposure to high energy radiation; e.g. skin cancer.
- Faulty (or non-functional) genes; e.g. cystic fibrosis, and haemophilia.
- **Hypersensitivity** to agents in the environment like pollen or dust mites; e.g. asthma, allergies
- Lifestyle choices, often related to diet and exercise patterns; e.g. heart disease, and Type II diabetes,
- Organ and tissue degeneration; e.g. kidney disease and arthritis.

Figure 211 shows some diseases that are non-infectious.

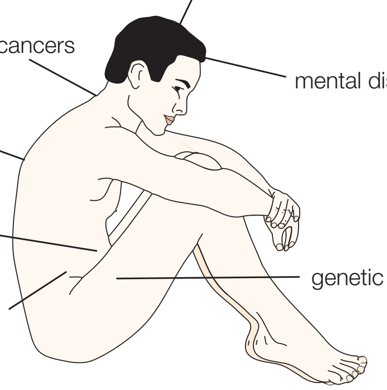


Figure 211 Types of non-infectious diseases

Infectious disease

A disease that in some way is transmitted from organism to organism is called an infectious disease. All infectious diseases are caused by agents called **pathogens**. Once inside the **host's** body a pathogen may cause disease by destroying cells, or by releasing chemicals that disrupt normal cell function called **toxins**.

Pathogenic organisms that cause disease

The human body contains around 10^{13} (10 trillion) human cells but also some 10^{14} (100 trillion) cells consisting of such microbial groups as bacteria, fungi and protozoa.

Pathogens are disease-causing microbes that have developed characteristics that enable them to exploit the warm, nutrient rich and moist environments of their hosts.

To achieve this, pathogens must be able to:

- cross the protective barriers of the host.
- multiply inside the host.
- avoid the host's immune system attempts to destroy them.

There are six main types of pathogens. They are:

- Bacteria; e.g. the bacteria that cause food-poisoning, tonsillitis, tuberculosis (TB)
- Fungi; e.g. the group of fungi called *Tinea* that causes athlete's foot
- Protists; e.g. Giardia that causes gastro-enteritis or 'gastro'
- Viruses; e.g. the influenza virus that causes 'the flu' and rhinovirus that causes 'colds'
- **Parasites**; e.g. the tapeworm *Echinococcus* that causes hydatid disease
- **Prions**; e.g. the prion that causes *Creutzfeldt-Jakob* disease (or CJD) in humans

Bacteria

As previously noted, bacteria are unicellular, prokaryotic organisms that reproduce by the process of binary fission.

The four main types of bacteria are rod shaped (bacilli), spherical (cocci), spiral shaped (spirilla) and curved (vibrio). They are true living organisms that are capable of movement, utilisation of energy and reproduction.

Refer to *Figure 212* illustrating some pathogenic (disease causing) bacteria and the organs they may target.

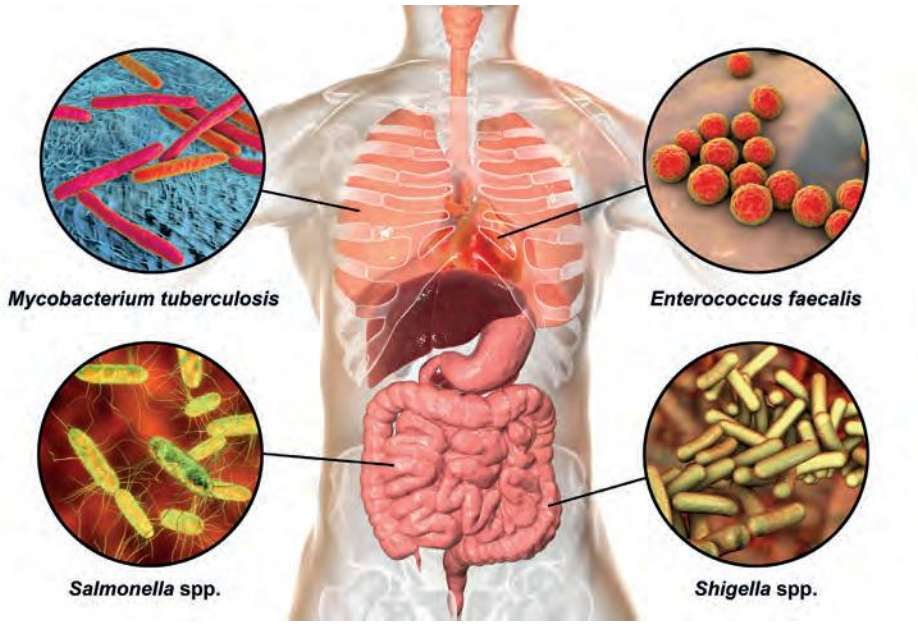


Figure 212 Bacteria can cause human infections

Some of the more common bacteria, the diseases they cause and the symptoms of the disease are summarised in the following table.

Disease	Symptoms	Bacteria
Food poisoning	nausea, vomiting, diarrhoea	*E. Coli, Salmonella*
Syphilis	sores around mouth and genitals, rash, fever, (and sometimes death)	*Treponema pallidum*
Tuberculosis	coughing blood, fatigue, weight loss	*Myobacterium tuberculosis*
Cholera	vomiting, diarrhoea	*Vibrio cholera*

Bacteria can damage host tissue in a number of ways, including:

- producing toxins or poisonous chemicals which may act by inhibiting protein synthesis, damaging membranes and hence the transport of materials in and out of cells or interfering with nerve function
- invading organs and tissues inside of the host.

Some bacteria produce **spores** that can survive for long time periods and are highly resistant to tough environmental conditions. After the spores enter the host they can germinate and the bacteria begin to replicate.

Figure 213 shows an electron micrograph of *Salmonella entenidis* which is the bacterium that causes salmonella. The food source or growth medium is shown in blue. The magnification is approximately 10000x.

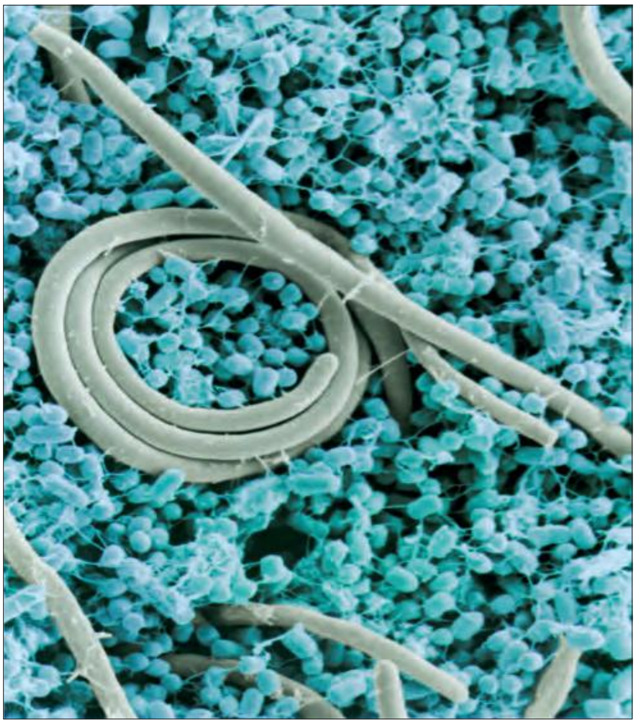


Figure 213 Salmonella enteridis

Figure 214 A calf with 'ringworm'

Fungi

Fungi are heterotrophs and generally fit into one of two groups; the yeasts and the filamentous moulds.

They grow by feeding on organic matter often by secreting enzymes and breaking down the organic matter. Fungi reproduce by forming spores which spread remarkably easily, numbers upwards of 100,000 per cubic metre have been recorded in the air.

Essentially, pathogenic fungi can be classified into four types depending on where they grow and reproduce:

1. on the surface of the host
2. on the superficial layers of the host e.g. skin and nails
3. in subcutaneous tissues i.e. in the inner layers of the skin
4. inside the host i.e. by infecting inner tissues and organs

Species of fungi can cause a variety of diseases. *Refer to the following table:*

Disease	**Symptoms**	**Fungal organism**
Toenail infections	discolouration and breakdown of nails	several including *Candida* yeasts
Ring worm	red patches and blisters on the skin	different fungi e.g. *Microsporum*
Invasive aspergillosis	fever, chest coughs, and pain	*Aspergillus*

Figure 214 shows a calf with ringworm which is a fungal infection of the skin.

Protists

It has already been noted that the protists are an extremely diverse group of unicellular eukaryotic organisms.

Pathogenic protists are heterotrophs, absorbing nutrients from their hosts. They can be classified into three groups according to their parasitic nature and the site of infection:

- intestinal
- uro-genital
- blood and tissue

Malaria is a very common protist disease infecting several hundred million people and killing over 1 million people per year. It is caused by members of the *Plasmodium* genus which are passed on to humans via the bite of the *Anopheles* mosquito. The protozoa infect liver and blood cells which may rupture and release new parasites into the bloodstream. Refer to *Figure 215* which illustrates the *Plasmodium* parasite emerging from a blood cell and also *Figure 227* (in the next Chapter) which illustrates the life-cycle of this parasite.

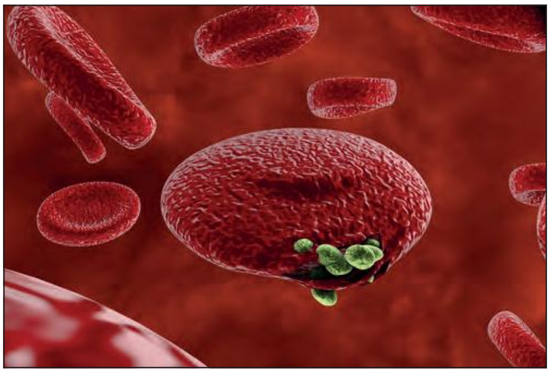


Figure 215 The malaria parasite emerging from a red blood cell (10000x)

The table below shows three common protists and the diseases they cause.

Name of disease	Symptoms	Protist
Giardia	Diarrhoea, nausea, cramps	*Giardia lamblia*
Uro-genital infection	Infection of the urinary tract or reproductive organs causing a foul-smelling discharge	*Trichomonas*
Malaria	Fever, chills, blood cells rupturing and often death	*Plasmodium*

Viruses

Viruses are perhaps better described as infective particles rather than organisms because they display very few of life's processes. A virus is extremely small (refer to *Figure 216*) when compared to cells, even prokaryotic bacteria.

Virus particles are little more than a nucleic acid (RNA or DNA) packaged in a protein coat. Either the entire virus enters the host cell it is infecting or the virus attached itself to the cell surface and injects its genetic material directly into the cell. The outcome is that the host cell replicates hundreds, even thousands of new virus particles which usually break open the cell and discharge the new virus particles. The cell is often killed by such a viral infection.

The table below shows three typical diseases caused by viral particles.

Name of disease	Symptoms	Virus
Flu/influenza	fever, cough, aches, chills etc.	influenza (many types)
Common cold	stuffy nose, sore throat, headache	over 200 different types of viral particles
HIV/AIDS	fever, sore throat, vomiting, immune deficiency	human **immunodeficiency** virus

Refer to *Figure 217* showing the life-cycle of a virus. *Figure 218* is an electron micrograph illustrating virus particles infecting a cell.

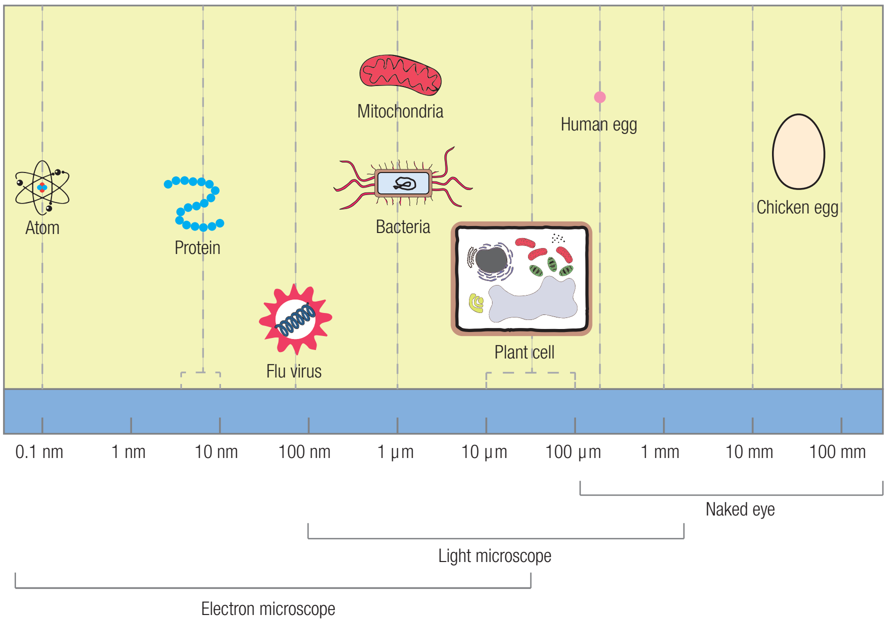


Figure 216 Some relative sizes

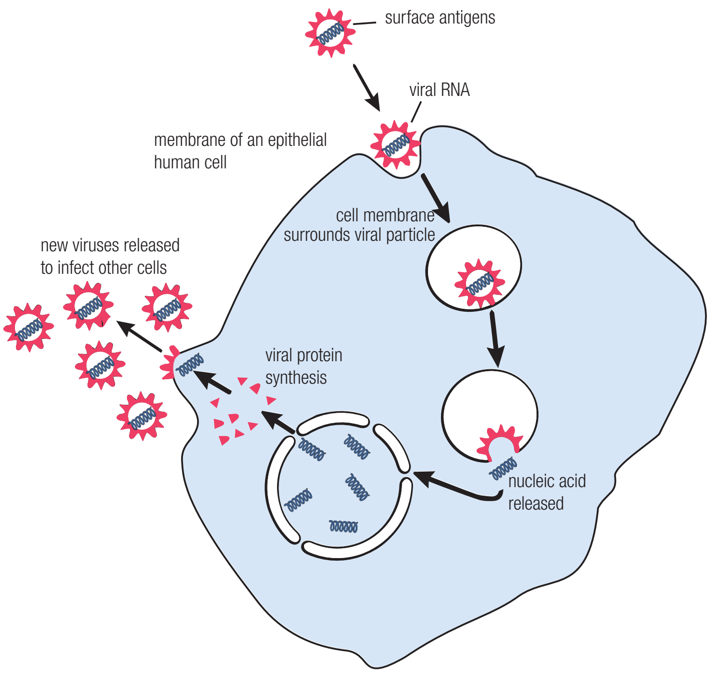


Figure 217 The life cycle of a virus

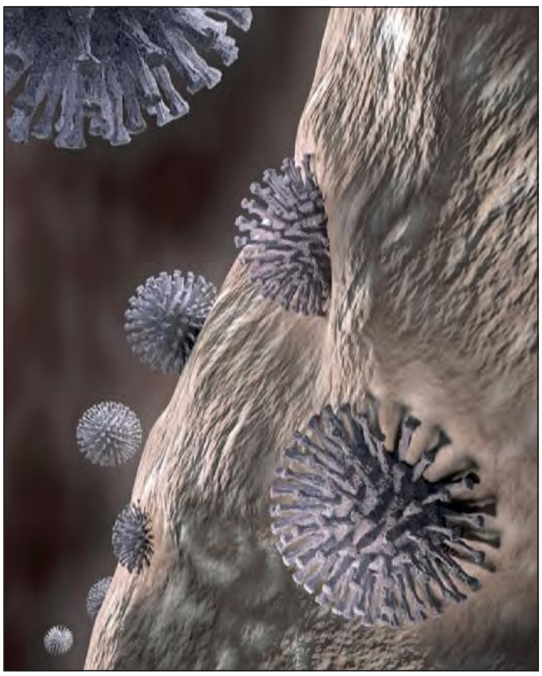


Figure 218 Virus particles infecting a cell

Parasitic worms

These worms generally live inside their hosts and they feed on the host's food inside their intestine which provides them with an adequate source of nutrients. Some of these parasites cause few, if any, symptoms in the host whereas others weaken their hosts significantly.

Worms are well adapted to their life cycles; they often lack digestive systems but have more highly developed reproductive systems, laying copious quantities of eggs which are then passed out in the faeces. The life cycles often have multiple hosts and are quite varied and some examples of these will be considered in the following Chapter (2.2).

Parasitic worms clearly cause infectious diseases as they spread easily between hosts. Thread worm is a typical parasite infecting the intestines of humans. When they mature they lay hundreds of eggs which are released near the anus of an infected person giving rise to a condition sometimes called 'itchy bottom'.

Refer to *Figure 219* which shows an illustration of a typical tapeworm.

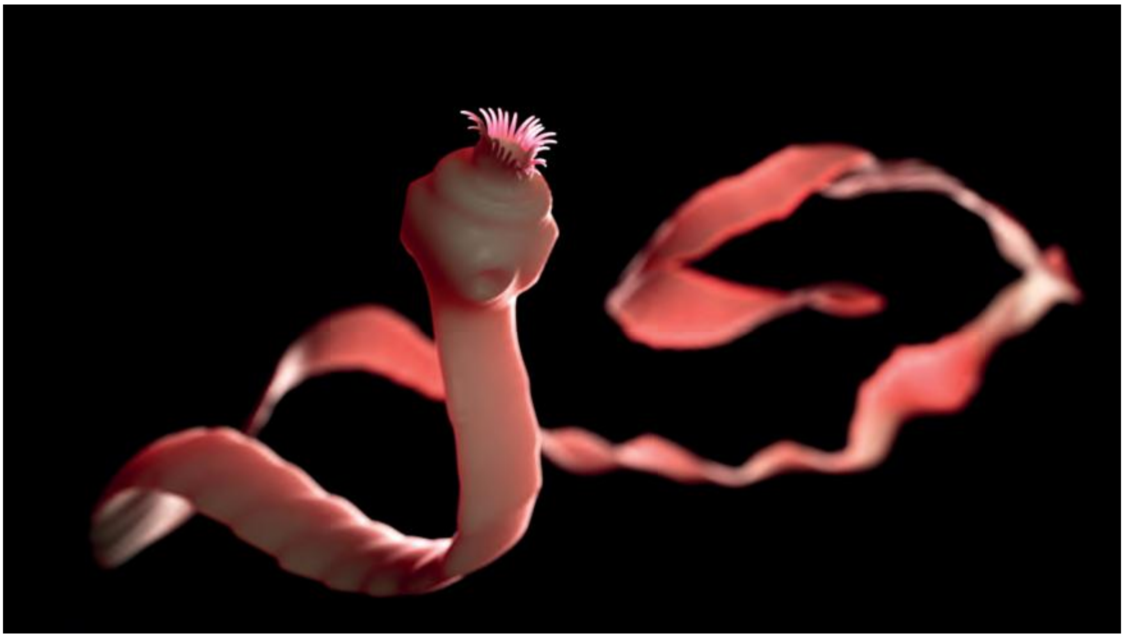


Figure 219 A tapeworm

The table below summarises three typical infectious diseases caused by parasitic worms.

Disease	Symptoms	Worm
Thread worm	itchy bottom, tiredness, irritability	pin worm or thread worm
Tapeworm infection	nausea, fatigue, weight loss	Tapeworm
Nematode infestation (plants)	weakened plant, stunted growth	root knot nematode

Prions

Protein molecules are vital in all living organisms as they are involved in both structural and functional roles. These molecules are made up of chains of building blocks called **amino acids** which are folded into specific 3-D shapes. It is this specific shape that is crucial for their function. One application or example of this relates to enzyme-substrate binding which is considered in Stage 2 Biology.

Prions are an unusual infective agent of the nervous system and are largely unknown to the general population. They are an infectious agent that is replicated in the host which copies a wrong or mis-shaped protein molecule which is identical to a normal host protein in its amino acid make up but differs crucially in its 3-D structure.

This ability of the prion to convert normal protein into abnormally shaped proteins is what gives the molecule its infectious nature. The infection is characterised by **lesions** in the brain which can be observed using a microscope to reveal holes in the cortex. Refer to the following table which shows three common examples of diseases caused by prions. Refer also to *Figure 2110* showing prions (stained red) attached to mouse nerve cells.

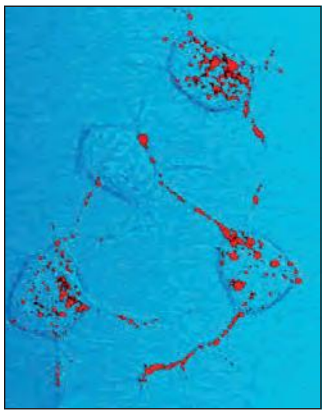


Figure 2110 Prions

Disease	Symptoms	Prion
Scrapie	fatal brain degeneration in animals	Scrapie prion
Mad-cow	abnormal posture, aggressive temperament, loss of body weight	BSE prion
Creutzfeldt-Jakob	failing memory, lack of coordination, total memory loss	CJD prion

Key Concepts

1. Infectious diseases are caused by pathogens.
2. Examples of non-infectious diseases include genetic disease, lifestyle induced disease, most cancers and hypersensitivity to agents e.g. asthma
3. The main groups of pathogens are bacteria, fungi, protists, viruses, parasitic worms and prions.
4. Each group of pathogens has specific characteristics or adaptations that enable them to thrive and reproduce in their hosts.

What have you learned?

Key Terms

infectious ....

non-infectious ....

pathogen ....

parasitic ....

toxin ....

spore ....

immunodeficiency ....

host ....

nematode ....

amino acids ....

prions ....

lesion ....

adaptation ....

hypersensitivity ....

Knowledge and Understanding

1. Explain the difference between infectious and non-infectious disease.

....

....

2. Describe the difference between a parasite and a pathogen and give an example of each to illustrate your answer.

....

....

....

3. The disease 'ring worm' is not actually caused by a worm. Explain your understanding regarding this statement.

....

....

4. State three characteristics that pathogens require to grow successfully on or inside a host.

....

....

....

5. Spores, produced by microbes, can have two quite distinct functions:
   a) Name these two functions

   b) Explain how each function provides an advantage to a species that uses them and give an example of each.

6. Write your answers in the space provided.
   a) Explain what a toxin is.

   b) Give an example of a toxin and describe how it can bring about negative effects on the host.

Application, Analysis and Evaluation

2.1

7. The human body contains about 10^{14} (100 trillion) cells of bacteria, fungi and protozoa yet remarkably remains mostly healthy with these microbes living on or inside of it. Explain how this is possible.

8. In the space below, prepare a table showing:
   a) each group of pathogen i.e. bacteria, fungi, protozoa, virus, worm and prion
   b) an example of a typical disease caused by the pathogen
   c) one adaptation for each, describing how this feature assists in their survival and/or transmission to other species

9. Do you think prions are alive? Explain your answer giving reasons to support your argument.

10. The table below lists some common diseases. Place a tick in the appropriate column(s) to indicate the type of pathogen(s) that is the causative agent. You may be able to add a few more of your own.

Disease	Bacterium	Fungus	Virus	Protist	Worm	Prion
Common cold						
Diarrhoea						
Malaria						
Sinusitis						
Skin infections						
Pneumonia						
Mad cow disease						
Genital herpes						

11. Refer to the table below showing recent global deaths from the most common infectious diseases, this data comes from the World Health Organisation website (*see HOR Box below*).

Disease	Year	Number of deaths globally
Malaria	2013	584,000
Diarrhoea	2012	1.5 million
HIV/AIDS	2012	1.5 million
Tuberculosis	2012	900,000
Ebola	2013-2015	10,000

a) Name some of the countries around the world where most of these deaths are occurring.

b) Describe the likely reasons for the deaths in these countries.

c) Explain the reasoning behind the following statement: “Most people from developing countries die from infectious disease whereas people from developed countries die from non-infectious disease”

Helpful Online RESOURCE about global diseases

To learn more about global diseases you can follow this QR code to:

<http://www.who.int/topics/infectious_diseases/en/>

Science Inquiry Skills 2.1 - Observing pathogens

Introduction

Pathogenic organisms may come from several groups such as bacteria, fungi, viruses, protists, prions and parasitic worms.

Your aims in this exercise are:

- to observe prepared slides and other images of some of the above pathogens
- to gain an appreciation of the relative sizes of these pathogens.

Materials

Prepared slides of various pathogens and possibly some preserved specimens of tapeworms and/or parasitic nematodes .Electron micrographs of prions,viruses etc.

Method

Make observations of the specimens available as directed by your teacher.

Results

1. Draw neat diagrams of your observations indicating the magnification used and the scale size.
2. Label any structures indicating how they provide a survival advantage for the pathogen.

Analysis

Refer to the table below to answer the questions that follow.

Cell or structure	Approximate size
Human cheek cell	60 μm
E. coli bacterium	2 μm
Influenza virus	100 nm
Prion	10 nm

(Hint: 1 mm = 1000 μm, 1 μm = 1000 nm)

1. How big is a human cheek cell in millimetres?
2. Approximately how many *E. coli* bacteria could you fit across one human cheek cell?
3. Approximately how many influenza virus particles could fit across one bacterium?
4. How many prions could fit across one human cheek cell?

Science as a Human Endeavour 2.1 - 'Mad Cow' disease

Applications and Limitations

Scientific knowledge...can enable scientists to develop solutions...

'Mad Cow' disease is caused by a prion which leads to nerve degeneration with associated symptoms in cattle, such as postural and mobility issues and aggressive behaviour (hence the name). The disease is also known as Bovine Spongiform Encephalopathy (BSE). The disease can be transmitted to humans and often leads to death.

In 1986 the first cattle appeared with symptoms of the disease in the UK and Europe and it was not long after that hundreds were identified. The disease was soon noticed in other animals such as pet cats which had consumed infected meat. By the mid-1990s it was acknowledged that BSE could be transmitted to humans and often cause death. As a result 4.5 million cattle were destroyed. Australia has very strict quarantine laws and the disease has never been detected here.

Human impact

177 humans died in the as a result of contracting BSE, the last in 2012. The economic and social impact was immense. At one stage it was estimated that three farmers were dying every week.

Disease control

Wide-ranging measures were put in place to control the disease including:

- killing infected animals
- banning imports from countries with infected animals
- bans on animal feed made from beef products
- bans on eating organ meat from cattle.

You may need to refer to the online resource below to answer the questions that follow:

1. To reduce the incidence of the disease BSE and prevent its spread international communication and cooperation was essential. Briefly describe two examples to illustrate this point.

2. Describe how the knowledge about prions helped scientists develop at least one of the solutions to help prevent the spread of the disease.

3. Suggest one difficulty or limitation in preventing the spread of this disease.

Helpful Online RESOURCE about Bovine Spongiform Encephalopathy

For more information about Bovine Spongiform Encephalopathy (BSE) use:

<http://www.foodstandards.gov.au/industry/bse/pages/default.aspx>

Chapter 2.2 Disease transmission

Science Understanding

Describe the methods by which pathogens may be transmitted between hosts, such as:

- air
- dust
- direct contact
- faeces
- food
- animals

Methods of disease transmission

Pathogens are transmitted from host to **host** and **vector** to host through a number of well understood pathways or mechanisms.

Droplet infection

When humans cough or sneeze, small droplets come from the mouth or upper respiratory passages. If a human is carrying an infection (viral/microbial) then these droplets contain the pathogenic organisms and anyone who inhales these droplets will probably become infected. It has been estimated that one cough or sneeze may release millions of microorganisms. Refer to *figure 221* showing a high-speed photograph of a man sneezing. The irritation in the respiratory passages has brought about the sneezing reflex and enables virus particles and other pathogens to be transferred easily to other people.

Figure 221 Droplet infection

Direct contact

Direct contact with an infected person can transmit pathogenic organisms from one person to another. Shaking hands with a person with a 'cold', who has just wiped their nose, can transmit mucus droplets containing thousands of **rhino-virus** particles to the hand. If the healthy person then touches their nose with the infected hand the virus will be transferred. Sexually transmitted viral diseases such as **genital herpes** are spread via direct physical contact during sexual activity.

Faeces

Water that has been contaminated by faecal matter, either human or animal, will contain pathogenic microorganisms that can cause serious disease if it is consumed. In many low income countries this is a significant cause of death as fresh, clean running water is not always readily available.

Contaminated food

Chapter 1.8 described both the pathogenic organisms that cause food spoilage and some likely consequences of ingesting contaminated food. As microbes feed on the same types of nutrients as humans any food that has exceeded a safe level of microbes has the potential to be poisonous by either toxins or ingesting live pathogens. Symptoms of food poisoning range from fever, cramps, diarrhoea to death.

Refer to *Figure 222* illustrating Salmonella bacteria on the outside of eggshells. In February 2019, 51 cases of salmonella food poisoning occurred when people ate Vietnamese rolls that contain raw egg butter contaminated with *Salmonella* bacteria.

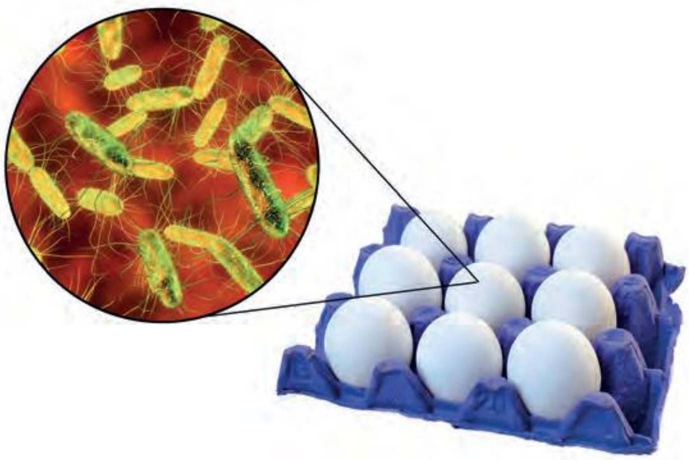


Figure 222 Bacteria on eggs

Animals

Some pathogens can be spread by direct contact with animals as the pathogen can grow equally well in both humans and certain species of animals particularly mammals. Bats and monkeys are known to harbour many species of virus and it is suspected that they have been responsible for many outbreaks over the years. Domesticated dogs and cats carry huge numbers of pathogenic bacteria which can be transmitted very effectively by a bite, or even a lick. Refer to *Figure 223* showing an owner with her affectionate pet.

Figure 223 Can you be sure you are only getting a kiss?!

Some particular groups of people in society are more vulnerable, including farmers, vets, abattoir workers and people working with exotic animals. Some animals or insects can spread pathogens from one host to another without suffering from the disease themselves, such animals are called vectors.

Body fluids

As pathogens thrive in the bloodstream and fluid secretions of their hosts, if fluid is transferred from one host to another it will have the potential to readily transfer pathogens. This could occur during sexual intercourse, through bleeding wounds, as well as sharing intravenous needles.

Refer to the table below which summarises these methods of disease transmission.

Method of disease transmission	**Microbe**	**Disease**
Droplet infection	influenza virus, bacteria	influenza, tuberculosis (TB)
Direct contact	fungus and herpes virus	**athlete's foot**, genital herpes
Faeces	**cholera** bacteria	cholera
Contaminated food	**Salmonella** bacteria	food poisoning
Animals	viruses	**Hendra**, **Ebola**, Zika
Body fluids	HIV	AIDS

Refer to *Figure 224* illustrating how a vector such as mosquito can penetrate a blood vessel and potentially pick up and transmit disease-causing microbes. Malaria and yellow fever are spread in this manner. Refer also to *Figure 225* illustrating how viral particles can be transferred to a developing embryo through the maternal blood stream.

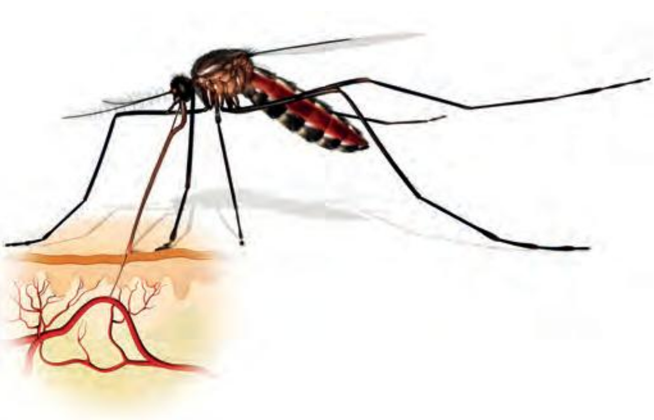


Figure 224 A mosquito is a vector

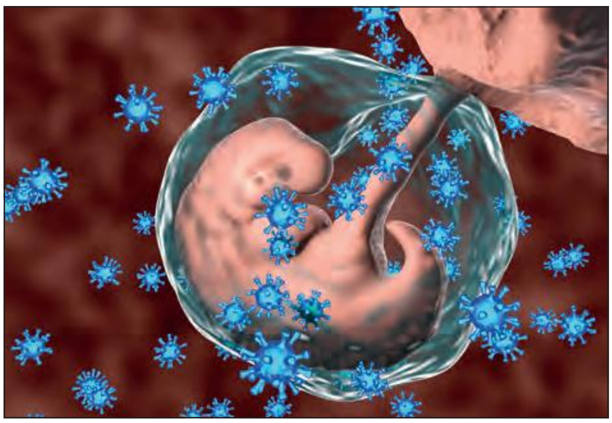


FIgure 225 A virus infecting a human embryo

The common forms of disease transmission are shown in *Figure 226*.

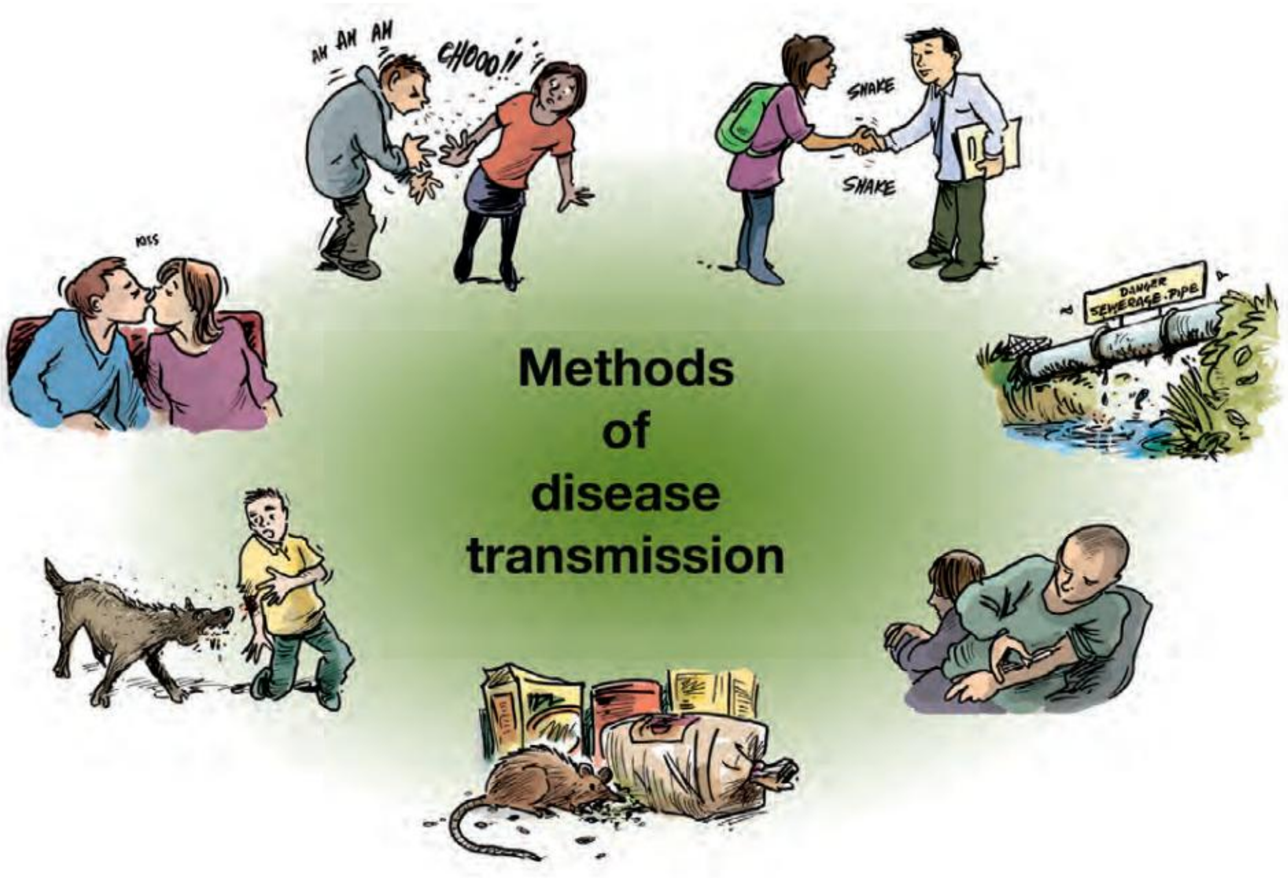


Figure 226 Common methods of disease transmission to humans

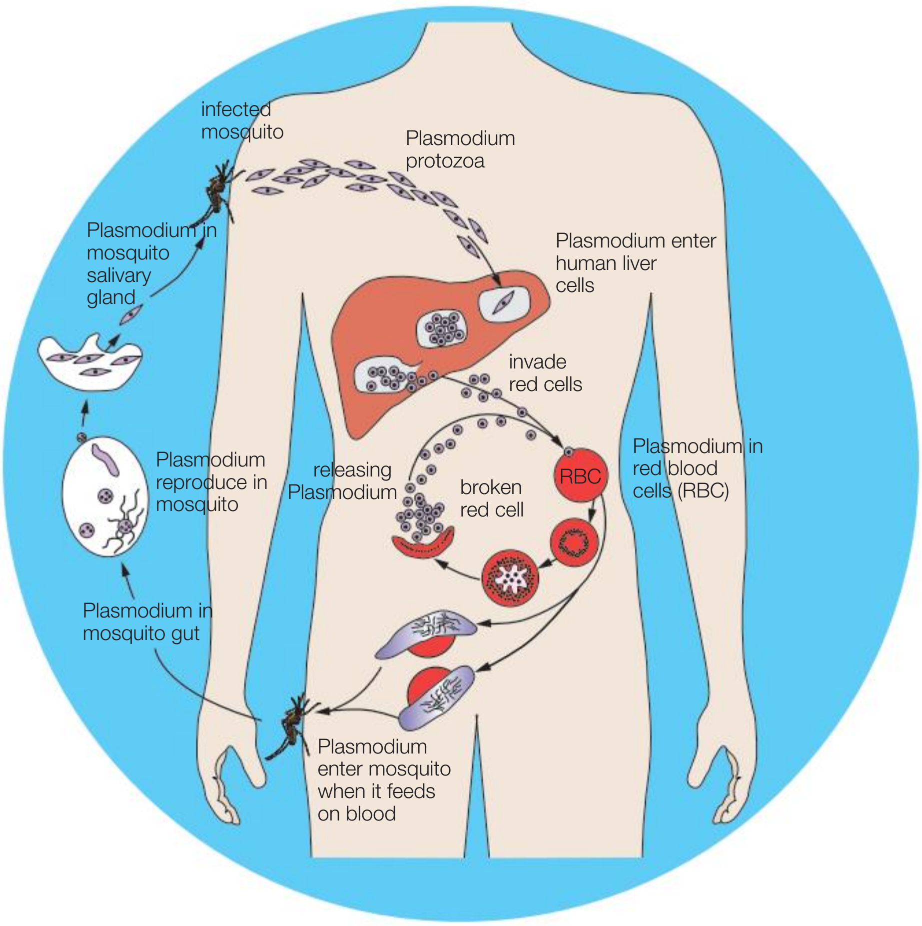


Figure 227 The life cycle of the protist Plasmodium that causes malaria

2.2

Some parasites have lifecycles that involve more than one host

Example 1: Malaria

This disease is very serious, causing hundreds of thousands of human deaths around the world every year. It is caused by a few species of a pathogenic parasite known as **Plasmodium**. The *Plasmodium* spends part of its life in humans and part of its life in the females of a species of mosquito (*Anopheles*) which acts as a vector in transmitting the disease. Refer to *Figure 227* which shows the life-cycle of the *Plasmodium* protozoan.

With some particularly **virulent** species, the symptoms are very severe including fever, coma and convulsions which can be fatal within a few days. As can be seen from *Figure 227*, the *Plasmodium* multiply inside the red blood cells, breaking them open and releasing new *Plasmodium*.

Example 2: Tapeworms

Another example of a parasite using multiple hosts is the tapeworm. These worms can also infect humans especially younger children. Refer to *Figure 228* which shows a typical life-cycle of such a tapeworm. The main host in this example is the household cat and **intermediate hosts** include rats, mice and fleas depending on the species of tapeworm. A heavy infestation of tapeworms in a cat can lead to loss of condition, lethargy and poor fur condition.

The tapeworms are well adapted to their parasitic way of life with such features as suckers or muscular grooves on their head enabling them to attach to the cats intestines. It is also noted that the tapeworms are **hermaphroditic,** that is, a single worm can contain both female ovaries and male testes.

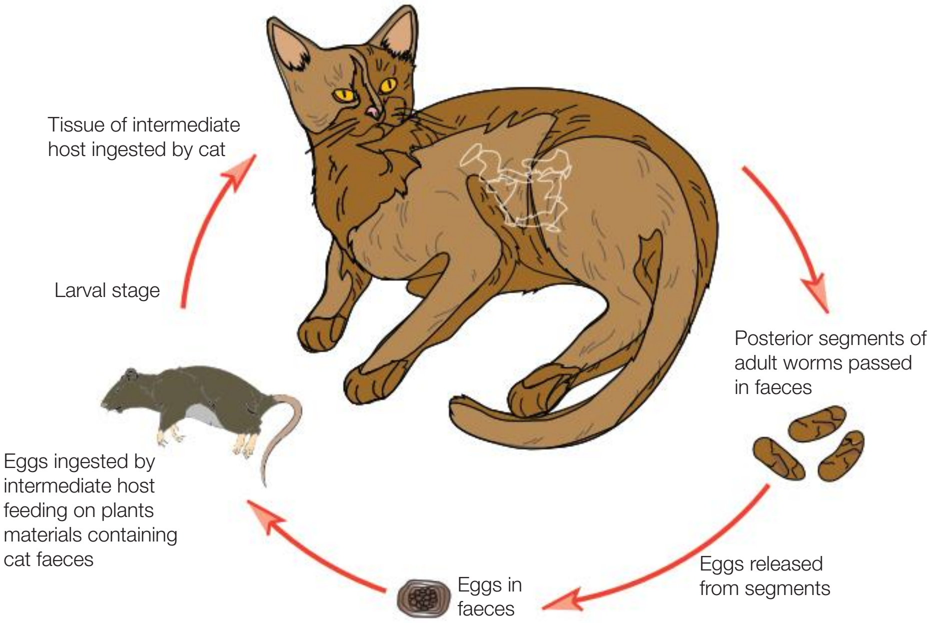


Figure 228 The life cycle of a tapeworm

Key Concepts

1. The main methods by which pathogens can be transmitted between hosts include:
   - droplet infection
   - direct contact
   - faeces
   - contaminated food
   - animals
   - body fluids
2. Pathogens have specific **adaptations** or characteristics that enable them to thrive inside their host, multiply rapidly and spread easily between hosts.
3. Many pathogens have evolved quite complex lifecycles that often involve insects and other animals as either vectors or intermediate hosts.

What have you learned?

Key Terms

host

vector

Rhino virus

Hendra virus

athlete's foot

Salmonella

genital herpes

ebola

cholera

Plasmodium

intermediate host

virulent

hermaphroditic

adaptations

Knowledge and Understanding

1. Name the four most common methods by which pathogenic organisms can be transmitted from host to host. For each, list two pathogens that are transmitted in this way.

2. From your knowledge of the transmission of pathogenic organisms, state the main ways that pathogens can gain entry into a human.

3. Describe three ways in which the HIV virus can be transmitted.

4. Most pathogens have characteristics or adaptations that enable them to both survive and reproduce to enhance their spread between hosts. As an example, suggest a reason why a tapeworm has:

   a) no digestive system

   b) no means of movement

   c) the ability to produce both male and female gametes (hermaphrodite)

Application, Analysis and Evaluation

5. *Salmonella* bacteria are a very common cause of bacterial food poisoning. Some foods, for example chicken seems to be highly susceptible to the transmission of this harmful bacteria. Suggest why this might be the case.

6. Hikers and people camping in the outdoors are often susceptible to ***Guardia*** infection. Describe the most likely source of this disease and explain why.

7. Cats are notorious for the bites they inflict when they fight with other cats. The wounds suffered are often particularly nasty, deep and infected, causing significant tissue damage. Explain why cat bites cause significant injury and infection.

8. Many scientists think that global warming is a consequence of human practices. It has been suggested that global warming may be a major factor in the increased spread of infectious diseases now, and in the coming decades, and that this may be linked to the vectors involved in the spread of disease. Explain likely reasons for this suggestion.

9. Refer to *Figure 223*, which illustrates the life-cycle of the pathogen that causes malaria, to answer the exercises that follow:

   a) Describe the role of the vector in the transmission of the malarial parasite.

   b) Explain how the actions of the Plasmodium might lead to human death.

   c) Some organisms in their life cycles reproduce both sexually and asexually at different phases. Describe where these two types of reproduction happen in the life-cycle of the malarial protozoan.

   d) Suggest one way to reduce the spread of the disease malaria.

Science Inquiry Skills 2.2 - Modelling disease transmission

Introduction

A disease that can be transmitted from one person to another is known as an infectious disease. Infectious diseases are caused by pathogens; for example, a type of virus or a species of bacterium. Pathogens move from person to person in a variety of ways. These include touching a person infected by the pathogen or something the infected person has recently touched.

This activity simulates how an infectious disease may be transmitted from person to person. In the simulation below a 30 mL plastic cup containing a clear solution is used to represent a person. One member of the class will, at random, get a cup of clear solution that simulates an infected person.

Materials

1 x 30 mL plastic measuring cup per student - each cup is labelled with a letter A-Z

All cups but one contain 5 mL of water (pH adjusted to 4 with 0.1M hydrochloric acid)

One cup contains 5 mL of 0.5 M sodium hydroxide

1 x 3 mL plastic transfer pipette per student

Phenol Red indicator

Lab coat

Safety glasses

Gloves (optional)

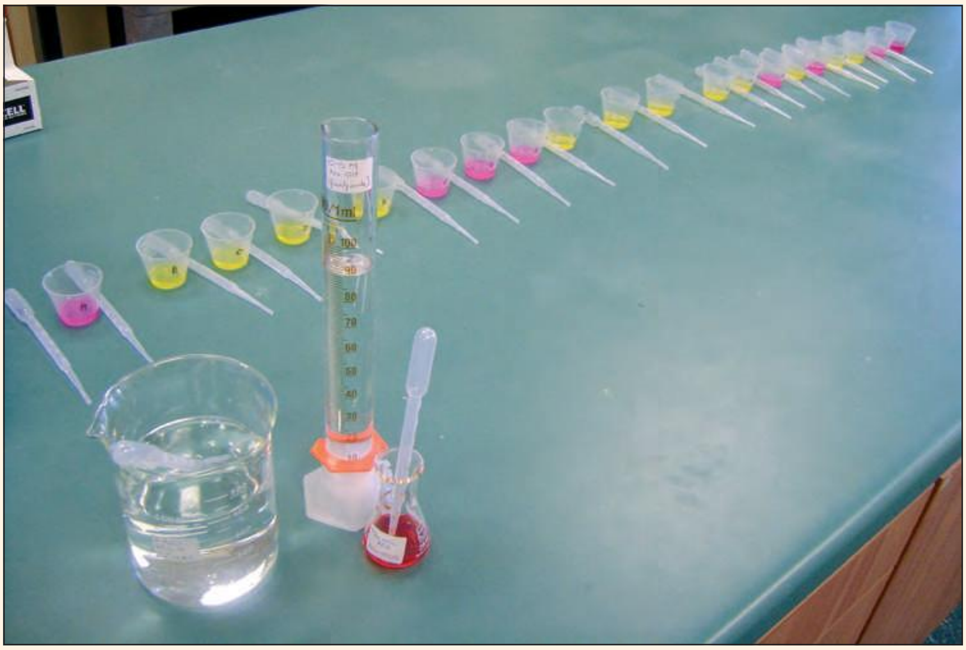
GLASSES

Part A: Performing the simulation

1. Collect a plastic measuring cup containing 5 mL of clear solution and a plastic transfer pipette.
2. When instructed, select a student randomly, and exchange 3 mL of your solution with them. To do this take up 3 mL of the clear solution and then pipette it into the other student's cup.
3. Record the name of the student and the cup's letter as Contact 1.
4. Repeat this process with a different student. This student is Contact 2.
5. Repeat again with another student. This student is Contact 3.
6. Use the table below to record all exchanges/contacts in the class.

Class Member	Contact 1	Contact 2	Contact 3
A			
B			
C			
D			
E			
F			
G			
H			
I			
J			
K			
L			
M			
N			
O			
P			

Science Inquiry Skills 2.2 - Modelling disease transmission (continued)



The equipment you will need

Part B: Assessing the transmission

1. At the end of the third exchange/contact, add 1 drop of phenol red indicator to the 30 mL measuring cup and observe. Use the following information to assess the transmission:

- If the solution in the measuring cup turns pink: You have been 'infected'
- If the solution in the measuring cup turns yellow: You are 'not infected'

2. Some students will have shown up as 'infected' while others will present as 'not infected'. Highlight the 'infected' students in the third round column of the class table.
3. Using the exchange/contact information in the class table, trace back to identify the original infected student who transmitted the disease to all others.
4. Dispose of your pipette and measuring cup of solution as directed by your teacher.

The space below may be used to extend the table if necessary.

? Science Inquiry Skills 2.2 - Modelling disease transmission (continued)

Analysis

1. In the list of ‘Equipment and Materials’ which cup simulates the infected person?

2. How many students in the class in total tested ‘infected’ by the end of the activity?

3. In Part A Step 2 what does ‘select a student and exchange some of your solution with them simulate?

4. Phenol red is a widely used ‘indicator’. If a liquid is initially yellow when tested with phenol red then turns pink when tested again after the addition of another liquid, what does that indicate has happened to the original liquid?

5. What is the maximum number of infected individuals possible for the class? Why might the observed number be expected to be lower than this?

6. Compare and contrast this model of disease transmission between humans to what might actually happen with a real disease.

2.2

Science as a Human Endeavour 2.2 - Early detection of malaria

Influence

Advances in one field of science influence/are influenced by other areas...

Despite 20th century steps to eradicate malaria (e.g. from USA, Australia, much of Europe) which have significantly reduced deaths globally, malaria remains a major health problem, especially in tropical regions. Nearly 250 million people are still infected every year causing more than 400,000 deaths most of whom are children under the age of 5 years old.

Efforts to further reduce infection and mortality rates are being hampered by several factors. They include the pathogen that causes malaria (a species of Protist of the genus *Plasmodium*) is becoming increasingly resistant to drugs being used to control it and the vector that transmits it (female members of a mosquito species of the genus *Anopheles*) have developed resistance to insecticides used to try and kill them. Furthermore, although a vaccine to malaria has been developed, it has only proved to be moderately effective.

One new approach to the problem concerns finding ways to detect infection by the malarial pathogen before people develop symptoms. Malaria is mainly spread when female Anopheles mosquitoes having obtained blood from a carrier of malaria then bite another person thus infecting them with the pathogen. Earlier detection of infection would reduce the time mosquitoes would have to spread the pathogen and thus reduce the number of infections.

To do this, medical researchers at the Doherty Institute at the University of Melbourne are striving to develop a saliva and urine test to detect before-symptoms levels of *Plasmodium* in the body. Their work has been influenced by a new electronic sensor (or biochip) developed by engineers at the University's Centre for Neural Engineering. The Doherty Institute team led by *Professor Stephen Rogerson* (refer to photo) coated the biochip with antibodies to the malarial pathogen. If Plasmodium is in blood or urine the idea is it will bind to the antibodies and cause a signal to be sent to the chip thus alerting the user they are carrying malaria.

You may need to refer to the online resource below to answer the questions that follow:

1. The goal to develop a saliva and urine test for malaria is a good example of the growing influence of the work of engineers on medical research. Briefly describe how the developments in another field of science have improved the choices of reducing the spread of malaria.

2. The saliva and urine test outlined above may evolve into some kind of hand-held scanner. Suggest which technologies might be called upon to help realize this.

Helpful Online RESOURCE about malaria and the challenges ahead

To learn more about eradicating malaria and challenges that lie ahead view the clip below:

<https://www.youtube.com/watch?v=NrF18Okr4Mk>

Chapter 2.3 Epidemics and other health issues

Science Understanding

Infectious diseases can cause widespread health issues for local, national, and/or global populations.

Describe the interrelated factors that can determine the spread of infectious disease, including:

- persistence of the pathogen within hosts
- the transmission mechanism
- the proportion of the population that is immune or has been immunised
- mobility of individuals of the affected population.

Epidemics

An **epidemic** occurs when a particular pathogen spreads its disease more than usual in a short space of time; the infection leading to widespread disease. When such a spread becomes global it is termed a **pandemic**.

Epidemics can be caused by a number of factors including:

- increased virulence of the pathogen often caused by **mutations** or genetic changes in the pathogen
- the transmission of the pathogen to a new group of humans not previously exposed
- the transmission of the pathogen is from animals to humans that previously had not occurred
- low **immunity** or natural defence to the pathogen in the population

Historical background

Epidemics have been recorded in history since the beginning of human civilisation with populations giving up nomadic lifestyles and settling in villages and towns. The human population size was kept in check by such infectious diseases wiping out millions of people. A range of factors contributed to such high mortality rates including poor **sanitation**, inadequate health system and little or no understanding of the causative agents of these diseases.

The bubonic plague or 'Black Death' was one such disease. It has been estimated that between 1347-1390, 25 million people died of this disease. This disease is caused by a bacterium *Yersinia pestis* which releases a deadly toxin in the body.

Figure 231 illustrates the 'Grim Reaper', an image that symbolised pandemics and was, somewhat controversially, used in the 1980s in Australia regarding the Human Immunodeficiency Virus (HIV) and AIDS.

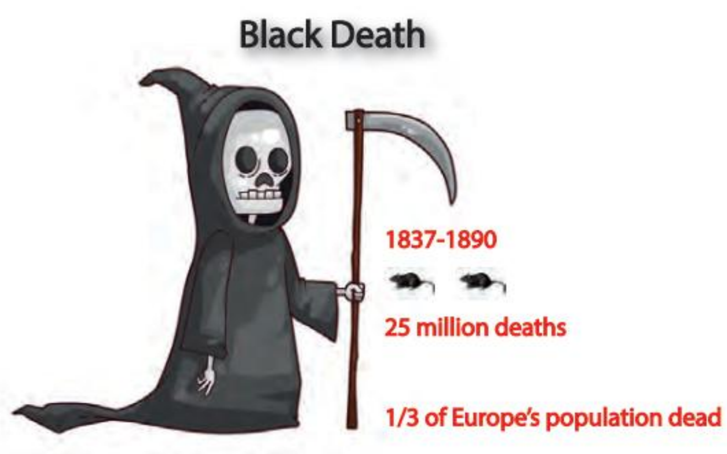


Figure 231 The 'Grim Reaper'

Helpful Online RESOURCE about the bubonic plague

To view an animation of the spread of this disease scan this QR code to go to:

<https://commons.wikimedia.org/wiki/File:Spread-Of-The-Black-Death.gif>

Recorded epidemics through the ages include many well-known diseases; typhoid, smallpox, influenza, public cholera, measles and malaria. Australia has not been immune to such epidemics. With colonisation and travel from Europe and around the world to our shores disease soon spreads. From the 1860s-1900 a range of epidemics occurred from measles (1867), smallpox (1880s), Asiatic flu (1890) and a range of other influenza epidemics. With better sanitation and the rapid development of health and medical practices such outbreaks were fewer and better contained in more recent times.

More recent epidemics

More recent epidemics include diseases such as HIV/AIDS, Zika, SARS, Ebola and new influenza strains.

The HIV virus first appeared in San Francisco in the early 1980's although it can be traced back to the Congo earlier than this. Refer to the table below showing the extent of people living with HIV and AIDS related deaths between 2007 - 2014.

Year	2007	2008	2009	2010	2011	2012	2013	2014
HIV infections (millions)	32.9	33.3	33.8	34.4	34.9	35.6	36.2	36.9
Deaths from AIDS (millions)	1.9	1.7	1.7	1.6	1.5	1.4	1.3	1.2

Refer to *Figure 232* showing a global perspective of HIV infections.

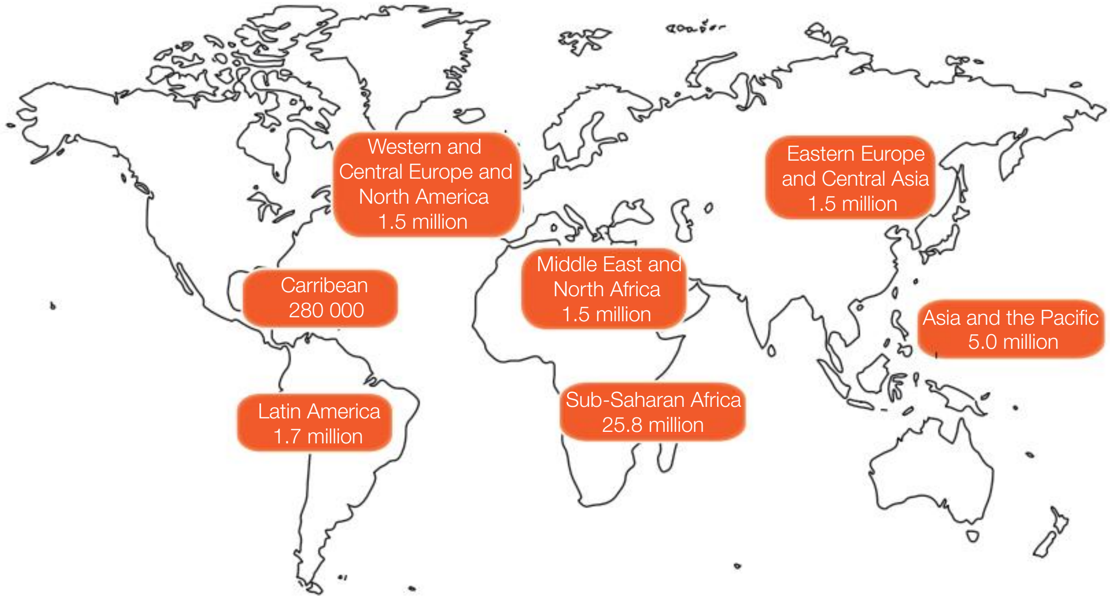


Figure 232 The frequency of HIV/AIDS in various countries

The deadly Ebola virus was first recognised around the mid 1970s in Africa, whilst SARS (Severe Acute Respiratory Syndrome) seemed to first appear in China around 2002. This quickly turned into a pandemic infecting over 8000 people in a few months, with hundreds dying.

Figure 233 shows a colour-enhanced electron micrograph of Ebola virus particles and *Figure 234* demonstrates some of the protective measures required by health workers when working with the virus.

Figure 233 An image of the Ebola virus

Figure 234 A health worker testing for Ebola

Some factors influencing the spread of infectious disease

Transmission mechanisms

Chapter 2.2 presented the main methods of transmission of infectious disease and it was noted that specific pathogens are usually transmitted in specific ways. The causes of epidemics can be readily understood in light of our knowledge of the transmission of pathogens.

Mobility of populations

Contagious diseases are spread by close contact between individuals and the advent of cheaper international travel enables the spread of diseases much more easily. AIDS was once a relatively obscure and isolated disease but this mobility of individuals and populations has been a big contributor to what was seen in *Figure 232*.

Use, mis-use and abuse of intravenous drugs

Sharing needles, in particular, enables the transfer of body fluid from one person to another and as seen in Chapter 2.2 many pathogens can be transferred in this manner. This is an extremely unsafe practice. Refer to *Figure 235*.

Figure 235 Unsafe use of intravenous needles

Poor sanitation

Many low income countries do not have adequate access to fresh clean water. Wars, conflict and persecution of minority groups often create poor living conditions e.g. refugee camps and these poor sanitary conditions are ideal for the spread of infectious diseases.

Spread from animals

Animals often act as reservoirs for pathogenic organisms. These may reside in animals for long periods of time before being transferred to humans. The clearing of vegetation may result in humans being exposed to infected animals (especially mammals) and keeping exotic (non native) pets may also aid the spread of disease. Monkeys and bats harbour many pathogens that can be transferred to humans. Refer to *Figures 236* and *237* for examples.

Helpful Online RESOURCE about diseases from animals

If you would like some more information about diseases that humans can catch from monkeys you can follow this QR code:

<http://www.2ndchance.info/mnky2man.htm>

Figure 236 A vervet monkey

Figure 237 A fruit bat

Characteristics of pathogens

The characteristics of pathogens often largely determine the spread of infectious disease. Pathogens are very diverse in a whole range of ways. Some act in what can be described as a 'hit and run' strategy and others 'hit and stay'. The 'hit and stay' variety are very well adapted to staying for long periods inside their hosts, evading the host's defences and immune systems. This naturally gives them a distinct advantage in their ability to spread effectively from one host to another over long periods of time. A virus such as HIV, causing AIDS, hides deep inside the **lymphatic system** inside cells to avoid detection. As such, the AIDS epidemic is notoriously difficult to stop, people who are infected often not knowing that they've contracted the disease for long periods of time.

Change in virulence and genetic structure

DNA can mutate or change its structure and it is possible that such a mutation in viral DNA can alter the structure of a gene and subsequently the protein it codes for. This feature of DNA provides pathogens with a very powerful weapon, enabling them to evade their hosts' immune system. This effect can be seen with the influenza virus which has the ability to change its antigenic proteins and 'trick' the human immune system. Refer to *Figure 238*.

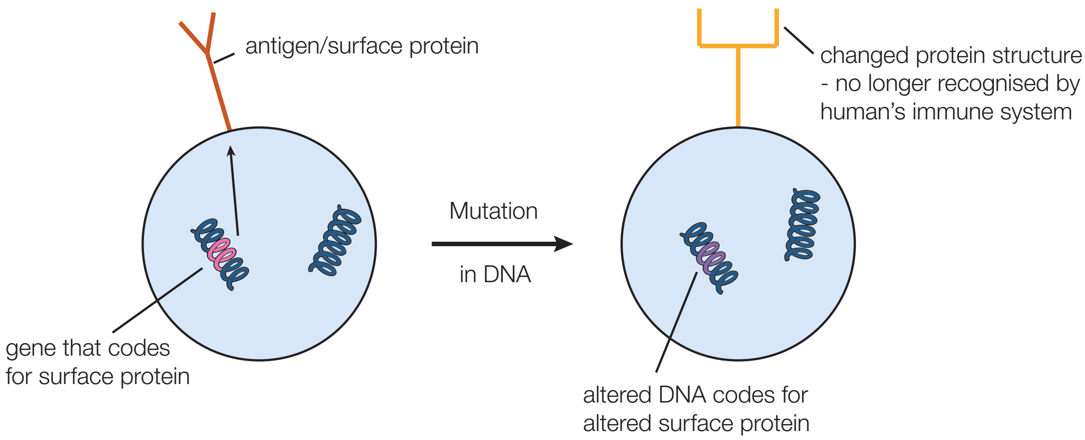


Figure 238 The possible result of mutation in a virus

Viral particles can be classified by their external proteins on the surface (**antigens**) and there are literally thousands of different combinations possible. The end result is that human populations can build up a certain level of immunity to a viral strain of the flu virus but this will be a very little use if next year a different strain with different antigens emerges. Refer to *Figure 238*.

Drug resistance in bacteria

Perhaps even of greater concern for human health is the emergence in recent decades of **antibiotic** resistant bacteria. Antibiotics that were once highly effective are often not so anymore; simply after exposure to antibiotics the more susceptible bacteria die off, leaving the more resistant strains whose offspring tend to be more resistant. There are now '**superbugs**' that are resistant to almost every known antibiotic.

A composite image showing how bacteria develop drug resistance is shown in *Figure 239*. Bacteria that are resistant to antibiotics can arise when changes occur to bacterial DNA. *Figure 2310* shows a prediction of the health problems caused by antimicrobial resistance (AMR) in the future.

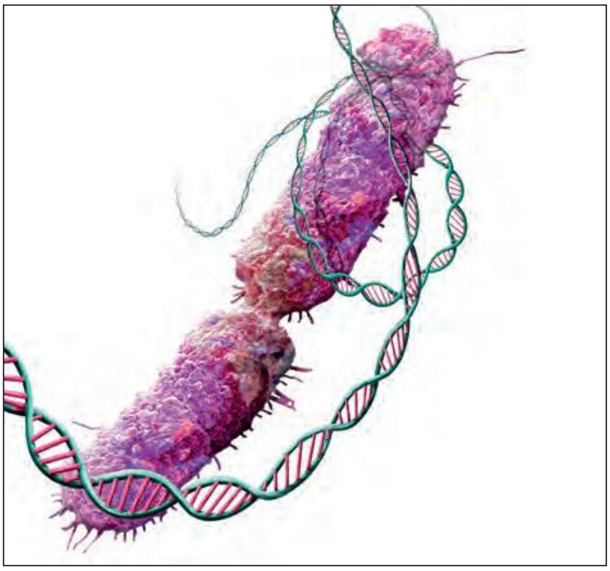


Figure 239 An image of antibiotic resistance

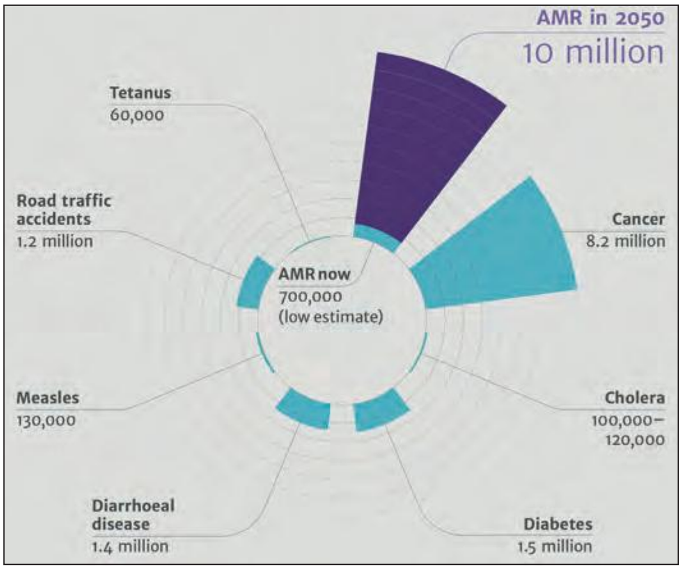


Figure 2310 A prediction of future health issues.

Helpful Online RESOURCE about antimicrobial resistance

Use this QR code to go to this website which will provide more information about this topic:

<https://commons.wikimedia.org/wiki/Category:Antibiotic_resistance#/media/File:Antimicrobial_resistance>

Population immunity

The term "immunity" refers to the acquisition of body defences enabling the host to fight off invading pathogens. This will be considered in more detail in Chapter 2.8. When this term is applied to a population it is referred to as protection for a population which arises due to the large percentage of individuals in the population that are immune to a specific infection.

This type of immunity is called '**herd immunity**' and could be brought about naturally (by infection) or artificially (by vaccination). Herd immunity provides a level of protection to all members of a population whether individuals are immune or not.

Helpful Online RESOURCE about herd immunity

To view an animation on this topic of herd immunity use this QR code:

<http://www.health.harvard.edu/herd-immunity-animation>

Compulsory vaccination of children

The issue of whether or not children should all be vaccinated for a number of diseases is a matter of some public debate.

Helpful Online RESOURCE about public vaccination

If you are interested in this matter more information can be found using this QR code and visiting this website <www.immunise.health.gov.au>

You may even be able to help arrange a debate in your class on this issue.

2.3

C Ethical understanding: ‘No Jab, No Play’

Ethics involves asking questions about what is right or correct for individuals and society. To understand ethics is to be able to think critically to determine the right course of action.

Government and community actions may prompt debate that includes ethics. One ongoing example concerns vaccinating children. Vaccines routinely given to children in Australia include the MMR vaccine that protects them against three debilitating diseases; measles, mumps and rubella. Children given a vaccine are said to be vaccinated (*refer to the photo*).

According to data published in February 2019 by the Federal Government’s Department of Health, the proportion of Australian children who are fully vaccinated (immunised) stands at just under 95%. The fact that the national immunisation coverage is not 100% is in part due to lingering opposition to the use of vaccines in certain parts of the country. For some, mandating the vaccination of children is not right as it amounts to forcing children to undergo a medical procedure for which they have been unable to give consent. To many Australians, however, to not vaccinate a child not only puts them at risk of contracting a disabling disease (for example, by attending a child-care centre or pre-school with under-vaccinated children), it also threatens the health and well-being of other (vaccinated) children.

To encourage even more parents to vaccinate their children, the Australian Government passed a law in early January 2016 that required children to be fully vaccinated for parents to be eligible to receive the Government’s assistance payments. South Australia implemented this ‘No-Jab-No-Play’ policy in September 2017. For some, decision-making like this was not inclusive. For most, it was positive step towards improving the well-being of young children.

In 2019, the Federal Government took steps to stop children coming into contact with under-vaccinated children in childcare, kindergarten and school. The ‘No-Jab-No-Play’ policy intends to prohibit the enrolment of an under-vaccinated child at a childcare service from July 2019. Though the exact timing will vary slightly from state to state, it is anticipated that during 2020 it will become impossible for under-vaccinated children to start kindergarten.

You may need to refer to the online resources below to answer the question that follows:

1. The Federal Government’s new ‘No-Jab-No-Play’ policy has benefits and limitations. Identify some of these, and discuss whether you agree this is the right course of action.

Helpful Online RESOURCE about the ‘No-Jab-No-Pay’ policy

To learn more about the Government’s 2016 No-Jab-No-Pay initiative view the clip below:

<https://www.youtube.com/watch?v=JMO6SxOsefY>

Helpful Online RESOURCE about the ‘No-Jab-No-Pay’ policy

To learn more about No-Jab-No-Play laws view the clip below:

<https://www.youtube.com/watch?v=Ve2mGIWB2Pg>

Key Concepts

1. When infectious diseases spread rapidly, an epidemic can cause widespread health issues.
2. The spread of infectious disease is influenced by a number of key factors, including:
   - the mode of transmission of the pathogen e.g. water, food, direct contact, vector
   - mobility of populations e.g. international travel
   - drug mis-use and abuse e.g. sharing needles
   - poor sanitation and poor hygiene
   - contact with animals that may be vectors
3. Pathogens have evolved a range of adaptations to facilitate their survival and spread, including:
   - persisting in hosts (e.g. HIV)
   - changing their virulence or evading host defences

What have you learned?

Key Terms

epidemic

pandemic

mutation

immunity

sanitation

contagious disease

lymphatic system

antigen

superbug

antibiotic

herd immunity

Knowledge and Understanding

1. State three factors that could increase the chances of an epidemic.

2. Complete the following table that lists the disease, the pathogen that causes the disease and the most important factors influencing the spread of the disease.

Disease	Pathogen	Factors influencing spread
Influenza		
		Poor sanitation in a refugee camp
	HIV	
		Poor herd immunity
Malaria		

3. Refer to the table in Chapter 2.3 concerning more recent epidemics and HIV/AIDS and *Figure 232* to help you answer the questions that follow:

   a) Use the grid below to plot the information on one graph.

   b) State two likely conclusions you can make from the data.

   c) State two factors that make curing AIDS so difficult.

   d) State two factors that might be helping to slow the epidemic.

4. Answer the following questions:

   a) Explain what antibiotic resistance means.

   b) Explain why there are now fears that this could be a greater risk to human health than AIDS.

5. Describe how a gene mutation might increase the virulence of a pathogen.

Application, Analysis and Evaluation

6. Explain why 'herd immunity' only applies to contagious diseases.

7. *Staphylococcus aureus* ('golden staph') is a relatively harmless bacterium for most people.
   a) Choose two groups of people in society who might be more vulnerable to golden staph infection and explain why.

   b) Explain why this relatively harmless bacterium kills so many people in hospitals.

8. Although there are occasional cases, explain why it is highly unlikely that an epidemic of the size of the bubonic plague could occur in this century.

9. In the first part of this chapter, a distinction was made between two types of strategies used: (a) 'hit and run' and (b) 'hit and stay'. Both methods are used effectively by a range of pathogens. Give an example of each and describe how each method provides an adaptive advantage for the pathogen.

Science Inquiry Skills 2.3 - Antibiotic resistance

Introduction

Various microorganisms including some fungi, produce substances that are toxic to bacteria. Such substances, which include penicillin and streptomycin, are known as antibiotics.

Resistance to antibiotics can develop through a range of mechanisms including changes to the permeability of bacterial cell walls or membranes and changes to metabolic pathways. This resistance is acquired by mutations of the bacterial genome and can occur with high frequency due to the short generation time and high population numbers of bacteria. The resistance can be spread rapidly as plasmids, containing the resistant genes, can be transferred between individual bacteria.

Changes in the population of bacteria are noticed with an increasing frequency of genes conferring resistance to antibiotics. This is evidence that the process of natural selection is at work.

Your teacher will explain health and safety procedures that you will need to follow.

The purpose of this activity is to investigate the effect of antibiotics or other antimicrobial agents on *Escherichia coli* and *Staphlococcus albus.*

Materials (per group)

distilled water

aqueous cultures of *E.coli* and *Staph. albus*

agar plates with nutrient medium(peptone /beef)

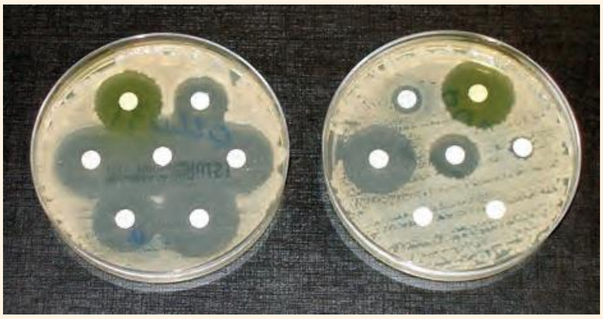
methylated spirits

sterile cotton buds

Mastring antibiotic rings (See Lab Notes)

forceps, swabs, adhesive tape, incubator

Method



1. Clear and sterilise your work area using the swab and methylated spirits.
2. Use your permanent texta to label the two plates with the bacteria species, your group and the date.
3. Remove the plug from the first culture of bacteria. Carefully flame the opening of the tube. Insert the cotton bud into the culture and remove. Replace the plug in the culture.
4. Use the cotton bud to gently streak the entire surface of the agar ensuring that all of the area is covered. Put the lid on the plate immediately and discard the cotton bud as directed by your teacher.
5. Repeat this procedure for the other species of bacteria and then leave for around 5 minutes.
6. Use forceps to place an antibiotic ring in the middle of each plate. Make sure that each disc makes contact with the agar.
7. Seal the agar plates as instructed and incubate at 35°C for 24 hours.
8. After the incubation period measure the diameter of the zone of inhibition for each antibiotic and then record this data in a suitable table in the space provided on the next page. The petri dishes must NOT be opened to do this.
9. The zone of inhibition is a clear area surrounding the antibiotic in which bacterial growth has been excluded. If the bacterial growth is not inhibited it can be inferred that the bacteria are resistant to that antibiotic.
10. In your table also record for each species of bacteria the level of resistance to the antibiotic; high, medium or low. You may also decide to include a diagram in the space provided.
11. Analyse your observations.

Science Inquiry Skills 2.3 - Antibiotic resistance (continued)

Results

Analysis

2.3

Science as a Human Endeavour 2.3 - 'Superbugs'

Application and limitation

Use of scientific knowledge may have...unexpected consequences

'Superbugs' is a term coined to name new strains of bacteria that are resistant to virtually all known antibiotics. Researchers in China have recently discovered a superbug strain of *E. coli* that is resistant to all types of antibiotics. This has been caused by the emergence of a new gene MRC-1 that has conferred resistance to the colistin class of antibiotics. This last resistant strain was found in livestock but soon appeared in humans.

Superbugs are a real problem in hospitals. An example is the normally harmless bacterium ***Staphylococcus aureus*** or golden staph. If however staph enters the bloodstream through a needle or catheter then this can give rise to bloodstream infections which are very difficult to eradicate due to antibiotic resistance. In Australia a figure of around 1500 golden staph infections was reported with the death rate of around 25% or 400 people per year.

You may need to refer to the online resource below to answer the questions that follow:

1. Explain how the use of antibiotics in livestock might provide benefits, but needs to be thoughtfully balanced with potential risks involved.

2. Explain how the emergence of a resistant strain of bacteria might be an unexpected consequence involved with the overuse of antibiotics.

Helpful Online RESOURCE about 'Superbugs'

Use this QR code to jump to this website which will provide a valuable start in your research for the Questions above:

<https://en.wikipedia.org/wiki/Colistin>

Chapter 2.4 Disease control

Science Understanding

Examples of disease control include:

- controlling the carriers (e.g. fleas, mosquitoes)
- killing the pathogen (e.g. antibiotics, antiseptics)
- quarantining carriers of the disease
- the immune response.

Controlling disease

Previous chapters have explored both the causes of disease and how these diseases can be spread giving rise to epidemics and pandemics, often with catastrophic consequences to human populations.

With greater understanding of diseases and their causes, as well as better sanitation and health care practices, humans are in a better situation to control the spread of disease.

Displacement of populations caused by armed conflict, natural disasters or lack of adequate food and water leads to a range of factors which increase the risk of diseases caused by infectious agents and hence the threat of epidemics. The World Health Organisation (WHO) and other related groups are faced with extreme challenges in responding to such crises.

Figure 241 shows conditions in refugee camps that may allow disease to spread.

Figure 241 Refugee camps (a) in Bangladesh and 241 (b) in Ethiopia

Examples of disease control

Controlling or killing vectors

Vectors have, in previous Chapters, been identified as intermediate hosts in the transmission of infective agents. Refer to the table below of some typical vectors and the human diseases they are associated with.

Vector	Infective agent	Disease
house fly	A variety of bacteria	diarrhoea
mosquito	*Plasmodium* protist	malaria, dengue fever
flea	Plague bacteria	plague
fox or dog	Rabies virus	rabies

Figure 242 Fumigating to destroy mosquitos

Refer to *Figure 242* that illustrates a worker fumigating a house to destroy mosquitoes which can transmit deadly viruses and other pathogens to humans. Described below are the main methods of controlling vectors:

Sanitation

- Eliminate or reduce the breeding grounds for insects such as mosquitoes, especially still or stagnant water.
- Rats can be controlled by good clearing practices and storing food properly.
- The availability of clean fresh running water helps significantly in the control of insects.

Barriers and traps

- the use of **insect repellents** on the skin
- the use of mesh screens in windows and doors
- using netting around beds
- a layer of oil or kerosene on water to prevent larvae growing
- manual rat traps
- adhesive or ultraviolet traps for insects

Insecticides

Insecticides are common chemicals which have been used to kill insects, examples are DDT, malathion and pyrethrums. There are many types of chemicals such as these which have been used extensively since World War II (1940s). Many of these are used as aerosols. Refer to *Figure 245* overpage.

Biological methods

Many of these methods involve genetic manipulation to interfere with the reproduction of insect species e.g. the production of sterile males.

The introduction of **predators** of the vectors can also be effective e.g. fish which eat insects and larvae help to keep the numbers of factors in check and help reduce the spread of disease such as malaria.

Helpful Online RESOURCE for the spread of disease

To learn more about this, use the QR code to view an animation of how a disease can spread: <www.shodor.org/interactivate/activities/SpreadofDisease/>

Helpful Online RESOURCE about a Cholera epidemic

For very comprehensive information about John Snow and the cholera epidemic in London about 150 years ago, you can use this QR code to go to:

<http://ehsc.oregonstate.edu/files/ehsc7/John%20Snow%202.05.pdf>

Killing pathogens

Antibiotics

Antibiotics are chemicals that work by killing or reducing the growth of bacteria. The first antibiotic, penicillin was discovered by Alexander Fleming in 1928. This was a chance discovery made when Fleming noticed that some of the bacteria he was culturing were destroyed by a naturally occurring penicillium mould. Refer to *Figure 243* illustrating the microscopic fungus ***Penicillium notatum*** growing on the surface of a mandarin. This fungus produces the antibiotic penicillin. Refer to *Figures 243* and *244*.

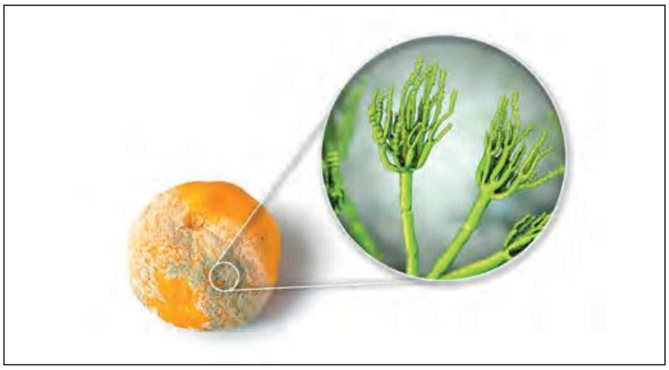


Figure 243 A mandarin covered in mould

Figure 244 A label for the drug penicillin

Refer to the table below which shows some common antibiotics and how they destroy bacteria:

Antibiotic	Mode of action
Erythromycin	interferes with protein synthesis
Neomycin	interferes with protein synthesis
Penicillin	interferes with the production of cell walls
Cephalexin	interferes with the production of cell walls

Different antibiotics are required as each antibiotic is not effective against all bacteria. **Bacterial resistance** is a term used to describe the feature of specific bacteria that are resistant to particular antibiotics. Antibiotic resistance (refer to Chapter 2.3) is considered one of the major risks to public health both now and into the future.

Antiseptics

Antiseptics are a group of chemicals that kill microbes on the outside of the body as distinct from antibiotics that operate inside the body. Antiseptics have been used for over 150 years to combat microbe infection and include such products as alcohol and its derivatives (e.g. methylated spirits), boric acid, hydrogen peroxide and iodine products. Refer to *Figure 246* which shows some common antiseptics and **disinfectants**.

Figure 245 A household insecticide

Figure 246 Some common antiseptics and disinfectants

2.4

Disinfectants

Disinfectants are a group of related chemicals that work in a similar way to antiseptics but are used to kill microbes on surfaces, floors, toilets and in other places. Refer again to *Figure 246*.

Disinfectants and antiseptics are used widely in hospitals, the food industry and homes to destroy harmful microbes. They often work as powerful chemicals that may oxidise or split open bacteria causing rapid destruction of the infective agents.

Quarantine

Quarantine involves keeping people infected with a particular disease separated from healthy members of the population in order to stop contagious diseases spreading.

Chapter 2.2 described methods by which these contagious diseases can be spread through individuals. With little understanding of microbes and infective agents and how they spread or how they could be destroyed, quarantining infective individuals was the basic and fundamental strategy to restrict the spread of disease throughout history.

The story of the 'Black Plague' (see Chapter 2.3) is a good example of the use that human populations made of quarantining. Medicine had no effect on the disease and the disease had spread rapidly across Europe with devastating consequences. Authorities set up armed forces to repel infected people from their cities. Using this as a disease control strategy was not without its problems.

Ships and the cargoes they transported were vital for trade and economy but naturally the sailors arriving at new ports often spread disease and stopping ships placed severe restrictions on trades between countries. Marginalised and poorer groups in society, with often less emphasis on sanitation and hygiene, were more at risk of infectious disease. Quarantining them raised issues of discrimination and a lack of social justice for such people.

Despite the problems and the vast increase in human understanding about disease and how to control it, quarantining is still a powerful strategy and a positive health response in many situations. In recent history the traditional measures of quarantining were implemented in response to the emergence of the disease *SARS* in 2003 in China and *Ebola* in western Africa in 2015.

Figure 247 Quarantine in the 19th century

Figure 248 Protection for health workers

Refer to *Figure 247* illustrating the practice of isolating people who were potentially infectious. This was in 1884 and shows a camp isolating potential cholera victims in Italy. It is vital that health workers also be protected against infection as shown in *Figure 248*.

Epidemiologists are scientists who study diseases in human populations. They analyse data about the disease, the causes and the distribution. They work with other healthcare individuals and organisations discussing and recommending cures, treatments and other ways to prevent the spread of disease.

The immune response

Humans have a range of defence mechanisms that help protect them from disease. Our bodies have the ability to detect and respond to what can be termed 'non-self' and mount a range of mechanisms and processes to destroy the invading organisms.

Cellular protection is provided by white blood cells which may either attack microbes directly or produce chemicals (antibodies) that bind to and destroy them. **Immunity** is the term used to describe either natural or acquired resistance in individuals of the population to specific diseases. If more people in the population are immune to a specific disease it is less likely to spread (refer Chapter 2.3: Herd immunity). The immune responses are presented and described in more detail in Chapters 2.7 and 2.8.

A Case Study - *Ebola* outbreak in Nigeria

Background

Ebola is a disease caused by a virus, that first appeared in Western Africa around 1976 in an area near the Ebola River, hence the name. It is a particularly virulent strain that is thought to be first found in wildlife such as fruit bats.

The disease is highly contagious and was able to spread in the dense and mobile populations before suitable interventions could be implemented. It is believed that over 10,000 deaths have occurred in the outbreak.

Spread of the disease

The virus is spread by contact, from person-to-person through such methods as:

- exchange of body fluids e.g. breast milk, blood (by sharing needles)
- possibly through sexual contact e.g. semen
- incorrect handling of victims of the disease

Strategies to control the disease

It is believed an infected man originally from Liberia travelled to Nigeria and some 19 other people contracted the disease. With the assistance of the World Health Organisation (WHO) and local authorities the spread of the disease was quickly contained. WHO declared Nigeria Ebola free after 42 days of no new cases.

The strategies used to control the disease were a combination of the following:

- early diagnosis and quarantining of infected individuals
- provision of full protective clothing for healthcare workers to avoid contact with infected patients
- education and awareness strategies for the local population e.g. procedures for burying the dead
- avoiding eating wildlife that may have been infected
- protective practices e.g. gloves when handling wildlife
- good sanitation
- fast tracking the development of promising vaccines

Ethical considerations

Some ethical considerations in this particular case were:

- cost of treatments including medication for critically ill patients in very poor countries
- isolation of infected individuals; civil liberties and associated costs and enforcement
- dangers to health care workers exposed to the risk of infection (*see pic*)
- healthcare workers returning to their home countries and the need for quarantining

Helpful Online RESOURCE about *Ebola*

Use this QR code for much more information about *Ebola*:

<http://www.who.int/csr/disease/ebola/en/>

2.4

C Critical and creative thinking: Dengue wipe out

Dengue fever is an infectious disease caused by the Dengue virus (DENV). It is mainly transmitted by female members of mosquito species **Aedes aegypti.** Infection leads to very severe flu-like symptoms and can result in death. Dengue is found in tropical and sub-tropical countries across the world, where it is most common in cities and large provincial towns. Each year just under 400 million people are infected, and tens of thousands die.

Using insecticides to kill the mosquito vectors and taking steps to clear large tracts of their habitat have been used for decades to try control the disease. Early detection and access to medical facilities both greatly reduce how many die. However, dengue is without a cure.

The fight against dengue though seems to have taken a turn for the better. *Scott O'Neill* from Monash University in Melbourne has proposed killing *Aedes aegypti* mosquitoes with *Aedes aegypti* mosquitoes! To this end, he and his team infected Aedes aegypti mosquitoes with a naturally occurring bacterium of the genus *Wolbachia* (*refer to the photo that shows some of these mosquitoes*). Mosquitoes infected with bacteria of the genus *Wolbachia* have an ultra-enhanced immune system that greatly reduces DENV's ability to replicate. As a result, mosquitoes infected with DENV have a dramatically lowered ability to transmit the virus to humans.

The world's first city trial to test the *Wolbachia* method to control dengue started in Townsville in Far North Queensland in October 2014. Over 28 months researchers and local residents released about 4 million *Wolbachia* infected mosquitos. Once released, the infected mosquitoes reproduced with normal mosquitoes and passed on the *Wolbachia* bacteria to their offspring, who also became poor at transmitting dengue to people.

By the end of 2018, there had only been 4 cases of dengue in Townsville compared with more than 50 cases between 2010-2014. The trial was the first time a 'modified mosquito' had been used successfully to eradicate a mosquito-borne virus from a city.

You may need to refer to the online resources below to answer the questions that follow.

1. Killing mosquitoes and destroying mosquito habitat are standard insect-transmitted disease control strategies. Explain why they are beginning to fall out of favour.

2. Creative thinking often drives successful applications of biological concepts to real-world problems. Outline why Scott O'Neill's work provides one example of this.

Helpful Online RESOURCE about the Townsville Dengue trial

To learn more about the Townsville dengue trial view the clip below:

<https://www.youtube.com/watch?v=iaBLJKKxeLg >

Helpful Online RESOURCE about the success of the Townsville Dengue trial

To learn more about how successful the Townsville trial was view the article below:

<https://www.nature.com/articles/d41586-018-05914-3>

Key Concepts

Examples of disease control include:

1. Controlling the carriers or vectors:
   - effective methods include sanitation, barriers and traps, chemicals and biological methods
2. Killing the pathogen:
   - effective methods include the use of antibiotics, antiseptics and disinfectants
3. Quarantining carriers of the disease:
   - necessary at all stages including diagnosis, transport and treatment
4. The immune response:
   - the body's natural defences which will be discussed in much more detail later in this Topic

What have you learned?

Key Terms

sanitation ....

insect repellent ....

insecticide ....

predator ....

antibiotic ....

antiseptic ....

disinfectant ....

bacterial resistance ....

quarantine ....

epidemiologist ....

immunity ....

Knowledge and Understanding

2.4

1. Name four examples of the ways that the spread of disease can be controlled.

....

....

2. List two ways that one of these measures can be achieved in order to help reduce malarial infection:
   a) mosquito numbers might be reduced OR

....

....

   b) people can reduce the risk of being bitten by mosquitoes

....

....

3. Name one insecticide and state how it can be used to stop the spread of a specific disease.

....

....

....

....

4. Describe the difference between an antiseptic and a disinfectant giving an example of each.

5. State two ways in which humans may respond to and destroy a microbe that has entered their body.

Application, Analysis and Evaluation

6. Explain why displaced populations are more vulnerable to disease epidemics.

7. Explain why targeting vectors can be an effective method of disease control. Give an example to illustrate your response.

8. Suggest possible reasons why not all species of bacteria are susceptible to the antibiotic penicillin.

9. Briefly discuss two ethical considerations involved with the current use of quarantining individuals suspected to be infected with disease.

Science as a Human Endeavour 2.4 - Preventing tooth decay

Application and limitation

Science informs public debate and is in turn influenced by public debate

There are many ways to minimise the onset and development of tooth decay. These include the way teeth are cleaned (use and type of tooth brush, toothpaste, dental floss, mouthwash) and to what extent good tooth cleaning behaviours are adopted (regular tooth brushing, flossing and rinsing, and a diet that minimises the consumption of sugary foods and drinks).

In order better prevent tooth decay (see photo) in more Australians, a substance called fluoride is added to drinking tap water. Fluoride in tap water makes teeth more decay resistant (strengthens enamel) and its presence in tap water helps to stop plaque bacteria in the mouth making acids that lead to tooth decay. It was introduced into tap water for the first time in Australia in the 1950s, and has been in Adelaide tap water since 1971. Today, more than 90% of South Australians have access to it.

There is public debate, however, about how effective adding fluoride to drinking water is at preventing tooth decay, and the safety of continuing to do so. Some people are of the opinion that the addition of fluoride to tap water does not help to prevent tooth decay, and may even encourage it. There is also a belief that adding fluoride to tap water causes types of cancer, and is associated with high blood pressure, kidney disease, and disruptions to intellectual development.

In response to these and other concerns about fluoridated tap water, the National Health and Medical Research Council (NHMRC) reviewed the science and published an information document in November 2017 called Water Fluoridation and Human Health in Australia. This states there is no reliable evidence that using fluoride does not help prevent tooth decay, or is unsafe. It concludes that adding fluoride to tap water not only helps prevent tooth decay, but that doing this has been one of Australia's greatest public health achievements.

You may need to refer to the online resources below to answer the questions that follow:

1. Describe how use of fluoridated water illustrates how public debate can influence science.

2. The use of fluoridated tap water in Australia provides many examples of the way science informs public debate. Describe some examples of this.

Helpful Online RESOURCE about concerns about fluoridated water

To see an Adelaide news report about concerns about fluoridated water see below:

<https://www.youtube.com/watch?v=kYpX3_JSrLg>

Helpful Online RESOURCE about evidence that supports fluoridated water

To learn more about the NHMRC's position on fluoridated water view the article below:

<https://www.nhmrc.gov.au/about-us/publications/2017-public-statement-water-fluoridation-and-human-health>

Chapter 2.5 Adaptations of pathogens

Science Understanding

Pathogens have adaptations that facilitate their entry into the cells and tissues of hosts.

- Describe how pathogens and host cells recognise each other.
- Explain that some pathogens enter cells to survive and reproduce.
- Describe the basic concept of molecular recognition (e.g. pathogens binding to cellular receptors).
- Explain that some pathogens must enter cells to ensure their survival replication, and to evade the immune system.

In Chapters 2.1 and 2.2, pathogens that give rise to infectious disease were examined in some detail. To cause disease all pathogens must colonise their specific host, avoid **immune systems,** multiply and then be able to spread themselves to other hosts.

Many pathogens are termed **intracellular** as they enter cells and it is here that they survive and multiply. The ability to cause disease in a host is called **pathogenicity** and **virulence** is the degree to which the pathogen causes disease. A pathogen with high virulence has properties that enable it to bring about a high level of disease in a host.

Humans are vulnerable to penetration and infection by pathogens in four main ways:

- respiratory surfaces
- wounds
- digestive system
- reproductive organs

Refer to *Figure 251* which illustrates how humans can be vulnerable to pathogen entry.

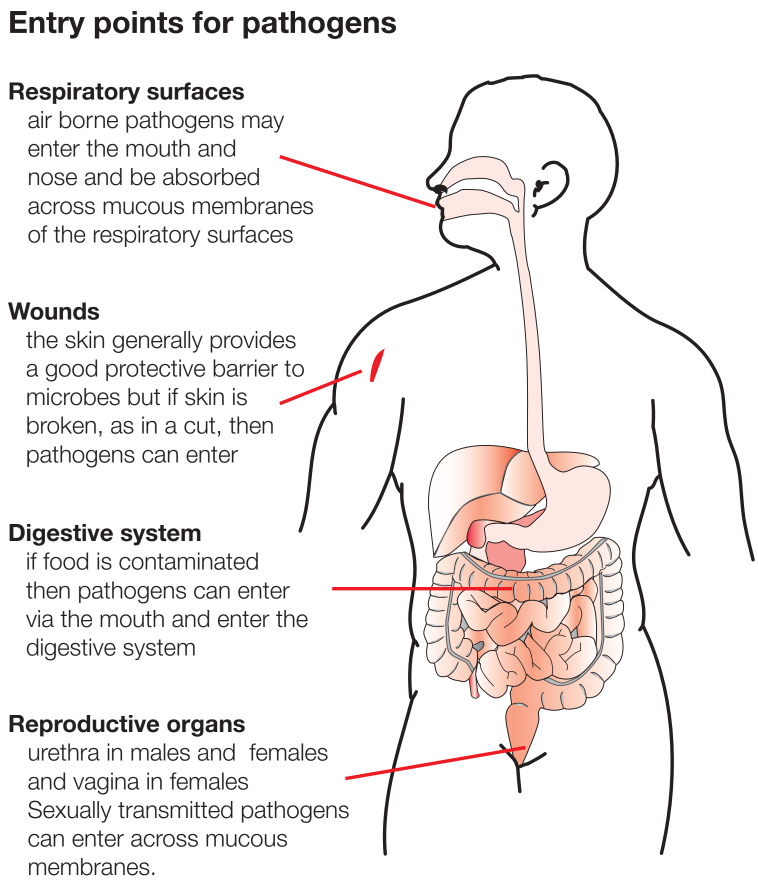


Figure 251 How pathogens can enter the body

Adaptations

There are many **adaptations** possessed by pathogens to facilitate their entry, survival and reproduction in hosts.

Using a vector

Some pathogens manage to enter the bloodstream by using a vector to assist them. A rather large group of microbes, including examples from bacteria, viruses and protists, have adapted to survive in certain insects so they can be transferred to their hosts. The disease of malaria is spread in this way with the Plasmodium organism being well adapted to living in the females of a certain species of mosquito.

Figure 252 shows a mosquito biting a human.

Attachment to host tissue

Many pathogens are well adapted, once inside the host, to attach to host cells so that food moving through the intestines or the washing action of urine flow does not expel them from the body. They produce specific proteins called adhesions that can recognise and bind in a complementary manner to molecules on host cells.

A profile of a Biologist is provided at the end of this Chapter to help develop your understanding of this.

Figure 253 shows surface projections (**pili**) that have proteins at the tip that can bind to cell receptors.

Figure 252 A mosquito biting a human

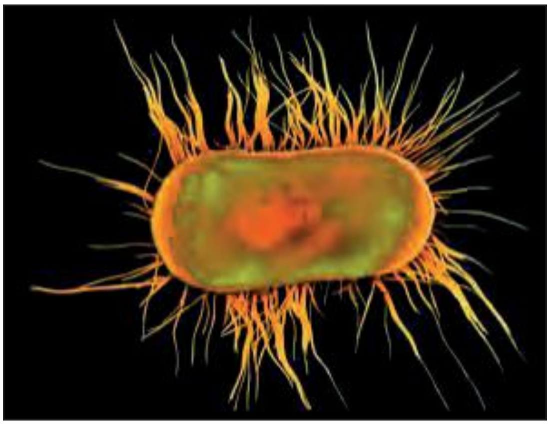


Figure 253 E. coli bacterium showing pili

Ability to withstand harsh environments

The human stomach provides a particularly harsh environment for pathogens; it contains acid with pH 2, thick mucous layers and continual churning action. Nonetheless, a bacterium, ***Heliobacter pylori***, which can cause stomach ulcers can survive and reproduce. One of its adaptations is its ability to secrete an enzyme which converts urea to ammonia which helps to neutralise the acidic environment.

Biofilms

More than 99% of bacteria exist in colonies known as biofilms, adopting a range of unique properties such as existing in a dormant state with reduced metabolism, becoming resistant by transferring genetic information within the colony and preventing antibiotic penetration by surrounding themselves in a slime-like matrix. All of these factors result in biofilm bacteria being difficult to identify using standard methods and are resistant to antibiotics.

One particular bacterium, ***Staph. aureus*** is known to cause many sinus infections and is very difficult to treat with antibiotics. See *Figure 254*.

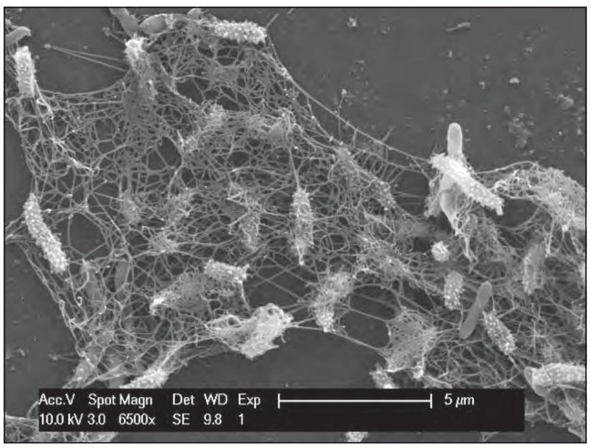


Figure 254 Staph areus and a biofilm

2.5

Producing toxins

It is often noticed that microbes may employ more than one specific adaptation to assist in their survival. In the above example of the bacterium *H. pylori*, they secrete adhesion molecules and also produce **toxins** that destroy the cells lining the stomach, thereby causing an ulcer.

Another bacterium, ***Bordetella pertussis,*** which causes whooping cough also produces toxins which destroy cells lining the respiratory tract which reduces the infected person's chance of clearing the infection.

Binding to molecules on the surface of host cells

Nearly all intracellular pathogens need to bind to **receptor molecules** on the surface of the host cells. This concept has already been described with the production of adhesion molecules produced by bacteria.

Virus particles possess surface molecules that can bind in a complementary manner with surface receptor molecules and this enables them, in many instances, to be taken into the cell by the process of endocytosis. Viral infection, including uptake and replication is examined later in this Chapter.

This binding of pathogens to receptor molecules on cells and cells engulfing foreign microbes illustrates the basic concept of molecular recognition through complementary binding of molecules. Refer to *figure 255* which illustrates a virus particle binding in a complementary manner to a cell. The yellow spikes on the virus represent proteins and these bind to the red receptors on the cell membrane.

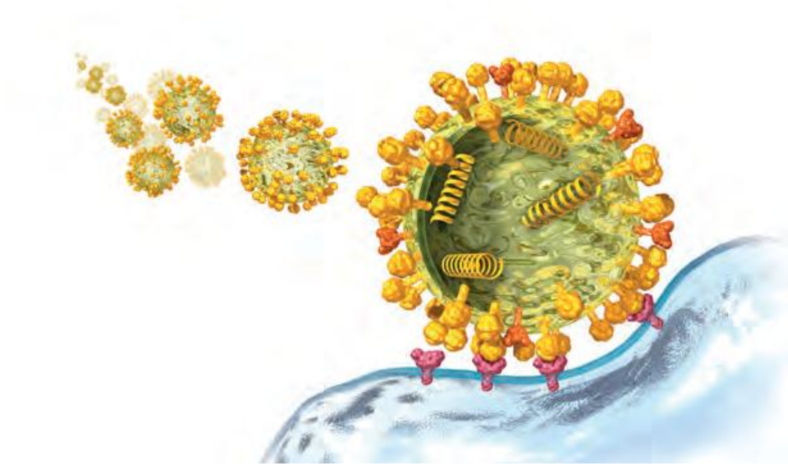


Figure 255 A virus binding to cell receptors

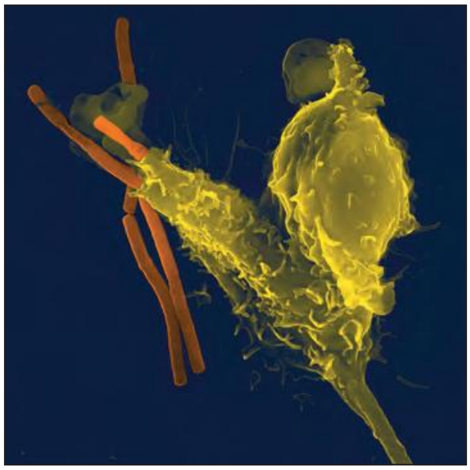


Figure 256 An example of endocytosis

Ability to survive inside white blood cells

Tuberculosis is caused by the bacterium ***Mycobacterium tuberculosis.*** It is taken into the lungs and from here white blood cells engulf the bacteria. The body's immune system contains the infection within a lesion (tubercule) and it is known that the pathogen can survive inside the white cells inside the lesion for decades.

The bacteria that causes Legionnaires disease has a similar adaptation. *Figure 256* shows a white blood cell engulfing a bacterium by endocytosis.

Altering the behaviour of the host organism

Pathogens may alter the behaviour of their host which may assist in the spread of the microbe to other hosts. Two examples of this type of action are:

- Inducing diarrhoea; whilst this may flush some bacteria from the intestine assisting the host, it also enables infections to spread via contaminated water. (e.g. cholera)
- Coughing and sneezing with colds or influenza will expel virus particles in tiny droplets which may then be inhaled by others to cause the spread of the disease.

It has been estimated that in one sneeze there may be up to 20,000 droplets and if the person is infected with rhinovirus this may be thousands of viral particles.

Changing antigens on the surface of the microbe

Antigens on the surface of pathogens are the molecules that are recognised by the host organism and represent a critical phase in the recognition and destruction of the invading organism. One powerful adaptation of many bacteria and viruses is that their outer antigen configuration may change, to help evade the human's immune system. This concept will be discussed further in coming chapters.

Drug resistance

Chapter 2.3 examined the ability of bacteria to develop resistance to antibiotics, with this looming as one of the most significant threats to human health in the coming decades. Superbugs is a term coined to describe the new strains of bacteria that are resistant to virtually all known antibiotics.

Avoiding white blood cells (phagocytes)

Figure 256 illustrated a white blood cell, called a **phagocyte**, engulfing a bacterium with the aim of destroying it. Most bacteria that are successful as pathogens have evolved ways to avoid being engulfed by these white blood cells.

Viral replication

Viruses are not cellular, they do not display many properties of other microbes but they can enter a host cell and use the host's DNA and **ribosomes** to make new viral particles that can leave the cell and infect other cells in either the same or other hosts. As such, viruses lack the necessary organelles such as ribosomes to make protein molecules. Viruses are specific in the cells they infect, this is determined by the **complementary binding** between their surface antigens and host receptor molecules. Refer again to *figure 255*.

Refer to *Figure 257* representing the life-cycle of the Ebola virus as it reproduces inside human cells. The basic steps illustrated are as follows:

- the virus binds to cell membrane receptors (upper centre)
- yellow DNA from the virus is released into the human cell (left side) and the cell then directs the production of new viral DNA and proteins
- membrane proteins (purple) coat new Ebola virus particles as they emerge from the cell (lower centre)

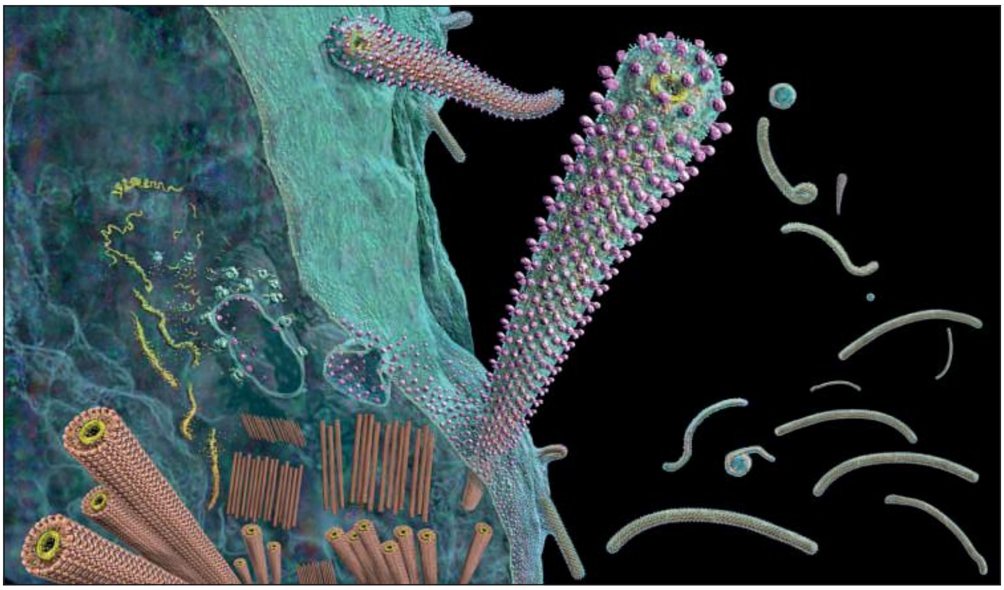


Figure 257 The life cycle of the Ebola virus

Helpful Online RESOURCES to see an EVA about viral replication

To view an Essentials Video Animation (EVA) on this topic, use this QR code to visit:

<http://essentialseducation.com.au/resources/sace-1/biology/viral-replication/>

2.5

The use of the drug *AZT* to treat AIDS

The drug AZT has been used since about 1987 in the treatment of HIV infection.

Do some research and write concise answers to the following questions.

1. Explain how the drug works to reduce the symptoms of the disease.
2. State reasons why the drug is not 100% successful in eliminating the virus.
3. Describe and state reasons for a complication or side effect of using the drug.
4. Explain one way in which HIV can change to develop resistance to the drug.

Use your own paper or a screen as directed by your teacher.

Helpful Online RESOURCE about *AZT*

Use this QR code to jump to the website below which will provide a valuable start in your research for this Assignment:

<http://www.britannica.com/science/AZT>

Plant pathogens

Organisms that can bring about plant disease are again many and varied and include pathogens such as fungi, bacteria, viruses and **viroids** and **nematodes**.

Fungi

Fungal pathogens can infect plant tissue and obtain nutrients from the plants cells. *Figure 258 (a)* shows 'Tomato Blight' a fungal infection of tomato leaves.

Phytophthora root rot is caused by the soil fungus *Phytophthora cinnamomi.* This disease can affect native plants and is a major threat to some rare and endangered species. The fungus often grows through the root system and in the process destroys the plant's ability to absorb water and mineral nutrients. The fungus produces spores which can survive for long periods of time in the soil.

The disease has spread over most of Australia and has been very difficult to diagnose and treat.

Methods of reducing the impact of *Phytophthora* include:

- quarantine-fencing off infected populations and reducing public access
- hygiene practices-e.g. sanitising tools and boots (see *Figure 259* overpage)
- spraying infected plants

Figure 258 (b) illustrates dieback caused by *Phytophthora*.

Figure 258 (a) Tomato blight

Figure 258 (b) Phytophthera dieback

Figure 259 (a) and (b) A boot cleaning station in a National Park in Queensland

Figure 2510 Bacterial infection

Figure 2511 A nematode

Bacteria

There are about 100 known species of disease-causing bacteria that infect plants. They bring about their pathogenicity by producing toxins or other proteins that cause disease.

Pseudomonas syringae causes tomato plants to yield less crop and has several adaptations to facilitate its spread including the production of chemicals that help evade the tomato plants immune system. *Figure 2510* shows an example of this bacterial infection.

Viruses and viroids

Viroids are smaller than virus particles and contain RNA. An example of one of the first of these to be discovered was the potato spindle tuba viroid. Often plant viruses and viroids can be transmitted by a vector.

Nematodes

Nematodes are small, wormlike creatures that have the capacity to cause significant damage to root cells in plants. There are a number which infect food crops e.g. potatoes, cucumbers and strawberries. *Figure 2511* illustrates a soil nematode.

Key Concepts

1. For pathogens to cause disease they need to:
   - colonise the host
   - avoid the immune system
   - reproduce
   - spread to other hosts
2. Different pathogens or members of related species have different levels of virulence.
3. Entry into human hosts is usually through:
   - wounds
   - respiratory surfaces
   - reproductive organs
   - digestive system
4. Pathogens have evolved a vast range of adaptations that enable them to survive and spread including hiding inside cells.
5. Viruses use the host cells nucleic acids and organelles to produce new viral particles.
6. Plants are also highly susceptible to pathogens which cause major problems to the agricultural industry.

2.5

A Case Study: The profile of a molecular biologist

Dr. Donald Gardiner

Research

My work aims to understand how a group of the most devastating fungal pathogens of wheat invades their host plant. The pathogens are called *Fusarium graminearum* and its close relative, *Fusarium pseudograminearum.* During infection they produce a toxin, called deoxynivalenol, which both assists with invasion of the plant and also contaminates any grain that is harvested from the crop. This toxin is highly harmful to humans and animals that may eat the grain. By understanding the mechanisms a pathogen uses to cause disease, we hope to be able to implement better control strategies that will assist the farmer to protect their crops and deliver safer food to consumers.

In modern molecular biology, having a genome sequence for your organism of interest is highly advantageous. With new DNA sequencing technology, obtaining genomes for fungi is relatively straight forward. However, the way the genome sequence is obtained means it remains in literally millions of pieces that need to be put back together and this can be a challenging task. With advanced software and high performance computing, we can now put most of these pieces back together. For our *Fusarium* species, when this is done we typically end up with genomes in about 500 pieces.

Each of these pieces will contain hundreds of different genes. By predicting the genes that are encoded by the genomes we can begin to understand how the pathogen has evolved and the mechanisms that it uses to invade its host. This is done by comparing all of the genes encoded by a pathogens genome with those of both closely and distantly related organisms. The general term for approaches like this is “comparative genomics”.

One of the most fundamental components of comparative genomics is the ability to compare the sequence of the genes or proteins encoded by an organism’s genome. One tool that is extensively used is BLAST; (basic local alignment search tool). I have previously used BLAST to compare the entire gene set of many different genomes of fungi all at once. These comparisons can be used to identify highly conserved genes, that might be important for basic cellular functions such as energy generation or DNA replication, and genes that are less well conserved or only present in a few species. It is this latter group that might contain genes involved in virulence on a particular plant host. Using this approach we recently discovered genes in the genome of *Fusarium pseudograminearum* that had been horizontally transferred between distantly related fungi that all shared a common plant host *(Gardiner, McDonald et al. 2012)*. In some example genes were also shown to be transferred between bacteria and fungi.

To test the hypothesis that these genes (shared exclusively between pathogens with a common host) are involved in virulence, mutant strains of the fungus are created and compared to the wild type strain in plant infection assays. This is done by replacement of the gene with an antibiotic resistance gene using homologous recombination. This creates a mutant organism that, apart from the deleted gene and antibiotic resistance is identical to the original pathogen. These strains are then compared for their ability to infect the host plant in a controlled environment room. Through this process we can begin to understand how these fungi cause disease on wheat.

Education and career

I studied a Bachelor of Biotechnology (honours) at the Flinders University of South Australia and completed a PhD in molecular plant pathology at Melbourne University where I researched the interaction between canola and a fungal pathogen. After a brief post doctoral fellow at the University of Queensland, undertaking research in mammalian genomics, I joined the Australian Commonwealth Scientific and Industrial Research Organisation (CSIRO) in 2005, where I have been researching *Fusarium* incited diseases of a number of crop plants ever since.

Gardiner, D. M., M. C. McDonald, et al. (2012). “Comparative pathogenomics reveals horizontally acquired novel virulence genes in fungi infecting cereal hosts.” PLoS Pathog 8(9): e1002952.

What have you learned?

Key Terms

immune system

adaptations

complementary binding

receptor molecules

pili

toxin

intracellular

phagocyte

rhinovirus

antigen

ribosomes

pathogenicity

virulence

viroids

nematodes

Knowledge and Understanding

1. Name three ways that pathogens enter the human body and give an example of a pathogen for each.

2. State the difference between pathogenicity and virulence.

3. Pathogens have a range of adaptations to assist them in entering, reproducing and exiting hosts. Complete the following table regarding the type of adaptation, how it provides an advantage and an example of a pathogen that possesses such an adaptation.

Adaptation	**Description of how the adaptation works**	**Example**
Using a vector		
	Attachment to host cells to avoid being flushed out of host	
		Helicobacter pylori
Production of toxins		
Hiding inside host cells		

4. Describe one way how fungal spores provide a reproductive and/or survival advantage to those species that produce them.

Application, Analysis and Evaluation

5. Compare two pathogens; one with high virulence and one with low virulence. Explain the features that contribute to the virulence.

6. High virulence can be seen as a disadvantage to the pathogen. Explain the reasons for this.

7. Compare and contrast two methods for controlling the spread of the plant fungus *Phytophthera*.

8. Causing diarrhoea can be seen as an advantage for both the host and pathogen. Argue how this is possible.

9. Discuss how a pathogen gains an advantage by hiding inside a host cell.

Chapter 2.6 Physical barriers to disease

Science Understanding

The human immune system protects the body against disease by:

- physical barriers
- innate (non-specific) immune response
- the adaptive (acquired) immune response.

The different responses work together to neutralise or prevent the entry of pathogens:

- Describe the function of the various physical barriers that exist to prevent the entry of pathogens.
- Define the term 'antigen'.
- Compare foreign antigens (non-self) with 'self' antigens.

The immune system

The **immune system** is the body's defence system used to protect the organism against pathogens. Lines of defence will be considered in three categories in the following three chapters to assist with the study and understanding of the barriers, structures, cells and processes involved in reducing our chances of contracting disease.

First line of defence

This refers to the physical barriers and traps that resist and prevent entry of pathogens and will be considered in this Chapter.

Second line of defence

This refers to the non-specific actions and responses which will be considered in Chapter 2.7.

Third line of defence

This refers to the adaptive immune response which will be considered in Chapter 2.8.

Physical barriers

In Chapter 2.5 the main entry points for pathogens were discussed; these were:

- respiratory surfaces
- wounds
- digestive system
- reproductive organs

It was seen that each of these entry points provides opportunities for well adapted pathogens to enter the host and potentially cause disease.

It is clear that the best line of defence against invading organisms is to prevent them entering the body in the first place. As such, the human organism has a range of barriers, traps and chemicals designed to do just that.

Skin

Refer to *Figure 261* (overpage) of the human skin showing the composition and structural features which provide an excellent barrier to pathogen entry. The skin is made up of tissues and is the largest organ of the body. The upper layer of the **epidermis** (*stratum corneum*), consists of dead cells which contain the protein **keratin** providing a hard, protective outer layer.

Lipid molecules are water repellent and the skin secretes lipids from glands which provide a waterproofing layer to again prevent access by microbes through moist layers.

The skin also secretes **antimicrobial substances** such as dermacidin which can kill microbes. If a wound or breach to the skin's barrier occurs, cell fragments called **platelets** initiate a clotting process to form a scab and seal the point of entry for pathogens.

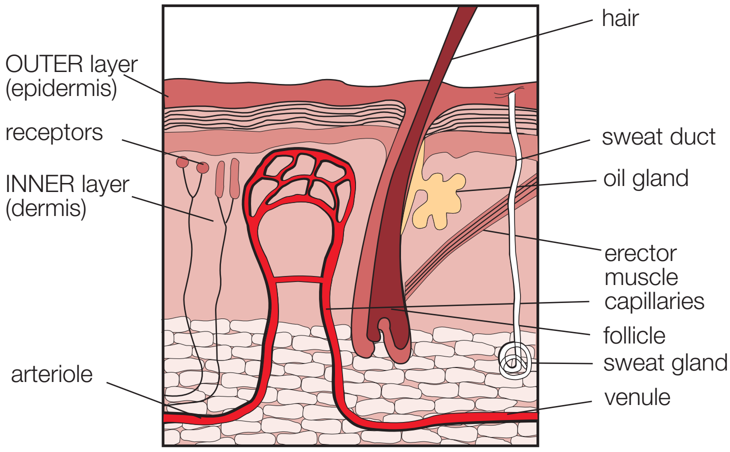


Figure 261 the structure of skin

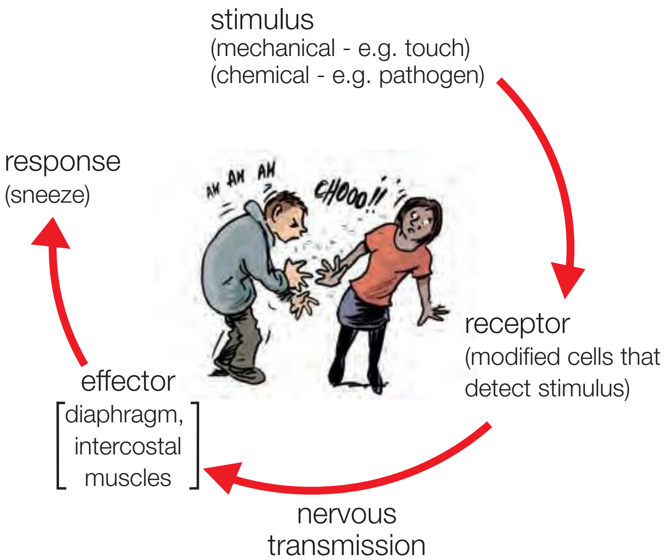


Figure 262 The coughing/sneezing reflexes

Coughing/sneezing reflexes

Coughing and sneezing are reflex responses brought about by either mechanical or chemical stimuli which can trigger this action. The term implies that this is a simple involuntary action. Refer to *Figure 262*.

Previous chapters have established that in a cough or sneeze there may be thousands of droplets and that inside these droplets there may be viral particles from an infected person. So whilst this is a method of transmission for the microbe, it also helps the host expel the pathogen.

Mechanical protection

Blinking is a reflex action initiated in response to irritation by particles, including pathogens. Tears, particles and pathogens are mixed so that they can be eliminated from the eye. The **cornea** provides a physical barrier and is made up of several layers of cells that effectively make it very difficult for pathogens to enter.

Tears, produced by the lacrimal gland above the eye, also provide mechanical protection in their action of flushing particles from the surface of the eye.

Chemical protection

? The cells in the eye secrete a range of chemicals that possess antimicrobial properties, including enzymes and special peptide molecules. **Lysozyme** is one chemical enzyme that has the ability to destroy cell walls in bacteria and thus killing them. Refer to *Figure 263* of the human eye.

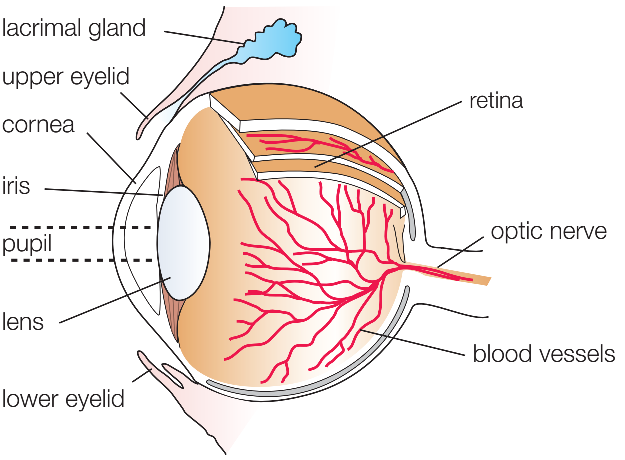


Figure 263 The human eye

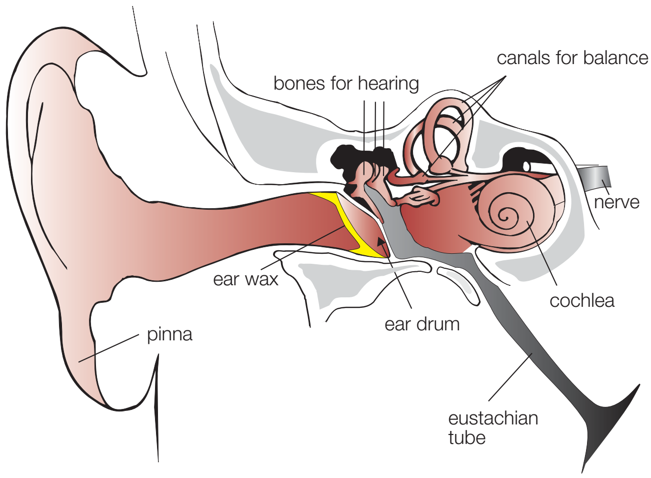


Figure 264 The human ear

Earwax

Like all possible entry points for pathogens, the human ear is extremely well protected. The ear secretes a range of chemicals which appear as a wax but in fact is a mixture of a range of chemicals that are antimicrobial and provide excellent protection. Refer to *Figure 264*.

Mucus

Mucus is a slippery secretion found on the surface of several body organs and systems:

- Respiratory system: nasal passages, **bronchi** and bronchioles
- Digestive system: **oesophagus**, stomach and intestines
- Uro-genital system: **urethra**, vagina

This **mucous** layer is produced by special epithelial (goblet) cells lining the organs of these systems.

On the surface of these epithelial cells are small hair-like structures called **cilia** that have a rhythmic motion which directs mucus and foreign matter in the respiratory organs towards the pharynx and mouth to be either swallowed or expelled from the body.

Refer to *Figure 265* (a) which illustrates a typical mucous membrane. The epithelial cells with cilia can be seen and the mucus is shown by a blue layer secreted by the cells. Refer to *Figure 265* (b) showing a magnified view of cilia (green/pink) and the epithelial cells (brown). (*Note that 'mucus' is a noun and '**mucous**' is an adjective.)*

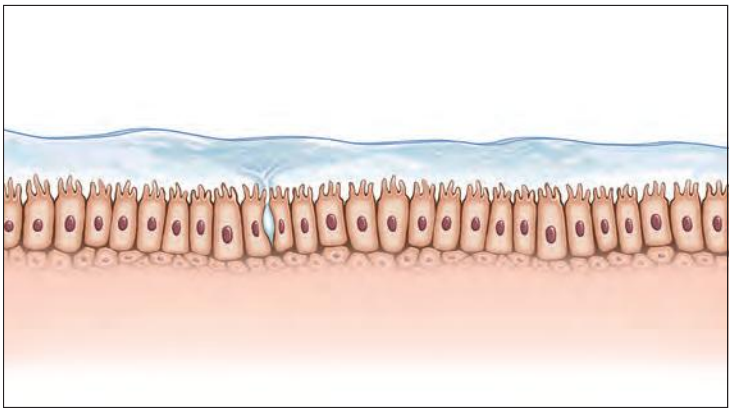


Figure 265(a) A typical mucous membrane

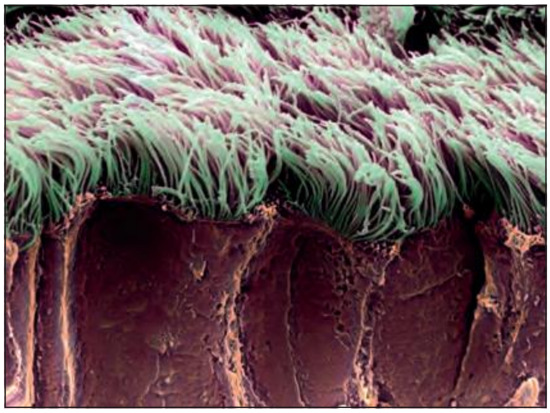


Figure 265(b) Magnified view of bronchial cilia

Stomach acid

The cells lining the stomach secrete acid giving the stomach environment a very low pH (high acidity). This is an extremely hostile environment (by human standards!) and many pathogens perish here. In the human body exist microorganisms that live both on and inside our bodies. As a general rule these do not cause disease, in fact they form very close relationships with the body and are vital to human health and well-being. This **microflora** actually flourishes and out competes and destroys many invading pathogens.

2.6

Figure 266 summarises the non-specific barriers of the human body which help stop pathogens either entering the body or if they do, stopping them entering the bloodstream and tissues.

Self and non-self recognition

This Chapter has focused on the barriers the human body possesses to keep pathogens out. Unfortunately these barriers do not work perfectly all the time and it is then that humans employ the second and third lines of defence protection.

The entry of pathogens initiates changes in the host organism. The cells of the immune system recognise particular molecules that are associated with pathogens. These types of molecules are quite unique to microbes and not found in humans. Such foreign molecules are referred to as '**non-self**' and the body's own molecules and surface receptors are referred to as '**self**'.

Such 'non-self' molecules or pathogens are termed **antigens**; foreign molecules that bring about **antibody** production. Antibodies are proteins produced by specific white blood cells that can bind to and neutralise antigens. These antigens which are usually protein molecules or **polysaccharides** are recognised by the special white blood cells and this initiates a response. This and other responses to pathogens will be considered in more detail in chapters 2.7 and 2.8.

Humans recognise their own tissue and marker proteins as 'self' and do not react to these. Failure to recognise 'self' can lead to a number of serious 'auto-immune' diseases e.g. rheumatoid arthritis, Type 1 diabetes and multiple sclerosis (MS).

Helpful Online RESOURCE about auto-immune diseases

Use this QR code to jump to this website which will provide more information and a list of autoimmune diseases:

<http://www.aarda.org/autoimmune-information/list-of-diseases/>

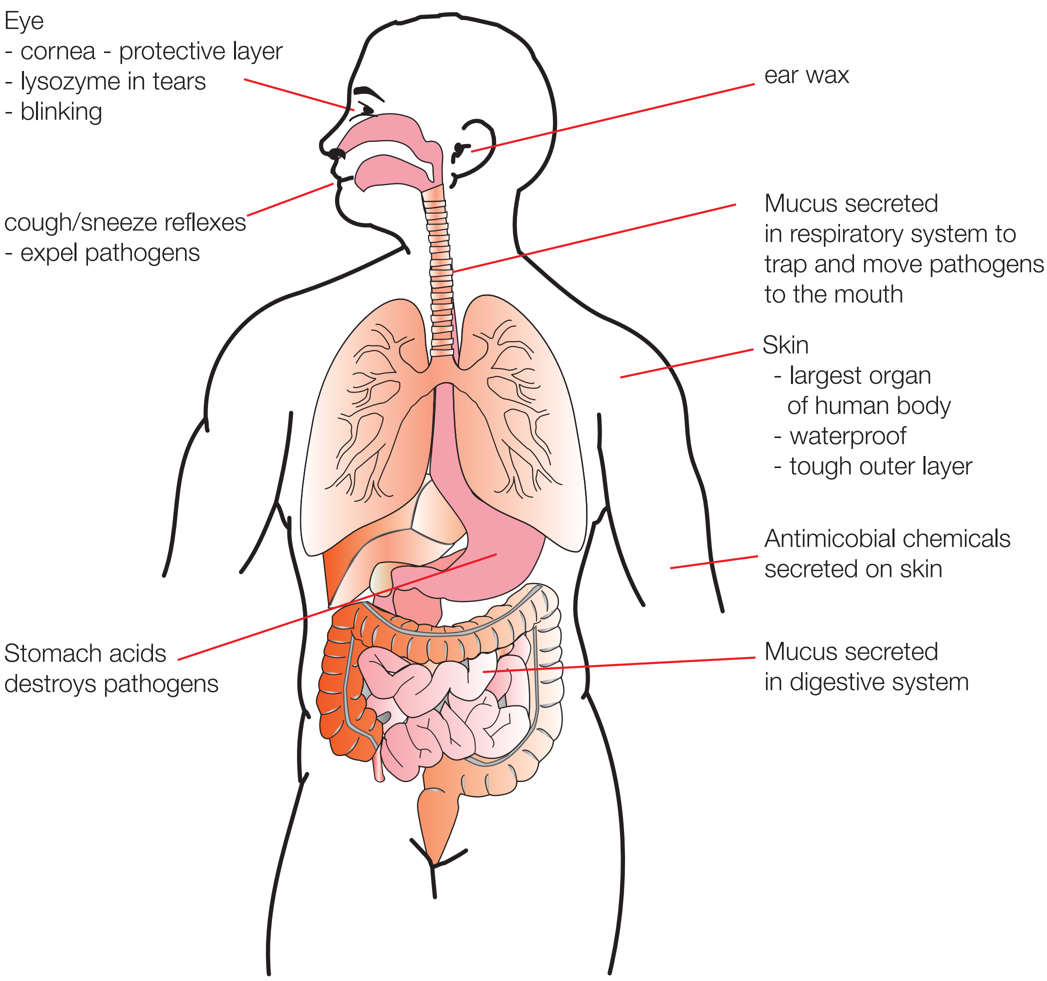


Figure 266 A summary of physical barriers for pathogens

Key Concepts

1. The immune system is the body's defence system used to protect against pathogens.
2. There are three lines of defence, the first consists mainly of barriers and traps that act to restrict pathogen entry either into the body or bloodstream and tissues.
3. The main barriers, traps and actions that humans possess to keep pathogens out include:
   - skin
   - coughing and sneezing
   - cornea and tear ducts in the eye
   - earwax
   - mucus production
   - stomach acid
4. The immune system can recognise 'self' from 'non-self'.
5. Antigens are 'non-self' molecules which stimulate the production of antibodies.

What have you learned?

Key Terms

immune system

epidermis

keratin

lipid

antimicrobial substance

platelet

cornea

lysozyme

mucus

mucous

self

non-self

bronchi

oesophagus

urethra

cilia

microflora

antigen

antibody

polysaccharide

Knowledge and Understanding

1. Name the four key entry points for microbes into the human body.

2. Complete the following table of some typical physical barriers to microbe entry into humans.

Feature	Mode of action in providing protection
Earwax	
	Forming a scab on the surface of the skin to seal a wound
Blinking	
Tears	
	Rhythmic action of hair-like structures to move mucus to the mouth

3. List three ways in which the skin is ideally suited to providing a barrier to pathogens.

4. Describe the coughing/sneezing action and explain why it is a reflex action.

5. In the case of a viral infection causing a cough/sneeze state:
   a) the stimulus
   b) the effector
   c) the response

6. Name two tissues or organs that secrete lysozyme and state why it is important in the body's defences.

7. Mucus is important in our defence against disease.
   a) Describe the action of mucus in preventing the entry of microbes into the blood.

   b) Name two areas inside the human body where mucus is useful in removing microbes.

Application, Analysis and Evaluation

8. Outline the likely reasons for an increase in mucus production when a person person has a 'cold'.

9. Burns victims are highly susceptible to infection. Suggest the most likely reason for this.

10. Suggest two likely reasons why healthcare professionals caution people about attempting to remove earwax from the ear canal.

11. Discuss differences between pathogenic microbes and what is termed our normal, healthy 'microflora'. In particular explain why one group of microbes causes disease but not the other.

12. Describe the difference between 'self' and 'non-self' tissue, pointing out how some cells in the human immune system can discern the difference.

Science Inquiry Skills 2.6 - Antimicrobial substances

Introduction

Human barriers such as the skin, earwax, chemicals in tears etc. have been discussed as methods of preventing microbe entry into humans.

To assist these natural barriers, scientists have developed a range of chemicals that have anti-microbial properties including antiseptics which have been discussed in Chapter 2.4 and hand sanitisers.

Purpose

To compare the effectiveness of a range of antimicrobial substances, some natural (e.g. tears) and others produced by humans

Materials

filter paper, forceps, liquid cultures of bacteria, sterile cotton buds, inoculating loops, 1 or 2 cleaning agents, 1 or 2 antiseptics, 1 or 2 antibiotics, onions (to cause tears!), 1 or 2 different hand sanitisers, Bunsen burners, Petri dishes with nutrient agar

BIOHAZARD

Method

At the direction of your teacher you can follow the technique described in Science Inquiry Skills 2.3 and adapt it for your purposes. Ensure that all aseptic procedures and health and safety guidelines are followed carefully.

Results

Record your data in whatever way you think appropriate, digital photographs may be helpful.

Analysis, Evaluation and Conclusion

What inferences can you make from your data about the relative effectiveness of natural and artificial antimicrobial agents?

Follow the guidelines given in the Appendix of this Workbook for your report and use extra paper or a screen as directed by your teacher.

Use this space below for any notes to help with your planning.

Helpful Online RESOURCE about aseptic techniques

To learn more about 'aseptic' techniques scan this QR code to go to:

<https://en.wikipedia.org/wiki/Asepsis#Aseptic_technique>

Chapter 2.7 The innate immune system

Science Understanding

When a pathogen enters a host, it causes physical or chemical changes which stimulate immune responses in the host.

The different responses of the innate system work together with a first line of defence to neutralise or prevent entry of pathogens.

Many organisms have an innate (non-specific) immune system to the presence of pathogens:

- Recognise that the innate (non-specific) immune system is the second line defence with responses that are non-specific
- Recognise that most organisms, including bacteria, fungi, plants, invertebrates and vertebrates display innate immune responses as a first line of defence against pathogens (e.g. histamine, complement, antibiotics etc.)

The **innate** immune system is what is often called the second line of defence that is triggered after the first line, which was discussed in Chapter 2.6. This innate system is found in all animals and also in **invertebrates**, plants and fungi. The word 'innate' literally means 'inborn or natural'.

In general, the innate immune system is characterised by:

- being non-specific
- being a rapid, non-learned response
- responding in a very similar manner each time there is an infection

The innate response involves:

- phagocytes and phagocytosis (a type of endocytosis)
- non-self recognition of particular molecular patterns found in pathogens
- cells such as white blood cells and killer cells
- chemicals e.g. **complement**, **histamine**
- the **inflammatory response**

Phagocytosis

One of the most important responses in the second line of defence is the action of certain white blood cells called **phagocytes** which are able to carry out the process of endocytosis (or phagocytosis).

Refer to *Figure 271(a)* which illustrates the process of **endocytosis**. Refer also to *Figure 271(b)* of a type of white blood cell called a macrophage digesting *E. coli* bacteria by endocytosis, the debris is removed by exocytosis. Note the red extensions from the cell that assist in finding and trapping the bacteria (blue).

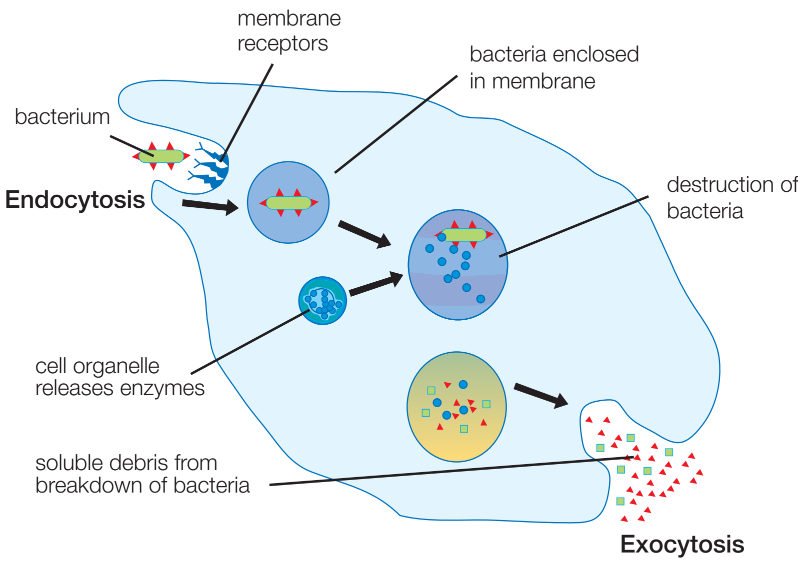


Figure 271(a) The process of endocytosis

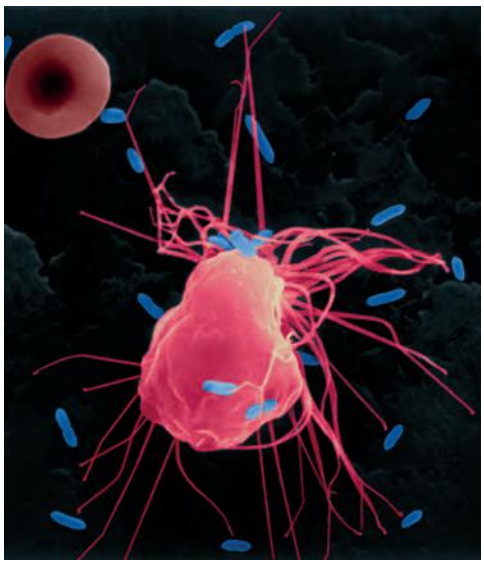


Figure 271(b) A macrophage and bacteria

2.7

In this process of phagocytosis the cells recognise and bind to surface molecules on bacteria (or antigens) and then engulf the pathogen taking it inside the cell for destruction. This process is carried out mainly by two types of white blood cell: **neutrophils** and **macrophages**.

These two types of cells actually work together with other immune responses including responding to chemical signals released when tissues become damaged or infected. These cells are found in many areas of the human body, organs, tissues; particularly tissues of what is termed the **lymphatic system** which is closely linked to the immune system.

Natural killer cells

Another type of cell which provides protection against cells infected with virus particles or changed by cancer are called **natural killer (NK) cells**. They carry out their actions by:

- recognising protein markers as 'non-self' on cells that need to be destroyed
- releasing **cytokines** which are cell-signalling molecules that guide other responses
- attacking in numbers and punching holes through the cells they need to destroy

Refer to *figure 272* which is a coloured scanning electron micrograph of a natural killer cell (orange) recognising and destroying a cancer cell (red).

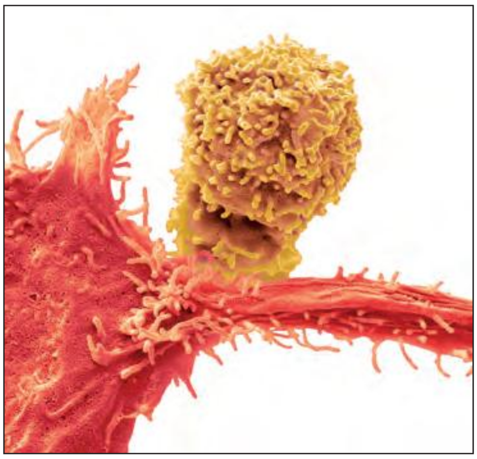


Figure 272 A natural killer cell destroying a cancer cell

Chemicals of the innate immune system

Complement

The complement system is a group of around 30 proteins that are secreted by a range of cells in the body. These molecules are inactive until they bind to receptors on the surface of pathogens. They bring about what is termed a cascade effect (a chain of events); stimulating a whole range of chemicals and their effects.

Three specific activities of the complement system are summarised in *Figure 273*.

1. Binding to and puncturing holes in cell membranes.
2. Binding to surface molecules on pathogens and increasing the chances of the pathogen being taken up and destroyed by phagocytes.
3. Binding to what are called **mast cells** stimulating them to release a chemical called histamine. This will be discussed in more detail in the inflammatory response.

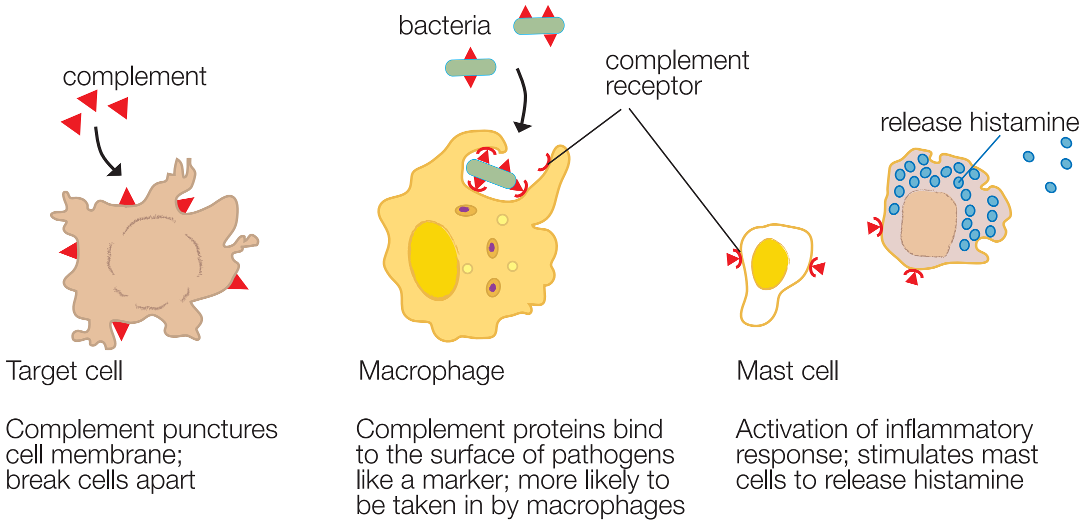


Figure 273 The main activities of the complement system

Interferons

Interferons are chemicals that can be secreted by cells which are infected by viruses. Interferons can exert their effects in a number of different ways which are aimed at limiting the spread and multiplication of the virus. Interferons have been mass produced by pharmaceutical companies using DNA technologies.

The inflammatory response

The inflammatory response is a major component of the innate immune system. This response is characterised by the swelling, redness, pain and heat that accompanies a wound from physical injury and entry of pathogens at the wound site.

Often the cells previously discussed (i.e. the macrophages and neutrophils) bind to an antigen on pathogens at the site of the wound and the cells then respond by secreting cell-signalling molecules such as cytokines. The cytokines can bring about a vast range of effects to help mobilise the innate system.

Physical injury can stimulate mast cells to release a chemical called histamine. Histamine causes small blood vessels called arterioles to dilate or widen at the site of infection. This widening brings extra blood supply to the region; carrying more white blood cells to engulf the microbes. Histamine also increases the permeability of the blood vessels, facilitating easier access of chemicals and white cells from the blood to the wound site. This helps to explain the swelling, redness and increased temperature associated with the inflammatory response. Blood clotting factors are released and seal the wound leading to the formation of a scab.

Pus formation in and around wounds and infection is the result of the action of white cells called neutrophils carrying out phagocytosis of microbes and then dying within a short space of time. **Pus** therefore consists of dead pathogens, dead white cells and other cellular debris.

Refer to *Figure 274* for a summary of the inflammatory response.

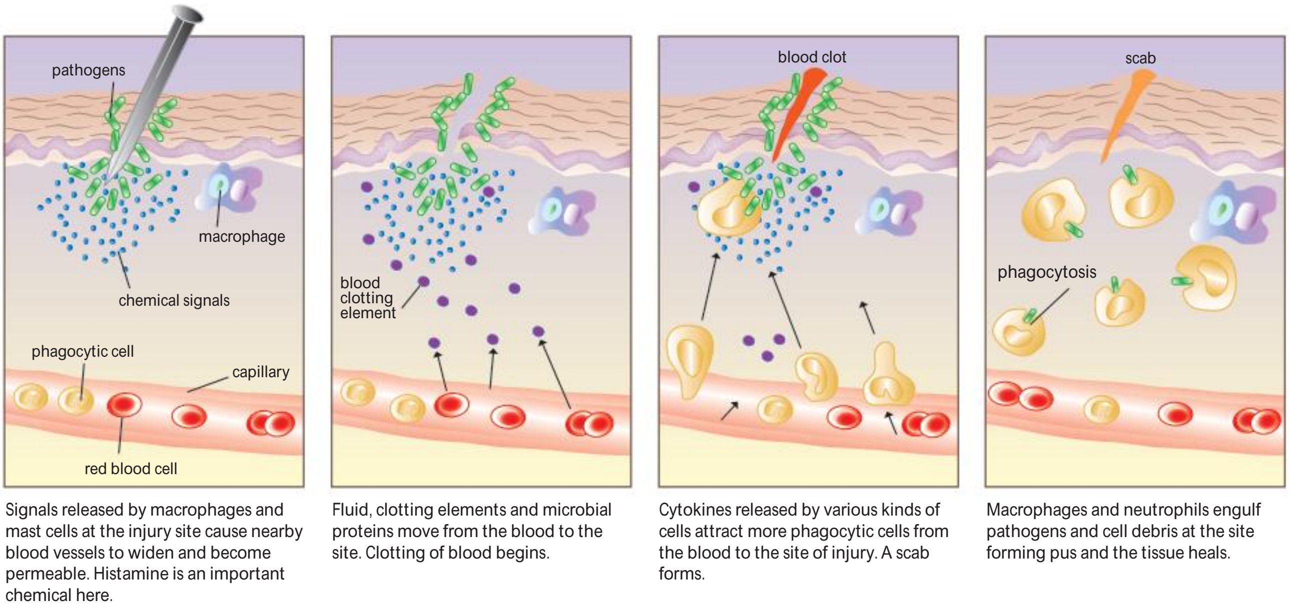


Figure 274 A summary of the inflammatory response

Innate immune responses in other organisms

Invertebrates

Invertebrates are those organisms that lack a backbone and typical examples are the huge variety of insects, slugs and spiders. To survive, these organisms have all needed to develop immune systems to protect them from infectious agents including bacteria and fungi.

The invertebrates process both a first and second line of innate defence that functions in much the same manner as vertebrates. For example insects are characterised by an external **exoskeleton** which provides a very effective external barrier to microbes. Refer to *Figure 275*.

Figure 275 Insects also have an innate immune system

Internally they have other similarities to vertebrates including:

- immune cells called **hemocytes** that can carry out phagocytosis
- cells that release antimicrobial chemicals to kill bacteria and fungi
- recognition (of self and non-self) systems that work when cells bind to molecules on the pathogens

Plants

Chapter 2.5 presented some of the large number of plant pathogens including species of fungi, bacteria, viruses and viroids. Like other species, plants have evolved their own defence system starting with a first line including barriers and protective layers. The main physical barriers are:

- waxy cuticles on the surface of leaves providing a waterproof layer that makes entry for many bacteria and fungi difficult
- bark which is an effective layer on many tree trunks
- hair like structures on leaves that provide protection against insects and bacteria.

Figure 276 (a) shows cuticles on leaves and *Figure 276 (b)* shows the bark on a tree.

Figure 276 (a) Waxy cuticle on leaves

Figure 276 (b) Bark on trees

If pathogens cross the first line of plant defence, plants have developed a second line of defence in the form of chemicals. Humans use many of these chemicals for their own benefit including uses as spices, condiments and naturopathic treatments. Some of these chemicals are termed **phenols** and **alkaloids**. Caffeine, tannins and cocoa are common substances used as antimicrobial and antifungal agents produced by plants that are very familiar to us.

The innate system in plants possesses some similarities with vertebrate and invertebrate systems. There are plant cells that bind to, recognise and respond to the presence of pathogens. The cells produce a number of chemicals that again can destroy pathogens. A number of effective insecticides are derived from plants e.g. pyrethrin is a chemical derived from members of the chrysanthemum (originally called pyrethrum) family.

Fungi and antibiotics

An example of innate immunity found in fungi is the production of the antibiotic penicillin by a fungus; penicillin is produced to provide protection for the fungus against bacterial attack. This property is precisely why penicillin has been commercially produced and so widely used to control infection in medical and veterinary sciences.

C ICT: Wireless wounds

Wounds that have not healed after three months are considered chronic wounds. Examples of chronic wounds include those caused by burns.

Patients with a chronic wound are extremely vulnerable to infection by bacteria. To reduce the risk of this, they must have the wound monitored on a regular basis. Typically, this involves having it physically inspected by medical staff. This usually means a patient can expect prolonged hospitalisation, or be required to make repeated return trips to hospital.

In addition to the inconvenience of having to make hospital visits, rising health care costs are promoting a demand for ICT-enabled remote health care. Chronic wound patients could return home earlier with their wound in a bandage complete with sensors to monitor how the wound heals.

One of these 'smart bandages' is in development at KAUST, a research University in Saudi Arabia. It has sensors to detect unexpected or irregular bleeding and changes in pH in the wound (a slight pH increase, making the site more alkaline, indicates a bacterial infection). Data collected is sent wirelessly to the patient's mobile device informing them to change the bandage, or is relayed to medical staff located remotely who determine what is to be done.

Researchers at Tufts University in Massachusetts in the United States have tdeveloped a high-tech bandage that not only spots an infection developing in a chronic wound, but also takes steps to treat it. The bandage has a pH sensor to detect bacterial infection and a temperature sensor to see if the wound is getting inflamed (which signals activation of the immune system's inflammatory response, hence infection). However, it also contains tiny drug capsules that, when the sensors find signs of infection, can trigger the release of antibiotics (drugs that kill bacteria) to treat the emerging infection.

You may need to refer to the online resources below to answer the questions that follow.

1. Explain how the use of ITC can reduce the risk of bacterial infection in wounds.

2. In particular, explain what sort of data is being analysed.

Helpful Online RESOURCE about the KAUST smart bandage

To learn about a smart bandage that can monitor chronic wounds view the clip below:

<https://www.youtube.com/watch?v=zg8BujvXBYs>

Helpful Online RESOURCE about the Tufts University smart bandage

To learn about a smart bandage that can sense and treat infections view the clip below:

<https://www.youtube.com/watch?v=w-njj9a2BFM>

Key Concepts

1. If barriers and traps are considered a first line of defence to pathogens, the second line of defence includes such factors as:
   - the complement system (chemicals that act inside tissues)
   - cells including macrophages and neutrophils (phagocytosis) and natural killer (NK) cells
   - the inflammatory response
2. The innate immune system is non-specific, rapid, not learned and works in a similar way each time there is an infection.
3. The complement system is a group of around 30 chemicals that work with other innate responses to mobilise the cells defence systems of organisms.
4. The inflammatory response is a key component of the innate immune system; it is accompanied by redness and swelling.
5. Innate immune systems exist in most species including invertebrates, plants and fungi.

What have you learned?

Key Terms

innate

invertebrate

complement

histamine

phagocyte

endocytosis

exocytosis

neutrophil

macrophage

natural killer cells

lymphatic system

cytokines

mast cells

interferon

inflammatory response

pus

exoskeleton

hemocytes

phenols

alkaloids

Knowledge and Understanding

1. State why the innate immune system is:
   a) non-specific
   b) rapid
2. Three modes of action for most innate responses involve cells, chemicals and inflammation. Describe:
   a) two cellular responses
   b) two chemicals or classes of chemicals and their mode of action
   c) how the inflammatory response acts to destroy pathogens
3. Describe the role of molecules that signal cells of the immune system to alert them to the presence of pathogens inside the tissues. Give an example to illustrate your answer.
4. Explain how the binding of complement molecules to pathogens can increase their chance of destruction.
5. State the role of mast cells in the inflammatory response.
6. Pus often accumulates near a site of injury and indicates a response to infection.
   a) Describe what pus consists of
   b) Explain the role of pus in innate immunity

2.7

Application, Analysis and Evaluation

7. Compare physical barriers to disease in humans and a typical plant.

8. Assess and comment on the importance of non-self recognition in the defence of disease involving cell binding to surface receptors in the innate response of organisms.

9. Explain how barriers; both physical and chemical provide protection for plants against pathogens.

10. Explain why the production of penicillin by fungus can be described as an innate immune response.

11. Correlate observations linked to the inflammatory response i.e. redness, increased temperature and swelling with the responses of the innate immune system.

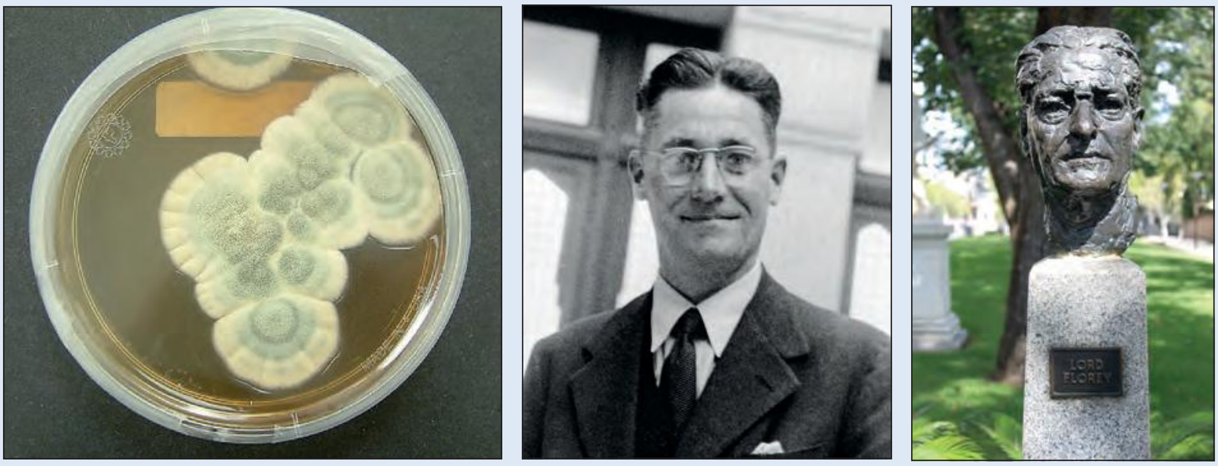
Science as a Human Endeavour 2.7 - The development of penicillin

Communication and collaboration

Collaboration is often required in scientific investigation...

Antibiotics were discussed briefly in Chapter 2.4. The first real discovery was made by ***Alexander Fleming*** in 1928 but at this time he was unable to either extract or produce quantities that made penicillin a medicinal drug of value in treating patients with infections.

A famous Australian; *Howard Florey* {see *Figure 277 (b)* and *(c)*} headed a team of highly specialised scientists at the University of Oxford in 1930. They all worked in their individual field of specialty towards a goal of producing, extracting and refining an antibiotic penicillin from a fungus called *Penicillium notatum {see Figure 277 (a)}.*



Figures 277 (a) Penicillium notatum (b) Howard Florey (c) Florey's statue on North Terrace in Adelaide

In May 1941, one of the most important medical experiments in history was conducted on mice which had been infected with pathogenic bacteria. Penicillin was clearly established as an antibiotic that could destroy pathogenic bacteria. In order to continue his research *Florey* moved to America to further develop the drug and assist in the mass production of it for wider use.

In 1943 penicillin was being mass produced and its contributions to patient survival towards the end of World War II were immense, saving tens of thousands, if not millions of lives.

In 1945 *Howard Florey*, along with his co-workers *Ernst Chain* and *Alexander Fleming,* was awarded the Nobel Prize for Physiology or Medicine.

You may need to refer to the helpful online resource to answer the question that follows:

1. Outline how the discovery of penicillin was a collaborative effort of so many people before it could be used medicinally.

Helpful Online RESOURCE about penicillin

Use this QR code to jump to this website which will provide a valuable start in your research for this Assignment:

<http://www.acs.org/content/acs/en/education/whatischemistry/landmarks/flemingpenicillin.html>

2.7

Chapter 2.8 The adaptive immune system

Science Understanding

- Describe how the adaptive (acquired) immune system responds specifically to antigens.
- Describe how the human body responds specifically to foreign antigens by the adaptive immune system.

Exposure to an antigen is required for acquired immunity. This may be acquired through passive or active processes.

Passive immunity may be acquired from maternal antibodies or antibody serum injection.

Active immunity may be acquired through natural exposure to a pathogen or through vaccination.

This chapter moves on to discuss the next line of defence; the third line of body defence.

This is termed the adaptive (or acquired) immune response and is characterised by the following:

- it involves specific **antigens** and specific pathogen recognition
- it operates therefore with specificity, it is highly selective and able to detect the differences between pathogens
- it retains memory of the pathogen in the event of subsequent infections
- the second exposure to the same antigen is enhanced or bigger than the first exposure

Organs of the immune system

The **lymphatic system** consists of a network of tiny vessels that are found very close to blood capillaries. This system is strongly linked to the defence system of humans; small nodes called the **lymph nodes** are found in specific locations throughout the system and contain many of the white blood cells of the innate and adaptive systems.

Lymph nodes often become swollen and sore when pathogens such as viruses and bacteria become trapped and the white cells become active in trying to destroy the infective particles or organisms.

Scientists classify the lymph organs as primary and secondary. The primary organs are those where the **lymphocytes** develop such as the **bone marrow** (B cells) and **thymus** gland (T cells) whereas the secondary organs such as the lymph nodes and an organ called the **spleen**, along with the tonsils, are where the white cells recognise pathogens and mount their response.

Refer to *Figure 281* which shows the main parts of the human lymphatic system.

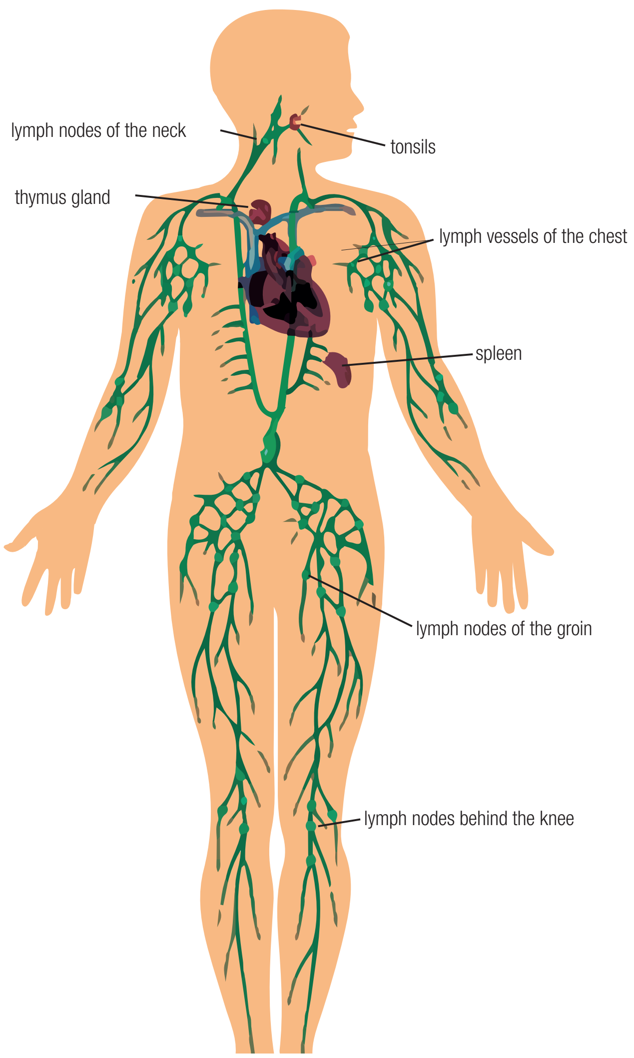


Figure 281 The human lymphatic system

Major Histo-compatability Complex

The Major Histo-compatibility Complex (**MHC**) is a set of protein markers found on the surface of cells. These proteins are coded for by a set of genes that are unique for all individuals.

Cells display two different groups of these marker proteins on their cell surface:

- 'Self' proteins that are unique for the individual
- Short sections of protein antigens from pathogens. The second group of proteins play a vital role in the adaptive immune response, these are referred to as 'non-self'.

Refer to *Figure 282* which shows a macrophage after engulfing a pathogen then displaying antigenic fragments from it on the MHC protein on the cell surface. This action enables recognition and binding by T lymphocytes (discussed later in this Chapter).

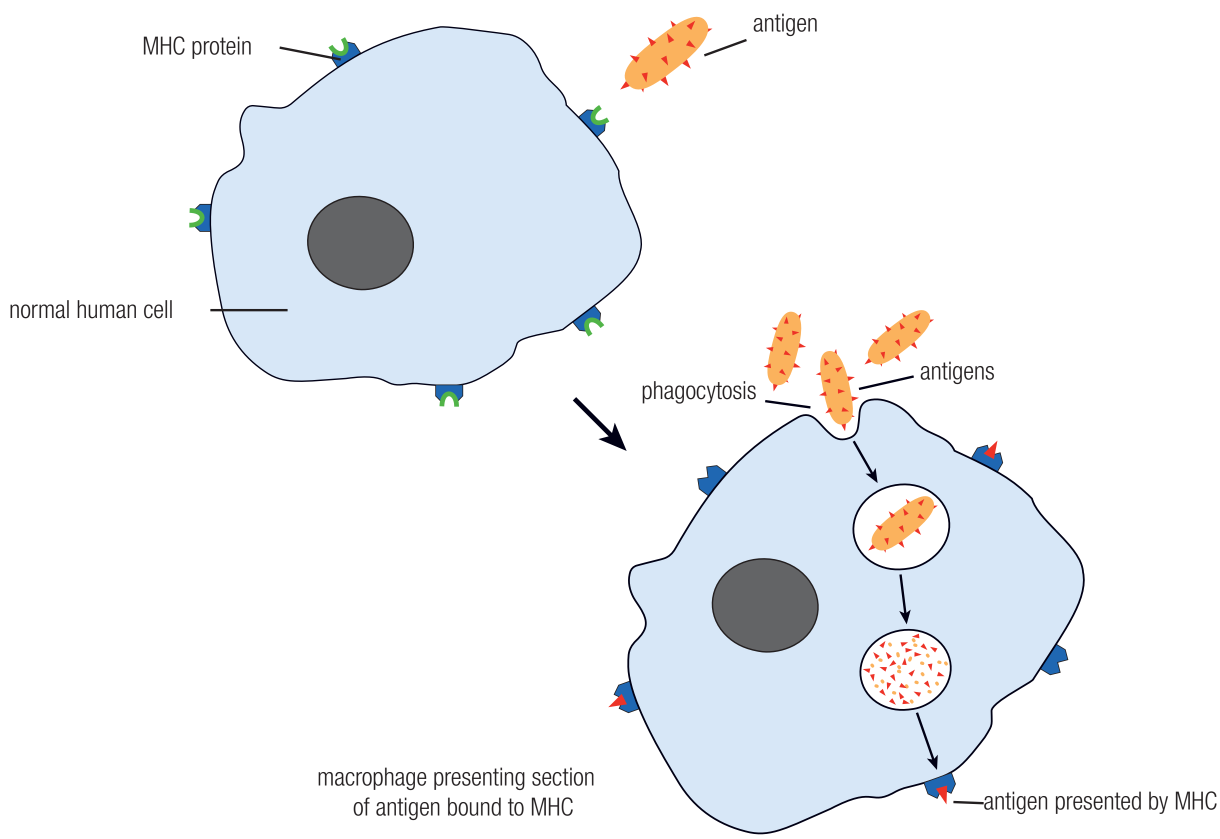


Figure 282 A macrophage engulfing a pathogen

Lymphocytes

The most important cells involved in the adaptive immune response are two categories of white blood cells called lymphocytes; B cells and T cells.

All blood cells come from bone marrow and in this instance B cells remain and mature in the bone marrow whereas T cells mature in a gland called the thymus gland.

Much like the collaborative responses of the first and second line of defence, the adaptive response (third line) has close links and works in conjunction with the innate immune response.

In Chapter 2.7 macrophages were noted to release chemicals that alert other cells to the presence of pathogens. These chemicals of the innate system are closely linked with the action of B and T cells.

B lymphocytes

B lymphocytes are white blood cells that originate in the bone marrow and then mature there. At birth, humans have large numbers of different types of these cells, each with its own cell receptor molecule which is designed to recognise one specific antigen. The way B lymphocytes work is to release a specific **antibody** which is a protein molecule that can bind to one specific antigen, thereby neutralising it. Refer to *Figure 283* which provides a summary of these ideas.

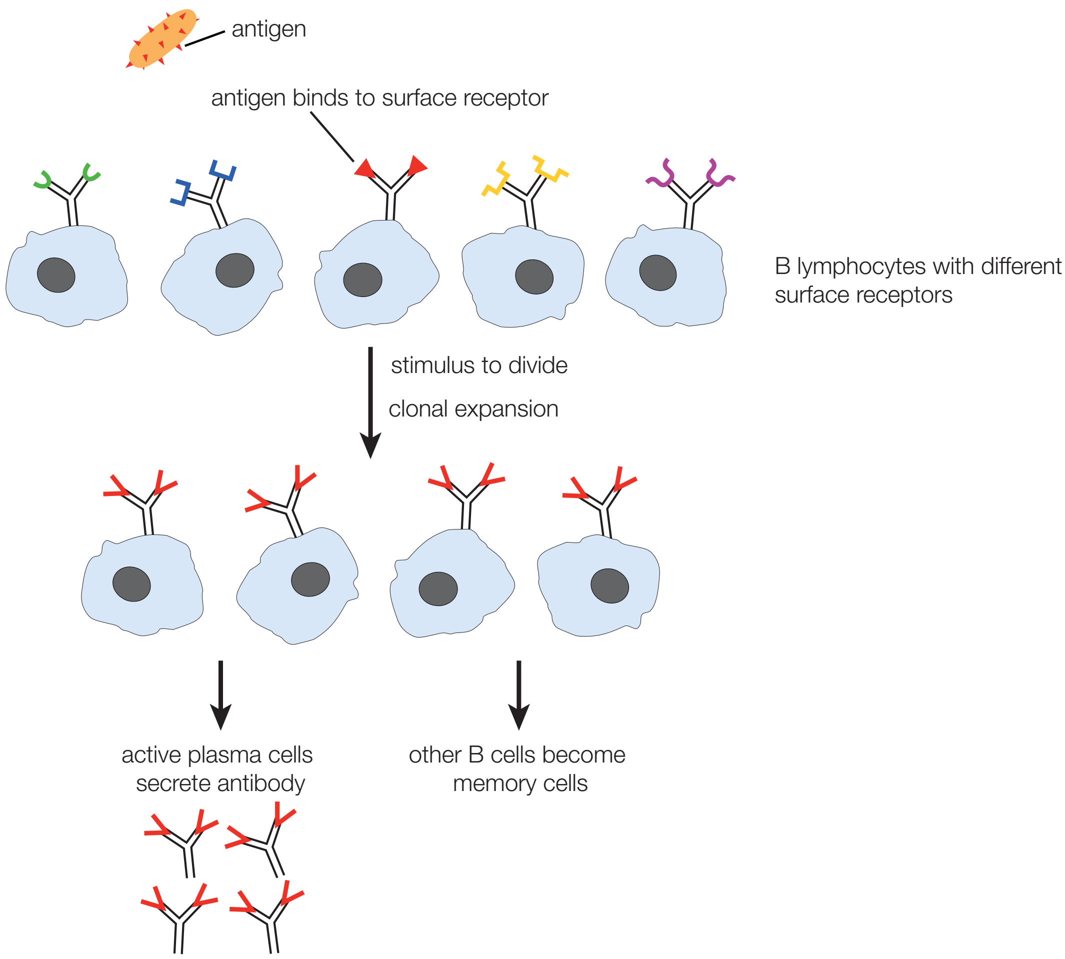


Figure 283 How B lymphocytes work

As can be seen in *Figure 283*, one specific antigen binds to one B lymphocyte with the surface receptor that is complementary to the antigen. These B cells then divide to give rise to more of this particular lymphocyte; this is called clonal expansion. Some become **plasma cells** which release antibodies, others become memory cells which remain behind in case of a second exposure to the same antigen or pathogen.

This process is one of the factors responsible for the much quicker response to the second exposure. This **'primary' response** to an antigen is therefore defined as the first exposure to an antigen whilst the **'secondary' response** which is faster and produces more antibodies, refers to a second, or further exposure to the same antigen.

Refer to *Figure 284* which represents some differences in antibody production between the primary and secondary response.

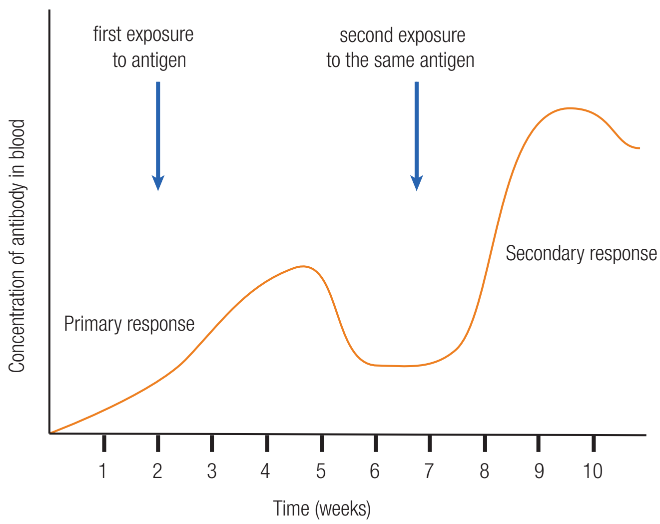


Figure 284 Some differences between the primary and secondary response

T lymphocytes

Each person has around 10 million different T cells, each with their own specific antigen binding capability. The response of the T cells is part of the cell-mediated **immunity** compared to the action of B lymphocytes which release antibodies as their prime mode of action. T cells possess receptors on the surface of their membranes that can bind to one specific type of antigen or fragment.

As seen previously, it is the T cells binding to antigen fragments bound to the Major Histo-compatibility Complex (MHC) that initiates the actions of the T cells. Macrophages have been established as the type of white cell that can engulf a pathogen, break it down and then display some of its antigen fragments by binding to MHC.

Refer to *Figure 285*(a) which represents a T cell binding to antigen fragments. Refer also to *Figure 285*(b) which illustrates T cell receptors on the cell membrane (purple) binding to the MHC antigen complex (orange-green). This binding helps to activate other aspects of the immune response.

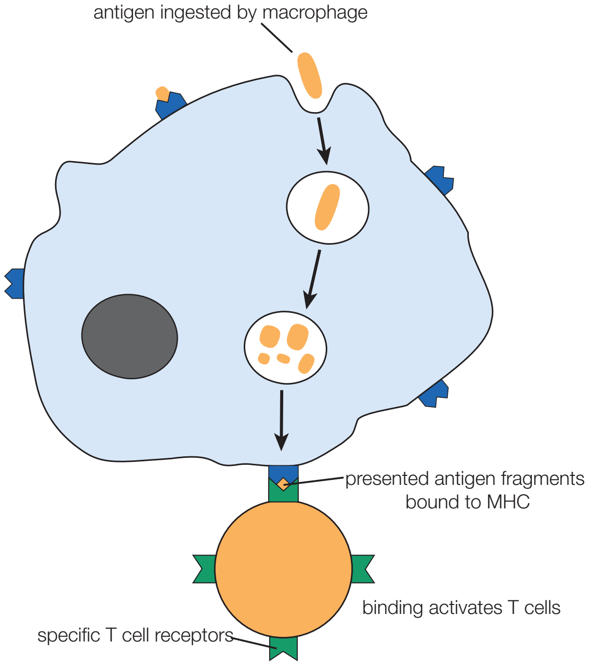


Figure 285(a) A T cell binding to antigen fragments

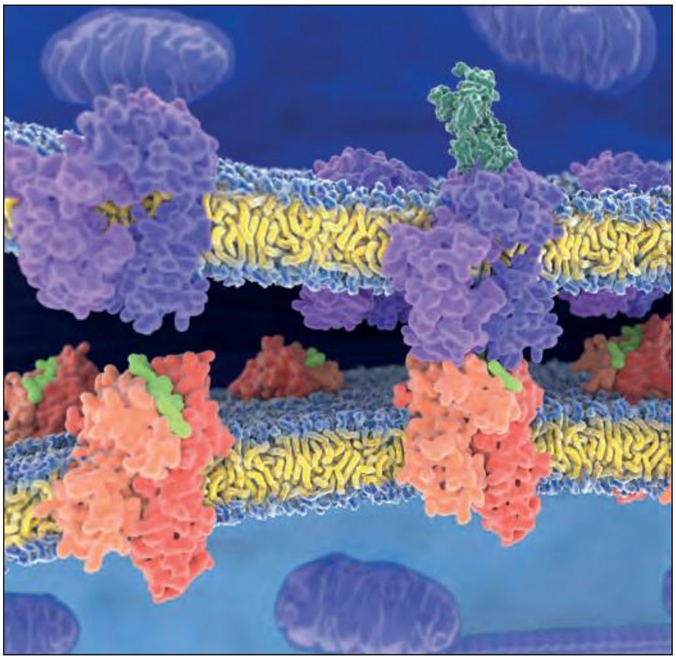


Figure 285(b) T cell receptors binding to MHC antigen

Different types of T cells can be identified according to their roles in the immune response.

Killer T cells

These cells are also known as 'cytotoxic' T cells; they identify infected cells and secrete chemicals that destroy them.

Helper T cells

These cells become activated and increase in number (clone) the types of T cells that respond to the specific antigen type. These **helper T cells** have several roles, they can:

- activate the **killer T cells**
- provide **memory T cells** for a subsequent exposure to the same antigen
- activate the specific B cells which ultimately can secrete antibodies

Refer to *Figure 286* which is a scanning electron microscope image of a macrophage (red) presenting antigens to a T-helper cell (yellow). This stimulates other cells of the immune system to get involved in destroying the pathogen.

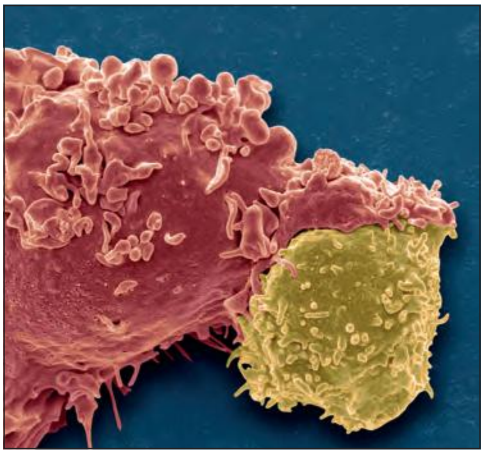


Figure 286 White blood cell antigen presentation

2.8

Memory T cells

Like the memory B cells, these T cells with their specific surface receptors have increased in number as a result of the initial infection. This memory bank of cells is again partly responsible for the quicker and larger response that can be seen (*Figure 284*) when an individual is exposed to the antigen for a second time. *Figure 287* provides a summary flowchart of the actions of the B and T lymphocytes after initial exposure to the antigen.

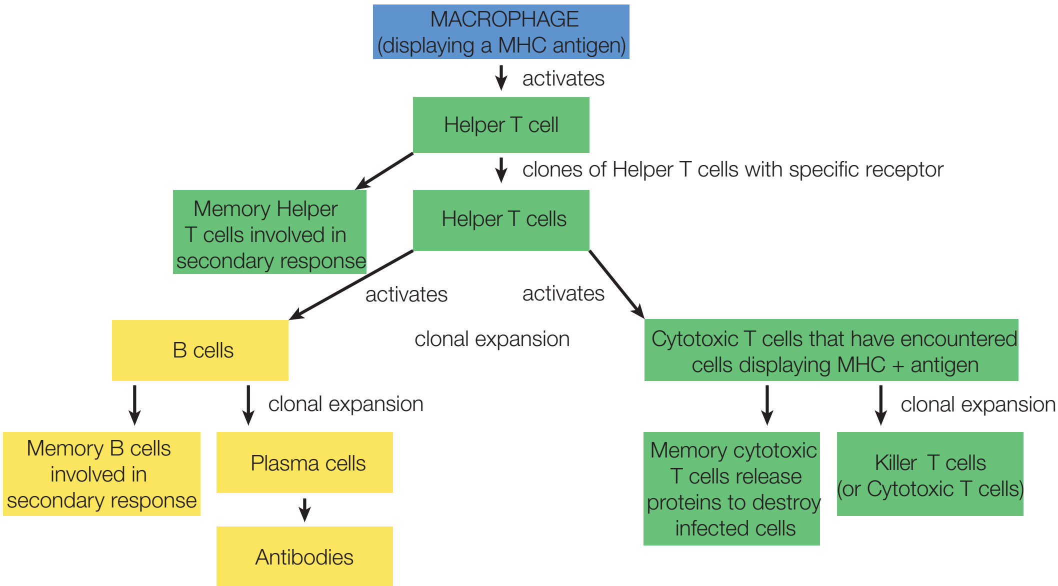


Figure 287 How B and T lymphocytes work together

Adaptive immunity

The responses of the adaptive immune system, whilst very effective are not always rapid and large enough to prevent humans getting very sick or even dying from an infection. If humans do survive exposure to a pathogen, it is noted that when they are exposed to the same pathogen a second (and subsequent) time the response is larger and more rapid providing a much greater level of protection.

Therefore, if an individual is to have immunity for a specific disease, it is necessary for that individual to have been previously exposed to the pathogen. *Figure 284* illustrated the difference between a primary and secondary response with respect to antibody production. It was established that both **B and T memory cells** are the lymphocytes that are responsible for this difference.

Two types of adaptive immunity can be identified: active and passive, as outlined below.

Active immunity

This is where the adaptive immune response is activated, B and T cells are involved and memory cells are produced and stored in the spleen and lymph nodes. **Active immunity** can be brought about in two ways:

- exposure to the actual pathogen and hence antigen
- exposure to a vaccine that consists of prepared (harmless) antigen derived from the pathogen, this is called a **vaccination**.

In Australia, most people are vaccinated for various diseases at various stages of their life. *Figure 288* shows the stages of a vaccination against influenza.

Figure 288 (a) before, (b) during and (c) after a 'flu' vaccination

Passive immunity

This is where antibodies provide the form of protection. It has already been discussed that antibodies are protein molecules produced by B lymphocytes that work by binding to specific antigens on pathogens bringing about their destruction. This type of immunity is relatively short lived as the antibodies have a limited time in which they are effective in providing protection. Antibodies can be produced commercially using other animals or genetic engineering techniques.

Nonetheless, **passive immunity** is important in several circumstances, by:

1. Providing protection for unborn babies and newly born infants who have yet to fully develop their immune system. In these instances the mother provides the antibodies via:
    - the placenta during pregnancy (refer *Figure 289*)
    - breast milk in the early stages of life (refer *Figure 290*)
2. Providing protection against particularly potent or virulent antigens/pathogens where immediate action is required to prevent death. Two examples are as follows:
    - protection against snakebite venom or poison (antigen)
    - a particularly virulent pathogen such as the rabies virus

Figure 289 Antibodies protect a foetus

Figure 290 Breastfeeding provides antibodies

A case study of vaccination - Poliomyelitis

Analysis of epidemiological data related to vaccination programs

Polio is a disease caused by a virus which invades the nervous system and causes it to stop working. It can kill the patient – usually a small child under 5 years of age, but more often causes life-long paralysis, usually in one or both legs. Polio cannot be cured.

UNICEF and the WHO have been involved in an active campaign promoting immunisation (vaccination) against polio. The result from this very effective campaign is shown in *Figures 2810 and 2811.*

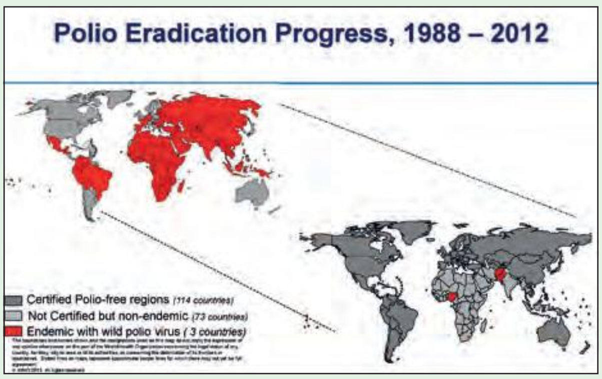


Figure 2810 Polio eradication by countries

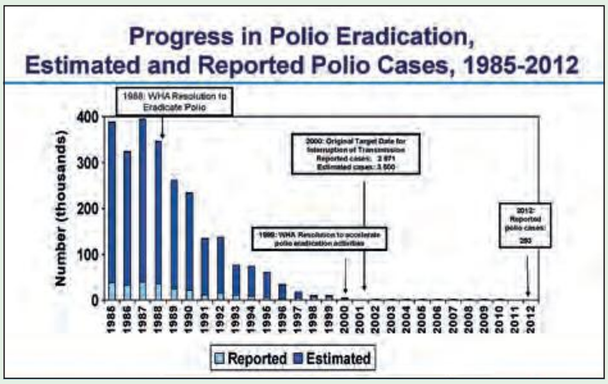


Figure 2811 Polio eradication by numbers

As can be seen from the data, the number of countries which are certified 'polio-free' regions has increased and almost no countries still have the wild polio virus endemic in their population. The number of confirmed cases has gone from about 40,000 in 1985 (with almost 400,000 estimated cases) to less than 300 cases in 2012. This is a drop of 99%! {Source: World Health Organisation (WHO)}

2.8

Key Concepts

1. The adaptive immune response is the third line of the body's defence and is characterised by the following:
    - specificity i.e. recognition of a specific antigens/pathogens
    - the second or subsequent exposure to the same antigen is quicker and larger due to the memory of the old antigen
    - primary and secondary organs of the lymphatic system that are vital for the adaptive immune response:
        - primary e.g. bone marrow and thymus gland
        - secondary e.g. lymph nodes and spleen
    - the Major Histocompatibility Complex (MHC) is a set of surface markers that are involved in self and non-self (antigen) recognition. Some cells of the immune system display sections of antigens on their surface attached to the MHC.
2. B and T lymphocytes are the main cells of the adaptive immune response. They both recognise specific antigens:
    - B cells work by releasing antibodies that bind to antigens.
    - T cells work by direct cell action releasing chemicals that destroy infected cells.
    - B and T memory cells, specific for a particular antigen, accumulate after exposure to the antigen and are responsible for the quicker and larger response after the second exposure to the antigen.
3. Active immunity is where the adaptive immune response is activated either naturally or by vaccination.
4. Passive immunity is brought about by the acquisition of antibodies either naturally (e.g. breast milk) or by injection (e.g. snake anti-venom).

Key Terms

lymphocyte

lymphatic system

lymph node

spleen

thymus

bone marrow

MHC

antigen

antibody

primary response

secondary response

B and T memory cells

plasma cells

killer T cells

helper T cells

immunity

active immunity

passive immunity

vaccination

Knowledge and Understanding

1. Describe the main way that the adaptive immune response differs from the innate immune response.

2. Summarise the main roles performed by the B and T lymphocytes in the adaptive immune response.

3. Explain the role of the Major Histocompatibility Complex (MHC) in the recognition of pathogens.

4. T lymphocytes are very important in the adaptive response.
   a) State the role of the helper T cells in initiating the adaptive immune response.

   b) Describe what must happen before a T cell is activated.

5. Place the terms listed below into the table in their correct category to illustrate your understanding of the first, second and third lines of defence: *antibodies, earwax, macrophages, cytokines, skin, inflammation, B cells, Major Histocompatibility Complex, cytotoxic T cells, lysozyme, neutrophils*.

First line of defence	Second line of defence	Third line of defence

6. Immunity is very important.
   a) State what it means to say that a person is immune to a particular pathogen.

   b) Describe the difference between active and passive immunity.

7. Vaccination is also very important.

a) Explain how vaccination can provide protection against a specific pathogen.

....

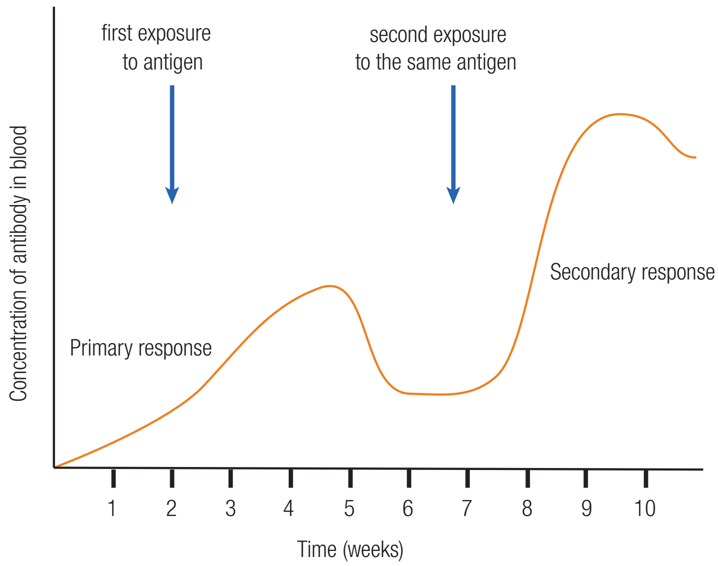
....

b) Sometimes, to provide continued protection against a pathogen, a booster injection is required. Suggest a reason for this.

....

....

8. Refer to this *Figure* to help you answer the questions that follow:



a) State two differences between the primary and secondary responses.

....

....

b) Explain how the differences relate to the fact that a person is generally immune to a specific pathogen if they have experienced a previous exposure to it.

....

....

....

....

c) Explain the role of memory cells (B and T) in bringing about this difference between the primary and secondary response.

....

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....

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....

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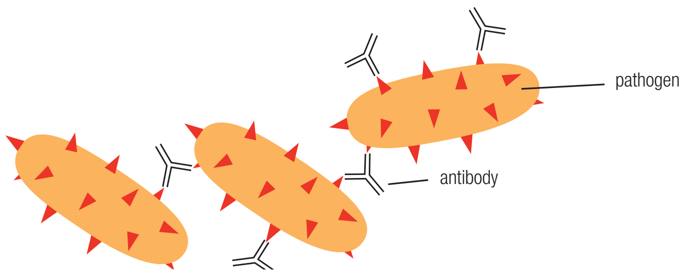
Application, Analysis and Evaluation

9. Below is a list of responses of the adaptive immune response system. Place these in the correct order in which they would generally occur in the human body.
   a) B plasma cells release antibodies
   b) cytotoxic T cells release chemicals to destroy infected cells
   c) macrophages display antigen fragments on the MHC
   d) antibodies neutralise antigens
   e) macrophages engulf pathogens
   f) helper T cells activate other B and T lymphocytes
   g) helper T cells bind to antigens attached to the MHC and then multiply
   h) memory cells move to the spleen and lymph nodes

10. Refer to the diagram below of one possible mode of action of antibodies in the destruction of antigens; called agglutination.



   a) Suggest what is happening in this process.

   b) Predict two ways in which this action of antibodies may assist in the destruction of the pathogen.

11. Outline briefly, in a couple of sentences, giving examples to illustrate how the innate and adaptive immune responses work together to help eliminate pathogens.

2.8

12. It has been noticed that some female primates may lick around the anus of their sick baby if they have diarrhoea. Explain how this may assist in destroying the pathogen in the baby that is causing the diarrhoea. (*Hint: passive immunity)*

13. Every year in Australia people die after being bitten by venomous snakes.
    a) After a person is bitten by a snake, predict why vaccination designed to stimulate the lymphocytes would be an ineffective treatment.

    b) Suggest the most effective method to save the life of a person who was bitten.

14. Active and passive immunity can both occur either by natural means or artificial means. Below is a list of examples. Choose the correct example for each section and write each in the table provided.
    a) exposure to a pathogen
    b) injection of antivenom
    c) typhoid vaccination
    d) breastmilk antibodies

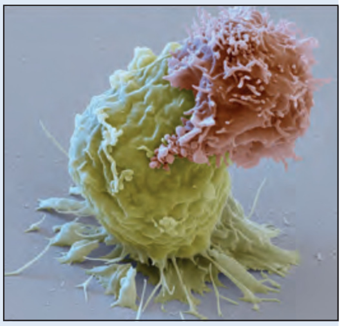
	Passive immunity	**Active immunity**
Natural		
Artificial		

15. Suggest why passive immunity does not demonstrate memory of a pathogen for long-term protection.

Science as a Human Endeavour 2.8 - Immunology treatment of cancer

Influence

Acceptance/use of science is influenced by social and economic considerations



Established cancer treatments include removing cancer cells from the body (surgery) or destroying cancer cells in the body using radiation (radiotherapy) or drugs (chemotherapy). New treatments, however, are in development. One of these is known as immunotherapy, which boosts the immune system so it can fight cancer better. In Australia, immunotherapies have been used to treat a variety of cancers including bladder and kidney cancer as well as melanoma (skin cancer) and leukaemia (cancer of blood forming cells e.g. bone marrow).

A particularly promising immunotherapy is called CAR T-cell therapy. This involves collecting T-cells from a cancer patient and using a virus to modify them so they can make protein receptors on their surface called chimeric antigen receptors (or CARs). The modified T-cells are known as CAR T-cells. They are cultured in the lab (many copies are produced) and then introduced into the patient's bloodstream. Courtesy of the acquired CARs, these engineered T-cells bind to the antigens of specific cancer cells prompting destruction of them (Refer to the photo, which shows a CAR T-cell (reddish) binding to a leukaemia cell (green).

News of CAR T-cell therapy has already had a significant influence. In March 2019, the Federal Government pledged $80 million to build the Peter Mac Centre of Excellence in Cellular Immunotherapy in Melbourne to further immunotherapy treatment and research, the only one of its kind in the Southern Hemisphere. In a further sign of its influence, the 'beyond the reach of most' cost of CAR T-cell therapy ($598,000 per treatment overseas) was listed in April 2019 as covered by Medicare for leukaemia patients up to 25 years of age who are diagnosed as in second or later relapse regardless of socio-economic background.

You may need to refer to the online resources below to answer the questions that follow:

1. Developing new technologies such as *CAR-T cell therapy* has wide-reaching economic considerations, discuss two of these.

2. Describe how at least 2 social factors that could impact on the economoic considerations in the use of this technology.

Helpful Online RESOURCE about CAR T-cell therapy

To learn more about CAR T-cell therapy view the clip below:

<https://www.youtube.com/watch?v=OadAW99s4Ik>

2.8

Helpful Online RESOURCE about immunotherapy for cancer in Australia

To learn about immunotherapy at the Peter MacCallum Cancer Centre see below:

<https://www.youtube.com/watch?v=0tMSOtuyydU>

C Intercultural understanding: Drone delivery of vaccines

Access to high quality health care for all is something people in Australia take for granted. This includes regular visits to a doctor, hospitalisation as required and immunisation with vaccines.

In many parts of the world, however, the availability of basic medical services like blood testing and vaccines is not a given. In remote locations and parts of developing countries, village-like communities can be hundreds of kilometres away from the nearest a modern hospital. The problem is made more significant if there is no effective system of roads.

This situation is reflected in many island nations in the South-Pacific. One is Vanuatu, a collection of 80 islands located about 2000 km to the northeast of Brisbane (*refer to the map*). Most are mountainous, sparsely populated, and lack roads and access to electricity.

In a good example of how progress in biology is influenced by cultural needs, the Australian Government helped to fund a trial that aims to improve access to vaccines using airborne autonomous vehicles, or flying drones. The trial took place in late 2018 on the Vanuatu island of Erromango and involved flying an 'esky-enclosed' vaccine for measles and rubella to a child living the tiny village of South River on Erromango's west coast. It used state of the art drone technology provided by Swoop Aero, a developing company based in Melbourne.

With an estimated one in five children in Vanuatu not fully immunised, the hopes that the iniatitve can meet cost-effectiveness tests are high. If drone-delivery of vaccines can be sufficiently scaled up, greater vaccine access for all in the South-Pacific is certainly possible.

You may need to refer to the online resources below to answer the questions that follow.

1. Outline possible cultural or other considerations that may be impacting on the low rate of immunization in Vanuatu.

2. Outline how the Australian Government might respect different cultural views and customs when implementing this vaccination program.

Helpful Online RESOURCE about life in a village on Erromango

To learn more about life in a remote Vanuatu village view the clip below:

<https://www.youtube.com/watch?v=NG6of5FU0H0>

Helpful Online RESOURCE about drone delivery of vaccines to Vanuatu

learn about the trial that used drones to delivery vaccines in Vanuatu view the clip below:

<https://www.youtube.com/watch?v=QjCSAM6vLX0 >

? Deconstruction

Introduction

In Topic 1 (and/or Topic 3) a Practical activity was given that incorporated three aspects of looking at and investigating a problem i.e.

- **Deconstructing** the Problem
- **Designing** an investigation based on your findings
- **Conducting** the investigation and preparing a report of it.

The activity presented here only involves the theoretical exercise of Deconstructing the problem to develop, in a formative manner, your knowledge and skills. It is important however that this should be able to lead on to the Design and implementation of a Scientific Investigation.

With direction from your teacher, present a one-page Deconstruction of one of the following Problems:

- Does the type of hand wash affect how well the growth of bacteria is prevented?
- Does the species of yeast affect the rate of alcohol fermentation?
- Does the age of the yeast (i.e. use-by-date) affect the rate of alcohol fermentation?
- Does the age of plant tissue affect the rate of osmosis?
- Does the lunar cycle affect bacterial growth?

Use the following steps as a guide to the process of Deconstruction

1. Research the particular Problem you are focussing on and interested in investigating.
2. Explore factors that impact on this particular problem.
3. Make informed decisions about determining experimentally how deliberately changing one factor could impact on the particular problem.
4. Explore and address the health and safety risk factors involved.
5. Select the one factor and develop a method to test the effect on the particular problem.

(Refer to the Guidelines and example on page 470 in the Appendix.)

Planning Notes

Introduction

These Answers have been suggested by the authors, they are not intended to be either comprehensive or exclusive. In some cases no answer is suggested because it relies on research or an individual response from students.

Chapter 2.1 Answers

1. An infectious disease can be transmitted from one organism to another either directly or by a vector. A non-infectious disease is unable to be transmitted.
2. A pathogen is a disease-causing microbe. A parasite is an organism that lives inside or on a host and may or may not cause disease.
3. 'Ring worm' refers to the appearance of the condition caused by infection by a fungal species.
4. Three characteristics are:
   - entering the host by having adaptations to avoid the protective barriers
   - able to reproduce inside the host
   - able to evade the host's immune system
5. Regarding spores:
   a) reproduction, dispersal and ability to survive harsh conditions
   b) reproduction e.g.1. fungi which enables it to spread very easily and rapidly and/or survive harsh conditions e.g.2. bacteria which enables bacteria to survive harsh conditions and germinate in favourable conditions.
6. Regarding toxins:
   a) A toxin is a poisonous substance secreted by a range of pathogens and other organisms.
   b) Botulinum neurotoxin is highly toxic and can lead to paralysis and death produced by a bacterium (*Clostridium botulinum*)
7. These are our natural microflora. They live in and on us in a mutually beneficial relationship, generally not causing harm as they have evolved with humans over time.
8. Your table should look something like this:

Pathogen	**Example of disease**	**Adaptation**
Bacteria	food poisoning	heat resistant and can survive high salt concentrations
Fungi	toenail infection	easily spread from nails to colonise new areas
Protozoa (Protist)	malaria	spread through vector e.g. mosquito
Virus (HIV)	AIDS	evades host's immune system and then disables it
Parasitic worm	nausea, fatigue	Well-developed reproductive system, hermaphroditic
Prion	Mad Cow disease (BSE)	Ability to stimulate the host to replicate infective agent

9. Not generally. They do not display characteristics associated with life e.g. responding to stimuli, using energy etc. They can only reproduce using the host's metabolism and processes.
10. Your table should look something like this:

Disease	**Bacterium**	**Fungus**	**Virus**	**Protist**	**Worm**	**Prion**
Common cold			T			
Diarrhoea	T		T	T		
Malaria				T		
Sinusitis	T (rare)	T (rare)	T			
Tapeworm infections					T	
Pneumonia	T	T	T			
Mad cow disease						T
Genital herpes			T			

11. With reference to the data table:
    a) Africa, Sudan, Southeast Asia
    b) low income, poor health facilities, ability to identify isolate and treat infected individuals, poor education, low vaccination rates, poor sanitation
    c) most people in low income countries die from infectious disease due to the reasons listed above. Lifestyle diseases are more common in high income countries, e.g. dietary and degenerative diseases.

Chapter 2.2 Answers

1. You may have used different examples:

Method	**Examples of pathogens**
Droplets (cough or sneeze)	Flu virus, cold virus
Direct contact	Fungal spores infection, herpes virus
Faeces	Cholera bacteria, hepatitis A virus
Contaminated food	Salmonella bacteria, E.coli bacteria

2. Touching, droplet infection, sexual practices, drug use, bites from infected species e.g. dogs, mosquitoes
3. Methods of transmission include:
    - exchanging needles for drug use
    - unprotected sex
    - breast milk
4. Regarding the tapeworm:
    a) Energy is not needed here as it uses food from the host. Energy is used in reproduction.
    b) This saves energy, it can use the movement of the host's digestive system for this.
    c) If it is the only tapeworm in the gut it can still self-fertilise and reproduce.
5. Salmonella bacteria are very commonly found in poultry. Unless good hygiene practices and thorough cooking occurs they can easily be transmitted to humans and cause disease.
6. In freshwater streams, creeks and lakes that may have undergone pollution by human waste.
7. Regarding cat bites:
    - The cat bite penetrates the protective barrier of the skin and into the underlying tissue.
    - Cats have high levels of pathogenic bacteria in their saliva which can be transmitted by biting.
8. A lot of these insects that are vectors of disease live in tropical areas. With global warming, new zones with higher temperatures enable the vectors to spread. This can increase the spread of disease.
9. With regards to malaria:
    a) The *Plasmodium* reproduces inside the mosquito and the mosquito spreads the disease to humans when they bite them to feed on human blood.
    b) Destroying red blood cells and interfering with liver function due to an increase in the inflammatory response.
    c) The asexual phase can occur in the human liver. The sexual phase which involves fusion of male and female gametes occurs in the mosquito.
    d) Some methods include spraying insecticides to kill the mosquitoes and reducing the amount of stagnant freshwater which is ideal for their breeding. There are many examples to mention here, you need to focus on the cyst as a protective phase able to resist harsh conditions enabling the protist to survive, reproduce and disperse.

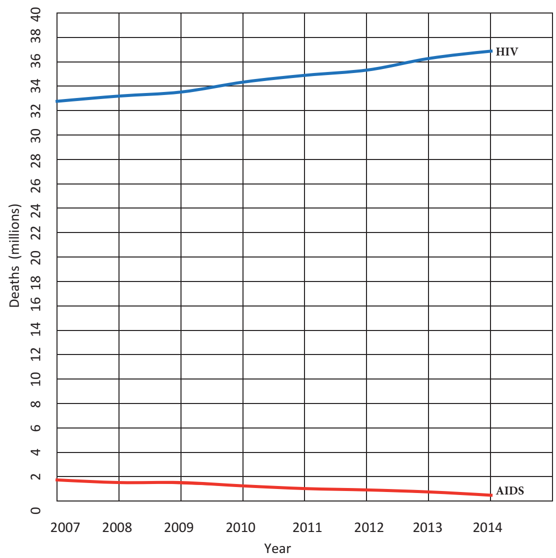
Chapter 2.3 Answers

1. Possibilities include:
   - increased virulence of the pathogen e.g. genetic changes to antigen
   - transmission to a new group of individuals not previously exposed
   - transmission from an animal of a new strain of pathogen
2. Suggestions are:

Disease	Pathogen	Factors influencing spread
Influenza	Flu virus	Low level of immunity in population
Cholera	Bacterium	Poor sanitation in a refugee camp
AIDS	HIV	Limited understanding of how the virus spreads
Colds	Virus	Poor herd immunity
Malaria	Plasmodium	Vector numbers; mosquito

3. With reference to *Figure 232*:

   a) Something like this:



   b) Two factors are:
   - either the number of HIV infections globally are rising or more cases are detected
   - although there are more infections, better treatments are reducing the fatality rate

   c) Two factors are:
   - it spreads so rapidly
   - low virulence so it can survive in a host for a long period of time

   d) Two factors are:
   - education of causes and methods of transmission of the virus
   - medication/drugs are having an impact on survival
4. Suggestions are:

   a) where an antibiotic that was once effective against specific bacteria now has reduced effectiveness

   b) there are some ‘superbugs’ that are resistant to all known antibiotics. Antibiotics are necessary to destroy bacterial infections and without them the whole human race is very susceptible to fatal disease caused by bacteria.
5. Virulence of a pathogen refers to its disease-causing features. A mutation changes the DNA which may change the virulence. It may be that humans have no immunity to a new strain and it may therefore cause higher levels of disease.

6. Herd immunity is where the population has a certain level of immunity due to the fact that most or many individuals within the population are immune, therefore the disease is less likely to spread. This term only applies to contagious diseases as these are the only ones that can spread from one individual to another.
7. Re: *Staphylococcus aureus*:
   a) e.g. the person may be on chemotherapy for cancer treatment. Those with wounds that are not healing e.g. old and/or frail people
   b) There is a lot of antibiotic use in hospitals but strains such as 'golden staph' have built up resistance to antibiotics and therefore they multiply and cause disease.
8. There is a better understanding of the cause of diseases and how they are spread. There are better treatments e.g. antibiotics, anti-viral medications and there is much better sanitation in most parts of the world.
9. Suggested answers are:
   a) 'Hit and Run'*.* e.g. Cold virus; infects victims, multiplies rapidly, it spreads quickly to others to keep reproducing and then the infection is defeated.
   b) 'Hit and Stay'. e.g. HIV causes the disease of AIDS. Avoids or disables the immune system often lying dormant inside cells. This is an advantage; fairly low virulence, the victim may spread the virus without even knowing that they are infected over a long period of time.

Chapter 2.4 Answers

1. Four examples include:
   - destroying or reducing the number of vectors
   - quarantine
   - killing the pathogen e.g. using an antibiotic or antiseptic
   - the body's own immune responses
2. Measures include:
   a) spraying with insecticide and/or reducing stagnant water to reduce breeding grounds
   b) using insect repellent, use of netting and screens, avoiding areas of mosquito infestation
3. Use of malathion to kill mosquitoes and hence reduce the spread of malaria.
4. Antiseptics kill microbes on the outside of the body e.g. *Dettol*, whereas disinfectants kill microbes on floors and surfaces e.g. bleach
5. Methods include:
   - white blood cell may engulf and destroy microbe
   - white blood cell produces a protein antibody that may bind to and destroy the antigen
6. Reasons include: poor sanitation, overcrowding leading to easy spread of disease, poor early detection and treatment and lack of medical facilities.
7. Vectors are necessary for some pathogens to spread otherwise they cannot be transferred between individuals. Spraying flies to reduce spread of pathogens which cause diarrhoea.
8. Possible reasons include:
   - antibiotics work in specific ways and some bacteria may already have adaptations that confer resistance
   - the bacteria may have evolved and developed a resistant strain
9. Ethical considerations include:
   - reducing civil liberties e.g. by holding people in quarantine or isolation.
   - this often further marginalises poorer groups who are frequently more susceptible to disease and infection

Chapter 2.5 Answers

1. Examples include:
    - respiratory surfaces: rhinovirus-colds and respiratory infections
    - digestive system: *Salmonella* - food poisoning, diarrhoea
    - reproductive organs: HIV-causing AIDS
2. Pathogenicity is the ability of a pathogen to cause disease, whereas virulence is the degree to which the pathogen causes disease. High virulence means that the pathogen brings about a high level of disease.
3. Suggestions include:

Adaptation	**Description of how the adaptation works**	**Example**
Using a vector	Enables transmission from one host to another	*Plasmodium* (Protist)
Adhesion proteins	Attachment to host cells to avoid being flushed out of host	Bacteria
Secretes enzymes	Neutralises stomach acid	Bacteria Helicobacter pylori
Production of toxins	Reduce the ability to clear infection	Bacteria: *B. Pertussis*
Hiding inside host cells	Avoid or disable the immune system	HIV virus

4. Advantages include:
    - reproductive: light, easily dispersed, some will end up in favourable environments and grow quickly
    - survival: some are resistant to harsh conditions and germinate when conditions are more favourable.
5. Comparing two pathogens:
    - high virulence: Ebola virus - evades immune system and will destroy human tissue rapidly
    - low virulence: HIV - hides inside white blood cells and may remain dormant
6. If the virus kills its host too quickly, this may impair its ability to spread and multiply.
7. Methods include:
    - Spraying: will have an immediate effect in destroying some of the fungus and enable some plants to recover but spores may survive and the disease may return.
    - Sanitising boots/tools: can assist in reducing spread into new areas and when used with spraying will produce some good outcomes.
8. Arguments include:
    - Host: enables host to expel some of the pathogen and assist the immune system.
    - Pathogen: helps spread and infect other hosts via contaminated water or food
9. By hiding inside a host cell, the pathogen reduces its chance of being attacked by the host's immune system e.g. white blood cells.

Chapter 2.6 Answers

1. The four key entry points are:
   - respiratory surfaces e.g. lungs
   - wounds or breaks in the skin surface
   - digestive system e.g. mouth, lining of intestines
   - reproductive organs e.g. urethra
2. Suggestions are:

Feature	Mode of action in providing protection
Earwax	Antimicrobial chemicals
Blood clotting agents	Forming a scab on the surface of the skin to seal a wound
Blinking	Moving pathogens across to the corner of the eye
Tears	Antimicrobial substances e.g. lysozyme
Cilia lining the respiratory tract	Rhythmic action of hair-like structures to move mucus to the mouth

3. Barriers include:
   - oil glands make the skin quite waterproof
   - consists of outer layer of dead, keratinised cells
   - secretes antimicrobial chemicals
4. An irritant such as a pathogen acts as a stimulus to bring about a reflex response cough/sneeze which acts to expel the pathogen from the body. It is called a reflex as it is an involuntary response.
5. In the case of a cough or sneeze:
   - the stimulus is viral particles
   - the effector is the diaphragm and intercostal muscles
   - the response is a sneezing or coughing action
6. Suggestions are: tears from the eyes and secretions from the skin which break down bacterial cell walls.
7. Suggestions are:
   - mucus is a thick secretion lining the respiratory surfaces that traps microbes and these are then swept towards the mouth by cilia to be expelled from the body or swallowed.
   - areas include the upper respiratory tract and reproductive organs e.g. vagina.
8. Cellular responses by respiratory and nasal passages to release more mucus to trap the virus before it can enter the bloodstream.
9. The skin is an effective first line of defence; burns victims have suffered damage to this layer allowing pathogens to enter into underlying tissues and the bloodstream causing infection.
10. Earwax is a normal, essential barrier containing antimicrobial chemicals necessary to prevent pathogen entry into the inner ear. People may cause damage or a wound to the ear, allowing pathogen entry if they use something like a cotton bud to clean their ears.
11. Pathogenic microbes cause disease whereas our microflora generally does not. Humans have evolved together with our normal microflora and therefore live in what is termed a symbiotic or mutualistic relationship benefiting both organisms.
12. ‘Self’ refers to our own tissue and cell marker proteins on cell surfaces. ‘Non-self’ refers to foreign tissue and markers not made by our tissues. Our white blood cells (lymphocytes) have special adaptations and markers that allow them to recognise the difference between ‘self’ and ‘non-self’.

Chapter 2.7 Answers

1. The innate immune system is:
   a) Non-specific because it has no recognition of a specific antigen and attacks 'non-self' in general. It also has no memory of a specific antigen.
   b) Rapid because it has a vast array of white blood cells ready for immediate action.
2. Suggestions are:
   a) Macrophages and neutrophils carry out phagocytosis and destroy pathogens. Cells release chemicals that bring about other responses.
   b) Cytokines signal other cells to respond to the pathogen. Complement proteins will punch holes in membranes of pathogens and assist in phagocytosis.
   c) The inflammatory response will increase permeability of blood vessels and allow more macrophages and neutrophils to enter body tissues. Clotting agents act to seal area and other chemicals will attract more white blood cells.
3. Their role is to have a cascade effect increasing the innate response; more cells will lead to more chemical action to destroy pathogens. Some chemicals bind to pathogens to alert macrophages e.g. cytokines are one such class of chemicals.
4. This makes the pathogens more able to be recognised by such phagocytic cells as macrophages and neutrophils.
5. Mast cells are important as they release histamine. Histamine increases permeability of capillaries allowing white blood cells and chemicals to move to the site of infection.
6. Regarding pus:
   a) Pus consists of dead pathogens, cellular debris and dead macrophages and neutrophils near the site of an infection.
   b) Pus is the end result of the death of pathogens and therefore is important in fighting and getting rid of the infection.
7. Similarities are that both have barriers to restrict entry of pathogens and both have an innate immune system with antimicrobial chemicals and cells that bind and recognise pathogens. However plants have no adaptive immune system with lymphocytes circulating in their sap.
8. Non-self recognition by binding is an important part as this binding, e.g. by macrophages, stimulates them to release chemicals like cytokines which in turn stimulate a range of effects to boost the immune response.
9. Physical barriers include leaf cuticles and wax which are waterproof and restrict access of airborne pathogens. Bark as it is an impervious hard outer layer. Chemicals like phenols and alkaloids are also produced and these have antimicrobial effects.
10. It provides a level of protection for the fungus against bacterial attack. It is innate as it is a general form of response against a range of bacteria.
11. Explanations are:
    - Redness; increased blood flow to the region.
    - Increase in temperature; increased blood flow and increase cellular activity.
    - Swelling; increased permeability of capillaries leaks more fluid into the tissue spaces.

Chapter 2.8 Answers

1. The main difference is that the adaptive response is specific in that the cells target only one type of antigen and are able to remember the antigens to which they have been exposed previously.
2. B cells release a specific protein antibody that can bind to the specific antigen that is associated with the pathogen. T cells have a few different types but generally this is direct cell action, releasing chemicals that punch holes in the infected cells.
3. This complex displays antigens on the surface of cells and this display enables other cells of the immune system to bind to them and thus become activated.
4. Regarding T lymphocytes:
   a) T helper is a specific cell and it increases in number producing clones of the required type. They develop into killer cells and stimulate B cells.
   b) The specific T-cell for the particular antigen needs to bind to the antigen (often displayed by MHC) before it is activated.
5. Suggestions are:

First line of defence	**Second line of defence**	**Third line of defence**
earwax	macrophages	antibodies
skin	cytokines	B cells
lysozyme	neutrophils	MHC
	inflammation	cytotoxic T cells

6. Regarding immunity:
   a) When infected or exposed to the pathogen the person will not become sick or diseased as they mount a very effective response to quickly destroy the pathogen.
   b) Differences are:
   - active immunity stimulates B and T lymphocytes either naturally or artificially.
   - passive immunity is an injection of antibodies and the lymphocytes are not activated.
7. Regarding vaccination:
   a) Vaccination can stimulate B and T lymphocytes producing memory cells that are stored in the spleen and lymph nodes. When infected this enables a quick secondary response.
   b) Memory cells may die over long periods and the ‘booster’ injection stimulates more of them to be produced and stored in case of an infection.
8. With reference to the graph:
   a) The primary response is slower and produces less antibody than the secondary response.
   b) In the secondary response it is quicker and larger, therefore the pathogen is generally destroyed before an infection can take hold.
   c) Memory B and T cells are stored in the spleen and lymph nodes, usually many of them specific to the particular antigen. When activated they mobilise plasma cells which produce antibodies and T killer cells quickly to destroy the pathogen.
9. The correct order is: e, c, g, f, a, d, b, h
10. Referring to the diagram:
   a) Antibodies are binding to surface antigens on pathogens causing several pathogens to clump together.
   b) Bacteria may now be inactive as they are clumped and in addition it now provides a bigger target for macrophages to engulf and destroy them.

11. It is a united effort of both the second and third line of defence working together. The innate response is the quick acting but non-specific action that acts as a first response and then immediately signals the adaptive response for assistance. This signalling can occur by chemicals such as cytokines. Macrophages display antigen fragments for T helper cells to alert them. This mobilises the entire adaptive response of killer T cells and antibodies. As seen above in question 10 antibody action is working to make it easier for macrophages to carry out phagocytosis.

12. The primate's immune system is stimulated to fight off the infective agent. Antibodies would be produced and these are then passed on to the baby during suckling to help fight infection.

13. Regarding snake bites:

    a) This would be too slow. By the time the lymphocytes are stimulated and B and T cell action begins, the venom would have spread and brought about its effects which can include death.

    b) Using passive immunity; i.e. an injection of anti-venom which is a preparation of ready made antibodies to combine with the antigen (venom) and de-activate it.

14. Regarding examples of active and passive immunity:

	Passive immunity	**Active immunity**
Natural	breast milk antibodies	exposure to pathogen
Artificial	injection of anti-venom	typhoid vaccination

15. To obtain memory to the pathogen, an accumulation of B and T memory cells stored in the secondary lymph organs is required. This does not occur with passive immunity.

Introduction

The Laboratory Notes are suggested, particularly for use by Teachers and Laboratory technicians, and again are advisory and not intended to be either comprehensive or exclusive.

SIS 2.1 Laboratory Notes

Prepared slides can be purchased from a number of Suppliers including:

- Southern Biological <www.southernbiological.com>
- Omega Scientific Pty Ltd <www.omegascientific.com.au>
- Livingstone School Science <www.livingstone.com.au>
- Haines Educational <www.haines.com.au>

SIS 2.2 Laboratory Notes

Preparation for this investigation is quite straightforward. The measuring cups are basic plastic medicine measuring cups, or alternatively, cheap plastic 'shot glasses' could be used.

- Label the cups A, B, C, etc. one for each student. An even number is needed. If necessary, the teacher can be included.
- Put sufficient tap water (allow 10 mL for each student) in a beaker and adjust the pH to 4 with 0.1M hydrochloric acid. The excess can be washed down the sink once the preparation is complete.
- Aliquot 5mL of the pH adjusted water into all but one (selected at random) of the measuring cups.
- Add 5mL of 0.5M sodium hydroxide to the randomly selected cup. (and note for the teacher which one it is, as this is the 'original infected student')
- 3mL plastic transfer pipettes are standard school laboratory equipment and available from commonly used suppliers.
- To prepare phenol red indicator, dissolve 1g phenol red (free acid) powder in 29 mL of 0.1M sodium hydroxide solution. Dilute to 1L with distilled or deionised water. The final colour should be bright red. If not, add a drop of 0.1M sodium hydroxide solution.

At each 'contact' the student draws up 3mL of their solution (there is a 3mL mark visible on the neck of the pipette) and exchanges it with their randomly selected contact. All students in the class should complete the first 'contact' before beginning the next one.

Once this has been done three times, add 1 drop of phenol red indicator to each measuring cup. The liquid in the cups will turn either yellow or pink (pink being infected).

By reviewing the contacts in the table it is possible to work out which cup was the ' initially infected ' one. Work backwards. For example, if cup K is yellow at the end, then none of the people they came into contact with was 'infected'. If D is pink and therefore 'infected' check who they have come into contact with.

By process of elimination, it should be possible to work back to one possibility (sometimes not, depending on how the students interact, but it will be possible to narrow it down).

SIS 2.3 Laboratory Notes

Most standard texts will provide information about aseptic techniques which are most likely well known but listed below are a few tips.

- For information regarding preparation of nutrient agar plates, aseptic technique, and disposal of plates, various sources are available, including Science ASSIST <http://assist.asta.edu.au> and local Laboratory Manager Associations. In SA laboratory staff who are members of the Laboratory Managers Association of SA (LMASA) will have access to their information.
- Prior to this Investigation, it will be necessary for Laboratory staff to prepare a liquid culture of each bacteria to be used. Using aseptic technique at each step, streak out on to a sterile nutrient agar plate, an inoculum from the bacterial culture. Incubate overnight at 35°C. Then select a single colony from the plate, and inoculate this into a small flask of sterile nutrient broth. Incubate overnight at 37°C. This sterile liquid culture can then be supplied to students to inoculate their plates to create a lawn of bacteria, which should be a pure culture.
- Together with many other resources, cultures of non-pathogenic bacteria are available from: <www.southernbiological.com> or phone them for more information on 03 9753 3896.
- It is a good idea to put several drops of distilled water or sterile isotonic saline in the middle of the agar and then to put the bacteria in this before trying to spread them around the plate.
- Used cotton buds should be placed immediately into a beaker covered with alfoil. These will be sterilised by the Laboratory staff prior to disposal.
- Students find it easier to spread a culture of bacteria evenly using a sterile cotton bud than with the traditional wire inoculating loop which tends to dig into the agar. This will provide a more even 'lawn' which will make observation a lot easier.
- *Mastring* antibiotic rings are available from Southern Biological (contact as per SIS 1.1. Laboratory Notes). They are expensive but can be purchased in packs of 10 to keep cost down and limit wastage. Other possible antimicrobial agents may include soaps, antiseptics, disinfectants, chlorine, methylated spirits, salt, toothpaste, herbal remedies and many more.
- A well known and quite successful technique is to soak filter paper discs in test solutions and then place them on the agar at a spacing of several cm. They should be clearly labelled so that they are not confused.
- To preserve aseptic conditions as far as possible, the hole punch should be sterilised possibly in boiling water and the filter paper taken from a new pack (using gloves if you like).
- Ensure that the plates are labelled on the bottom, sealed, stored upside down and then disposed of properly by your laboratory staff. The plates must not be re-opened.

SIS 2.6 Laboratory Notes

Refer to Science Inquiry Skills 2.3 Laboratory Notes - the Science Inquiry Skills activity here is the same process but in a different context.

TOPIC 2 Test Yourself

Answer all of the questions in the spaces provided. The number of marks for each question is shown in brackets. Answers are suggested for all questions at the end of the test. Note that they are not intended to be the only possible answer. Read these carefully after the test and use them as part of an assessment for learning activity.

1. The term 'herd immunity' refers to the immunity in a population. Which one of the following is **not** a true statement regarding herd immunity?

   J It provides general protection for a population which arises as large numbers of the population are immune to a specific infection.

   K It can be brought about by natural or artificial means.

   L It only provides protection to those members of the population who have been exposed to the pathogen.

   M The immunity refers to a specific pathogen

2. Which of the following would be the least effective in controlling the spread of malaria?

   J Isolating infected individuals in quarantine.

   K Spraying with insecticides.

   L Using netting surrounding sleeping areas at night.

   M Wearing clothing that fully covers the skin.

3. Which one of the following correctly identifies a disease, the microbe that causes this disease and the most frequent mode of transmission of the disease?

	Disease	**Type of microbe**	**Method of transmission**
J	Influenza	Bacteria	Droplet infection
K	Food poisoning	Bacteria	Vector
L	Cholera	Virus	Faeces
M	Ring worm	Fungus	Airborne spores or contact

4. Which of the following is true concerning infectious and non-infectious diseases?

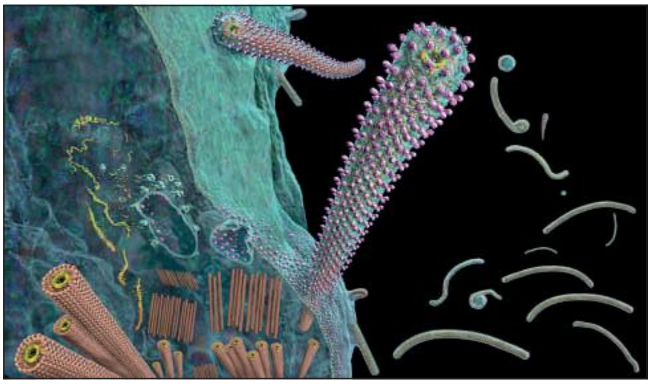
   J Cancer is an infectious disease that can be caused by a virus.

   K Non-infectious disease can sometimes be spread from one organism to another.

   K All infectious diseases are caused by pathogens.

   M Faulty genes can cause infectious disease.

5. *Refer to the diagram of the Ebola life-cycle below to help you answer the question that follow:*



Choose the correct statement:

J It is the human cells DNA which is responsible for making new viral particles inside the cell.

K The viral particles move into the cell by exocytosis.

L Human cells are generally un-harmed by the virus.

M The viral particles make the proteins (coloured purple) that surround them as they leave the cell.

6. Which one of the following identifies a component or response by the human immune system in each of the appropriate categories?

	First line of defence	Innate response	Adaptive response
J	Skin	Phagocytosis	Inflammatory response
K	Coughing/sneezing	Histamine	Antibodies
L	Stomach acid	Antibodies	Helper T cells
M	Mucus	Inflammatory response	Complement proteins

(1 mark each)

7. Diseases can be spread in a range of ways. Droplet infection is one of these mechanisms.

   a) Explain what droplet infection is, how it enables the spread of the pathogen and give an example to illustrate your answer.

(3 marks)

   b) Name one other way in which a pathogen can be transmitted, giving an example to illustrate your answer.

(2 marks)

8. An epidemic can occur when a particular pathogen spreads disease in a short space of time. Epidemics can be caused by a number of factors. Using a relatively recent epidemic, from the last decade or so:

   a) Select the most likely factor that caused the epidemic to occur, explaining the reasons for your choice.

(3 marks)

   b) Predict the most likely method(s) that you believe are being used or should be used to contain such outbreaks.

(2 marks)

9. The virus which gives rise to AIDS consists of ribonucleic acid covered with a protein coat. One of the adaptations of the virus which assists in its survival and spread is its ability to change its protein coat. Explain how this ability can aid in its survival and spread.

(3 marks)

10. Pathogens possess or display a range of adaptations that facilitate their entry, survival and reproduction inside hosts.

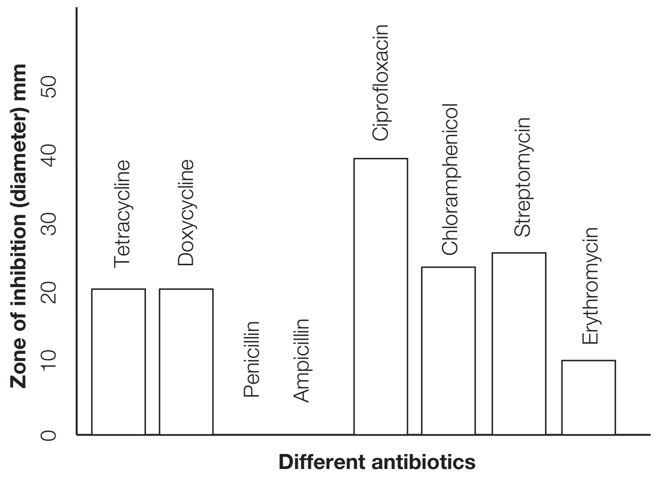
Give two specific examples of pathogens and the adaptations they possess.

Describe for each, how these adaptations increase their chances of survival and in the spread of the pathogen from host to host.

(6 marks)

Science Inquiry Skills

11. *Refer to the information and graph below* of an investigation into the effectiveness of eight different antibiotics on the growth of one bacterial species. The antibiotics are soaked into filter paper which is placed on an agar plate coated with the bacteria. To measure the effectiveness of the antibiotics in inhibiting bacterial growth a measurement is taken of the 'zone of inhibition'. The greater the zone, the more effective the antibiotic is in reducing bacterial growth.



a) Write the aim of the investigation.

(2 marks)

b) Explain a possible reason why different antibiotics are not equally effective at inhibiting the growth of the bacteria.

(2 marks)

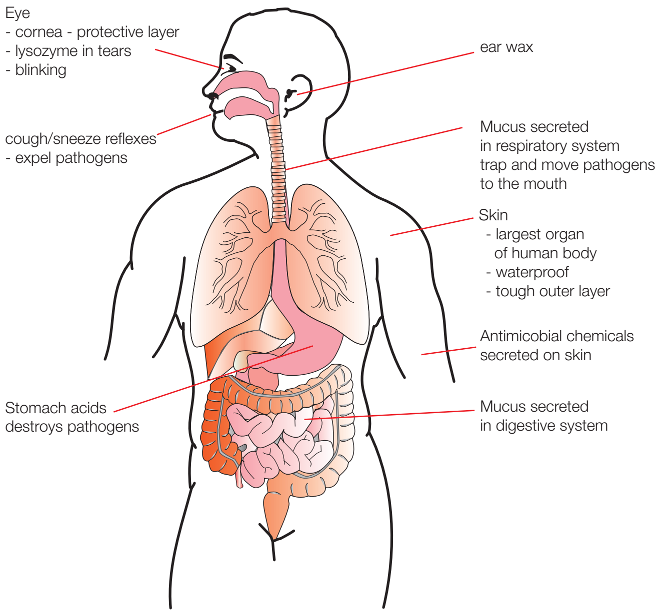
c) State which antibiotic you would use on a person who was infected with this particular strain of bacteria and give your reasons.

(2 marks)

d) Explain the difference between antibiotics and antiseptics, describing where each is most effective in reducing the negative impact of pathogens.

(3 marks)

12. Explain why the ability to change its outside protein coat makes it difficult to develop a vaccine against the HIV virus. Refer to the diagram below to assist you in answering the questions that follow.



a) This diagram illustrates examples of non-specific or innate defence mechanisms. Describe the difference between non-specific and specific defence mechanisms.

(2 marks)

b) There are both physical and chemical mechanisms that provide non-specific protection against invading pathogens. Give an example of each and describe how each example helps protect humans from attack by pathogens.

- Physical

(3 marks)

- Chemical

(3 marks)

13. An experiment was conducted to observe responses of an organism to infection by a pathogen. For each of the observations below explain the likely biological processes responsible.

a) An increase in red colour and temperature of the skin.

(2 marks)

b) An increase in the number of white blood cells in the area.

(2 marks)

14. Name the cell types that carry out particular roles in the specific defence (adaptive immune) system.

a) Cells that produce antibodies.

(1 mark)

b) Cells that can destroy human cells infected with virus particles.

(1 mark)

c) Cells that can provide memory to a specific pathogen and boost the secondary response.

(1 mark)

15. When a woman is pregnant, antibodies for some specific diseases may move across the placenta and enter the bloodstream of the foetus.

a) State the name of this type of immunity.

(1 mark)

b) Give reasons why this immunity does not last for very long.

(2 marks)

c) In individuals who are allergic to certain substances (e.g. pollen), it is often noticed that this allergy gets worse as the person is exposed on many occasions to the pollen. The allergic response is caused by the immune system. Put forward an argument to explain this observation.

(2 marks)

Assessment Key

Assessment Design Criteria	Questions where this could be assessed
IAE1	11a
IAE2	-
IAE3	11b, 11c
IAE4	-
KA1	1, 2, 4, 5, 7a, b, 8a, b, 9, 11d, 12a, b, 14a-c, 15a
KA2	3, 6, 13a, b, 15b, 15c
KA3	-
KA4	10

Topic 2 Test Yourself - Suggested answers

These answers for each part of each question provided here are suggestions. They are not intended to be the only answer. Read and use them carefully to self-assess your performance in the test. Consider asking someone in your class to peer-assess them as well, then discuss. Make notes of errors for future reference and seek the assistance of your teacher as required.

1. L 2. J 3. M 4. K 5. J 6. K

7. Regarding the spread of diseases:

   a) Droplet infection is when a pathogen is transmitted from one person to another by droplets of moisture from the upper respiratory tract. The pathogens are present in large numbers, trapped inside the bubbles or droplets of moisture which are expelled by a cough or sneeze. Colds can be spread in this manner.

   b) Several possibilities including direct contact (sexually-transmitted HIV), faeces, contaminated food (salmonella).

8. Regarding epidemics:

   a) For example Ebola; caused by the Ebola virus. May have been caused when hunters of infected animals consumed meat products. No prior exposure, very virulent strain therefore no immunity built up. Other diseases include SARS, Zika etc.

   b) One very important method is education; to better inform communities of the risks and how to better protect themselves. Another important method is better hygiene and medical practices to treat and isolate diseases and contain the outbreaks.

9. Humans develop their ability to fight off specific pathogens by recognising specific antigens on the exterior of the pathogen. If this antigen changes, the human does not recognise it as the same pathogen, and they need to build up protection or immunity over again. This period of time allows the virus to evade the immune system, survive and spread.

10. *There are a range of possibilities here, two {(a) and (b)} have been presented below in note form for convenience. Note that the accepted format in a test or examination needs to be in the form of sentences and paragraphs.*

    a) **Pathogen** - virus e.g. influenza virus

    Adaptation - the ability to change its outer antigen by coding for different proteins

    Survival - this enables the virus to evade the immune systems of people who may have been previously exposed to the virus or received a previous vaccination.

    Spread - the virus can now be spread e.g. droplet infection

    b) **Pathogen** - A Protist (e.g. Plasmodium)

    Adaptation - life cycle with more than one host, in this case a human and a mosquito

    Survival - Very difficult to control with spread of the protist via mosquitos

    Spread - Anyone who is bitten by an infected mosquito could contract the disease

11. With reference to the data:

    a) To investigate a range of antibiotics and compare their effectiveness in destroying the specific bacteria.

    b) Antibiotics work in a range of ways including stopping cell wall production or interfering with protein synthesis. Some bacterial strains may be resistant to particular antibiotics as they have evolved changed genetic make up which enables them to overcome the effects of this antibiotic.

    c) Ciprofloxacin; it has the greatest zone of inhibition implying that it inhibits or destroys the bacteria more than any of the other antibiotics tested.

    d) Antibiotics operate inside the body, chemicals that destroy bacteria internally. Antiseptics kill microbes on the exterior of the body e.g. hydrogen peroxide, iodine

12. With reference to the diagram:
    a) Non-specific defence mechanisms are mechanisms that are more general in their mode of action, they are usually barriers or traps and are effective against a range of pathogens. Specific defence mechanisms target specific pathogens e.g. lymphocytes producing a specific antibody.
    b) Defence mechanisms include:
    - Physical; coughing and sneezing. Irritation by pathogens in the upper respiratory tract initiates the physical actions of coughing/sneezing which act to push or expel pathogens from the body.
    - Chemical; stomach acid. Acids in the stomach have a low pH which simply destroys many bacteria and thus reduces their numbers either totally or significantly and thereby reduces the chance of disease.
13. Regarding likely biological processes:
    a) This is most likely related to the inflammatory response which is designed as a non-specific response to destroy pathogens. The red colour and temperature are both linked to increased blood flow to an area carrying white blood cells and chemicals associated with destroying the pathogen.
    b) When chemicals within the body are secreted in response to the pathogen e.g. complement proteins, one of the effects is that white blood cells are attracted to the area. The white blood cells could be macrophages that engulf and destroy pathogens like bacteria.
14. The cells are:
    a) B lymphocytes --plasma cells
    b) natural killer cells
    c) B and T lymphocyte memory cells
15. Regarding pregnancy:
    a) Passive immunity
    b) Antibodies are protein molecules produced by plasma cells. They work by combining with and inactivating antigens but last only for a relatively short period. The B cells and T cells involved in active immunity have not been stimulated so there is no memory to the disease.
    c) The pollen is seen as 'non-self' or foreign and brings about an immune response against the pollen antigens. This also stimulates B and T memory cells which build up in the lymph system over time and then on subsequent exposures, therefore the response is greater and lasts longer.

Topic 3 Multicellular Organisms

Chapter 3.1 Cell differentiation

Science Understanding

Specific cell structure and functions develop through cell differentiation.

Recognise that:

- cells in a multicellular organism are genetically identical.
- gene expression is responsible for cell specialisation.

(Note: there is some overlap between Topics 1 and 3 so our apologies if you have seen some of this before!)

Cell specialisation

Multicellular organisms consist of large numbers of specific types of cells. Specific cell types have a different structure. The structure of some different types of animal and plant cells is shown in *Figure 311.*

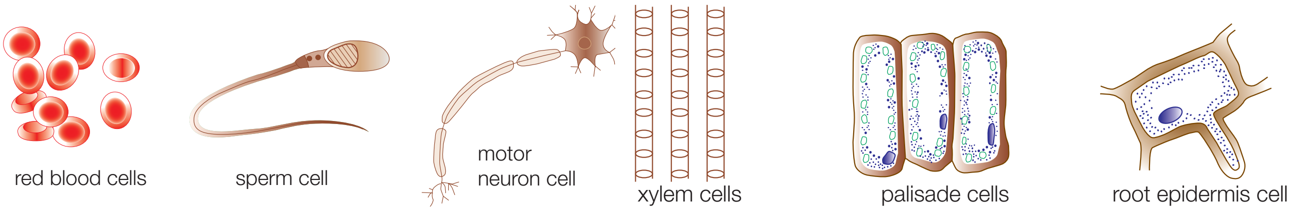


Figure 311 A variety of specialised animal and plant cells

Specific cell types have a different structure to permit them to perform a specific function. This is called **cell specialisation.** The structure and function of some specialised cells in animals and plants is shown in the following table.

Cell type	One structural aspect	Function
Sperm cell (in testes)	Has a tail-like structure called a flagellum	To move sperm towards an ovum
Motor neuron (in a nerve)	Has a very long insulated extension called an axon	To transmit nerve impulses efficiently and at high speed to a muscle or a gland
Red blood cell	Has a cytoplasm without a nucleus packed with haemoglobin	To help maximise the transport of oxygen in blood around the body
Palisade cell (in leaves)	Has a cytoplasm with large numbers of chloroplasts	To help maximise the absorption of light for photosynthesis
Xylem cell (in roots, stems and leaves)	Has a tube-like structure supported by rings of a substance called lignin	To transport water and dissolved minerals from the roots to cells in leaves
Root epidermis cell	Has a thin cell wall and a cytoplasm extension called a root hair	To maximise the absorption by roots of water by osmosis and minerals by active transport

DNA

Cells with a specific structure and function form during the development of all multicellular organisms. This involves segments of **DNA** and the synthesis of vital molecules called **proteins.**

DNA is a very long molecule that carries genetic information. For most of the life of a cell from a multicellular organism, the DNA in the nucleus consists of long, loosely packed strands called **chromatin**. Just before such cells divide, however, chromatin coils up around proteins called histones and forms into pairs of short, tightly packed strands of DNA called **chromosomes**. The organisation of a chromosome in the cell of a multicellular organism is shown in *Figure 312.*

Helpful Online RESOURCE to learn more about DNA

To learn more about chromosomes use this QR code to visit:

<https://learn.genetics.utah.edu/content/basics/dna>

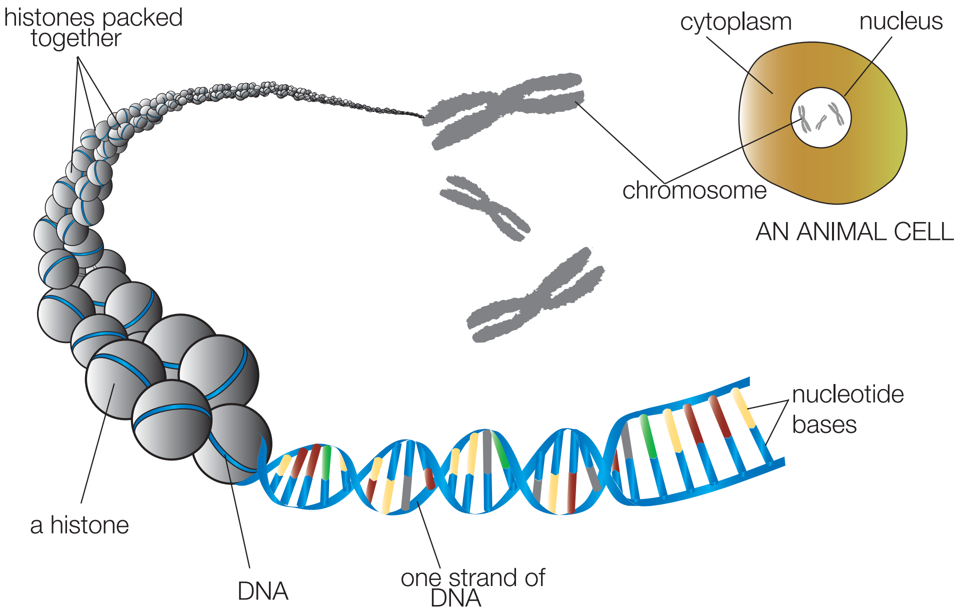


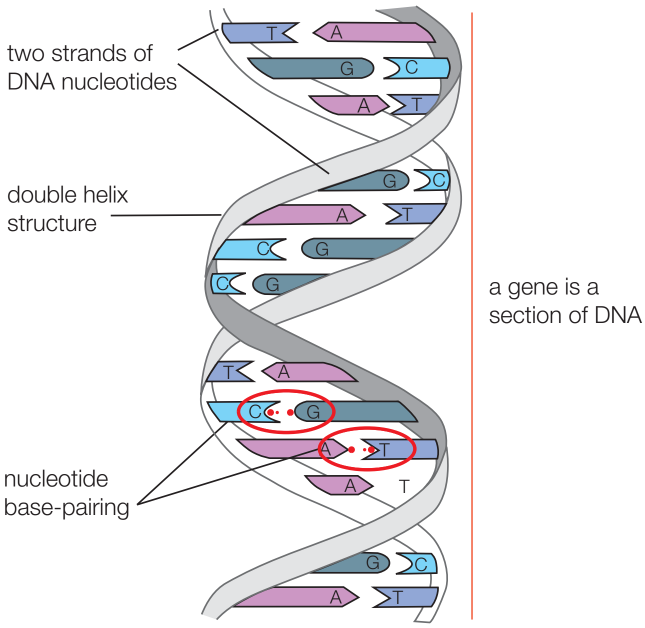
Figure 312 The relationship of the cell, a chromosome and DNA

Genes

DNA is made up of two strands of smaller molecules called **DNA nucleotides.** These carry one of four chemicals called nucleotide bases – adenine (A), thymine (T), cytosine (C) and guanine (G). According to the Watson and Crick model for DNA structure, the two strands of DNA are twisted about each other to form a double helix. The double helix is stabilised by weak forces of attraction that form between pairs of bases called hydrogen bonds. A always base-pairs (or hydrogen bonds) with T at the same location on the other DNA strand, and C base-pairs with G.

The sequence of DNA bases (or A, T, C and G) on one DNA strand is called the genetic code. Segments of many thousands of bases on this strand that store genetic information are called **genes**. Most genes have regions of **coding DNA** (or exons) between a lot of **non-coding DNA** (or introns). All the genes in a cell of a multicellular organism are called the **genome**. Recent research estimates the human genome at approximately 21,000 genes.

Part of a DNA molecule, with its double helix structure is shown in *Figures 313(a)* and *313(b)*. *Figure 313*(a) illustrates the double helix molecule with complementary base pairing A-T and G-C. *Figure 313*(b) illustrates the double helix with the possible location of a gene (orange glow).



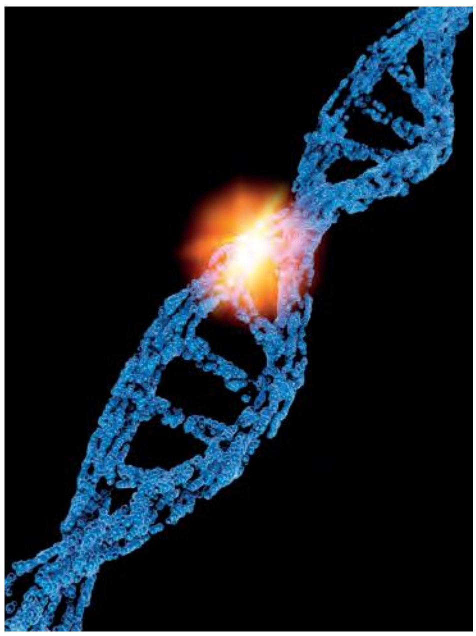


Figure 313(a) and (b) Models illustrating part of a DNA molecule showing a hypothetical gene

Helpful Online RESOURCE to learn more about proteins

To learn more about genes, use this QR code to visit:
<https://learn.genetics.utah.edu/content/basics/proteins/>

Protein synthesis

The cytoplasm contains a large collection of chemicals called **amino acids**. Twenty types of amino acids are found in the cells of multicellular organisms. The coding DNA carries genetic information the cells of multicellular organisms use to produce a sequence of amino acids called a **polypeptide**. A polypeptide, or several polypeptides, fold in a precise way to form a molecule called a **protein**. The production of a protein by cells using genetic information encoded in a specific gene is called **protein synthesis.**

Protein synthesis includes:

- the unwinding of the DNA double helix to 'expose' the gene.
- a protein called **RNA polymerase** binding to DNA near the gene.
- RNA polymerase moving along the whole gene to make a new molecule called **messenger RNA**; this process is called **transcription.**
- messenger RNA (mRNA) being transported out of the nucleus to ribosomes in the cytoplasm.
- ribosomes moving along the mRNA strand and assembling amino acids into a specific polypeptide; this process is called **translation**.
- the polypeptide folding into a precise 3D shape forming a functional protein.

Transcription in the nucleus and translation at a ribosome are shown in *Figure 314*. Note that these processes are shown for a eukaryotic cell with a nucleus. In prokaryotic cells the process is similar but there is no nucleus.

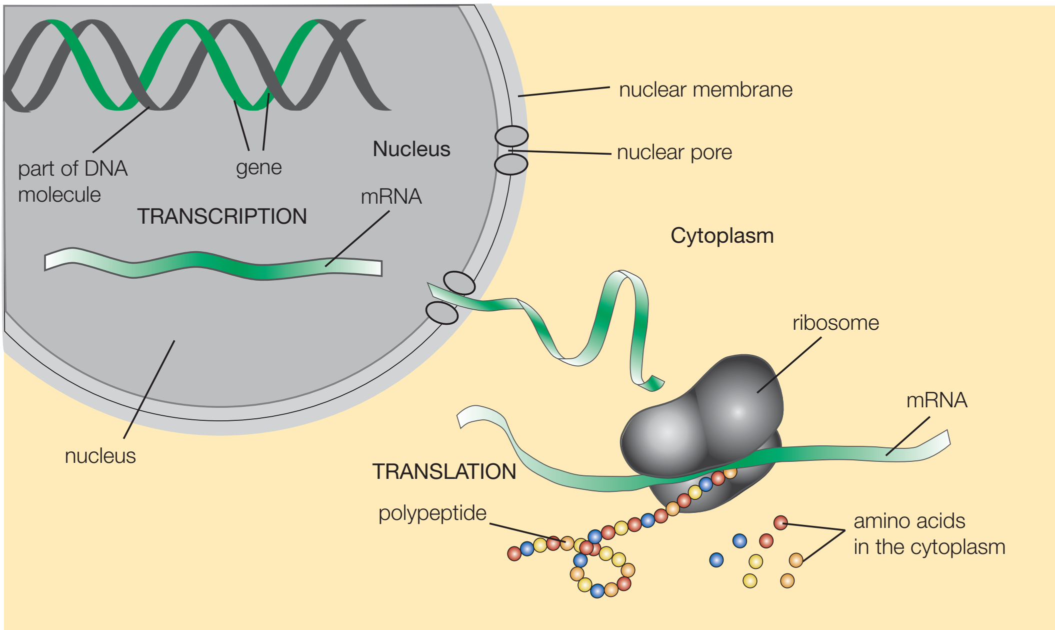


Figure 314 The main processes involved with protein synthesis

Helpful Online RESOURCE to view an EVA on protein synthesis

To view an Essentials Video Animation (EVA) on this topic, use this QR code to visit:
<http://essentialseducation.com.au/resources/sace-1/biology/protein-synthesis/>

3.1

Cell differentiation

Cells in a multicellular organism develop differently to become specialised. The production of specialised cells is called **cell differentiation.** All cells differentiate by producing specific proteins; for example, a tail-like flagellum arises during the development of a sperm cell due to the production of strands of proteins called **microtubules** that move the flagellum from side-to-side. This structure of a sperm cell flagellum is shown in *Figure 315*. Refer to *Figure 316* which illustrates the first stage of gene expression. The chromosome and DNA is unravelled and then transcription (see *Figure 314*) occurs to produce a molecule of mRNA.

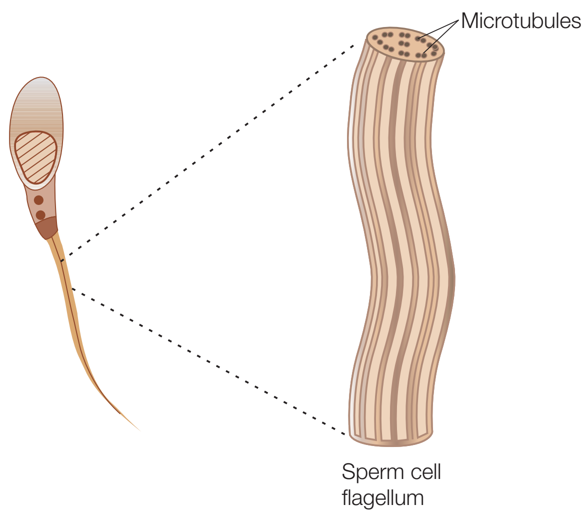


Figure 315 Cell differentiation in a sperm cell

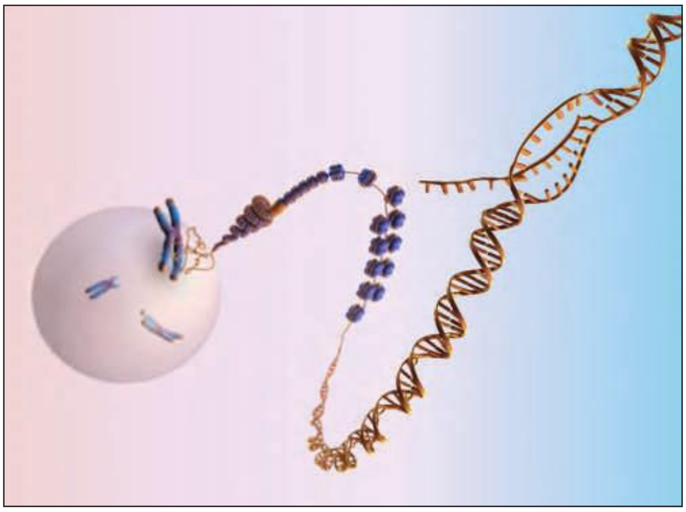


Figure 316 The first stage of gene expression

Gene expression

It is important to recognise that cell differentiation does not take place in different types of cells in a multicellular organism because they carry different genes. All of the cells are genetically identical, or have same genome. Different types of cells form in multicellular organisms because their cells use some genes to produce specific proteins, but not others. This is called **gene expression**.

Switching genes on/off

Gene expression in cells is very tightly controlled. Any gene that is expressed, which means the genetic information it carries is being used to produce a specific protein, is said to be switched on. Genes that are present in cells but are not expressed are said to be switched off.

The cells of all organisms continually switch genes on and off; for example, in response to chemical 'signals' in their internal environment and from the external environment around them. Switching genes on and off permits periods of development; for example, cell differentiation, **embryo** development and growth and development after birth. The switching on and off of different genes by cells with identical genomes is called **differential gene expression**.

One way cells switch genes on/off is by allowing or preventing transcription. If RNA polymerase can bind to DNA near a gene called the **promotor**, the gene is switched on because transcription occurs. A gene is switched off when RNA polymerase cannot bind to the gene's promotor.

Cells may control the access RNA polymerase has to a gene in a variety of ways. These include:

- the action of **activators**. When these proteins bind to a gene's promotor, DNA in that region changes shape slightly. This 'opens DNA up' making the gene accessible to RNA polymerase.
- the action of **repressors**. When these proteins bind to the promotor of a gene the structure of some of the surrounding histones changes. This causes DNA in that region to more tightly coil making the gene less accessible to RNA polymerase.

Gene expression during embryo development

If sperm are present in a fallopian tube at around the same time as a 'live' ovum there is a chance one of them will fertilise it. The initial product of fertilisation is a single cell called the **zygote**.

After fertilisation, the zygote divides many times by a type of cell division called **mitotic division**. This causes it to form into a ball of genetically identical cells called **embryonic stem cells**. During the next 5-7 days the dividing ball of cells then forms into a morula and later a blastocyst that may attach to and implant into the uterus lining. After implantation the blastocyst continues to make new genetically identical cells by mitotic division and forms into a large mass of cells called an embryo. The journey of a dividing ball of cells to its attachment to the uterus lining is shown in *Figure 317*.

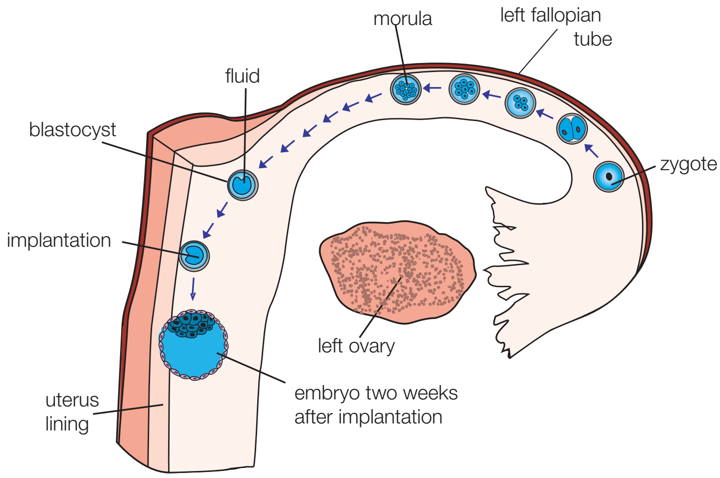


Figure 317 The formation of an embryo

Once produced, the embryo's cells begin to differentiate. Selective switching of genes on/off causes its cells to grow and develop in different ways. This leads to the formation of different cell types that are specialised to perform a specific function. In humans the development of the zygote through mitotic division and cell differentiation ultimately leads to the production of 230 different cell types. Some of these are shown in *Figure 318.*

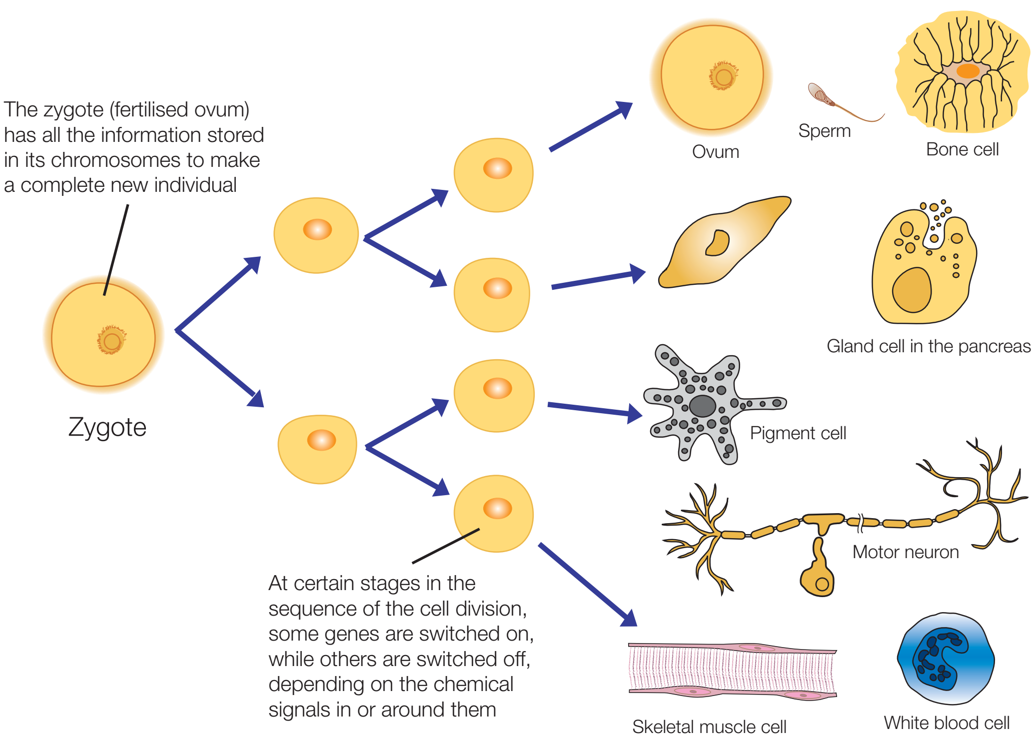


Figure 318 The differentiation of some cells in a human

As the embryo develops, different cell types become organised into tissues, organs and organ systems. During **morphogenesis**, the general structure and shape of the baby takes place.

The role of environmental factors in gene expression

The growth and development of a multicellular organism after birth is carefully regulated by differential gene expression. Specific genes in the **genotype** of an organism are switched on/off at key moments during a multicellular organism's life to ensure it becomes a fully functional, healthy adult. This is done in response to chemical signals inside cells that regulate the transcription of genes; for example, through the roles of activator and repressor proteins.

It has been discovered that factors in a multicellular organism's environment influence the expression of its genes. This is because DNA and the histones around which it is coiled in chromosomes are covered with a structure of chemicals called the **epigenome**. The epigenome is able to tightly coil collections of genes which switches them off, or 'silences' them, and uncoil other sets of genes switching them on, or 'activating' them. The scientific study of the epigenome and factors that affect it is called epigenetics.

Researchers have found that 'epigenetic chemicals' respond to signals that are associated with a multicellular organism's diet, how much physical activity it does and the amount of stress it is under. Signals like these trigger changes in gene expression that in turn influences the **phenotype** of the organism, or its physical structure, appearance and internal physiology. In recent years, there has been a lot of interest in the effect of diet on the epigenome; for example, regular consumption of broccoli and garlic for a sustained period of time has been shown to switch on 'anti-cancer' genes. The scientific study of the connections between the epigenome and diet is called **nutrigenomics**.

Figure 319 'Identical' twins are rarely identical

Studies of the development of identical twins provide an example of the role environmental factors have on the phenotype of individuals. Identical twins result when an embryo splits in two and continues to grow and develop into two babies. When they are born both of the twins have identical genomes and virtually identical epigenomes because they are living in the same house/environment. As the twins get older and become more independent, their environments start to become more different; for example, they consume different foods or may do different amounts of exercise. This leads to different signals interacting with their epigenomes, activating or silencing different genes. Hence why the middle-aged identical twins shown in *Figure 319* do not look exactly the same.

Key Concepts

1. Cells are specialised in structure to perform a specific function.
2. The information cells need to synthesise proteins is carried in segments of DNA called genes.
3. Protein synthesis involves transcription of a gene and then translation of mRNA.
4. Cells of a multicellular organism are genetically identical, or have the same genome.
5. During development a multicellular organism's cells differentiate, or develop in different ways.
6. The specialisation of cells is caused by differential gene expression.
7. Cells have a variety of mechanisms for switching genes on and off.
8. Gene expression is tightly regulated during embryo development, and after birth.
9. Environmental factors alter gene expression, and therefore a multicellular organism's phenotype.

What have you learned?

Key Terms

cell specialisation
DNA
protein
chromatin
chromosome
gene
coding DNA
non-coding DNA
genome
transcription
translation
polypeptide
cell differentiation
amino acid
protein synthesis
RNA polymerase
messenger RNA
gene expression
differential gene expression
microtubule
promotor
activator
repressor
zygote
embryo
epigenome
genotype
phenotype
DNA nucleotide
mitotic division
embryonic stem cell
morphogenesis
nutrigenomic

Knowledge and Understanding

1. Draw a diagram of one type of cell from a plant and another from an animal. Label one structure specific for each cell and briefly outline how this structure permits each cell to perform its particular function.

-
-

2. Describe the structure of DNA according to the Watson and Crick model. Explain the importance of base pairing in this model.

3. Explain the difference between a polypeptide and a protein.

4. The making (synthesis) of polypeptides and proteins in cells is a vital process for cell growth and functioning. Protein synthesis consists of two main processes. What are these processes called and for each, describe in no more than two sentences and, possibly using a diagram, what is involved.

-
-

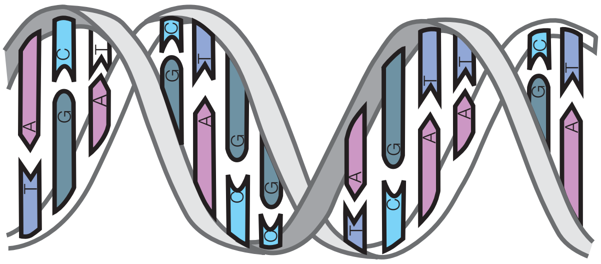
5. Genetically identical organisms, humans and otherwise, rarely appear the same, particularly when they are mature. Explain how such organisms become different as they grow and develop.

Application, Analysis and Evaluation

6. Cells in a multicellular organism are genetically identical; they all carry the same genes. How then can they form into specific cell types that are different in structure and function?

7. Compare the actions of activators and repressors in controlling gene expression.

8. The following diagram shows part of a molecule found in cells.



Provide two pieces of evidence that this is part of a molecule of DNA.

These URLs are relevant to the SHE activity on the next page

Helpful Online RESOURCE about children with SMA

To learn more about the devastating impact of SMA on children view the clip below:

<https://www.youtube.com/watch?v=63yMbYMTFD8>

Helpful Online RESOURCE about the case for SMA screening

To learn more about the case for SMA screening in Australia view the clip below:

<https://www.youtube.com/watch?v=lAFnZzFKmEs>

Science as a Human Endeavour 3.1 - Genetic screening for SMA

Communication and collaboration

Science ... relies of clear communication ... review and verification ...

Every newborn baby in Australia is able to have a standard newborn genetic screening test. This involves taking a blood sample from the baby's heel (***Refer to the photo***). DNA isolated from the blood is then tested to identify genes associated with the development serious genetic conditions. Examples include disorders of the respiratory and/or digestive system (e.g. cystic fibrosis that results in the excessive production of mucus) and of cell metabolism (e.g. phenylketonuria or PKU that can lead to brain damage and intellectual disabilities).

Research that provided the groundwork for newborn genetic screening began in the 1950s. By the early 1960s, the results of those early studies led to the introduction in America of a genetic screening test for PKU, the first to be developed. Review of the PKU test by doctors in other countries saw the PKU test adopted elsewhere, including in Australia in 1964. Communication between scientists and medical practioners throughout the 1970s and 1980s saw new tests added to newborn genetic screening. This included a test for cystic fibrosis in Australia in 1981 and in some American states shortly after in 1982. By the mid-1990s, newborn genetic screening being done by many countries could identify 30 genetic disorders.

In late 2018, a two-year trial began in New South Wales to monitor a genetic test for spinal muscular atrophy (SMA), a condition caused by the progressive death of motor neurons (nerve cells that control muscle movement). SMA affects about one in 10,000 births in Australia. It is the leading cause of infant death in Australia, and there is no cure.

The test is now part of the NSW newborn genetic screening program (and that of the ACT) details of which have been communicated Australia-wide as well as to an international audience of researchers, medical policy experts and a diversity of other interested onlookers.

You may need to refer to the online resources (previous page) to answer the questions that follow:

1. Suggest how collaboration between scientists, governments and other agencies was instrumental in implementing these infant tests.

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2. Suggest how national and international communication may assist Australian medical practitioners in deciding whether to include the SMA test in newborn screening programs.

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Chapter 3.2 The organisation of multicellular organisms

Science Understanding

Multicellular organisms have a hierarchical structural organisation of cells, tissues, organs and systems.

- Use examples from plants and animals to explain organisation of cells into tissues, tissues into organs, organs into systems.
- Illustrate the relationship between the structure and function of cells, tissues, organs and/or systems.

Organ systems in a multicellular organism are interdependent and function together to ensure the survival of the organism.

Lifestyle choices affect the functioning of organs and systems.

Hierarchical structure of organisation

A system that is based on different levels of organisation in which each level of organisation forms part of the next higher level is called a **hierarchy**; for example, in an army, soldiers report to Sergeants who report to Majors who themselves report to Colonels who are supervised by Generals.

All multicellular organisms have a hierarchical structure of organisation. Their cells are organised into **tissues**, different tissues are organised into **organs**, and organs are organised into **organ systems.** The hierarchy of organisation of multicellular organisms is shown in *Figure 321.*

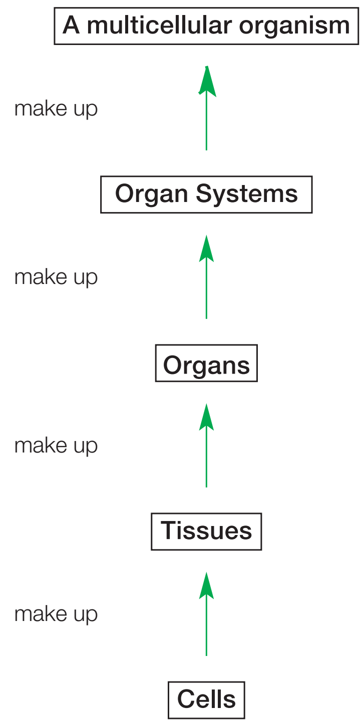


Figure 321 The hierarchy of organisation in living things

Animal cells and tissues

A good example of the way an animal is organised is a human being. The human body is made up of 230 different specialised cell types. A collection of specialised cell types grouped together to perform a specific function is called a tissue. Four types of human tissue are:

- Nerve tissue; for example, nerve tissue in the brain made up of nerve cells called **neurons.**
- Muscle tissue; for example, muscle tissue in the arm made up of muscle cells called fibres.
- Connective tissue; examples include skin and blood that is made up of red and white blood cells.
- Reproductive tissue; for example, in a male, tissue in the testes that produces sperm.

Some types of human cells and tissues are shown in *Figure 322.*

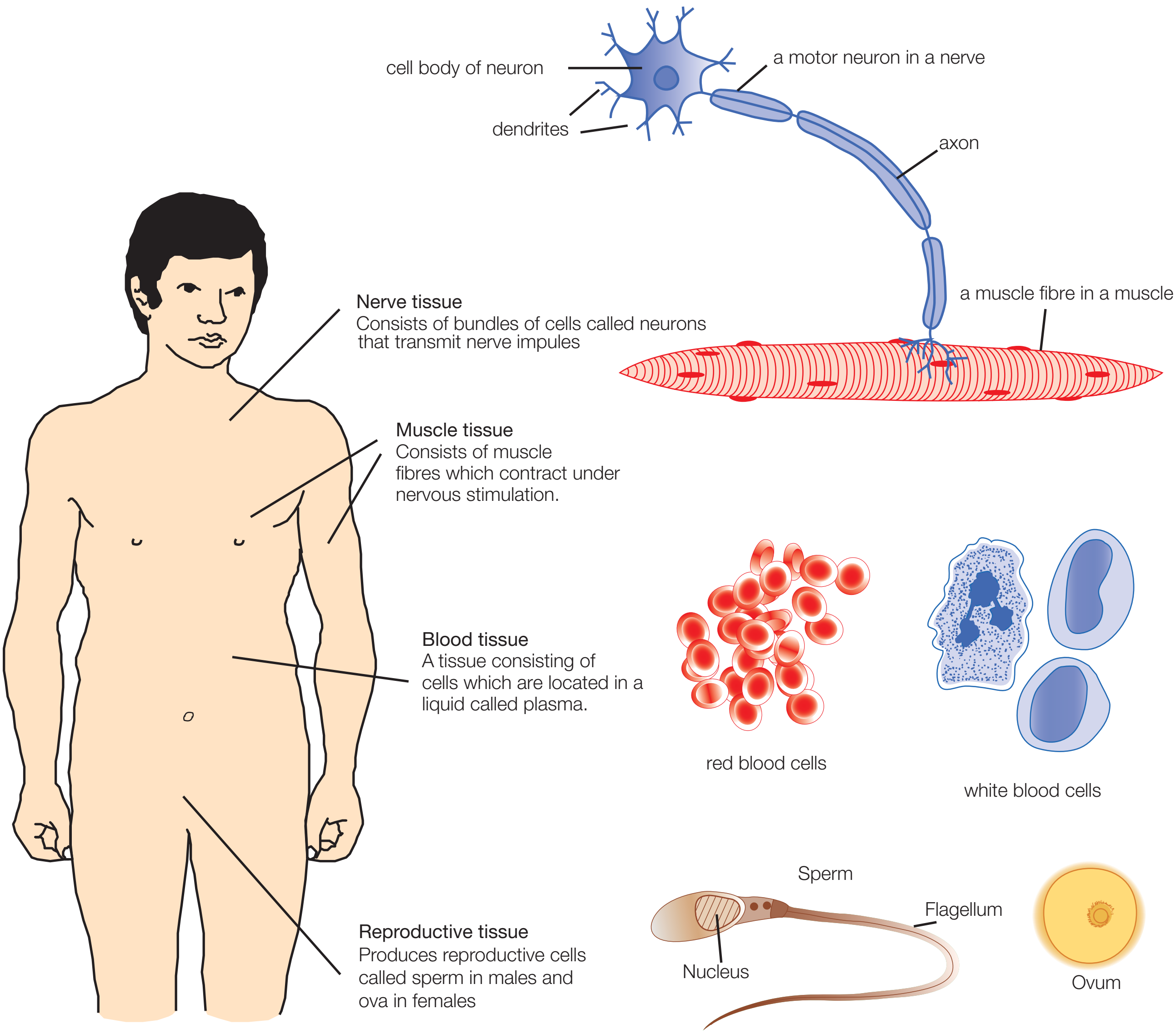


Figure 322 Some human cells and tissues

The structure and function of animal tissues

Different tissues in the body consist of different specialised cells to permit them to perform a specific function. Nerve tissue is able to transmit nerve impulses because it consists of a bundle of neurons. Many nerves contain two types of neurons; sensory neurons and motor neurons. The ‘bundle of fibres’ structure of muscle tissue allows it to contract and cause movement. Skin (epidermal) tissue consists of tightly packed skin cells and serves as a barrier to protect underlying tissues from dehydration, invasion by pathogens and other damage as shown in *Figure 323.*

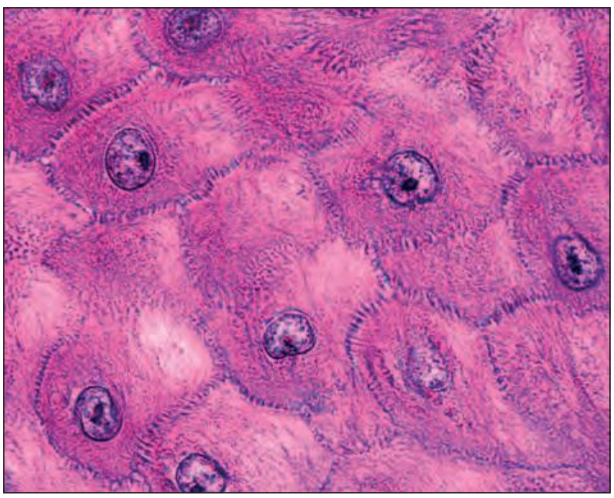


Figure 323 Skin epidermis (~x800)

Animal tissues and organs

A collection of different tissues grouped together to perform a specific function is called an organ. Examples of human organs are:

- The heart that includes a muscle tissue called **cardiac muscle**, nerve tissue and blood.
- Bones that include mineralised or strengthened connective tissue, nerve tissue and blood.

The structure and function of animal organs

The structure of an animal organ is related to its function. For example, the function of the stomach is to help mechanically digest food, kill bacteria and start chemical digestion of protein. Mechanical (or physical) digestion involves forces breaking down food into smaller pieces. The stomach can contribute to this type of digestion because its walls contain smooth muscle tissue that can contract, slowly turning its contents. This function of the stomach is supported by the presence of loose connective tissue in the walls. The stomach can kill bacteria in food because cells in its epithelial tissue can produce and release a 'lethal-to-bacteria' acid into the stomach called hydrochloric acid. The stomach is able to begin chemical digestion of proteins in food because there are also cells in its epithelial tissue that produce and release protein-digesting enzymes called **proteases**. These types of tissue and how they are organised in the stomach is shown in *Figure 324*.

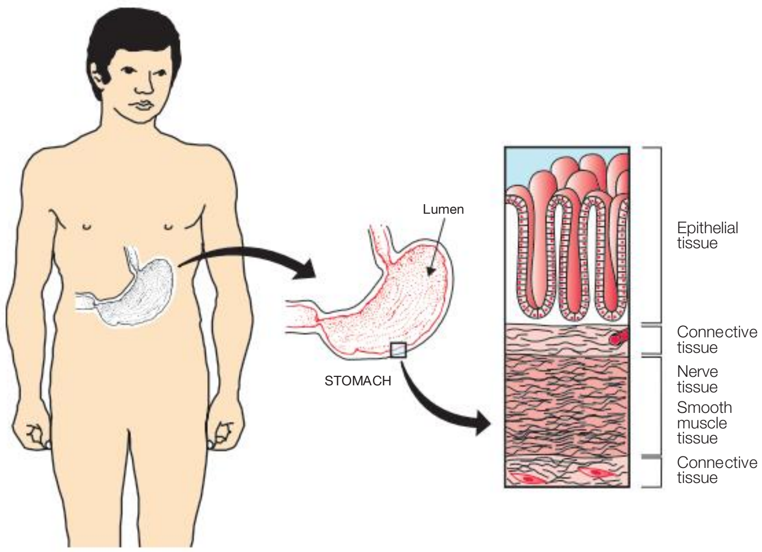


Figure 324 Some tissues of the stomach

Animal organ systems

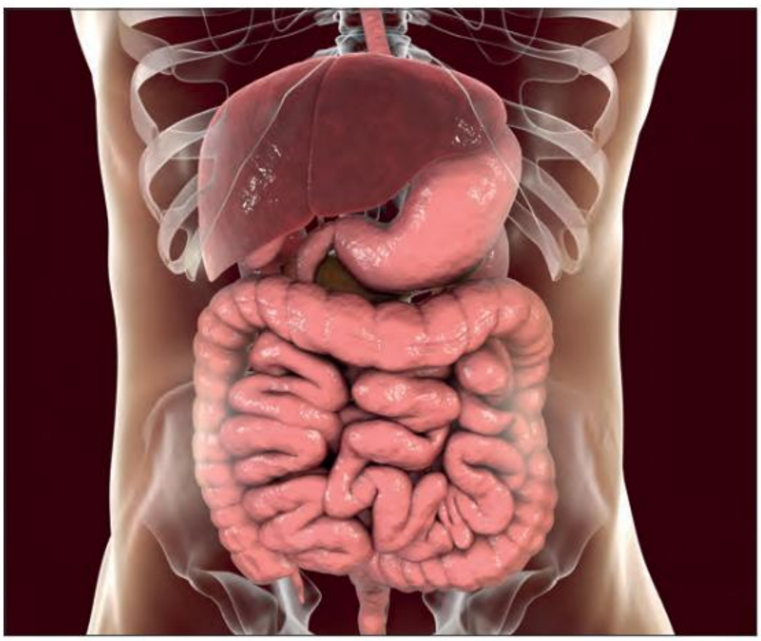


Figure 325(a) The Human Digestive system

Figure 325(b) The Human Circulatory system

Refer back to *Figure 325(a)* illustrating the human digestive system and several of the organs that work together to enable the body to break down (digest) food and absorb the products. Organs visible include the liver, stomach, gall bladder and intestines. Refer also to *Figure 325(b)* illustrating the human circulatory system showing the heart, arteries and veins.

Different organs grouped together to carry out a function are called an organ system. Some human organ systems, organs they consist of and their main functions are shown in the following table.

3.2

ORGAN SYSTEM	Major organs	Main function in the body
Respiratory system	Trachea, lungs, bronchi, bronchioles, diaphragm	Uptake of oxygen, removal of carbon dioxide
Digestive system	Oesophagus, stomach, small intestine, large intestine, pancreas, liver	Breakdown of food to form products that may be absorbed
Excretory system	Kidneys, ureters, bladder, urethra	Removal of nitrogen-containing waste, maintaining water/salt balance in blood
Circulatory system	Heart, arteries, veins	Transport of materials, exchange of materials, maintaining body temperature
Nervous system	Brain, spinal cord, sense organs	Coordination of body activities, detection of/response to stimuli

C

Plant cells and tissues

A good example of the way a plant is organised is a flowering plant; for example, a rose or a eucalypt. Like animals, specialised cell types group together to form tissues in flowering plants. Four types of flowering plant tissue are:

- **Epidermis tissue**; for example, epidermis in which cells with a root hair are found near root tips.
- **Xylem tissue**; for example, xylem inside the stem made up of tube-like cells called xylem vessels.
- **Mesophyll tissue**; for example, mesophyll in leaves made up of palisade and spongy mesophyll cells.
- **Reproductive tissue**; for example, in a flower cells in the ovary that produce ova.

Some types of flowering plant cells and tissue are shown in *Figure 326.*

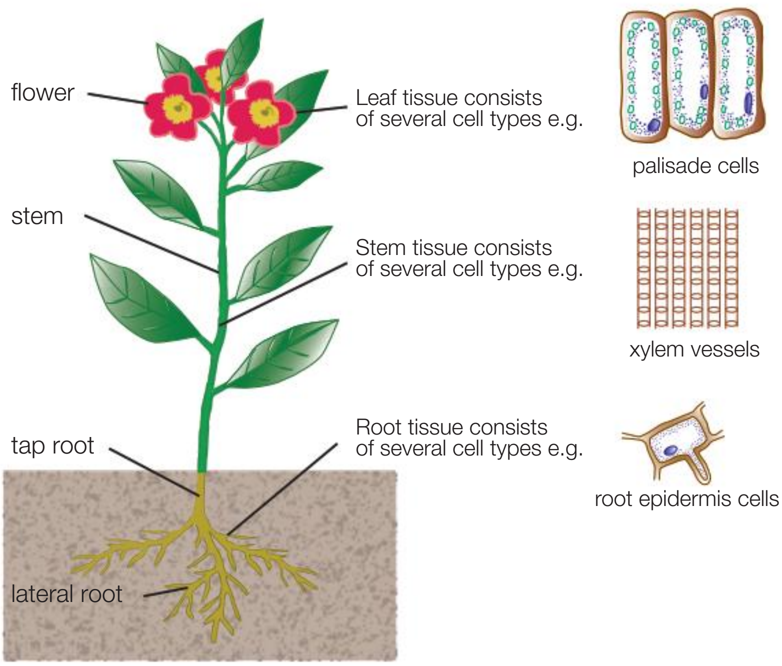


Figure 326 Some flowering plant cells and tissues

The structure and function of plant tissues

Flowering plants have different tissues made up of groups of different specialised cells to enable them to carry out a specific function. Near root tips, the epidermis is a one-cell thick layer of tissue that includes root hair cells with an extension to maximise uptake of water/minerals from soil. The 'chains of xylem vessels' structure of xylem in the stem allows it to transport water and dissolved minerals from roots to other parts of the plant. This relationship between the structure and function of flowering plant tissue is shown in *Figure 327*.

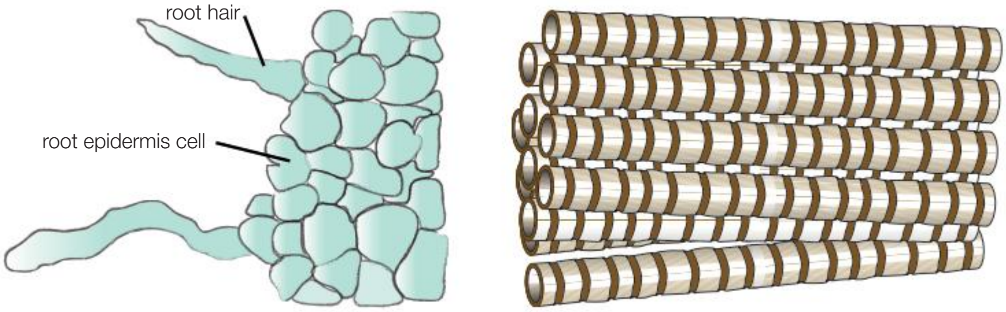


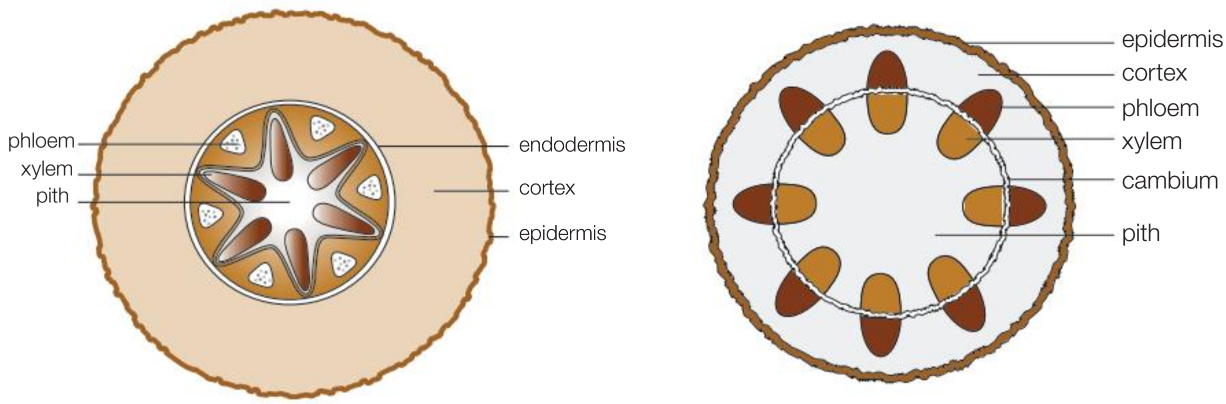
Figure 327 (a) Epidermis tissue near a root tip and (b) Xylem tissue in the stem

Plant tissues and organs

Like animals, plants have organs that consist of different tissues grouped together to perform a specific function. Examples of flowering plant organs are:

- Roots that include epidermis tissue, tissues called cortex and **endodermis**, a central collection of xylem, another tube-like tissue called **phloem**, and an inner-most tissue called **pith.**
- The stem that includes epidermis tissue, tissue called **cortex**, bundles of xylem and phloem and pith.

The root and stem tissue in flowering plants that are **dicotyledons** are shown in cross-section in *Figure 328*.



Figures 328(a) Tissues in a dicotyledon root and 328(b) in the stem

The structure and function of plant organs

The structure of a plant organ is related to its function. The function of the leaf is to carry out photosynthesis to produce carbon containing molecules called organic molecules; for example, glucose. Photosynthesis can take place in leaves because its mesophyll tissue contains cells packed with organelles called **chloroplasts**. The structure of the leaf enables it to provide the mesophyll with the simple inorganic molecules it needs for photosynthesis – carbon dioxide and water.

Carbon dioxide can enter the mesophyll because there are pores in the lower epidermis tissue called stoma. Water can reach the mesophyll because veins in the leaf contain xylem that transport water to it. Enough light can enter the mesophyll because the upper epidermis tissue of the leaf is only one-cell layer thick. These types of tissue and how they are organised in the leaf is shown in *Figure 329*.

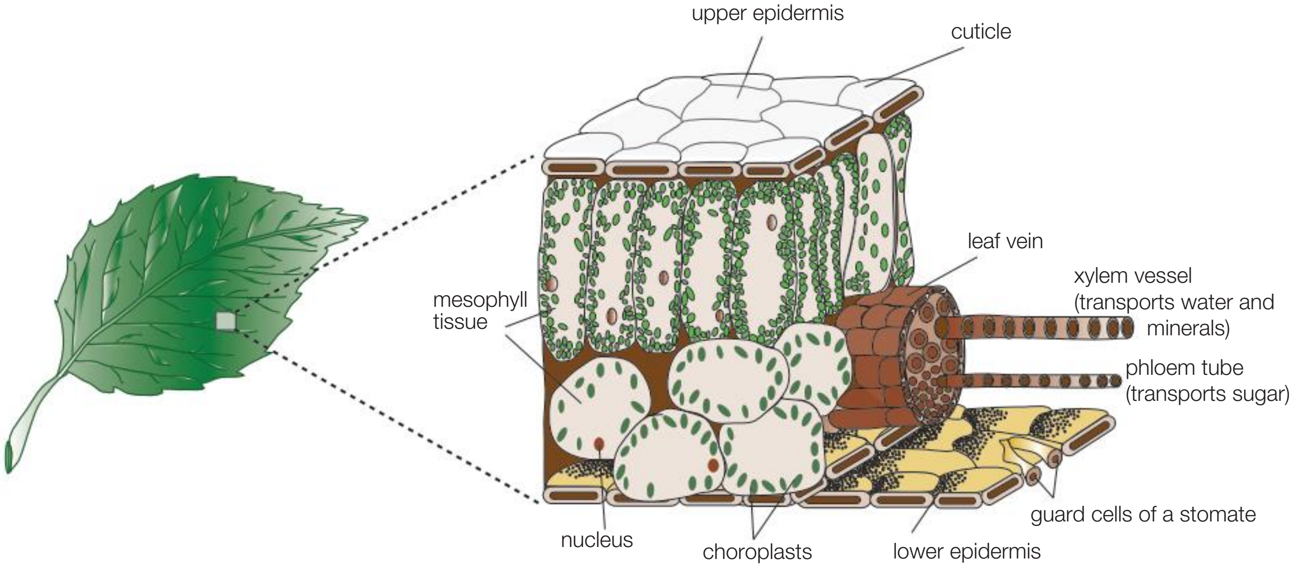


Figure 329 Tissues of a plant leaf

Plant organ systems

Plants have two organ systems; the **root system** and the **shoot system**. These are shown in *Figure 326.* Flowering plants that are dicots (dicotyledons) have a root system that consists of a central root called the taproot from which extend branching roots called lateral roots; for example, roses and eucalypts. Flowering plants that are **monocotyledons** lack a taproot – the monocot root system consists of many shallow roots that extend from the base of the stem; for example, grasses.

The base of the stem in some monocots is specialised to form a bulb that stores food for the plant; for example, daffodils. The shoot system of flowering plants usually consists of a stem and leaves and, at certain times of the year, specialised parts of the shoot system produce flowers. The organ systems of a flowering plant, the organs they are composed of and their main function are shown in the following table.

ORGAN SYSTEM	Major organs	Main function in a flowering plant
Root system	Taproot, lateral roots – in dicots	Anchor the plant
	Shallow roots – in monocots	Take up water and minerals from the soil
Shoot system	Stem	Transport of materials
	Leaves	Produce organic molecules and exchange gases

The interdependence of organ systems

Organ systems do not operate in isolation. They are interdependent. The function of each one is dependent on the proper function of the other organ systems in the multicellular organism.

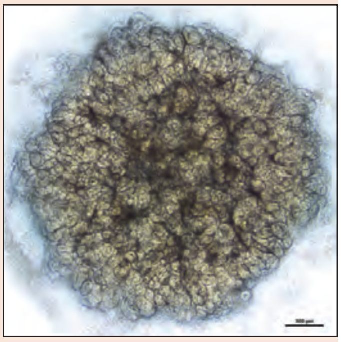
The interdependence of a multicellular organism's organ systems ensures all of them can function effectively together to ensure its health and survival. Some examples in the human body include:

- The respiratory system; that permits the uptake or entry of oxygen into blood for transport to the cells of all organ systems; e.g. to make energy available.
- The digestive system; that breaks food down to products that are absorbed and pass into blood for transport to the cells of all organs; e.g. amino acids used to produce protein molecules.
- The circulatory system; that transports oxygen and the products of digestion to the cells of all organ systems; e.g. glucose to make energy available.
- The nervous system**;** that regulates the activity of organs in all organ systems; e.g. the rate at which the diaphragm contracts and how quickly the heart pumps.

C Ethical understanding: 3D mini brains

Ethics involves asking questions about what is right or correct for individuals and society. To understand ethics is to be able to think critically to determine the right course of action.

In recent years, it has become possible to create tiny human organs to act as models of real ones. These 'organoids' are grown using stem cells. One example is a kidney organoid that is made to help scientists learn more about the causes of kidney failure (refer to the photo).



The ability to create organoids now includes brain organoids or '3D mini brains' as they are called. Growing and using clumps of human brain tissue in the lab is an area of neuroscience that is getting a lot of funding, and attention. The reasons for this include that producing 3D mini brains permits a lot more to be learned about early brain development in humans, and why things go wrong that can lead to conditions like epilepsy, motor neuron disease, schizophrenia, and Alzheimer's disease.

Creating 3D mini brains, however, is an area of research that raises ethical questions. As stem cells are required, where will they come from? Will people who donate stem cells know they might be used to grow brain organoids? And will such people need to give their consent? Furthermore, it has been shown that 3D mini brains can respond to stimuli, such as light. Could they become complex enough to develop something approaching feelings, or thoughts? Might it be possible for these organoids to think for themselves, or develop a consciousness?

The consensus as of mid-2019 seems to be the 3D mini brains do not have self-awareness or the ability to feel, perceive, or experience things (sentience). Perhaps, however, the possibility of this is becoming less unlikely. If the research is to continue, scientists, ethicists and the public must all be involved in deciding how far things should go, and decide exactly what that means.

You may need to refer to the online resources below to answer the questions that follow.

1. The use of 3D mini brains has some support from animal welfare groups. Explain why that might be the case.

2. If you were part of a team looking at developing an ethics framework to guide the creation and use of 3D mini brains, name three points would you want considered?

Helpful Online RESOURCE about growing 3D mini-brains

To learn more about the development and present uses of 3D mini brains view this clip:

<https://www.youtube.com/watch?v=-1P0HKfTrfY>

Helpful Online RESOURCE about brain organoids and ethicse

To learn more about the ethics of the latest brain organoid research view the clip below:

<https://www.youtube.com/watch?v=YXOZel6-UWo>

Lifestyle choices and the function of organ systems

A person whose organ systems are functioning efficiently is said to be in good health, or healthy. The 'lifestyle' of an individual plays a major role in determining how efficiently their organ systems function day-to-day. This not only affects how healthy they are now but also the state of their health when they are older.

People can control many aspects of their lifestyle. These are called lifestyle choices. Over time an individual's lifestyle choices may enhance their health and well-being, or harm it. The possible implications of some lifestyle choices are shown in the following table.

Lifestyle choice	Health and well-being is enhanced	Health and well-being may be harmed
Diet	Reduced risk of cancers like bowel cancer, high blood pressure and heart disease	High salt levels are correlated with high blood pressure. High levels of simple sugars arel inked to diabetes, overweight and obesity.
Exercise	Moderate exercise reduces the risk of heart disease and increases muscle strength	Excessive exercise leads to muscle soreness, increased risk of injury and fatigue. Low levels can lead to overweight and obesity.
Prescription medications	Using antibiotics treats bacterial infection and anti-cancer drugs help treat cancer	Increased risk of an allergic response, other side-effects, or in some cases, dependency
Alcohol	Drinking alcohol in moderation makes it easier to relax, to socialise more, or to cope better with stress	Excessive drinking of alcohol leads to dependency, domestic violence and heart and/or liver disease

Key Concepts

1. Multicellular organisms like animals and plants have a hierarchical structure of organisation.
2. Cells form into tissues, tissues make up organs, and groups of organs form organ systems.
3. The structure of tissues and organs is related to their function.
4. The organ systems of multicellular organisms are interdependent.
5. A person's lifestyle choices affect the function of their organ systems, and therefore their health.

What have you learned?

Key Terms

hierarchy ....

tissue ....

organ ....

organ system ....

neuron ....

cardiac muscle ....

protease ....

epidermis tissue ....

xylem tissue ....

mesophyll tissue ....

reproductive tissue ....

parenchyma ....

endodermis ....

phloem ....

cortex ....

pith..

chloroplast..

monocotyledon ..

dicotyledon.

root system..

shoot system ..

Knowledge and Understanding

1. Use your understanding of the hierarchical organisation in organisms to explain the links between cells, tissues, organs and systems.

2. Explain the meaning of the following: 'xylem tissue in the stem consists of chains of xylem vessels'.

3. 'The bodies of all multicellular organisms consist of cells that are arranged in various tissues to perform particular functions'. Use an example of a particular type of cell to explain what is meant by this statement.

4. Draw a diagram of a layer of epidermis with a root hair cell. Label one structure specific to the root hair cell and briefly outline how this structure permits the cell to function.

5. The human stomach is a vital organ in our body:

   a) List two different tissues present in the stomach

   b) Describe two functions of the human stomach.

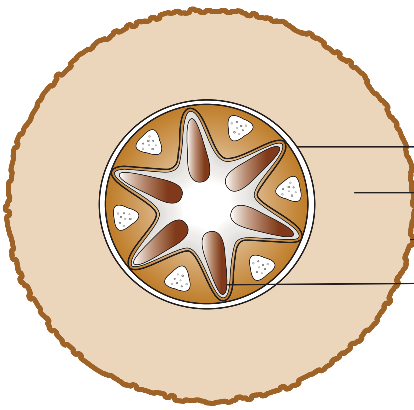
6. Name a lifestyle choice that harms well-being and one that enhances well-being.

Application, Analysis and Evaluation

7. Roots do not have any mesophyll tissue. From your knowledge of this tissue, explain why you would not find this tissue here.

8. Compare the function of the human respiratory system with the circulatory system. Explain how these systems work together to provide materials to cells and remove wastes.

9. The following diagram shows a very thin piece of an organ from a flowering plant as it would look when viewed using a light microscope.



a) Outline the evidence that suggests that this is an organ in a plant.

b) Justify why it is classified as part of one of the roots of a plant.

10. Select one lifestyle choice that has a positive impact on the function of an organ system of the human body. Name the lifestyle choice and point out how this can impact positively on the organ system

Science Inquiry Skills 3.2 - Dissecting a daffodil flower

Introduction

A daffodil is a flowering plant that is a monocotyledon. Like some other types of monocots, it germinates from a bulb in winter and a shoot system grows in spring. The shoot system consists of a long green stem, narrow and long leaves and a large, distinctive flower.

A flower is a specialised part of the shoot system. It has organs called petals, stamens and the pistil, or carpel. Many have leaf or petal like sepals. Stamens produce pollen that contain sperm and part of the carpel produces ova.

Materials

Daffodil including roots, bulb, stem, leaves and a flower

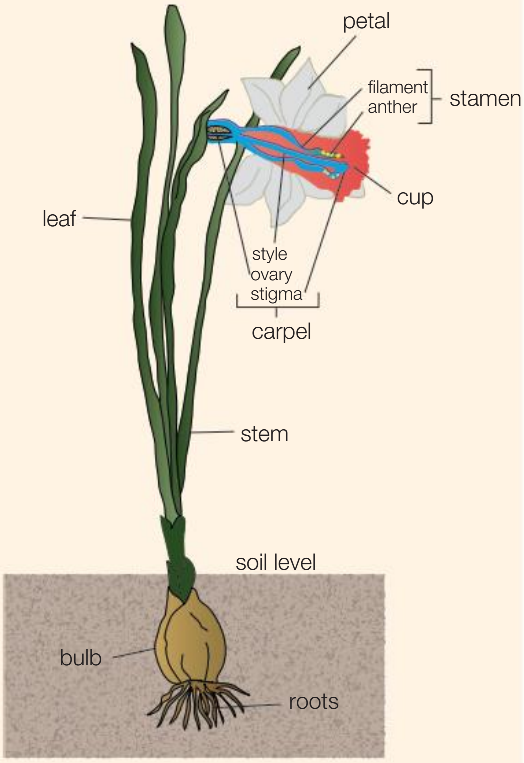
Dissection board

Scalpel or blade and scissors

Dissection probe

Forceps

Hand lens



Part A: Viewing the structure of a daffodil

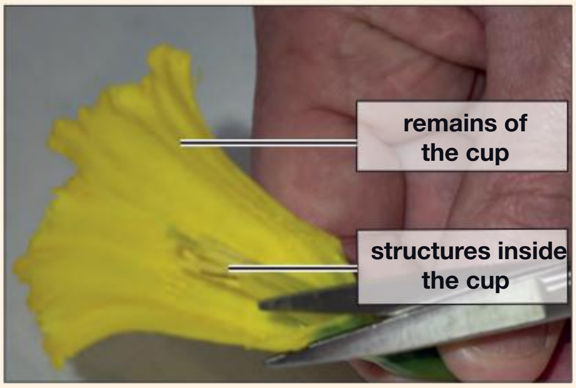
1. Place the daffodil plant on the dissection board.
2. Locate the roots, bulb, stem, leaves and the flower.
3. Use the adjacent Figure to help you.
4. Look closely at the flower – note that it has two layers of petals.
    a) Both layers consist of three petals.
    b) The external layer of petals are separate from each other.
    c) The inner layer of petals is fused to form the cup or corona.
    d) Also note that a daffodil flower does not have sepals.
5. Prepare a table to classify the roots, bulb, stem, leaves and flower as part of the root system or part of the shoot system.

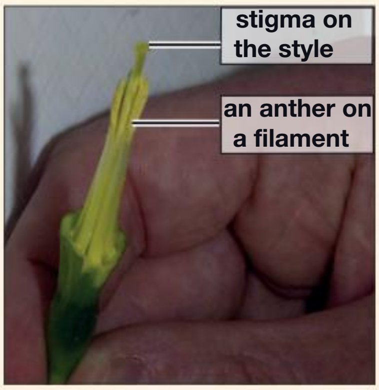
? Science Inquiry Skills 3.2 - Dissecting a daffodil flower (continued)

Part B: Examining the structure of a daffodil flower

1. Cut the daffodil flower from the stem, leaving a short section attached. The remainder of the plant can be placed to one side.
2. Carefully tear off each external petal. Use scissors to remove the cup – this is shown in the left hand photo. Do not damage structures inside.
3. Observe the flower structures that remain – these are shown in the right hand photo.

Locate the stalk-like stamens clustered around the central, taller stalk-like style.





4. Use forceps to remove a stamen – note that it has two parts. The stalk-part is called a filament. The oval structure on top of it is called an anther.
5. Draw a labelled diagram of a stamen to show the filament and the anther.

....

6. Use a hand-lens to look closely at the anther – note that it has a lot of tiny, yellow grains. What are these grains?

....

7. Use forceps to remove all of the remaining stamens. How many stamens do daffodil flowers have?

....

8. The flower structure that remains is an organ called the carpel – note that it has three parts.
   a) The rounded part at the base of the carpel is called the ovary.
   b) The thin, stalk-like structure that extends from the top of the ovary is called the style.
   c) The flat tip of the style is called the stigma.
9. Draw a labelled diagram of the carpel to show the ovary, style and stigma.

....

10. Use the scalpel to very carefully cut the middle of the ovary in half – note that it contains a collection of small, oval structures called ovules. These contain cells that produce ova.
11. Thoroughly clean your workplace and dispose of the remains as instructed.

Science Inquiry Skills 3.2 - Dissecting a daffodil flower (continued)

Discussion

1. A bulb is a modified stem. Unlike the rest of the stem its main function is not to transport materials. Why do daffodils and many other monocots have bulbs?

2. Monocots have leaves with parallel veins. Microscopic examination of the structure of these veins shows they contain xylem. What is the function of this tissue in daffodil leaves?

3. The anther part of a stamen contains cells that produce pollen. Why are stamens often described as being ‘the male part’ of the flower?

4. The daffodil flower’s petals are large and brightly coloured and the inner ones are fused to form a cup. Why is a daffodil flower organised like this?

5. Pollen is transported between daffodil flowers by animals called pollinators. How are daffodil flowers organised to receive pollen carried to them on the body of a visiting pollinator?

Helpful Online RESOURCE for flowering plants

To find out more about the structure of flowers and how flowering plants reproduce:
<http://passel.unl.edu/pages/animation.php?a=486601flowerparts3-8-12.swf&b=1057774853>

3.2

Science as a Human Endeavour 3.2 - Bionic eye

Application and limitation

Science understanding/inquiry enables scientists to develop solutions ...

The application of how living organisms 'work' to the design of new technologies is known as biologically inspired engineering or 'bionics'. Examples include wind turbine blades (whale fin), stiletto heels (bird skull) and collection of water from fog (Namibian beetles).

Over the last ten years, scientists have been working to provide a bionic eye. Normally, tissues in a human eye function together to cause nerve impulses to be sent to the brain via a nerve called the optic nerve. These are processed by the brain resulting in normal vision. Many people, however, either are born with or otherwise acquire vision that is reduced to a point where it affects day-to-day life. One possible solution to this type of vision impairment is a bionic eye.

Today vision impairment is a problem for more than half a million Australians. Examples include blurred vision, blind spots, and total or near total blindness. Patients fitted with a bionic eye can have at least some of their sight restored.

One promising bionic eye is the product of Australian scientists working with the Melbourne-based company Bionic Vision Technologies (BVT). In November 2018, BVT announced the results of a trial involving a retinal-implant system that aims to provide vision to people that suffer retinitis pigmentosa, a visual impairment that affects two million people globally. Patients were asked to wear glasses with a small side-mounted camera that captures images. These were wirelessly transmitted to an implant in the retina at the back of their eye causing the implant to send electrical signals to the brain. Using the device enabled the small group of people who took part in the trial to walk unaided and see objects whereas previously they were unable to see anything in front of them.

You may need to refer to the online resources below to answer the questions that follow:

1. Suggest what scientific knowledge and understandings BVT may have used in the development of their bionic eye.

2. From the article, describe two innovations that enable the bionic eye to function like the human eye.

Helpful Online RESOURCE about what it is like to be visually impaired

To learn more about what it is like to have a visual impairment view the clip below:

<https://www.youtube.com/watch?v=v9VGvQHilRY>

Helpful Online RESOURCE about the BVT bionic eye

To learn more about the bionic eye being developed by BVT view the clip below:

<https://www.youtube.com/watch?v=0qaWgINNE7E>

Chapter 3.3 Exchange of materials with the environment

Science Understanding

Multicellular organisms exchange materials with their environment.

Exchange surfaces in an organism must be thin, moist and have a large surface area. In many animals a rich blood supply is also essential.

In animals, the exchange of gases by diffusion between the internal and external environments of the organism is facilitated by the structure and function of the respiratory system.

- Describe the process of diffusion of respiratory gases as a passive process that does not require additional input of energy.

Exchange with the environment

The surroundings of a living organism are called the environment. All unicellular organisms exchange materials with their environment. The exchange of the gases oxygen and carbon dioxide between an amoeba (a unicellular organism) and its environment is shown in *Figure 331.*

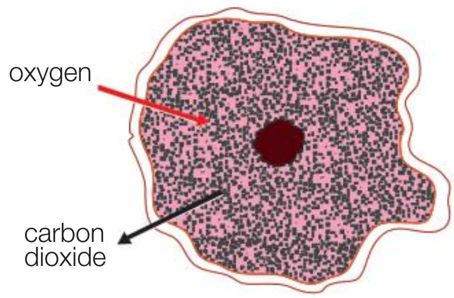


Figure 331 An amoeba exchanges gases

Multicellular organisms exchange materials with their environment too. Materials taken in by animals include oxygen, water and a variety of substances contained in food; for example, carbohydrates, proteins, lipids, vitamins and minerals. Materials released by animals include excess water, salts and toxic substances produced by various biochemical reactions inside cells called wastes (or waste products); for example, carbon dioxide and nitrogen-containing waste like urea or uric acid. **Exchange of materials** between a species of lizard called a marine iguana and its environment is shown in *Figure 332*.

Figure 332 Exchange of materials between a marine iguana and its environment

Exchange surfaces

Unicellular organisms exchange materials directly with the environment. For most cells in a multicellular organism this cannot happen because they are not in direct contact with the environment. To cope with this problem, multicellular organisms have structures composed of cells in certain organs specialised for exchange called exchange surfaces. Some exchange surfaces in animals, the organ and organ system in which they are located are shown in the following table.

Exchange surface	Organ located in	Organ system
Alveoli (singular alveolus)	Lungs	Respiratory system
Villi (singular villus)	Small intestine	Digestive system
Nephrons	Kidneys	Excretory system

To ensure the exchange of materials is efficient, exchange surfaces:

- are thin, which reduces the distance that materials need to move during exchange.
- are moist, which assists the transport of materials across the exchange surface.
- have a large total surface area, which provides more surface for exchange to take place.

In animals, the exchange of materials is also facilitated by exchange surfaces being close to a supply of blood that transports materials from the exchange surface to all cells in the body. *Figure 333* shows how the circulatory system connects exchange surfaces to each other and body cells.

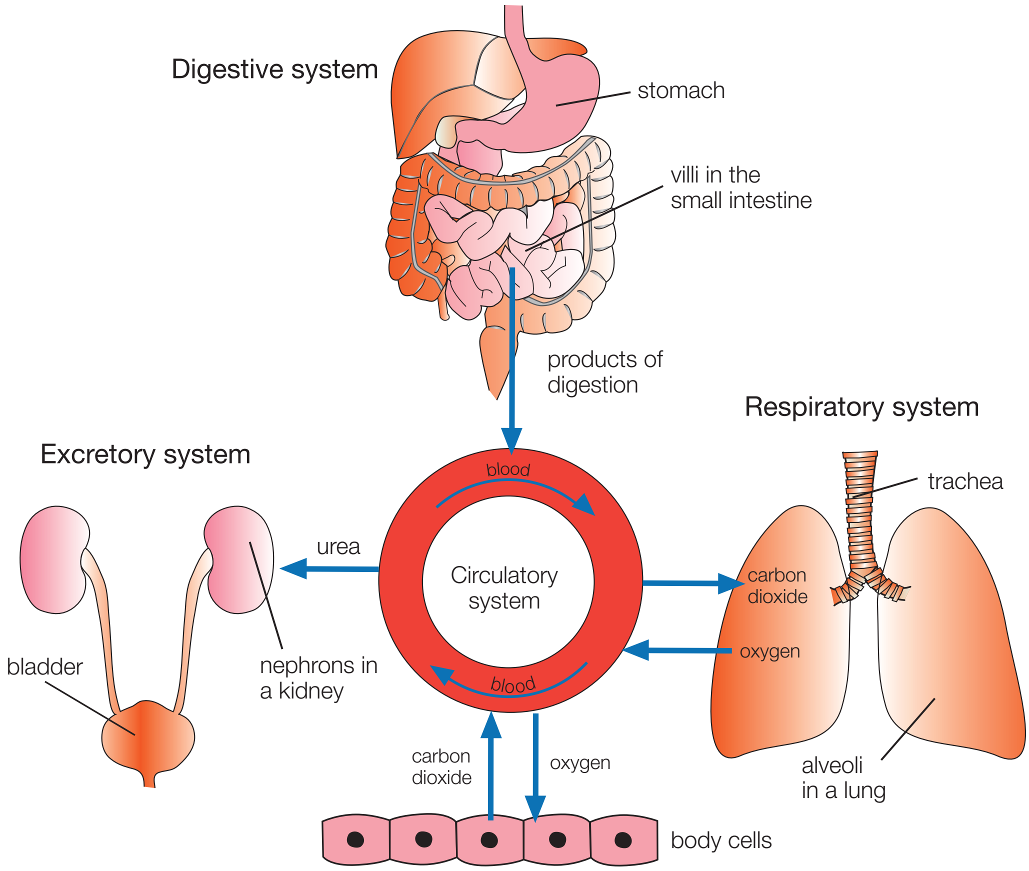


Figure 333 The circulatory system connects exchange surfaces and body cells

Diffusion

The actual movement of substances across an exchange surface often occurs by a process called **diffusion** – substances being exchanged like this are said to diffuse. Diffusion is the nett movement of a substance from a region of higher concentration to a region of lower concentration until the two regions have an equal concentration of the substance.

Another way to describe diffusion is the nett movement of a substance down its **concentration gradient** until equilibrium has been reached. Diffusion occurs across exchange surfaces but it takes place without them as well; for example, perfume diffusing through air, or sugar diffusing through water.

Substances that consist of small, uncharged molecules move by diffusion across an exchange surface; for example, oxygen and carbon dioxide. Refer to *Figure 334* which illustrates some ions diffusing into the cell through pores or channels. The molecules diffuse from a higher concentration outside the cell, to a lower concentration inside the cell.

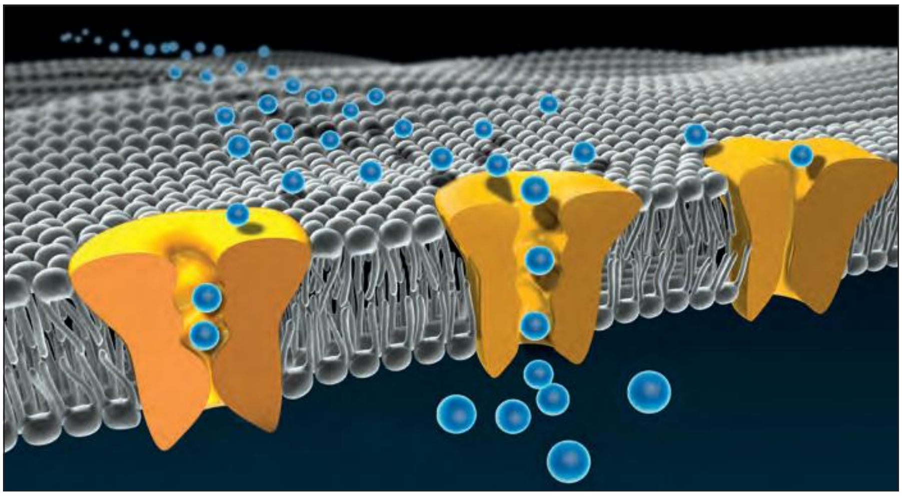


Figure 334 Diffusion across a cell membrane

Diffusion is a passive process because it occurs without any additional input of energy. If there is a difference in concentration of molecules between two regions, diffusion just takes place. Diffusion of oxygen and glucose molecules from a higher concentration in a close-by blood vessel, called a **capillary** into muscle cells where their concentration is lower is shown in *Figure 335*. Diffusion of carbon dioxide down its concentration gradient into the capillary is also shown.

Oxygen diffuses into cells because it is needed for a process inside cells called aerobic respiration. This enables cells to make energy available for them to function. Carbon dioxide is a waste produced by aerobic respiration that accumulates to toxic levels if not removed from cells. Hence its diffusion out of cells into blood.

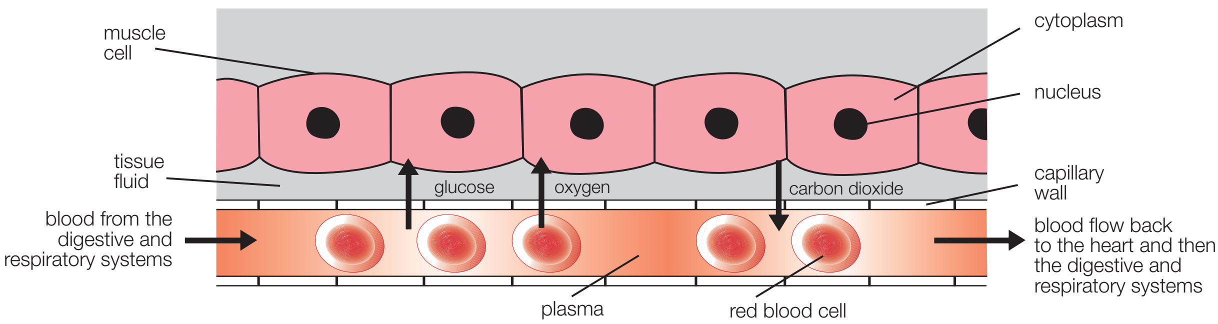


Figure 335 Diffusion of substances into and out of body tissues

Helpful Online RESOURCE about the respiratory system

To view an Essentials Video Animation (EVA) on this topic, use this QR code to visit:

<http://essentialseducation.com.au/resources/sace-1/biology/respiratory-system/>

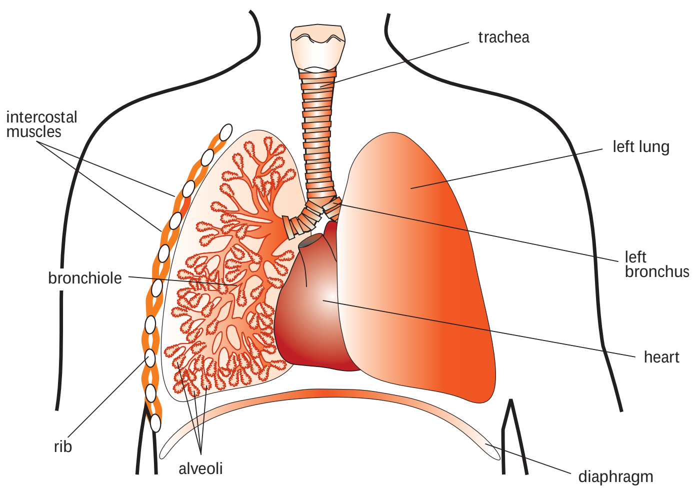
External and internal environments

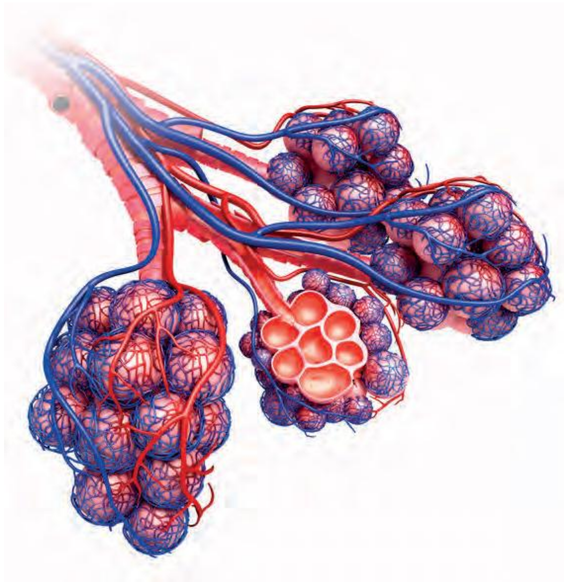
When discussing exchange of materials by multicellular organisms it is helpful to refer to the environment around them as the external environment. The blood supply and body cells of a multicellular organism form the inside or internal environment. The function of exchange surfaces then, is to permit the exchange of materials between the internal and external environments of the organism.

The respiratory system

In animals, exchange of gases between the internal and external environments occurs at exchange surfaces located in the respiratory system called alveoli. The structure of the human respiratory system is shown in *Figure 336(a).* Note the right lung is cut open to show some bronchioles and the location of alveoli.

Refer to *Figure 336(b)* which illustrates alveoli at the end of the bronchial branches. Note the vast network of tiny blood vessels (capillaries) which facilitate gas exchange.





Figures 336(a) and (b) Alveoli in the lungs are an exchange surface

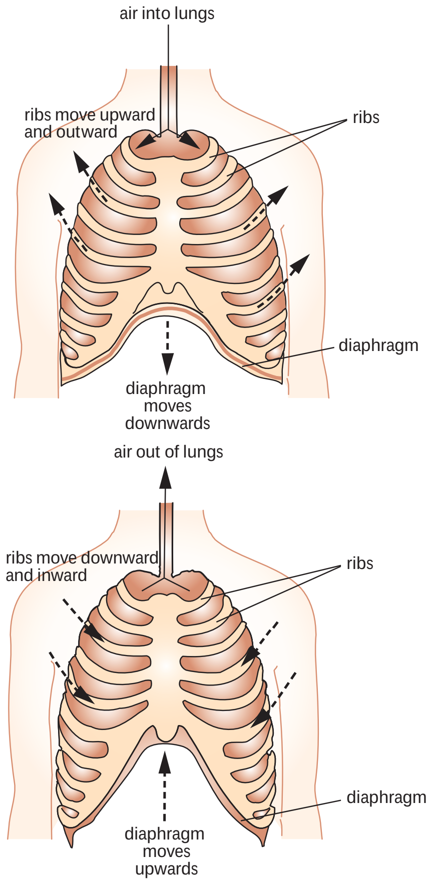
The structure of the respiratory system facilitates exchange of gases by moving the external environment (i.e. air outside the body) to/from the alveoli. Gas exchange by diffusion takes place because air in the alveoli is in close contact with the internal environment – blood transported to/from the lungs. The parts of the respiratory system that function to move air to/from the alveoli are shown in the following table.

Part of the respiratory system	**Function**
Trachea	To allow air to pass into/out of the bronchi.
Right and left **bronchus**	To allow air to pass into/out of each lung.
Bronchiole	To allow air to pass into/out of alveoli.
Diaphragm and intercostal muscles between ribs	To move air into/out of the alveoli.

Ventilation

The movement of air into/out of the alveoli is called ventilation. When air that moves into the lungs and alveoli it is called **inhalation**. Air is inhaled when the air pressure inside the lungs is lower than the air pressure outside the body. This is achieved by contraction of the diaphragm and the intercostal muscles that move the diaphragm downwards and the ribs upwards and outwards respectively.

When air moves out of the alveoli and lungs it is called **exhalation**. Air is exhaled when lung air pressure is greater that air pressure outside the body. This occurs when the diaphragm and intercostal muscles relax causing the diaphragm to move upwards and the ribs to move downwards and inwards. Inhalation and exhalation and the movements of the diaphragm and intercostal muscles are shown in *Figure 337(a) and (b).*



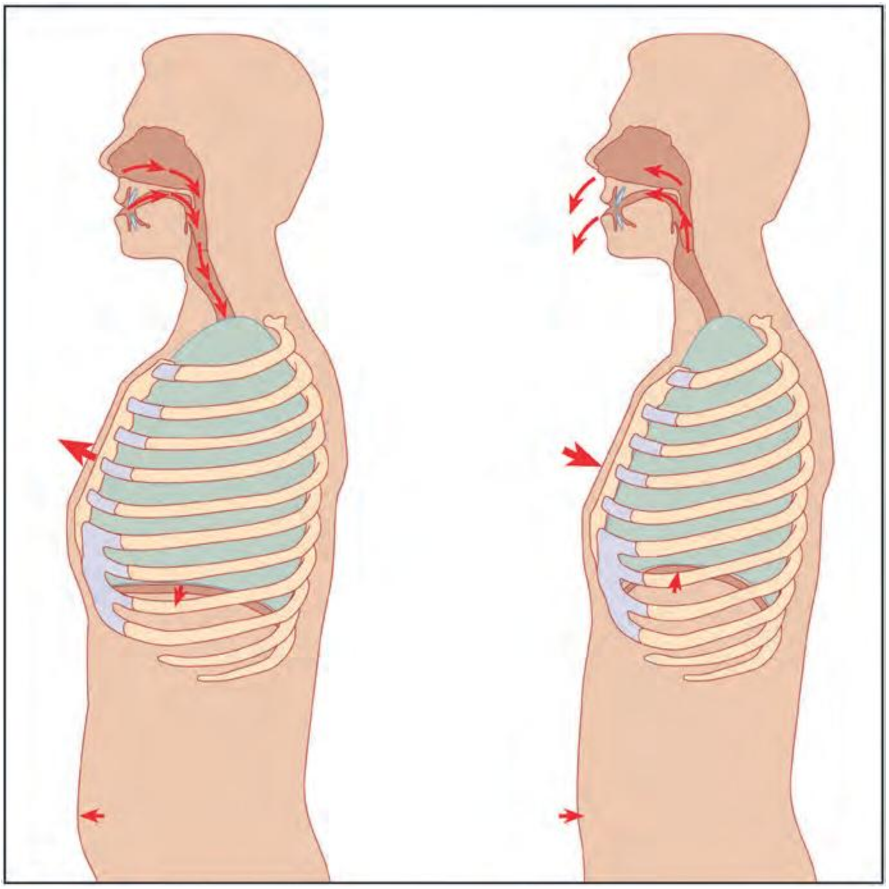


Figure 337 Inhalation and exhalation (a) from the front and (b) from the side

Gas exchange in alveoli

The exchange of gases by diffusion at alveoli is facilitated in a number of ways. These include:

- each lung has a huge number of alveoli which creates a very large surface for exchange to occur.
- the outside surface of alveoli is covered with a lot of capillaries that transport blood to/from them.
- the distance for diffusion is very small because the alveoli surface consists of a single layer of epithelial tissue which makes it very thin. The exchange of gases across alveoli is assisted by the presence of a film of moisture that covers the inside surface of them.

Oxygen in air inhaled into alveoli has a higher concentration than oxygen in red blood cells flowing through capillaries. This causes oxygen to diffuse out of alveoli into red blood cells. Exhaling air causes the carbon dioxide concentration in the alveoli to fall below the capillary carbon dioxide concentration. As a result, carbon dioxide diffuses out of the blood plasma into alveoli. The exchange of oxygen and carbon dioxide across the wall of one alveolus is shown in *Figure 338.*

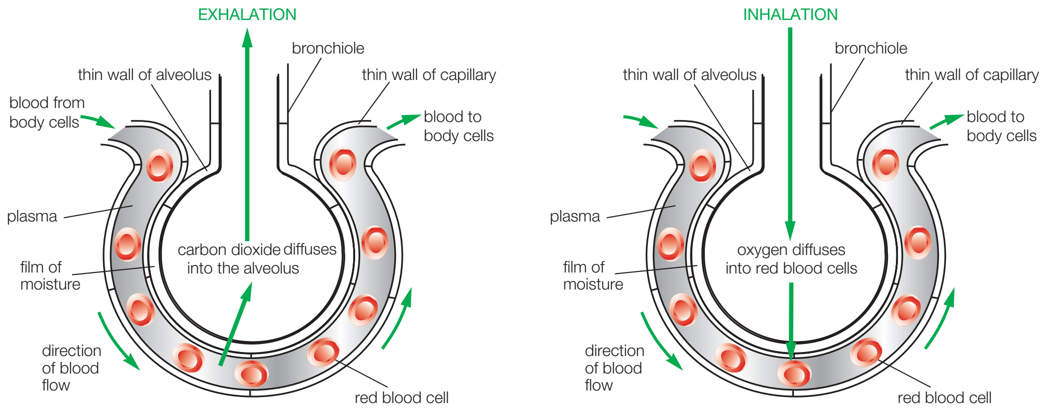


Figure 338 Exchange of oxygen and carbon dioxide by diffusion at an alveolus

Lung capacity and breathing rate

The movement of air into and out of the alveoli is often simply referred to as breathing. Air moving into the lungs causes them to inflate while air moving out deflates them. The total volume of the lungs when they are fully inflated with air is called the lung capacity. In an adult human this is about 5 litres. During breathing at rest a person only breathes in and breathes out about 10% of the lung capacity, or about half a litre of air. This volume is called the **tidal volume**.

During forced breathing the tidal volume increases. Taking an extra deep breath in increases the volume of air taken into the lungs and taking an extra deep breath out forces a larger volume of air out. The maximum possible tidal volume is called the **vital capacity**. It is not possible to breath out all the air in the lungs – a certain volume of air remains regardless of how hard a person breathes out. This volume is called the **residual volume**. The number of times air is inhaled and exhaled per minute is called the breathing rate. At rest breathing rate is typically about 15 breaths per minute.

The balloon lung model

One physical analogy of the human respiratory system is called the balloon lung model. This model consists of a large glass jar with a pair of balloons inside it and a rubber membrane at its base. The glass jar represents the ribs, the pair of balloons the lungs and the rubber membrane the diaphragm. A typical balloon lung model is shown in *Figure 339*.

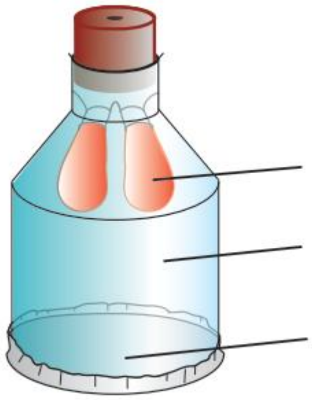


Figure 339 A model of the lungs, rib cage and diaphragm

The balloon lung model can be used to visualise lung capacity concepts and breathing rate. Holding the model in one hand while gently but rhythmically pulling the rubber membrane towards the floor then releasing it simulates breathing in and out respectively. The inflating and deflating of the balloons illustrates tidal volume during 'quiet' breathing. Pulling the rubber membrane downwards and pushing it upwards more forcibly makes it possible to observe the vital capacity of the lungs. Pushing the membrane upwards as hard as possible does not result in the balloons becoming fully deflated. Doing this models the residual volume of the lungs. The number of times the rubber membrane is pulled down and pushed up per minute demonstrates the meaning of breathing rate.

Asthma

One medical condition that disrupts healthy breathing and gas exchange is asthma. This is usually an allergic reaction to an inhaled trigger like pollen, fur from pets or dust mites. The result is swelling and inflammation of the walls of bronchioles, reducing the diameter of them. Thereafter breathing is characterised by shortness of breath and wheezing until treated by medication.

Lifestyle diseases of the respiratory system

An individual's lifestyle contributes to the development of a variety of 'later-in-life' diseases. These are often called **lifestyle diseases**. Three lifestyle diseases related to the respiratory system, lifestyle factors that may cause them and some consequences of the disease are shown in the following table.

Helpful Online RESOURCE about the respiratory system

To learn more about more about the respiratory system, use this QR code to visit:

<https://www.youtube.com/watch?v=hc1YtXc_84A>

Lifestyle disease	Lifestyle factors	Consequences of the disease
Emphysema	Repeated exposure to chemical irritants; for example, as a result of cigarette smoking, working in a cigarette smoke-filled environment, or working with certain industrial chemicals.	Breakdown of alveoli leading to reduced lung capacity and breathlessness even during mild activity, and general fatigue.
Lung cancers	Long-term exposure to cancer-causing chemicals or carcinogens; for example, as a result of cigarette smoking, living and/or working in city smog, or working with asbestos.	Uncontrolled cell division in the bronchioles or bronchi leading to lung tumours which cause impaired function, mucus coughed up streaked with blood, and pain when coughing.
Pneumonia	Exposure to pneumonia-causing bacteria or viruses; for example, inhaling infected air droplets in crowded classrooms or damp outside environments and/or buildings.	Filling of alveoli with fluids and mucus and therefore reduced gas exchange leading to breathing difficulties, high breathing rate, fever, and prolonged fatigue.

Key Concepts

1. Unicellular and multicellular organisms exchange materials with their environment.
2. Exchange of materials by multicellular organisms involves specialised exchange surfaces which are thin, moist and have a large surface area.
3. In animals, the structure of the respiratory system, which is usually includes lungs or gills, facilitates the exchange of gases by diffusion.
4. The respiratory and circulatory systems function together to permit gas exchange.
5. Asthma and lifestyle diseases associated with the respiratory system affect its healthy function.

What have you learned?

Key Terms

exchange of materials

alveolus

villus

nephrons

diffusion

capillary

trachea

bronchus

bronchiole

inhalation

exhalation

concentration gradient

tidal volume

vital capacity

residual volume

lifestyle disease

emphysema

lung cancer

pneumonia

Knowledge and Understanding

1. Very small cells measure about 10μm and very large cells are about 100μm. Supposing that each of these cell shapes is approximately cubic; explain which of these cells would be more easily be able to exchange materials with their environment and why.

2. Using the lines below, prepare a table to show three major organs in the body with exchange surfaces and for each, list the materials exchanged and note how the surface area for exchange is maximised.

3. Outline, using examples, how each of the following three characteristics of exchange surfaces assist in the exchange of materials by diffusion between an organism and its environment.

   a) Thin

   b) Moist

   c) Large surface area

4. Draw a diagram of a single alveolus. Label one feature that is vital to the function of the alveolus and briefly outline how this helps to ensure gas exchange is efficient.

5. Explain the difference between the 'tidal' volume of the lungs and the 'residual' volume. Predict how this concept is very important to an athlete.

Application, Analysis and Evaluation

6. Suppose that the bronchioles of a person suddenly narrow to half their usual diameter.
   a) Predict the likely changes to breathing that the person would experience.
   b) Suggest a likely treatment that might help manage the situation.
7. The oxygen and carbon dioxide content of inhaled and exhaled air is shown in the following table.

Gas	Inhaled air (%)	Exhaled air (%)
Oxygen	20	16
Carbon dioxide	0.04	4

   a) 'Only 1/5 of inhaled oxygen diffuses out of the alveoli into the blood'. Verify this mathematically.
   b) 'We breathe out about one hundred times more carbon dioxide than we breathe in'. Explain how the process of diffusion is responsible for this situation.
   c) Predict how increasing the rate of flow of blood to the lungs would affect the rate of diffusion of gases into and out of the blood.
8. When cooking vegetables (e.g. potatoes), it is recommended that they be chopped into smaller pieces rather than cooked whole. Explain why this is good advice.

Science Inquiry Skills 3.3 - Investigating lung capacity

Introduction

During inhalation the lungs become inflated with air. The total volume of air in the lungs when fully inflated is called the lung capacity. Lung capacity can be estimated using a piece of science equipment called a spirometer (*refer to the photo*). An individual takes a breath and then exhales fully into the mouthpiece of the spirometer. The scale is read which indicates the lung capacity (cm^3).

Materials

Spirometer, mouthpieces

(Note: If Spirometers are not available in your school ,you may wish to use the water displacement equipment and technique as described in the First Edition of this Workbook.)

Part A: Lung capacity before physical activity

1. Establish a working group with two other students.
2. Select a volunteer who is prepared to have their lung capacity measured.
3. Ensure the volunteeer is at rest and is breathing normally.
4. Set the end of of the mouthpiece to the nozzle of the spirometer.
5. Hold the spirometer by one hand and confirm that the indicator is pointing to zero. If the indicator does not point to zero, adjust to zero by moving the upper outside ring right or left.
6. Ask the volunteer to set the mouthpiece between their lips and breath out fully in one motion.
7. After breathing out, read the measurements (in cm^3) on the indicator - this is the lung capacity.
8. Record below:

9. Follow the procedure twice more using the same individual and record the data.

10. Calculate the average estimated lung capacity of this individual in litres.

Part B: Lung capacity after moderate physical activity

Modify the procedure in Part A to test the effect of moderate physical activity on lung capacity. Briefly note your changes to the method and record the data.

3.3

Science Inquiry Skills 3.3 - Investigating lung capacity (continued)

Part C: Lung capacity and gender

Modify the procedure in Part A to test if an individual's gender affects lung capacity. Briefly note your changes to the method and record the data.

Part D: Analysis and conclusions

1. Describe how the method your group used for Part B (exercise) could be improved to collect more meaningful, or valid, data.

2. Using the data you collected, do you think you can you draw any conclusions about the effect of moderate exercise on lung capacity?

3. Describe how the method your group used for Part C (gender) could be improved to collect more meaningful, or valid, data.

4. Using the data you collected, do you think you can you draw any conclusions about the effect of gender on lung capacity?

Science as a Human Endeavour 3.3 - Breath test for cancer

Development

New technologies improve ... scientific procedures, data collection ...

One cancer of the digestive system is called oesophageal cancer, or cancer of the oesophagus. Over 1200 Australians are informed by a cancer specialist that they have this cancer every year.

The diagnosis of oesophageal cancer involves inserting into the oesophagus a flexible tube with a light and camera attached to it called an endoscope. This is used to look at the walls of the oesophagus for evidence of the cancer. This often has to be done several times and may also involve taking tissue samples for analysis, both of which make diagnosis time consuming and expensive.

New technologies are in development that aim to improve the efficiency of cancer diagnosis procedures like this. One involves a person breathing into a device like a police 'breathalyser' which is connected to a bag (*refer to photo*). The exhaled air in the bag is analysed for the presence of waste products cancer cells produce called volatile organic compounds. These find their way into a patient's bloodstream, in a way similar to alcohol. A cancer breathalyser test such as this would be much faster, cheaper and potentially more accurate than endoscopy procedures used now.

You may need to refer to the online resource below to answer the questions that follow:

1. State the evidence that was discovered that led to the new method for detecting oesophageal cancer.

2. Explain how the new technology is improving the efficiency of testing for oesophageal cancer.

Helpful Online RESOURCE about some common cancers

These QR codes and websites will provide some useful information for this assignment:

Cancer Council Victoria: Stomach & Oesophageal cancer

<http://www.cancervic.org.au/about-cancer/cancer_types/stomach_and_oesophageal_cancer>

Helpful Online RESOURCE about new cancer research

Breath test for cancer on the way under Flinders University research project:

<http://www.adelaidenow.com.au/lifestyle/health/breath-test-for-cancer-on-the-way-under-flinders-university-research-project/news-story/441d70acf8c0ff7c954880cd9a783eb6>

Chapter 3.4 Gas exchange in plants

Science Understanding

In plants, gas exchange is facilitated by the structure of the leaf.

Gases are exchanged mainly via stomata. Their movement within the plant is by diffusion and does not involve the plant transport system.

- Describe and explain how gases move into, through, and out of plants.
- Describe the loss of water through open stomates.

Plants and exchange of materials

Like animals, shrubs, trees and all other types of plants exchange materials with their environment. In daylight when **photosynthesis** is taking place, plants take up carbon dioxide and give out oxygen. Other materials taken in by plants during the day include liquid water and a variety of mineral nutrients from the soil; for example, minerals like **nitrates** and **phosphates**. Materials released by plants during the day also include water in the form of **water vapour**, and in the case of plants that live in soil or mud with a very high salt content, salts; for example, mangroves. The exchange of some materials between a Eucalyptus tree and its environment in bright sunlight is shown in *Figure 341*.

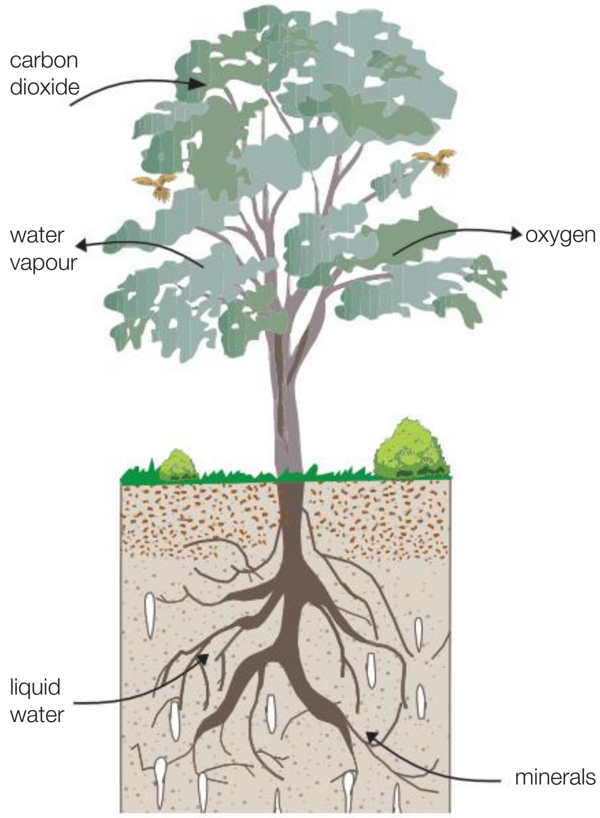


Figure 341 Exchange of materials between a tree and its environment

Photosynthesis and aerobic respiration

One exchange surface of plants is the leaf. To understand gas exchange by leaves it is important to know more about photosynthesis and a process that occurs in all cells called **aerobic respiration**.

Photosynthesis is a series of biochemical reactions that takes place in cells that contain green organelles called **chloroplasts**; for example, palisade cells that form part of the mesophyll tissue in leaves. Plants use photosynthesis during the day to synthesise the organic compounds required for survival. For this reason, a plant is called an **autotroph**. In photosynthesis plants chemically change carbon dioxide and water into a sugar called glucose and oxygen gas. Light energy is also converted into stored chemical energy.

Photosynthesis can be summarised using the following word equation:

$$\text{carbon dioxide} + \text{water} \rightarrow \text{glucose} + \text{oxygen}$$

Aerobic respiration is a series of biochemical reactions that mostly take place in an organelle found in all cells called a **mitochondrion** (pl. mitochondria). Plants (and animals) use aerobic respiration all the time to chemically change glucose and oxygen into carbon dioxide and water to release the chemical energy stored in glucose for use; for example, to produce new cells, or to grow. Aerobic respiration can be summarised using the following word equation:

glucose + oxygen → carbon dioxide + water

Gas exchange at leaves

During daylight hours, plants perform photosynthesis and aerobic respiration. For most of the day the abundance of bright light causes photosynthesis to occur much faster than aerobic respiration. This means all the carbon dioxide produced by aerobic respiration is used for photosynthesis, and there is more oxygen produced by photosynthesis than is needed for aerobic respiration. The result is an input to the leaves of carbon dioxide (CO_2) and release of oxygen (O_2) during the day. This is shown in *Figure 342 (a).*

Photosynthesis occurs more slowly in low light; for example, during the early morning or evening. At some point photosynthesis will occur at the same speed as aerobic respiration. The lack of nett exchange of gases that results is shown in *Figure 342 (b*). In darkness photosynthesis does not take place but respiration continues. The input of oxygen and release of carbon dioxide that results during darkness is shown in *Figure 342 (c).*

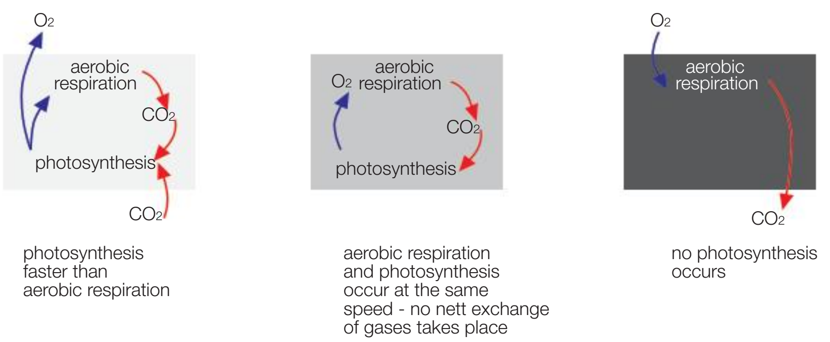


Figure 342 (a) Gas exchange at leaves in bright light, (b) low light and (c) darkness

Leaf structure and gas exchange

In plants, the main site of exchange of gases between the external and internal environments is the leaf. The typical structure of a leaf is shown in *Figure 343 (a)*. It is attached to the stem by a structure called a petiole that continues into most leaves to form the mid-rib. The surface of the leaf is called the **lamina**. In dicotyledons, a network of **veins** extends from the mid-rib across the lamina. A vertical slice or section through the lamina is shown in *Figure 343* (b). Note the presence of xylem and phloem tissue within the vein.

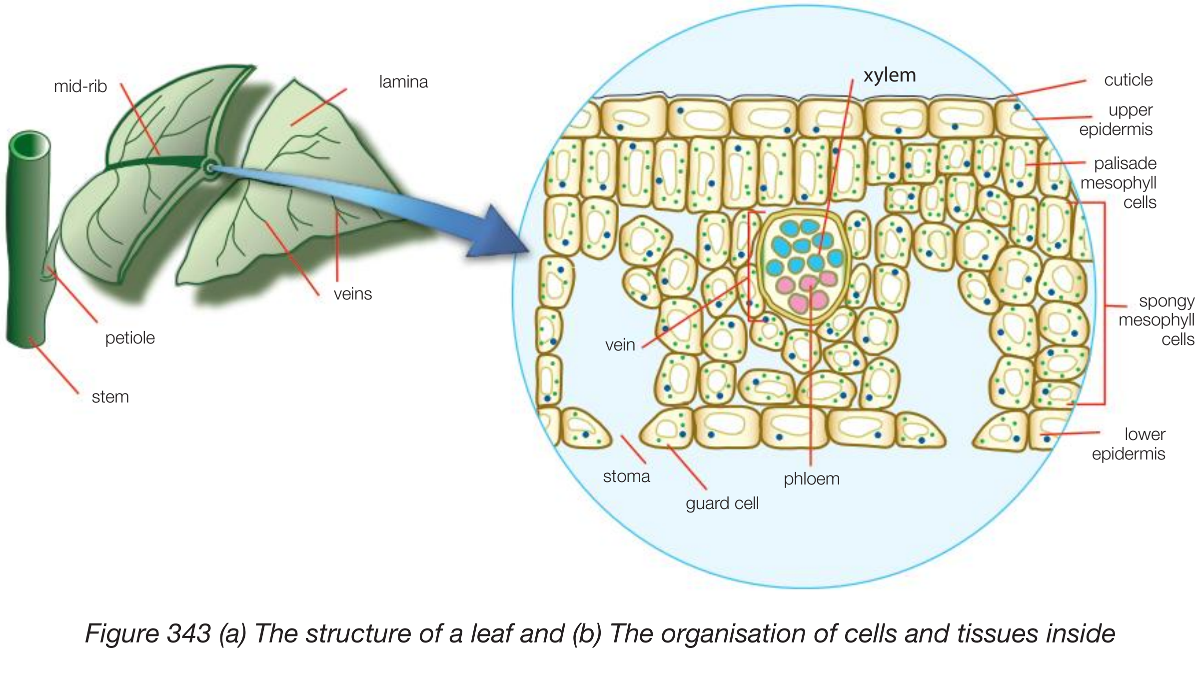


Figure 343 (a) The structure of a leaf and (b) The organisation of cells and tissues inside

The structure of the leaf facilitates gas exchange. Gases are exchanged via leaf structures called **stomata**. Their movement into and out of the plant is by **diffusion**. Parts of a dicotyledons leaf that facilitate the movement of gases into and out of the leaf are shown in the following table.

Part of the leaf	How the part facilitates gas exchange
Lamina	Is thin to reduce the distance gases have to move by diffusion and is broad and flat to increase the surface area for gas exchange
Lower epidermis	Contains stomata to permit gases to diffuse into and out of the mesophyll
Spongy mesophyll	Loosely packed to provide the mesophyll with air spaces that assist the diffusion of gases through the leaf

Stomata

The lower epidermis of the dicotyledon leaf contains a large number of stomata (singular; stoma(te)). Each stoma consists of a pair of cells called **guard cells** that surround an opening called a pore. Changes in the shape of the guard cells cause stomata to open or close. As a rule, stomata are open during daylight hours while photosynthesis occurs, and closed during the early evening and at night. An open and a closed stoma is shown in *Figure 344 (a) and (b).* Refer also to *Figure 345*(c) which is a scanning electron micrograph (SEM) of a stoma surrounded by guard cells, it is from a tobacco leaf and has been magnified ~X2500.

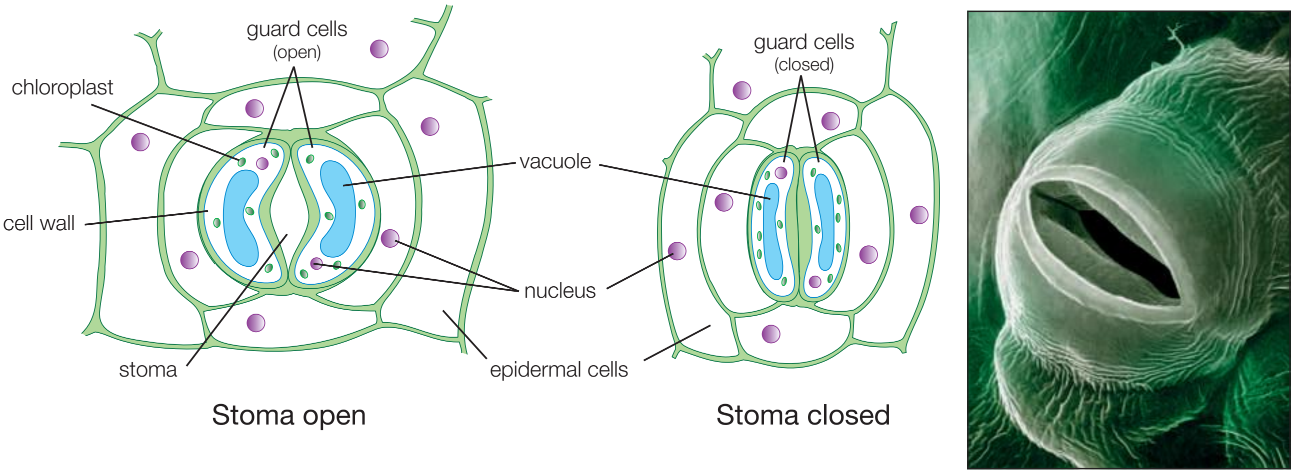


Figure 344 A stoma(te) that is (a) open (b) closed and (c) viewed with a SEM

Diffusion of gases into and out of leaves

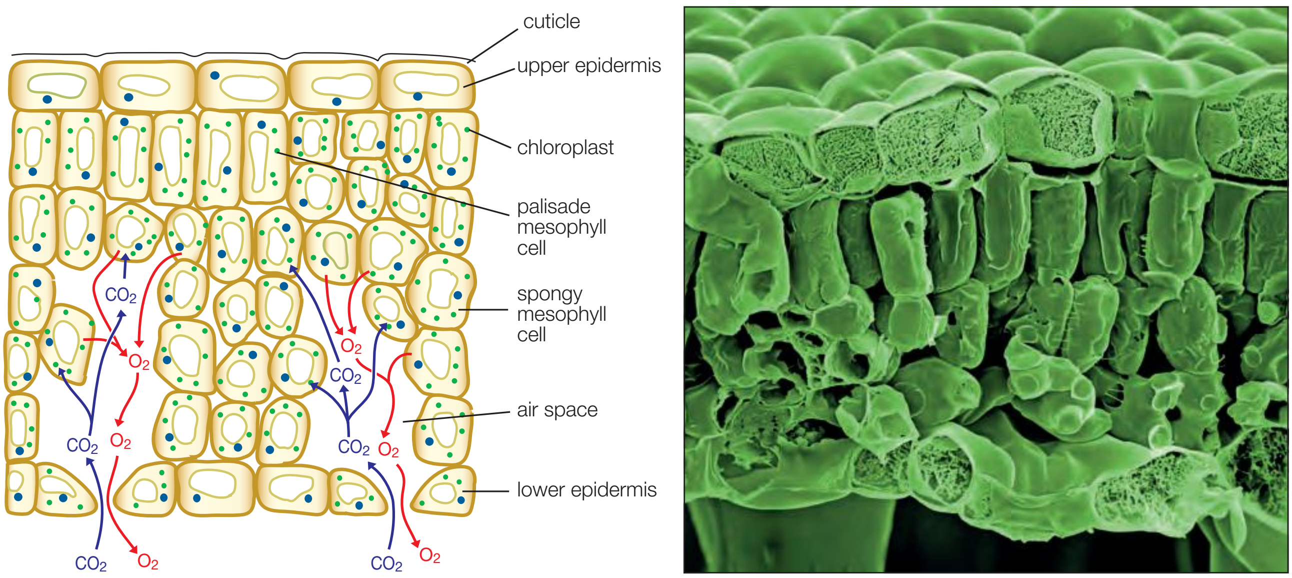


Figure 345 Cross section of a leaf shown (a) as a drawing and (b) an electron micrograph

In daylight, carbon dioxide enters the air spaces in the mesophyll via the open stomata by diffusion. It then diffuses into chloroplasts in the mesophyll cells. Oxygen that is produced by mesophyll cells during photosynthesis diffuses out of the mesophyll into the air spaces and then diffuses out of the leaf via the stomata.

Carbon dioxide diffuses into a leaf when mesophyll cells are photosynthesising, or when they are 'using up' carbon dioxide. This causes carbon dioxide in the air spaces to remain at a concentration lower than in the outside air. The result is that carbon dioxide diffuses from the outside air via stomata into the air spaces. The presence of air spaces permits the carbon dioxide concentration to increase enough for it to continue to diffuse into mesophyll cells.

Oxygen production by mesophyll cells during the day means the concentration of oxygen in the cells remains higher than in the air spaces, so oxygen diffuses into these air spaces. As the oxygen concentration in the air spaces rises, it then diffuses out through the stomata. The movement of carbon dioxide (CO_2) and oxygen (O_2) into and out of a leaf is shown in *Figure 345(a).* Refer to *Figure 345(b)* which is a scanning electron micrograph of a cross-section through a stinging nettle. Note the structures are very similar to the diagram of the leaf shown adjacent in *Figure 345*(a).

3.4

Helpful Online RESOURCES to view an EVA on leaf structure and function

To view an Essentials Video Animation (EVA) on this topic, use this QR code to visit:

<http://essentialseducation.com.au/resources/sace-1/biology/leaf-structure-function/>

Leaf structure and photosynthesis

The structure of the leaf facilitates photosynthesis as well. Some are shown in the following table.

Part of the leaf	How the part facilitates photosynthesis
Cuticle	Is transparent to maximise the absorption of light by mesophyll cells
Upper epidermis	Is thin to maximise the absorption of light by mesophyll cells
Lamina	Is broad and flat with a large surface area – this allows mesophyll cells to be spread out over a wide area to maximise the absorption of light
Palisade mesophyll	Cells are just under the epidermis, are upright and packed with green chloroplasts to maximise the absorption of light
Spongy mesophyll	Cells have chloroplasts to perform photosynthesis Air spaces between them helps carbon dioxide diffuse to mesophyll cells
Veins	Contains **xylem vessels** to deliver water and mineral nutrients to leaf cells Contains **phloem tubes** to move sugars out of leaves
Lower epidermis	Contains stomata to permit gases needed/produced by photosynthesis to diffuse into/out of the mesophyll

Key Concepts

1. Plants exchange materials with their environment.
2. Gas exchange by plants is influenced by the rates of photosynthesis and aerobic respiration.
3. In plants, the structure of the leaf facilitates the exchange of gases.
4. Leaves have stomata that permit gases to enter and leave the mesophyll tissue.
5. Stomata generally open during daylight hours and close during the early evening and at night.
6. Gases move into, through and out of leaves by diffusion.
7. Water can be lost from a plant through open stomates.

What have you learned?

Key Terms

water vapour

nitrates

phosphate

photosynthesis

aerobic respiration

chloroplast

autotroph

mitochondrion

stomata

guard cell

diffusion

lamina

lower epidermis

spongy mesophyll

palisade mesophyll

upper epidermis

cuticle

veins

xylem vessel

phloem tube

Knowledge and Understanding

1. Draw a simple, labelled diagram of a magnified side view of a leaf. On this diagram, use different coloured arrows and more labels to indicate the flow of energy and matter into and out of the leaf. In a sentence or two, explain why leaves are sometimes referred to as the 'the world's largest factory'.

2. List examples of materials that are exchanged between plants and their environment.

3. Describe the effect of opening and closing of the stomata on the rate of gas exchange between the leaf and the external environment.

4. Describe the gas exchange that takes place at a leaf during bright sunlight.

5. In contrast to the answer above, explain why plants only take up oxygen at night and give out carbon dioxide.

6. Explain why the presence of air spaces in the spongy mesophyll assists the diffusion of carbon dioxide through the leaf.

Application, Analysis and Evaluation

7. During the summer, many species of Eucalyptus drop some of their leaves. Correlate this observation with the possible survival advantage for these plants.

8. Leaves of plants in tropical forests usually have a very large surface area and are very dark green in colour. Explain how these features assist these plants to survive.

9. Refer to *Figures 344 (a) and (b)* to help answer these questions:

a) Describe the difference in the vacuoles in the guard cells when the stoma is open and closed.

b) Propose a possible mechanism that would explain the opening and closing of stomata.

10. The results of a study of gas exchange by a Eucalypt woodland is included the following table:

Gas	Concentration at leaf level at 7am	Concentration at leaf level at 1pm
Oxygen	18%	21%
Carbon dioxide	0.05%	0.02%

a) Describe the pattern of results observed for O_2 and CO_2 levels in the air at different times of the day.

b) Use an understanding of gas exchange to formulate a possible conclusion based on the data.

Science as a Human Endeavour 3.4 - Green walls

Application and limitation

Scientific knowledge may have beneficial ...consequences...

A 'green wall' is a wall that is partly or completely covered with living plants. Green walls may be located outdoors or indoors *(refer to photo)*.

The construction of green walls dates back to the 1970s. In recent years there has been a great deal of interest in constructing green walls inside buildings, including in offices, and not just because they provide employees with something attractive to look at. Evidence is emerging that suggests that greenery in the office may provide real health benefits to those who work there.

Recent research by the University of Technology Sydney (UTS) provides a good example. This UTS study found that exchange of materials between green wall-plants and their building/office environment can lead to an overall improvement in air quality. Given the increasing amounts of time people spend working indoors in office-like environments, such results may prove to be significant.

You may need to refer to the online resources below to answer the questions that follow:

1. Suggest how green-wall plant gas exchange might improve office air quality? Consider the role of photosynthesis, and a process indoor plants are known to carry out called bio-filtration.

2. The use of extensive indoor green walls by Companies might result in unexpected economic and environmental benefits. Describe one such possible economic benefit and one possible environmental benefit.

Helpful Online RESOURCE about 'Green wall' research

This website will provide some useful information for this assignment:

<http://www.efig.co.uk/index.php/item/uts-study-shows-green-office-walls-purify-air-and-body>

Helpful Online RESOURCE about 'Green walls

This website will provide some more useful information about 'green walls':

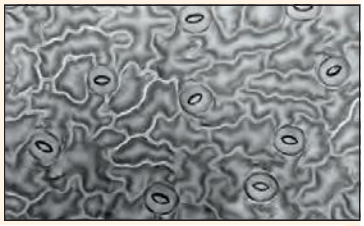
<https://en.wikipedia.org/wiki/Green_wall>

Science Inquiry Skills 3.4 – Examining stomata

Introduction

In most plants that are dicotyledons stomates are only distributed throughout the lower epidermis. In monocotyledons stomata are located in both the upper and lower epidermis. Stomata can be examined using a microscope to see the guard cells and stoma. It may also be possible to observe the fact that guard cells have chloroplasts. The shape and size of guard cells and stoma vary across different plant species. The number of stomata per unit area, or the stomatal density, varies as well.

Materials



samples of dicot and monocot leaves

white tile

colourless nail varnish

light microscope

slide

clear cellotape

small dropper bottle of water

coverslip

dissection needle or toothpick

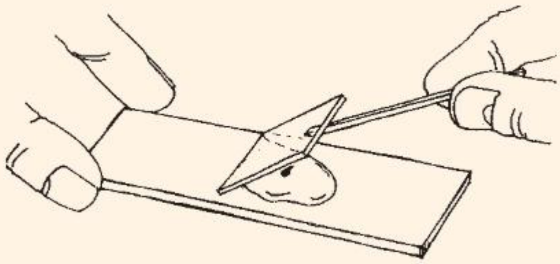
Part A: Measuring stomatal density in a dicot

1. Lay the leaf on a white tile, lower epidermis side up.
2. Paint a layer of nail varnish onto the leaf, as shown in the accompanying photographs.
3. Wait for the nail varnish to dry.
4. Press a piece of cellotape down over the varnish.
5. Peel the tape off.
6. Put the tape sticky side up on a microscope slide.
7. Observe at 100X and count the number of stomata, sample shown in adjacent Figure.
8. If the field of view is 2mm (or 2000um), calculate the stomatal density.

Science Inquiry Skills PRACTICAL 3.4 – Examining stomata (continued)

Part B: Observing guard cells and stoma in monocots

1. Fold a piece of leaf over near one end.
2. Carefully tear away some lower epidermis.
3. Place the piece of lower epidermis on a slide.
4. Add a drop of water, then lower a coverslip onto the tissue, as shown in drawing opposite.
5. Observe at 100X and look for pairs of guard cells.
6. Draw a labelled diagram of a stomate.



7. Describe the shape of the guard cells, and estimate the size of them and the stoma.

Chapter 3.5 The digestive system in animals

Science Understanding

In animals, the digestive system is responsible for the breakdown of food and absorption of nutrients required for survival.

- Relate the structure of organs of the digestive system to their function.
- Describe the structure and function of villi in the human digestive system. *© SACE 2019*

A living organism that cannot synthesise the nutrients required for survival is called a **heterotroph**. All animals are heterotrophs. To obtain the nutrients they require animals depend on a regular supply of food. This comes in the form of other organisms (or parts of them) that must be eaten or consumed. Animals that do this by only consuming plants are called **herbivores**; for example, kangaroos and giraffes. Animals that only consume other animals to obtain essential nutrients are called **carnivores**; for example, snakes and eagles. Animals that consume both plants and animals are called **omnivores**; for example, bandicoots and magpies.

Nutrition

The process of taking in food and making nutrients it contains available to an organism is called **nutrition**. In most animals, nutrition involves four main processes. These are often called **ingestion**, **digestion**, **absorption** and **egestion**. The processes of nutrition are illustrated in *Figure 351*.

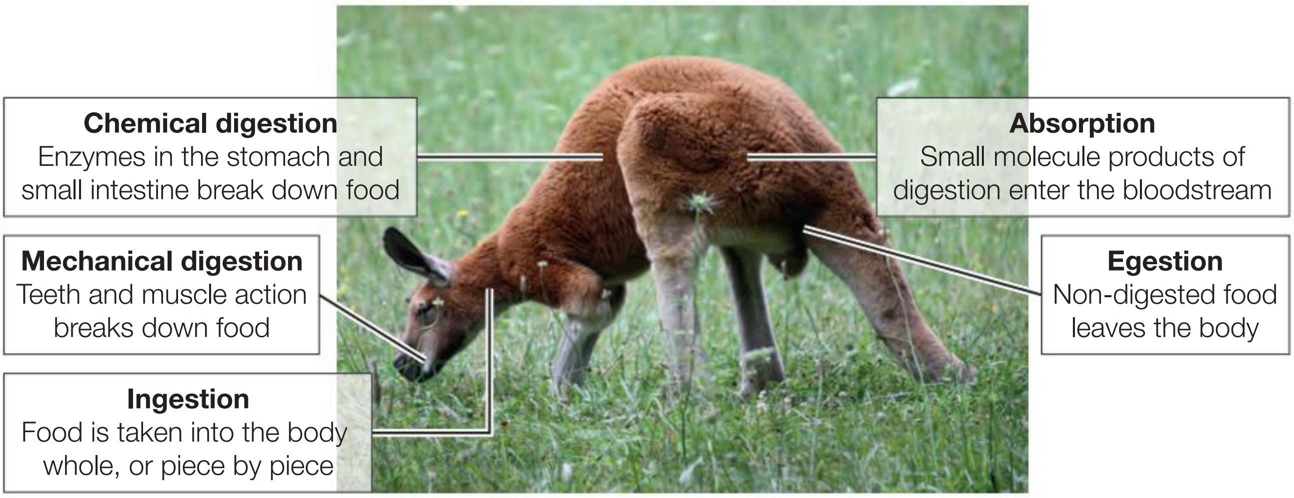


Figure 351 The processes of nutrition in an animal

Food and digestion

Food is a complex mixture of many substances. Nutrients in food include vitamins, minerals, water, and large molecules called **macromolecules**; for example, proteins, carbohydrates and **lipids**. Taking food into the body is called ingestion. The breakdown of food is called digestion.

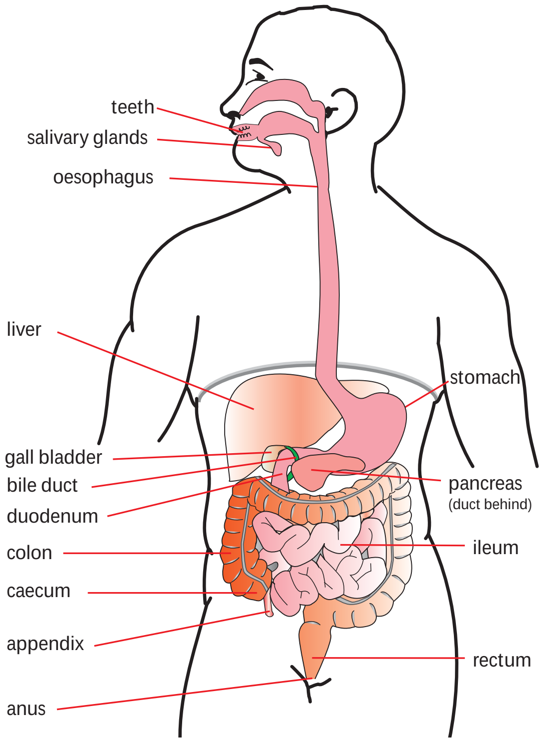
The digestion of food into small pieces by the action of teeth or muscles is called **mechanical (or physical) digestion**; for example, biting and chewing food. The breakdown of nutrient macromolecules (or **polymers**) by digestive enzymes to produce small molecules that can be absorbed is called **chemical digestion**. The small molecule products of digestion are called **monomers**.

The major macromolecules, with several examples, the digestive enzyme that chemically digests them and the monomer produced are shown in the following table:

Major macromolecule	Type of digestive enzyme	Monomer that is produced
Proteins e.g. in meat, eggs	**Proteases**	Amino acids
Carbohydrates e.g. starch, glycogen	**Amylases**	Glucose
Lipids e.g. fats, oils	**Lipases**	Fatty acids and glycerol

The digestive system

C In animals, the processes of nutrition involve a long tube that runs the length of the body called the **alimentary canal**. The structure and organs of the human digestive system is shown in *Figure 352(a)* and the human anatomy has the digestive system highlighted in *Figure 352(b)*.



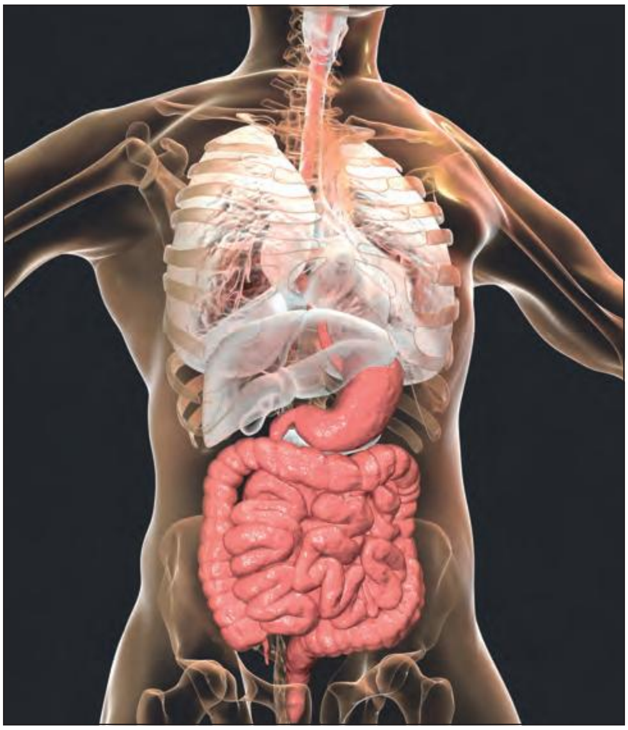


Figure 352(a) and (b) The human digestive system

Digestive system glands

An organ that produces and releases a liquid is called a gland. Several glands associated with the digestive system open into the alimentary canal and release fluids containing enzymes or other substances that assist digestion. These are the salivary glands, the pancreas, and the gallbladder. The fluids released are called **saliva**, **pancreatic juice** and bile respectively. The lining of the stomach also has a gland-like function. The fluid released by the stomach is called **gastric juice**.

The structure and function of digestive system organs

The structure of organs of the digestive system is related to their function. One example concerning the stomach was illustrated in Chapter 3.2. This and other examples are shown in the following table.

Organ	Structure	Function
Salivary glands	Saliva-making tissue	Produce saliva to moisten and lubricate food
	Amylase-making tissue	Produce amylase to start chemical digestion of starch
	Salivary ducts	Allow saliva and amylase to enter the mouth
Oesophagus	Tube-like	Allow pieces of partly digested food to travel to the stomach
	Walls with muscle	Push pieces of food to the stomach
Stomach	Bag-like	Store partly digested food after a meal
	Walls folded, and elastic	Allow the stomach's volume to increase to store more food
	Gastric juice-making tissue	Produce hydrochloric acid to kill bacteria and activate proteases
		Produce proteases to start chemical digestion of protein
	Walls with muscle	Turn stomach contents to increase contact with gastric juice
		Contribute to mechanical digestion
Pancreas	Pancreatic juice-making tissue	Produce an alkaline fluid to form a pH neutral environment needed by enzymes released into the duodenum
		Produce amylases to finish chemical digestion of carbohydrates
		Produce proteases to finish chemical digestion of proteins
		Produce lipases to start and finish chemical digestion of lipids
	Pancreatic duct	Allow pancreatic juice to enter the duodenum
Liver	Bile-producing tissue	Produce bile to break up lipid droplets so that the contact of lipids with lipases is increased to digest lipids
Gallbladder	Bile storage tissue	Store bile until needed
	Bile duct	Allow bile to enter the duodenum
Duodenum	Tube-like	Allow chemical digestion of carbohydrates, proteins and lipids
	Walls with muscle	Push the duodenum's contents to the ileum
Ileum	Tube-like	Allow chemical digestion to be completed
	Walls lined with villi	Allow products of digestion, vitamins and water to be absorbed
	Walls with muscle	Push non-digestible material to the colon; for example, fibre
Colon	Walls with a thin lining	Allow minerals and a variable quantity of water to be absorbed
	Muscle in walls	Push the colon's contents (to become faeces) to the rectum
Rectum	Tube-like	Store faeces
	Walls with muscle	Push faeces out of the rectum at egestion

Helpful Online RESOURCE to view an EVA on the digestive system

To view an Essentials Video Animation (EVA) on this topic use this QR code to visit:

<http://essentialseducation.com.au/resources/sace-1/biology/digestive-system/>

Absorption

The movement of nutrients in food and the products of digestion from the alimentary canal into the bloodstream is called absorption. Most absorption in the human digestive system occurs in the small intestine, especially in a region called the ileum. Absorption of water and minerals also takes place in a region of the large intestine called the colon.

The ileum

The ileum's structure facilitates the absorption of nutrients and the products of digestion. In the human digestive system this includes:

- The walls of the ileum have circular folds to increase the surface area for absorption.
- The lining of the ileum is very thin because it only consists of a single layer of epithelial tissue. This reduces the distance substances have to enter the bloodstream.
- The **epithelium** lining the ileum consists of a huge number of finger-like projections called **villi** which further increase the surface area for absorption (*see Figure 354(b)*).
- The ileum's epithelium is moist which assists the transport of substances being absorbed.

The structure of the ileum is shown in *Figure 353*, note that the cavity inside is called the lumen.

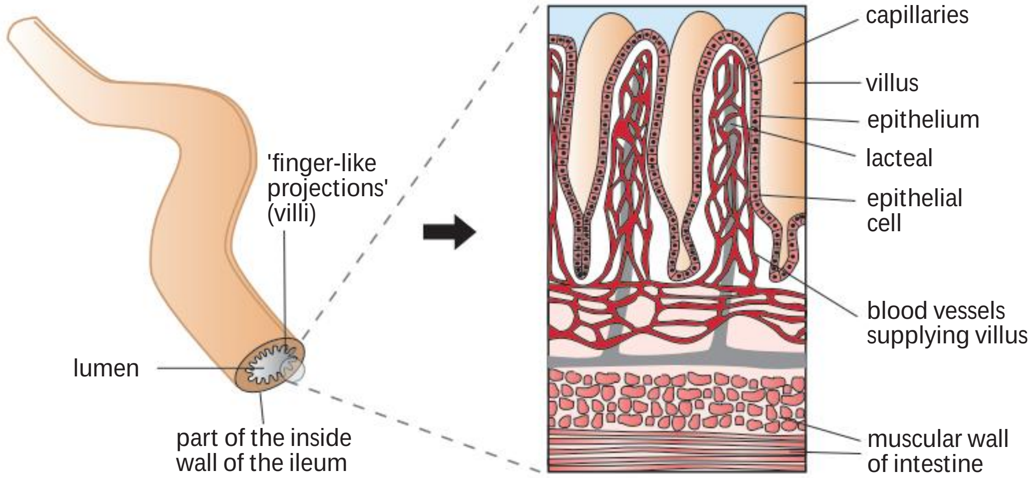


Figure 353 A section through the ileum showing villi and the ileum's epithelium

The structure and function of villi

The epithelium of each villus encloses a network of tiny blood vessels of the circulatory system called capillaries. At the core of a villus is a small vessel of the lymphatic system called a lymph capillary or **lacteal**. Nutrients and the products of digestion are absorbed across the epithelium of the villi into the capillaries or lacteals. Glucose, amino acids and many vitamins are absorbed into the blood capillaries compared with fatty acids and glycerol that pass into lacteals.

The labelled structure of a villus is shown in *Figure 354(a)*. Refer to *Figure 354*(b) which is a coloured scanning electron micrograph showing some of the villi in the small intestine.

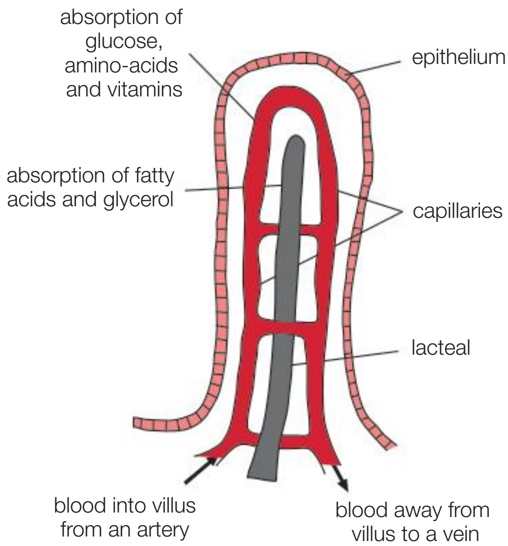


Figure 354 A magnified view of a villus as (a) a diagram and (b) a SEM photomicrograph (~x100)

A variety of transport processes are involved in moving products of digestion and vitamins from the ileum through the villi and into the bloodstream. In some cases, glucose absorption takes place by diffusion, the passive process that was discussed in Chapter 3.3. Most of the time, however, the absorption of glucose and amino acids takes place by a different process called **active transport.**

Unlike diffusion, substances that are moved by active transport are pumped by cells against the concentration gradient; in other words, they are transported from a region of lower concentration; outside the villi in the ileum, to a region of higher concentration; inside the villi. Fatty acids and glycerol, and most vitamins are also actively transported into villi. A few vitamins, however, are transported through villi by a process that involves the inward folding of the epithelial cell membrane called **endocytosis**; for example, absorption of vitamin B_{12}. These processes are more thoroughly discussed in Chapter 1.5.

Helpful Online RESOURCE about endocytosis (and exocytosis)

To view an Essentials Video Animation (EVA) on this topic, use this QR code to visit:

<http://essentialseducation.com.au/resources/sace-1/biology/endocytosis-exocytosis/>

The colon

As faeces is moved through the colon, minerals it contains are absorbed. This includes salts like sodium that is absorbed through the colon lining by active transport. Varying amounts of water are absorbed through the lining of the colon as well by a process called osmosis.

Egestion

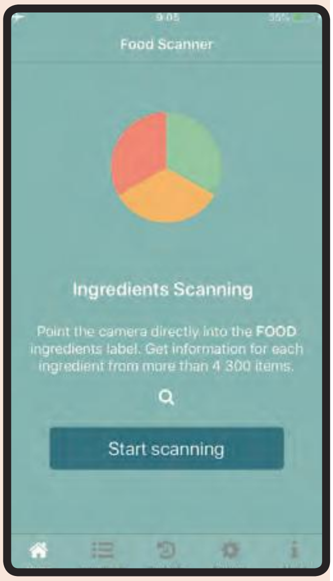
The end portion of the large intestine is called the rectum where faeces is stored until it can be eliminated from the body. The removal of faeces begins with strong contractions of muscle in the walls of the colon. The process of removal of faeces from the body is called egestion (or defecation).

Key Concepts

1. Animals depend on a regular supply of food to obtain nutrients essential for survival.
2. Animal nutrition involves ingestion, digestion, absorption and egestion.
3. The digestion of food involves both mechanical and chemical processes.
4. The animal digestive system consists of the alimentary canal and digestive system glands.
5. The structure of organs of the digestive system and villi is related to their function.
6. Most nutrients and all the products of digestion are absorbed through villi in the ileum.
7. Villi provide a large SA:V ratio for absorption. They also contain thin, moist membranes and have a dense capillary network and rich blood supply to assist with absorption.
8. Certain minerals and water are absorbed through the walls of the colon.
9. Absorption takes place by a variety of transport processes including osmosis, diffusion, active transport and endocytosis.
10. Non-digestible material is removed from the body as faeces at egestion.

C ICT: Food labelling scanner

The substances naturally occurring in a food are listed in a panel on the food labelling called Nutritional Information e.g. protein, dietary fibre, and sodium. Any other substance added to a food is listed in a section called Ingredients e.g. malt extract, acidity regulator, and water.



Food ingredients also include substances known as food additives. These are added for specific purposes during processing, storage, or packaging. The reasons for including food additives in food include maintaining the quality and freshness of the food, making the food more appealing to consumers, and extending the shelf life.

Additionally, an E number describes some food additives. These are codes for substances that used as additives within European Union (EU) countries. Food products imported from EU countries have them associated with food labelling e.g. E101 that is riboflavin, a colouring additive.

Reading and being guided by food labelling makes digestive system function and health more likely. For many people, however, the information provided is too difficult to understand. Taking the time to learn what to look for in food labels is a good idea. One way to do this is to access online the Australian Government Department of Health's The Australian Dietary Guidelines.

In a new development, a software company based on the Gold Coast in Queensland called *MaxSoft* has launched an app to permit a smartphone to serve as a food ingredients scanner (see pic). Armed with this piece of technology, all a consumer needs to do is to point the camera at a food's Ingredients, wait for a few seconds, and then substances in the Ingredients are displayed on screen by colour: red for hazardous, orange for fair, and green for safe to use.

You may need to refer to the online resources below to answer the questions that follow.

1. State what type of data might be located and accessed electronically using this App.

2. Explain how the use of such a food labelling scanner may enable more people to take better control of their nutrition.

Helpful Online RESOURCE about how to read food labelling

To learn more about how to read the information in food labels view the clip below:

<https://www.youtube.com/watch?v=sm4O5u-JeDY>

Helpful Online RESOURCE about the *MaxSoft* food ingredients scanner

To learn more about the MaxSoft scanner and how it could be used view the clip below:

<https://www.youtube.com/watch?v=CNmATcyuTFQ>

What have you learned?

Key Terms

heterotroph
herbivore
carnivore
omnivore
nutrition
ingestion
digestion
absorption
egestion
amylase
protease
lipase
lipid
macromolecule
mechanical digestion
chemical digestion
polymer
monomer
alimentary canal
saliva
gastric juice
pancreatic juice
epithelium
villus
lacteal
active transport
endocytosis

Knowledge and Understanding

1. Select one important organ of the human digestive system and explain how its structure enables it to perform its function. A diagram may be helpful.

2. Draw a diagram of a single villus in the space provided. Label the features that are vital to the function of the villus and briefly outline how they help to ensure absorption is efficient.

3. Describe the function(s) of saliva in digestion.

4. Use examples to help explain the difference (s) between mechanical (or physical) digestion and chemical digestion.

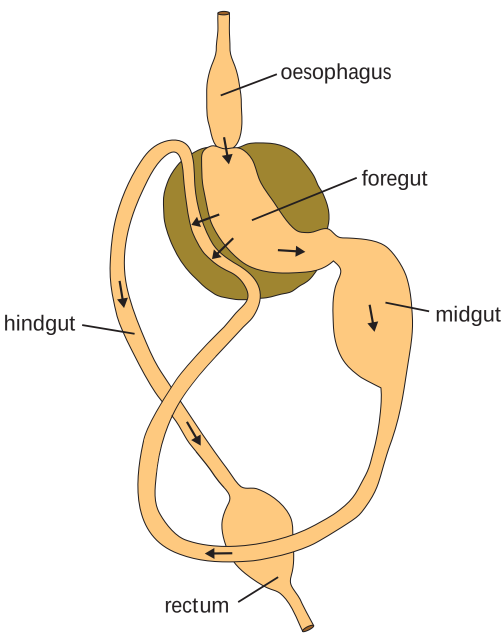
Application, Analysis and Evaluation

5. Over time, the muscles in the wall of a person's oesophagus may lose the ability to contract. Predict a likely effect that this would this have on the nutrition of the person.

6. The human ileum is about 3 metres long. Suggest how this feature is related to its function.

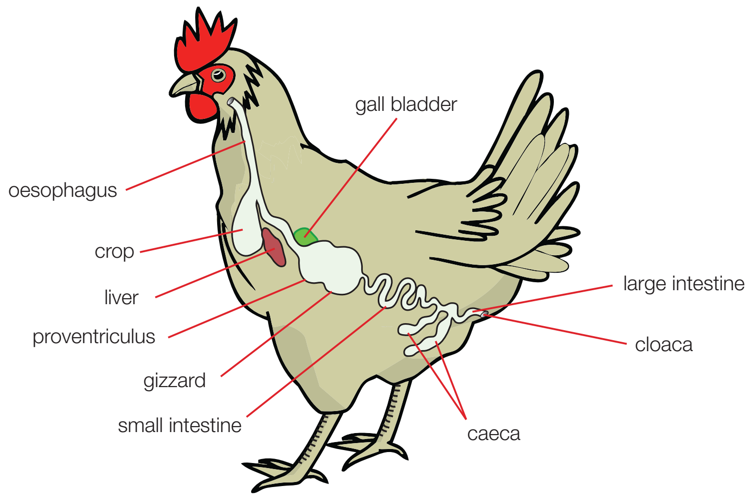
7. A drawing of the 'inside' of a living organism is shown in the Figure on the right.

Provide and explain two pieces of evidence from the drawing that suggest the living organism is a type of animal.



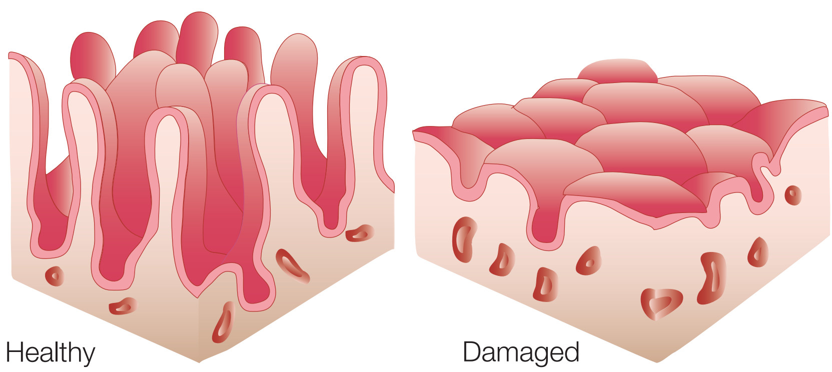
8. Compare the function of the duodenum in the human body with the function of the colon.

9. The digestive system of a domestic fowl is shown in the Figure below.



Identify three organs of the bird digestive system that are not present in the human digestive system, and find out the main function of each of them.

10. Coeliac disease occurs when the immune system responds abnormally to a protein found in some foods called gluten. One consequence of this is villi in the small intestine become inflamed and flattened. Healthy and damaged villi are shown in the Figure below. Coeliac disease can lead to insufficient absorption of essential nutrients leading to various types of malnutrition.



a) Describe the effect of coeliac disease on the amount of surface area for absorption provided by villi.

b) Predict likely symptoms of this disease, giving reasons for your answer.

11. The relative amounts of substances in the mouth, ileum and colon during and after a person eats a meal is shown in the following table.

Substance	Amount in mouth	Amount in ileum	Amount in colon
Starch	High	None	None
Glucose	Very little	High	None
Protein	High	None	None
Amino acids	None	High	None
Fibre	High	High	High

a) Explain the observations for starch and glucose.

b) Suggest reasons for the high levels of the products of digestion in the ileum.

c) Put forward a reason to explain why the amount of fibre in the colon is high, compared with other substances.

Science Inquiry Skills 3.5 - The action of the enzyme amylase

Introduction

Starch is one example of a carbohydrate that is a macromolecule. The chemical digestion of starch starts in the mouth where there is one type of amylase enzyme in saliva called salivary amylase. The products of chemical digestion of starch are simple sugars (monosaccharides) including glucose.

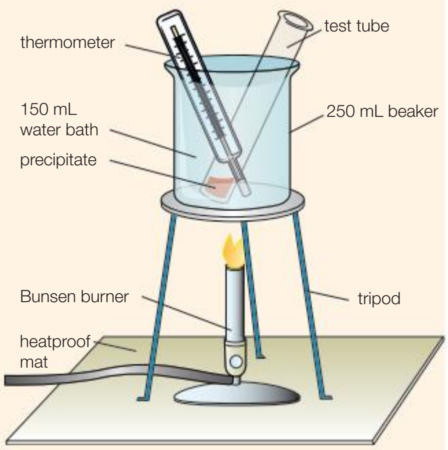
Starch can be identified using iodine solution. If starch is present, iodine solution turns a blue-black colour. One way to show the presence of simple sugars is to use blue Benedict's solution. If simple sugar is present, when mixed with Benedict's solution, a solid, called a precipitate (or 'ppt') forms. The colour of the precipitate indicates how much sugar is present. This information is shown in the following key.

Blue solution	Green / yellow ppt	Orange ppt	Brick-red ppt
No sugar	Traces	Moderate	Large amt.

Materials

10% diastase (salivary amylase) solution (this is used as 'artificial saliva' in the investigation), plastic pipette, 6 test tubes (tt) (labelled A,B,C,D,E,F) in a large beaker or a test tube rack, 2 × 250 mL beakers, Bunsen burner and heating equipment, thermometer, a test tube holder, 1% starch solution, iodine solution, 5% glucose solution, Benedict's solution, watch or clock

(Note: an alternative test for simple sugars is to use *Clinistix* or *Multistix*)



Method

A test for starch

Into tt A add 4mL of starch solution and 5 drops of iodine solution, mix thoroughly and place in a warm (35°-40°C) water bath for about 5 minutes. Record the colour change below.

A test for glucose

Into tt B add 4mL of 5% glucose solution and 4mL of Benedict's solution, mix thoroughly and place in a hot (75°-95°C) water bath for about 5 minutes. Record the colour change below.

Testing to see if salivary amylase breaks down starch to simple sugars (e.g. glucose)

1. Into tt C place 4mL of starch solution and 4mL of distilled water, mix thoroughly and place in a warm (35°-40°C) water bath for about 5 minutes.
2. Mix well and transfer approximately half of the contents of this tt (approx 4mL) to another tt D.
3. Conduct the test for starch on the contents of tt C and record the colour change.
4. Conduct the test for glucose on the contents of tt D and record the colour change.
5. Into tt E place 4mL of starch solution and 4mL 10% diastase, mix thoroughly and place in a warm (35°-40°C) water bath for about 5 minutes.
6. Mix well and transfer approximately half of the contents of this tt (approx 4mL) to another tt F.
7. Conduct the test for starch on the contents of tt E and record the colour change.
8. Conduct the test for glucose on the contents of tt F and record the colour change.

Results

1. Describe the colour change indicating the presence of starch in tt A ....
2. Describe the colour change indicating the presence of glucose in tt B ....

Science Inquiry Skills 3.5 - The action of the enzyme amylase (cont.)

Results (continued)

Using the lines below, devise and draw a suitable data table to display the results you obtained in these tests in tt A,B,C,D,E,F.

Discussion

1. Outline the evidence that suggests that diastase (amylase) can break down starch into simple sugars.

2. Outline any factors that should be held constant in this experiment and give reasons why.

3. Explain the importance of using a 'fair test' in scientific experiments.

4. State which test tubes in this experiment are used to ensure it is a 'fair test' and explain how.

Science as a Human Endeavour 3.5 - The cause of stomach ulcers

Development

New technologies ... can reveal new evidence that may modify or replace ....

Until the mid-1980s it was taken as medical fact that peptic ulcer disease was caused by the over-production of acid by gastric juice making tissue in the stomach lining. Lifestyle choices that increased the likelihood of this occurring were believed to be; work-related stress, a poor diet and/or too many spicy foods, and smoking.

Two West Australians Barry Marshall, a physician and Robin Warren, a pathologist showed that a bacterium H.pylori I caused stomach ulcers and could be linked to stomach cancer. They collected evidence from a range of sources including biopsies from ulcers and electron microscope images in 1983. There was much scepticism in the scientific world as very few gastro-enterologists believed that a bacterium could be responsible.

To provide almost irrefutable evidence, Barry Marshall drank broth infected with *H. pylori* and subsequently developed stomach ulcer symptoms. Today, stomach ulcers can be biopsied using endoscopy and tests conducted for the presence of the bacteria. A carbon-14 breath test can also check for the presence of the bacterium.

Marshall and Warren's discovery was eventually seen as ground-breaking and led to them being awarded in 2005 one of Science's highest honours, the Nobel Prize in Physiology or Medicine (pic). It has seen the 'over-production of stomach acid' model for peptic ulcer disease replaced by a new model. This includes a role played by a species of microorganism.

You may need to refer to the online resources below to answer the questions that follow:

1. Describe the evidence that eventually led to the replacement of the old model regarding peptic ulcers.

2. Describe a new technology that improves detection of a bacterial induced stomach ulcer.

Helpful Online RESOURCE for information about ulcers

For more information about stomach ulcers use this QR code to access:

<https://www.betterhealth.vic.gov.au/health/conditionsandtreatments/stomach-ulcer>

Helpful Online RESOURCE for information about Marshall and Warren

For more information about the work of Professors Barry Marshall and Robin Warren:

<https://aips.net.au/florey-award/the-florey-medal/2002-professor-barry-marshall-professor-robin-warren/>

Chapter 3.6 The excretory system in animals

Science Understanding

In animals, the excretory system is responsible for the removal of wastes.

- Describe the structure and function of nephrons in the kidney in the human excretory system.
- Explain the importance of filtration and reabsorption.

Metabolism

All the biochemical reactions carried out by a living thing are called **metabolism**. How quickly metabolism occurs is called the metabolic rate. Each biochemical reaction that is part of a cell's metabolism is called a **metabolic reaction**. Processes vital to life, made possible by metabolic reactions, are called metabolic processes; for example, aerobic respiration and photosynthesis.

Excretion

Some of the metabolic reactions in cells produce harmful substances that need to be removed called **metabolic wastes**. The removal of the wastes of metabolism is called **excretion**. In animals, wastes that are excreted include carbon dioxide and nitrogen-containing waste; for example, urea. Faeces are not a metabolic waste because they are not produced by metabolic reactions – it is mostly indigestible food material. The term 'excretion' also refers to the removal of excess water and salts absorbed from the alimentary canal into the bloodstream, as well as removal of the break-down products of hormones and drugs.

Organs that permit excretion are called **excretory organs.** The main excretory organs in humans and the substances they excrete are shown in *Figure 361.*

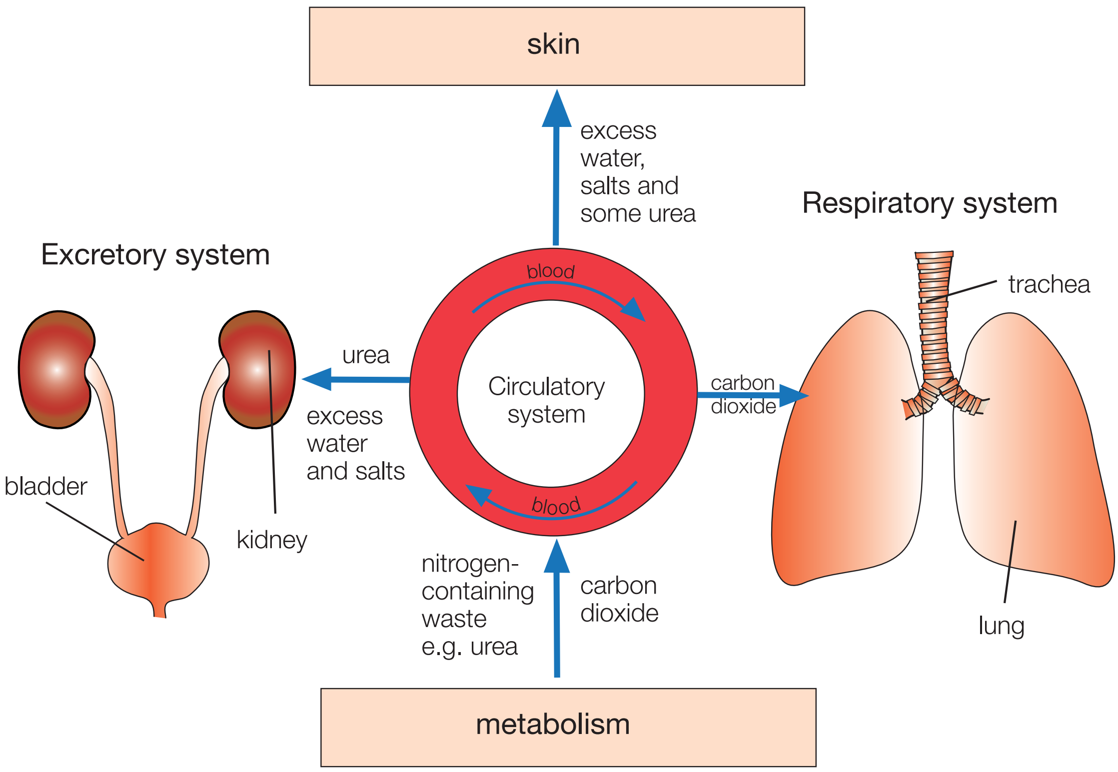


Figure 361 Excretion by humans

The excretory system

In animals, the excretory system is responsible for the removal of most nitrogen-containing waste like urea. The structure of the human urinary system is shown in *Figure 362(a) and (b)*.

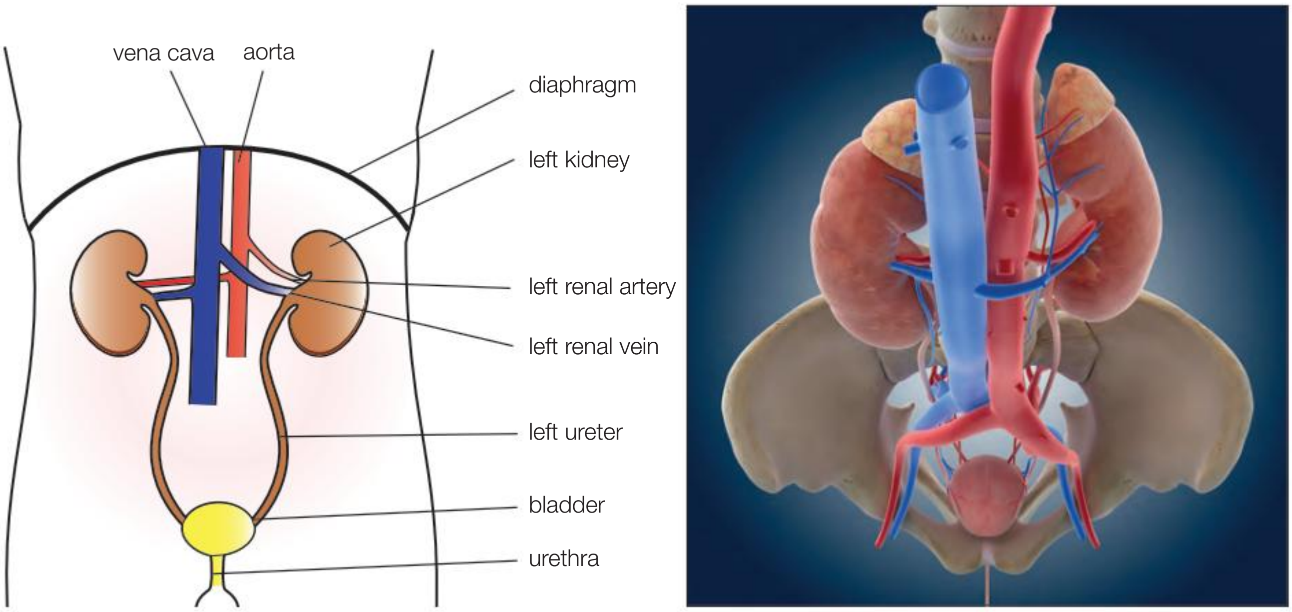


Figure 362 The human urinary system as (a) a diagram and (b) computer artwork

The excretory system is located in a region of the body below the diaphragm called the **abdominal cavity**. Blood flows into a kidney in an artery called the **renal artery**. Blood that has passed through a kidney flows out of it in a vein called the **renal vein**. The major organs of the urinary system and their function are shown in the following table.

Organs	Function
Kidney	Produces urine to remove nitrogen-containing waste Maintains the balance of water and salts in the blood
Ureter	Transports urine from the kidneys to the bladder
Bladder	Stores urine
Urethra	Transports urine out of the bladder during urination

Helpful Online RESOURCE to view an EVA about kidney function

To view an Essentials Video Animation (EVA) on this topic use this QR code to visit:
<http://essentialseducation.com.au/resources/sace-1/biology/excretory-system/>

Kidney tissue

Each kidney is packed with tiny renal tubules that are type of tube-like epithelial tissue. Renal tubules have blood vessels associated with them and are held in place by connective tissue.

The kidney tissue consists of two distinct regions. The outer region is called the **cortex** and the inner region is called the **medulla**. In between the medulla and top of the ureter is a structure called the pelvis. The two regions of kidney tissue and other kidney structures are shown in *Figure 363.*

The nephron

The structure that permits nitrogen-containing waste to be removed by the kidney is called a **nephron**. Each nephron consists of a renal tubule and a cluster of capillaries located in the cortex called a **glomerulus**. The glomerulus is located in the cup-like structure of the nephron called **Bowman's capsule.**

Parts of a nephron's tubule are coiled and one part is organised into a loop that extends down to the medulla. The end of the tubule joins a tube called a **collecting duct** that passes through the medulla and opens into the pelvis. There are about a million nephrons in each kidney. The location of a few of them is shown in *Figure 363.*

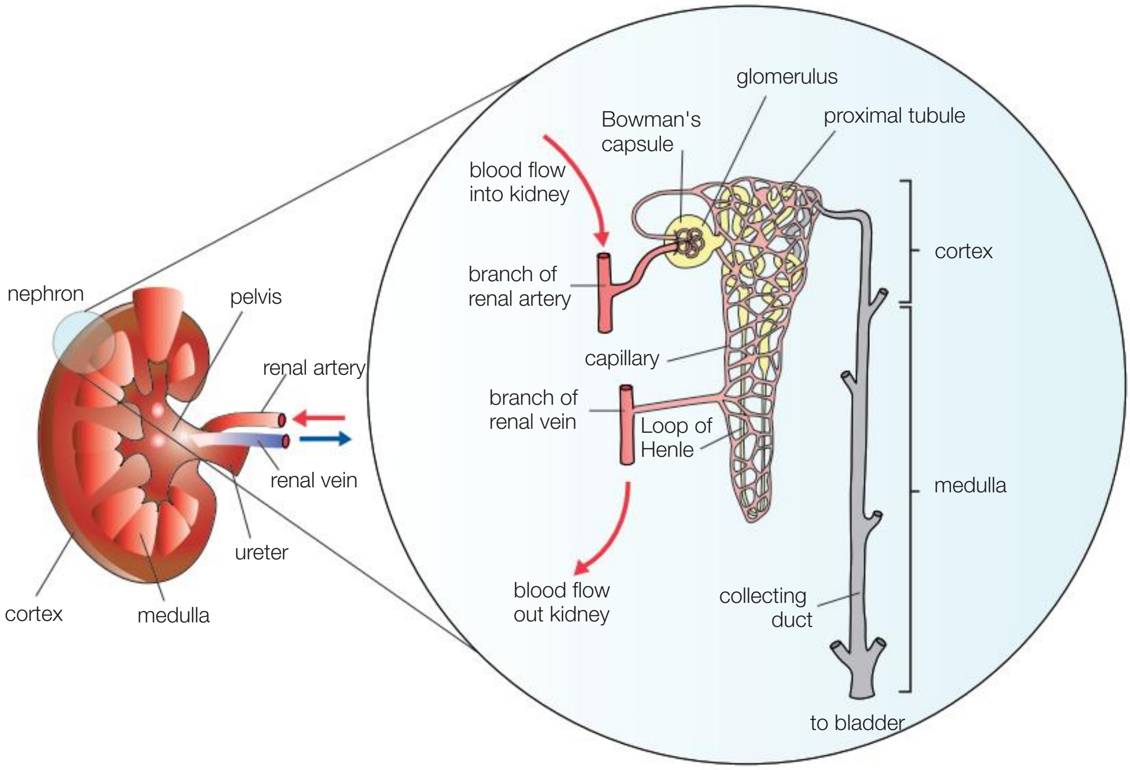
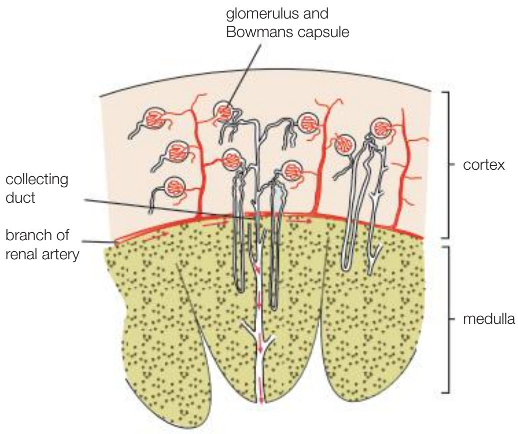


Figure 363 Kidney structure and the structure of the nephron

Filtration and selective reabsorption

Blood transported into a kidney passes from a branch of the renal artery under high pressure into the glomerulus where it undergoes a process called **filtration**. This causes water and other 'small' materials to leave the blood and enter the Bowman's capsule; for example, glucose, amino acids, salts and the nitrogen-containing waste urea. The larger components of blood (blood cells and plasma proteins) are not filtered, and thus remain in the blood. The liquid that passes into the Bowman's capsule is called the glomerular filtrate.

The filtered blood moves through capillaries that surround the proximal tubule, the Loop of Henle and the distal tubule. As this happens, some filtered materials are returned to the bloodstream by a process called **reabsorption**; for example. reabsorption of water, glucose and amino acids at the proximal tubule. Nitrogen-containing waste is not re-absorbed. Blood then passes to a branch of the renal vein for transport out of the kidney. The structure of a nephron is shown in ***Figures 363*** and ***364(a)***. Refer to ***Figure 364(b)*** showing a scanning electron micrograph of a tubule. Note the specialised cells (green) that are modified for reabsorption.



Figures 364(a) Showing the location of some nephrons and 364(b) a SEM photomicrograph of a tubule

The structure and function of nephrons

A nephron's structure is related to its function. Some examples are shown in the following table.

Part of nephron	Structure	Function
Glomerulus	A cluster of semi-permeable capillaries	Blood pressure high enough for filtration. Blood cells and large blood proteins are not filtered
Bowman's capsule	Cup-shaped and hollow	Surrounds the glomerulus to collect water and other substances that leave the blood by filtration.
Proximal tubule	Tube-like	Allows glomerular filtrate to flow within it
	Walls lined with micro-villi	Large surface area for reabsorption
	Walls very thin and moist	Distance for reabsorption of water by osmosis and other substances by active transport is reduced
	Surrounded by capillaries	Transport reabsorbed substances from the proximal tubule to a branch of the renal vein

The importance of filtration and reabsorption

Filtration provides a way to remove from the bloodstream nitrogen-containing waste and other small substances the body does not require; for example, the breakdown products of hormones and drugs. Reabsorption is selective, so specific substances in the glomerular filtrate can be returned to the bloodstream but not others; for example, substances the body needs like water and glucose. Together, filtration and selective reabsorption allow unwanted substances to leave the body in urine.

Osmoregulation at the collecting duct

In order for the body to function normally the temperature and content of its 'body fluids' have to be kept relatively constant; that is the tissue fluid in which cells in tissues sit, and the blood. Maintaining a stable internal environment is called **homeostasis**. One example of homeostasis is **osmoregulation** which involves maintaining the correct balance of water and salts in the blood.

The main site of osmoregulation is the collecting duct of a nephron. Osmoregulation at collecting ducts is controlled by large chemical-messenger proteins transported by blood called hormones. One hormone that plays an important role in osmoregulation is **antidiuretic hormone** (ADH). ADH is released from an organ of the endocrine system called the **pituitary gland**. The presence of more ADH makes the collecting duct walls more permeable to water; in other words, it allows more water in the glomerular filtrate to move through the collecting duct wall into the medulla by osmosis. When less ADH is released the collecting duct walls become less permeable to water.

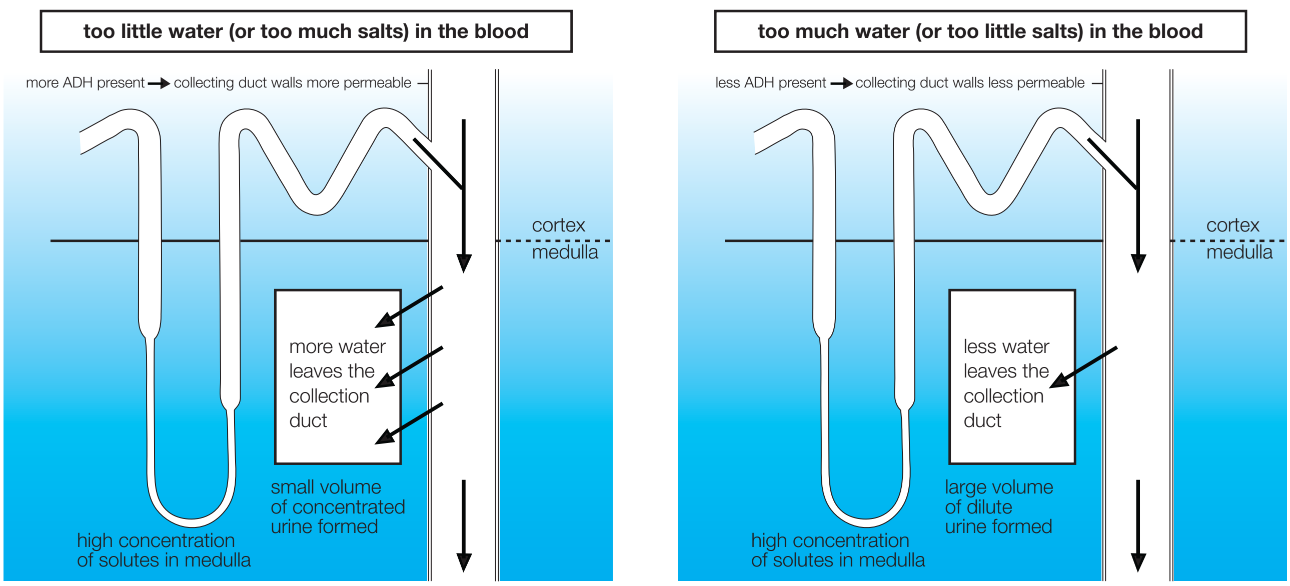


Figure 365 Osmoregulation and its control by the hormone ADH

If the water content of the blood starts to become low, or it contains too much salts, more ADH is released from the pituitary gland. This permits more water to leave the collecting ducts and enter the medulla from where it moves into the bloodstream. As a result, the water and salts content of the blood is returned to the correct balance and a small volume of quite concentrated urine is produced. If the water content of the blood starts to become high or it contains too little salts, less ADH is released. This causes less water to leave the collecting ducts and move into the medulla. A large volume of dilute urine is produced and the water and salts content of the blood is returned to the correct balance. Osmoregulation at the collecting duct is summarised in *Figure 365*.

Effect of alcohol and caffeine on osmoregulation

Substances that promote the formation of urine are called **diuretics**. Two common examples of diuretics are alcohol (in beer, wine and spirits) and caffeine (in coffee, tea and some soft drinks). Consumption of any of these beverages leads to the production of a large volume of dilute urine.

Drinking alcohol increases urine production because its presence in the bloodstream causes the pituitary gland to stop releasing ADH. This results in less water leaving the collecting ducts by osmosis. Therefore, more water drains into the pelvis and down the ureters to the bladder prompting the release of a large volume of dilute urine. Continued consumption of alcohol leads to more trips to the toilet to urinate, and dehydration, which in turn may cause the symptoms of a 'hangover'.

Why caffeine contributes to increased urine production is not as straightforward. Caffeine is thought to block the action of **angiotensin**, a hormone in the blood that constricts structures that stem from branches of arteries called **arterioles**; for example, the arteriole shown in *Figure 365* that passes blood from a branch of the renal artery into the glomerulus. The result is slightly wider arterioles, greater blood flow into the glomerulus and a higher rate of filtration, and so a higher volume of glomerular filtrate. This may lead to more water passing down the collecting ducts and therefore more urine.

Changes to urine composition

The composition of urine is altered by many factors. High air temperatures, exercise and eating a high-salt meal all lead to the production of urine with a low water content, as does severe diarrhoea. Drinking water, alcohol or caffeine results in urine with a high water content. Sudden kidney damage due to a physical blow or an accident leads to blood in urine and/or lower urine volume. The development of disease affects urine composition too; for example, diabetes leads to glucose in urine and liver disease results in a waste called bilirubin being in urine. Poor kidney function leads to kidney disease that may result in the presence of blood and/or large proteins in urine.

Treating kidney disease

Most people are able to survive normally with one of their kidney's functioning. But near or complete breakdown of function of both kidneys results in severe kidney disease, and death if not treated. The only way to treat severe kidney disease is by some form of kidney replacement therapy.

One kidney replacement therapy is called **dialysis**. In this treatment the function of the kidneys is performed artificially by a kidney dialysis machine. Blood from a vein in the arm is pumped through tubing in the dialysis machine that sits in a fluid. The walls of the tubing have lots of tiny pores in them to mimic filtration – water and small substances including nitrogen-containing waste are filtered out of the blood into the dialysis fluid, but blood cells or large blood proteins remain in the blood. The concentration of glucose and salts the body needs in the dialysis fluid is monitored to ensure it stays higher than in the blood – thus loss of these substances from the blood by diffusion is prevented.

A patient with severe kidney disease has to be connected to the dialysis machine up to three times a week. The alternative to dialysis is a complex surgical replacement procedure called a **kidney transplant.** This treatment involves removing a diseased kidney from the patient and transferring to them a healthy, functional kidney from another person. The patient is the **recipient** and the person who provides the kidney is known as the **donor**. A live donor is a relative who donates one of his or her kidneys. A deceased donor is a healthy person who has died; for example, due to a car accident.

Helpful Online RESOURCE about treating kidney disease

To learn more about treating kidney disease, use this QR code to visit:

<https://www.youtube.com/watch?v=-EpyICbTkSc>

C Intercultural understanding: Purple House

When Aboriginal people use the word 'Country', it means something else. In this context, it refers to a connectedness between culture, nature and the land. Being on Country is more than just a place to live, obtain physical sustenance, and find employment. It provides spiritual nourishment as well. Country contributes to and reinforces Aboriginal identity and feelings of belonging. Critically, then, it helps to define for Aboriginal people who they are.

Over the last few decades, an ever-increasing number of Aboriginal people have been diagnosed with kidney disease. Though this can be as the result of excessive drinking of alcohol, it is more often a consequence of diabetes brought by a diet high in simple sugars. The absence of dialysis facilities near remote Aboriginal communities has meant many Aboriginal people with kidney disease have been forced to move off Country to live in towns or cities hundreds of kilometres away. Already sick and often in the later part of their lives, this disconnection from Country can lead to a sense of helplessness and place patients at a high risk of developing depression.

In response to this, the *Western District Nganampa Wlaytja Palyantjaku Tjukaku Aboriginal Corporation* in 2001 established an Aboriginal owned and run health service in Alice Springs. Known as the *Purple House*, it provides dialysis for Aboriginal people in the Alice Springs area who therefore do not have to leave Country completely.

Purple House has also established 'dialysis in the bush' centres in the remote locations elsewhere in the Northern Territory and Western Australia keeping people connected instead of having to go to someone else's Country for treatment. *Purple House* has a vehicle with a 2-chair dialysis unit (*refer to photo*) which is able to take dialysis patients home for a period of weeks or months to reconnect with Country.

You may need to refer to the online resources below to answer the questions that follow:

1. In 2017, Australian scientists published work that suggested that Aboriginal people have a strong sense of Country because they have been living on it for at least 40,000 years. Describe this sense of Country as felt by Aboriginal Australians.

2. *Purple House* provides an example of how different cultural views and customs can be respected. Briefly explain why.

Helpful Online RESOURCE about the meaning of 'Country'

To learn more about an example of the importance of Country view the clip below:

<https://www.youtube.com/watch?v=w0sWIVR1hXw>

Helpful Online RESOURCE about Purple House

To learn about the Purple House initiative including the Purple Truck view the clip below:

<https://www.youtube.com/watch?v=XcGtRO8QZkQ>

Key Concepts

1. Some products of metabolism are wastes that are removed from the body through excretion.
2. In animals, nitrogen-containing waste is removed by the excretory system.
3. Nephrons are structures in the kidneys with very a high surface area/volume ratio that enables excretion of nitrogen-containing waste in the urine.
4. Each nephron consists of a Bowman's capsule, glomerulus and tubule, the structure of which are closely related to their functions of absorption and excretion.
5. Kidney filtration and selective reabsorption removes unwanted substances, and retains useful ones.
6. The balance of water and salts in the blood is maintained by the kidneys.
7. Severe kidney disease may be treated by dialysis, or kidney transplant.

What have you learned?

Key Terms

metabolism ....

metabolic reaction ....

waste ....

abdominal cavity ....

excretory organ ....

excretion ....

renal artery ....

renal vein ....

cortex ....

medulla ....

nephron ....

glomerulus ....

Bowman's capsule ....

collecting duct ....

filtration ....

reabsorption ....

osmoregulation ....

antidiuretic hormone ....

pituitary gland ....

diuretic ....

angiotensin ....

dialysis ....

kidney transplant ....

recipient ....

donor ....

homeostasis ....

arteriole ....

Knowledge and Understanding

1. Name the three structural components of the nephron and state the main function of each.

2. Draw a diagram of a nephron in the space provided.

   a) Label the glomerulus and Bowman's capsule and briefly explain how these structures help to ensure filtration is efficient.

   b) Label the renal tubule and the capillaries that surround the nephron and briefly explain how these structures help to ensure reabsorption is efficient.

3. Describe the role of the lungs in excretion.

4. Explain the difference between filtration and re-absorption.

Application, Analysis and Evaluation

5. With ageing, the blood pressure of an individual often increases.

   a) Explain what effect that would gradually have on how much blood is filtered per unit time.

   b) Explain what effect you would expect that to have on the volume of urine produced.

6. Outline one difference in solute concentration you would expect to find between:
   a) blood plasma and glomerular filtrate

   b) glomerular filtrate and urine

7. Predict differences in the composition of blood in the renal artery compared with blood in the renal vein.

8. The table shows the proportion of glucose and urea in blood entering the glomeruli (sing. glomerulus) in the kidney, and in urine.

Substance	Blood (%)	Urine (%)
Glucose	0.1	0.0
Urea	0.03	2.0

   a) Provide evidence from the data that suggest the kidney is functioning normally.

   b) Describe the path of a glucose molecule through a nephron.

   c) Describe the path of a urea molecule through a nephron.

9. Provide possible explanations for each of the following observations:
   a) If a section of renal tubule is cooled, glucose and amino acids begin to appear in the urine.

   b) After a physical impact to the kidney, blood may appear in the urine'

   c) One gram of kidney tissue requires more energy than one gram of heart muscle.

Science Inquiry Skills 3.6 - Dissecting a kidney

Introduction

The kidney is the main organ of excretion of nitrogen-containing waste in mammals. All mammals have a pair of kidneys that form part of the excretory system. The kidneys also play an important function in maintaining the balance of water and salts in the blood.

A good way to become familiar with the structure of a mammal kidney is to perform a dissection. Sheep kidneys are good to use, especially if they can be ordered with as much structural detail present as possible.

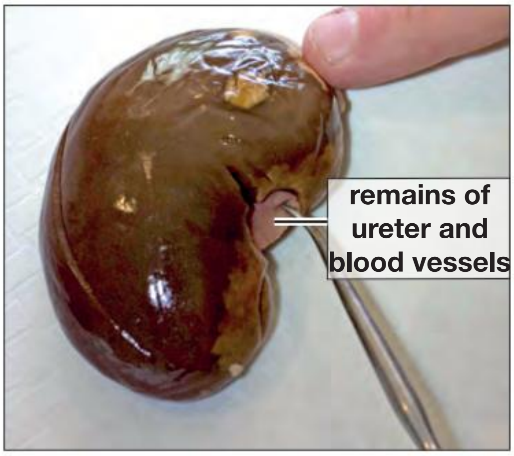
Materials

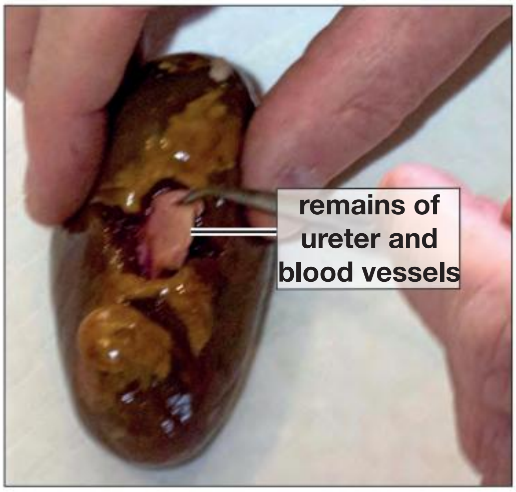
sheep kidney, dissection board, scalpel and/or scissors, dissection probe, forceps

dissection gloves (or as instructed by your teacher)

Part A: Viewing the external structure of a kidney

1. Place the kidney on its side on the dissection board.
2. Arrange the kidney so that the remains of the ureter and blood vessels are located at the middle right edge of the kidney.
3. Use the dissection probe and forceps and look for evidence of where the renal artery enters the kidney.
4. Also look for evidence of where the renal vein leaves the kidney.
5. Draw a labelled diagram of the external structure of the kidney in the space provided below.

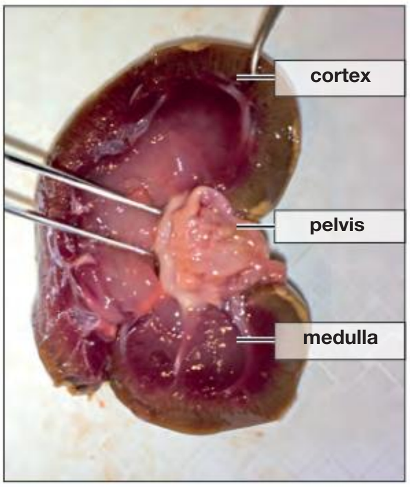




Science Inquiry Skills 3.6 - Dissecting a kidney (continued)

Part B: Investigating the internal structure of a kidney

1. Use a scalpel to cut parallel to the dissection board right through the kidney to form roughly two equal halves.
2. Place one half of the kidney on the dissection board with its cut-surface facing upwards.
3. Identify the cortex which is the outer layer of tissue in the kidney.
4. Identify the medulla which is the inner layer of tissue between the cortex and the pelvis.
5. Identify the pelvis which is white and has branches that extend up into the medulla.
6. Carefully cut into the medulla along one branch of the pelvis.
7. Draw a labelled diagram of the internal structure of the kidney in the space provided below.
8. Thoroughly clean your workplace and dispose of the remains as instructed.



Discussion

1. What is the function of the renal artery?

2. What is the best way to distinguish the cortex of the kidney from the medulla?

3. In which tissue of the kidney would you expect to find the glomerulus, the loop of Henle and a collecting duct?

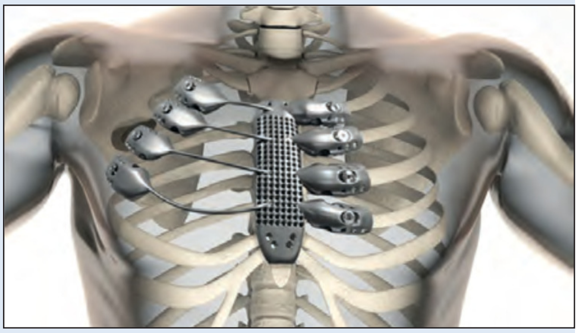
4. Urine drains out of nephrons and collects in the pelvis. How does it get to the bladder?

5. Suppose after a fight, a boxer urinates and notes there is blood in his urine. Why does this suggest he has suffered kidney damage? State which kidney structure is likely to have been damaged.

Science as a Human Endeavour 3.6 - 3D printed rib-cage

Influence

Acceptance/use of science is influenced by cultural and ethical considerations



Today there are 3D printers that can very precisely print metal. Biomedical engineers can use these to design medical devices such as artificial internal organs, replacement body parts, or implants of one kind or another. These can be produced in a way that is unique to the patient's anatomy and thus function properly without discomfort.

One emerging use of 3D printing in medicine is to treat bone cancer. In a world first in 2015, for example, a patient suffering from a bone cancer called chondrosarcoma that had spread throughout the rib cage was implanted with a new 3D printed rib cage. The engineered structure was printed using titanium and mimicked so closely the shape and function of the original rib cage that the patient was able to breathe normally.

The acceptance of 3D printing in medicine more widely by society, however, is likely to be influenced by a variety of cultural considerations. Improvements in 3D printed internal organs may see the need to harvest organs for transplantation, a step that could be welcomed by people from cultures opposed to organ donation. But could 3D printing also usher in super-enhanced types of cosmetic surgery that would permit completely re-shaped cartilage to be printed onto the face, in which case people could alter racially determined facial features, and so reduce their 'cultureness'.

There are ethical considerations surrounding using 3D printing for medical treatments. One is the cost. Is it right that these are only be available to those who can afford them? Another concerns safety. Although 3D printed implants made from metals like titanium are considered safe, will new advances be subjected to strict safety testing regimes especially if demand for newer and ever better treatments intensifies? And might advances in 3D printing one day 'cross the line' between using the technology to help people needing replacement body parts to using it to create beyond human capabilities, thus reducing their 'humanness'.

You may need to refer to the online resource below to answer the question that follows:

1. Describe 3 ethical, cultural or social considerations that may need to be taken into account regarding the availability of the 3D-printed body parts to the wider community.

Helpful Online RESOURCE about the 3D printing of a rib cage

To learn more about treating a bone cancer using a 3D printed rib cage view this clip:

<https://www.youtube.com/watch?v=gEwV61dA0ho>

Chapter 3.7 The circulatory system in animals

Science Understanding

In many animals, the transport and exchange of materials is facilitated by the structure and function of the circulatory system.

The lymphatic system is closely connected to the circulatory system.

- Compare the role of blood capillaries and lymph capillaries in the exchange of materials.

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Internal transport of materials

Cells require a supply of nutrients like glucose,amino acids, water and oxygen. They also need to remove the wastes produced by metabolism like carbon dioxide and nitrogen-containing waste. In unicellular organisms this can be done efficiently by diffusion because the distance substances need to move into/out of the organisms is very small. For multicellular organisms, however, this is not the case. These organisms require an internal transport system to meet the needs of their cells.

Open and closed circulatory systems

In animals, the transport of materials is facilitated by a circulatory system that consists of tubes, a fluid pushed through them, and a pump. Insects have an **open circulatory system**. This means movement of the fluid – which in insects is called **haemolymph** - is not wholly confined to tubes. Instead, it is pumped through vessels by a tube-like heart before passing into spaces in which organs sit, called sinuses, where materials are exchanged between the haemolymph and cells. Haemolymph returns to the heart through pores called ostia. An open circulatory system in an insect is shown in *Figure 371(a).*

In a **closed circulatory system**, the movement of the fluid – usually blood - is completely confined to tubes. Blood is pumped through **arteries** by a heart before passing through tiny blood vessels located next to cells called **capillaries** where materials are exchanged between the blood and cells. Blood is returned to the heart in **veins**. Fish have a two-chambered heart and a single circulation system – blood passes once through the heart per circulation. Humans and other mammals have a four-chambered heart and a **double circulation system** – blood passes twice through the heart per circulation. The closed circulations of fish and mammals are shown in *Figures 371(b) and (c).*

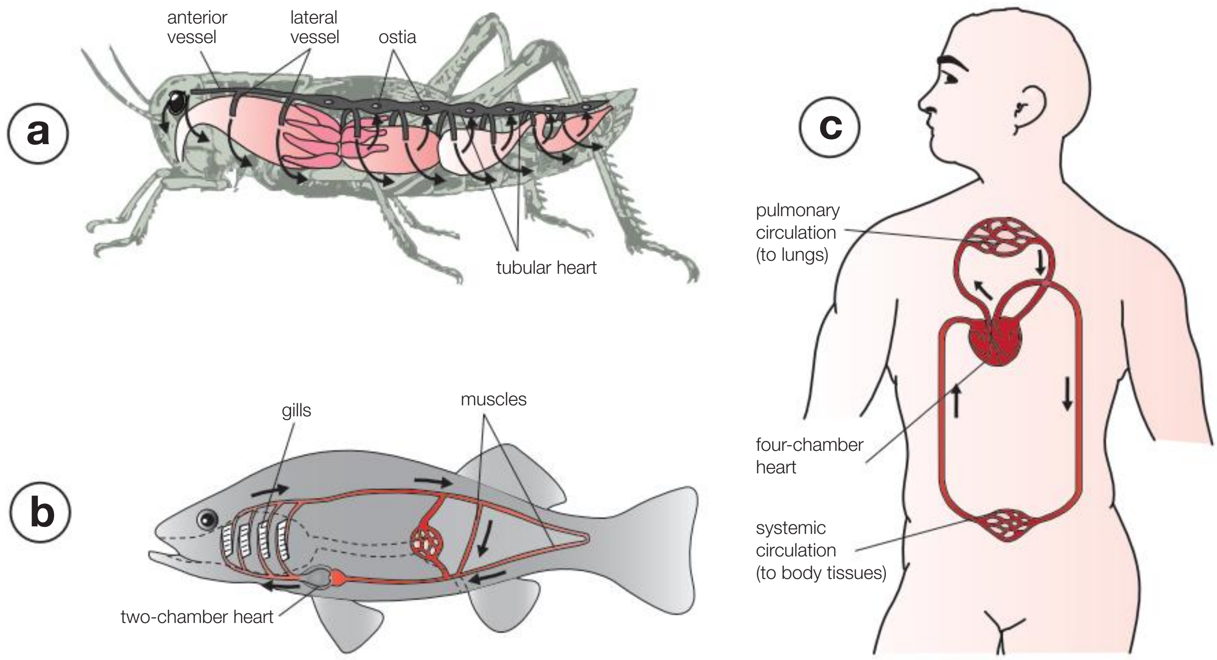


Figure 371 (a) Open and (b) and (c) Closed circulatory systems

Blood

Blood is a tissue that consists of a liquid called **plasma** and cells. The cells component of blood consists of red blood cells, white blood cells and platelets. The liquid component is mostly water which contains a wide variety of substances. The composition of blood is shown in *Figure 372*.

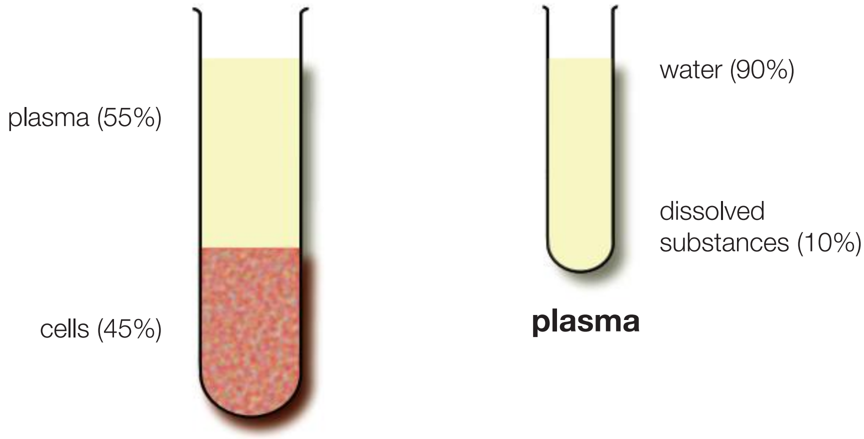


Figure 372 The different components of human blood

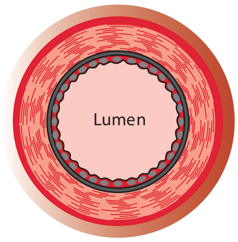
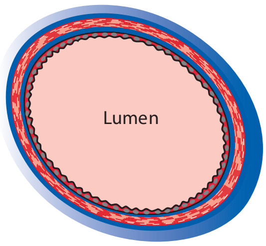
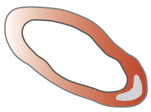
The different components of blood and their functions are shown in the following table.

Component	Composition	Function
Plasma	Nutrients and products of digestion	Transport to all cells for metabolic processes e.g. aerobic respiration
	Carbon dioxide	Transport to lungs for excretion from the body
	Hormones	Transmit chemical messages to organs to maintain a stable internal environment
	Plasma proteins	Involved in the clotting of blood and the transport of some substances
	Nitrogen-containing waste and breakdown products of hormones	Transport to kidneys for excretion from the body
	Antibodies	Bind to the surface of bacteria or viruses to enable destruction of them
Cells	Red blood cells	Transport of oxygen to all cells for aerobic respiration
	White blood cells	Destroy bacteria and viruses that have invaded the body
	Platelets (cell fragments)	Contribute to the clotting of blood

The structure and function of arteries, veins and capillaries

In the human circulatory system, there are three types of blood vessels. Arteries transport blood at high pressure away from the heart to organs and tissues. Capillaries move blood through tissues very close to cells. Veins return blood at low pressure from tissues and organs back to the heart.

The structure of arteries, veins and capillaries is related to their function. Some examples of this are shown in the following table. The images show each type of blood vessel cut in cross section. Note the term **lumen** here refers to the space inside a blood vessel.

Type of blood vessel	Structure	Function
Artery 	Tough outer layer and thick middle layer Middle layer is elastic Narrow lumen	Transport blood at high pressure without leaking or bursting Help pump blood (in pulses) Maintain high blood pressure
Vein 	Tough outer layer Wide lumen Valves	Can be squeezed by skeletal muscle to return blood at low pressure to the heart Reduce resistance to blood flow back to the heart Prevent the backflow of blood
Capillary (not to the same scale as above) 	Wall one cell thick Very narrow lumen making them very small	Reduce distance for exchange of materials Can pass very close to cells reducing the distance for exchange of materials

The circulatory system

The double circulation system of humans and other mammals consists of the **pulmonary circulation** that carries blood to/from the lungs and the **systemic circulation** that moves blood to/from all other organs. The structure of the human circulatory system is shown in *Figure 373(a)*; arrows show the direction of movement of the blood. Red and white blood cells within a vessel are depicted in *Figure 373(b)*.

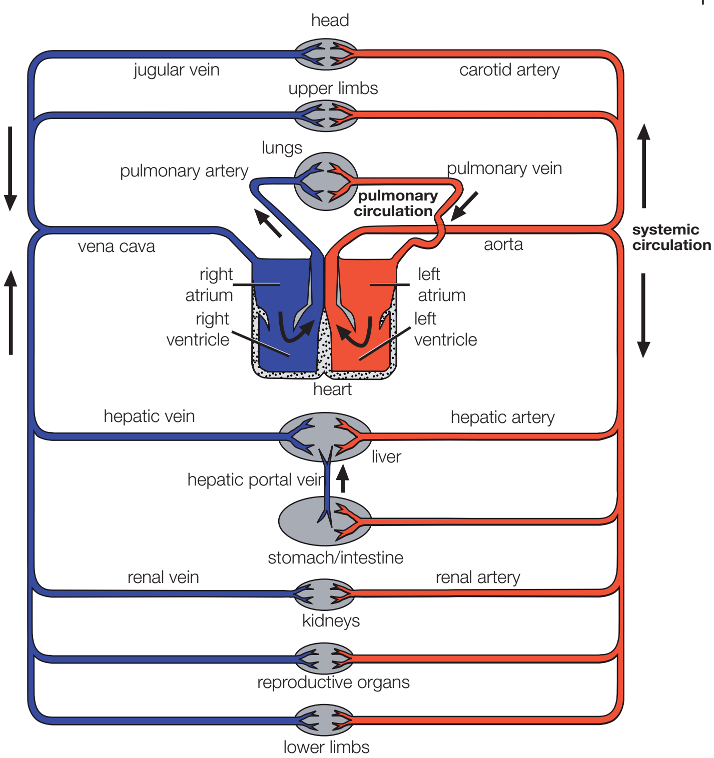


Figure 373(a) The human circulatory system

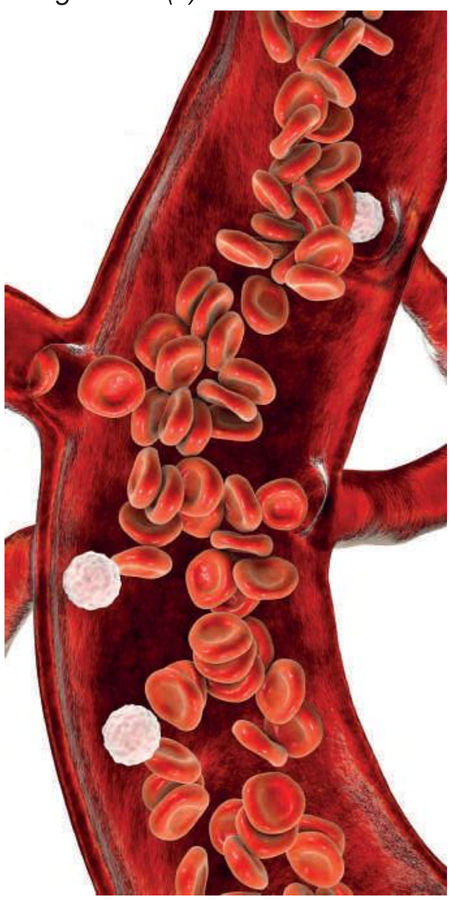


Figure 373(b) Blood cells inside a vessel (~x2000)

Oxygenated and deoxygenated blood

Blood that leaves the lungs, flows into the left-side of the heart and is pumped out to organs is oxygenated – it carries a high concentration of oxygen and a low concentration of carbon dioxide. Blood that is returned from organs to the right side of the heart to be pumped to the lungs is deoxygenated – it has a low concentration of oxygen and a high concentration of carbon dioxide. The location of oxygenated and **deoxygenated blood** is shown in *Figure 373*(a) – red is used to highlight where blood is oxygenated and blue is used to show where it is deoxygenated. Note that oxygenated blood is transported by arteries, except the pulmonary artery, which transports deoxygenated blood. Similarly, all veins transport deoxygenated blood, except the pulmonary vein, which transports oxygenated blood.

The heart

The human heart is located in the thorax between the lungs. Heart or cardiac muscle is supplied with **oxygenated blood** by **coronary arteries** and deoxygenated blood leaves cardiac muscle in coronary veins. The external heart structure is shown in *Figure 374*.

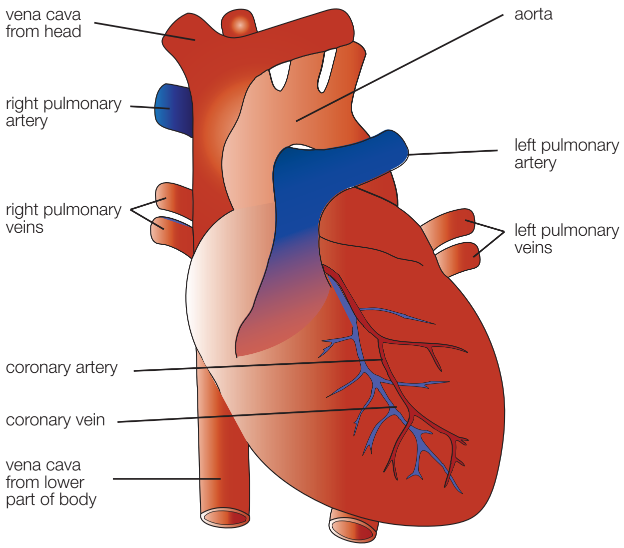


Figure 374 Outside the heart

The heart is divided into four chambers – the two on the right are separated from two on the left by a wall-like septum. Blood enters the heart via two upper chambers called atria (singular: **atrium**). Blood is pumped out of the heart by the muscular walls of two lower chambers called **ventricles**. The left ventricle wall is the thicker of the two as it must pump blood to all organs except the lungs.

The heart has four valves, which maintain the direction of blood flow through the heart by preventing backflow. Two valves called **atrioventricular valves** are between the atria and ventricles and prevent blood from the ventricles flowing back to the atria. The other two valves are called **semilunar valves**. One separates the right ventricle and the pulmonary artery while the other one separates the left ventricle from the aorta. These valves prevent blood flowing back into the ventricles. The internal heart structure is shown in *Figure 375*.

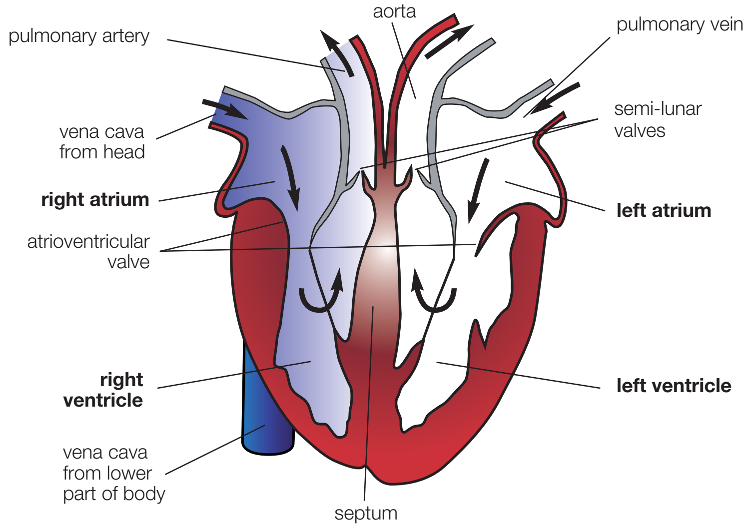


Figure 375 Inside the heart

The heart as a pump

At rest the heart pumps or beats 70-80 times per minute. The sequence of events of a heartbeat is called the cardiac cycle. One cardiac cycle is shown in *Figure 376*.

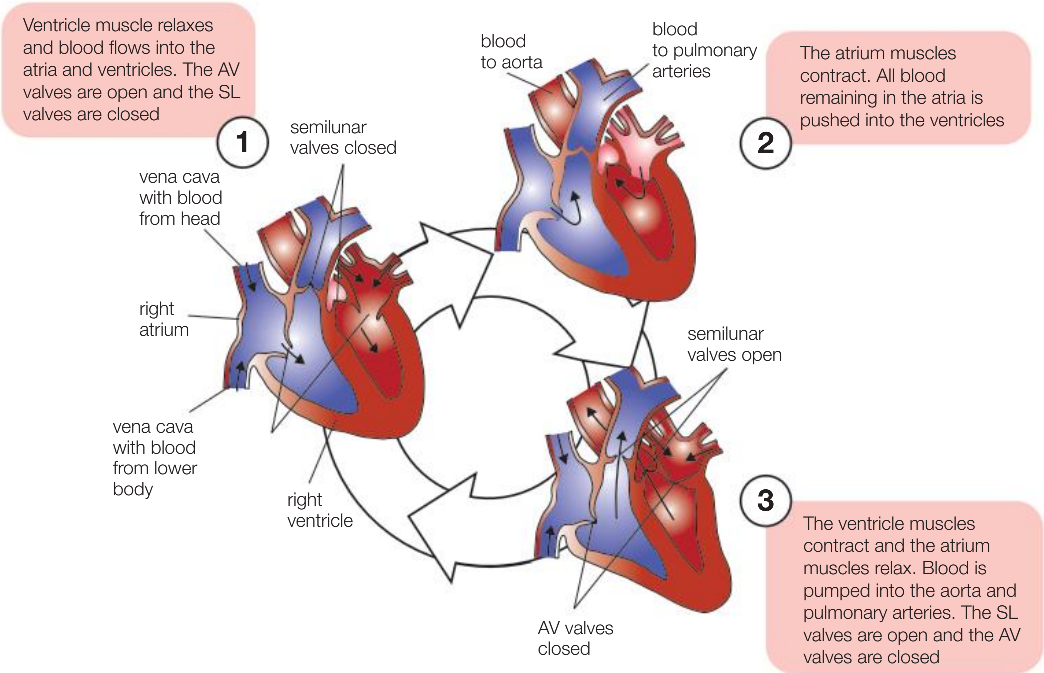


Figure 376 The events in a heartbeat.

Helpful Online RESOURCE about how the heart pumps blood

To learn more about the pumping action of the heart, use this QR code to visit:

<http://www.kscience.co.uk/animations/heart.swf >

Tissue fluid

Blood pumped into the aorta is transported in arteries to all parts of the body (except the lungs). Arteries divide into small **arterioles** that carry blood from an artery into a network of capillaries. Capillary networks in all tissues ensure all cells are very close to a capillary. As blood flowing into a capillary network from the arteriole end is at high pressure, some of the plasma is pushed out of capillaries through the tiny pores they have in their walls. This fluid in which all cells in the tissue sit is called **tissue fluid**. The capillaries join larger **venules** that carry blood at very low pressure from the capillary network to a vein. A capillary network and production of tissue fluid is shown in *Figure 377*.

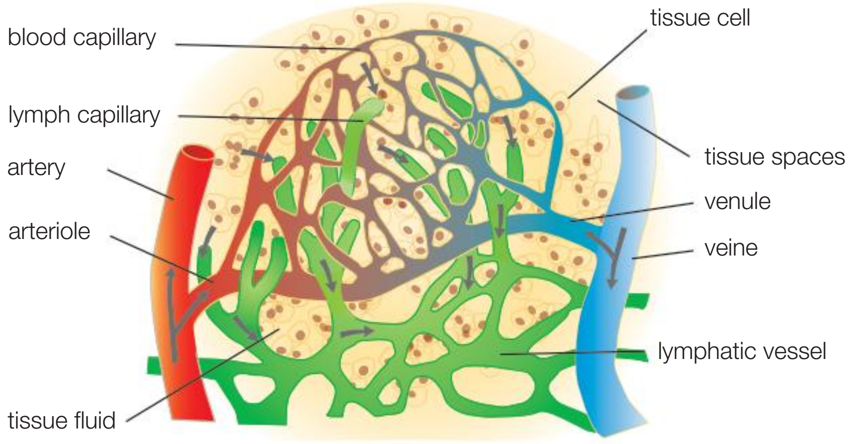


Figure 377 The blood and lymph vessels

Exchange of materials in tissues

Tissue fluid has a composition similar to plasma. It contains water, nutrients from food, salts, products of digestion like glucose and amino acids, but lacks most of the plasma's proteins. It also contains oxygen and carbon dioxide. Substances in tissue fluid that cells require, move from tissue fluid into cells. Most substances diffuse down concentration gradients into the cells; for example, glucose and oxygen. Wastes diffuse down concentration gradients into the tissue fluid and then into plasma in capillaries; for example, carbon dioxide. Although most plasma is forced out of the capillaries at the **arteriole** end, it re-enters the capillary plasma by osmosis at the **venule** end, the blood pressure there (and in veins) is much lower. Exchange between a capillary, tissue fluid and cells is shown in *Figure 378*.

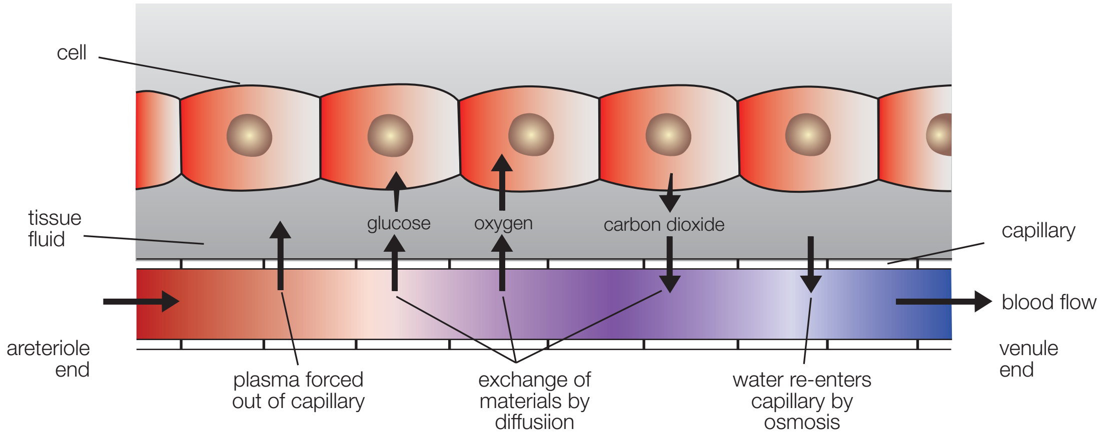


Figure 378 The role of blood capillaries in the exchange of materials

The lymphatic system

Between blood capillaries are vessels of the **lymphatic system** called lymph capillaries. Some of these are shown in *Figure 377*. Water that does not re-enter blood capillaries can also move by osmosis into lymph capillaries. The fluid in lymph capillaries is called **lymph** and is similar in composition to tissue fluid. Lymph capillaries are characterised by having thin walls and by being closed at one end. Cells in the walls of lymph vessels are able to move apart slightly in a way that permits water to move in to lymph vessels but not out (due to tissue fluid having a higher pressure than lymph). Exchange between cells, tissue fluid and a **lymph capillary** is shown in *Figure 379*.

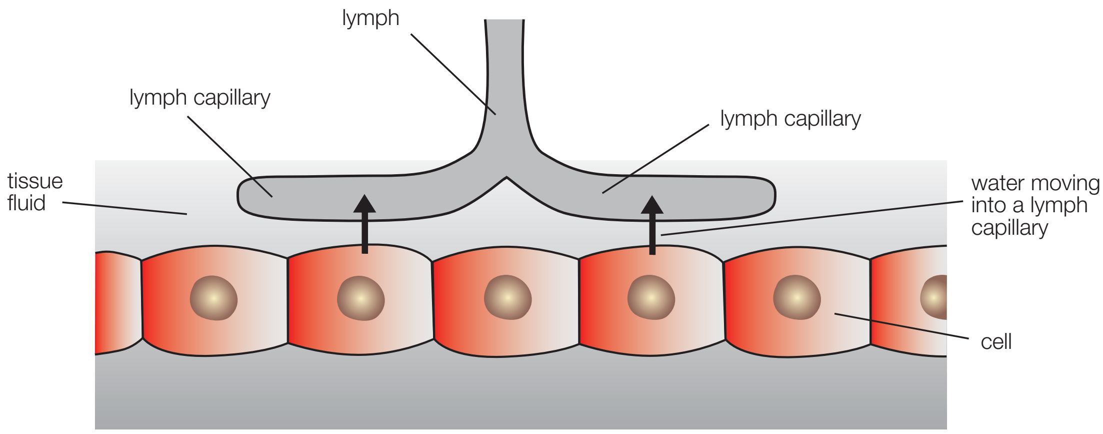


Figure 379 The role of lymph capillaries in the exchange of materials

Lymph capillaries join larger vessels called lymphatics that extend throughout the body. Along the lymphatics there are swellings called **lymph nodes** which contain white blood cells. Bacteria and viruses not already destroyed by white blood cells are moved in lymph to a lymph node to be destroyed there. Thus, lymph nodes play an important role in the immune system. Lymph and water it contains are returned to blood plasma via a pair of tubes that join veins in the neck called **thoracic ducts**.

Lacteals in villi in the small intestine, shown in *Figure 354*, are connected to a thoracic duct too. This allows the products of lipid digestion (fatty acids and glycerol) transported by lymph from the small intestine to enter the bloodstream. Refer to *Figure 380* illustrating the human lymphatic system. The lymphatic vessels are coloured green, the main organ of the lymphatic system is the thymus (yellow) and the largest organ is the spleen (red).

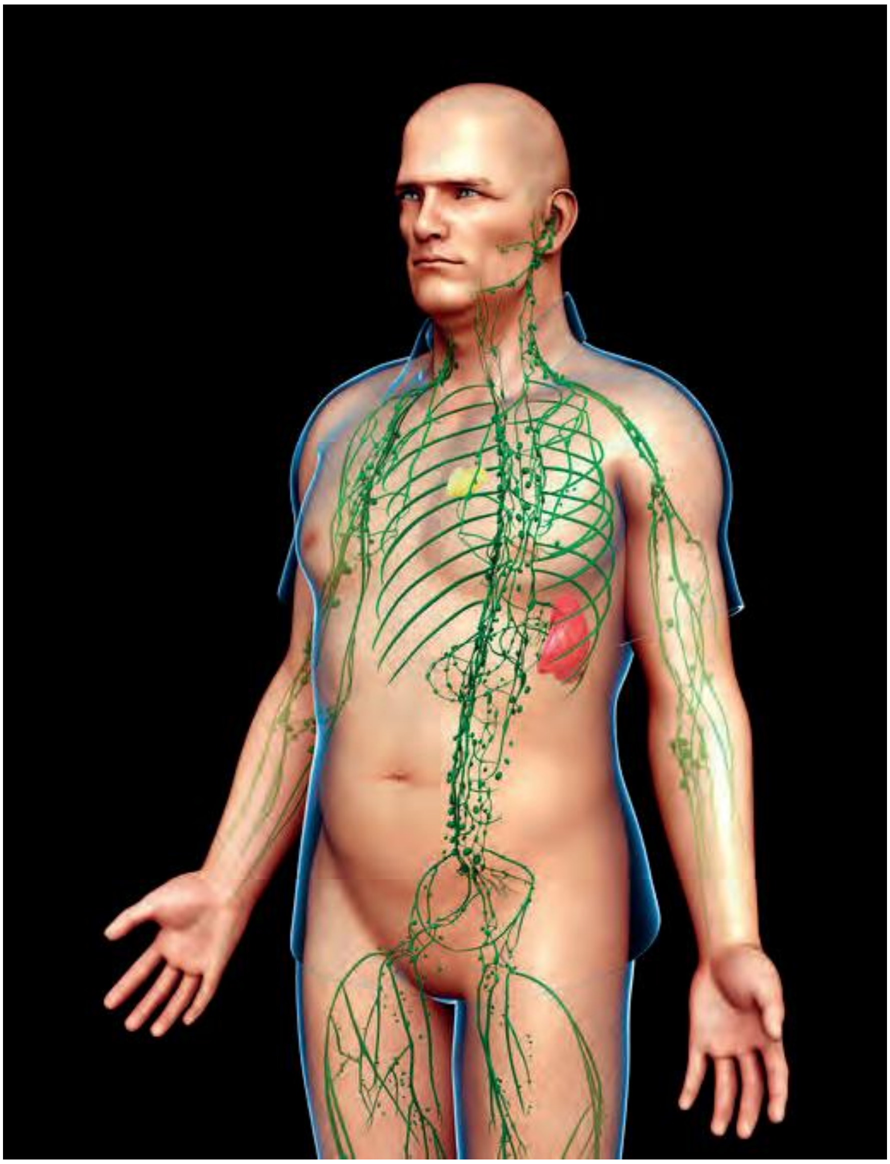


Figure 3710 The human lymphatic system

Key Concepts

1. Animals transport materials within their bodies using open or closed circulation systems.
2. The structure of arteries, veins and capillaries is related to the function of them.
3. Humans and other mammals have a double circulation system.
4. The oxygenation and pressure of blood varies in the circulatory system.
5. The heart is divided into a left and right side and contains four chambers.
6. A heartbeat involves contractions of cardiac muscle and opening/closing of valves in the heart.
7. All cells are bathed in tissue fluid that forms in capillary networks.
8. The lymphatic system is closely associated with and connected to the circulatory system.
9. The lymphatic system is a low pressure drainage system which is driven by the contraction of skeletal muscles rather than the heart.
10. Exchange of materials occurs between cells and plasma in blood capillaries, and between cells and lymph in lymph capillaries.

C Critical and creative thinking: Tumour nanosensor

The term ‘neoplasm’ refers to a type of excessive growth of tissue. This usually forms a mass called a tumour. A tumour that has not invaded neighbouring tissue is said to be benign. Tumours that have started to invade tissue around them are termed malignant. A malignant tumour is also known as cancer. Malignant tumour cells spread (from a primary tumour) to other locations in the body (leading to secondary tumours) by a process called metastasis. Methods used to combat tumours include removing tumour cells from the body (surgery) or destroying tumour cells in the body using radiation (radiotherapy) or drugs (chemotherapy).

According to data published by the Cancer Council of Australia in 2019, one in two Australian men and women will be diagnosed with cancer by the age of 85. The number of new cases of cancer diagnosed in Australia per year is tipped to exceed 150, 000 people for the first time during 2020. Nearly 50, 000 Australians died from a type of cancer in 2019.

Understandably, then, there is a lot of research into improving the efficiency of existing cancer treatments, and developing new ones, especially regarding how early cancer can be diagnosed. For some cancers, this may be as long as ten years, by which time they are tens of millions of cells strong. Clearly, if more tumours that are malignant could be detected when they are just getting started, the lives of many more cancer patients would be saved.

A team of scientists led by *Sangeeta Bhatia* at the Massachusetts Institute of Technology (MIT) in the United States have been developing a ‘nanosensor’ to travel in the body to do that. It consists of a nano-sized (100nm) detector that, when injected into the bloodstream can pass through the tiny pores in the walls of capillaries into a tumour. If certain enzymes are present that have been secreted by tumour cells to allow them to spread to neighbouring tissue (indicating the tumour is malignant) the nanosensor makes a kind of signal molecule that is small enough to be filtered by the kidneys and get into urine. The idea is that the presence of the signal molecule would then detected by a paper-based urine test.

You may need to refer to the online resources below to answer the questions that follow.

1. The tumour nanosensor test (TNT) does not need electricity or an expensive screening facility. Discuss why that strengthens the case for funding its development to completion.

2. The work of *Sangeeta Bhatia* is an example of using creative thinking to solve a problem *(refer to photo)*. Using two examples from the text above, explain why this is the case.

Helpful Online RESOURCE about tumours and metastasis

To learn more about tumours and metastasis view the clip below:

<https://www.youtube.com/watch?v=mQVq_en-2vA>

Helpful Online RESOURCE about finding a tumour using a nanosensor

To learn more about early tumour detection and Sangeeta Bhatia’s work view the clip below:

<https://www.youtube.com/watch?v=fR0bWB3O9_Q>

What have you learned?

Key Terms

open circulatory system

closed circulatory system

plasma

artery

vein

haemolymph

pulmonary circulation

systemic circulation

oxygenated blood

deoxygenated blood

double circulation system

lumen

coronary artery

atrium

ventricle

atrioventricular valve

semilunar valve

tissue fluid

venule

lymph capillary

lymph

lymph node

thoracic duct

lymphatic system

Knowledge and Understanding

1. Draw a simple diagram of the cross section of the heart and using labels and arrows and describe the main events that occur in one compete cycle of contraction and relaxation.

2. Draw a diagram of a section through an artery. Label one feature that is vital to the function of the artery and briefly outline how this helps to ensure blood reaches organs at high pressure.

3. Describe the function of hormones and white blood cells carried by blood.

4. Explain the difference between the pulmonary circulation and the systemic circulation. Use a simple diagram to help in your explanation.

5. Tissue fluid is vital to the internal environment of animals.

   a) Describe the difference between plasma and tissue fluid.

   b) Describe the process by which water moves into the lymph capillaries.

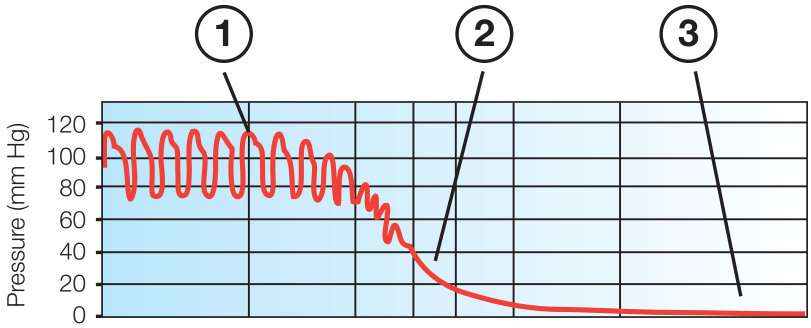
Application, Analysis and Evaluation

6. The volume of blood pumped out of the heart per contraction of the left ventricle is called the stroke volume. In humans at rest this is typically 75 mL. What changes to stroke volume would a person experience during heavy exercise?

7. Cardiac muscle contains a special type of connective tissue that is elastic. Explain why.

8. Compare the function of semilunar valves in the human heart with the function of valves in the femoral vein in the leg.

9. The graph shows blood pressure in the human circulatory system at three different locations.



a) Describe the overall pattern(s) of this data.

b) Suggest, with reasons, likely locations in the circulatory system for the readings at points 1, 2 and 3.

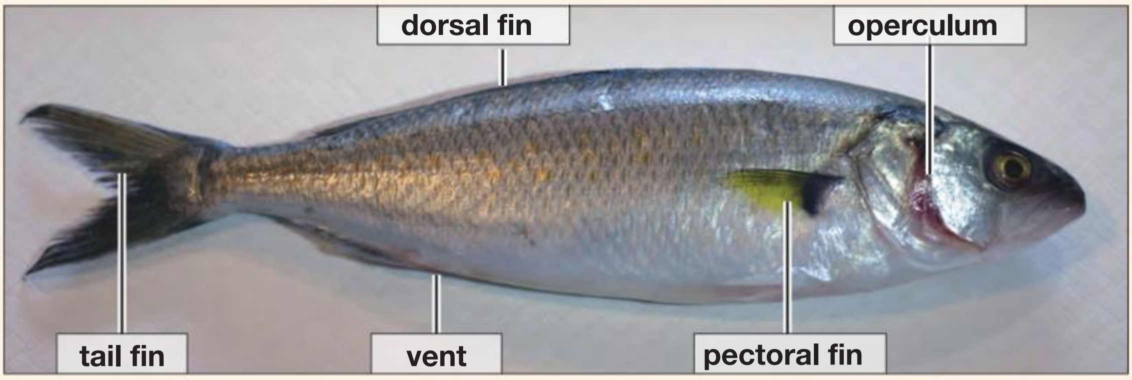
10. Compare and contrast the lymphatic system and the blood circulatory system. Aspects to consider could include: pressure, open/closed system and comparisons of fluid transported.

3.7

Science Inquiry Skills 3.7 - Dissecting a fish

Introduction

Bony fish have wet over-lapping scales and a collection of fins and gills on each side of the head that are protected by a cover of skin called the operculum. Each gill consists of a boomerang-shaped bone called a gill arch that supports hundreds of tiny flaps of skin called gill filaments. These serve as a fish's gas exchange surface. The general structure of a fish can be seen in the Figure below.

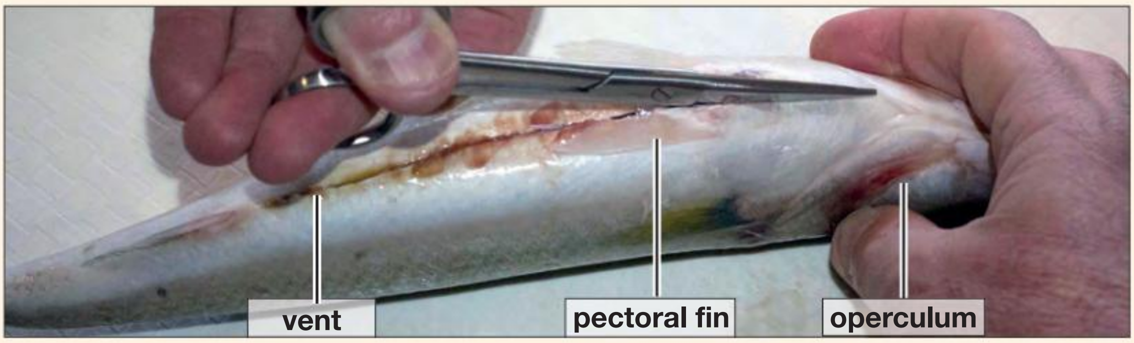


Materials

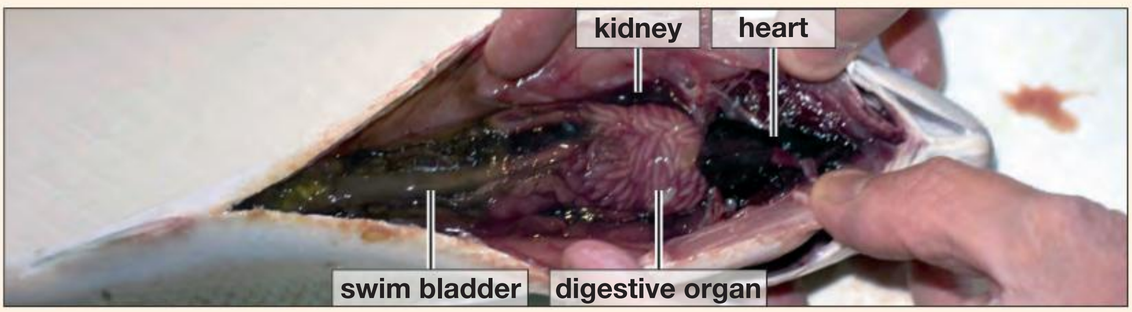
a dead fish (fresh or refrigerated), dissection board, scissors, forceps, dissection gloves (as instructed)

Part A: Viewing inside the body cavity

1. Place the fish on the dissection board.
2. Hold the fish ventral (or belly) side up.
3. Insert the scalpel into the vent (or anus).
4. Use the scalpel to cut the ventral surface towards the pectoral fins.
5. Use scissors to cut the bones associated with the pectoral fins and continue cutting to the space between each operculum and the head.



6. Gently pull apart the body cavity walls so the internal organs can be seen. Locate the heart.

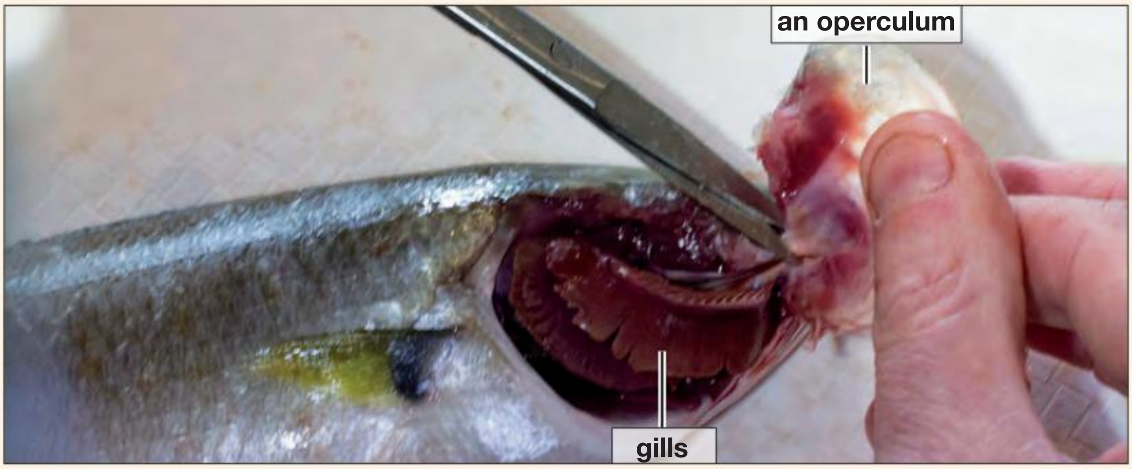


7. Carefully remove the alimentary canal. Locate the kidneys, digestive organs and swim bladder.

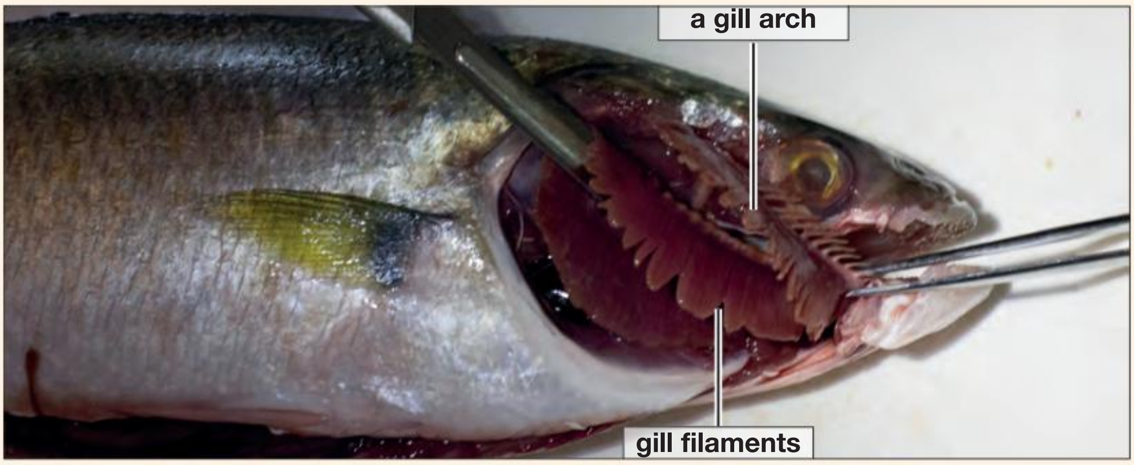
Science Inquiry Skills 3.7 - Dissecting a fish (continued)

Part B: Examining the gills

8. Use scissors to remove one operculum.



9. Use the scalpel and a pair of forceps to study the gill arches and gill filaments.



3.7

10. Use the forceps to suspend some of the gills in a beaker of water. What do you notice about the gills? Explain why this structure is important to their function.

....

....

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....

11. Thoroughly clean your work place and instruments and dispose of the remains as instructed.

Science Inquiry Skills 3.7- Dissecting a fish (continued)

Discussion

1. Fish have a two-chambered heart and a single circulation. State what that means.

2. Why is blood pumped by the heart to the gills first and then to muscles in the tail?

3. The surface of each gill filament is very thin and is packed with blood capillaries. Why?

4. Each gill arch has a very large number of gill filaments. Why are there so many of them?

5. As most bony fish have a swim bladder it must improve their chances of survival in some way. What is the function of a swim bladder, and how does it improve the chance of survival of fish?

6. Why do fish that are active swimmers have a stream-lined body and very smooth outer surface?

Science as a Human Endeavour 3.7 - Blood circulates

Development

Development of complex theories often requires a wide range of evidence …

Before the beginning of the 17th century, the predominant theory about the origin and movement of blood was that it was made in the liver and the heart from where it moved to tissue, and was consumed. Blood made in the liver was carried to tissues by veins to provide them with nourishment. Blood made in the heart was carried to the lungs and then to tissues by arteries to deliver them with 'the spirit of life' (oxygen in blood had yet to be discovered).

In the later part of the 16th century, however, pieces of evidence had emerged that would eventually contribute to the development of a new theory. One of these was the description of valves in veins by Italian physician *Hieronymous Fabricus* in 1579. This evidence was used by English physician *William Harvey* (*refer to the photo*) who showed for the first time that valves are one-way systems that allow blood to flow from tissues back to the heart.

This early work by Harvey suggested that blood might not move in the body in one direction. Harvey subsequently measured the heart's pumping capacity, and worked out it pumped about 250 litres of blood per hour. He recognised that this was far more than the liver and heart could make, so he proposed that blood must be circulating through veins and arteries. After 30 years of investigation, William Harvey published his results in 1628 in a book *De Motu Cordis et Sanguinis in Animalibus* (*On the motion of the Heart and Blood in Animals*).

Initially, however, the blood circulation theory had many critics. For instance, where were the tiny blood vessels (later called capillaries) that Harvey's work stated must exist to enable blood to pass from arteries to veins? Although *William Harvey* died in 1657, Italian doctor *Marcello Malphighi* went on to observe them microscopically for the very first time in 1661. By 1700, the theory that blood circulates throughout the body had become the standard view.

You may need to refer to the online resource below to answer the questions that follow:

1. Describe how Harvey's famous 'Ligature experiment' provided evidence that valves in veins allowed blood to move back to the heart.

2. Harvey was one of the first 'true scientists' because he formed conclusions after taking careful measurements. How did his measurements of the heart provide evidence that helped to overturn the 'blood flows in one direction' theory common at the time?

Helpful Online RESOURCE about the discovery of the circulation of blood

To learn about the development of the theory that blood circulates view the clip below:

<ttps://www.youtube.com/watch?v=w6q50_qNMoA>

3.7

Chapter 3.8 Transport of materials in plants

Science Understanding

In plants:

- the uptake of nutrients and water is facilitated by the structure of the root system.
- waste material may be removed or stored.

In plants transport of water and mineral nutrients from the roots occurs via xylem involving:

- root pressure
- transpiration
- cohesion of water molecules
- osmosis

Explain how water moves in, through, and out of a plant.

Transport of the products of photosynthesis and some mineral nutrients occurs by translocation in the phloem. They may be stored for later use.

Describe the transport and storage of materials in plants.

Tubes of xylem and phloem

The **xylem** and **phloem** in plants are called **vascular tissue**. In leaves, **vascular bundles** are located within the veins. Refer to *Figure 381* which is a 3D computer image of a leaf showing the vascular bundles. It is important to realise that xylem in vascular bundles is really a collection of tubes, each one consisting of a long unbroken end-to-end chain of xylem vessels. Phloem is similarly organised of phloem tubes. Tubes of xylem and phloem extend from the roots up to and through the leaves, in the stem they exist in long hollow columns.

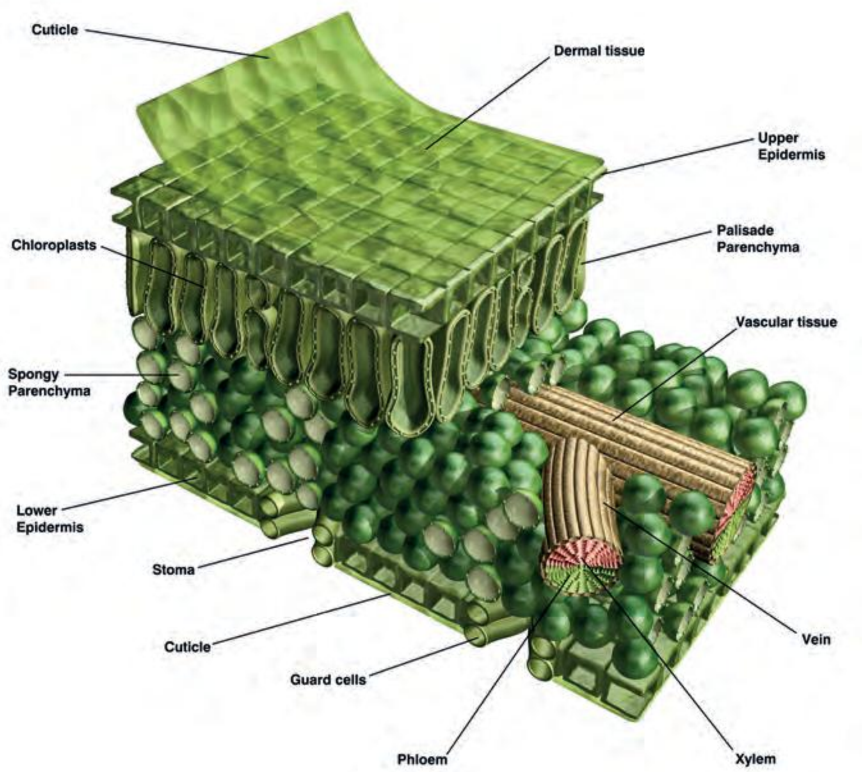


Figure 381 A 3D computer image of a leaf

A diagram showing end-to-end xylem vessels is shown in *Figure 382*, these extend from roots to the leaves.

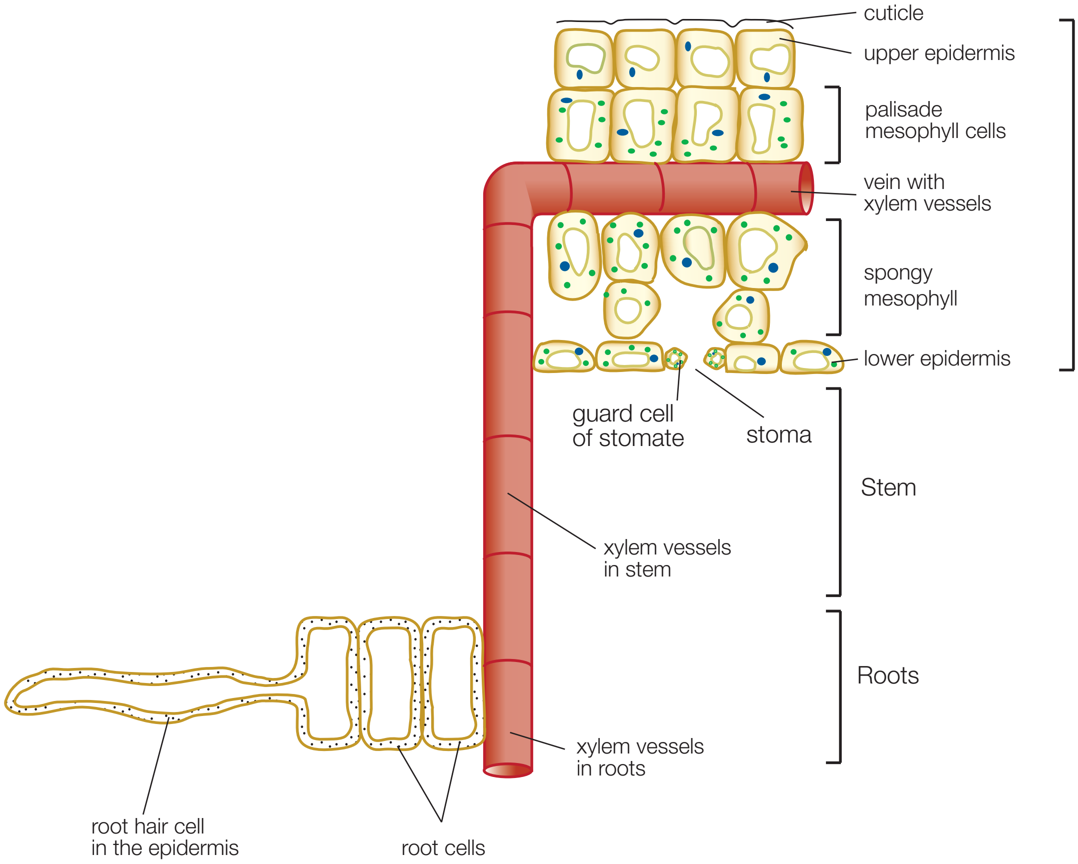


Figure 382 A chain of xylem vessels

Refer to *Figures 383(a) and (b*) which shows a scanning electron micrographs of vascular tissue in a root *Figure 383*(a) and stem *Figure 383*(b).

In *Figure 383*(a) xylem is seen as the four yellow circles with phloem surrounding these. Note the root hairs on the surface of the root are clearly visible. In *Figure 383*(b) note the arrangement of the vascular tissue in bundles with the xylem (pink) on the inner and phloem (yellow) on the outer edge.

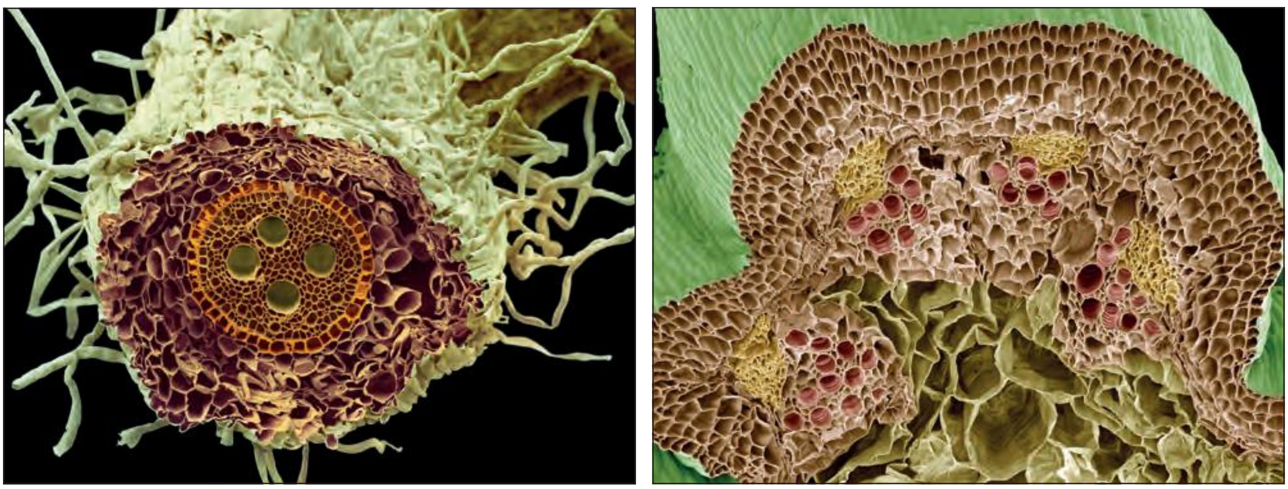


Figure 383 Showing vascular tissue in (a) root and (b) stem of a plant

Diffusion, osmosis and active transport

The nett movement of a substance from a region of higher concentration to a region of lower concentration, until the two regions have an equal concentration of the substance, is called **diffusion**. Some substances diffuse across exchange surfaces; for example, oxygen at alveoli in the lungs. Diffusion is a passive process because it occurs without any additional input of energy.

Water moves by a process called **osmosis** that is also passive. The direction water moves is due to the concentration of substances dissolved in it called solutes. Osmosis is the net movement of water from a region of lower solute concentration to a region of higher solute concentration until the two regions have an equal solute concentration. Another way to describe osmosis is the net movement of water from a more dilute region to a region that is less dilute, or more concentrated. Osmosis occurs across cell membranes; for example, the movement of water from tissue fluid into lymph capillaries in tissues.

The nett movement of a substances from a region of lower concentration to a region of higher concentration is called **active transport**. The process is described as being active because it only occurs across cell membranes when cells make additional energy available. Examples of active transport include the absorption of glucose and most vitamins at villi in the small intestine.

Uptake by plants of nutrients and water

The soil plants grow in contains air spaces and a dilute solution of water with a range of substances dissolved in it. This mixture is called the **soil solution**. Plants take in nutrients from the surrounding soil solution that are minerals. These are dissolved in the soil solution and exist in a charged form called an **ion**. Mineral ions taken into plants include nitrate, phosphate and potassium ions. The uptake of ions is carried out by the roots and takes place by active transport. Water is taken up by roots too, but this occurs by osmosis. Oxygen in soil air spaces enters roots by diffusion.

The root system

The root system of a plant consists of a collection of structures that usually grow down into the soil called roots. The root system of most flowering plants is organised in one of two major ways. Those that are dicotyledons (dicots) have a root system that consists of a central root called the **taproot,** from which extend several branching roots called **lateral roots**; for example, roses and eucalypts. Flowering plants that are monocotyledons (monocots) do not have a taproot. Instead, the monocot root system consists of many shallow, fibrous roots that extend from the base of the stem; for example, grasses.

The uptake of mineral nutrients and water is facilitated by the structure of the root system. This is because the root system has a huge surface area that is in contact with the soil solution. This is achieved in two main ways. Firstly, plants have roots that are either long and spread widely through the soil (in dicots) or are numerous and mesh-like (monocots). Secondly, plants have regions near their root tips that have an epidermis that includes huge numbers of cells with an extension called **root hair** cells. The structure of the root system of a dicot is shown in *Figure 384*.

In addition to taking up dissolved mineral ions, water and oxygen, the root systems of some plants store sugar produced during photosynthesis in swollen roots and underground stems called tubers. The sugar is stored as a carbohydrate called starch in cells that make up the tuber. Carrots, turnips and beetroot are root tubers. The most common example of a stem tuber is a potato.

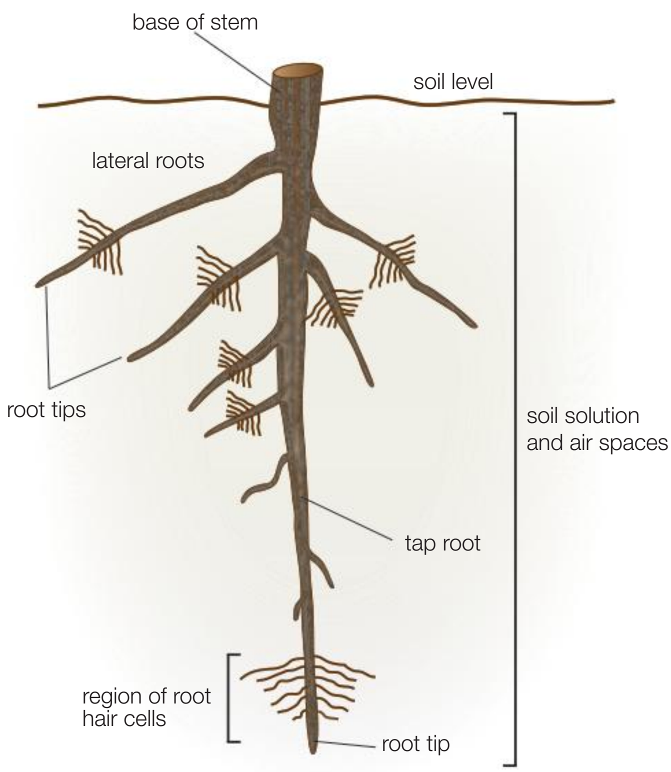


Figure 384 The structure of a dicot root system

Transport by plants of water and mineral nutrients

The lower solute concentration of the soil solution ensures water enters root hair cells in the epidermis by osmosis. Mineral ions are actively transported from the soil solution across root hair cell membranes. Once in the epidermis, most water flows by osmosis to xylem vessels in the inner root between spaces in the root cell walls. Most minerals reach xylem vessels carried in this flow of water. The movement of water into xylem vessels generates an upward push on the fluid they contain called **root pressure**. The transport of water and minerals from the soil solution, through root cells and a short distance up xylem vessels as a result of root pressure, is shown in *Figure 385*.

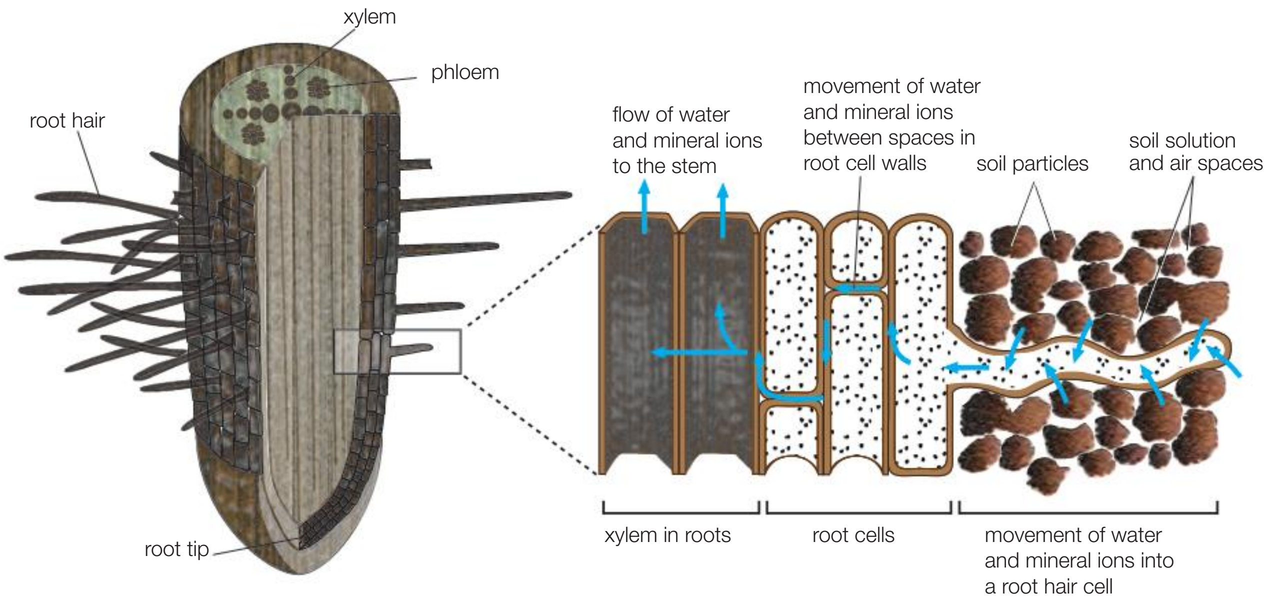


Figure 385 Transport of water to xylem vessels

Once they have entered the xylem tissue, water and dissolved minerals are transported to the mesophyll tissue in leaves within the continuous end-to-end columns of xylem vessels shown in *Figure 382*. This upward flow is called the **transpiration stream.**

The push of water into the xylem due to root pressure, however, is insufficient to generate the transpiration stream. Instead, it is mostly a product of a strong upwards pulling force within plants. This is generated because water in the mesophyll tissue of the leaves evaporates during the day and forms water vapour. As was discussed in Chapter 3.4, leaves have structures in the lower epidermis called **stomates** that have a tiny pore. These are usually open during the day and function to exchange gases. The water vapour produced by evaporation diffuses out of leaves through the stomata, into the air. The release of water vapour from leaves in this way is called transpiration.

The force that pulls water and dissolved minerals it contains up to leaves from the roots is called the **transpiration pull**. To understand how this transpiration pull causes water to move upwards in this way it is important to know that water molecules weakly attract one another. This force of attraction is called **cohesion**. As a result of cohesion, water in xylem vessels occurs in long unbroken chains.

As water evaporates from mesophyll cells a region of low pressure is generated inside them. This causes water in nearby xylem vessels (now at a higher pressure) to move towards the mesophyll cells. As a result of this and cohesion water is pulled up xylem vessels and passes into mesophyll cells. During the day there is constant pulling of water up the xylem vessels. The higher solute concentration in root cells ensures that the water keep moving into the roots by osmosis.

The flow of water and mineral nutrients up the xylem vessels is also assisted by attraction between water molecules and the walls of the xylem vessels. This force of attraction is called **adhesion**. Transport by plants of water and mineral nutrients is summarised in *Figure 386*. It is caused mainly by root pressure and transpiration pull.

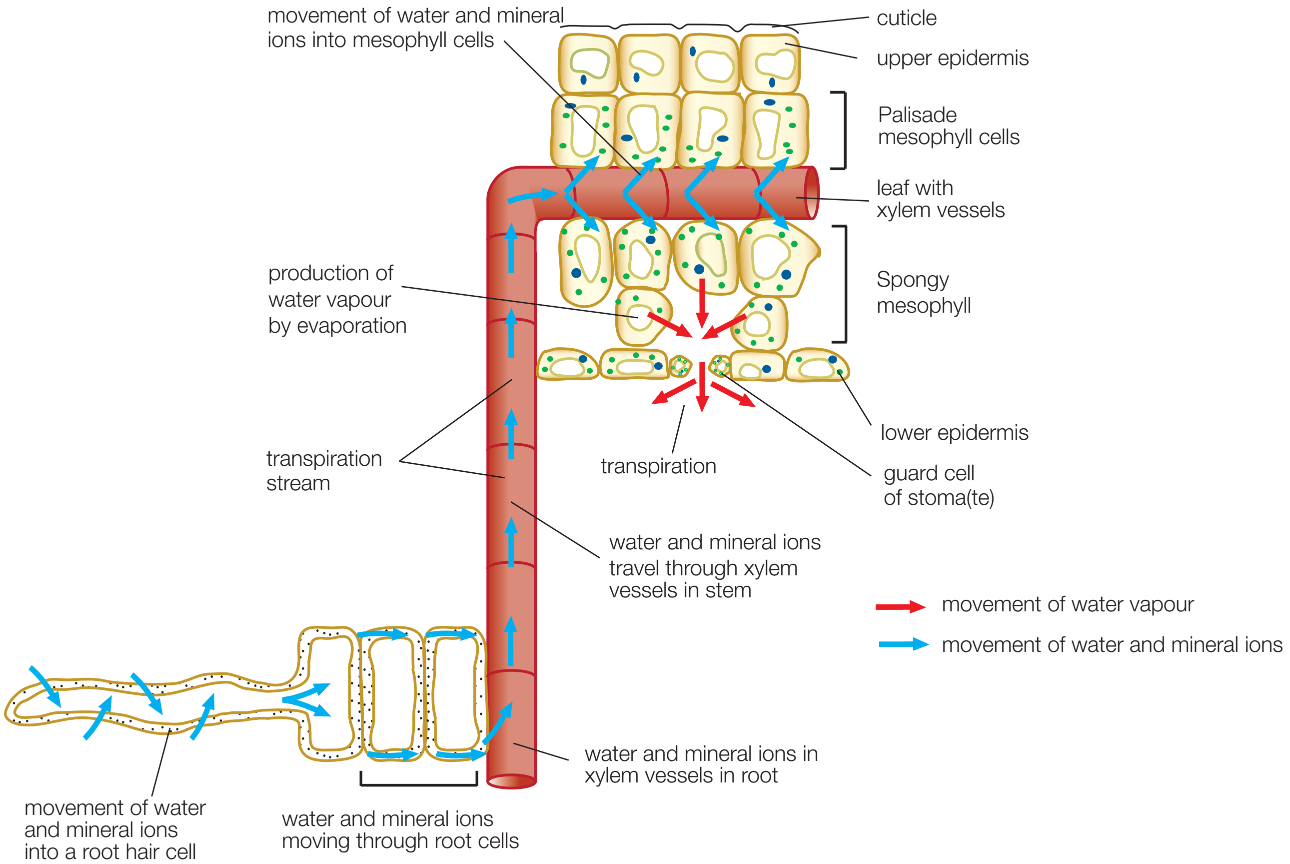


Figure 386 The flow of water and minerals in plants

Dealing with waste products

As was discussed in Chapter 3.6, metabolism by organisms generates waste that must be removed. The term waste is also used to refer to non-useful substances. Some plants, particularly trees, 'remove' non-useful substances by storing them in dead woody tissue in the middle of the trunk. Trees may also store wastes within leaves or bark which are lost to the ground from time to time.

In all plants, the carbon dioxide waste produced by aerobic respiration is excreted by diffusion. When plants are not photosynthesising, carbon dioxide is excreted out of leaves via stomates. Carbon dioxide produced by all the cells in the stem of woody shrubs or tree trunks is excreted through tiny pores called **lenticels**. In roots, excretion of carbon dioxide occurs via the epidermis.

Plants living in environments that are salty need to excrete salt due to the large quantity of it that is transported to their leaves in the transpiration stream; for example, salt removal by mangroves. Some species of mangroves store salt in the vacuoles of cells in certain leaves where it accumulates before it exits the plant by leaf fall. Others have leaves with **salt glands** that pump salt out of the leaf by active transport where it forms salt crystals that are blown or washed away e.g. mangroves.

Leaf structure and water conservation

All plants take up liquid water via the roots and release water vapour during the day via the leaves. It is important, however, that the rate of water loss does not exceed the rate of water uptake, or at least not for very long. Ongoing plant survival of depends on an adequate supply of water present in their tissues at all times. Reasons for this include the idea that, water uptake and its transport, enables plants to transport minerals from the soil they need for survival. Water is also required as a raw material for photosynthesis, it provides a medium for metabolic reactions to occur inside cells and its' presence provides support for the stem and leaves.

Because leaves are the main site of water loss, they tend to have a structure that facilitates the conservation of water. Some examples are shown in the following table.

Part of the leaf	How the part may facilitate water conservation?
Cuticle	Waxy to prevent evaporation of water through the cell wall of the upper epidermis cells
Lamina colour	Paler green in plants living where it is warm to decrease heat gain and thus excessive transpiration
Shape	Smaller near the top of the canopy in deciduous trees to decrease heat gain and thus excessive transpiration
Stomata	Close when transpiration is too rapid which virtually prevents any further water loss
	Mostly located in the lower epidermis in dicots to avoid direct sunlight and thus excessive transpiration

Translocation

Plants and animals carry out aerobic respiration using glucose to make chemical energy available for use; for example, to grow, or for active transport. In animals, the glucose is made available to cells by the digestive and circulatory systems. In plant leaves, the glucose is made available to cells by photosynthesis. Cells of other parts of plants that do not perform photosynthesis must have a solution of sugar transported to them; this is done by the phloem. Transport of the sugar solution or 'sap' in the phloem is called **translocation**. Most sugar made by photosynthesis is translocated as sucrose. Some mineral nutrients are moved to areas of growth by translocation; for example, nitrate and phosphate ions from old dying leaves to young growing ones, refer to *Figure 387*. Refer also to the next page for more information.

3.8

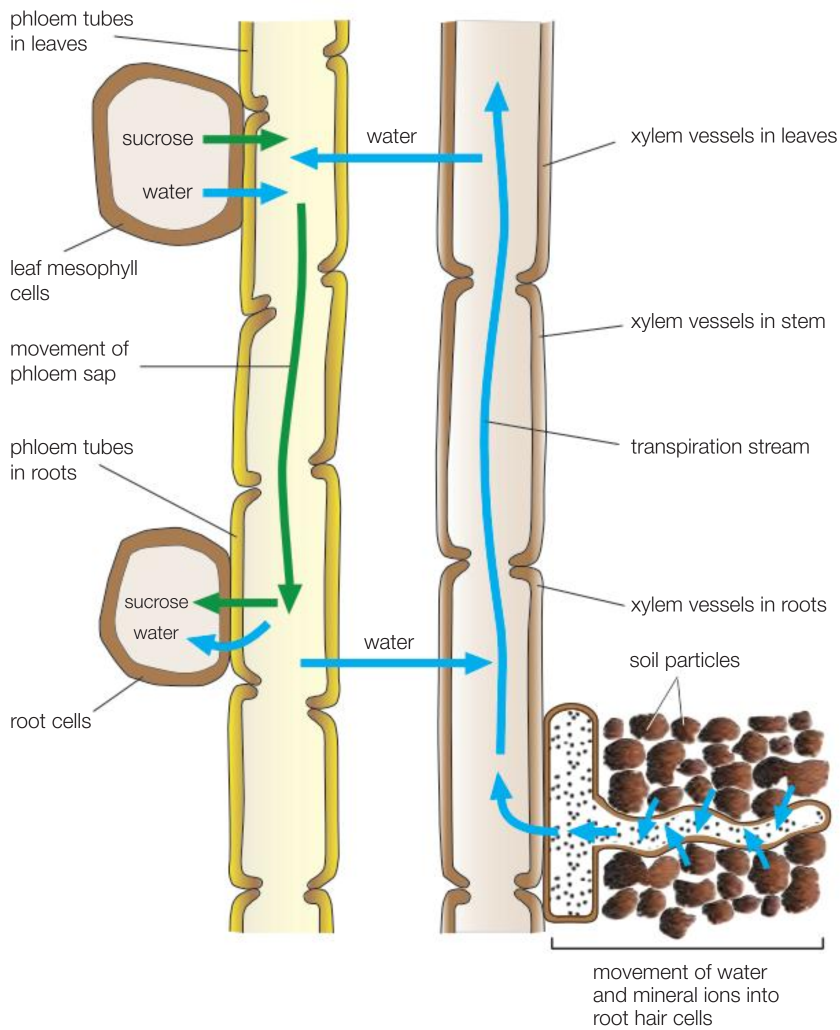


Figure 387 A summary of the accepted mechanism of leaf-to-root translocation

In leaf-to-root translocation, transport of sap, and therefore of sugars, and other substances it contains is thought to begin with active transport of sucrose out of mesophyll cells into the phloem sieve tubes in leaves. This increases the solute concentration in the sieve tubes which causes water to move into them from mesophyll cells by osmosis. The movement of water into phloem sieve tubes raises the pressure of the **phloem sap** in the leaves which forces it to move towards a region of lower phloem sap pressure; in this case, the roots. Once in the roots, sugar is pumped out of phloem sieve tubes into roots cells by active transport where it is converted to starch for storage. Some water follows by osmosis which helps to maintain the phloem sap **pressure gradient**. The rest flows into the xylem where it is returned to mesophyll cells via the transpiration stream. Leaf-to-root translocation and root-to-leaf transpiration are both shown in *Figure 387*.

Storage of sugar produced by photosynthesis

As discussed earlier, the products of photosynthesis can be stored as starch in tubers for later use. They may also be stored as starch in the modified leaves of a shortened below-ground stems, usually called bulbs; for example, in daffodils and onions. In spring, the stored starch is broken down and converted to sucrose for transport to areas of growth. Once there, it is converted to glucose to be used in aerobic respiration; for example, in flowering plants, where leaves and flowers are growing, and fruits and seeds are developing.

Key Concepts

1. Plants transport materials using long hollow columns or tubes of xylem and phloem.
2. Water and mineral ions are transported in xylem.
3. Products of photosynthesis and some mineral nutrients are transported in phloem.
4. Transport of materials by plants involves evaporation, diffusion, osmosis and active transport.
5. The structure of the root system facilitates plant uptake of water and mineral ions.
6. Transport of water and mineral ions up plants is partly caused by root pressure and assisted by the cohesion between water molecules.
7. Most materials that enter xylem are transported in the transpiration stream.
8. Plants produce waste that is removed, or stored.
9. The structure of the leaf facilitates conservation of water.
10. Materials that enter the phloem are moved as sap by translocation.
11. Plants use products of photosynthesis in aerobic respiration, or store them in tubers or bulbs.

Case Study: The profile of a plant biologist

Dr. Megan Shelden

Research

Environmental stresses, such as drought and soil salinity, cause major crop yield losses in agriculture, significantly impacting on agriculture sustainability. Soil salinity is estimated to affect more than 800 million hectares of land. Currently, 67% of the land affected in Australia is in the cereal (wheat, barley) growing regions, particularly impacting south-western and south-eastern Australia. Dryland salinity significantly reduces crop yields and is estimated to cost the Australian farming industry around $1.5 billion a year.

Two major factors are driving the need to improve agricultural yields. The first is climate change, which means that wheat and barley are grown in increasingly hostile environments with soil salinity and drought both expected to increase this century, reducing the availability of arable land. The second is the increase in global population, expected to reach 9 billion by 2050. An increase in global agriculture productivity will be needed to meet the increase in demand for global food supply. Cereals comprise 50% of global food production. Investment in research aimed at improving the salinity tolerance of cereal crops will provide both economic and environmental benefits to the Australian agriculture industry.

In agricultural crops, the root system plays a critical role in determining crop yield. The root system is the first part of the plant to sense changes in the soil environment, thus roots need to rapidly adapt to these changes to maintain growth. Soil salinity and water deficit impose an immediate stress on the root system that results in a reduction in support the root system can provide and plant growth. The ability of the roots to maintain growth in response to salinity is an important adaptation that allows increased soil exploration for water and nutrient uptake. In order to improve crop performance and yield in salinity-affected regions we require a better understanding of how cereals respond and adapt to salinity stress.

My research is aimed at understanding salinity tolerance in the agricultural crops, barley and wheat. Of particular interest to me is how the root system adapts to salinity stress and maintains growth, thereby continuing optimal uptake of nutrients and water from the soil. To identify crops that have root systems better adapted to saline soils, we can measure root growth in genetically different barley and wheat (domesticated, landraces and wild) that are adapted to grow in different climates around the world. My research has identified two genetically different barley varieties (tolerant and susceptible) that differ in their root growth in response to salinity. We aim to understand these adaptations (traits) by identifying the gene variants (alleles) that are responsible for the differences in root growth in response to salinity. We can obtain more information about how these alleles function in plants by using technologies such as genetic modification (GM) and the relatively new technology, 'CRISPR'. These gene variants can then be incorporated into breeding programs by traditional breeding or GM to develop new and improved wheat and barley varieties that are better adapted to saline soils.

Education and Career

Bachelor of Science (Honours in Botany) at The University of Adelaide, 1997

Doctor of Philosophy (PhD) in Plant Science at The University of Adelaide, 2008

Currently employed as an Australian Research Council Discovery Early Career Researcher Award Fellow at The University of Adelaide.

Helpful Online RESOURCE about the use of genetic modification

This website will provide some useful information and a variety of views about this topic:

<http://theconversation.com/au/topics/gm-food>

3.8

What have you learned?

Key Terms

xylem

phloem

vascular tissue

vascular bundle

root hair

stomate

diffusion

osmosis

active transport

soil solution

ion

taproot

lateral root

tuber

root pressure

transpiration stream

transpiration pull

cohesion

adhesion

lenticel

salt gland

translocation

phloem sap

pressure gradient

bulb

Knowledge and Understanding

1. The table below shows some materials that are taken into plants via roots. Complete the table to show how each material is taken into the plant roots and why this process is used.

Material	How is it taken in?	Why is this process used?
mineral nutrients e.g. phosphate		
oxygen		
water		

2. Explain the role of root pressure in the movement of water from the soil solution through the root to xylem vessels.

3. Explain how evaporation in the mesophyll and cohesion of water molecules leads to water being pulled up the xylem to leaves.

4. The process of translocation is vital in most plants:
   a) What is the main purpose of translocation?
   b) What materials are transported in this process?
   c) Name and describe the structures in the plant where this process occurs.

5. Sugars produced by photosynthesis can be stored in particular structures in plants.
   a) Name the carbohydrate plants use to store sugar produced during photosynthesis.
   b) Name two structures in which this carbohydrate can be stored.
   c) State when and why this stored material is likely to be broken down and used by the plant.

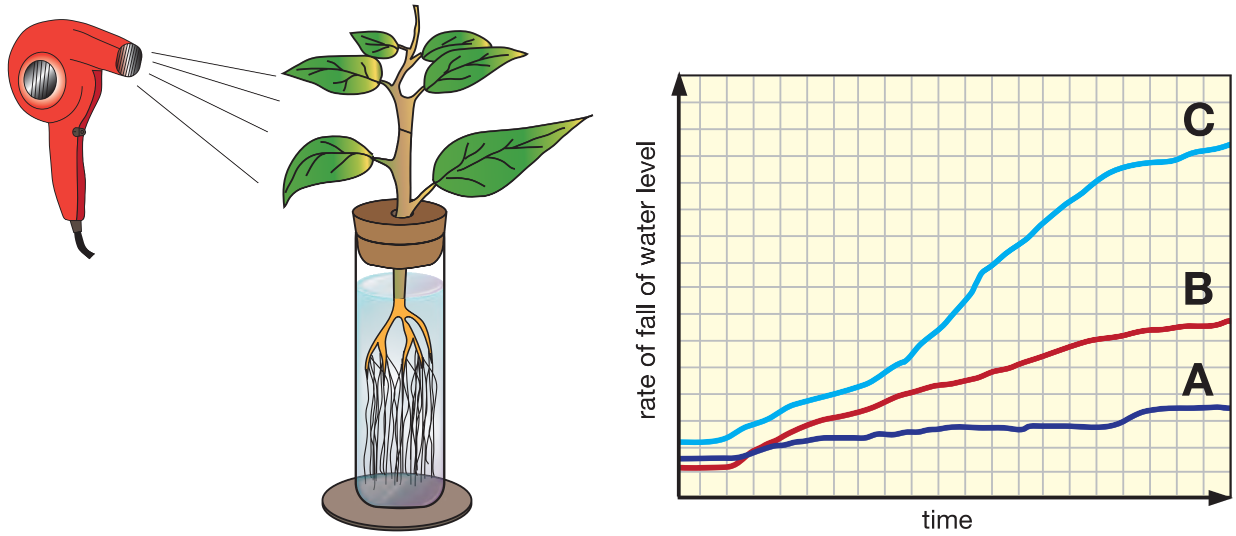
Application, Analysis and Evaluation

6. Careless use of a 'whipper-snipper' around the base of shrubs can cause columns of xylem vessels to break. Outline how this might affect transport of materials by such shrubs.

7. Explain why carnivorous plants are able to grow in soils very low in nitrates and other mineral nutrients.

8. Compare the function of the transpiration stream with the function of translocation in plants.

9. A hair drier with settings A = 10°C, B = 20°C and C = 30°C was used to investigate the effect of air temperature on water uptake by a plant. The equipment and the data obtained is shown in this Figure.



a) Suggest a likely question that could be investigated using this equipment.

b) Name the independent variable.

c) Name the dependent variable.

d) Suggest a likely conclusion based on the data.

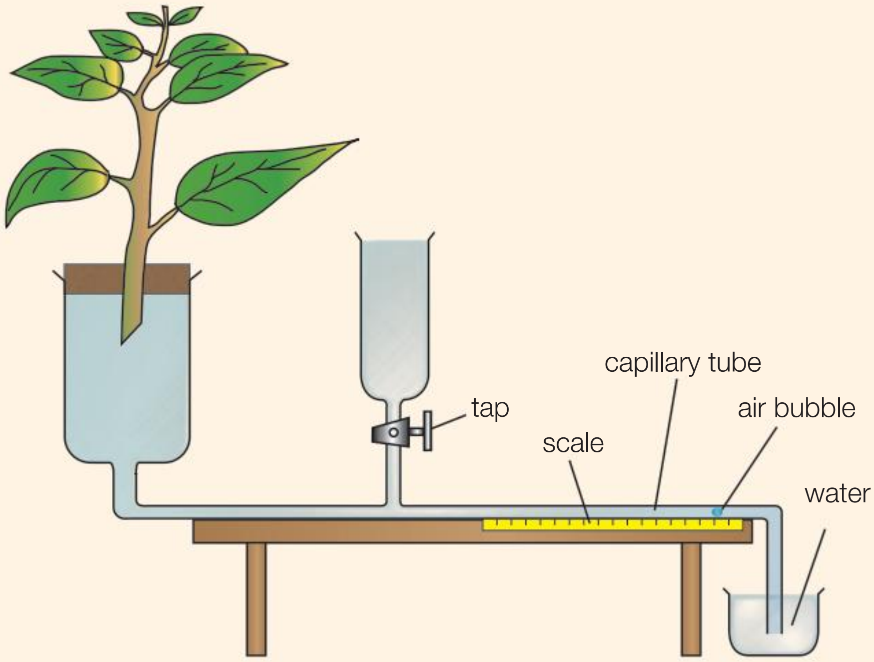
e) Outline some possible limitations of the conclusion formulated above.

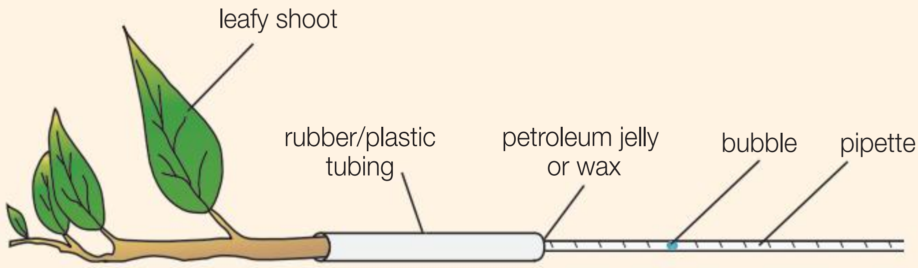
Science Inquiry Skills 3.8 - Transport of water through plants

Introduction

Water moves into and through plants from roots to leaves in the xylem. How quickly this 'transpiration stream' moves upwards can be estimated using a bubble potometer. Although the design of potometers varies, most consist of a capillary tube mounted next to a scale marked in millimetres or centimetres, a reservoir of water with a tap and a length of glass or rubber tubing with a tight stopper into which is inserted part of the shoot system of the plant being investigated.

The following Figures shows the main components of typical bubble potometers.





Equipment and materials

Potometer (as instructed)

100 ml beaker

Suitable shoot system (already cut when submerged and kept under water in a container)

Sharp razor blade or scalpel

Plastic container (big enough to allow cutting of the stem underwater without wetting the leaves)

Petroleum jelly or vasoline

Electric fan with at least three different speed settings

3.8

Science Inquiry Skills 3.8 - Transport of water through plants (cont.)

Part A: Setting up the potometer

1. Half fill the plastic container with tap water.
2. Quickly transfer the shoot system to be investigated to the plastic container, cut-end submerged.
3. Take care to ensure the leaves do not get wet.
4. Use the razor blade to carefully cut the shoot again approx. ½ cm from the existing cut-end.
5. Holding the cut-end underwater, insert it through the potometer stopper or tube.
6. Hold the shoot and stopper underwater for 5 minutes while keeping the shoot upright.
7. Fill the potometer with water and ensure it can flow along the capillary tube into the beaker.
8. Approximately ¾ fill the reservoir and beaker with tap water.
9. Quickly remove the shoot and stopper from the plastic container and insert the stopper into the opening of the glass tubing of the potometer.
10. Use vasoline to seal the base of the stopper.
11. Put an air bubble into the capillary tube. To do this, lift the potometer up so the end of the tube leaves water in the beaker for approx. 2 minutes, then blot the end of the tube with some paper towel and return the potometer to its original position i.e. with the end of tube underwater again.
12. Leave the potometer for at least 5 minutes to allow the shoot to adjust to it.

Part B: Estimating the rate of water transport

1. Note and record in millimetres (mm) the location of the air bubble in the capillary tube. ....
2. Leave the shoot to take up water for a fixed period of time; e.g. 10 minutes.
3. Measure the distance moved by the air bubble (mm). ....
4. Calculate the rate of water uptake in using the equation below:

$$\text{Rate of uptake of water} = \frac{\text{distance moved by the air bubble}}{\text{time taken}}$$

Show your working. Express your answer in millimetres per minute (mm/min).

....

....

....

....

....

....

5. Explain why the air bubble moves along the capillary tube.

....

....

....

....

....

....

....

....

Science Inquiry Skills 3.8 - Transport of water through plants (cont.)

Part C: Investigating the rate of water transport and wind speed

1. Modify the procedure in Part B to test if wind speed affects the rate of transport of water.
2. Briefly note how the method was changed and record the data.

Part D: Analysis and evaluation

1. Describe how the method used for Part C could be improved to collect more reliable data.

2. Using the data collected, is it possible to draw a conclusion about the effect of wind speed on the rate of water transport? If yes, state why and then write a valid conclusion.

3. The rate of water uptake is roughly equal to the rate at which transpiration occurs – as water is lost from leaves by transpiration it is replaced by water pulled up the xylem from the roots. What changes to a plant's shoot system, however, would be visible if the rate of transpiration exceeded the rate of water uptake for a significant period of time, like several hours, and why?

4. Describe two adaptations plants in high-wind environments have to prevent these effects.

Science as a Human Endeavour 3.8 – Genetically modified plants

Science informs public debate and is in turn influenced by public debate...

It has been possible since the 1980s to modify the genetic make-up of plants used to provide raw materials or those used to produce foods; for example, cotton and canola, respectively. Thus far relatively few plants are genetically modified (GM) for commercial use - those that have been are mainly produced to tolerate herbicides used to kill weeds, or insecticides used to kill insect pests.

In the United States, an industry of GM plant products has already emerged. Corn, soya beans and maize are all genetically modified, routinely available and are ingredients in a diverse range of foods. Currently, no GM vegetables, or fruit, are approved for direct consumption in Australia, although according to a recent report by the Australian Council of Learned Academies (ACOLA), canola and cotton seed oil that is made from GM crops is used in spreads, deep frying and salad dressings.

Advocates of GM crops maintain that they provide a way to help meet growing global demands for more food. Opponents fear GM plants are unsafe to eat, and growing them harms the environment.

Answer the questions below or on separate paper or on screen, as requested by your teacher.

You may also wish to refer to the Profile on the previous page for more information on this topic.

1. Give some examples of how Science informs public debate about growing and consuming GM plant products; for example, whether it is safe to eat them.

2. Give some examples of how GM crop development in Australia has been influenced by public debate; for example, whether safety testing should be mandatory and communicated more clearly.

Helpful Online RESOURCES about GM crops

This website will provide some useful information for this assignment: A report that informs public debate about GM crops internationally:

<http://www8.nationalacademies.org/onpinews/newsitem.aspx?RecordID=23395>

More Helpful Online RESOURCES about GM crops

This website will provide some useful information for this assignment: A report that discusses how GM plant developments are influenced by public debate – see p. 15, 16:

<http://acola.org.au/PDF/SAF05/4Genetically%20modified%20crops.pdf>

? Deconstruction and Design - Factors affecting the enzyme amylase

Introduction

Starch is one example of a carbohydrate that is a macromolecule. The chemical digestion of starch starts in the mouth where there is one type of amylase enzyme in saliva. The products of chemical digestion of starch are simple sugars (monosaccharides) including glucose.

Possible factors for investigation

There are several factors that may affect the rate of digestion of starch.

Some possible Problems that might arise include:

- Does the type of food containing the starch affect the rate of digestion?
- Does the type of drink taken with a meal impact on the rate of starch digestion e.g. caffeine, carbonated soft drink
- Does the temperature of food eaten impact on the rate of starch digestion?
- Do other foods eaten with starch affect the rate of starch digestion?
- Does cooking the food impact on the rate of starch digestion?
- Do some other factors inhibit the rate of starch digestion?

With the direction of your teacher you will Deconstruct the problem and then Design and conduct an experiment to determine the effect of one factor on the digestion of starch.

A Deconstructing the problem *(Refer to the Guidelines on page 470 in the Appendix.)*

1. Research the process of starch digestion and its relevance to organisms, focussing particularly on the factor you are interested in investigating.
2. Explore factors that impact on the rate of starch digestion such as those mentioned above.
3. Make informed decisions about determining experimentally how one factor that might affect the rate of starch digestion could be measured.
4. Explore and address the health and safety risk factors involved.
5. Select the one factor and develop a method to test the effect of changing this on the rate of starch digestion.

B Designing your own investigation *(Refer to the Guidelines on pages 471, 472 in the Appendix.)*

Use the guidelines from the General Appendix of this Workbook and/or the SACE Subject Outline to help you Design your own investigation.

Justify the decisions you have made about such factors as:

- the type of tissue you have chosen
- the independent and dependent variables
- how the independent variable will be changed
- how the dependent variable will be measured (a blank data table should be included)
- what variables will be held constant and why
- the variables that may not be able to be held constant or controlled and consider their potential impact.

C Conducting the investigation

Your teacher will set out guidelines, including health and safety considerations, about how this is to be achieved.

D Writing a report *(Refer to the Guidelines on page 473 in the Appendix.)*

The requirements of the practical report are to be found in either the SACE Subject Outline or in the Appendix of this book. In particular, the word count for the Introduction, Analysis of results, Evaluation of method/procedure and Conclusion should not exceed 1000 words in Stage 1 (and 1500 words in Stage 2). The Deconstruction and Design, including the method chosen and the justification of the plan of action must be a maximum of four sides of an A4 page and needs to be attached to the practical report.

Introduction

These Answers have been suggested by the authors, they are not intended to be either comprehensive or exclusive. In some cases no answer is suggested because it relies on research or an individual response from students.

Chapter 3.1 Answers

1. Suggestions include:
   - A palisade cell from a plant is drawn. At least one chloroplast is labelled.
     The presence of chloroplasts permits the cell to perform photosynthesis.
   - A sperm cell from an animal is drawn. The flagellum is labelled.
     The presence of the flagellum permits the sperm to move towards an ovum.
2. According to the Watson and Crick model:
   - DNA consists of two strands with complementary base pairs
   - The strands of DNA are twisted around each other to form a double helix.

   The importance of base pairing in this model includes:
   - It helps to stabilise the structure of DNA.
   - It provides a mechanism for replication of the molecule
3. A polypeptide is a sequence or chain of amino acids. A protein is a polypeptide that has folded in a precise way and therefore has a specific 3-D shape. Note some proteins consist of a small number of different polypeptides that fold together in precise ways.
4. The two processes are:
   - Transcription

   In this process a gene is used to make a molecule called mRNA. The process takes place in the nucleus and involves an enzyme called RNA polymerase.
   - Translation

   In this process mRNA is used to make a polypeptide. The process takes place in the cytoplasm and involves ribosomes.
5. The reason involves:
   - Factors in the environment lead to genes in identical organisms being switched on/off.
   - Genes switched on/off effect the organism's phenotype, or its structure and physiology.
   - Exposure to different environmental factors leads to the organisms developing differently.
   - These differences are more apparent in older organisms because gene switching on/off has been occurring for longer resulting in more changes to the phenotype.
6. The answer involves:
   - Selective switching on/off of genes takes place. This causes cells to grow and develop in different ways.
   - Cells that grow and develop differently have a different structure. This permits them to perform a different function.
7. Suggestions include:
   - Both are proteins.
   - Both play a role in the regulation of transcription.

   Activators 'switch on' genes by making them more accessible to RNA polymerase, the enzyme that is involved in transcription. Repressors 'switch off' genes by making them less accessible to RNA polymerase.
8. Evidence includes:
   - Two strands of DNA are present.
   - The two strands are coiled into a double helix.
   - Base pairing can be seen between the two strands.

Chapter 3.2 Answers

1. Suggestions include:
   - Cells are organised into tissues.
   - Different tissues are organised into organs.
   - A collection of different organs makes up organ systems.
   - A multicellular organism is made up of a collection of different organ systems.
2. Xylem is a tissue and so is made up of specific cells. In the case of xylem, the cells are called xylem vessels. These are organised end-to-end in chains that extend from roots to the leaves.
3. Two possibilities are:
   - Neurons are organised into nerve tissue. These are capable of transmitting nerve impulses and therefore permit coordination of body activities.
   - Muscle cells are organised into muscle tissues. These are capable of contraction and therefore permit movement.
4. A layer of epidermis is drawn. At least one root hair is labelled. The root hair's shape maximises the uptake of water and minerals from the soil.
5. Regarding the stomach:
   a) Two tissues include epithelial tissue and smooth muscle tissue.
   b) Two functions of the human stomach are to help mechanically digest food and to kill bacteria present in food.
6. One lifestyle choice that harms well-being is excessive drinking of alcohol. One that enhances well-being is following a balanced diet.
7. One possible answer is:

   Mesophyll consists of cells that contain chloroplasts and therefore perform photosynthesis. Root tissue is below ground and so cannot carry out photosynthesis. Thus it lacks mesophyll.
8. Differences between the human respiratory and circulatory systems include:
   - The respiratory system permits the uptake of oxygen and the removal of carbon dioxide.
   - The circulatory system permits the transport of materials throughout the body.
9. Regarding the diagram shown:
   a) The evidence includes there are several types of tissues present/labelled suggesting it is an organ. These are found in plants; for example, cortex (parenchyma), endodermis and xylem. Thus the organ is a plant organ.
   b) The reason for this is that the root system is made up of roots. The diagram is likely to show part of one of the roots because of the way its tissue is organised is very typical of roots; for example, the star-shaped arrangement of xylem, endodermis and parenchyma.
10. Regarding healthy lifestyle choices:
    - One lifestyle choice that has a positive effect is doing moderate exercise. This reduces the risk of heart disease and therefore helps maintain the function of the circulatory system.
    - Another lifestyle choice might be eating a healthy diet and the benefits for the digestive and circulatory systems.

Chapter 3.3 Answers

1. Smaller cells have a much greater surface area compared to their volume. If you do the calculations for these cells you will find that the smaller cell has ten times as much surface area compared to its volume in contrast to the larger cell. If you have not yet done Topic 1 you can learn about this concept by referring to Chapter 1.5.
2. Examples are shown below:

Organ	Materials exchanged	How surface area is maximised
Lungs	Oxygen and carbon dioxide	Large numbers of alveoli
Intestine	Products of digestion glucose, amino acids	Large numbers of villi
Kidney	Glucose, urea, water	Large numbers of nephrons

3. Regarding characteristics of exchange surfaces:
   a) Thin surfaces reduce the distances materials have to move; for example, villi.
   b) Moist surfaces assist the transport of materials across the surface; for example, alveoli.
   c) Large surface area provides more surface for exchange to occur; for example, nephrons.
4. An alveolus is drawn. The wall of the alveolus is labelled as thin. A thin wall ensures gas exchange is efficient because it reduces the distance gases need to move by diffusion.
5. Suggestions include:
   - The tidal volume is how much air a person breathes in and out.
   - The residual volume is how much air remains in the lungs regardless of how hard a person exhales.

   The more air an athlete can breathe in and out, or the larger their vital capacity, the more oxygen and carbon dioxide can enter and leave the blood during gas exchange respectively. Training designed to increase vital capacity of athletes will help to boost performance.
6. Regarding bronchioles:
   a) Narrowing of bronchioles would cause difficulty breathing, shortness of breath and wheezing.
   b) The usual treatment is to inhale a medication that dilates or widens the diameter of the bronchioles.
7. An example is shown below:
   a) % Oxygen not exhaled = (20-16)/20 × 100% = 0.2 × 100% = 20%. Therefore only 1⁄5 of the air inhaled diffuses into the blood.
   b) There is much less carbon dioxide in the alveoli when air is inhaled than in the blood, so the concentration of carbon dioxide in the alveoli is much lower than it is the blood. As a result, carbon dioxide diffuses rapidly out of the blood down the concentration gradient and into the alveoli.
   c) An increase in blood flow will increase the rate of diffusion of gases into and out of blood.
8. The movement of boiling water into the pieces of potato during cooking is very similar to the movement of materials into cells. Smaller pieces of potato have a relatively large surface area to their volume compared to larger pieces and will therefore cook more quickly.

Chapter 3.4 Answers

1. A diagram of a magnified view of a leaf is shown. The diagram contains the following:
   - Labels for the upper and lower epidermis, the mesophyll, xylem and phloem and one stomate (stoma and two guard cells).
   - One colour shows the entry of light into the mesophyll through the upper epidermis.
   - A different colour shows the diffusion of carbon dioxide into the leaf via the stomate and the diffusion of oxygen out of the leaf through the same stomate.
   - Another colour shows the flow of water from the xylem into surrounding mesophyll cells.

   Like factories leaves make products. In leaves the products are glucose and oxygen. There are an infinite number of leaves across the globe making them the world's largest factory.
2. Examples of materials exchanged include:
   - Gases e.g. oxygen and carbon dioxide
   - Water
   - Minerals
3. Suggestions include:
   - Opening of the stomata leads to an increase in the rate of gas exchange at leaves.
   - Closing of the stomata results in the rate of gas exchange at leaves decreasing.
4. One possible answer includes:
   - Carbon dioxide diffuses into a leaf from the air that surrounds it.
   - Oxygen diffuses out of a leaf into the surrounding air.
5. Suggestions include:
   - Photosynthesis does not take place at night but aerobic respiration does.
   - Oxygen is needed for aerobic respiration so it diffuses into leaves.
   - Carbon dioxide is produced by aerobic respiration so it diffuses out of leaves.

6. The presence of air spaces in spongy mesophyll means the carbon dioxide concentration can momentarily increase. This enables carbon dioxide to continue to diffuse further into the leaf.
7. Suggestions include:
   - Loss of water vapour via leaves is greatest in summer.
   - Dropping of some leaves by Eucalyptus species is one way to reduce this.
   - Species of Eucalyptus that do this have a greater chance of survival during summer.
8. The reasons include:
   - The leaves of plants in tropical rainforests growing at ground level receive very little light.
   - Having a very large surface area maximises the absorption of light for photosynthesis.
   - Having very dark green leaves allows the mesophyll cells contain a very high number of chloroplasts (that are green) which improves the absorption of light.
9. Regarding the opening and closing of a stomate:
   - When the stomate is open the vacuoles are inflated or occupy a greater volume. When the stomate is closed the vacuoles are deflated or occupy a smaller volume.
   - Vacuoles are membrane-enclosed organelles that contain water. Stomata opening may involve water entering the vacuoles. Closing occurs if water moves out of the vacuoles.
10. Regarding the study about gas exchange by a Eucalypt woodland:
   a) In the early afternoon there is a slightly higher concentration of oxygen at leaf level than early in the morning. There is a slightly lower concentration of carbon dioxide at leaf level in the early afternoon than there is in the early morning.
   b) The data suggests that at 1pm photosynthesis is occurring faster than aerobic respiration. This is because at that time there is more oxygen produced by photosynthesis than is needed for aerobic respiration – the excess diffuses out of leaves. More carbon dioxide is needed for photosynthesis than can be produced by aerobic respiration – the additional carbon dioxide diffuses into leaves.

Chapter 3.5 Answers

1. Examples include:
   - Oesophagus. It has a tube-like structure to transport food to the stomach.
   - Stomach. It has walls that are folded and elastic to maximise the storage of food.
2. A villus is drawn. The epithelial tissue (or the epithelium), capillaries and lacteal are labelled.
   - The epithelium is very thin to reduce the distance substances to be absorbed need to travel.
   - The capillaries are located very close to the epithelium to facilitate the absorption of glucose and amino acids and their transport out of the villus.
   - The lacteal extends into the villus to maximise the transport of absorbed fatty acids and glycerol out of the villus.
3. The functions include:
   - Moisten and lubricate food.
   - Bring food into contact with the enzyme amylase to start the chemical digestion of starch.
4. The differences include:
   - Mechanical digestion is digestion caused by the action of teeth or muscles; for example, chewing in the mouth and the slow-turning of the contents of the stomach.
   - Chemical digestion is digestion caused by digestive enzymes; for example, the digestion of proteins by proteases and the digestion of lipids by lipases.
5. Predictions include:
   - Less food is transported to the stomach. Less nutrients would be absorbed because less products of digestion would be made available.
   - The person would be at high risk of developing a dietary-deficiency disease; for example, osteoporosis or scurvey.
6. Suggestions include:
   - By being 3 metres long the surface area for absorption is maximised.
   - More time is available to absorb the products of digestion.

7. Two pieces of evidence include:
   - There appears to be an alimentary canal – opening just before the oesophagus and just after the rectum. An alimentary canal of some kind is found in many animals.
   - The presence of an oesophagus and a rectum is consistent with a digestive system typical of many animals.
8. Comparisons include:
   - The duodenum permits chemical digestion of carbohydrates, proteins and lipids.
   - The colon permits minerals and water to be absorbed into the bloodstream.
9. Suggestions include:
   - Crop. In birds the crop is a part of the bird oesophagus in which food is stored.
   - Proventriculus. This organ is a front part of the stomach where chemical digestion occurs.
   - Gizzard. The gizzard is a back part of the stomach where products of chemical digestion are ground up into tiny particles.
10. Regarding coeliac disease:
    a) The amount of surface area the villi provide for absorption is greatly decreased.
    b) Likely symptoms include abdominal pain due to less absorption of the products of digestion, fatigue and weight loss due to less absorption of glucose and anaemia due to less absorption of iron.
11. Regarding the table:
    a) Starch is chemically digested to sugars like glucose. This is completed in the duodenum so no starch should be present in the ileum (or colon). The levels of glucose in the ileum should be high because as soon as it is produced in the duodenum glucose is moved to the ileum. All of the glucose is absorbed in the ileum so none is present in the colon.
    b) Both glucose and amino acids are the products of chemical digestion that is completed in the duodenum. As soon as they are produced they are transported to the ileum where they accumulate for a short period of time before being absorbed.
    c) Although it is a carbohydrate, fibre is not chemically digested by the human digestive system. Therefore, the amount of fibre in the colon is high.

Chapter 3.6 Answers

1. The three components of a nephron are:
   - Glomerulus; the function is to filter the blood, as a result of filtration some substances temporarily leave blood.
   - Bowman's capsule; the function of Bowman's capsule is to collect the filtered substances (or glomerular filtrate).
   - Renal tubule; the function of the renal tubule is to permit selective reabsorption of substances in the glomerular filtrate i.e. some are returned to the blood.
2. Regarding a diagram that has been drawn of a nephron (Refer to *Figure 363*).
   a) The glomerulus and Bowman's capsule are labelled. The tiny size of the glomerulus causes blood pressure to be high enough to maximise filtration. The walls of the capillaries have tiny pores in them that facilitates the movement of substances out of the blood. The hollow and cup-like structure of Bowman's capsule allows it to surround the glomerulus to maximise the collection of the glomerular filtrate.
   b) The renal tubule and capillaries surrounding the nephron are labelled. The capillaries that surrounded the nephron are very close to the renal tubule. This reduces the distance substances need to move during reabsorption. The renal tubule is tube-like to permit the glomerular filtrate to flow inside it and its walls are very thin and moist to maximise the efficiency of return of selected substances to the blood.
3. The functions of the lungs in excretion include:
   - Carbon dioxide is a waste produced by respiration in cells.
   - This CO_2 diffuses from the blood into alveoli and is removed from the body during exhalation.

4. Differences include:
   - During filtration specific substances leave the blood and enter Bowman's capsule.
   - During re-absorption specific substances leave the glomerular filtrate in the renal tubule and re-enter the blood.
5. Regarding blood pressure and ageing:
   a) More blood would be filtered per unit time. This is because the pressure of blood flowing into the glomerulus would be even higher than is usually the case.
   b) Initially a greater volume of urine would be produced. This is because more water will be filtered by the glomerulus - most will pass along nephrons before it can be re-absorbed.
6. Regarding solute concentration:
   a) The solute concentration in blood plasma is greater than it is in the glomerular filtrate since not all solutes are filtered.
   b) The solute concentration of urine is greater than it is in the filtrate since water is reabsorbed.
7. Differences include:
   - Blood in the renal artery has a higher concentration of oxygen and glucose.
   - Blood in the renal artery has a higher concentration of urea.
   - Blood in the renal artery has a lower concentration of carbon dioxide.
8. Regarding the table:
   a) There is no glucose in urine. This means all of the glucose that would have been filtered has been re-absorbed. Also there is a lot more urea in urine than in the blood. This suggests that urea has not been re-absorbed.
   b) A glucose molecule enters Bowman's capsule as a result of filtration. It is transported along the renal tubule to the proximal tubule where it re-enters the bloodstream as a result of re-absorption.
   c) A urea molecule enters Bowman's capsule as a result of filtration as well. It is transported the whole length of the renal tubule and then leaves the nephron via a collecting duct.
9. Regarding the observations:
   a) Cooling a section of the renal tubule reduces the rate at which glucose and amino acids can be reabsorbed. This is probably because tubule cells cannot provide as much energy for active transport when they are cooler.
   b) If the physical impact ruptures or tears enough glomeruli, red blood cells will be able to enter Bowman's capsule. These cannot be re-absorbed so will eventually end up in urine.
   c) A lot of re-absorption occurs constantly via nephrons in the kidneys and there are a huge number of nephrons. As most substances are re-absorbed by active transport both kidneys require a lot of energy, even more than the heart.

Chapter 3.7 Answers

1. The labelled diagram drawn should be similar to *Figure 375*. You may also refer to *Figure 376* to help with this answer. The main events in the cycle are;
   - The ventricles relax, the semi-lunar valves are closed, the atrio-ventricular (AV) valves are open and blood flows into the atria and ventricles.
   - The atrial muscles contract and blood is pumped into the ventricles through the AV valves.
   - The ventricles contract with the AV valves closed and the SV valves open forcing blood into the pulmonary artery (right side) and the aorta (left side).
2. A section through an artery is drawn. The artery wall is labelled tough or thick. A tough/thick wall ensures blood reaches organs at high pressure because it is unlikely to leak, or burst.
3. Suggestions include:
   - Hormones is to transmit chemical messages to organs.
   - White blood cells to destroy bacteria and viruses that have entered the body.
4. Suggestions include:
   - The pulmonary circulation transports blood to/from the lungs.
   - The systemic circulation transport blood to/from all other organs.
5. A simple diagram showing this is drawn. Regarding tissue fluid:
   a) Plasma is the liquid part of the blood. Tissue fluid is the liquid surrounding all cells and tissues.
   b) Water moves from tissue fluid into lymph capillaries by osmosis.
6. During heavy exercise stroke volume increases. For most people it would increase significantly above 75 mL.
7. When cardiac muscle contracts (during a heartbeat) it occupies a smaller volume. The elastic tissue it has allows it to return to normal volume between heartbeats.
8. Semilunar valves prevent backflow of blood into the ventricles in between heartbeats. Femoral artery valves stop blood flow back down the leg in between heartbeats.
9. Regarding the blood pressure graph:
   a) Blood pressure is high at location 1 then decreases sharply to location 2 and is very low indeed at location 3.
   b) Suggestions are:
   - Location 1 is likely to be in an artery. This is because arteries transport blood at high pressure.
   - Location 2 is likely to be at the venule end of a capillary network because the blood pressure has decreased (due to plasma being forced out of the blood at the arteriole end).
   - Location 3 is likely to be in a vein as the blood pressure is very low.
10. The systems are similar in that they both contain and transport plasma containing white blood cells. They are both closed systems with valves, although the lymph vessel walls are more porous to cells and fluid. In contrast the lymph vessels are low pressure vessels that rely on gravity and skeletal muscles to move the fluid along. Lymph fluid does not usually contain red blood cells.

Chapter 3.8 Answers

1. Suggestions are:

Material	How is it taken in?	Why is this process used?
Mineral nutrients	Active transport	Concentration of mineral nutrients in soil solution is less than in root hair cells
Oxygen	Diffusion	Concentration of oxygen in the soil air spaces is greater than in root hair cells
Water	Osmosis	Solute concentration is the soil solution is less than in root hair cells.

2. Water moves from the soil solution into root cells by osmosis. This inward movement causes water to be pushed towards the xylem vessels.
3. Evaporation in the mesophyll causes a region of low pressure. As a result, water (at higher pressure) moves towards the mesophyll. There is cohesion (or a force of attraction) between water molecules in the xylem. Therefore columns of water are pulled up the xylem towards the leaves.
4. Regarding translocation:
   a) The main purpose of translocation is to transport the products of photosynthesis from leaves to other parts of plants (that cannot perform photosynthesis).
   b) Mostly sugar but also some mineral nutrients; for example, nitrate and phosphate ions.
   c) Translocation occurs in the phloem which is a chain of end-to-end phloem tubes.
5. Regarding the products of photosynthesis:
   a) The carbohydrate plants use for this purpose is starch.
   b) Tubers and bulbs.
   c) In spring because plants need to transport sugar to areas of growth at that time – it cannot be transported as starch.
6. Transport of water to leaves by shrubs would decrease. Transport of mineral nutrients to leaves would also be reduced.
7. Carnivorous plants consume small animals; for example, insects. The bodies of insects are rich in nitrates and other mineral nutrients. Absorption of these by carnivorous plants permits them to grow in soils like this.
8. The function of the transpiration stream is to transport water and minerals dissolved in it to mesophyll tissue in leaves. The function of translocation is to transport sugar and some mineral nutrients to parts of plants that do not carry out photosynthesis; for example, the roots.
9. Regarding the investigation about water uptake by a plant:
   a) What effect does air temperature have on water uptake by a plant?
   b) Temperature of the air.
   c) Water uptake by the plant or rate of fall of water level.
   d) As the temperature of the air increased the speed of water uptake or rate of fall of water level increased.
   e) There are no indications measurement of water uptake were replicated. So the conclusion is based on unreliable data. There is no information to suggest the method was repeated. So the conclusion is based on data whose accuracy is unknown as well.

SIS 3.2 Laboratory Notes

This activity provides a hands-on opportunity to learn about the structure and function of a flower that is a specialised part of the shoot system. Daffodil flowers are suggested because availability coincides with the timing of the activity if done in semester 2 – early spring. The flower of other plants can be used; for example, those of the very common lilies displayed in the Helpful Online RESOURCES at the end of the chapter. Other options include large fuchsia flowers, freesias, or gladiolus. The last two are particularly useful in that they have multiple flowers on each stem (decreasing the cost/flower if it is necessary to buy them)

Viewing the structure of a daffodil

- The daffodil flower season in Adelaide is roughly late June-October. Daffodil flowers generally start appearing in markets/florists from early to mid-August so new season flowers should be available in large numbers for multiple dissections.
- Unless pre-arranged it is unlikely that whole daffodil plants including the bulb, will be easy to obtain. Discuss this with your local market/florist. It may be possible to access home grown daffodils if you know someone who has them in their garden.
- Students should have been forewarned by the Biology teacher of the potential for the dissection to trigger hay-fever, asthma or related responses. The risk assessment for the activity should include this, as well as make clear appropriate action.

Examining the structure of a flower

- Sharp dissecting scissors and scalpels are obtainable from the usual Educational Laboratory equipment suppliers – see the list at the end of SIS 3.8 Laboratory Notes.
- Whenever scalpels are to be used for a dissection, they should only be put out in the laboratory just prior to the lesson.
- Some flowers / plants which may be used for this activity may contain toxic and/or irritating sap, so the use of gloves is advised.
- Hands should always be washed at the conclusion of the activity, whether gloves are worn or not.

Equipment and materials after the dissection

- Teaching staff should ensure that all scissors, scalpels and other dissection equipment are collected and counted before students leave the lab.
- All flower tissue and gloves should be disposed of via a separate plastic bag.
- To clean the dissection boards, wash with hot soapy water.

SIS 3.3 Laboratory Notes

(Note: If Spirometers are not available in your school, you may wish to use the water displacement equipment and technique as described in the First Edition of this Workbook.)

SIS 3.4 Laboratory Notes

This activity provides a hands-on opportunity to examine stomata in flowering plants and to estimate stomatal density.

Measuring stomatal density in a dicot

- Suitable dicot leaves include Geranium, or Spider plant (*Chlorophytum comosum*), which is a common indoor plant, or Elephant's Ears (*Bergenia*).
- Any clear nail varnish can be used, although ones containing acetone can damage the plant tissue. An alternative would be to use a water-based varnish from a Hardware store, which can be aliquoted into suitable smaller containers, and applied with a small paint brush. (easily cleaned in water)
- Microscopes should be used following the procedures detailed in chapters in Topic 1.
- Students should have been forewarned by the Biology teacher of the potential for the activity to trigger hay-fever, asthma or related responses. The risk assessment for the activity should include this, as well as make clear appropriate action.

Observing guard cells and stoma in monocots

- Suitable monocot leaves to use, include Peace Lily (*Spathiphyllum*), the Red Hot Poker plant (*Kniphofia*), or some succulent plants; for example, *Aloe* or *Haworthia*.

SIS 3.5 Laboratory Notes

This activity is an experiment that shows the product of starch digestion is a sugar.

Method

- Diastase (Amylase) is a safe substitute for saliva. This can be purchased in powder form from the usual Educational Suppliers - see the list at the end of SIS 3.8 Laboratory Notes.
- To prepare 1% starch solution, mix 10g of starch with 10-20mL of cold deionised or distilled water in a 2L beaker. Boil approximately 800mL of deionised or distilled water in a kettle, and then add to the starch slurry while stirring. Return to the boil on a hot plate, then allow to cool before making up to 1L. Store in the refrigerator.
- To prepare Iodine solution, add 1g of Iodine, and 5g of potassium iodide to 20mL of distilled or deionised water, mix well, and make up to 1L. (with distilled or deionised water). Store in a dark glass bottle, at room temperature.
- Benedict's solution is an indicator used to test for reducing sugars. This includes all monosaccharides; for example, glucose, fructose and galactose. And most disaccharides; for example, maltose and lactose. But not sucrose, that is not a reducing sugar.
- Benedict's solution can be purchased from the usual Educational suppliers.
- For best results pre-warm the Benedict's solution in the 80°C water bath for two minutes.
- Students should have been informed by the Biology teacher that using human saliva for this experiment is prohibited. The risk assessment for the activity should include this.

SIS 3.6 Laboratory Notes

This activity provides a hands-on opportunity to dissect and examine a mammalian kidney.

Viewing the external structure of a kidney

- Kidneys from a sheep are good to use for the dissection. If possible order kidneys with as much structural detail as possible and with a minimum of damage. These can be sourced from any butcher, and as such are food grade.
- Students should have been adequately prepared by the Biology teacher about what to expect when they see a 'real' kidney. Students feeling sick or fainting is not uncommon. The risk assessment should include this, as well as making clear appropriate action.

Investigating the internal structure of a kidney

- Sharp dissecting scissors or scalpels are obtainable from the usual Educational Laboratory equipment suppliers - see the list at the end of SIS 3.8 Laboratory Notes.
- Whenever scalpels are to be used for a dissection, they should only be put out in the laboratory just prior to the lesson.
- Hands should be washed at the conclusion of the activity, whether gloves are worn or not.

Equipment and materials after the dissection

- Teaching staff should ensure that all scissors, scalpels and other dissection equipment are collected and counted before students leave the lab.
- All kidney tissue and gloves should be disposed of via a separate plastic bag.
- To clean the dissection boards, spray with an approved disinfectant and then wash with hot soapy water.

SIS 3.7 Laboratory Notes

This activity provides a hands-on opportunity to dissect a fish to investigate elements of the digestive, circulatory and respiratory systems.

Viewing inside the body cavity

- There are several medium-sized and relatively inexpensive fish that can be used for the dissection; for example, mackerel, mullet and salmon trout. These fish should be obtainable from fresh fish shops or markets, but should be pre-ordered and your requirements discussed with the supplier.
- Sharp dissecting scissors and scalpels are obtainable from the usual Educational Laboratory equipment suppliers - see the list at the end of SIS 3.8 Laboratory Notes.
- Whenever scalpels are to be used for a dissection, they should only be put out in the laboratory just prior to the lesson.
- Gloves should be worn for the dissection, and hands washed at the end of the activity.
- Students should have been adequately prepared by the Biology teacher about what to expect when they start to cut into a 'real' fish. Feeling sick or fainting is not uncommon. The risk assessment should include this, as well as making clear appropriate action.

Equipment and materials after the dissection

- Teaching staff should ensure that all scissors, scalpels and other dissection equipment are collected and counted before students leave the lab.
- All fish remains and gloves should be disposed of via a separate plastic bag.
- To clean the dissection boards, spray with an approved disinfectant and then wash with hot soapy water.

SIS 3.8 Laboratory Notes

This activity provides a hands-on opportunity to estimate the rate of water transport by a plant and to investigate the effect of wind speed on it.

Setting up the potometer

- Potometers can be purchased from Southern Biological, Haines Educational, and Omega Scientific, from between $75 - $120, depending on their configuration and construction.
- Alternatively, a simple and cheap potometer can be constructed as shown; possibly held vertically with a retort stand and clamps. The junctions will need to be sealed with petroleum jelly or otherwise. A hypodermic syringe may be used by staff to inject water into the tubing to replace the water lost by tranpiration.
- Virtually any species of flowering plant with a well-formed shoot system could be used; for example, a species of *Eucalyptus*.
- Whenever scalpels or single sided razor blades are to be used for an activity, they should only be put out in the laboratory just prior to the lesson.
- A suitable plastic container would be a 4L or larger ice cream container, or a plastic storage tub or deep tray, sufficiently large enough to enable safe manipulation of the shoot system and scalpel, while keeping the stem underwater.
- A suitable, inexpensive electric fan can be sourced from a discount department or electrical store. Make sure it has multiple speed settings.
- Students should have been forewarned by the Biology teacher of the potential for the activity to trigger hay-fever, asthma or related responses. The risk assessment for the activity should include this, as well as making clear appropriate action.

Investigating the rate of water transport and wind speed

- Placement of the fan will need to take into account the strength of the airflow produced so as not to compromise the stability of the potometer and other equipment.
- It is important to ensure that the fan used is tested and tagged as per WHS requirements.
- Equipment and materials after the investigation
- Teaching staff should ensure that all scalpels/blades are collected and counted before students leave the lab.
- All plant material should be disposed of via a separate plastic bag.
- Hands should be washed at the conclusion of the activity, whether gloves are worn or not.

Suppliers catering for Educational Science equipment include:

Livingstone International School Science	<www.livingstone.com.au>
Omega Scientific Pty Ltd	<www.omegascientific.com.au>
Southern Biological	<www.southernbiological.com.au>
Westlab	<www.westlab.com.au>
Serrata Pty Ltd	<www.serrata.com.au>
Haines Educational	<www.haines.com.au>

TOPIC 3 Test Yourself

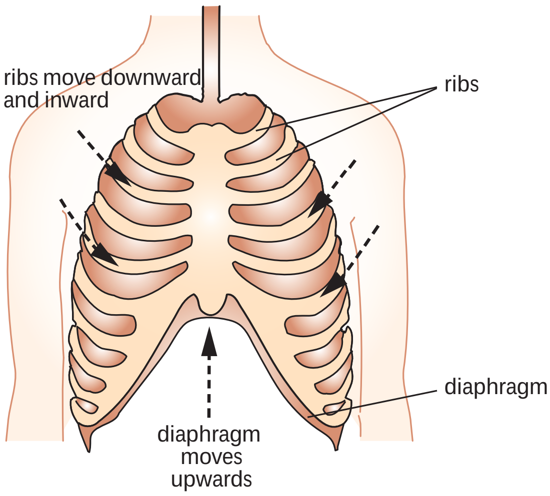
Answer all of the questions in the spaces provided. The number of marks for each question is shown in brackets. Answers are suggested for all questions at the end of the test. Note that they are not intended to be the only possible answer. Read these carefully after the test and use them as part of an assessment for learning activity.

1. Which of the following correctly identifies a possible example of a cell, tissue, organ and organ system (not all necessarily in the one organ system).

	Cell	Tissue	Organ	Organ system
J	Blood	Nerve	leaf	Shoot
K	Cuticle	Stomach	Epidermis	Lung
L	Neuron	Blood	Lung	Excretory
M	Lung	Connective	Stem	Smooth muscle

2. *Refer to the diagram below to answer the question that follows:*

   Which one of the following is correct concerning the movement of air into and out of the lungs as illustrated in the diagram?



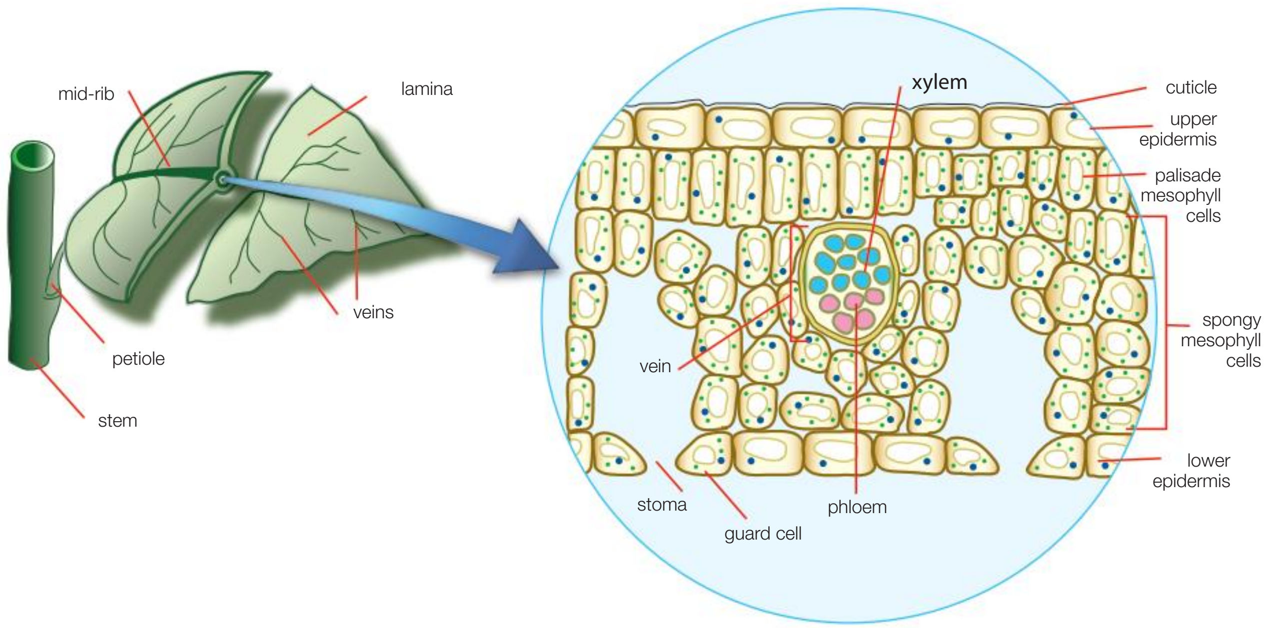
J Inhalation where the diaphragm and intercostal muscles relax.

K Exhalation where air pressure is greater in the lungs than air pressure outside the body.

L Inhalation where air pressure is greater outside the body than in the lungs.

M Exhalation where the diaphragm and intercostal muscles contract.

3. *Refer to the diagram below to answer the question that follows.*

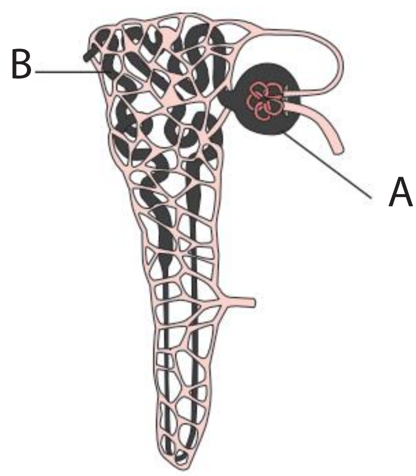


Which one of the following correctly identifies the movement of gases in and out of the leaf during daylight and the name of the process involved?

- J There is a nett movement of CO_2 into the leaf spaces and a nett movement of O_2 out of the leaf by diffusion.
- K There is a nett movement of CO_2 out of the leaf spaces and a nett movement of O_2 into the leaf by diffusion.
- L There is a nett movement of CO_2 out of the leaf spaces and a nett movement of O_2 into the leaf by active transport.
- M There is a nett movement of CO_2 into the leaf spaces and a nett movement of O_2 out of the leaf by active transport.

4. *Refer to the diagram below showing the structure of a kidney nephron and the comparison of its contents at two locations A and B.*

The composition of 4 substances at each location is shown in the table below:

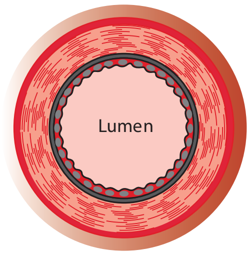
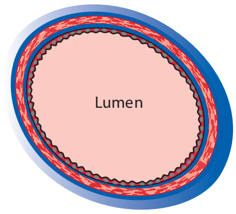
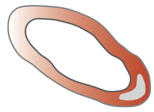


Substance	**A**	**B**
Glucose	0.10%	0%
Urea	0.03%	2%
Protein	8%	0%
Ions	0.75%	1.5%

Which one of the following actions occurring in the nephron could give rise to the differences noted between locations A and B?

- J Ions are filtered into the Bowman's capsule but not reabsorbed back into the blood.
- K Proteins are filtered in the Bowman's capsule and then reabsorbed back into the blood.
- L Glucose is filtered into the Bowman's capsule but not reabsorbed back into the blood.
- M Reabsorption of water by osmosis is a major factor contributing to the increase in concentration of urea from A to B.

5. *Refer to the diagram below of three blood vessels in the human circulatory system to answer the question that follows, note that they are not drawn to scale.*

Blood vessel A	**Blood vessel B**	**Blood vessel C**
		

Which one of the following correctly names the vessel and describes a structural feature that is related to a function of the vessel?

J B is an artery with a tough outer layer that helps pump blood in the circulatory system.

K A is an artery with an elastic middle layer that helps maintain blood pressure.

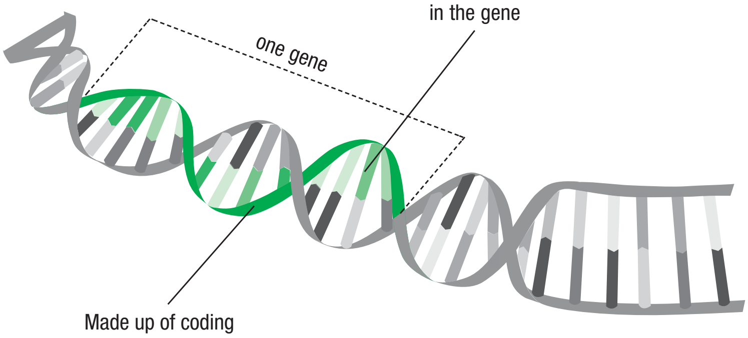
L C is a vein that prevents the backflow of blood.

M B is a capillary with a wall that is one cell thick to maximise the exchange of materials.

6. Which one of the following, in plants, correctly identifies a substance, the vessel it moves in and the name given to the process?

	Substance	**Vessel**	**Process**
J	Mineral ions	Phloem	Transpiration
K	Water	Xylem	Translocation
L	Sugar	Phloem	Translocation
M	Carbon dioxide	Xylem	Transpiration

7. *Refer to the diagram below* which shows a very short part of a DNA molecule and a hypothetical gene.



a) Briefly describe the structure of a gene.

____

____

(2 marks)

b) Explain the function of a gene.

____

____

____

____

____

2 marks)

c) Explain how gene expression is responsible for cell specialisation.

____

____

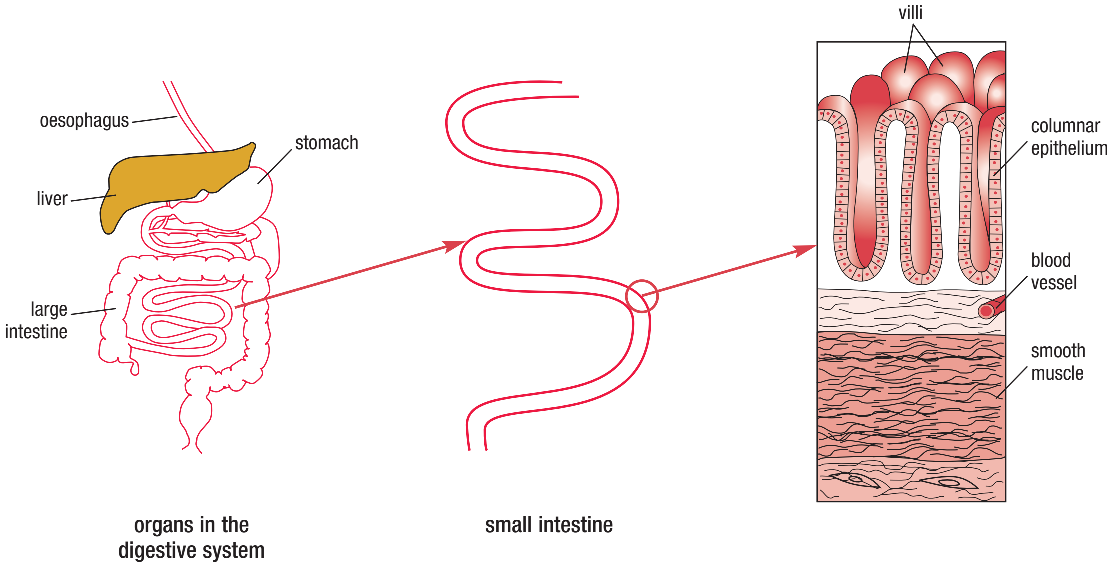
____

____

____

(3 marks)

8. *Refer to the diagram below* which shows the location of the small intestine and some of the tissues that make up its wall.



a) Name two different types of tissue that are labelled in the diagram.

(2 marks)

b) 'Cells are organised into tissues'. Explain the meaning of this statement using an example from the diagrams above.

(2 marks)

9. A leaf is an important organ of most plants.

a) State one important function of a leaf.

(1 mark)

b) Describe using two examples how the structure of a leaf is related to its function.

(2 marks)

10. Multicellular organisms exchange materials with the environment around them using specialised exchange surfaces.

a) State two features of all exchange surfaces.

(2 marks)

b) The exchange of oxygen and carbon dioxide across the walls of alveoli in lungs is similar to how these gases enter and leave unicellular organisms. Explain two reasons why this is the case.

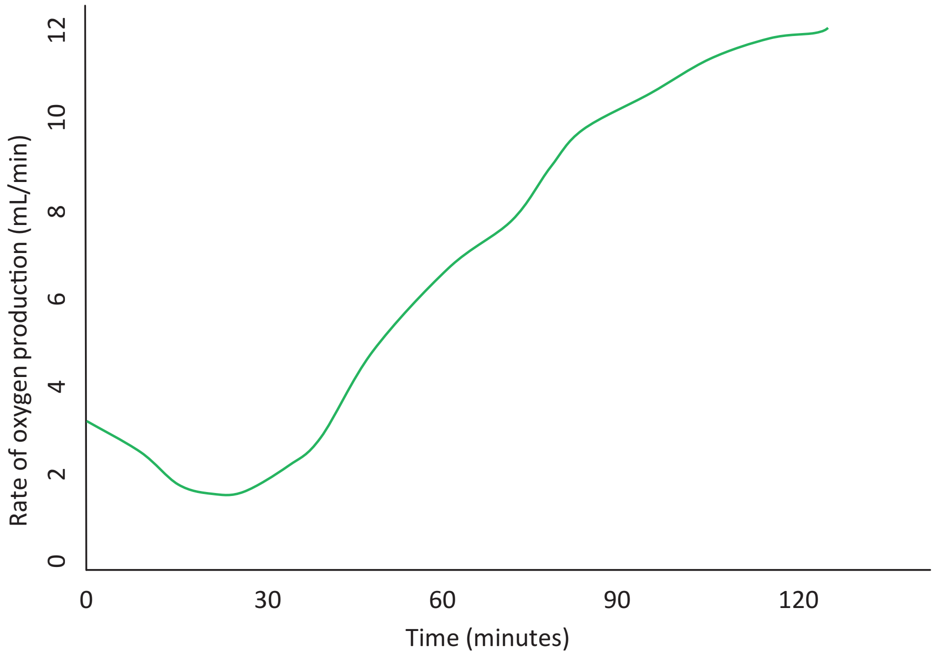
(2 marks)

c) Hyperventilation is where a person rapidly increases the rate and depth of breathing. Explain the effect this would have on the concentration of oxygen in the blood.

(2 marks)

Science Inquiry Skills

11. *Refer to the graph below* which shows data collected about the rate of production of oxygen near leaves of a species of plant over a period of 120 minutes. The plant was removed to a low light environment for 20 minutes and then exposed to bright light.



a) State a likely conclusion from analysing this data about photosynthesis during the 120-minute period.

(2 marks)

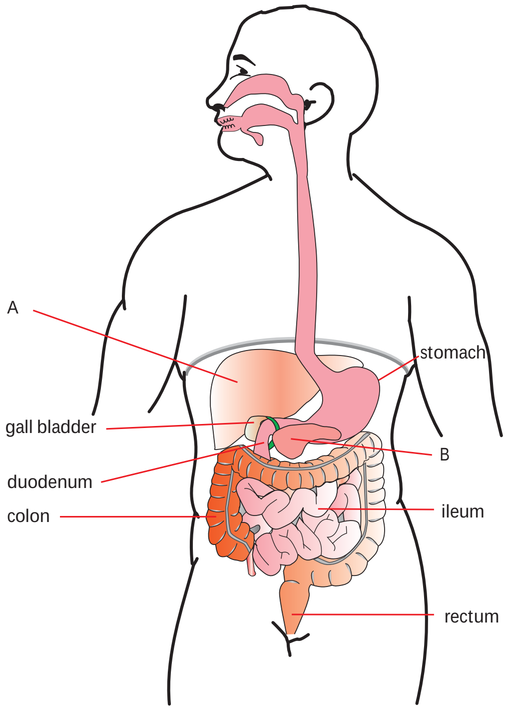
b) Use the data presented in the graph to justify your conclusion.

(2 marks)

c) In the original experimental design, the measurements of oxygen concentration were not replicated. Explain what implications this might have for the conclusions reached.

(4 marks)

12. *Refer to the diagram below* which represents the human digestive system without the salivary glands.



a) The oesophagus is tube-like in structure. State one other structural feature of the oesophagus, and describe how this contributes to the function of the oesophagus.

(2 marks)

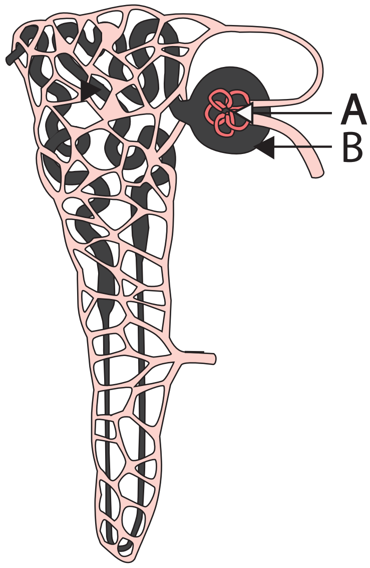
b) Name the structures labelled A and B.

(2 marks)

c) Science provides knowledge and understanding that is applied to the treatment of digestive system disorders. One example of this is how to support a patient suffering from a blocked bile duct. State why does this often includes following a very-low fat diet.

(2 marks)

13. *Refer to the diagram below* which shows an example of an exchange surface surrounded by capillaries that is found in very large numbers in the human kidney.



a) Name the structures labelled A and B.

(2 marks)

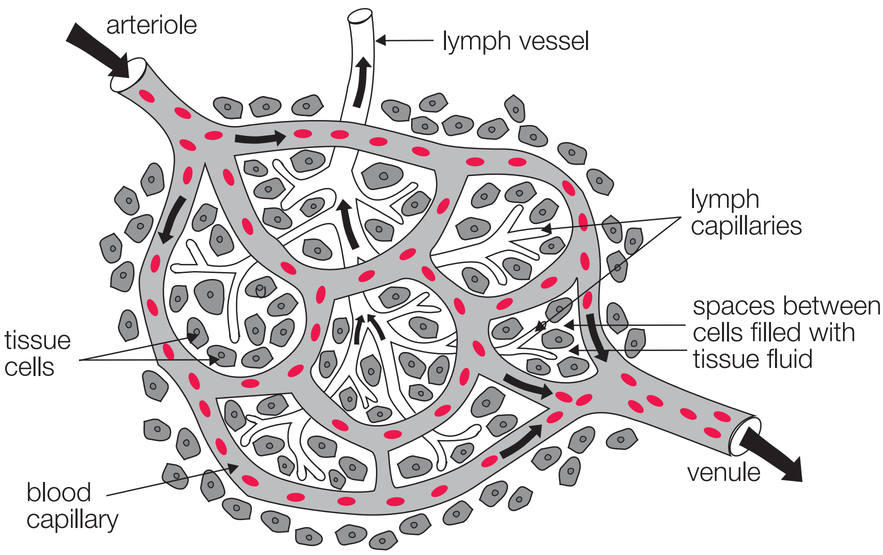
b) Describe what takes place in structure A.

(2 marks)

c) Detailed scientific study by many scientists over a very long period of time has determined that high blood pressure can lead to permanent damage of structure A. Explain why patients with persistent high blood pressure face a future where their ability to naturally remove unwanted substances in urine is greatly reduced.

(2 marks)

14. *Refer to the diagram below* which shows blood flow into and out of a network of capillaries in a muscle tissue.



a) State the relative concentrations of oxygen and carbon dioxide in the arteriole compared with the venule at the end of the capillary network.

(2 marks)

b) The muscle cells shown in the tissue are surrounded by a liquid called tissue fluid. Describe the origin of tissue fluid.

(2 marks)

c) Capillary walls are an exchange surface. Describe the nett movement of water at the arteriole and venule ends of the capillary network.

(2 marks)

d) State two ways capillary network structure facilitates the movement of substances between the capillary network and the tissue fluid.

(2 marks)

15. *Refer to the following information which has been adapted form a scientific report:*

The Babyseq Project

Currently the risks and benefits of genomic sequencing for newborn babies are not well understood. All newborns receive a state-mandated' heel-stick' blood test shortly after birth in order to screen for approximately 30 heritable, treatable conditions such as blood, endocrine and metabolic disorders. Genomic sequencing has the potential to allow for significantly more extensive screening of disorders that newborns could be at risk for developing during childhood. Early diagnosis of these conditions could in turn lead to specific screening, surveillance and treatment options, allowing for more personalised and preventative health care.

The BabySeq project is a 'first-of-its-kind' trial designed to examine how best to use genomics in clinical children's medicine by creating and safely testing methods for integrating sequencing into the care of newborns. Parents and their Babies will receive a Genomic sequencing report. This report contains information about known or likely disease-causing variants associated with childhood-onset conditions identified in the infant. It may also contain information on 'Pharmaco-genomic' variants, genetic changes that could affect response to certain medications and the baby's blood type. Babies who have health conditions that may have an underlying genetic cause may also receive an 'Indication-based analysis' that can re-examine the baby sequencing information, with a specific focus on genes that have previously been associated with the baby's specific health condition.

(*adapted from <https://www.genomes2people.org/research/babyseq/>*)

Discuss how this example demonstrates one or more of the key concepts of 'Science as a Human Endeavour.'

(6 marks)

16. River Red gums (*Eucalyptus camaldulensis*) are some of the biggest flowering plants in Australia. Some of these trees can be nearly 60 metres high.

a) A water molecule has entered the roots of a River Red gum. Describe the journey it takes from the roots to a mesophyll cell in a leaf at the top of the tree.

(3 marks)

b) Describe the forces enabling water to be pulled up the trunk of such a large tree.

(3 marks)

c) River Red gums have a series of adaptations to prevent them from losing too much water by transpiration. State two adaptations and for each describe how it assists in reducing water loss.

(4 marks)

Assessment Key

Assessment Design Criteria	Questions where this could be assessed
IAE1	-
IAE2	-
IAE3	11a, b
IAE4	11c
KA1	1, 2, 3, 6, 7a-c, 8a, b, 9a, b, 10a, 12b, 14a-d
KA2	4, 5, 10b, c, 12a, c, 13a-c
KA3	15
KA4	15

Topic 3 Test Yourself - Suggested Answers

The answers for each part of each question provided here are suggestions. They are not intended to be the only answer. Read and use them carefully to self-assess your performance in the test. Consider asking someone in your class to peer-assess them as well, then discuss. Make notes of errors for future reference and seek the assistance of your teacher as required.

1. L 2. K 3. J 4. M 5. K 6. L

7. Regarding DNA and genes:
   a) A gene is a length of DNA bases or a segment of DNA.
   b) The function of a gene is to store genetic information that can be used by a cell to make a polypeptide or protein.
   c) Differential gene expression means that in different cells genes are switched on or off. Switching different genes on/off enables cells to develop differently hence cell specialisation.
8. Regarding tissues and organs in animals and plants:
   a) Two types of tissue that are labelled are epithelial tissue and muscle tissue.
   b) Muscle tissue is a collection of muscle cells or fibres that perform a specific function; for example, to permit contraction.
9. Regarding leaves:
   a) One important function of a leaf is to carry out photosynthesis to produce organic molecules.
   b) One example of leaf structure related to function is that a leaf has stomata to allow carbon dioxide to enter mesophyll cells for photosynthesis. Another example is a leaf has xylem to send water to mesophyll cells where it is needed for photosynthesis.
10. Regarding exchange surfaces:
    a) Two features of all exchange surfaces are they are very thin and have a very large surface area.
    b) Gas exchange at alveoli is similar to gas exchange by unicellular organisms because it takes place by diffusion. In both alveoli and unicellular organisms, the gases being exchanged also diffuse down the concentration gradient.
    c) Hyperventilation would increase oxygen concentration in the blood because it will lead to a higher oxygen concentration in the alveoli. This will increase the oxygen concentration gradient causing more oxygen to diffuse into the blood.
11. Regarding photosynthesis and evaluation of the procedure:
    a) The data indicates that a higher light intensity promotes a faster rate or photosynthesis.
    b) The first conclusion is supported by the fact that there is a decrease in the rate of oxygen production. Oxygen is a product of photosynthesis therefore a decrease in the rate of its production indicates a decrease in the rate of photosynthesis. The second conclusion is supported by the fact that the rate of oxygen production steadily increased after the plant was exposed to bright light. The photosynthetic process is dependent on light therefore an increase in light intensity should make it occur faster.
    c) The measurements of oxygen concentration are not reliable. This is because the procedure did not permit the effect of random error on the measurements to be minimised (i.e. because the measurements were not replicated).

12. Regarding knowledge and understanding of the digestive system:
    a) The structure of the oesophagus includes muscles in its walls. These periodically contract to push pieces of food to the stomach.
    b) The structure labelled A is the gall bladder. Structure B is the pancreas.
    c) Knowledge and understanding of the digestive system provided by science makes clear the patient will have difficulty chemically digesting lipids. Placing the patient on a low-fat diet will reduce discomfort until the blocked bile duct can be cleared. Bile helps break down fats so they can more easily be chemically digested.
13. Regarding the exchange surface located in the kidney:
    a) The structure labelled A is the glomerulus. Structure B is Bowman's capsule.
    b) Blood plasma is filtered in structure A. This means small materials leave blood that flows into structure A and pass into Bowman's capsule; for example, water and urea.
    c) The patient is less able to selectively remove waste from the bloodstream by filtration. Reabsorption of filtered substances needed by the body does not occur effectively.
14. Regarding capillary networks in tissues:
    a) The concentration of oxygen in the arteriole is high. The carbon dioxide concentration there is low.
    b) Tissue fluid is a product of blood flowing into the capillary network at high pressure. This causes plasma to be pushed out of the capillaries into the spaces between cells.
    c) Water moves out of capillaries at the arteriole end of the capillary network and most returns to blood before the venule end.
    d) To facilitate the exchange of water capillaries in the network have very thin walls. There are also a very large number of capillaries which provide a large surface area for the exchange of materials.
15. The answer should discuss matters such as humans endeavouring to:
    - use a wide range of evidence from different sources
    - use new technologies collecting data and analysing it with new knowledge
    - use knowledge that can be influenced by social, ethical and cultural considerations
    - use new evidence and techniques should enable medical professionals to make reliable predictions
    - recognise there are limitations to the full understanding of how these genes determine health and well-being
16. Regarding transport of water up trees:
    a) The water molecule moves from root cells to a xylem vessel in the root. It then travels in a xylem vessel up the trunk and along a branch, then through a vein to the mesophyll cell.
    b) The pulling of water up the tree starts with evaporation of water in leaves to form water vapour. This generates a region of low pressure. There is cohesion between water molecules all the way down to the roots so water can be pulled up to replace it.
    c) Adaptations that prevent River Red gums from losing too much water include closure of the stomata and the pale colour of the lamina of the leaves. Closure of stomata reduces water loss by evaporation. The pale colour reduces light absorption which will reduce heat gain by the leaf which would otherwise lead to greater water loss.

Topic 4

Biodiversity and Ecosystem Dynamics

Chapter 4.1 Biodiversity

Science Understanding

Biodiversity is the variety of all living things and includes diversity in genetics, species and ecosystems.

- Distinguish between a species, population, community, and an ecosystem.
- Describe diversity in examples of:
  - species
  - ecosystems.

In general, the higher the biodiversity of an ecosystem the more stable it is.

Populations with reduced genetic diversity face increased risk of extinction.

- Explain why genetic diversity is important for a species' survival in a changing environment.

(adapted from) © SACE 2019

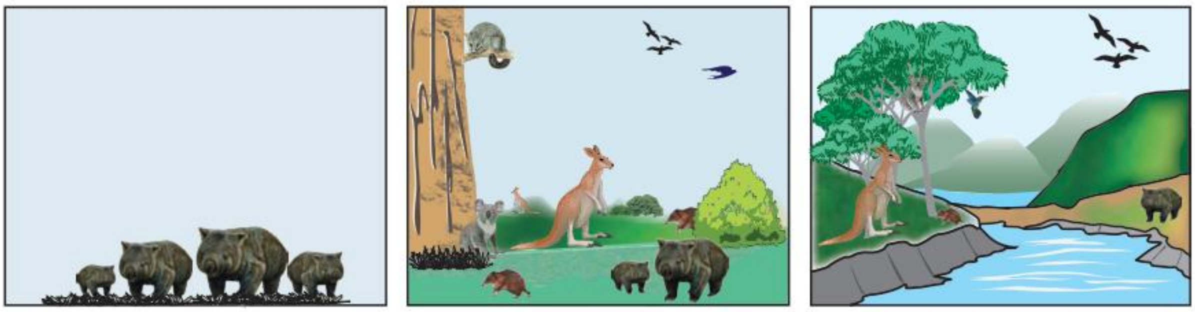
The term **biodiversity** refers to the variety that exists in life forms on this planet. The biodiversity of life is generally expressed at three different levels.

- molecular (genetic) diversity within the genes in a particular **population** or **species**
- population (species) diversity referring to the variety of different species that exist in a particular **habitat** or living space
- **ecosystem** diversity which refers to the different ecosystems that exist

This biodiversity is important for many reasons, including:

- the provision of oxygen, food and fresh water
- the provision of resources and raw materials
- it is a source of organic molecules for medicinal purposes
- the breakdown of waste materials
- provision of natural sites for recreation and appreciation of the beauty that exists in nature's ecosystems

Refer to *Figure 411* which illustrates three levels of biodiversity.



Genetic diversity in a wombat population

Species diversity in a woodland ecosystem

Ecosystem diversity in an entire region

Figure 411 Three levels of biodiversity

Refer to *Figure 412* which illustrates various ways in which we depend on ecosystems.

Figure 412 Ecosystems are useful in various ways

Estimates suggest that there are over 13 million different species of organisms on earth; from microorganisms to a large range of plants and animals. Australia has around 1 million different species representing about 7% of the world's total. More than 80% of our plant and animal species are endemic, meaning that these species are only found naturally in Australia. No other country has as many **endemic** flowering plants or marsupials (pouched mammals) as are found in Australia. As such, Australia is regarded as **mega-diverse**; possessing a high level of diversity of species and ecosystems.

Figure 413 shows three species that are endemic to Australia; two animals and a plant.

Figure 413 (a) A parrot (b) A platypus and (c) A species of banksia

Molecular (genetic) diversity

The term 'species' is generally accepted as referring to a group of organisms that have much of their DNA sequences and genetic make up in common. As such, they share similar physical characteristics as well as the ability to reproduce and have fertile offspring with another member of the same species.

Considering members of one species, it can be seen that the individuals generally conform to a set of structural and biochemical characteristics, although there may be change over time. The appearance of an organism, its **phenotype,** is a direct expression of its **genotype** (the genes it has), together with the effects of the environment.

4.1

Figure 414 shows a group of animals which belong to the same species, possessing similar genotypes and hence phenotypes.

Figure 414 A population of King penguins on Macquarie island

An important feature of species is that members of the one species are **reproductively isolated** from members of another species; they do not interbreed under natural conditions to produce fertile offspring.

Genes are sections of DNA on the chromosomes of organisms that code for particular proteins and these become expressed as the features or characteristics (phenotype) of the organism. The genetic make up of an organism therefore determines its genotype, which in turn determines its phenotype or appearance.

Genetic diversity is the variety of genes and forms of the genes that occur within a particular species. Each species has individuals that will each have their own genotype or genetic composition.

A population is a group of individuals of the same species that interbreed together in a particular living place. One species will consist of many populations that are isolated from one another by being located in different areas. Different populations may have different genetic compositions. Not all groups or species have the same degree of genetic diversity, but this diversity is important for the survival of the species

If a population has a diverse set of genes then it is more likely that the population will be able to survive changing environmental conditions that may threaten the survival of individuals. If all individuals were exactly the same then one particular disease could wipe out all of the members of the population. If on the other hand, some individuals have different genotypes then they may be able to survive the changing conditions. This mechanism or process is called **natural selection**; first proposed by Charles Darwin in 1859.

Genetic drift is where a population of organisms may experience variation in the frequency of different genotypes due to the loss of genes as individuals die or are lost from the population. Where population sizes are reduced significantly (e.g. by disease or hunting) for one generation or more, genetic biodiversity may also be lost. This has been noted with a population of platypus on King Island in Bass Strait which has very low genetic biodiversity in the population rendering them highly susceptible to disease or other environmental pressures. Such a change in the gene pool caused by drastic reduction in population size is called the **bottleneck effect**.

Figure 415 shows some diversity between members of the same species who live together in a local population. Upon close examination of these penguins, small differences can be seen in structure (e.g. beak, feet), physiology (e.g. heat production, nutrition) and behaviour (e.g. mating, hunting).

Koalas are an example of a species that exhibit low genetic diversity and it has been suggested that this may be one of the reasons for the incidence and spread of the disease chlamydia.

Figure 416 shows a koala in its natural habitat.

Figure 415 A close up of some of King penguins

Figure 416 The koala species has low genetic diversity

Population (species) diversity

It has already been established that a population of organisms all belong to the same species. A **community** represents all of the living organisms found together in a particular area or habitat. The ecosystem represents the sum of all of the organisms found living together in a particular area, along with the habitat and the physical components of the environment that affect the organisms.

A population can be thought of as a unit of the community. Populations that are members of a community inhabit a common environment, for example savanna woodland which is a grassy plain with few trees, and interact with one another. The interactions between populations shape the ecosystem, the individuals in each population, and the number of different species in the community. In a typical Australian ecosystem, for example, the savanna woodland, we could expect to find several species of eucalypt, acacia, herbaceous plants, mosses, lichens and a unique mix of animals including ants, scorpions, grasshoppers, butterflies, magpies, kookaburras, koalas, kangaroos and emus.

These populations make up the community for this ecosystem. A community has its unique set of properties. It has its defining form of vegetation, which is often used to name the community. An example would be a 'river red gum' community. This would have its unique mix of organisms making up its biodiversity and its trophic structure: the **producers**, which mainly consist of the photosynthetic organisms, the **consumers** feeding on others to obtain their essential requirements, and the **decomposers**, feeding on dead and decaying material and recycling essential elements it contains.

When careful observations are made, it is noticed that particular species of plants are not scattered at random, but only occur in locations or habitats that suit their particular requirements. The River Red gum (*Eucalyptus camaldulensis*) can be found near a creek-bed, while the South Australian Blue gum (*Eucalyptus leucoxylon*) can be found on hill slopes. Plant communities differ in their appearance depending on the most dominant plant type. Forests and woodlands are plant communities dominated by trees, while shrubs dominate scrub, and grasslands have virtually no trees or shrubs. *Figure 417 (a) and (b)* illustrate typical Australian woodland communities.

Figure 417 (a) E. camaldulensis and (b) E. leucoxylon communities

Interactions between organisms can be between members of the same species or members of different species. These interactions can generally be classified into three main areas: **competition**, **predation** and **symbiosis**.

Competition

This is where organisms are competing for the same resources, for example; light, space, oxygen and food. This competition is most intense between members of the same species and also amongst species that are similar and/or have similar requirements. Competition for resources can be seen quite clearly in the intertidal zone on a rock platform. Refer to *Figure 418(a) and (b)* overpage*.* Looking at the species, as you move from the area that is submerged under water for most of the day to the driest area, quite clear differences in the populations of organisms that inhabit each zone can be observed. Barnacles are found in the spray zone and tend to compete better for the available spots than the periwinkles which are driven to drier zones.

4.1

Figure 418 (a) and (b) Examples of intertidal zones

In grasslands, the grey kangaroo and the rabbit both compete for grasses as a food source. No two populations have identical requirements, but often there is overlap and this is usually where there is competition for resources.

Predation

This is where one organism feeds on or eats another live organism or parts of it. This could be an animal feeding on plants or other animals or even plants feeding on animals (e.g. *Drosera*, an insect-eating plant). **Predation** again shapes the community. It affects the number of organisms in a population, the biodiversity of the community and the evolution of the organisms involved. The feral cat is a predator of organisms such as invertebrates, fish, amphibians, reptiles, native and introduced mammals, and birds. *Figure 419* shows two examples of a predator and its prey.

Figure 419 (a) A species of heron eats a lizard and (b) A predatory mite (left) attempts to eat another mite

Symbiosis

Symbiotic relationships are distinct relationships between organisms of two different species. Generally, these relationships can be placed into three categories: **mutualism**, **commensalism** and **parasitism**. These relationships play an important role in shaping the community.

Mutualism

This relationship is where both organisms from different species benefit. A lichen is an organism formed by the close association of an alga and a fungus. The alga provides food and oxygen through the process of photosynthesis and the fungus absorbs water and mineral nutrients. It is only by this close association that both species can survive in particular environments.

In the stomach of a cow, bacteria exist that have a warm environment with a plentiful food supply and provide the necessary enzymes to break down cellulose, which is the main food type in the cow's diet. Again, both benefit from this close relationship.

Commensalism

In commensalism only one species benefits, but the other species is unharmed. Examples can be seen in the marine environment where certain filter-feeders, like barnacles, may attach themselves to other shellfish, like razorfish. Barnacles gain a habitat and the razorfish is basically unharmed.

Parasitism

This is a form of symbiosis that involves an organism called a parasite and an organism called the host. The parasite lives in or on the host from which it obtains food and shelter. The host is harmed by the symbiosis, and is sometimes even eaten. Parasites include lice, ticks and fleas, and in the plant kingdom organisms like mistletoe. Some species of fungi are also parasites.

The following table summarises these relationships:

Type of relationship	Both benefit	One benefits, neither is harmed	One benefits, the other is harmed
Mutualism	✓		
Commensalism		✓	
Parasitism			✓

Refer to *Figure 4110*(a) showing an example of mutualism where the small remora fish cleans the mouth of the shark gaining food itself and benefiting both organisms. *Figure 4110*(b) shows an example of commensalism with the bird picking insects off the back of the animal and *Figure 4110*(c) is an example of parasitism with tapeworms feeding inside the human intestines.

Figure 4110 Examples of (a) Mutualism, (b) Commensalism and (c) Parasitism

Types of Nutrition

There are basically two types of nutrition that organisms use to obtain their essential requirements:

Autotrophs

Autotrophs are those organisms that have the ability to convert inorganic materials into the organic molecules needed to sustain life. Plants are autotrophs and carry out the process of photosynthesis where light energy is trapped and converted into chemical energy. Organisms that carry out autotrophic nutrition are called **producers**. In a terrestrial environment, this could include the grasses, shrubs, herbaceous plants and forest trees. In an aquatic environment, the producers include various species of algae and phytoplankton.

Heterotrophs

Heterotrophs are those organisms that need to feed on other organisms to obtain their requirements. In humans and many other animals, this will involve eating the organic material of other organisms, and digesting this food so that the essential nutrients are absorbed for use by cells. If a heterotroph feeds only on producers it is known as a **herbivore**. A **carnivore** feeds only on other heterotrophs, whereas **omnivores**, like most humans, feed on both autotrophs and other heterotrophs.

Heterotrophs in a community are called **consumers**. Insects, wallabies and koalas are examples of herbivores or primary consumers, whereas dingoes and eagles are carnivores and are high order consumers. Organisms like bandicoots, possums and bush rats feed on a variety of plants and animals and are therefore examples of omnivores. Every community of living organisms in an ecosystem has what is called a **trophic structure**.

The trophic structure is a pattern of the feeding relationships in the ecosystem and can be seen in *Figure 4111(a)*, which represents a typical food chain in an Australian forest or grassland. Everything relies on the producers in the community, to trap the Sun's energy and store this energy as chemical bonds in organic molecules. *Figure 4111(b)* illustrates a typical example of the different trophic levels in a marine ecosystem. The pyramid gives an indication of the decreasing number of organisms at the higher trophic levels.

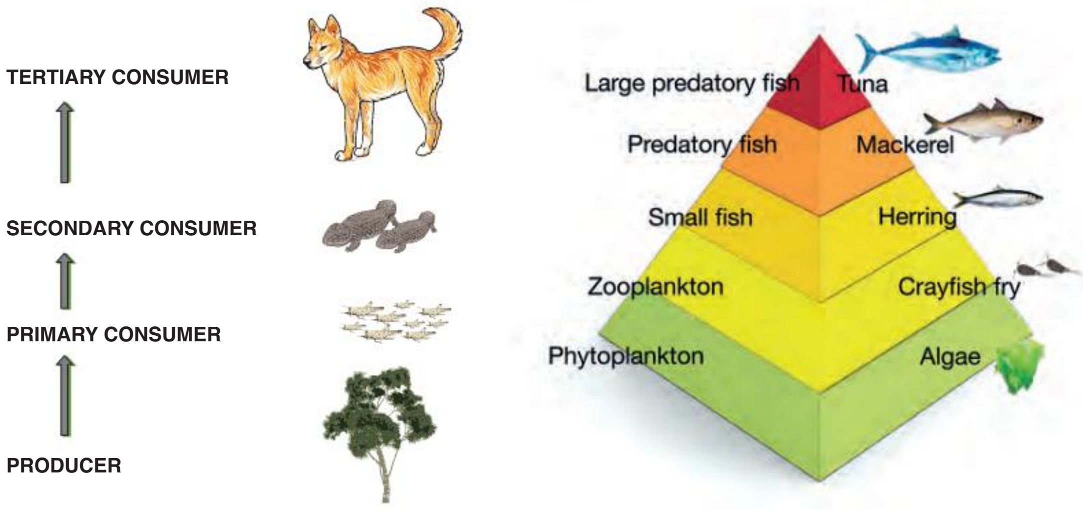


Figure 4111 Simple food chains (a) on land and (b) in the sea

Primary consumers feed on producers, secondary consumers feed on primary consumers and so on. There can exist higher order consumers and in an Australian terrestrial ecosystem they include such organisms as dingoes and wedge-tailed eagles. An important group not yet mentioned are the decomposers. These include such groups as bacteria and fungi. These organisms obtain their nutrition from the dead material that is produced at all trophic levels. The dead material could include animal waste, plant material and dead organisms. They are the recyclers of the community and are responsible for breaking down the organic material and returning essential nutrients to the environment.

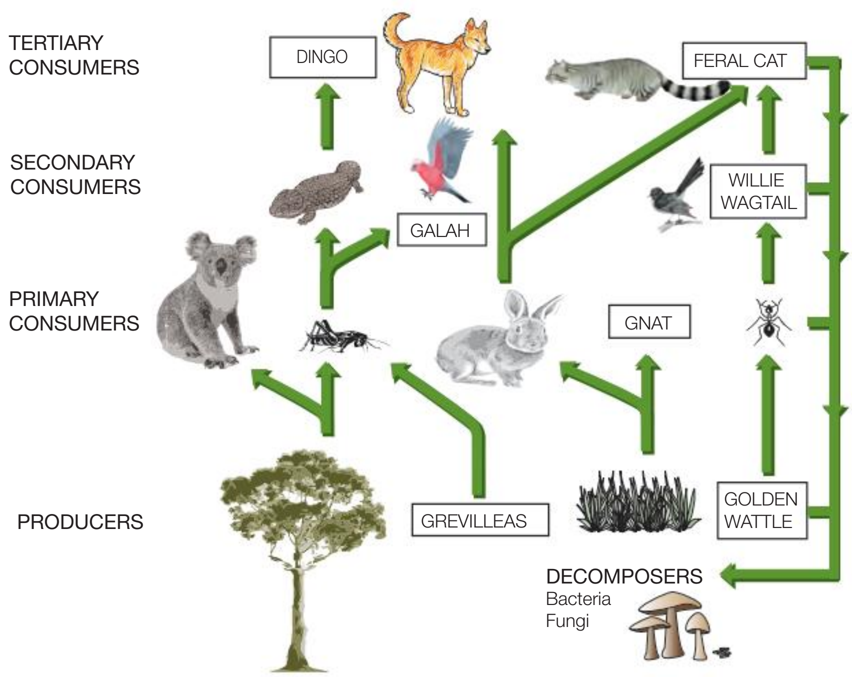


Figure 4112 A simplified food web showing feeding relationships

Most consumers in the community usually eat a range of foods and thus a food chain does not adequately represent the true feeding relationships. Many consumers will be represented at several trophic levels. A more realistic representation of the trophic structure of an ecosystem is a food web, which is really constructed from many linked food chains. *Figure 4112* shows a typical, simplified food web in an Australian **sclerophyll forest**. The decomposers breakdown the remains of dead organisms at each level.

Ecosystem diversity

Environmental factors determine the type of community of organisms that survive in a particular ecosystem. The environment that the community occupies is called the habitat and in ecosystems this can vary significantly from one area to another. Habitat provides the organisms with the basic resources they need to carry out life processes; these include:

- optimum temperature
- oxygen
- water
- breeding sites
- shelter

The inter-related roles of producers, consumers and decomposers in the community ensures that most ecosystems will have organisms from each of these groups. Australia is a large island continent with a diversity of plant communities. It is typified by habitats that are arid, with variable water availability and is subject to fire and high salinity with poor soil and nutrient levels. Most native plants are well adapted to survive these harsh conditions.

In determining which species will survive in a given habitat, there are several factors that are important. These include:

- interactions between the organisms
- resource availability
- climate
- impact of human activities

Each species has evolved characteristics and features that enable it to survive in its particular environment. Chapter 4.4 will further explore the diversity of ecosystems in Australia, looking at both the non-living and living components that tend to characterise specific ecosystems.

Diversity within an ecosystem refers to the number of and abundance of species; an ecosystem with a large number of different species is said to have a high degree of **species richness**. An Australian rainforest would have a greater species richness and abundance of organisms compared with an Australian desert. *Figure 4113 (a) and (b)* illustrate two examples of biodiverse or species-rich ecosystems. The Great Barrier Reef has the largest number of species in an ecosystem on earth, some 9000 species.

Figure 4113 (a) A tropical rain forest ecosystem and (b) A Great Barrier reef ecosystem

Ecosystems that have a high degree of biodiversity are more stable and have the ability to recover from disasters more easily compared to those with lower biodiversity. Each species within the community has its own particular role in the ecosystem as has already been observed. The populations in the community depend on and interact in special and unique ways with others.

Key Concepts

1. Biodiversity refers to variety in life forms and can be seen at three levels:
   - molecular (genetic)
   - species (population)
   - ecosystem
2. Genetic drift may occur in a population over time and this may lead to a genetic 'bottleneck'.
3. Australia is mega-diverse with a large variety of species, many of which are endemic.
4. Members of one species share similar DNA and generally can breed with individuals of the same species to produce fertile offspring.
5. A population consists of members of one species living in a particular place at a particular time.
6. The community refers to all of the organisms of different species living in the same ecosystem.
7. An ecosystem consists of the community, habitat and the physical components of the environment.
8. Interactions occur between members of the community, these can be identified as competition, predation and symbiosis.
9. Symbiotic interactions can be of three types:
   - mutualism
   - commensalism
   - parasitism
10. Each community of organisms in an ecosystem has what is termed a trophic structure. This refers to food chains and food webs.
11. The higher the biodiversity of an ecosystem, the more stable it is. Likewise, populations with greater biodiversity are more likely to be more robust and survive in a changing environment.
12. Populations with reduced genetic diversity are more prone to extinction.

What have you learned?

Key Terms

biodiversity

species

endemic

genetic drift

genetic bottleneck

mega-diverse

phenotype

genotype

reproductively isolated

population

community

natural selection

habitat

ecosystem

producer

consumer

decomposer

competition
predation
symbiosis
mutualism
commensalism
parasitism
autotrophic
heterotrophic
herbivore
carniore
omnivore
trophic structure
sclerophyll forest
species richness

Knowledge and Understanding

1. Complete the following table, showing the three levels of biodiversity, an explanation of each and an example to illustrate each.

Level of biodiversity	Brief explanation	Example

2. Explain why typical ecosystems have a variety of different populations.

3. List some typical natural resources that an ecosystem provides for the community.

4. Australia has been described as 'mega-diverse' with many 'endemic' species. Explain what this means.

5. Interactions between organisms can be classified as competition, predation or symbiosis. Describe each type of interaction using an example.

6. Name the three types of symbiotic relationships that can be observed in communities and give an example of each.

7. Explain what it means when scientists state that members of different species are 'genetically isolated'.

8. List several likely populations that add to the biodiversity of an Australian sclerophyll woodland.

Application, Analysis and Evaluation

9. Predict reasons why the species definition is difficult to apply in some situations and outline one limitation of the definition.

10. Distinguish between the following terms:
    a) species and population.
    b) population and community.
    c) ecosystem and habitat.

11. The cassowary is a bird that feeds on fruits and berries. When the birds eat the fruits, seeds are not digested but when passed from the bird's digestive system are able to germinate and grow into new plants.

    a) Explain why this is an example of a mutualistic relationship.
    b) Outline how this relationship contributes to biodiversity in the ecosystem in which it is found.

12. Using your knowledge, judge the likely type of interaction involved in each of the following examples, choose from: ***predation, competition, mutualism, commensalism and parasitism.***
    a) brumbies and wallabies feeding together in an ecosystem.
    b) a tick feeding on a kangaroo through its skin.
    c) a remora fish attaching to a shark.
    d) cellulose-digestive bacteria feeding in a cow's stomach.
    e) a platypus and a yabby.

13. In the adjacent diagram the areas enclosed show the range of temperature and rainfall in which species 1, 2 and 3 can exist. On the basis of the information shown:

a) Which species can survive over the greatest temperature range?

....

b) Explain why species 2 and species 3 are more likely to compete with each other than with species 1.

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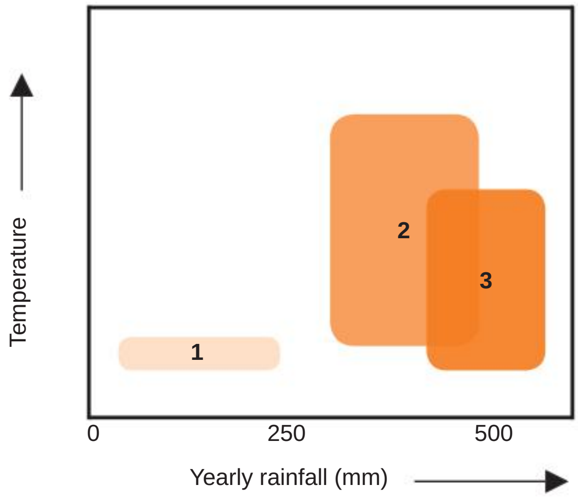
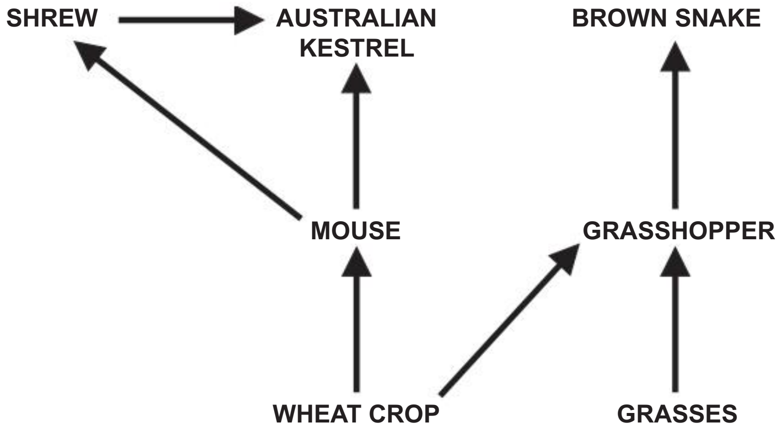


14. The food web below represents some of the feeding relationships in an agricultural ecosystem.

If the mouse population was effectively wiped out by a disease:



a) Explain two reasons why the shrew numbers might fall.

....
....
....
....

b) What possible effect could this have on grasses in the ecosystem? Explain your reasoning.

....
....
....
....

15. The following account was recorded by some biologists observing the feeding relationships in a typical Australian woodland.

"One of the most aggressive predators was the feral cat. It fed on invertebrates, reptiles, birds and several native animals up to the size of possums. Another high order consumer was the dingo that fed mainly on koalas, ring tail possums, and the yellow-footed antechinus. It was open woodland dominated by two species of eucalypt. There were some small shrubs, grasses and the occasional golden wattle. The koala and ring tail possums obtain their requirements feeding on the leaves of trees. Invertebrates like spiders, hunt for gnats and other insects, and ants feed on nectar from flowers. The birds like the grey fantail and willi-wagtail feed on a variety of invertebrates. The kookaburra had a varied diet consisting of insects and small birds. The yellow-footed antichinus feeds mainly on spiders and large insects. The main decomposers were bacteria and fungi."

a) From this description, draw a single food chain to include a producer, first, second and third order consumer.

b) Complete the table below, listing each organism in the correct column.

Producers	**Primary consumers**	**Secondary and higher order consumers**	**Decomposers**

c) Name an organism which is a:

- carnivore ....
- herbivore ....
- omnivore ....

d) From the information given, construct a food web to show the feeding relationships between the organisms.

16. Regarding different levels of biodiversity:

a) Explain why the higher the level of species diversity, the more stable the ecosystem.

b) Give examples to illustrate why ecosystem biodiversity is important to human populations.

c) Predict why the species richness in an Australian sclerophyll forest would generally be higher than in an Australian grassland ecosystem.

Science Inquiry Skills 4.1 - A woodland ecosystem

Introduction

This activity involves taking a supervised visit to a dry-sclerophyll woodland and experiencing first-hand the environment and the community.

There are a variety of types of dry-sclerophyll woodland. One is dominated by a species of eucalypt called ***Messmate Stringybark*****.** Messmate Stringybark woodland occupies large areas of the Southern Mt Lofty ranges; for example, in Belair National Park and in the Cleland, Horsnell Gully and Morialta Conservation Parks.

The tree layer of this woodland is a mixture of trees, including populations of Messmate Stringybark, Brown Stringybark, Blue Gum, Manna Gum and Pink Gum. The shrub layer is an often dense collection of populations of plants, including species of *Acacia*, *Banksia* and *Hakea.* The ground plant layer is a very diverse mixture of small shrubs, herbs, grasses, groundcover species and weeds.

Messmate Stringybark woodland has a wide range of populations of vertebrates and invertebrates. Tree-dwelling vertebrate species include koalas, possums, kookaburras, galahs and owls. The shrub layer is occupied by honeyeaters, finches, rosellas and pigeons. The ground layer typically has populations of echidnas, kangaroos, bandicoots, wrens, magpies, skinks, geckos and frogs.

Part A: Investigate and describe the environment

1. Walk a short distance into the dry-sclerophyll woodland, preferably along, or close to, a track.
2. Stop and note the temperature, humidity, light intensity and the direction and strength of any wind. *Use your own note book or device to record your observations.*
3. Look for evidence to indicate the amount of rainfall, and of recent fire.
4. Observe and describe the substrate; photographs may be useful.
5. List examples of dead matter on the substrate.
6. Document any other examples of non-living matter in the area.

Part B: Observe plants and animals in the community

1. Describe the vertical distribution of plant populations; for example, what layers can be seen?
2. What kinds of plants occupy the woodland at ground level?
3. How densely mixed are shrub populations?
4. Is one tree species dominant? Or is the tree layer made up of several equally dominant species?
5. Document any animal populations that you see, and describe their habitat.
6. Are there animals that can be heard, but not seen? To what group of vertebrates do they belong?
7. Describe some examples of competition taking place between plant populations.
8. Document any evidence of human activity.
9. Observe and record examples of plant and animal adaptations to the woodland you encounter.

Science Inquiry Skills 4.1 - A woodland community (continued)

Analysis

1 Does the wind speed vary on entering the woodland? If yes, give an explanation. If no, attempt to account for that too.

2 What kinds of biological processes are probably taking place amongst the 'leaf-litter' on the woodland floor?

3 In order to survive, plants and animals in woodlands require intact and preferably undisturbed habitats. Why do plants and animals need habitats to be able to survive?

4 Introduced species of plants and animals also occupy woodlands. What are introduced species, and how have introduced species come to be living in this community?

Science as a Human Endeavour 4.1 - Feral cats

Application and limitation

Science informs public debate and is in turn influenced by public debate ...

Ever since their arrival in Australia, cats have in one way or another ended up living and surviving outdoors, separate from human contact. Over many generations, the offspring of these wild-living cats have become less and less comfortable with direct human interaction, preferring instead to remain hidden. Today, these 'feral' cats are typically larger and much more aggressive than human owned domestic cats (Refer to photo).

The impact of feral cats on Australia's biodiversity has been nothing short of devastating. This is particularly true of native mammals that have no means of defence against them. According to a statement by the Australian Government's Threatened Species Coordinator in 2016, feral cats have played a role in the extinction of 20 species of Australian mammals. As feral cats also kill small birds, lizards and species of insects, it is now acknowledged that just one feral cat may kill as many as a thousand animals a year. Moreover, because they have few predators, feral cat numbers continue to increase and thus so does the impact of them.

Unsurprisingly then, programmes have been developed to try to control feral cat numbers. These include culls that target feral cats in remote parts of Australia. In recent years, however, it has been determined that the number of feral cats living and breeding in suburban ecosystems is on the rise. This has intensified debate about the responsibilities of cat ownership and has led to calls from some local Councils to permit members of the public to be able to play a more direct role in the management of them.

The Campbelltown Council in the north-eastern suburbs unveiled one such plan in 2017. Under the scheme, residents may hire a Council possum trap to catch cats wandering the streets at night. A trapped cat must be checked to see if it is tagged (a registered owned cat). If such a cat is not tagged residents are to take it to an agreed animal organisation where it is then checked by the RSPCA to see if it is a feral cat (for example, it is not microchipped).

You may need to refer to the online resources below to answer the questions that follow:

1. Describe how feral cats in Australia illustrates how science informs public debate.

2. The threat posed by 'suburban feral cats' provides an example of how public debate can influence science. Briefly explain why.

Helpful Online RESOURCE about the effect of feral cats on biodiversity

To learn more about the effect feral cats have on Australian biodiversity view this clip:

<https://www.youtube.com/watch?v=ZUjli3P42xl>

Helpful Online RESOURCE about a plan to allow residents to trap feral cats

To learn about a plan to allow Adelaide residents to trap feral cats view the article below:

<https://www.adelaidenow.com.au/messenger/east-hills/plan-to-trap-feral-cats-to-save-native-animals-in-campbelltown-council-area/news-story/7b3a65583a9bb7f7a94c5e16363bfe71>

Chapter 4.2 Biological classification

Science Understanding

Biological classification is hierarchical and indicates the relationship between organisms based on their physical structures and the similarities in shared molecular sequences.

There is an internationally agreed system of nomenclature of species which undergoes revision.

- Distinguish between scientific names and common names for species.
- Recognise that very closely related species have similar scientific names.
- Discuss the advantages of an internationally agreed system of nomenclature.

Different species show different features that help maintain their reproductive isolation.

Reproductive isolating mechanisms may be pre-zygotic or post-zygotic.

Classification of biodiversity

The binomial system of nomenclature was designed by *Carolus Linnaeus*, (also known as *Carl von Linné*), in the 18th century (refer to *Figure 421* which shows a portrait of him).

This system is based on the idea that every species has a Latin name, made up of two parts (i.e. binomial). The first part is the name of the genus, and the second part specifies the species. The name should be printed in italics (or underlined when handwritten) and the first part (but not the second) is capitalised e.g. humans are classified as *Homo sapiens*. This is termed the scientific name, in contrast to the common name of a species which is the normal name given in everyday language.

In addition to the concept of the binomial system, Linnaeus came up with a way of sorting organisms into hierarchical groups. These have become the various taxa and the language used to name them is usually Latin. Linnaeus' idea is still the basis of the binomial system in use today.

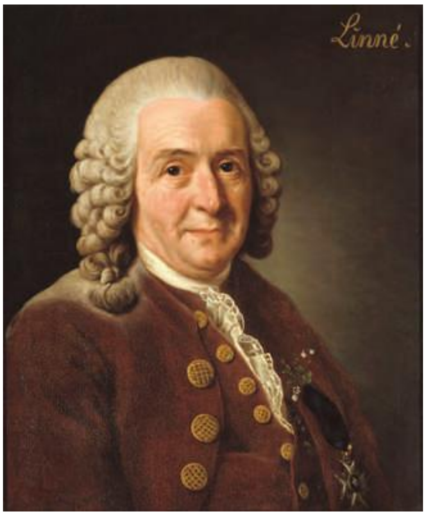


Figure 421 Carolus Linnaeus

Hierarchical classification

This grouping by Linnaeus placed organisms into a hierarchy of categories; Domain, Kingdom, Phylum, Class, Order, Family, Genus and Species. These groups are known as taxa or **taxonomic levels**. This sorting is based on shared characteristics as well as molecular similarities. Each group is a part of the next higher group. The current estimate of species on Earth is about 10 million and this is thought to be only a small percentage of the actual number of species on Earth.

In the 1960s, five kingdoms were recognised; Monera (prokaryotes), Protista, Plantae, Fungi and Animalia. With emerging technologies of molecular sequencing of DNA and proteins, it became evident that there were problems with this system. At the moment, the most accepted version is of three domains; Eukarya, Archaea and Bacteria. Eukarya are eukaryotic, whereas Archaea and Bacteria are prokaryotic.

The main reason for this next level was that it was noted that the Archaea were very different from bacteria when studied closely with both structural and molecular differences. Refer to *Figure 422* which shows the first two divisions of the hierarchy; Domain and Kingdom levels. There is not universal agreement about this.

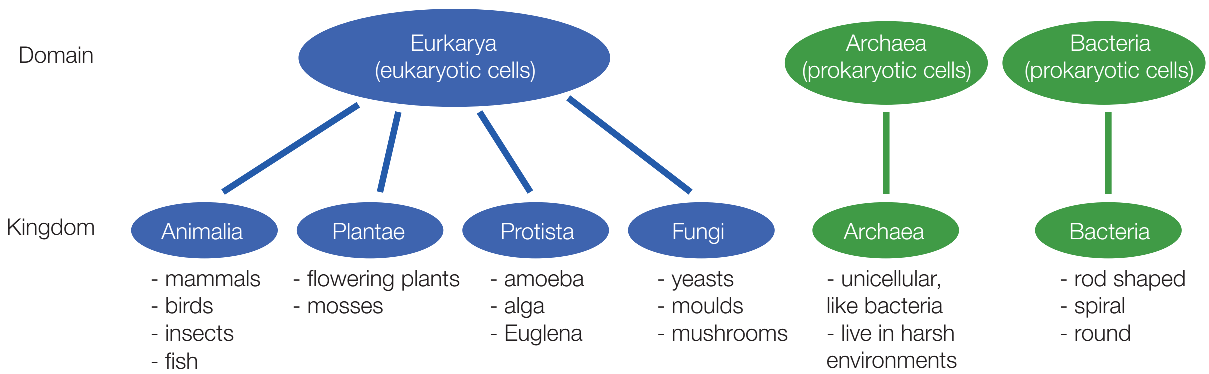


Figure 422 Domains and Kingdoms

Refer to *Figure 423* which illustrates the **hierarchical classification** showing each level of classification for a koala. The common name is 'koala' (aboriginal term meaning 'no drink') and the scientific name is ***Phascolarctus cinereus.***

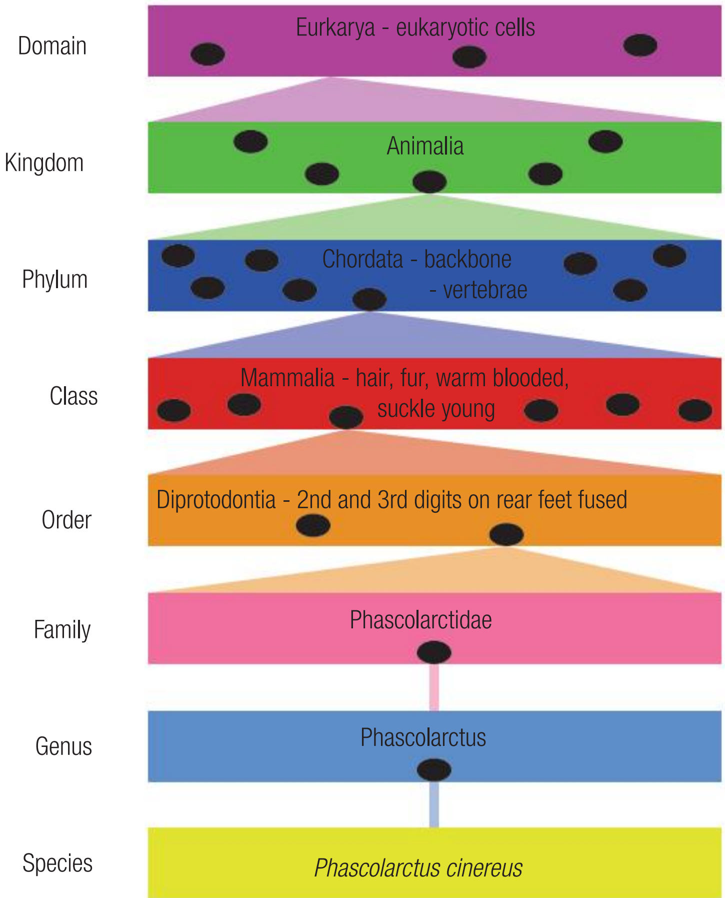


Figure 423 The classification of a koala

The table below illustrates the five Kingdoms and some characteristics used to identify groups that are classified.

Kingdom	**Prokaryotic or Eukaryotic**	**Has a cell wall?**	**Type of nutrition**	**Other**
Animalia	Eukaryotic	No	Heterotrophic	Mostly multicellular, mobile and specialised organs and systems
Plantae	Eukaryotic	Yes	Autotrophic	Mostly photosynthetic and non-mobile
Protista	Eukaryotic	No	Heterotrophic or Autotrophic	Extremely diverse group, some animal like (amoeba) and some plant like (alga)
Fungi	Eukaryotic	Yes	Heterotrophic	Reproduction by spores
Archaea	Prokaryotic	Yes	Heterotrophic or Autotrophic	Unicellular, live in harsh environments
Bacteria	Prokaryotic	Yes	Heterotrophic or Autotrophic	Unicellular with a variety of different shapes (rod, spiral, spherical)

Classifying Animals

Porifera - *Sponges*

- the most primitive animals with a simple body
- live in water
- do not move around
- no mouth, but many small holes through which water is pumped into body
- filter water for food and pump it out through larger holes

Cnidaria - *Jellyfish and sea anemones*

- have stinging cells (cnidocytes)
- **radially symmetrical**
- have a gastro-vascular cavity (hollow space in the centre of the body)
- one opening to cavity
- often have tentacles around the opening

Platyhelminthes - *Flatworms*

- soft flattened body, definite head region
- **bilateral symmetry**
- gastro-vascular cavity (hollow space in the centre of the body)
- usually one opening to cavity
- live in water or damp environment
- can be free-living but often are parasitic

Classifying Animals (cont.)

Annelida - *Leeches and worms*

- bodies consist of ring-like segments
- have mouth and anus
- live in water/moist earth
- may be free-living or parasitic
- no legs
- bristles from body which help movement

Mollusca - *Squid, slugs and snails*

- soft unsegmented bodies
- may have shell

Arthropoda - *Spiders and insects*

- **exoskeleton** made of chitin (a polysaccharide)
- segmented body
- appendages to each segment
- at least 3 pairs of jointed legs
- many free-living but also some parasitic

4.2

Classifying Chordates

Chordates are animals with a dorsal nerve cord connecting the brain with muscles and organs. The largest group are known as 'vertebrates'.

They have:

- an **endoskeleton** made of bone
- a tail, although not always at all stages of their lives

The following are the main groups of chordates

Mammals *e.g. dingo*

- **endothermic** animals (keeping a constant body temperature by heat from internal processes)
- have hair
- females have mammary glands
- include the largest animals on the planet (Blue whales)

Birds *e.g. lorikeet*

- endothermic animals
- have feathers, beaks and wings
- lay hard shelled eggs

Classifying Chordates (cont.)

Reptiles *e.g. crocodiles*

- **ectothermic** animal (use external heat to regulate body temperature)
- dry, scaly skin
- eggs with leathery shell

Amphibians *e.g frogs*

- ectothermic
- smooth, moist skin
- larvae often aquatic with gills, adults terrestrial with lungs
- eggs (in water) surrounded by jelly like substance

Fish *e.g. Reef fish*

- ectothermic
- wet, scaly skin
- aquatic, streamlined with gills, fins.

Classifying Plants

In the Kingdom of the Plantae, we can distinguish a number of groups, including:

Bryophyta - *Mosses and liverworts*

- small terrestrial plants
- do not have true roots, stems or leaves but they might have structures resembling them
- leaf-like structures are often arranged in a spiral
- usually live in clusters which act like sponges holding water

Filicinophyta - *Ferns*

- have true leaves
- new leaves unroll
- have an underground creeping stem (rhizome)

Coniferophyta - *Conifers*

- all conifers are woody plants, most are trees with a single wooden trunk with side branches
- leaves are long thin needles, often arranged in spirals, usually a dark green colour
- produce seeds found in cones

Angiospermophyta - *Flowering plants*

- have flowers, although they may be small in wind-pollinated angiospermophyta
- Produce seeds that develop from fertilised structures in the ovaries called ovules.
- The ovary and its contents (seeds) develops into a fruit that may be hard or soft
- leaves usually as leaf blade and leaf stalk, with veins visible on the lower surface

Dichotomous Keys

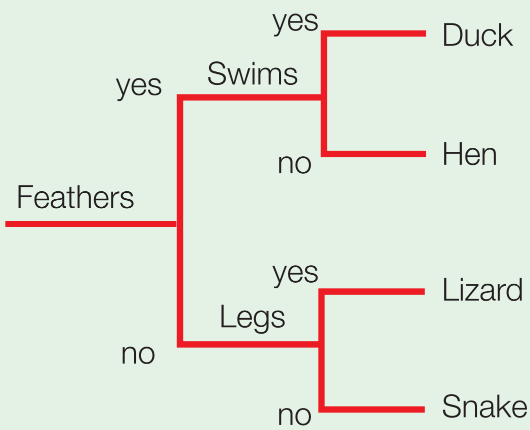
The construction of dichotomous keys can be used in identifying specimens.

In Biology, a key is used to identify an organism. Imagine that you are taking someone to a farm who does not know the appearance of a cow, a horse, a chicken or a pig. You could give this person the following key:

1.	Animal is taller than 1.5 metres	go to 2
	Animal is smaller than 1.5 metres	go to 3
2.	Animal is black and white	cow
	Animal is brown	horse
3.	Animal has feathers	chicken
	Animal is pink with curly tail	pig

A key in table format

A key can also be shown in a different way, for example :



A key in flowchart format

You can make a key to identify items of any group of things. If there are two choices at each stage it is called a dichotomous key. The important thing is that it works.

In Biology, dichotomous keys are most commonly used to identify plants, insects and birds. These are often area specific, for example, plants of Tasmania.

This Skill is best addressed in a Practical Exercise which your teacher may arrange for the class.

Basis of classification

When classifying organisms into their respective groupings the following characterstics are often used: physical features, reproductive strategies and molecular sequencing.

Physical features

As physical features are an expression of the genotype and the environment, it is logical that organisms with similar features are often closely related. As has been seen in the diagrams on previous pages, these physical features can be used in classifying a range of different organisms.

Plants: e.g. no true roots, stems or leaves, underground stems, flowers

Animals: e.g. stinging cells, radial symmetry, soft flattened body, exoskeleton, hair or fur, feathers, limb structures, organs (e.g. lungs)

Reproductive strategies

Methods of reproduction are also used in classification. Some species reproduce by sexual means, fusion or fertilisation of gametes, others by asexual means, not involving gametes.

Three groups of mammals are separated by differences in reproduction:

Placentals: e.g. humans, cats; give birth to live young, placenta is involved in nourishing the fetus.

Marsupials: e.g. kangaroo, wallaby; the young develops in a pouch

Monotremes: e.g. platypus, echidna; lay eggs but still suckle their young on mammary glands which means they are mammals.

Molecular sequencing

In recent times, the practice of examining DNA sequences and protein sequences of organisms has been of great assistance in either helping to classify species or to support other evidence, such as physical features. DNA is made up a very long sequences of four bases: adenine, guanine, cytosine and thymine.

By comparing DNA and known gene sequences, inferences can be drawn regarding common ancestors and henceforth, the degree of relatedness. Refer to *Figure 424* illustrating DNA and the genetic code.

'Cytochrome c' is a protein that is necessary for the aerobic respiration pathways of virtually all living organisms. This protein varies from one species to another and the degree of similarity indicates the closeness of the evolutionary relationships. The sequences for humans and chimpanzees match at all 104 amino acid positions. Human cytochrome c varies in nine amino acids from a rabbit, 13 amino acids from a turtle and 45 amino acids from yeast. Data provides support for classifying some species as more closely related to a particular group when compared with other groups. It has been found that the evolutionary relationships based on this protein are generally in agreement with those based on physical features.

The table below indicates the differences between cytochrome c amino acid sequences in six species. It is assumed that the first organisms had cytochrome c and that over billions of years there have been changes in the gene coding for the protein.

	Human	**Monkey**	**Rabbit**	**Duck**	**Turtle**	**Yeast**
Human	0					
Monkey	1	0				
Rabbit	9	8	0			
Duck	11	10	6	0		
Turtle	13	14	9	7	0	
Yeast	45	45	15	46	49	0

Figure 424 The DNA code

Very closely related species have similar scientific names. For example two Australian marsupials, the eastern grey kangaroo (*Macropus giganteus*) and the agile wallaby (*Macropus agilis*).

These two marsupials are in the same kingdom (Animalia), phylum (Chordata), class (Mammalia), order (Diprodontia), family (Macropodia) and Genus (Macropus) and share many characteristics in common. Refer to *Figure 425*(a) and *Figure 425*(b).

Figures 425 (a) The Eastern grey kangaroo and (b) and the Agile wallaby

Reproductive isolation

In Chapter 4.1 it was noted that an important feature of a particular species is that, whilst they can interbreed with members of the same species, they are what is termed 'reproductively isolated' from members of another species. This effectively means that separate species cannot interbreed with each other and have fertile offspring.

Many species have unique and quite involved courting rituals that are designed to attract only members of the opposite sex of the species. The time of flowering plays an important role in sexual isolation in flowering plants. Certain closely-related animal species are also reproductively isolated as their breeding seasons do not coincide. Differences in the shape of animal genitalia may prevent mating and differences in flower shape may prevent pollination.

A mechanism that maintains **reproductive isolation** between groups of closely related species is a biological feature that prevents gene flow between the groups, even though the groups' habitats may overlap. Barriers that prevent fertilisation will either prevent mating between individuals or will interfere with the actual fusion of ova and sperm in animals, or ova and pollen in plants.

An important aspect of reproduction in animals is the attraction of mates. In nature this attraction is normally brought about by specific chemicals called **pheromones,** which are released by one of the sexes, or by specific mating calls and rituals. Frogs emit unique mating calls that attract only members of their own species and female moths release sex attractants (pheromones) that lure the male of the species for mating.

Even if mating does occur, there are instances where the sperm may not unite with the ova. This could occur as the sperm may be destroyed in the reproductive system, fail to be attracted to the ova, or be unable to penetrate the ova. On rare occasions when members of different species do succeed in mating, there are often other factors that will prevent the development of a fertile adult. The fertilised egg may have unequal numbers of chromosomes from the male and female and thus development does not proceed. The well documented case of a horse mating with a donkey and producing a strong, robust mule, that is none the less sterile, is a good example of how reproductive isolation is maintained between the the two species of horse and donkey.

Reproductive barriers form isolating boundaries around closely related species.

These **pre-zygotic** and **post-zygotic** isolating mechanisms can be divided into two groups as shown below.

Pre-zygotic mechanisms

- Different mating calls and rituals
- The use of species specific chemicals to attract members of the opposite sex
- Differences in flower shape or genitalia
- Different seasons or times for reproduction
- Inability of sperm to survive in the reproductive system
- Pollen tubes are unable to grow towards the ovules in a flower

Post-zygotic mechanisms

- Zygotes fail to develop
- Young fail to reach sexual maturity
- Offspring are infertile

Figure 426 illustrates some of the barriers that maintain reproductive isolation between populations.

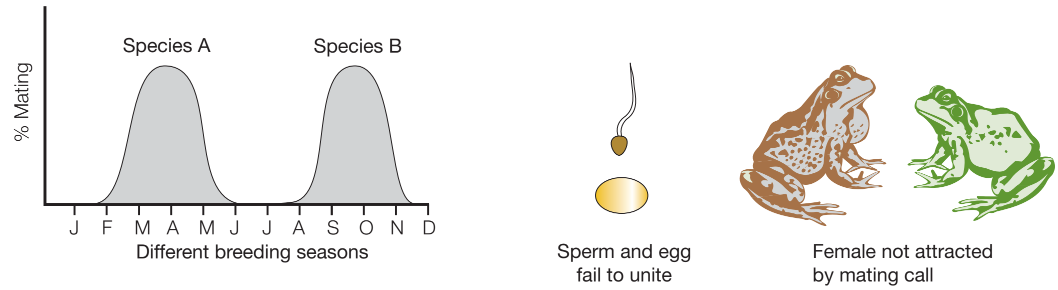


Figure 426 Some of the mechanisms that maintain reproductive isolation

Using dichotomous keys

A **dichotomous key** is a key or a guide that can be used to identify an already known and classified organism into a particular group e.g. into which Kingdom, Phylum, Class etc.

Keys are made up of pairs of questions about the organism to be identified.

In dichotomous keys:

- there are numbered paired questions
- each paired question describes two alternative descriptions of a characteristic
- the instructions ensure that a decision about a characteristic leads to a different pair of statements.

Refer to the table below which is an example of a dichotomous key that can be used to classify a range of some members of the plant kingdom, as well as members of the animal kingdom.

An example of a simple dichotomous key

1.	Has leaves	Go to 2
	Does not have leaves	Go to 4
2.	Grows flowers	*Flowering plant*
	Does not grow flowers	Go to 3
3.	Leaves are needle-shaped	*Conifer*
	Leaves made up of pairs of small leaves or leaflets	*Fern*
4.	Has a backbone	Go to 5
	Does not have a backbone	Go to 10
5.	Has skin that is wet and covered with scales	*Fish*
	Does not have wet, scaly skin	Go to 6
6.	Has skin that is moist and smooth	*Amphibian*
	Does not have moist, smooth skin	Go to 7
7.	Has skin that is dry and covered with scales	*Reptile*
	Does not have dry skin that is scaly	Go to 8
8.	Has skin with feathers	*Bird*
	Does not have feathers	Go to 9
9.	Has skin with fur or hair	*Mammal*
	Does not have fur or hair	Go to 10
10.	Has a body made up of segments	Go to 11
	Body enclosed in a hard shell	*Mollusc*
11.	The segments are fused to produce two body parts	*Arachnid*
	The segments are not fused into two body parts	Go to 12
12.	The segments are fused to produce three body parts	*Insect*
	The segments are not fused into three body parts	Go to 13
13.	Each segment has one pair of legs	*Chilopod*
	Each segment has two pairs of legs	*Diplopod*

C ICT: Cyborg insects

An organism that has altered or enhanced abilities owing to some form of technology humans have integrated into its body is known as a cybernetic organism or 'cyborg'. Fictional examples of cyborg humans as shown in Hollywood movies include The Borg in Star Trek, Darth Vader in Star Wars, and the lead character in Terminator 2: Judgment Day in 1991.

Today, human-cyborgs are confined to the realm of science fiction, but non-human animal cyborg technology is already here. For instance, a lot of work has been done over the last decade to develop cyborg insects. One of the first of these was the 'RoboRoach', a walking and otherwise fully functional cyborg cockroach produced by the University of Michigan in 2010. Many different types of cyborg insects that have subsequently been realised including examples of cyborg beetles, locusts, and dragonflies (*refer to photo*).

The ability to engineer insect cyborgs is not without its critics – it remains unclear, for example, whether this causes them to feel pain. However, there are good reasons for pushing the work forward. These include cyborg insects have proven abilities to better find people trapped after an earthquake and locate bombs (both owing to sensors they can carry), and to serve as aerial cameras.

Even more important, though, cyborg insects have certain advantages over drones. For starters, this is because they are much cheaper to produce. Insect cyborgs that fly function more effectively in weather that is more turbulent. Walking cyborg insects have the potential to navigate much better through tight spaces than drones; for example, a pile of rubble. As they are living organisms, the 'range' of them is not limited by the storage capacity of a battery (a significant limitation for drones) – they need only to be able to feed.

You may need to refer to the online resources below to answer the questions that follow.

1. The use of cyborg insects provides a novel way to collect data vital to assist the work of emergency teams. Give some examples of the kinds of data they could be used to collect following an earthquake.

2. Outline why some members of society may have ethical concerns with the design and development of cyborg insects.

Helpful Online RESOURCE about cyborg animals

To learn more about different kinds of cyborg animals in development view the clip below:

<https://www.youtube.com/watch?v=MuPeLNH-sdQ>

Helpful Online RESOURCE about cyborg cockroaches

To learn about cyborg cockroaches and the possible use of them in search and rescue view the clip below:

<https://www.youtube.com/watch?v=oGf0UXq9V3s>

Key Concepts

1. Species are named using a binomial system, the first name is the genus to which the organism belongs and second name is the species, e.g. a human is classified as *Homo sapiens*.
2. All organisms can be classified in a hierarchical system of classification.
3. The levels (taxa) are: Domain, Kingdom, Phylum, Class, Order, Family, Genus, Species.
4. Although there is not universal agreement, six Kingdoms are recognised: Animalia, Plantae, Protista, Fungi, Archaea and Bacteria
5. The six Kingdoms form part of three larger groups called Domains.
6. To classify organisms, scientists use a combination of physical (morphological) features, reproductive strategies and molecular information.
7. Members of different species are reproductively isolated from other species, i.e. they do not interbreed and produce fertile offspring. Two categories are identified: pre- and post-zygotic.
8. Dichotomous keys are useful in enabling organisms to be identified and placed into their correct hierarchical classification.

Key Terms

binomial system

hierarchical classification

taxonomic level

placental mammal

monotreme

marsupial

reproductive isolation

dichotomous key

pre-zygotic

post-zygotic

radial symmetry

bilateral symmetry

exoskeleton

endoskeleton

ectothermic

endothermic

pheromones

Knowledge and Understanding

1. With regard to hierarchical organisation:

   a) Explain what it means to say that the system used to classify organisms is 'hierarchical'.

   b) Place the following taxa of the hierarchy in the correct order:

   Order, Species, Kingdom, Domain, Family, Phylum, Genus, Class

2. Name of the three domain levels of classification used to classify life on Earth and for each list its main identifying characteristics.

3. Describe, using examples, the binomial system that is used to name organisms.

4. Regarding common names and scientific names:
   a) State the differences between the common names used for organisms and the scientific names.

   b) Describe an advantage for each method of naming organisms.

5. Describe the three types of information that can be used to separate organisms into different groups.

6. Explain what it means to say that "the phenotype of an organism is an expression of its genotype".

7. Describe the reproductive strategies used to classify mammals into three separate groups.

8. Explain what it means to say that the members of one species are genetically isolated from other species.

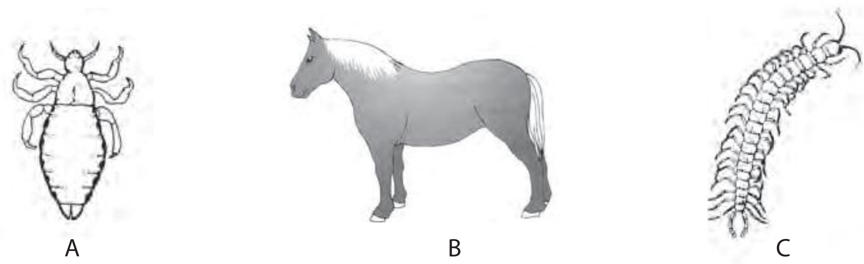
4.2

Application, Analysis and Evaluation

9. Point out how the use of molecular analysis of DNA and proteins has added to scientists' ability to place organisms correctly in the hierarchy of classification.

10. Outline reasons why it may be difficult, in certain instances, to determine whether different populations are members of the same species or different species.

11. A dichotomous key can be used to work out the correct group to which a living thing belongs.



a) Use the dichotomous key in this Chapter to work out to which group the animals, A, B, and C, belong.

b) Write a description of these three animals, using the information obtained from the key.

12. Contrast pre-zygotic and post-zygotic reproductive isolating mechanisms.

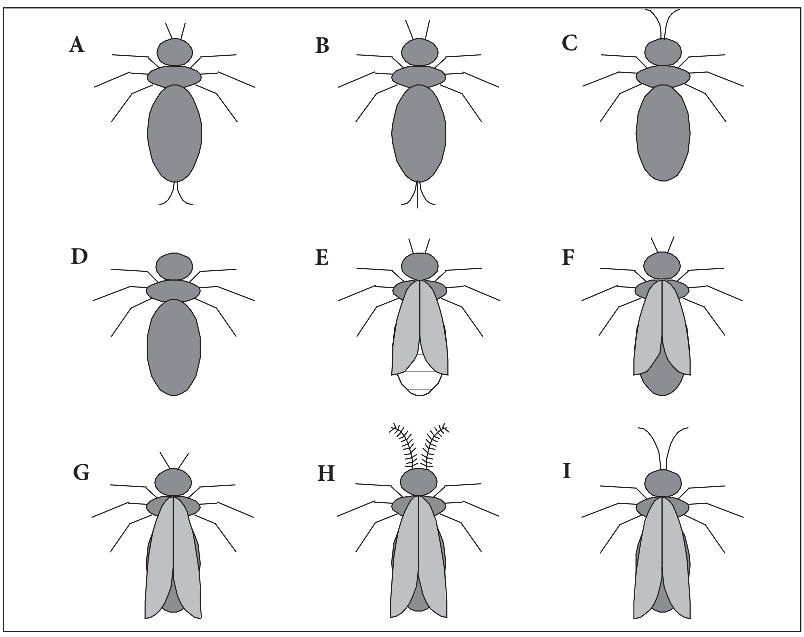
13. Discuss examples of reproductive isolating mechanisms that might prevent gene flow between:

a) two groups of flowering plants

b) two groups of closely related frogs

c) a horse and a donkey

14. Design a dichotomous key to classify each of these insects into a separate group (*use separate paper*).



Using a dichotomous key

Introduction

A range of structural, reproductive and molecular features can be used to classify organisms into various groups. Simple dichotomous keys are useful tools to assist in both understanding the characteristics that are used in classifying organisms into different groups and identifying the groups (e.g. Phyla, Classes etc.) that the organisms belong to.

Materials

Either

- images of particular organisms (e.g. next page)
- specimens of particular organisms in the laboratory
- live specimens (e.g. zoo, other excursion) from a range of animal phyla.

Method

Use the dichotomous key provided to help identify the structural features associated with each animal that are used to identify the Phylum each belongs to.

You will be required to fill in the table provided to identify the characteristics, the Phylum and the scientific name of the organism.

To assist in completing the table you may need to conduct research to enable you to understand:

- differences between bilateral and radial symmetry
- differences between an exoskeleton and an endoskeleton (internal skeleton)
- body segmentation
- scientific names for particular species.

A simple key to classify the animals into Phyla is provided below:

1 a	has bilateral symmetry	go to 2
1 b	does not have bilateral symmetry	go to 3
2 a	has an exoskeleton and jointed legs	Phylum Arthropoda
2 b	does not have an exoskeleton or jointed legs	go to 4
3 a	has radial symmetry	Phylum Cnideria
3 b	does not have radial symmetry	Phylum Porifera
4 a	animal has an internal skeleton	Phylum Chordata
4 b	animal does not have an internal skeleton	go to 5
5 a	body consists of similar segments	Phylum Annelida
5 b	body does not consist of similar segments	Phylum Mollusca

4.2

Using a dichotomous key (continued)

Results

Complete the following table from your observations of the images/specimens and using the dichotomous key provided.

Organism's common name	Image	List of characteristics used to classify the organism into a Phylum	Phylum	Scientific name (research required)
				
				
				
				
				
				
				
				
				
	Yourself			

Chapter 4.3 Adaptations

Organisms have adaptations that help them survive and reproduce.

- Discuss examples of adaptations (behavioural, structural and physiological) in plants and animals.

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Science Understanding

Adaptations

It is DNA found in the nucleus of cells that makes up the genetic structure of multicellular organisms. The genes, found on chromosomes, code for all of the characteristics of an organism.

An **adaptation** is a characteristic or feature of an organism that will assist the organism to survive in its particular environment. Generally, adaptations can be grouped into three types:

- structural adaptations
- **physiological** (functional) adaptations
- behavioural adaptations

Structural adaptations

These adaptations are part of the physical make up of an organism (**morphology**).

Examples of structural adaptations are the large ears of the bilby, which serve to cool the animal down, or the streamlined shape of dolphins that assist their movement through the ocean. *Figure 431 (a)* shows the structural adaptations of a bilby and *Figure 431 (b)* shows those of a dolphin.

Figure 431 (a) A bilby and (b) A dolphin

4.3

Physiological adaptations

Physiological or functional adaptations are generally based on features that are not visible, are associated with **metabolic** processes and are usually based on body chemistry. Examples include the excretion of very concentrated urine by desert animals or the presence or secretion of **toxins** by plants to assist in defending themselves against herbivores.

Behavioural adaptations

Behavioural adaptations are those associated with patterns of activity or behaviour. Bilbys tend to be more active at night when conditions are cooler. Animals that do this are termed **nocturnal**.

Courtship rituals by birds or the mating calls of frogs are behavioural adaptations that help increase the chance of finding a mate and reproducing. *Figure 432* shows part of the mating ritual of albatrosses.

Figure 432 Courting albatrosses

The next section examines three separate ecosystems: a Freshwater pond, a Woodland and a Desert.

For each, the major environmental factors that determine the community are listed, along with the typical organisms found in the ecosystem and the specific adaptations the organisms possess to assist in their survival. In these sections, the living components of ecosystems will be referred to as **biotic** factors and the nonliving components as **abiotic** factors or components.

A Freshwater pond ecosystem

Abiotic factors:

- low oxygen availability
- variable light intensity, from the top of the pond to the bottom
- low solute concentration
- higher **density** of water compared to air
- high water **viscosity** compared to air

Biotic factors:

- **predation**
- **competition**
- disease
- activity of humans

The community

Plants

- floating plants like duckweed
- plants along the perimeter; reeds, sedges and bulrushes
- amphibious plants e.g. waterlilies
- fully submerged plants e.g. pond weeds

Animals

- surface dwelling insects e.g. pond skaters
- organisms that attach themselves just under the water e.g. mosquito larvae
- birds e.g. ducks, swans, herons
- insects e.g. water beetles
- fish e.g. mosquito fish
- amphibians e.g. frogs
- reptiles e.g. turtles
- molluscs e.g. snails

Refer to *Figure 433* which illustrates some adaptations of organisms living in a pond.

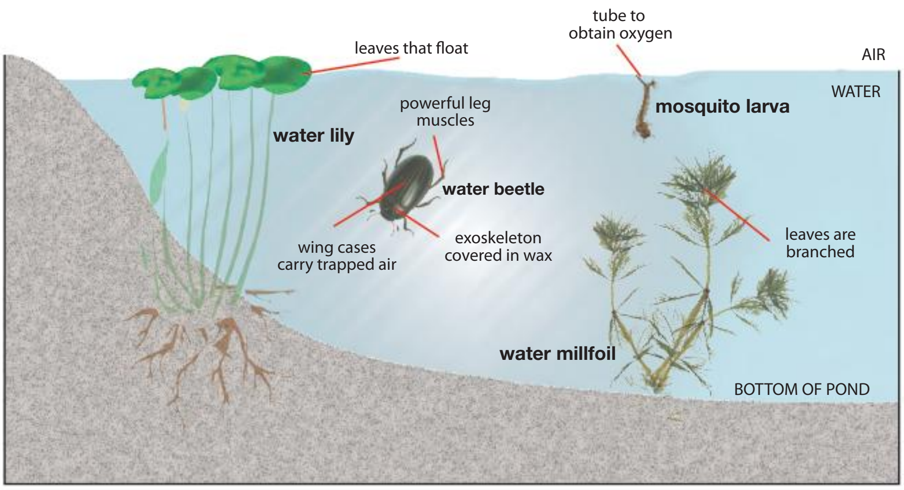


Figure 433 The adaptations of some organisms living in a freshwater pond

The table that follows illustrates the type of adaptations employed by pond organisms to overcome the specific challenges of their environment.

Environmental factor	Adaptation and how it assists the organism	Category of adaptation	Example of organism
Low oxygen levels	Leaves with large airspaces; floating and gas storage and exchange	Structural	waterlily
	Gills; efficient extraction of oxygen from water	Structural	fish
	Air tube that extends to water surface, to exchange gases	Structural	mosquito larvae
	Wing cases to trap air bubbles; gas storage and exchange	Structural	water beetle
	Hold breath whilst diving; gas storage and exchange	Behavioural	duck
Low solute concentration	**Contractile vacuoles**; to expel water that enters by osmosis	Physiological	*Paramecium* (protist)
	Leaves covered with a waxy cuticle; to prevent water from entering	Structural	duckweed
	Exoskeleton; stops water entry into cells	Structural	insects e.g. water beetle
	Efficient kidneys; excrete water and salts	Physiological	fish
High viscosity of water	Streamlined body shape; to reduce friction when moving	Structural	fish
	Webbing between toes; to help thrust and movement	Structural	frogs
Low light intensity	Broadleaves; high surface area for light absorption	Structural	waterlily
Biotic factor (e.g. predation)	change in body shape e.g. erection of body spike (refer to *Figure 434*)	Physiological	water flea

4.3

Refer to *Figure 434* which shows a scanning electron micrograph (SEM) of a dragonfly and a water flea. The water flea is adapted to change its body shape in response to chemicals given off by a predator such as the dragonfly, in this case a long tail spike (***refer to table above***).

Figure 434 Water flea defence

A Woodland ecosystem

Dry sclerophyll woodland ecosystems are quite common in South Australia. These communities can be classified according to the main or predominant native tree and the type of leaves of the plants.

In dry sclerophyll woodland the plants have leaves that are either soft or tough and hardened. Plant populations with tough hardened leaves form a type of vegetation called sclerophyll; examples of such plants include species of eucalyptus, wattles and banksias. Refer to *Figure 435* showing examples of specific adaptations found in some eucalypt species. Refer also to *Figure 436* of a Banksia, named after Sir Joseph Banks who collected plants on James Cook's first expedition to Australia. Banksias are adapted to bush fires, releasing seed when triggered by fire.

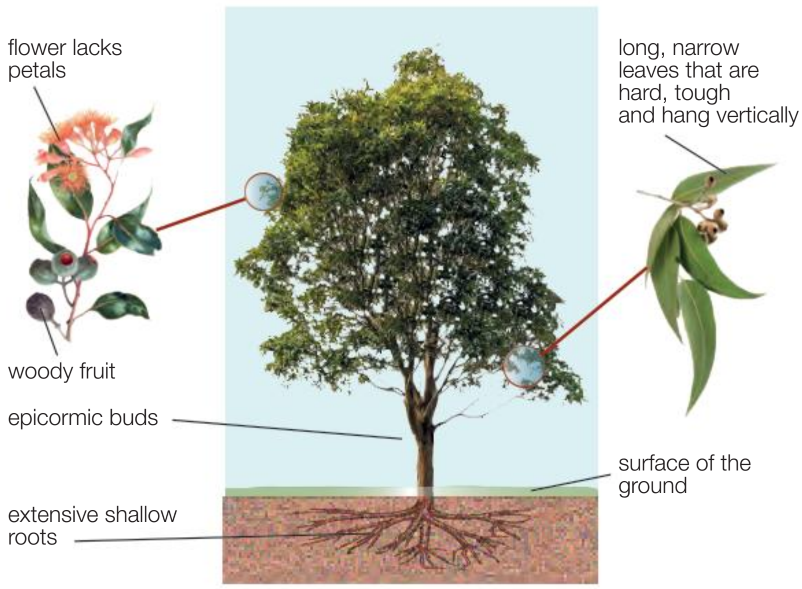


Figure 435 Some adaptations of Eucalypts

Figure 436 A specimen of Banksia

Abiotic factors:

The main abiotic factors that shape the dry sclerophyll woodland include:

- high temperatures
- little water availability
- high light intensity
- low nutrient levels
- high frequency of fire

Biotic factors:

- predation
- competition
- **symbiosis**
- disease
- human activity

The community

Plants

- low level shrubs and grasses e.g. acacias and banksias
- large trees e.g. Eucalyptus species including stringybark, manna gum

Animals

- insects e.g. termites, ants
- reptiles e.g. skinks, snakes
- mammals e.g. kangaroos, koalas, possums
- birds e.g. honeyeaters, rosellas, kookaburras

The table that follows illustrates the type of adaptations employed by these woodland organisms to overcome the specific challenges of these environments.

Environmental factor	Adaptation and how it helps the organism	Category of adaptation	Example of organism
High temperature	Hard, tough leaves; to reduce damage in heat	Structural	Eucalypt, Acacia
	Large ears with rich blood supply; to increase radiant heat loss	Structural/Physiological	bilby
	Nocturnal; active at night to reduce heat gain	Behavioural	possum
Low availability of water	Long, narrow cylindrical leaves; reduce water loss	Structural	grasses and shrubs
	Exoskeleton; reduces water loss	Structural	beetles
	Skin covered with scales; reduces water loss and provides protection	Structural	snakes
	Leaves with oil glands; reduces water loss	Physiological	eucalypts
	Use of uric acid crystals for excretion; reduces water loss	Physiological	termites
	Concentrated urine; reduces water loss	Physiological	kangaroo
Low nutrient levels	Large surface area roots; increased uptake of water and nutrients	Structural	acacia
	Nitrogen-fixing bacteria in roots (symbiosis); uptake of nitrates and other nutrients	Physiological	'bush peas'
	Liver breaks down oils and leaves; to increase nutrient uptake	Physiological	koala
High frequency of fire	Buds just under surface of trunk; sprout after fire	Structural	Eucalyptus
	Woody fruit carries lots of seeds; germinates after fire	Structural	Eucalyptus
	Move to burrows; to avoid being killed or burnt by fire	Behavioural	wombat
Predators	Camouflage due to colouration and/or shape	Structural	spiders
	Hiding in tree trunks and hollows	Behavioural	kookaburra

An Australian desert ecosystem

As can be seen in *Figure 437* much of Australia is covered by desert. These desert ecosystems often seem barren to most life forms but on closer inspection and often under the cover of darkness, an amazing variety of (nocturnal) organisms appear.

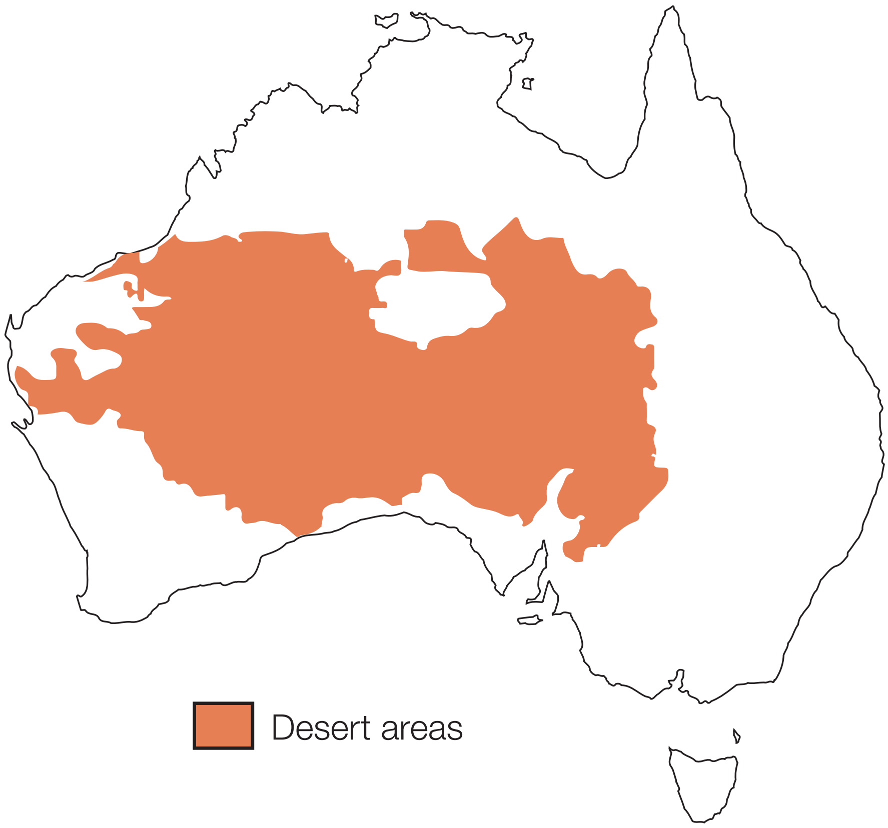


Figure 437 Desert areas in Australia

It might appear that lack of rain is the main abiotic factor influencing the type of community that can survive here and this is mostly true. However, whilst a desert may go without rain for years it often then pours with teeming rain giving rise to floods. These unique conditions have enabled a range of special adaptations to evolve in both animal and plant populations.

Abiotic factors:

- high light intensity
- very poor nutrient levels
- very low rainfall, although this can be unpredictable and can cause flooding

Biotic factors:

- very little vegetation
- very little humus or leaf litter
- competition
- predation

The community

Plants

Examples include Sturts Desert Pea, spinifex and saltbush.

Animals

- birds are often involved in **migration** e.g. budgerigars
- reptiles e.g. bearded dragon, thorny devil, perentie (a large goanna-like lizard), legless lizards
- crustaceans e.g. shield shrimps
- mammals e.g. red kangaroo, bilby, Spinifex hopping mouse
- insects e.g. fog beetles
- amphibians e.g. desert frogs

Refer to *Figure 438* for some examples of desert plants and animals.

Figure 438 A variety of desert plants and animals.

For the Pond and Woodland communities, tables have been presented that outline the particular adaptations, how they assist in the survival of organisms and the type of adaptations.

(Note: For the desert community you will be required to complete a similar table as the response to one of the Questions at the end of this Chapter.)

Key Concepts

1. Adaptations are characteristics or features of organisms that assist them in survival in their particular environment.
2. Scientists identify three types of adaptations:
   - structural
   - physiological (functional)
   - behavioural
3. Abiotic factors; these are the non-living components of an ecosystem that influence the survival of organisms.
4. Biotic factors; these are the living components i.e. the community of organisms and their interactions and relationships.
5. The environmental factors of a pond community e.g. low oxygen availability, mostly low light intensity, low solute concentration and high density and viscosity of water provide a very different set of challenges to the dry sclerophyll forest where high temperatures, low water availability, low nutrient levels and fire are the main environmental factors influencing organisms.
6. When biotic and abiotic factors vary between ecosystems so do the communities that inhabit them along with the specific adaptations of organisms.

What have you learned?

Key Terms

adaptation

physiological

morphology

metabolic

toxin

nocturnal

courtship ritual

abiotic

biotic

viscosity

density

predation

symbiosis

competition

contractile vacuole

sclerophyll community

nitrogen-fixing bacteria

migration

Knowledge and Understanding

1. Name the three different categories of adaptations and give an example of each to illustrate your understanding.

2. Describe, using examples, how the abiotic factors of a pond ecosystem differ from those of a dry sclerophyll woodland.

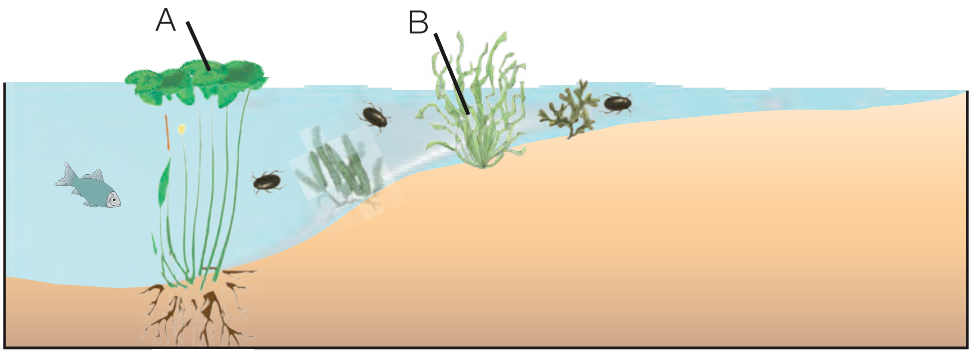
3. For each of the organisms listed below, state one or more adaptations they possess to assist in their survival:
   a) eucalypt
   b) possum
   c) bush pea
4. Regarding symbiosis:
   a) State the meaning of the term symbiotic relationship.

   b) Outline one symbiotic relationship and explain how this might be seen as an adaptive advantage for both species involved.

5. Complete the following table to indicate why each abiotic factor listed is important for particular organisms:

Environmental factor	**Why it is important for survival**
Light	
High nutrient levels	
Water	
Oxygen	
Shelter	

6. Refer to the diagram below of a simple pond community:



a) Predict three ways that the abiotic factors may differ from the top of the pond compared to the bottom.

b) Explain how having large floating leaves provides an adaptive advantage for the plant labelled A.

c) The leaves labelled B are branched. Infer how this adaptation assists in plant survival.

d) It is noticed that a water beetle has bubbles trapped under its wing when it dives, this is an adaptation, explain the reason for this.

e) Pond water is quite fresh, and therefore has a low solute concentration.

- Outline the particular problem that this poses for organisms living in pond water.

- Name one organism and explain how the adaptation it has helps overcome this problem.

Application, Analysis and Evaluation

7. Regarding adaptations and survival:

   a) Illustrate some examples of biotic interactions between different populations that influence the survival of members of other populations.

   b) Outline examples of adaptations that organisms have evolved to help them survive in the above situations.

8. Illustrate your understanding of the link between genetic composition of organisms and adaptations using an example to show your understanding.

9. Using the information in this Chapter and some research where required, complete the following table regarding Australian deserts and their organisms:

Main environmental factor involved	Adaptation	How the adaptation aids survival	Category of adaptation	Example of organism
	A short life-cycle; i.e. germinate, grow, flower, set seed			Sturt desert pea
		Increases radiant heat loss		bilby
	Hopping			red kangaroo
		Ensures some new offspring hatch from eggs		shield shrimps
	Nocturnal			

Investigating an ecosystem

Multi-media communication

This activity is an opportunity to practice the skills of scientific communication in a multi-media format.

Introduction

There are ecosystems in Australia that exist nowhere else in the world with many of the species endemic to our continent. Within these ecosystems, communities are associated with specific habitats and their unique environmental conditions.

Materials

- DVD; *Wild Australasia* episode 1 (*refer to Laboratory Notes*)
- Other resource packages on Australian ecosystems
- Personal/family experiences including photographs/videos
- Internet resources
- Library books

Tasks

Prepare a *PowerPoint* presentation (or similar) on one Australian ecosystem to address the following:

Part A: Identifying and locating an ecosystem

1. Suggest a name for this particular ecosystem giving reasons for your suggestion.
2. Mark the general location of the ecosystem on a map of Australia (*see Figure below*)

Part B: Preparing and presenting a multi-media report

3. Describe the community of organisms present in the ecosystem and point out specific examples of some interactions between the biotic and abiotic factors.
4. Select a particular plant and animal and identify and discuss at least 1 adaptation of each.

Your teacher will provide more information about how you should present your Powerpoint.

Chapter 4.4 Ecosystem diversity

Science Understanding

Ecosystems can be diverse, and can be defined by their biotic and abiotic components and the interactions between elements of these components.

- Distinguish between biotic and abiotic components of ecosystems.
- Compare the characteristics of at least two ecosystems.

Patterns within a community include zonation and stratification.

Environmental components determine the type of community

Most ecosystems have their own particular producers, consumers and decomposers. The actual composition of the community is primarily determined by the environmental conditions of the habitat. If regions with similar conditions on different continents are compared it can be seen that similar types of producers have evolved. Australia is a large island continent with a diversity of plant communities. It is typified by habitats that are arid, with variable water levels, subject to fire and high salinity and have poor soil with low nutrient levels.

Most native plants are well adapted to survive these harsh conditions. A sclerophyll plant has leaves that are rigid and a thick waxy **cuticle**. Adaptations to arid conditions are found in some of the most common species of plant; the acacias and eucalypts. As fire is an integral part of Australian ecosystems, species have evolved adaptations to enable them to survive regular bushfires.

In determining the survival of a particular species in a given habitat, there are several important factors that need to be considered.

These factors include:

- interactions between other organisms; either the same or different species
- the availability of resources
- the weather and climate
- the impact of human activities

Each species has evolved characteristics and features that enable it to survive in its particular environment. Some of the more important environmental factors shaping the evolutionary history of species are briefly discussed below.

Sunlight

Sunlight is the energy source of the photosynthesising plants. It is through the process of photosynthesis that light energy is converted into chemical energy which is trapped in the chemical bonds of organic molecules like glucose. Competition for light can be quite intense in a rainforest, with plants in the understory often receiving filtered light of low intensity, which severely limits the type of species that can grow there.

In marine environments, plants do not exist below 100 metres in depth, as there is insufficient light. The majority of the producers are phytoplankton and found mainly near the surface. Different species of algae are found with different pigments to absorb light, for example brown algae which contains fucoxanthin, a brown pigment. This enables the brown algae to absorb longer wavelengths of light and thus survive at greater depths.

Water

Australia is the driest continent, except Antarctica, and thus much of the land is covered by **desert**, **grassland** and **shrubland** ecosystems. The main plant species are saltbush, grasslands, herbaceous plants and **mallee** trees. With high temperatures, and wind accelerating evaporation, the only organisms that can survive are those that can keep water loss to a minimum. Most organisms like trees, birds, reptiles and mammals are distributed throughout Australia on the basis of water availability.

Plants have evolved such characteristics as specialised leaves, for example, saltbush stores water and has waxy cuticles to prevent water loss through the surface and its narrow leaves have a smaller surface area exposed to the sun. Another plant, commonly known as 'pigface', is a **succulent** herb that grows readily on sand dunes where fresh water is often scarce, it has thick fleshy leaves that store water.

Some mammals have evolved specialised excretory systems that enable them to excrete nitrogenous waste as almost crystalline uric acid to help reduce water loss. Arid conditions and drought are major factors that have determined the evolution of Australian ecosystems. Even in the marine environment, where the amount of water is not a problem, the high solute concentration means that fish have evolved mechanisms to excrete salt from their tissues.

Near the coastal or higher regions where more rainfall is experienced a completely different community can often be found. Rainforests are high-density plant communities with many plant species that have high water requirements. They may include large trees, ferns (plants with very large leaves (fronds) to maximise the absorption of filtered light), **lichens**, mosses and a variety of climbers that can grow around other forms in an attempt to access any available light. With high moisture levels and a lot of leaf litter, the environment is well suited to a range of insects and decomposers such as millipedes, bacteria and fungi. These organisms will provide food for a variety of other consumers including reptiles, mammals and birds, and of course, high order consumers like dingoes that feed on the lower order consumers. *Figure 441* shows the distribution of rainfall in Australia.

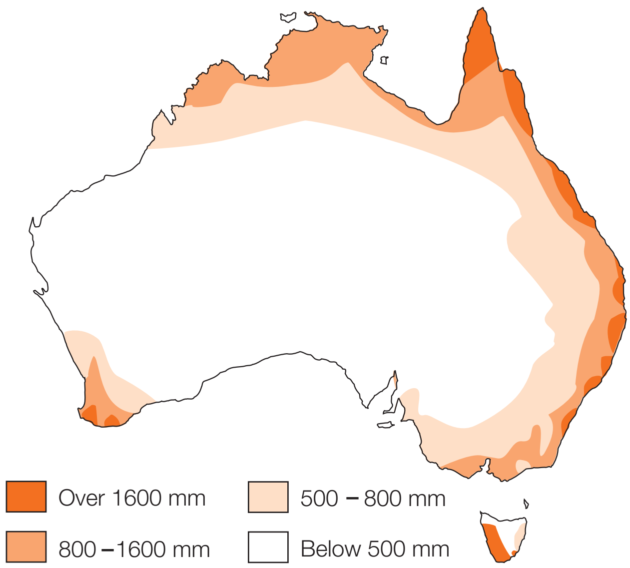


Figure 441 Distribution of rainfall in Australia

Temperature

Human blood temperature is critical for cellular metabolism. Enzymes, which catalyse cellular reactions, work best at around 37°C, and consequently, humans need to carry out homeostatic processes to ensure that blood temperature remains fairly constant' this is similar for many organisms. At high altitude in alpine regions, a different mix of species will be found when compared to the hot desert regions, as the adaptations required will be quite different. Temperature also links in with water availability; as high daily temperatures tend to cause a high rate of evaporation. Generally, higher temperatures are associated with higher activity and growth in both plants and animals.

Nutrients

Plants need to obtain essential mineral nutrients like phosphates, nitrates and sulfates from the soil to incorporate into their tissue and build important organic molecules. Plants that are able to survive in nutrient-poor soils must have developed mechanisms that enable them to obtain their essential requirements; for example plants that have the ability to grow in nitrogen-poor soil by having **nitrogen–fixing** bacteria in root nodules. A species of carnivorous plant, *Drosera*, is able to trap insects and digest them to obtain its needs.

Insectivorous plants are often found in nutrient-poor soils, such as rainforests, where many essential substances are leached from the soil and they obtain nutrients from animals' bodies. A feature of Australian soils is that they are very old, and often low in nutrients. Most soils seem to be low in phosphorous and consist of only a thin layer. Some plants can increase their phosphate absorption through using a special relationship between the roots and fungi (mycorrhiza).

Wind

Strong winds can affect the types of plants that can survive in a particular environment. Plant species that can survive strong winds need to have a deeper or more extensive root system to provide stability in these regions.

Salinity

The solute level in soil water is an important influence in determining the community. Plants and animals exposed to elevated solute concentrations need special adaptations to prevent tissue dehydration; several organisms excrete salts using active cellular processes to help maintain the correct salt-water balance in their tissues.

Wave action

The force of waves in an **intertidal** rock platform ecosystem acts as a strong environmental factor that needs to be countered. Many shell creatures, like barnacles and limpets, possess strong muscular tissue that enables them to clamp down on the rock substrate.

Figure 442 shows the distribution of ecosystems in Australia. Compare the distribution with the average annual rainfall patterns, seen in *Figure 441.*

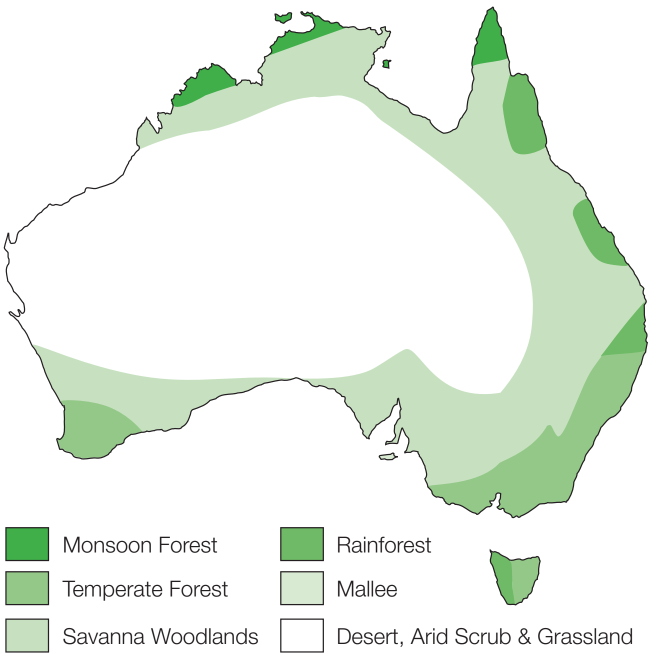


Figure 442 Distribtion of ecosystems within Australia

4.4

In summary, several typical ecosystems and their respective community of organisms, can be recognised in Australia. Some of these ecosystems are shown in the table below. Others are illustrated in *Figure 443*.

Ecosystem	**Some important abiotic components determining the community**	**Examples of vegetation**
Desert/Grassland	high light intensity, low rainfall, high daily temperatures	saltbush,spinifex, grasses
Mallee	shallow soils lacking nutrients, low rainfall, high daily temperatures	mallee trees, grasses, shrubs
Savanna woodland	semi-arid (low rainfall) conditions	trees, grasses, herbaceous plants
Rainforest	high rainfall, usually shallow soils, with low mineral reserves	trees, lichens, moss, palms, climbing species of plants
Intertidal zone	varying water levels, dehydration, high salinity	algae e.g. kelps
Mangrove	submerged by tides, high salinity	mangrove trees

Figure 443 (a) A Saltlake ecosystem (b) A Coastal heath ecosystem (c) A Termite mound ecosystem (d) A Grassland ecosystem (e) An Estuarine ecosystem (d) A Mallee ecosystem

Zonation

A good example of **zonation** can be seen in an intertidal rock platform ecosystem.

Rock platform ecosystems form when rock cliffs and rocky sections have been pounded by waves together with erosion caused by the boulders to form a platform that can host a great variety of life. Such ecosystems are called intertidal due to the actions of the rising and falling tides of the sea which provide a very unique set of environmental conditions; these pose specific issues for the organisms that live there.

Due to this phenomenon of high and low tidal movement, a very distinctive feature called zonation is evident. Zonation is described as the zones or regions from the sea to the upper reaches of the splash zone at high tide, where specific organisms form horizontal bands or zones as follows:

- The splash zone is called the supra-littoral or supra-tidal zone.
- The zone that is in between high and low tide is called the inter-tidal zone.
- The zone that is submerged or underwater permanently is called the sub-littoral zone.

The abiotic components associated with these zones

Listed below are the main environmental abiotic factors associated with each zone which, in turn influence the populations of organisms in each zone.

Supra-littoral (splash) zone

- **desiccation** or drying out when exposed to the sun
- fluctuating temperatures
- obtaining oxygen/carbon dioxide without dehydration
- nutrient deficiency

Inter-tidal zone

This is a variable region, depending on the tides, that ranges from being fully submerged to fully exposed to the abiotic elements.

- heat stress and desiccation at low tide
- oxygen depletion; not much oxygen is dissolved in seawater
- wave action; physically pounding organisms
- high solute concentrations e.g. in some rock pools near the supra-littoral zone

Sub-littoral zone

- much more stable conditions of temperature and buoyancy
- low oxygen levels in sea water
- low light intensities at greater depths

The community of organisms

Refer to *Figure 444* which shows a typical rock platform and the three zones and some typical organisms found in each zone.

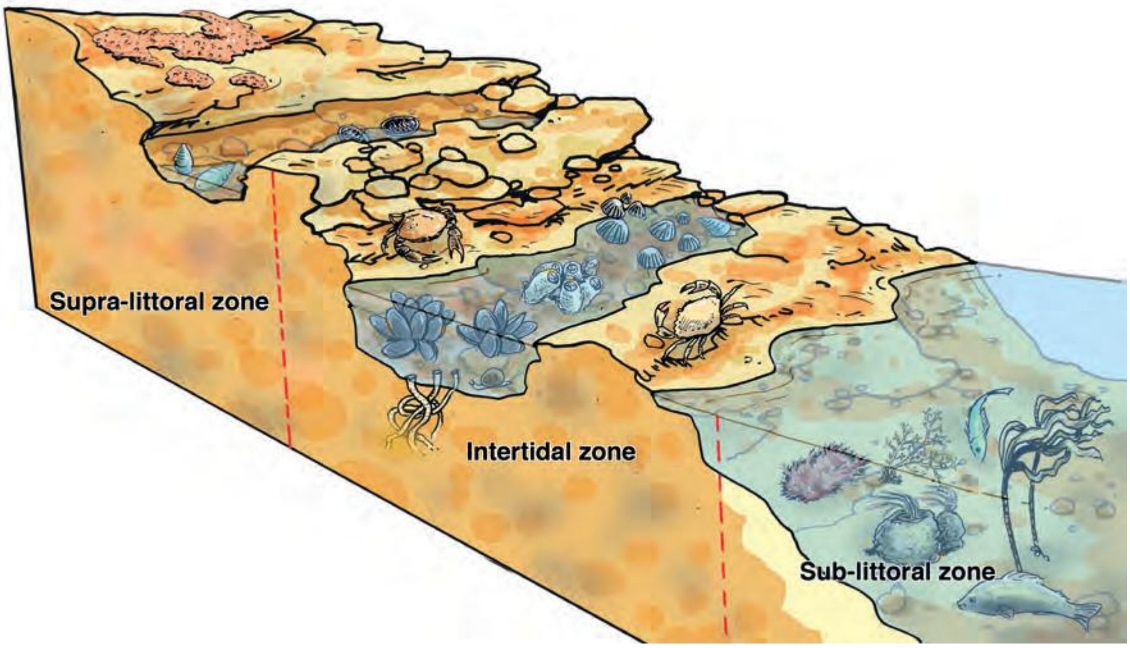


Figure 444 Zonation on a rock platform

Seaweeds

Most of the producers found are the seaweeds which are actually algae, a type of protist. Algae can live in rock crevices and have special **holdfasts** enabling them to fasten to the rock surface. These algae can be different colours; green, red or brown, depending on the pigment used for photosynthesis; they are called producers. The examples shown in *Figure 444* include kelp, cork weed and red algae. Refer to *Figure 445* showing a seal in a marine ecosystem swimming in a kelp (type of alga) forest.

Figure 445 Algae in the ocean

Lichens are organisms that consist of a symbiotic relationship between a fungus and an alga. These can survive in the supra-littoral zone as they can withstand drying out. Refer to *Figure 446(a).*

There are also other producers, often microscopic, that provide valuable food for the grazing sea animals.

Figure 446 (a) Lichen (b) Sea snails (periwinkles) (c) A crab

Animals

Periwinkles graze on various algae and have adapted well to life in and out of the water. A couple of their adaptations include trapping water inside the shell and seeking shelter in cracks in the rocks. Other animals include some barnacles and limpets. In the intertidal zone a large range of animals including mussels, the giant barnacle, limpets, tube worms, rock crabs and chitons can be found. Refer to *Figure 446 (b) and (c).*

There are a range of different adaptations shown by these animals; a few are listed below:

- limpets; a large, flat 'foot' to attach to the rocky surface
- barnacle; close fitting valves to avoid drying out when exposed to the sun and air
- sea squirts; filter feeding animals that pump water through their bodies filtering out microscopic organisms for food.

The importance of rocky platforms

These ecosystems are important for a variety of reasons. These include:

- an important habitat for many shell creatures and other organisms
- a breeding area or nursery for many fish species.
- a source of food for many organisms including fish and at low tides several species of wading birds.
- in the sub-littoral zone which is submerged by the sea are found a large assortment of fish, crustaceans and larval forms of many sea creatures.

Stratification

Stratification refers to the vertical layering or gradations that can occur within an ecosystem. In a rainforest this can be seen quite clearly as the community of organisms found at different vertical layers (strata) can differ quite significantly. Moving from the ground layers to the upper layers, a range of abiotic components change quite significantly. The important abiotic factors here are light intensity, water, humidity and temperature.

In a rainforest ecosystem, the layers could be described as follows;

- forest floor; mainly herbaceous plants
- shrub region
- small trees, including creepers and vines
- large, uppermost levels or **canopy**

Refer to *Figure 447* which illustrates a typical rainforest indicating the changes in light intensity, humidity and average daily temperature at different strata.

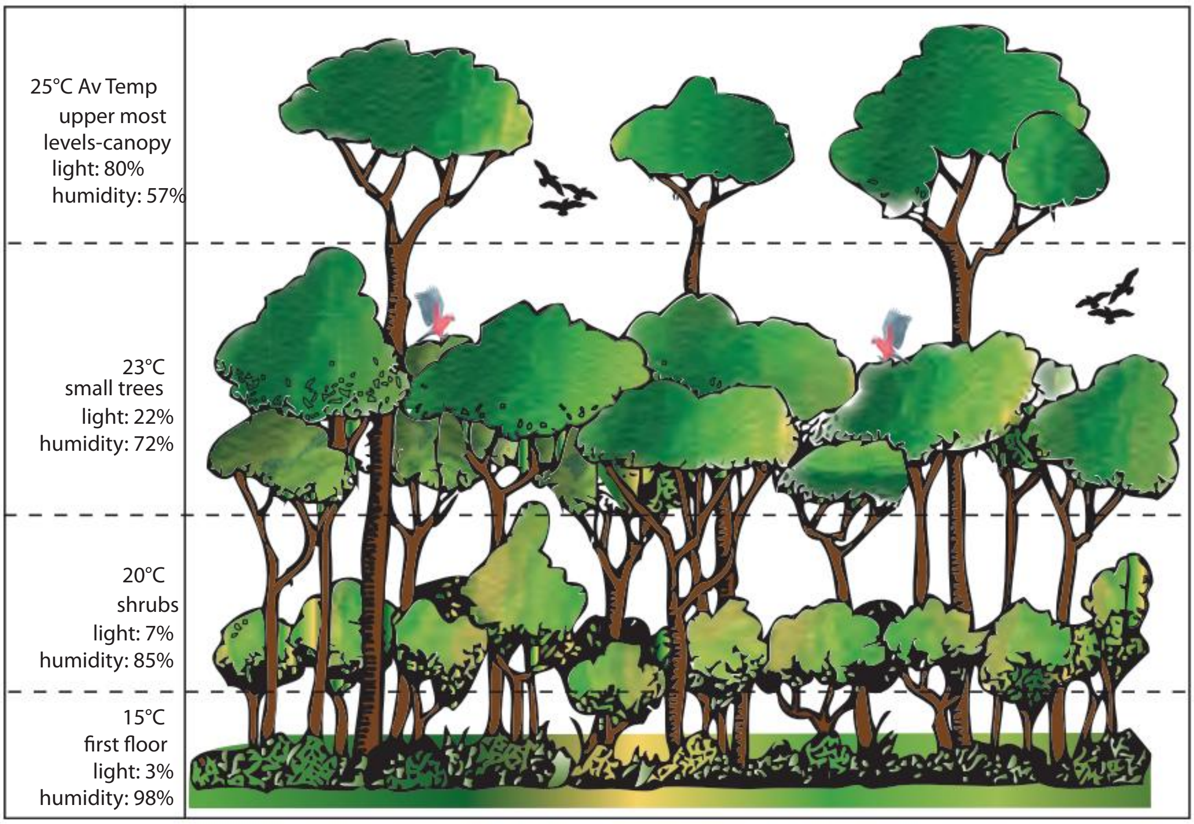


Figure 447 Stratification in a typical rainforest

Key Concepts

1. Environmental factors determine the type of community.
2. Both biotic (living) and abiotic (non-living) components are important in determining the community of organisms in an ecosystem.
3. Some important abiotic components influencing the distribution of organisms include:
   - light intensity
   - water availability
   - temperature
   - nutrient levels
   - wind strength
   - salinity
4. A diverse range of ecosystems exists in Australia, ranging from deserts, woodlands, rainforests and mangroves to aquatic and marine environments.
5. Zonation can be seen along an intertidal rock platform where different zones are clearly evident that come about due to different environmental factors.
6. Three different zones in a rock platform environment are:
   - supra-littoral
   - intertidal
   - sub-littoral
7. Each zone is characterised by specific environmental components and the particular organisms that have adaptations to enable them to survive in this zone.
8. Stratification is a term used to describe the layers that occur vertically in some ecosystems e.g. rainforest, due to different environmental components at different strata.

What have you learned?

Key Terms

cuticle

succulent

lichen

intertidal

mallee

shrubland

grassland

desert

zonation

desiccation

holdfast

nitrogen-fixing

stratification

canopy

Knowledge and Understanding

1. State the differences between the biotic and abiotic components of an ecosystem using examples to illustrate your answer.

2. Select three of the Australian ecosystems from this chapter and for each name:
   a) The main environmental factors influencing the type of community present.

   b) The main producers or plants found in the community.

3. Name three abiotic and three biotic components that would be important in determining the type of biological community found in a habitat.

4. Use *Figure 442* in this Chapter showing the distribution of Australian ecosystems, to assist you in completing the following table.

Ecosystem	Important environmental components determining the community	Examples of typical animals and plants in the community
Desert/Grassland		
Mallee		
Savanna woodland		
Rainforest		
Mangrove		

5. Many Australian plants are found in scleropylll woodlands.

a) Explain what the term 'sclerophyll' means.

b) What evolutionary components would have led to the evolution of these features?

6. Describe the characteristics of the zonation in an intertidal rock platform and select the main components giving rise to the zonation.

Application, Analysis and Evaluation

7. In an ocean, several factors change with the descent from the surface waters to depths greater than 100 metres.

a) Select three of these environmental components and for each illustrate how they would most likely change; justify your reasons.

•

•

•

b) Predict the likely impacts of one of these changes on organisms at the different levels.

4.4

8. This data table refers to rock pools at various points from the sea to the high water mark.

Environmental factor	Pool A (near high water mark)	Pool B (intertidal zone)	Pool C (close to sea)	Sea
Solute concentration (salinity)	46 g/L	39 g/L	37 g/L	34 g/L
Average temperature (9 am-4 pm)	31°C	30°C	27°C	16°C
% O_2 dissolved (compared with sea water)	17%	53%	67%	100%

Refer to the data table above to answer the questions that follow:

a) Describe the gradient that exists in the rock platform, moving from the sea to Pool A for each of the three environmental factors.

b) As has been observed, the solute concentration is an important factor in determining the survival of organisms. Some rock pools in the supra-littoral zone are noted to have varying levels of salinity. Sometimes, the pool may have very saline conditions but at other times the same pool may be mainly freshwater with low solute concentrations.

- Predict possible explanations for this wide fluctuation in salinity.

- Outline some possible problems that this fluctuation poses for the organisms living in these pools and point out some adaptations that the organisms possess to overcome these problems.

c) Relate the average temperatures from the sea to Pool A with the % dissolved oxygen recorded.

d) Briefly outline how you might test the relationship in (c) above.

e) Conclude what you think are the most important abiotic features influencing zonation by ranking them from most important to least important. Justify your rankings.

9. Refer to *Figure 447* in this Chapter to assist in answering this question concerning stratification in a rainforest:

   a) Describe the gradient that exists in the rainforest for the three environmental factors: light intensity, temperature and humidity. For each factor explain the most likely reasons for the fluctuations.

-
-
-

   b) Predict possible advantages and some disadvantages for organisms living at the different levels or strata in the rainforest.

10. Biodiversity is vital in ecosystems.

   a) Distinguish between species diversity and ecosystem diversity, using examples to illustrate your understanding.

   b) Point out the relationship between species diversity and ecosystem diversity.

11. Compare the two different ecosystems to provide evidence about why the communities of organisms differ.

? Science Inquiry Skills 4.4 - Estimating population size

Two techniques for estimating population size

Introduction

People around the world are becoming more and more concerned about environmental changes, often caused by the effects of human activities. Biologists have a vital role to play in observing, recording and attempting to understand these changes, and possibly advising government agencies, and humans in general, on how we can live in harmony with other species, and thus minimise our impact. In this investigation you will need to work at a suitable location to develop some biological sampling techniques and use these to test a hypothesis. You will be required to collect some data from the field.

Technique 1: The capture/re-capture method

Your teacher or laboratory staff will have spread a known number of toothpicks on the ground in a defined area. The toothpicks represent the species of stick insect, *Insectus toothpithecus.*

1. In 30 seconds 'capture' as many of these toothpick creatures as you can.
2. Take your catches back to the laboratory, and record the number in the first catch space in the table. After all class groups have their data, enter this total number also.

	Your data	**Class data**	**Total**
Number caught and labelled in the first catch			
Number in the second catch			
Number labelled in the second catch			

3. Mark each toothpick clearly but try not to change its appearance or colour in any way. A lead pencil dot on the broad end would suffice.
4. Give all of the marked toothpicks to your teacher or laboratory staff who will release them back to the environment.
5. Go back to your original area, whiich will now contain marked and unmarked toothpicks, and again capture as many as you can in 30 seconds.
6. After taking your captures back to the laboratory, count the number of marked and unmarked toothpicks, and using your class totals, fill in the appropriate squares in the table.

Use the following formula to give you an estimate of the total population size.

$$\text{Estimated Population size} = \frac{\text{Number of toothpicks caught in the first capture} \times \text{Number of toothpicks caught in the second capture}}{\text{Number of marked toothpicks caught in the second capture}}$$

Discussion

1. Briefly explain the theory behind the technique.

2. This technique can be used to estimate the population size of some animal populations. Name two populations where it might be appropriate to use this technique, and two populations where the technique might not be appropriate. In each case give a reason (s) for your answer.

Science Inquiry Skills 4.4 - Estimating population size (continued)

3. This technique would only provide an estimation of population size. Suggest factors that might cause the estimation to be inaccurate.

4. Suggest two other techniques that may be useful for estimating animal population sizes.

Technique 2: The quadrat method

A technique that can be used to sample populations that are basically fixed in position uses a quadrat. A quadrat is a frame, made from wood, wire or plastic, which can be used to sample a given area. Its size could vary, depending on the size of the organisms being sampled, but a useful size would be 1m x 1m. As a general guide you should include 10 samples in your given area. After choosing your sample you could either:

- mark a transect line that runs through your area, and sample 10 spots, equidistant from each other along the transect, or
- divide up your sample area into a grid with co-ordinates, and, using some means of generating random numbers, select your 1m x1m area to sample at random.

A brief example is given below to illustrate this technique

The aim is to use a quadrat to estimate the number of broad-leaf weeds in an area of 1,000 square metres.

Method

1. Randomly select 10 sample areas (quadrats).
2. Count the number of weeds in each of the ten areas of 1m x 1m quadrats.
3. Tally the number of weeds, and use this to estimate the population of weeds in the whole area.

The simple formula given below can be used:

$$\text{Population size} = \frac{\text{Total number in quadrat samples}}{\text{Total area of the quadrat samples}} \times \text{Total area}$$

For example, if the number counted in 10m^2 is 65 weeds, then in the 1,000 m^2, it can be estimated that there would be around 6,500 weeds.

To work out a density for the area the formula below can be used:

$$\text{Population density (per square metre)} = \frac{\text{Total number in the sample urea}}{\text{Area of the sample}}$$

4.4

Science Inquiry Skills 4.4 - Estimating population size (continued)

Discussion

1. In what situations might a smaller quadrat be more appropriate?

2. Name two populations that you might sample using this technique. Give reasons why it might be appropriate.

3. This technique would only provide an estimation of the population size. Suggest factors that might cause the estimation to be inaccurate.

Chapter 4.5 Energy and matter in an ecosystem

Science understanding

The biotic and abiotic components of ecosystems interact with each other to capture, transform, and transfer energy.

Nutrients within an ecosystem are involved in biogeochemical cycles.

- Represent the water cycle and biogeochemical cycles, for elements such as nitrogen, phosphorous, and carbon.

Humans can interfere with natural cycles.

The Sun

The Sun is the primary source of energy for most ecosystems. Energy is vital for all organisms; life cannot exist without it. Organisms need energy to move, synthesize important molecules and structures, uptake vital chemicals, maintain a stable internal environment, defend themselves against diseases, reproduce, and to grow and repair tissue.

In Chapter 4.1 it was noted that the Sun provides a source of radiant energy that is the primary source of energy for all life on Earth. Refer to *Figure 451*.

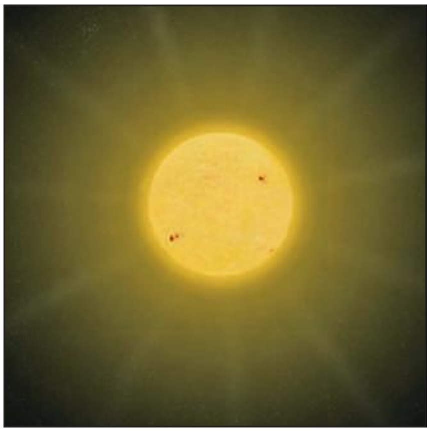


Figure 451 The Sun

Transforming energy

The producers in a community are the basis or starting point for all life on Earth. Through the process of photosynthesis, they trap the Sun's energy and store it as **chemical energy**. This process demonstrates one of the basic fundamentals about energy. Energy is neither created nor destroyed but can be converted from one form to another. In the case of the producers, light energy from the Sun is being transformed into chemical energy and trapped in the bonds of organic molecules, such as glucose. One molecule of glucose can be represented by the following chemical formula: $C_6H_{12}O_6$. Six carbon atoms are bonded with 12 hydrogen atoms and six oxygen atoms to make one molecule of glucose. It takes **radiant energy** from the Sun to enable the plant to make such molecules; the radiant energy is transformed into the chemical energy of the bonds in glucose.

Transferring energy

A community consists of various trophic levels and each level obtains the energy it requires from the level below. First order (or primary) consumers feed on producers, second order (or secondary) consumers feed on first-order consumers and so on. The Earth receives far more energy in the form of sunlight than is ever trapped by the producers. Most of the energy is either absorbed or reflected by the surface of the Earth or the atmosphere. It is estimated that only around 1% of this energy striking the Earth is ever trapped and converted to chemical energy by plants.

The plants themselves use a considerable amount of the energy they trap in maintaining their life processes. They use the glucose produced in photosynthesis for aerobic respiration to provide energy for movement, growth, repair, synthesis reactions and reproduction. As a consequence there is considerably less energy available to the next trophic level.

When energy is converted from one form to another it is never going to be totally efficient. In food webs a great deal of energy is lost along the way as heat energy, as organisms respire carbohydrates for their energy provision and life processes.

In this example of a food chain from a sclerophyll woodland;

eucalypt tree → insect → lizard → eagle

energy flows from the eucalypt tree to the insect then to the lizard and ultimately to the eagle. The flow, or transfer, of energy through a producer is represented in *Figure 452*.

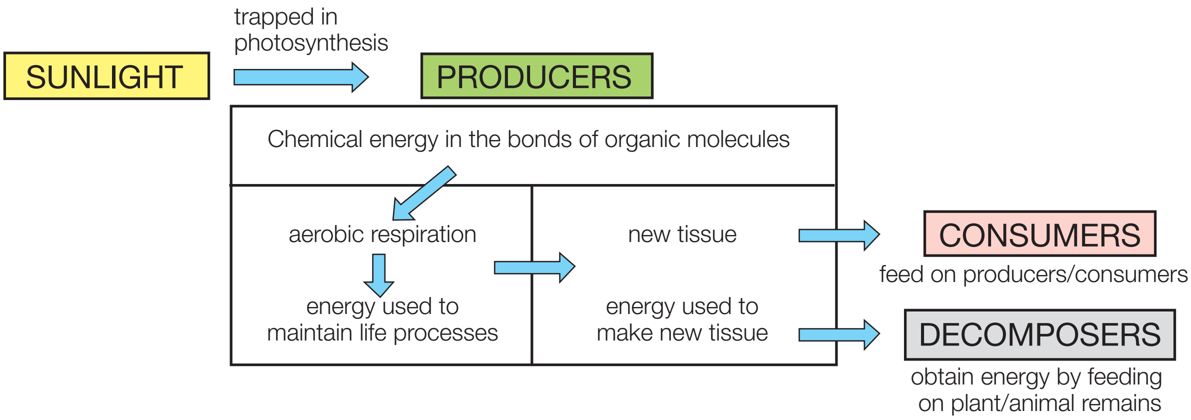


Figure 452 The flow of energy from producers to consumers

As most energy is lost along the way only a small percentage of the energy trapped by the tree is available for the insects. It is estimated that the energy available for the insects is only about 10% of the energy trapped by the tree, likewise, the lizard only gets about 10% of the energy made available to the insects. This represents about a 90% drop in energy at each trophic level. Most of this energy is lost as heat into the atmosphere. Refer to *Figure 453* which shows the loss of energy at each trophic level.

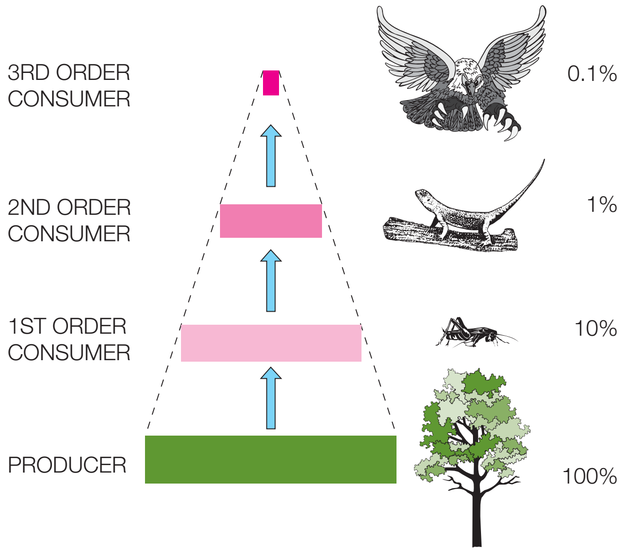


Figure 453 Most of the energy is lost between trophic levels

In summary:

- Energy is transferred through a community of organisms from one trophic level to the next as organisms feed on other organisms.
- As energy flows through the community, some is used by organisms, some is converted into chemical energy in organisms and some is lost as heat.

Biogeochemical cycles

Chemical elements and simple nutrient molecules needed by organisms are cycled within ecosystems. The cycling of elements and inorganic compounds, like water, involves interactions between the biotic and abiotic components of an ecosystem and thus both biological and geochemical processes.

As a result, this type of cycling is called a **biogeochemical cycle**. Refer to *Figure 454*.

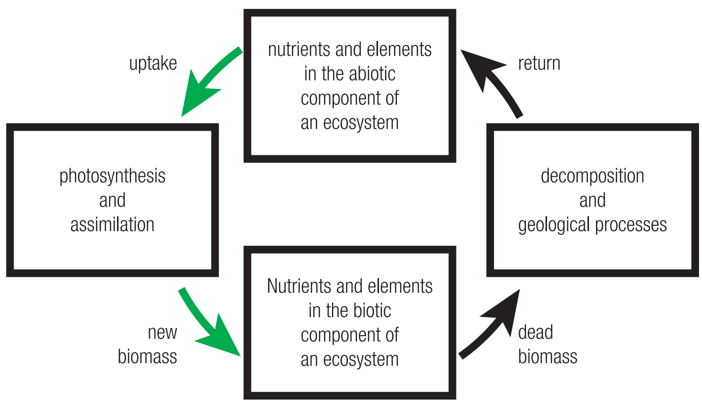


FIgure 454 A biogeochemical cycle

The main elements that make up tissue are carbon, oxygen, nitrogen, sulfur, phosphorus, potassium and calcium. As matter is neither created nor destroyed in the ecosystem, it is important to cycle matter from the abiotic environment through living organisms and then back to the abiotic environment.

The process of cycling involves the action of the **decomposers** including bacteria and fungi. By feeding on dead and decomposing material, the metabolic action of decomposes breaks down the organic material like carbohydrate, protein, nucleic acids and lipids into inorganic substances. These are returned to the environment to be taken up by producers and incorporated back into new plant material and in turn to the bodies of consumers.

The water cycle

The biogeochemical cycling of water within an ecosystem is called the 'Water Cycle' which includes:

- Uptake of water by plants, in which water is obtained from soil by roots and transported to leaves
- Ingestion of water by animals, in which drinking water is obtained from surface sources
- Evaporation, in which water from oceans, rivers, lakes and animals forms into water vapour
- **Transpiration**, in which water evaporates from the leaves of terrestrial plants
- **Condensation**, in which water vapour cools and forms liquid water
- Precipitation, in which water falls from clouds to the ground as rain, hail, or snow
- Melting, in which snow and ice forms into liquid water
- Run-off, in which water flows to oceans as rivers, streams or creeks
- Leaching, in which water that has entered soil returns to oceans underground.

Refer to *Figure 455* which illustrates some of the processes in the water cycle.

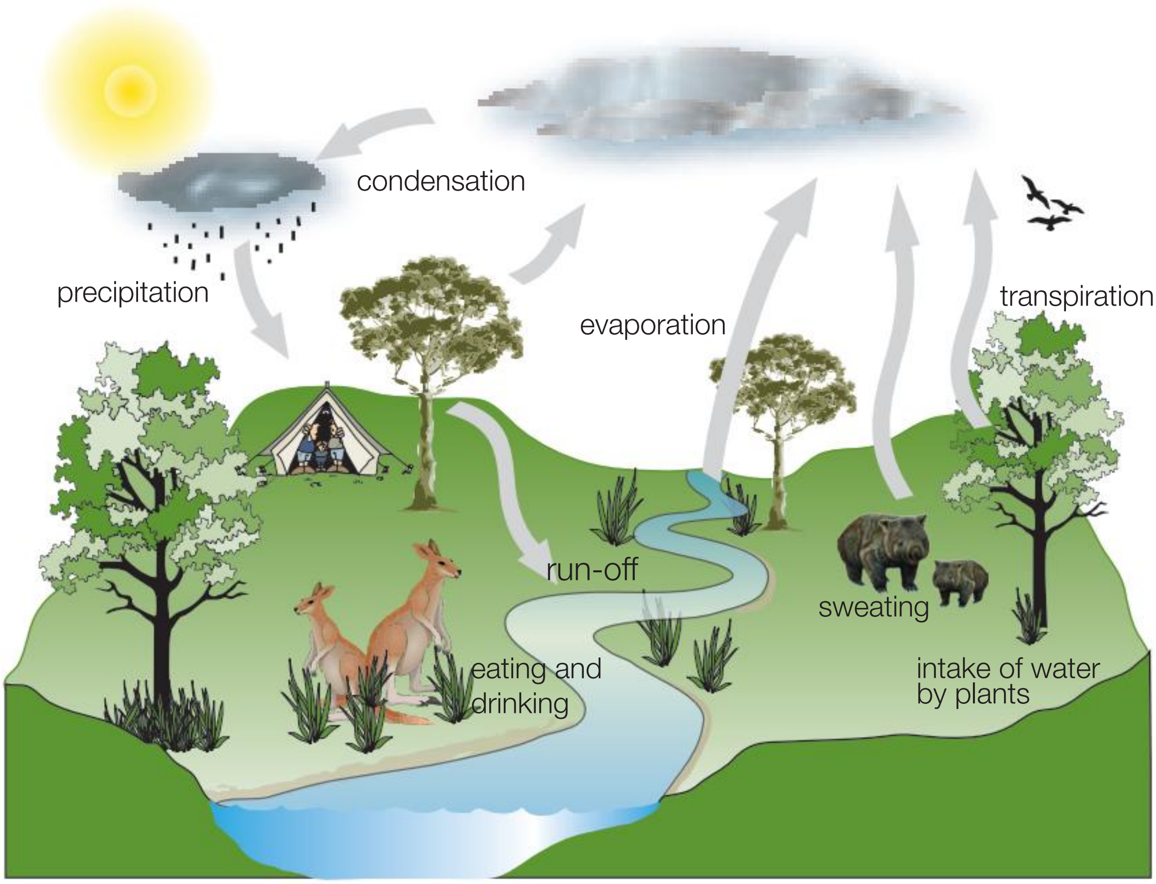


Figure 455 A simplified water cycle

4.5

The carbon cycle

Carbon is an element that is a very important component of the organic molecules as previously mentioned. Carbon dioxide (CO_2) in the atmosphere is incorporated into the tissues of plants as they use the process of photosynthesis to build up carbohydrate. This carbohydrate may be incorporated into the other organic molecules, or respired by the plant to release energy that is used for life processes, and carbon dioxide, which is released back to the atmosphere, mainly at night.

When consumers feed on plants, they are consuming the plant organic material and incorporating this as their tissue. As this process continues at the different trophic levels, the element carbon is either transferred on or released as carbon dioxide. When organisms die, their tissues are broken down by the action of decomposers, which further release carbon dioxide to the atmosphere. The carbon cycle does depend on both photosynthesis and respiration, and these processes generally balance each other.

There are large stores of carbon in fossil fuels like coal and oil that are the remains of organisms that lived many millions of years ago. As humans have used large amounts of fossil fuels since the middle of the 20th century, there has been a steady increase in the level of atmospheric carbon dioxide. The overwhelming majority of scientists today are concerned about this increase and the effects it is having in causing an increase in **global warming**. Refer to *Figure 456* illustrating a simplified carbon cycle.

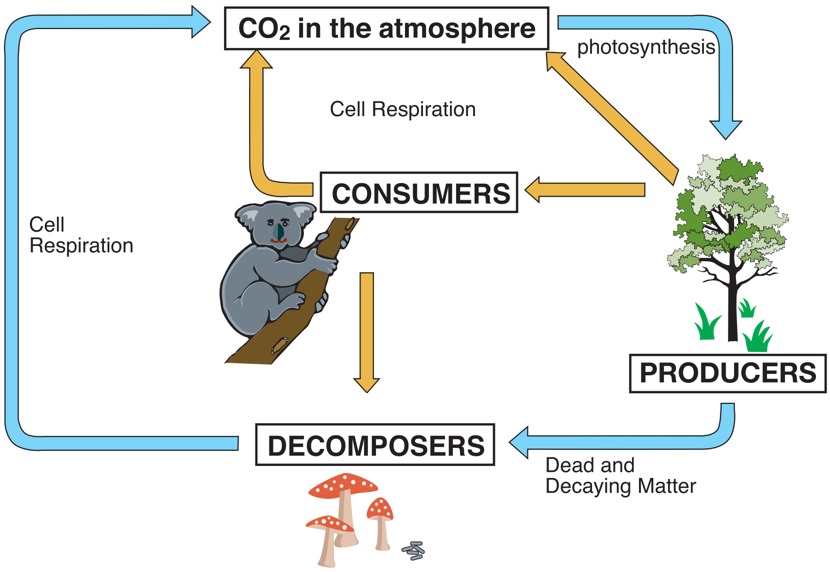


Figure 456 A simplified carbon cycle

The nitrogen cycle

Nitrogen is an important element found in the proteins and nucleic acids of organisms. There is an abundance of nitrogen in the atmosphere, present as a gas, N_2, which is not in a form that can be used by many organisms. Some bacteria can convert nitrogen gas into other nitrogen compounds, especially nitrates. Nitrates can be used by plants to incorporate the element nitrogen (N) into protein and nucleic acids.

Some plants, known as legumes, like peas, beans and clover, possess **nitrogen-fixing** bacteria inside nodules on their roots. Crops like these are used to increase the nitrogen content of soils in agriculture and are often in rotation with other crops like cereals. Bacteria and fungi can decompose dead and decaying material back into ammonium compounds, which are also available to plants. Other bacteria can convert soil nitrates to nitrogen gas, and complete the cycle. Refer to *Figure 457*.

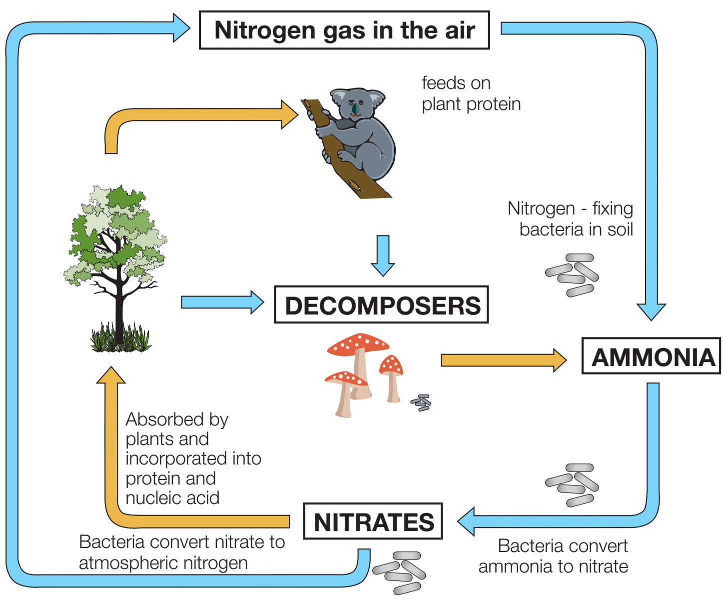


Figure 457 A simplified nitrogen cycle

The phosphorus cycle

Even though organisms require much less phosphorus when compared to elements like carbon and nitrogen, it is nonetheless essential for existence. Phosphorus is a critical component of nucleic acids, RNA and DNA. It is also needed to make a cell energy-carrying molecule called ATP and is an essential component of cell membranes. It is a rare element, the principal store on Earth is phosphate rock formed in past geological time. Erosion of rocks, particularly by rainfall, dissolves phosphate out of rocks and into the soil. The plants can absorb the phosphorous as soluble phosphate ions from either soil water or dissolved in aquatic ecosystems. Crop growth is supported by the addition of phosphorus to soil through use of fertilisers.

Some plants have evolved **mycorrhiza** that enable them to grow in phosphate poor soils. Animals obtain most of their phosphate by eating other organisms. When plants and animals die, decomposers return phosphate back to the ecosystem. As phosphate is often scarce, organisms are particularly well adapted at extracting it from solution. Refer to *Figure 458*.

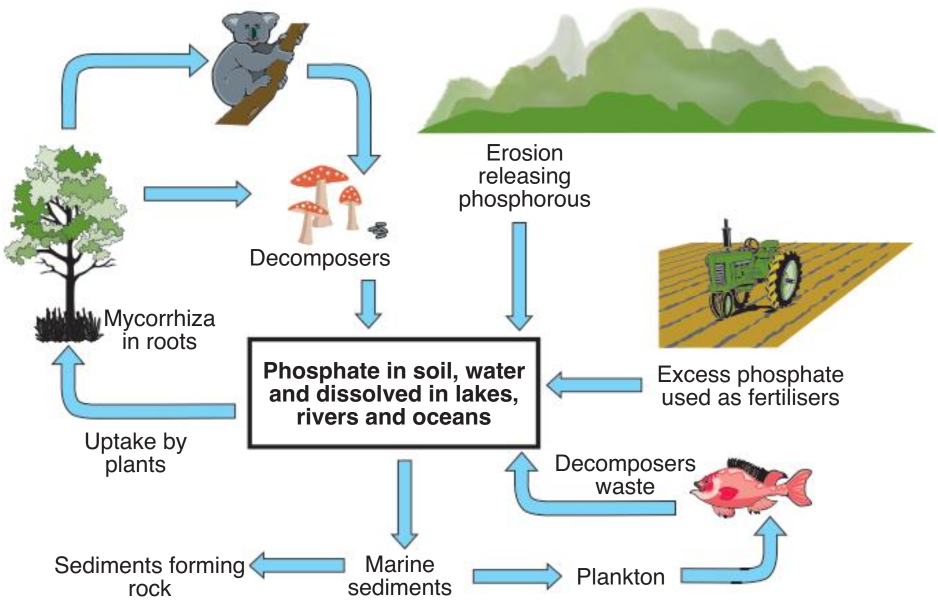


Figure 458 A simplified phosphorous cycle

Humans can interfere with natural cycles

Chapter 4.8 examines in some detail the impacts of human activities on ecosystems. As such, this section will briefly look at just a few of the ways that humans interfere with some of the biogeochemical cycles.

Water cycle

Impacts include:

- removing large quantities of fresh water from rivers for irrigation e.g. River Murray
- releasing pollutants which enter waterways, either directly or indirectly
- **deforestation** where trees that normally release water vapour into the atmosphere are cut down. With less water vapour, less water is available for precipitation.
- global warming that is increasing evaporation, hence changing rainfall patterns.

4.5

Carbon cycle

Humans have had major impacts on the carbon cycle through such activities as:

- the burning of fossil fuels
- deforestation

Both of these activities give rise to an increase in atmospheric carbon dioxide; burning fuels releases carbon trapped in the fossil fuels and by cutting down trees there is less photosynthesis occurring which normally removes carbon dioxide from the air. Most scientists are convinced that the increase in carbon dioxide is one of the major factors leading to global warming, which is causing many severe impacts on Earth's climate and ecosystems.

Nitrogen cycle

Nitrogen is a critical element for life and many human activities are interfering with the natural cycle. Refer back to *Figure 457*.

Examples include:

- the use of nitrogen-based fertilisers where excess run-off enters streams and waterways
- the burning of fossil fuels and the use of fuel in combustion engines releasing huge quantities of nitrogen based gases
- agricultural practices, including the use of **monocultures,** involving nitrogen-fixing crops such as legumes.

The use of fertilisers has been associated with **algal blooms**, upsetting the natural balance of populations leading to a reduction in biodiversity. The increase in nitrogen based gases and depletion of oxygen causes **acidification** of soils and aquatic environments and contributes to the greenhouse issue.

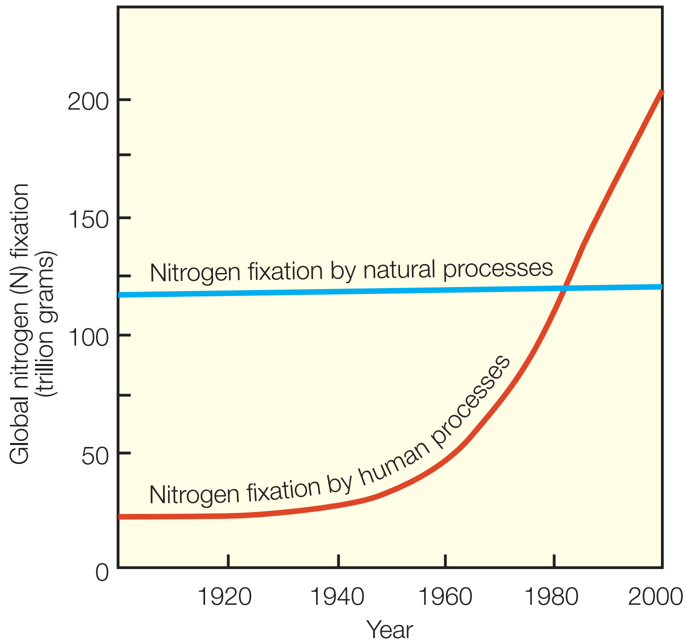


Figure 459 Nitrogen fixation

Nitrogen fixation is the process in which atmospheric nitrogen is assimilated or converted to nitrogen containing organic compounds. Nitrogen is probably the most important nutrient in determining the productivity and species diversity in ecosystems. Refer to *Figure 459* illustrating the exponential increase in nitrogen fixation caused by human activities.

Phosphorus cycle

Human activities that disrupt the phosphorus cycle include:

- Run-off in fertilisers, similar to nitrogen, can cause similar issues and loss of biodiversity.
- Sewage, including household waste water introduces vast quantities of phosphorus to aquatic environments.
- Use of fertilisers depletes stores of phosphate, releasing it to the environment, often with detrimental effects.

Key Concepts

1. Biotic and abiotic components of ecosystems interact to capture, transform and transfer energy.
2. The Sun is the primary source of energy for all life and energy enters ecosystems through producers and photosynthesis.
3. Energy is neither created nor destroyed but can be transformed from one form to another.
4. Radiant energy from the Sun is transformed into chemical energy by the process of photosynthesis.
5. Energy is transferred through ecosystems from one trophic level to the next.
6. Only about 10% of the energy trapped by one trophic level is transferred to the next trophic level.
7. Matter is cycled through biotic and abiotic components of ecosystems through biogeochemical cycles.
8. Important cycles in nature include water, carbon, nitrogen and phosphorus.
9. Human activities negatively impact on the natural cycling of water and elements.
10. Some environmental problems that arise as a result of such impacts include:
    - global warming
    - algal blooms
    - loss of biodiversity
    - acidification of soils
    - disruption to rainfall patterns.

What have you learned?

Key Terms

radiant energy

chemical energy

biogeochemical cycle

transpiration

condensation

decomposers

global warming

nitrogen-fixing

mycorrhiza

deforestation

monoculture

algal bloom

acidification

Knowledge and Understanding

1. State the role of producers in capturing energy from the Sun to make energy available to consumers.

2. Describe the energy transformation that occurs to convert radiant energy from the Sun into a form that can be used by organisms in a community.

3. Explain how energy is transferred from one trophic level to the next throughout a community.

4. State reasons why only about 10% of the energy trapped by a trophic level is transferred to the next trophic level.

5. Name the most important chemical elements that need to be cycled in nature.

6. Explain the meaning of the statement ‘the decomposers are the recyclers of the community’.

4.5

7. Name of the processes in the carbon cycle that:
   a) Release carbon dioxide into the atmosphere ....
   b) Remove carbon dioxide from the atmosphere. ....
8. Name the form in which the element nitrogen is taken into producers. ....
9. Describe some ways in which excess phosphate from wastewater entering waterways can impact on the phosphate cycle.

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Application, Analysis and Evaluation

10. Explain how decomposers convert organic molecules into inorganic ones and thus provide the link in cycling elements back to producers.

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11. Explain why most food chains are limited to around 3-4 trophic levels.

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12. Explain the meaning of the term 'biogeochemical cycle' and relate this name to the interaction occurring between abiotic and biotic components in an ecosystem.

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13. Predict the likely consequences to an ecosystem if the decomposes are destroyed.

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14. Compare and contrast the movement of energy through an ecosystem with the cycling of matter.

15. Outline the most likely impact on the carbon cycle of the following activities:
    a) Deforestation

    b) Burning of fossil fuels.

16. Suggest the most likely reasons why there are so few wedge-tailed eagles in Australian ecosystems.

Science as a Human Endeavour 4.5 - Polychlorinated biphenyls (PCBs)

Application and limitation

The use of science may have beneficial or unexpected consequences

One development of early 20th century industrial chemistry was the invention of plastic, in particularly polyvinylchloride (PVC). This was used to make electrical components for the emerging electronics industry, to make pipes and to insulate electrical cables.

The first forms of PVC, however, were not particularly resilient and so were vulnerable to the effects of weathering, especially by heat (and light). This was improved by the addition of very slow to degrade compounds called polychlorinated biphenyls (PCBs). These increased the usable life of PVC products. The heat-resistant properties of PCBs made electrical components more fire-resistant and the addition of them to coloured oils led to the emergence of brighter and longer-lasting paints.

Initially, however, it was not understood that the very properties that made PCBs so useful (slow to degrade, heat-resistant) also made them harmful to wildlife. Eventually, it became clear that PCBs stay in the environment for decades, increasing the likelihood of them ending up in the ocean. It was then discovered that once there, PCBs bind to sediments and end up stored in body fat of small fish (that eat sediment). Even worse, because PCBs cannot be broken down by vertebrates, they 'bio-accumulate' up food chains and thus can reach very high concentrations in body fat of large, 3rd order consumers, such as sea eagles and killer whales (*refer to photo*). For these reasons, a global 'phasing-out' process was initiated in 1993.

Unfortunately, the consequences of wide spread PCB use last century have not diminished. High PCB levels in killer whales in particular reduce the fertility of females and the sizes of killer whale populations are decreasing as a result. PCBs weaken the killer whale immune system causing more to die young from bacterial or viral infections. The threat to killer whales was captured in work published in New Scientist in October 2018 and concluded that PCB pollution might wipe out half the world's killer whales within a century.

You may need to refer to the online resources below to answer the questions that follow:

1. Explain why, despite being used to the great benefit of many, the development of PVC has led to unexpected and devastating environmental consequences, especially for killer whales.

2. Some researchers fly drones over killer whales when they surface to exhale, to find out if they have PCBs in their body. What evidence could these 'snot-bots' collect that would be consistent with PCB contamination?

Helpful Online RESOURCE about the use of PCBs

To learn about why PCBs were used and the consequences of their use view this clip:

<https://www.youtube.com/watch?v=wJjVUZV2aDk>

Helpful Online RESOURCE about the impact of PCBs use on killer whales

To learn about how the use of PCBs continues to affect killer whales view the clip below:

<https://www.youtube.com/watch?v=gUmvXE57azE>

Chapter 4.6 Niche and keystone species

Science Understanding

Ecosystems include populations of organisms that each fills a specific ecological niche.

Describe a niche in terms of key indicators within the ecosystem, including habitat, feeding relationships, and interactions with other species.

Keystone species play a critical role in the maintenance of their ecosystem.

- Explain the significance of keystone species in their ecosystem.

Populations

Ecosystems typically consist of a very large number of different species. It is important to realise that the members of most species in an ecosystem do not live in isolation; they are found in **populations**. A population is a group of living organisms of the same species which live in the same ecosystem at the same time. One population of Australian fur seals that form part of the ecosystem on Friar Island near Tasmania is shown in *Figure 461*.

Figure 461 A population of Australian fur seals

Populations of different species in an ecosystem interact with one another; for example, to obtain food. All the populations of different species that interact with one another make up the **community** of the ecosystem. A small part of a community, consisting of populations of sharks, many species of fish and coral in a coral reef ecosystem is shown in *Figure 462.*

Figure 462 An example of a coral reef community

4.6

Ecological niches

As was discussed in Chapter 4.4 different ecosystems are defined by many and various biotic and abiotic environmental components. The populations of organisms that make up an ecosystem are the ones that, for one reason or another, can tolerate the influence these environmental components exert on the community.

The way a population of organisms functions in an ecosystem is called its **ecological niche**. A **niche** may be described in terms of the population's habitat and the roles the organisms in the population play in the habitat; for example, photosynthetic activity, feeding relationships and interactions with other species. Some information about the niche of a River Red gum tree is shown in *Figure 463*. The habitat of this species is throughout coastal and central Australia where there is water near the soil surface or below the ground.

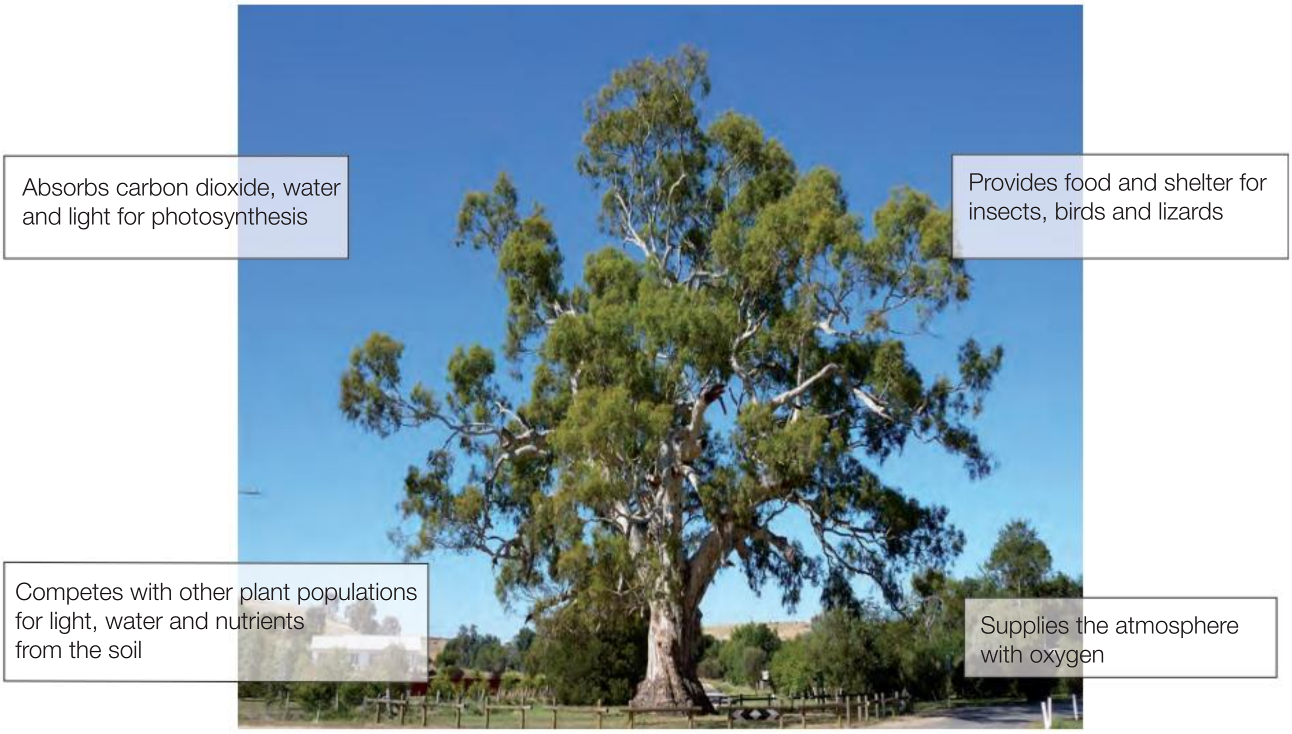


Figure 463 The niche of a River Red gum in a farmland ecosystem

The populations of organisms in an ecosystem each fill a specific ecological niche. *Figure 464* shows the niches of different populations of bird species that form part of a mudflat ecosystem.

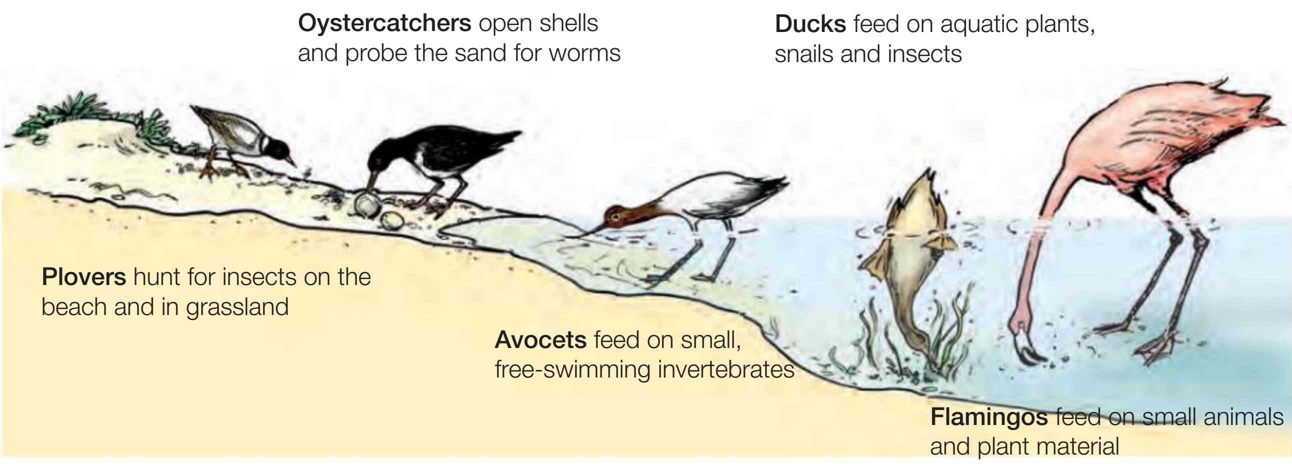


Figure 464 Populations of different bird species occupy specific niches in a coastal ecosystem

Representing the niche of different species

If the populations of two species have a similar niche they will compete where parts of the niche overlap; for example, for the type of food eaten. One way to represent how much niche overlap exists is to draw a **niche overlap graph.** If the zone of overlap is small there is relatively little competition between the species. This means the species will probably co-exist in the ecosystem. The extent of niche overlap between populations of two species with identical niches, however, will be very high. As a result, the competition between the species will be intense throughout the ecosystem. The end result is usually the disappearance of populations of one of the species from the ecosystem. An example of a niche overlap graph of different species co-existing in an ecosystem is shown in *Figure 465*.

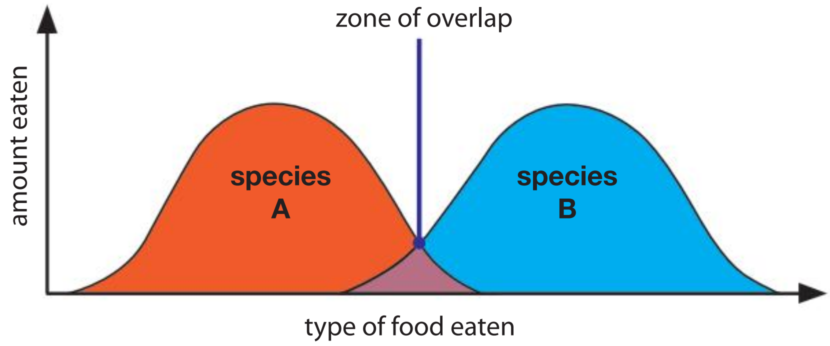


Figure 465 The niche of two species, showing the extent of overlap

The fundamental versus the realised niche

In the absence of significant interactions with other species, populations of a species range widely across an ecosystem. This is called a species' **fundamental niche**. The actual niche occupied by a species, however, is much narrower because of interactions with other species, such as competition. This is called the **realised niche.** The establishment of realised niches in ecosystems reduces niche overlap that, in turn, facilitates co-existence and, over time, the diversity of species. *Figure 466* illustrates the concept of realised niche by referring to populations of different species of warblers. Although they can inhabit the whole tree each species of bird has a different realised niche.

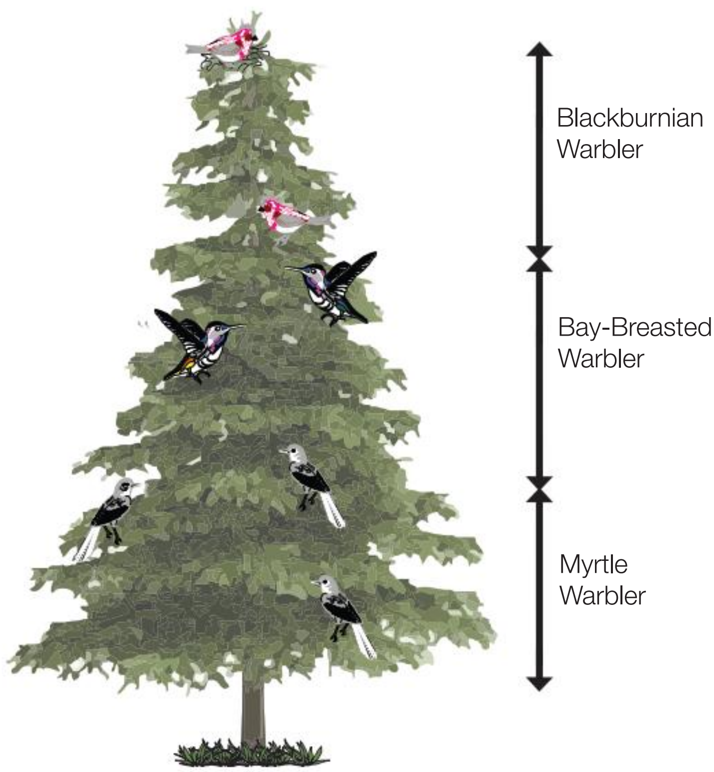


Figure 466 An example of realised niches

Ecosystem stability

Ecosystems persist if they can capture, transform, and transfer energy, and cycle essential nutrients and chemical elements. All the species in an ecosystem play a role in helping ecosystems to complete these functions. As a rule, ecosystems with a rich diversity of species are most likely to resist change and remain intact. Ecosystems that are maintained over long periods of time are called **stable ecosystems.** Low species diversity ecosystems are not as resilient: these ecosystems that are more vulnerable to change are called **unstable ecosystems.**

4.6

Keystone species

The arches of stone buildings used to have a special stone at the top of the arch called a keystone. Although all the stones were needed, the keystone was the most important – its' presence ensured the arch's stability would be maintained. Like the stones in an arch, all of the species of an ecosystem contribute to its stability. The ecological niche of a few of them, however, affects the stability of the ecosystem much more greatly than the numbers or size of them would suggest. These organisms are called **keystone species.**

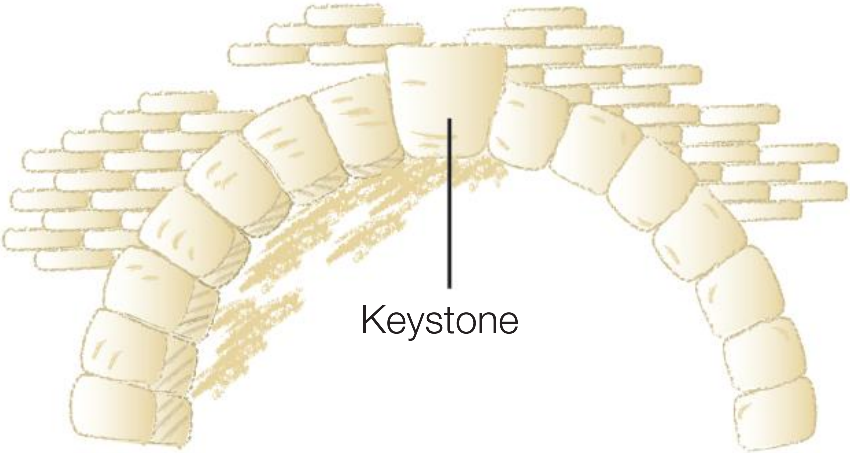


Figure 467 The use of a keystone

Figure 468 Kelp is a keystone species

A diagram showing a keystone is shown in *Figure 467.* Refer to *Figure 468* showing kelp, a type of algae. This enables the formation of kelp forests in the ocean which form a unique base for the development of an ecosystem providing food and shelter for a vast range of species.

Keystone species exist in ecosystems all over the world. Two Australian keystone species and the role they play in the maintaining the stability of their ecosystem, are shown in the following table:

Keystone species	Ecological niche and role in ecosystem maintenance
Grey-headed flying fox	East Coast rainforests; ranging from southern Queensland to Victoria. Pollination and seed dispersal. Facilitates the reproduction and thus survival of dozens of species of palms and other rainforest plants.
Grey nurse shark (Eastern states population)	Coastal waters; ranging from southern Queensland to Victoria. Consumer of fish, crustaceans, sharks, rays and squid. Keeps the population size of many species of these organisms in balance.

No keystone species usually means no future for the ecosystem

The extinction or loss of any species in the wild is regrettable and to some extent weakens the stability of its ecosystem. The prospect of keystone species going extinct is particularly serious. The existence of the East Coast rainforests 'hangs in the balance' in part because Grey-headed flying foxes are a **vulnerable species** and face a high risk of going extinct in the wild.

Maintenance of marine ecosystems along coastal eastern Australia is unlikely because Grey nurse sharks are now a **critically endangered species** – the risk of them going extinct in the wild is extremely high.

Another case study of a keystone species is given on the following page.

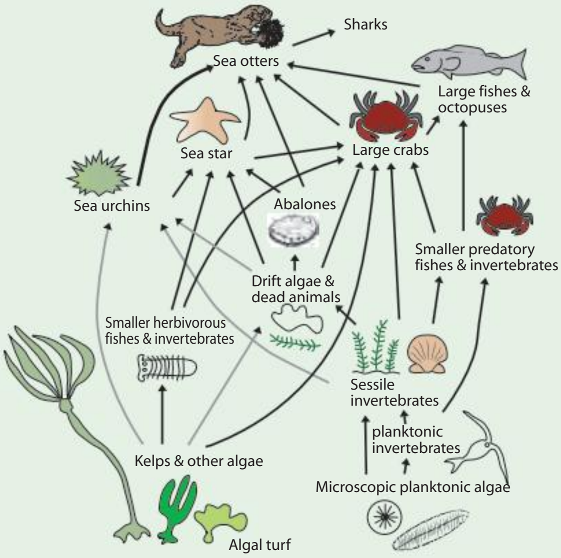
Key Concepts

1. Ecosystems include a wide diversity of organisms that tend to be found in populations.
2. Interactions between populations of different species form the community of an ecosystem.
3. Populations in an ecosystem each have a specific ecological niche that is shaped by competition.
4. The niche of an organism is the inter-relationship of its biotic and abiotic environment.
5. Keystone species are essential for an ecosystem's stability and thus its long-term maintenance.

Case Study - The sea otter is/was a keystone species

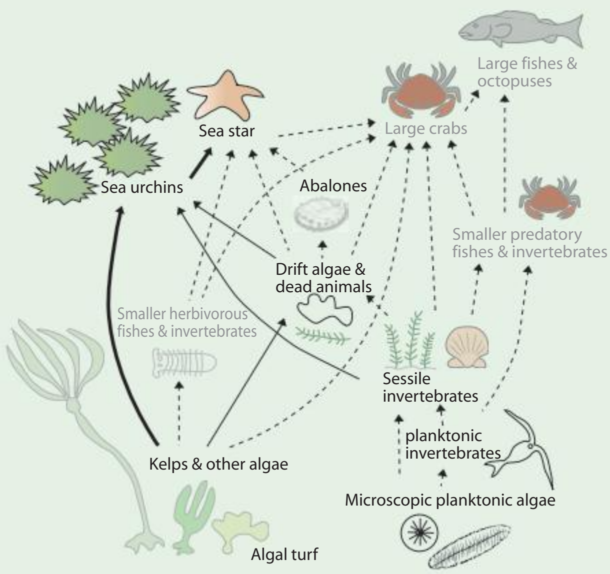
What can happen if populations of keystone species decline significantly?

One of the best known studies about keystone species and the critical role they play in their ecosystem took place in California in the 1970s and concerned sea otters. Sea otters are a coastal marine species of mammal that consume invertebrates called sea urchins. Populations of sea urchins consume a type of seaweed called kelp. The kelp's niche includes providing marine organisms with a source of food and shelter and, via photosynthesis, oxygen for aerobic respiration. The study showed that large populations of sea otters kept the size of sea urchin populations relatively low. This allowed the kelp populations to be maintained as large, well-developed underwater forests. The species diversity of the kelp forest ecosystem was high as there was ample oxygen, food and shelter. *See Figure (a)*.



(a) The kelp forest ecosystem with sea otters

A subsequent study showed that the decrease in the population size of sea otters along the Pacific North West coast in the 1990s – apparently mostly due to an increase in predation by killer whales – caused sea otter populations to sharply decline. This caused the size of sea urchin populations to radically increase which in turn led to much less kelp forest, and, very quickly, a catastrophic decrease in species diversity of the ecosystem. *These changed relationships are shown with dotted lines and the affected species are shown greyed-out in Figure (b) below*.



(b) The kelp forest ecosystem without sea otters

4.6

What have you learned?

Key Terms

population

community

ecological niche

niche

niche overlap graph

fundamental niche

realised niche

stable ecosystem

unstable ecosystem

keystone species

vulnerable species

critically endangered species

Knowledge and Understanding

1. Describe the ecological niche of an Australian River Red gum by referring to both abiotic and biotic components of the ecosystem.

   a) Abiotic components

   b) Biotic components

2. List three of the most important factors that organisms generally need to fulfill their ecological niche in order to survive.

3. Explain why competition for resources is usually greater between members of the same species, compared to competition with different species.

4. 'The presence of a keystone species is vital to the organisation and diversity of the community'. Using your knowledge of keystone species explain the above statement.

Application, Analysis and Evaluation

5. Refer to the case study of the sea otter in this chapter, to help answer the questions that follow:
   a) Outline the niche of the kelp.
   b) Compare the food web with and without the sea otter. Describe at least two major losses of biodiversity that have occurred, outlining the reasons for these changes.
6. Refer to *Figure 465* in this Chapter of the niche overlap graph.
   a) Briefly explain what is meant by the 'zone of overlap' and what it represents.
   b) State the relationship between the size of the overlap and the ability of two species to survive in the same environment.
7. Consider the statement below:

   Sheep and kangaroos are found living together throughout southern Australia. The presence of sheep alters the fundamental niche of kangaroos, causing them to have a very different niche.

   a) Use this statement to illustrate the difference between a 'fundamental niche' and a 'realised niche'.
   b) Describe two other biotic factors that influence the realised niche of kangaroos.
8. It has been observed over many years that two different species rarely occupy the same habitat unless their niches are sufficiently different. Outline likely reasons for this observation.
9. In Chapter 4.4 the biological concept of stratification was discussed. Use an understanding of niche overlap to explain the stratification of similar species of birds that inhabit the same tree.

4.6

Science Inquiry Skills Investigation 4.6 - Niche and ecosystem stability

Oral communication

This activity is an opportunity to practice the skills of scientific communication in an oral format that must not exceed 5 minutes.

Introduction

Planet Earth is characterised by supporting a huge diversity of ecosystems. Although many ecosystems are land-based, even more are to be found in marine, freshwater and subterranean environments. Regardless of where they are located, all ecosystems consist of a very large number of interacting populations of different species. All of the species in an ecosystem have defined roles or niches that collectively contribute to maintaining the stability of the ecosystem, and thus its long-term survival.

Part A: Selecting an ecosystem and collecting information.

1. Choose an ecosystem to investigate.
2. List the main abiotic components of the ecosystem.
3. Identify some of the main species of plants and animals that exist in the ecosystem.
4. Obtain images of the ecosystem and of some of its plant and animal species.
5. Describe the ecological niche of plants in the ecosystem.
6. Select three animal species in the ecosystem and discuss the ecological niche of each of them.
7. Decide whether or not the ecosystem is likely to be maintained. Justify your decision using knowledge and understanding of ecosystem stability.

Part B: Preparing for and giving the oral communication

1. Finalise the content for the oral communication – see ‘Things to consider’ below.
2. Prepare the oral communication.
3. Trial the oral communication to ensure that it will not exceed 5 minutes.
4. Give the oral communication.
5. Submit a list of sources of information, and any notes used, for assessment.

Things to consider

1. Be as concise as possible when listing the main abiotic components of the ecosystem. Decide on the most important 5 or 6 components to refer to.
2. A huge list of plants and animals is not required. Select species that are easy to describe using an image and that have a clearly defined ecological niche.
3. Approach the decision about the maintenance of the ecosystem by finding out about its diversity of species. The greater the species diversity the more likely it is the ecosystem will persist.
4. Construct a *Powerpoint* to use while giving the oral communication.
5. Resist the temptation to bombard the audience with images and detailed text - careful use of a small number of images well-supported by some concise text is much more effective.
6. Try not to talk too fast - use ‘cue-cards’ to assist with the presentation. Also, try not to give a ‘reading-only’ presentation. Look up from time to time and make eye-contact with the audience.
7. Your teacher may allow you to prepare a poster or a *Powerpoint* slide show (i.e. no text) to illustrate your oral presentation.

Science as a Human Endeavour 4.6 - Managing tropical rainforests

Application and Limitation

Scientific knowledge, understanding and inquiry can enable scientists...

Australia's Wet Tropical Rainforest ecosystems range between Townsville and Cooktown on the far north-east coast of Queensland. They consist of a huge diversity of plant and animal species, many of which are not only ancient in origin but are found nowhere else on the planet.

Over the last few decades, the size of human communities in far north Queensland has steadily increased and with it clearing of rainforest to make way for urban developments. One place where this has occurred is Mission Beach, a medium-sized town half-way between Townsville and Cairns.

In addition to being a major tourist destination, Mission Beach is noteworthy as home to Australia's largest population of the Southern Cassowary, a large flightless bird distantly related to the emu (*refer to photo above*).

Cassowaries consume the fruit of rainforest plants whose seeds pass unharmed through its digestive system to the ground, a distance away from the parent plant. Seeds of about 150 species of plants are dispersed this way, of which more than 70 are entirely dependent on cassowaries for seed dispersal. This means that populations of the cassowary are critical to maintaining the diversity of rainforest plants and therefore the long-term sustainability of the Wet Tropical Rainforest ecosystems.

You may need to refer to the online resources below to answer the questions that follow.

1. The Southern Cassowary is a keystone species. Describe how human activities in the past and other factors have jeopardised the sustainability of the cassowary populations at Mission Beach.

2. Scientists who study Wet Tropical Rainforests have designed action to implement and help sustain populations of cassowaries. List some examples taken up by the Mission Beach town.

Helpful Online RESOURCE about the Cassowary

General information about the Southern Cassowary, including threats to its existence:

<https://www.environment.gov.au/biodiversity/threatened/publications/factsheet-southern-cassowary>

Helpful Online RESOURCE about local action

How Mission Beach residents and the government are supporting cassowary populations:

<https://www.ehp.qld.gov.au/wildlife/threatened-species/endangered/endangered-animals/cassowary.html#recovery_actions>

4.6

Chapter 4.7 Ecosystems change over time

Science Understanding

Ecosystems can change over time.

Ecological succession involves changes in biotic and abiotic components and their dynamic influence on each other.

- Describe examples of succession.

Evidence for longer term changes can be found in geological deposits including the fossil record.

Change to ecosystems

The location and composition of an ecosystem is influenced by its abiotic and biotic components and how these influence each other; for example, the air temperature and the water and mineral nutrient content of the soil solution, influences the number and size of plant populations, that affects, and is affected by, animal populations in the ecosystem. Unsurprisingly, change to the abiotic and/or biotic components of an ecosystem can change the make-up of its community and may alter the range (or distribution) over which it is found.

Daily change

The abiotic components of an ecosystem change during the day and as day passes into night; for example, changes include light intensity, and the temperature and humidity of the air. These, and other short-term abiotic changes, nonetheless exert a powerful influence on the presence and numbers of populations of animals; for example, populations of herbivores and thus predators may be present and quite active in a grassland ecosystem during the early and later part of the day, but less so at night.

Seasonal change

Another short-term ecosystem change, that is also **cyclic,** is driven by the changing of seasons. The abiotic components of many terrestrial ecosystems in spring support the reproduction of most plant and animal species and the growth and development of offspring they produce. The size of populations of many species may change so much that the community begins to visibly change. *Figure 471* illustrates an example of seasonal change in a woodland ecosystem.

Figure 471 A woodland ecosystem in mid-winter (left) and early summer (right)

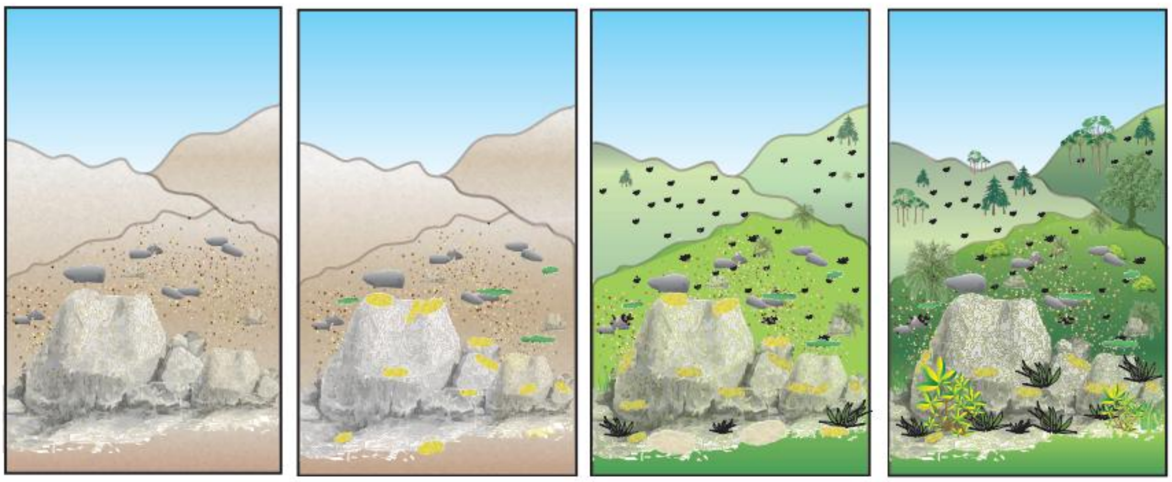
Long-term change

Not all ecosystem change is short-term and cyclic. Long-term change to ecosystems occurs if the abiotic and biotic components of the ecosystem are significantly altered; for example, by the colonisation of new species to the area, a natural disaster or some kind of human activity. Events like this may change the abiotic and biotic components so much that instead of supporting earlier collections of species in the ecosystem, they favour different living things. Over time, this slowly and permanently changes the mix of species in the ecosystem. This more **unidirectional** type of ecosystem change is called **ecological succession.**

Primary succession

Ecological succession may start in a virtually lifeless area that lacks soil; for example, beginning on bare rock uncovered by a gradual decrease in sea level, lake level or the retreat of a glacier. It also occurs after the formation of volcanic islands, e.g. the Galapagos Islands. This type of succession is called **primary succession.**

Primary succession on bare rock begins when spores of autotrophic organisms blown by the wind settle in crevices in the rock produced by erosion; this includes the spores of lichens (yellow) and later, mosses (green). Populations of these colonising species grow and die and their remains, together with tiny pieces of eroded rock, form a **simple soi**l. Over time, this becomes more stable and nutrient-rich and thus more suited to supporting the germination of seeds of wind dispersed plants; for example, grasses and small, non-woody or **herbaceous plants**. The growth of the root systems of these plants in the rock crevices widens the crevices, and the eventual death of the plants leads to very nutrient-rich, deeper soil that is suitable for small woody shrubs. Over time, populations of these shrubs and animals that colonise the developing ecosystem, seeking food and shelter, live and die and the rock continues to erode and break up due to weathering and the action of plant root systems. Eventually, this leads to the formation of a **mature soil** that permits seeds of trees, dispersed by animals travelling to the ecosystem, to become established. After several hundred years the once almost lifeless and bare rock has been transformed into a living species-rich ecosystem. *Figure 472* illustrates this example of primary succession: *Figure 472 (a)* is the first stage and *(d)* is the last stage.



(a) Bare sand, gravel and rocks left after the retreat of a glacier

(b) Lichen and mosses colonise the rocks and help to form simple soils

(c) Grasses and small plants form nutrient rich and deeper soils

(d) Shrubs and trees form mature soils and a new ecosystem

Figure 472 (a) → (d) Primary succession following the retreat of a glacier

Secondary succession

Ecological succession may also occur in an already mature ecosystem if it experiences a natural disaster or is subjected to a major human activity; for example, a woodland burnt by a bushfire or cleared for agriculture. This type of succession is called **secondary succession.**

? Secondary succession in a *Eucalyptus* woodland after a bushfire begins with the germination of the seeds of wind-blown herbaceous plants. Germination of the plants and the growth of seedlings is rapid because the soil is warm and, as its ash content is high, it is nutrient-rich. The underground seeds of species present prior to the fire that are undamaged also germinate quickly and grow. As a result, a new mixture of populations of plant species soon becomes established. Populations of animals in the original ecosystem that escaped the fire may return seeking food and shelter, as do populations of new animal species. Specialised structures in the trunks of Eucalypt species called 'epicormics buds' germinate giving rise to new leaves, and in time, new branches to support them. Competition between populations of colonising species of plants, and between returning and new species of animals, influences how many species become established, the size of their populations and ultimately how different the post-fire ecosystem is from the original ecosystem it replaces.

Figure 473 (a) A forest fire and recovery after (b) (top right) 1 year, (c) (bottom left) 2 years and (d) 9 years

Figure 473 shows images of a forest fire and recovery of the ecosystem in the years following. This illustrates a good example of secondary succession. As a rule, secondary succession occurs more quickly than primary succession although how long it takes is determined by factors including the size of the original disturbance and the stability of the original ecosystem.

Very long-term change

Studies have shown that ecosystems can develop and change a great deal over just a few decades let alone centuries. It stands to reason that given much, much longer periods of time – tens or hundreds of millions of years – very large ecosystem change indeed should occur. If true, ecosystems today should bear little or no resemblance to ancient ecosystems in the same location tens or hundreds of millions of years ago.

Ediacaran biota

One example of very long term change concerns the discovery of an ecosystem that once existed in what is now the northern Flinders Ranges in South Australia. Today, ecosystems of the northern Flinders are very dry and hot for most of the year with sparse populations of arid shrub and woodland. These support a diversity of arid-adapted animals that includes species of insects, reptiles, birds and mammals. During the **Ediacaran Period** (600-543 million years ago), however, the region was the bottom a shallow sea. There was no life on land and no animals and plants in the sea. The multicellular forms of life were soft-bodied sponge-like organisms and plant-like algae that lived attached to the sea floor.

The existence of the Ediacaran **biota**, and thus of the abiotic components of the ecosystem at the time, is supported by fossil evidence. The fossils of these Ediacaran species are on display in the Museum of South Australia. Studies of the Ediacaran and Flinders ecosystems have gone on to improve understanding of ecosystem change over very long periods of time.

Helpful Online RESOURCE about Ediacaran biota

To learn more about the Ediacaran biota, use this QR code to visit:

<https://www.youtube.com/watch?v=RZcvbxlf9yk>

Helpful Online RESOURCE about a probable Ediacaran ecosystem

To see what an Ediacaran ecosystem probably looked like visit:
<https://www.youtube.com/watch?v=v361IQh6dPE> (several parts)

Dinosaurs in Australia

Another example of very long-term ecosystem change that has taken place in Australia can be seen in central western Queensland near the town of Winton. Today the ecosystems in this part of Australia are semi-arid and mostly consist of vast flat grasslands and extensive river flats that flood with summer rains. There is a large diversity of animal species, many of which are threatened by the persistence of cattle farming that remains vital to the local economy. Around 95 million years ago in the **Cretaceous Period** (146-65 million years ago) the ecosystem was quite different. Then the ecosystem included rivers and mudflats that ran into large lakes. These were surrounded by lush rainforest that consisted of many species of plants. Species of small bi-pedal dinosaurs inhabited the rainforest and edges of the lakes and periodically wandered out onto the mudflats to drink water and to feed.

The existence of the Winton Cretaceous ecosystem is supported by the discovery of pollen and spores of the now extinct rainforest plants and fossils of the dinosaurs that lived with them at the time. Evidence for small bi-pedal dinosaurs in the ecosystem was demonstrated by the spectacular discovery of a complex series of fossilised footprints at nearby Lark Quarry that captured a 'dinosaur stampede' that took place on a mudflat 95 million years ago. Refer to *Figure 474* of a photo of the preserved dinosaur prints from Lark Quarry in Queensland.

Helpful Online RESOURCE about the Lake Quarry dinosaur stampede

To learn more about a dinosaur stampede at Lake Quarry use this QR code to visit:
<https://www.youtube.com/watch?v=jRWFXr60kUk>

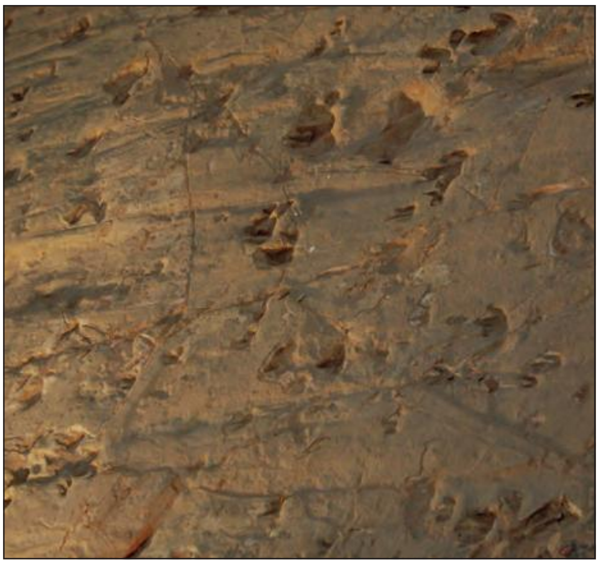


Figure 474 A dinosaur stampede

FIgure 475 A Thylacaleo attacks a DIprotodon

Megafauna

A third case of a very long-term ecosystem change involves the ecosystem that existed in the **Pleistocene Period** (2 million-10,000 years ago) in the south-east corner of South Australia near Naracoorte. For most of that time the area was colder and drier than it is today, with only occasional periods that were warmer and wetter. Analysis of the soil shows that this supported a sparse mixture of species of tough-leafed grasses and shrubs. Large numbers of fossils discovered in the Naracoorte Caves confirm that these were consumed by a **megafauna** that consisted of giant species of marsupials; for example, *Diprotodon* a '4-wheel drive size' herbivore and *Procoptodon* or short-faced giant kangaroo that stood 2.5 metres high and ate leaves. The main predator at the time was *Thylacoleo* or the marsupial lion that was the size of a leopard. Refer to the image in *Figure 475*; the *Diprotodon* is a herbivore and *Thylacaleo* a marsupial lion.

None of these plants and animals feature in ecosystems in the Naracoorte area today. Fossil evidence suggests that the megafauna had become extinct by about 35,000 years ago, either as a result of a warming environment, the arrival of the first humans, or both.

Helpful Online RESOURCE about fossils in the Naracoorte caves

To find out more about the Naracoorte Caves fossil site, use this QR code to visit:

<http://www.nfsa.gov.au/digitallearning/heritage/naracoorte.html>

Helpful Online RESOURCE about megafauna

To see what some of the megafauna looked like visit:

<https://www.youtube.com/watch?v=06BfyKUYjbc>

Key Concepts

1. Ecosystems change occurs over short and very long-term time scales. These changes generally involves both biotic and abiotic components.
2. Over hundreds of years almost lifeless environments can develop into ecosystems full of life.
3. If sufficiently disturbed, an ecosystem may gradually be replaced by another ecosystem.
4. Ecosystem change is supported by geological evidence.
5. Fossils discovered in Australia have improved understanding of ecosystem change.

What have you learned?

Key Terms

cyclic

unidirectional

ecological succession

primary succession

simple soil

herbaceous plant

mature soil

secondary succession

Ediacaran Period

biota

Cretaceous Period

Pleistocene Period

megafauna

Knowledge and Understanding

1. State one example of a short-term change to an ecosystem and describe the cause of the change.

2. Describe how fossil evidence provides support for succession in ecosystems over very long time spans.

3. Ecosystems are almost always changing.
   a) Suggest two reasons that might cause an established ecosystem to start to change.

   b) Describe some likely changes that might occur in the ecosystem as a result.

4. Primary succession can occur on bare rock:
   a) Outline the role played by autotrophic organisms in primary succession that takes place on bare rock.

   b) Suggest some possible adaptations that these autotrophs may possess.

Application, Analysis and Evaluation

5. In 2011, Mission Beach in far north-east Queensland was hit by Cyclone *Yasi*. Suggest how this led to secondary succession in the local wet tropical rainforest ecosystems and what changes may have occurred.

6. Fossilised Ediacaran biota has been discovered elsewhere in the world besides Australia, most notably in the south-east corner of Canada. Given that there is no evidence of Australia and Canada ever being connected to one another, what is the likely reason for parts of both countries having a similar biota in the Ediacara Period?

7. The Tasmanian World Heritage Wilderness Area in the south-west of the state contains cool wet rainforest that has remained virtually unchanged for the last 40 million years. Suggest why succession has had little impact on this region.

8. Succession is a change in the mix of species in an ecosystem over time. As new species appear, they change the environment making it more suitable for other new species. Predict how each of the following may make an ecosystem more suitable to new species:

   a) Small plants growing on bare rock.

   b) Spinifex grass taking hold in a sand dune.

   c) Insects moving into leaf litter which has accumulated

9. Suggest, giving examples, why secondary succession (e.g. after fire) usually occurs more quickly than primary succession.

10. Put forward possible suggestions to explain the following observations regarding succession.

    a) There is greater level of biodiversity in mature, stable ecosystems compared to ecosystems in an early succession communities.

    b) Ecosystems late in succession recycle essential nutrients and chemical elements better than ecosystems early in succession.

    c) In mature ecosystems there are a greater number of heterotrophic species compared to autotrophic species.

Science Inquiry Skills 4.7 - Secondary succession after fire

Introduction

Ecological succession is a process that involves the mix of species in an ecosystem changing over time. Disturbances such as fire are normal occurrences in Australia that trigger secondary succession in many established ecosystems. Regardless of whether it is a product of lightning or human practices, fire has the potential to fundamentally alter an ecosystem, either directly by killing organisms or indirectly by destroying sources of food and shelter or as a result of new species competing for these essential resources.

Inappropriate use of fire by humans and of machinery that can spark fires can lead to the development of bushfires that are difficult to manage and contain. Human practices designed to reduce fire fuel loads in human-dominated woodland ecosystems, like prescribed burning, may contribute to fragmentation of them, increasing the vulnerability of some species to extinction. Steps taken to prevent fire, however, can result in very large fires and thus quite widespread local extinction of many species.

Part A: Using secondary data

The information below refers to a study by *Don Driscoll* of the School of Biological Sciences, Flinders University and *Meredith Henderson* who works in Science and Conservation, Department for Environment and Heritage. This was completed on the Eyre Peninsula at four locations, two areas that were burnt between 3 and 7 years ago and two areas that had not been burnt for more than 18 years. Each site was a Mallee ecosystem that consisted of multi-stemmed eucalyptus trees, 3-5 metres in height and a mixture of shrubs, herbaceous plants and grasses that supported a fairly rich diversity of animals including many species of insects, spiders, scorpions, lizards and birds.

Responses to fires

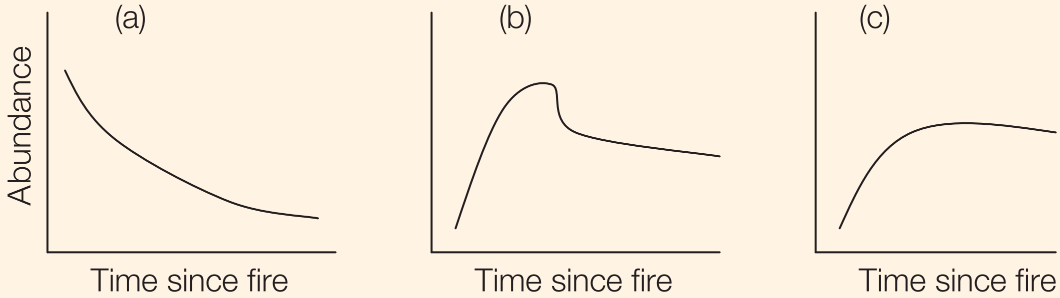
Studies have shown that reptiles can respond in different ways to fire:

d) Burrowing species are most common in recently burned sites.

e) Species that shelter in *Triodia*, a prickly clumping grass, are most abundant after six years when *Triodia* recovers.

f) Litter dwelling species do not peak until 25 years after fire, when the leaf litter layer is well established.

The *Figures* below shows three typical responses in reptiles after the occurrence of a fire.



In total 1585 reptiles were captured, including 42 reptile species and 15 species with at least 20 records.

Ctenophorus fordi, a species of dragon, and the geckos *Nephrurus stellatus* and *Diplodactylus damaeus* were all more abundant at the recently burnt sites.

Ctenophorus fordi are capable of digging burrows for nests and of burying themselves to escape harsh surface conditions.

The opposite pattern was shown by the gecko *Ctenophorus cristatus*. Although *Ctenophurus cristatus* is a burrowing species, it also shelters in fallen logs and branches.

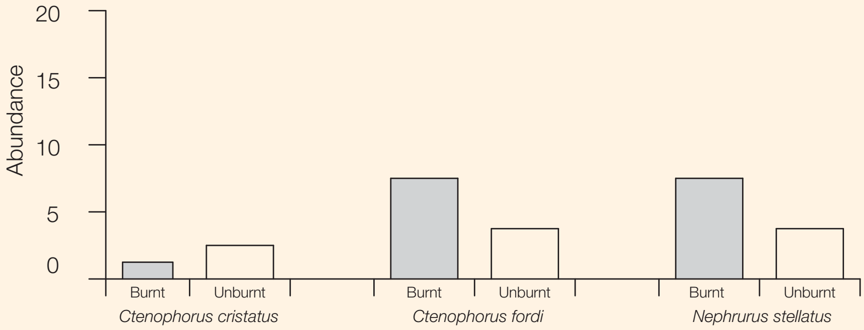
Reptiles showed responses to fire consistent with four processes. These were:

- creation of open habitat after fire
- rapid recovery of a major plant species
- gradual recovery of leaf-litter
- availability of fallen branches

4.7

Science Inquiry Skills 4.7 - Secondary succession after fire (cont.)

The graphs below shows the abundance of three different reptile species at the burnt and unburnt sites used in the study.



1. State and give possible reasons for the differences noted in the abundance of *Ctenophorus cristatus* compared to *Ctenophorus fordi* in the 'recently burned' and the 'not burned for a long time' sites.

2. Describe why periods of no fires for decades followed by major incineration of an ecosystem is likely to drive many species to extinction.

3. Initially, species that reproduce quickly and produce many offspring tend to have the advantage in fire-disturbed ecosystems but as the ecosystem matures and becomes stable, species that produce less offspring less often tend to be the ones that increase in numbers. It has been noted that post-fire plant species can be attractive to insect species that colonise the ecosystem. Use this data to help explain why ecosystems often show a rapid increase in the numbers of birds between 0-15 years after fire and then why the number of birds decreases but the diversity of species of them continues to increase.

4. Some species are called successional specialists. This means they are most abundant in the ecosystem at a particular time after fire; early stage succession species are most common 1-2 years after fire. *Nephrurus stellatus* is one example of an early successional species in the Mallee ecosystems of the Eyre Peninsula. Speculate about the likely form of shelter and diet for this species.

5. Prescribed burning of ecosystems is one strategy used to prevent fire fuel loads reaching levels that would support a fire that would have a catastrophic impact on human-occupied ecosystems. Not doing this also threatens populations of early successional species of gecko like *Nephrurus stellatus* as well. Explain why.

? Science Inquiry Skills 4.7 - Secondary succession after fire (cont.)

Some of the reptiles found in this ecosytem

Part B The impact of human activity on ecosystems

That the removal of native vegetation has an impact on species is beyond doubt, but often there is less understanding of why it has the effect it does and how to best minimise species losses.

For example:

- Why are particular species more vulnerable to a decline in numbers than others?
- How important is complete loss of habitat compared with fragmentation of habitat?
- What is the relationship between the amount of habitat that remains and the amount of biodiversity?
- How do introduced species or disturbances like fire contribute to fragmentation and loss of habitat and what impact does this have on native species, and why?

Different plant and animal species have different ecosystem requirements. This means no human activity can ever impact all species equally. In the case of prescribed burning, no single fire management strategy can favour all species. A diversity of prescribed burns and other strategies need to be employed to conserve plant and animal diversity. Therefore, too infrequent and too frequent fires are both likely to seriously damage ecosystems both in the short and long-term and undermine attempts to conserve them.

Part C Prescribed burning

Prescribed burning is conducted to remove fuels less than 6mm in diameter like leaf litter, bark and shrubs that are burnt during fire. Prescribed burning therefore reduces the amount of combustible material that may ignite and cause spot fires. Prescribed burns in Mallee ecosystems are conducted as intensely as is feasible to remove as much of this fuel as possible.

How and why organisms colonise an ecosystem after fire, including as a result of prescribed burning, is often not well understood. Although carefully considered, prescribed burning is designed to minimise the impact on biodiversity, and in certain cases goes a long way to supporting it, however the practice can also lead to reductions in biodiversity.

1. Give an example of where fuel reduction burning could be a threat to biodiversity.

2. Prescribed burning can encourage biodiversity. Give an example.

3. Human activities significantly impact on ecosystems such as those found on the Eyre Peninsula. Outline how research of the kind mentioned in Part A of this activity can be used to better inform on how to protect species from extinction in the face of fire.

4.7

Science as a Human Endeavour 4.7 - Once upon a time in Winton

Application and Limitation

Scientific ... inquiry can enable scientists to make ... discoveries ...

Winton is a small town in central western Queensland. Like many towns in that part of Australia, its flat semi-arid grasslands make it suitable for cattle and sheep grazing.

In the Cretaceous Period, what is cattle and sheep country today, was part of a vast collection of floodplains. There were rivers, lakes and rainforest ecosystems made up of a rich diversity of plants. These provided food and shelter for a huge number of animals including many species of insects, birds and reptiles, including dinosaurs.

Serious interest in Winton's dinosaur past began in 1999 when local grazier David Elliot found a huge thigh bone or femur on his property while rounding up sheep. It was soon discovered that the femur was part of a 95-million-year old skeleton of a giant four legged plant-eating dinosaur. Nicknamed 'Elliot' the dinosaur's remains were dug-up by scientists from the Queensland Museum in 2001. Nearly 20m long and standing 3.5m high at the hip it was the biggest dinosaur discovered in Australia. *(Refer to the image that shows the size of 'Elliot' relative to a person)*

You may need to refer to the online resources below to answer the question that follows.

Suggest how the discovery has enabled scientists to make predictions about the type of environment that existed 95 million years ago in Queensland.

Helpful Online RESOURCE about Australian dinosaurs

To learn more about dinosaurs that have been discovered in Australia click here:

<http://www.australianageofdinosaurs.com/page/28/australian-age-of-dinosaurs-%7C-australian-dinosaurs>

Helpful Online RESOURCE about dinosaurs in the Winton area

To learn more about dinosaurs that have been discovered in near Winton click here:

<https://www.youtube.com/watch?v=TU4yf-MCvAo>

Chapter 4.8 Human impact on ecosystems

Science understanding

Humans have significant impacts on ecosystems.

- Explain how the destruction of habitats as a result of human activity speeds changes in ecosystems and impacts on biodiversity.

By measuring key aspects of the biotic and abiotic components of the ecosystem, it is possible to make predictions relating to the impact of environmental change.

- Describe how these predictions can help to develop strategies to minimise the adverse effects of such change

The key threats to ecosystem and species diversity include:

- habitat fragmentation
- climate change
- introduced species/pathogens
- agriculture (cropping and grazing)

Habitat fragmentation

Habitat **fragmentation** occurs when natural forests are broken up into smaller, isolated patches of natural ecosystems which can not adequately sustain communities of organisms and rich biodiversity.

Habitat destruction is the main contributing factor driving many species towards endangerment or extinction. In Australia, since European settlement, humans have cleared native vegetation for agriculture, pasture and urban development. Prior to the 1860s most of the clearing was near urban settlements, but with the development of machinery and the economic and social policies put in place by governments of the day, clearing soon spread to fertile areas that enabled the wool and wheat industries to expand and flourish.

Globally, the world's forests continue to reduce in size as human population sizes increase with land being used for agriculture and forest products. Approximately 129 million hectares of forest have been lost since around 1990. Recently, however, an increasing number of forests are under protection and management practices are improving. Over the last 25 years the rate of net global deforestation has slowed considerably. *Figure 481* shows logging and the destruction of forest habitat.

Figure 481 Logging destroys habitat

Figure 482 Global biodiversity hotspots

Natural forests are rich in biodiversity and contribute to the preservation of species by providing essential habitats for many endangered species, of both plants and animals. Refer to *Figure 482* which illustrates where global biodiversity hotspots are, demonstrating the importance of sensible and sustainable forestry management.

In the woodlands of eastern Australia, some five million hectares of forest are logged commercially, with the forest being repeatedly cut and replanted. When the native vegetation is cleared, habitats for native species are destroyed, the diversity of habitats is reduced and there are major disruptions to ecological processes.

Below is a list of some of the reasons it is vital to maintain natural vegetation:

- to provide a range of habitats to help maintain species diversity
- to provide vegetation with deep roots which maintain water table levels and help prevent salinity
- to help maintain and protect the soil from erosion
- to absorb carbon dioxide, a greenhouse gas, and produce oxygen
- to help maintain regional rainfall patterns
- to help reduce weeds and feral animals.

Temperate woodlands are one of the most threatened types of ecosystems in Australia. It has been estimated that around 80 per cent of these woodlands have been cleared. These woodlands now contain a very high number of threatened native animals and plants. These regions have had the largest numbers of birds that have become extinct of any habitat in Australia. When native vegetation is cleared there are a number of impacts on the environment, some that are not observed for considerable periods of time. The clearing of older trees is a major threat to native birds, as many of these species require the nesting sites and hollows that are only found in mature trees of 100-400 years of age. When individual species are threatened or destroyed there is often a ‘chain reaction’. These ‘chain reaction’ effects could be related to biological processes such as predation, decomposition, pollination, seed dispersal, pest control or other relationships. As surviving woodlands are placed under pressure by the action of introduced animals like rabbits and foxes, as well as the grazing by domestic stock, other significant changes occur.

The loss of native grasses and herbaceous plants destroys both a food source for native species and their natural habitat. The conditions of a disturbed ecosystem are ideal for different species to move in and colonise. Many introduced plants and weeds often take over, along with feral animals, further leading to a breakdown of the remaining woodland habitat. In Victoria it was found that small heavily grazed patches support fewer forest birds but more farmland birds, who aggressively compete with native species, excluding them from nesting sites. Refer to *Figure 483 (a), (b) and (c)* for examples.

Figure 483 Some aggressive birds (a) Noisy miner, (b) Galah and (c) Magpie

Through clearing, fragmented patches or islands of native vegetation are created in between pasture land and paddocks. When these islands are relatively small they cannot sustain important ecological processes like water and nutrient cycling as effectively as before. This habitat fragmentation will generally cause a decline in species diversity, and other more aggressive species of birds, in particular the noisy miner, the galah, the Australian magpie and the Australian raven, will tend to increase in number at the exclusion of others. When the native species of deep-rooted plants are removed, there is often a rise in the water table and associated problems of soil salinity, which affect not only the remaining native vegetation but also agricultural crops. Some research also suggests that native vegetation clearance can also affect the rainfall patterns of a region. It was observed that convection clouds possibly form early in the day over areas of native vegetation when compared to similar areas that had been cleared. The study indicated that annual rainfall was being reduced by up to 1.5 mm/year and that there had also been an increase in surface temperatures by 1-5°C. This change in rainfall and temperature will also affect native species.

Climate change

Measuring the impact

It is now accepted by the overwhelming majority of scientists that global warming is leading to **climate change** and therefore changes in physical and biological systems worldwide. Australia has warmed by approximately 1°C since records began (about 100 years ago) and current modelling suggests that as this continues the impact on biodiversity will be immense. With higher carbon dioxide concentrations, increasing temperatures, altered rainfall patterns, rising sea levels and **acidification** of the oceans the impacts on habitats, ecosystems and species will also be widespread.

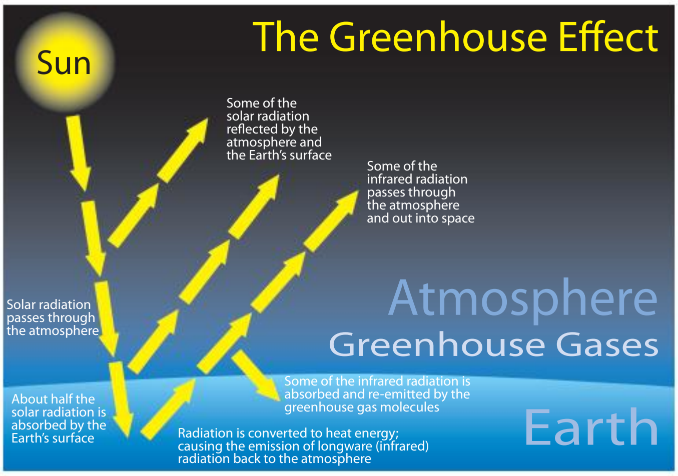
Environmental scientists use data to study trends or patterns in biotic and abiotic components of ecosystems and thus make predictions regarding the potential impact on ecosystems.

Global temperature and carbon dioxide

Greenhouse gases are gases whose presence in the atmosphere causes an increase in the Earth's temperature. Life on Earth depends on these gases in our atmosphere: without them, the average temperature on Earth would be below zero, water would be frozen and life would be impossible.

Greenhouse gases cause the '**Greenhouse Effect**', this name refers to the action of greenhouse gases which can be compared with the glass panes of a greenhouse. The (light) waves emitted by the Sun include radiation with a short wavelength. These waves pass through the glass of the greenhouse. They are changed into (heat or infra-red) radiation with a longer wavelength; some of these cannot pass back out through the glass as easily and are emitted back into the greenhouse, raising its temperature. In addition, the glass in the greenhouses stops the flow of air, reducing convection and the cooling effect of wind – this does not apply to the greenhouse gases in our atmosphere.

Figure 484 illustrates that some of the infrared radiation is not (immediately) re-radiated and lost into space but is emitted back to Earth by the presence of greenhouse gases. This causes the Earth's atmosphere to increase in temperature.



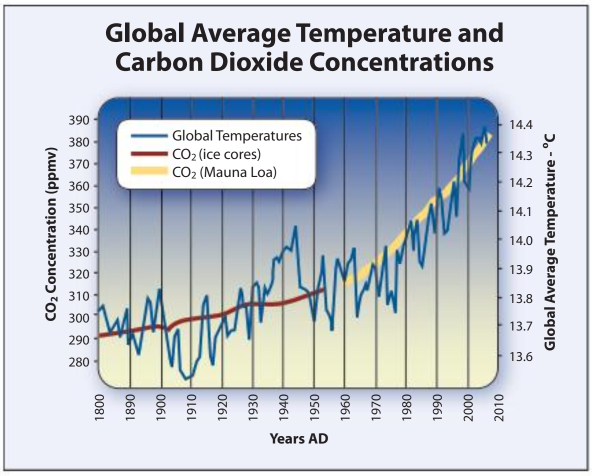


Figure 484 Causes of the Greenhouse Effect *Figure 485 Temperature and CO_2 levels*

Humans can interfere with the natural biogeochemical cycles including the carbon cycle. Correlations can be seen between global temperatures and carbon dioxide concentrations in *Figure 485*. As noted in Chapter 4.5, two common practices e.g. **deforestation** and burning fossil fuels both cause atmospheric carbon dioxide levels to rise.

Ocean temperatures and changes in pH

Disruption of the global carbon cycle is not only impacting on the atmosphere but also in our oceans. Approximately 93% of the heat from the sun is absorbed by the oceans, 4% by the continents (including Antarctica) and only about 2% by the atmosphere.

Impacts of global warming on the oceans

- rising sea levels
- rising water temperatures; there is evidence that as the oceans warm, marine plants and animals will relocate changing food webs and impacting on these ecosystems.
- ocean acidification; when excess carbon dioxide dissolves in the oceans, the water becomes more acidic lowering the pH. This also has negative consequences on shell forming species as well as other impacts that are not yet well understood.

Refer to *Figure 486* showing a polar bear on an ice floe. How much is the warming of the oceans leading to glacial and polar ice melting?

Figure 486 Less sea ice is one effect of global warming

4.8

Refer to *Figure 487* which shows the correlation between increasing carbon dioxide concentrations and ocean pH levels in the past and a prediction for the future.

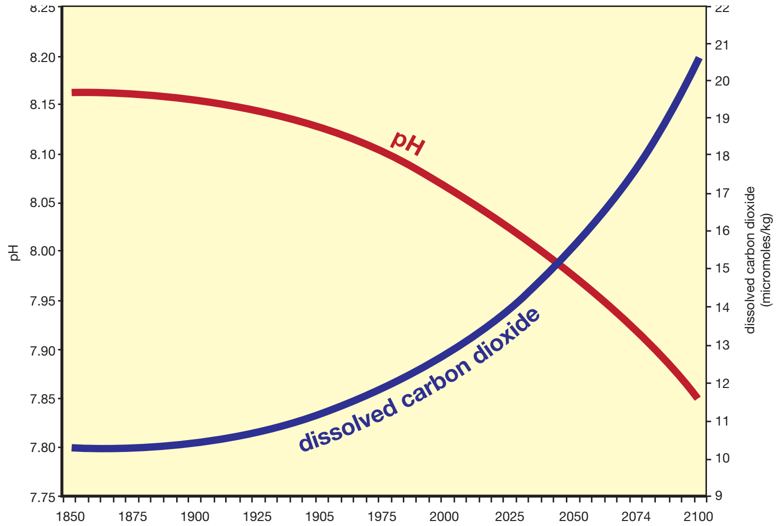


Figure 487 Dissolved carbon dioxide concentrations and acidity of the oceans

Threats to coral reefs

The increased level of carbon dioxide in the atmosphere causes more of the gas to dissolve in water, including seas and oceans. Some of the carbon dioxide dissolving in water will chemically react with water and form hydrogen carbonate and hydrogen ions. It is these hydrogen ions which increases the acidity of the water. As a gas, carbon dioxide will dissolve easier in colder water but some effect is still noted in warmer water. The resulting acidification is indicated by a drop in the pH value. Unfortunately increasing water temperatures will also reduce the solubility of oxygen which will starve organisms of this vital resource and threaten their health and life.

Due to some accompanying chemical reactions, carbonate will be less available to corals, which makes it more difficult for them to build their skeleton. If the pH drops further, the calcium carbonate of the skeletons will actually start to dissolve in the water, breaking down ecological niches, such as the Great Barrier Reef (*see Figure beneath*) which plays a vital role in the life cycle of a huge range of different groups of species. Coral reefs are estimated to be the habitat of 25% of marine species.

'The International Union for Conservation of Nature (IUCN)' publishes an annual 'Red List', which details threats to animals and plants. The 2018 report assessed more than 105,000 species. Coral reefs are among the most threatened ecosystems on Earth, with 33% threatened with extinction. According to the IUCN, more than 275 million people are dependent on coral reefs for food, coastal protection and livelihoods, .

Global temperatures and ice

The sea level has been rising now for many years due partly to the melting of the world's land ice as atmospheric temperatures rise. The world's major ice sheets of Greenland and Antarctica are of significance here due to their massive sizes; together they contain potentially around 75% of the world's freshwater. Note that melting icebergs (e.g. in Arctic and Antarctic regions) do not increase the sea level.

Measurements of land ice elevation are being made by NASA with sophisticated laser and photon altimeters aimed at measuring changes in the Earth's elevation with an accuracy of less than 1 cm. Information gathered from both land ice and sea ice changes can be put into climate modelling studies with a view to simulating future climate conditions and likely impacts.

Using indicator species to assess environmental changes

It is important to know when and how much the environment changes, especially if human actions might have caused the change. Careful environmental monitoring can warn in advance of undesired changes and action may be able to be taken which prevents the damage from becoming worse.

It is important to consider monitoring **eutrophication**. Eutrophication is nutrient enrichment of an aquatic environment which results in an explosive growth of water plants, particularly algae. The large number of algae growing at the surface of the water will block the light which causes lower plants or algae to die. Bacteria will decompose the dead material, using up oxygen in the process. The overall result is a significant decrease in dissolved oxygen levels in the water which may cause heterotrophs like fish or crustaceans to die. These are then also decomposed, further reducing oxygen levels.

Eutrophication can be measured chemically, for example, by measuring oxygen levels. The rate of oxygen depletion by organisms is the 'biochemical oxygen demand' (BOD). It reflects the activity of micro-organisms in decomposing organic material.

Algal blooms

An **algal bloom** is the abundance of algae in an aquatic system. Algal bloom occurs both in both marine and freshwater ecosystems. It can involve one or more species of algae. If the species involved are toxic, the result can be described as 'harmful algal bloom', although that does not imply that other algal blooms are not harmful.

The problem with algal bloom is that there are so many algae in the water that they block the light reaching any further than the top surface. This is likely to kill any plants not at the surface, this includes other species but also algae which were overgrown by others. The dead plants will be decomposed, a process that requires oxygen and therefore significantly reduces the oxygen available to aquatic animals. If they also die, they are decomposed, a process which further decreases oxygen levels.

An algal bloom is often caused by eutrophication: a situation where the water has become too rich in nutrients, especially phosphates and nitrates. Human actions are a common cause of eutrophication. Actions include over-fertilising agricultural land which causes some of the nutrients from these fertilisers to run-off with rain water and untreated sewage getting into waterways. A natural cause of eutrophication can be seasonal flooding which brings nutrients from manure and partly decomposed vegetation into the water. *Refer to Figure above.*

4.8

Helpful Online RESOURCES to learn about the greenhouse effect

To view an Essentials Video Animation (EVA) on this topic use this QR code to visit:
<http://essentialseducation.com.au/resources/sace-1/biology/climate-change/>

Strategies to reduce human impact

In 2015 a historic agreement was reached in Paris at a United Nations Accord where 200 countries drew up a series of goals with the aim of cutting greenhouse gas emissions over the coming decades. *Refer to the Figure below.*

The key features of the *Paris Agreement* include the following:

- to keep global temperatures below 2°C above pre-industrial times
- to limit greenhouse gases emitted by humans to the same level that ecosystems can absorb naturally beginning between 2050 and 2100
- to review each country's contribution to cutting emissions every five years
- developed (rich) countries are required to help developing (poorer) countries by providing 'climate finance' to adapt to climate change with an emphasis of moving to renewable energy
- ultimately, it is up to individuals to make lifestyle changes to help reduce carbon dioxide levels. One of the biggest contributions of carbon dioxide is the burning of fossil fuels for the power use for homes, air conditioners, cars, mobile phones and so on.

Here are some ways we can all reduce our impact on carbon dioxide levels:

- reduce the need for heating and cooling; dress sensibly, insulate homes
- use energy-efficient household appliances; look for the 'Energy Star' label to purchase the most efficient refrigerators and washing machines
- don't waste food and consider reducing meat consumption
- use **LED lighting** which is more efficient
- drive a smaller car and/or walk or ride a bicycle where practical
- reuse and recycle materials
- develop sustainable gardening and farming practices
- overall; reduce our **carbon footprint**

C Ethical understanding: Climate change

Ethics involves asking questions about what is right or correct for individuals and society. To understand ethics is to be able to think critically to determine the right course of action.

Over the last two centuries, combustion of fossil fuels has brought many benefits. These include generation of electricity, making energy available for heating, cooling, cooking, and powering systems of transport. Today, combustion of fossil fuels supports the high standards of living people have become accustomed to in developed countries and has the potential to transform the lives of billions who live in poverty in developing countries.

It is the consensus of the international scientific community that combustion of fossil fuels has contributed to a gradual increase in atmospheric temperature, or 'global warming'. This is because burning of fossil fuels produces carbon dioxide which traps infra-red (or heat) radiation emitted by the earth's surface. As fossil fuel combustion steadily increased over the 20th century (disruption of the carbon cycle), more and more infra-red radiation has been trapped, leading to measurable increases in warming at ground level.

Evidence has been collected for many decades that supports the fact that global warming is altering weather patterns, something termed climate change. Good indicators of climate change include changing patterns of rainfall, sea level rises, and more extreme weather events ***(refer to photo)***.

The combustion of fossil fuels, therefore, raises ethical questions. As the evidence linking climate change to more flooding and droughts, for example, strengthens, who should be responsible for doing something about it? Is it fair to deny developing countries more access to fossil fuel driven technologies that do so much to improve the living standards of their people? Should families in developed countries be able to own multiple cars, travel widely and indulge in high meat diets, all of which cause very high carbon dioxide footprints per person? Is it right that most Australians maintain lifestyles that we know contribute to climate change, yet we strive to live like this anyway? What then are the consequences of today's 'lifestyle first-climate change later' world for the just born, or the yet to be born?

You may need to refer to the online resources below to answer the question that follows.

1. It has been suggested that 'developed' countries should take more responsibility for climate change and its effects than 'developing' countries. Discuss whether or not you agree with this suggestion, with reference to ethical responsibility.

Helpful Online RESOURCE about burning fossil fuels and climate change

To learn more about how burning fossil fuels causes climate change view the clip below:

<https://www.youtube.com/watch?v=gBLQUplzZZo>

Helpful Online RESOURCE about the ethics of climate change

To learn about some ethical principles associated with climate change view the clip below:

<https://www.youtube.com/watch?v=tz8w8z__-R8>

4.8

Key Concepts

1. Habitat destruction is the key factor in disruption to ecosystems and reducing biodiversity.
2. Around the globe humans need to continue to improve forestry and other land management to ensure biodiversity 'hotspots' are protected.
3. Measuring both biotic and abiotic components provide indicators to scientists regarding the impact of humans on ecosystems.
4. Increasing greenhouse gases in the atmosphere are causing an increase in the Earth's temperature and this is called 'global warming'.
5. Strong correlations can be observed between CO_2 (a main greenhouse gas) and increased global temperatures.
6. Other impacts of global warming include:
   - rising sea levels
   - acidification of the oceans
   - increased melting of ice sheets including glaciers
   - climate change
   - faster changes to ecosystems and loss of biodiversity
7. Humans have a good understanding of better practices that are required to reduce our carbon footprint.

What have you learned?

Key Terms

fragmentation ....

deforestation ....

greenhouse effect ....

climate change ....

greenhouse gas ....

algal bloom ....

eutrophication ....

acidification ....

carbon footprint ....

LED lighting ....

Knowledge and Understanding

1. Briefly demonstrate your understanding of the following statement: 'whenever individual species are threatened or destroyed there is often a chain reaction'.

....

....

....

2. List two reasons why it is important to maintain natural vegetation.

....

....

3. Explain why loss of habitat often reduces biodiversity.

....

....

4. Scientists collect data to enable them to measure human impact and make predictions about the future. State three types of data and describe how each might be used to indicate human impact.

   a) ..

   b) ..

5. The amount of carbon dioxide in the atmosphere is slowly increasing.

   a) State the link between atmospheric carbon dioxide concentrations and atmospheric temperature.

   b) Briefly describe the reasons for this link.

6. Describe three possible effects of global warming on communities of organisms.

7. Explain why the acidification of the oceans is threatening coral reef organisms.

8. An 'indicator species' is an organism that may increase rapidly and can be used as an indicator of human impact on ecosystems. Name one such species and indicate the likely human impact causing the changes.

Application, Analysis and Evaluation

9. Lowering of the oxygen levels in aquatic ecosystems is often associated with disruption to the ecosystem and loss of biodiversity.

   a) Predict a possible human activity that could cause such a fall in oxygen levels.

   b) Point out possible reasons why this may lead to a loss of biodiversity.

10. Extinction is a normal occurrence in ecosystems. This being the case, outline the most likely reasons why scientists today are so concerned about species extinctions.

11. Compare the number of pests and parasites generally found in natural ecosystems with the numbers in most agricultural ecosytems.

12. The 'Green Revolution' was an attempt in the 1960s to introduce into developing countries new varieties of cereal crops that yielded more seed. This was possible, as these varieties did not have an extensive stem and root system; to offset this, farmers depended heavily on fertilisers and irrigation. Using your understanding of human impact on ecosystems, decide on the most likely reasons that ultimately this approach failed to meet the original high expectations of feeding more of the world's population.

13. Refer back to *Figure 487* to help you answer the questions that follow:

    a) Correlate the link between increasing atmospheric carbon dioxide concentratoins and a lowering of the pH in the ocean.

    b) Much of the data here is extrapolated. Give evidence to support this statement.

    c) Predict how scientists might use this data to reinforce the need to restrict such activities as deforestation and the burning of fossil fuels.

14. Scientific research has indicated that some species of plants compete more effectively when atmospheric carbon dioxide concentrations are raised. It has also been demonstrated that under these conditions some plants produce significantly lower quantities of seed. Explain how these observations provide support for the argument that increasing atmospheric carbon dioxide levels may lead to a loss of biodiversity.

15. Relate your understanding of environmental sustainability to argue the case for feeding the world's population with more plant products compared to animal products.

16. Choose five things you personally could do to reduce your carbon footprint.

A Case Study - Sustainable farming

Scientific knowledge...can enable...design action for sustainability...

Farm Profile

Fat Goose Fruits is an organic farm at Renmark of approximately 20 hectares, it is owned by *Humphrey Howie and Michelle Medhurst.*

The Howie family and some of their fat geese are shown below.

They are producers of a range of fruit including: oranges, lemons, mandarins, limes, grapefruit, avocados and persimmons.

They are certified organic with the National Association for Sustainable Agriculture (NASAA).

Fat Goose Fruits were recognised by the Natural Resource Management Board in 2014 for attention to innovative practices encouraging sustainable farm management with an emphasis on promoting integration between farming and a maintenance of biodiversity.

To be certified as ‘organic’ and achieve such recognition, a range of practices have been implemented, including:

- No synthetic chemical pesticides
- Encouraging native vegetation and a variety of native birds and animals
- Implementing a range of crops and produce – not monoculture
- A holistic approach to farming – integration of agriculture crops and native animals and plants
- Use of animals to regulate the weeds and unwanted species (the fat geese!)
- Minimal use of fertilizers – using the wastes of the animals and the fat geese.
- The use of compost, mineral additives and organic fertilisers.

Helpful Online RESOURCE about *Fat Goose Fruits*

Use this QR code to jump to this website which will provide valuable information about *Fat Goose Fruits*:

<http://www.fatgoosefruits.com.au/>

Helpful Online RESOURCE to see a video about *Fat Goose Fruits*

Use this QR code to jump to this website which will provide more valuable information about *Fat Goose Fruits (first section only)*:

<https://www.youtube.com/watch?v=rzQgjA7Hc3o>

A Case Study - Sustainable farming (continued)

These farmers demonstrate Science as a Human Endeavour as follows:

Communication and Collaboration

University agricultural students from France come over to the farm each year. Studying agriculture in their home country, they spend a 12 week internship at the farm as a part of their studies to pass on the sound environmental practices so that these innovations can be shared globally.

Development

Monoculture, which is quite common in the region, has been replaced on this farm with a more sustainable holistic approach to farming – creating more biodiversity.

Evidence is continually being collected from soil and water – obtaining and analysing data to evaluate and inform new approaches to refine the model of farming. These new approaches reduce the need for powered equipment, reducing carbon emissions.

Influence

The use of scientific knowledge has led to better economic and social outcomes. Other farmers are taking note of how the farm is productive and taking care of the environment.

Education is making buyers aware; many people are now buying organic foods at the Farmers' Market held each week in Adelaide. The Willunga farm operates all year providing regular employment for local workers. *Fat Goose Fruits* sells their fruits at the Farmers' Market and at the Willunga farm.

Applications and Limitations

New solutions are continually being sought, tested and evaluated.

A recent initiative by the owners is a cat and fox proof fence being tested for its effectiveness in protecting native wildlife.

Limitations have been found with geese as sole grazers of weeds; they tend to be surface grazers and, as such, some native marsupial animals with different grazing patterns are being trialled to test their effectiveness.

After reading the account and watching the associated video, answer the question below.

Use the information given to explain how scientific knowledge, understanding and inquiry has been used on the farm to develop solutions, design action for sustainability and reduce environmental impacts.

Deconstruction

Introduction

In Topic 3 (and/or Topic 1) a Practical exercise was given that incorporated three aspects of looking at and investigating a problem i.e.

- **Deconstructing** the Problem
- **Designing** an investigation based on your findings
- **Conducting** the investigation and preparing a report of it.

The exercise presented here only involves the theoretical exercise of Deconstructing the problem to develop, in a formative manner, your knowledge and skills. It is important however that this should be able to lead on to the Design and implementation of a Scientific Investigation.

With direction from your teacher, present a one-page Deconstruction of one of the following problems:

- Does the pH of seawater affect oxygen production by phytoplankton?
- How does the type of diet influence the composition of your urine?
- Does BMI (Body Mass Index) influence resting blood pressure and/or pulse rate?
- Does atmospheric temperature (or another environmental factor) affect the transpiration rate of plants?
- Does light (or another environmental factor) affect the activity of an invertebrate e.g. slaters

Use the following steps as a guide to the process of Deconstruction

1. Research the particular Problem you are focussing on and interested in investigating.
2. Explore factors that impact on this particular problem.
3. Make informed decisions about determining experimentally how deliberately changing one factor could impact on the particular problem.
4. Explore and address the health and safety risk factors involved.
5. Select the one factor and develop a method to test the effect on the particular problem.

(Refer to the Guidelines and example on page 470 in the Appendix.)

Planning Notes

Introduction

These Answers have been suggested by the authors, they are not intended to be either comprehensive or exclusive. In some cases no answer is suggested because it relies on research or an individual response from students.

Chapter 4.1 Answers

1. Suggested answers are:

Level of biodiversity	Brief explanation	Example
Molecular	Differences in genetic make up in one species	Different shaped beaks in birds of the same species
Population	Different species within one community	Producers, consumers in an ecosystem
Ecosystem	Different ecosystems on Earth	Woodland and desert ecosystems

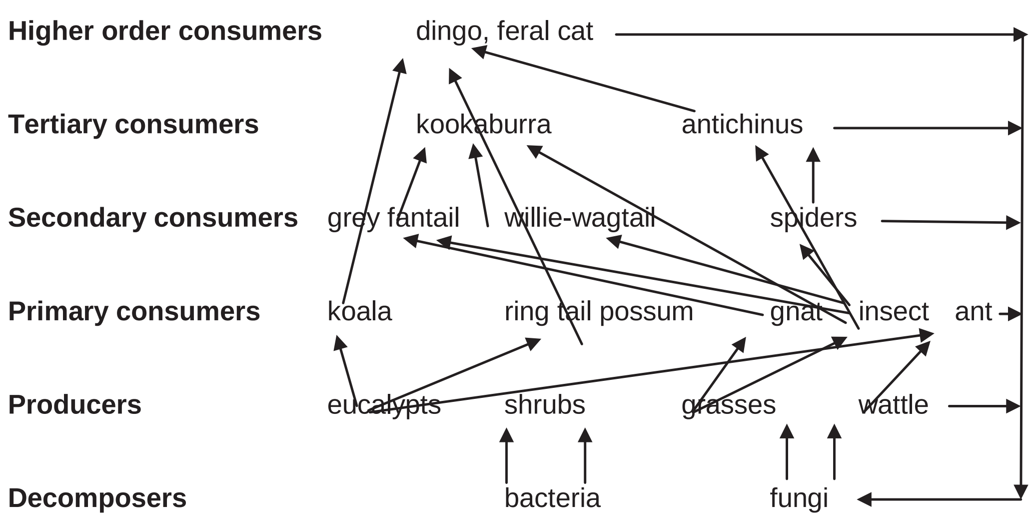
2. Stable ecosystems have a diversity of species. Some are producers, trapping the Sun's energy to provide food, populations interact promoting survival, decomposers recycle nutrients.
3. Resources include suitable temperature, oxygen, water, shelter, breeding sites.
4. Mega-diverse refers to a region or country with an exceptionally high level of species diversity i.e. lots of different species. Endemic species are those that are found naturally in only one region or country.
5. Examples include:
    - competition; two populations competing for one resource in a particular habitat e.g. kangaroos and rabbits competing for grass
    - Predation; one organism killing and feeding on another e.g. a falcon eating a lizard.
    - Symbiosis; a close relationship between individuals of different species e.g. mutualism (see next answer for example).
6. Examples include:
    - Mutualism; e.g. bacteria living inside a cow's stomach or an alga and a fungus existing together as a lichen.
    - Commensalism; a barnacle attached to a razor shell fish.
    - Parasitism; e.g. a tick feeding on a kangaroo.
7. Different species are unable to breed together and have fertile offspring. Therefore the two groups genes do not interact and there are separate gene pools.
8. Examples include: grasses, gum trees, koalas, fungi, acacias, kangaroos, reptiles
9. Some species reproduce asexually, therefore breeding or not breeding together does not apply, this therefore limits the definition because information about the gene pools are not known without biochemical testing. Another example is where some animals will interbreed in captivity but not naturally.
10. Differences include:
    a) Members of one population are members of one species. One species can consist of several populations.
    b) A community consists of several interacting populations. A population consists of organisms all of the same species.
    c) An ecosystem consists of a habitat and community. Habitat is just the abiotic component of the ecosystem.
11. Regarding the cassowary:
    a) Both species benefit. Cassowaries obtain food from the fruit and the plants benefit with dispersal and reproduction.
    b) This fosters or encourages both species to thrive and other species that interact with them.

12. Suggestions are:
    a) competition
    b) parasitism
    c) commensalism
    d) mutualism
    e) predation
13. With reference to the graph:
    a) Species 2
    b) Water is an important resource and greatly influences the ecosystem and its community. Species 2 and 3 overlap with their requirements for yearly rainfall and are therefore more likely to live in the same ecosystem or environment.
14. Referring to the food web diagram:
    a) Reasons include:
    - Shrews feed on mice and will therefore lose a food source.
    - The Australian kestrel loses mice as a food source and will therefore eat more of the shrews
    b) With a fall in mice numbers the wheat crop would increase. More food and possibly more grasshoppers that would begin to feed and thereby reduce the grass in the ecosystem when the wheat crop is finished.
15. Suggestions include:
    a) Eucalypt → Insect → Fantail
    b)

Producers	**Primary consumers**	**Secondary and higher order consumers**	**Decomposers**
Eucalypt	Koala	Feral cat	Bacteria
Shrubs	Possum	Dingo	Fungi
Grasses	Insects	Spiders	
Golden wattle	Antichinus	Fantail	
	Ants	Willie wagtail	
	Gnats	Kookaburra	
		Antichinus	

    c) Examples include:
    - feral cat
    - koala
    - birds

    d)



16. Regarding biodiversity:
    a) The stability of an ecosystem is a reflection of its ability to respond to and recover quickly from challenges or disasters and will last over time. A well-established ecosystem with lots of species can function in this manner, trapping energy to make food, recycling nutrients with the populations interacting.
    b) Humans rely on ecosystems for food, oxygen, water, resources, recreation and more. Healthy ecosystems need to be biodiverse.
    c) Generally the sclerophyll forest has more resources and hence a larger number of producers which can maintain more species hence 'species-richness'.

Chapter 4.2 Answers

1. Regarding hierarchical organisation:
    a) It implies there are levels or taxa and each level is a part of the next higher level. At the top level all species are grouped into three Domains.
    b) Domain, Kingdom, Phylum, Class, Order, Family, Genus, Species.
2. The three domains are:
    - Eukarya; unicellular or multicellular made up of eukaryotic cells
    - Archaea; prokaryotes but differently structured and chemically different to bacteria
    - Bacteria; three types are rod shaped, spiral and spherical, they are prokaryotic cells
3. The binomial system uses two names for each species, the first is the genus and the second is the species e.g. Homo sapiens.
4. Regarding common and scientific names:
    a) Common names are not strictly bound by convention, the same animal may have more than one common name whereas scientific names are always two words. Common names are usually in the native language (e.g. English) whereas scientific names are in Latin (which is an ancient Roman language).
    b) The common name can be easily recognised by all people and is usually easy to remember. However the scientific name is more precise, it indicates much more to scientists about their characteristics and classification.
5. The three main features are:
    - Physical features or morphology: e.g. appendages (e.g. wings or legs), body covering (e.g. hair or feathers).
    - Reproductive strategies: sexual or asexual, egg laying or live birth.
    - Molecular sequencing: comparing the base sequences of DNA and the amino acid sequences of proteins.
6. The genotype means the type of genes or DNA. When the DNA is expressed it codes for the features of an organism. Therefore the type of genes directly reflects and influences the appearance or phenotype of the organism.
7. The three main groups of mammals are:
    - placentals; the unborn are nourished in the uterus and are attached to a placenta
    - monotremes; mammals that lay eggs
    - marsupials; the young are born at a very early stage of development and develop in a pouch
8. Members of one species can interbreed with each other under natural conditions to produce fertile offspring but cannot do so with members of another species. If they cannot interbreed then they are genetically isolated which means they have separate genetic material and separate gene pools.
9. Members of closely related species share common sequences of DNA, more so than members of species that are distantly related. This comparison of DNA base sequences and amino acid sequences when comparing proteins is used, along with other data to understand common ancestry and relatedness.
10. The populations may be completely separated so they are unable to breed together even if it was physically possible. The populations may reproduce asexually and as such the normal definition does not apply and only biochemical information can be used.
11. With reference to the diagrams:
    a) A: Insect, B: Mammal, C: Chilopod
    b) Characteristics are:
    - A: no backbone, body made up of segments, segments are fused into three body parts

- B: backbone, skin with hair or fur
- C: no backbone, body segments, each body segment has one pair of legs

12. They differ in when the reproductive isolation occurs i.e. before the zygote is formed e.g. different mating calls, incompatible genitals OR after the zygote is formed e.g. sterile offspring.
13. Some examples include:
    a) flowering at different times
    b) different mating calls
    c) sterile offspring that are unable to mate and breed.
14. Your Key should consist of about six 'Yes or No' questions as shown in the chapter. It is suggested that you exchange your Key with a friend and see whether it works properly.

Chapter 4.3 Answers

1. The three different categories are:
    - Structural; thick, waxy leaves on a gum tree to prevent water loss
    - Physiological; excretion of concentrated urine by desert mammals to reduce water loss
    - Behavioural; wombats burrow to avoid extremes of heat
2. Suggestions include:
    - The pond's main abiotic factors include: variable light, viscosity of water, density of water, low oxygen levels, low solute levels
    - The sclerophyll woodland's main abiotic factors include: high temperature, low water availability, high light intensity, low nutrient levels
3. Adaptations include:
    a) buds that sprout after fire
    b) it is nocturnal, which means that it moves and hunts at night to conserve water
    c) it has a symbiotic relationship with nitrogen fixing bacteria to help gain nitrogen from the atmosphere
4. Regarding symbiosis:
    a) Symbiosis is a relationship between two species of organisms e.g. mutualism
    b) Organisms called lichens are actually relationships between a fungus and an algae; the algae produces food and oxygen and the fungus helps in water conservation.
5. Suggestions include:

Environmental factors	Why it is important for survival
Light	Energy source for autotrophs
High nutrient levels	To manufacture organic compounds
Water	Important solvent in the transport systems of both plants and animals
Oxygen	Needed for aerobic respiration and energy production
Shelter	Protection from the weather and predators

6. Referring to a pond community
   a) Differences include:
   - light; higher intensity at the top compared to very low or nil at the bottom
   - pressure; lower at the top and increases with depth
   - oxygen; is higher near the surface and decreases with depth

   b) A greater surface area will mean more efficient light absorption for photosynthesis and may also include large airspaces to assist flotation and gas storage for photosynthesis.
   c) Branching increases the surface area of the leaves which in turn increases the surface area for light and gas absorption for photosynthesis.
   d) There are low oxygen levels deeper in the lake and the bubbles which contain oxygen can be used by beetles for aerobic respiration when they dive.
   e) Regarding low solute concentrations (fresh water):
   - In water with low solute concentration, water tends to move by osmosis into the cells of the organisms who have a higher solute concentration in their tissues. This poses problems for organisms as their cells begin to swell.
   - A small protist (e.g. *Paramecium*) has a contractile vacuole which collects the excess water and expels this from the cell.
7. Regarding adaptations and survival:
   a) Predation is such an interaction. Birds prey on a variety of reptiles and insects. This is an example of pressure on the species to become better adapted, members of the population with better adaptations will avoid being eaten.
   b) Adaptations could include structural e.g. camouflage, physiological e.g. maintaining a constant body temperature and behavioural e.g. living in burrows.
8. Examples include:
   - The use of uric acid crystals for excretion: termites have evolved the biochemistry to produce uric acid which depends on genes in their DNA.
   - Similarly a beetle's exoskeleton is coded for by genes in the DNA of the beetle.
9. Suggestions include:

Main environmental factor involved	**Adaptation**	**How the adaptation aids survival**	**Category of adaptation**	**Example of organism**
Water only available for a short period of time	A short life-cycle; germinate, grow, flower, set seed	Enables full cycle of reproduction to occur so the species can survive	Physiological	Sturt desert pea
High temperatures	Large ears with rich blood supply	Increases radiant heat loss	Structural and physiological	Bilby
High temperatures	Hopping	Quickly move long distances to find water and shade	Behavioural	Red kangaroo
Harsh temperatures and low water	Lays large numbers of eggs	Ensures some new offspring hatch from eggs	Physiological	Shield shrimps
High temperatures	Nocturnal	Avoid the heat of the day	Behavioural	Possum

Chapter 4.4 Answers

1. Biotic features are the community of organisms e.g. barnacles and algae. The abiotic features are the non-living components e.g. climate and rocks.
2. WIth reference to three of the main ecosystems:
   a) The main environmental factors are:
   - Desert: poor soil, low nutrients, high light. low water
   - Woodland: usually hot, dry conditions, relatively low nutrients
   - Rock platform: wave action, sometimes submerged in seawater, high salinity

   b) The main producers include:
   - Desert: spinifex grasses, low shrubs, some trees
   - Woodland: gum trees, shrubs, mallee, acacias, banksias
   - Rock platform: algae, phytoplankton
3. Suggestions are:
   a) abiotic: water availability, nutrients, shelter, light
   b) biotic; predators e.g. birds, main producers; e.g. grasses/trees, decomposers; fungi and bacteria
4. Suggestions are as follows:

Ecosystem	**Important environmental factors determining the community**	**Examples of typical animals and plants in the community**
Desert/Grassland	Low rainfall, high temperatures	Saltbush, lizards, snakes, birds
Mallee	Low nutrients, low rainfall, high temp.	Mallee trees, grasses, insects, kangaroos
Savanna woodland	Low rainfall	Eucalypt, birds, reptiles
Rainforest	High rainfall, low nutrient, variable light	Large trees, shrubs, birds
Mangrove	High salinity	Mangroves, crabs, small fish

5. Regarding sclerophyll plants:
   a) The term refers to plants such as Eucalyptus that have hard, often leaves with waxy cuticle.
   b) The important factors include high temperatures and low water availability.
6. Three separate zones can be observed; supra-littoral, intertidal and sub-littoral. The environmental conditions vary from hot, high salinity to constant wave action and then under seawater with low light intensity and high viscosity. Different organisms live in different zones.
7. With respect to ocean depth:
   a) Examples of environmental factors are:
   - Temperature; higher at surface, colder at depths. Surface water may warm slightly with sunlight.
   - Light; more light in surface layers compared with lower levels. Light does not penetrate to great depths.
   - Pressure; increase at greater depths because there is a greater volume of water above resulting in greater force per unit area.

   b) Choosing light intensity: photosynthetic organisms may only survive in the upper layers, some algae may have different coloured pigments.

8. With reference to the data table:
   a) Environmental gradients include:
   - salinity; an increase in salinity from the sea to Pool A
   - temperature; the temperature increases from the sea to Pool A
   - oxygen levels; a decrease in oxygen from the sea to Pool A

   b) Regarding salinity:
   - At high tide and with wave action, sea water splashes into the pools of the supra-littoral zone (solute is 34 g/L). At lower tide and with high temperatures, water evaporates from the pools increasing the solute concentration.
   - The organisms need to cope with vast ranges of solute concentrations. An example is a barnacle that has strong valves that can close to prevent dehydration and keep out the water when it is too salty. Other organisms secrete salts.

   c) The pattern is that at high temperatures there is less oxygen. This is expected since the solubility of gases in water decreases as the temperature increases.
   d) Design an experiment where the independent variable is temperature and is controlled. An oxygen probe connected to a computer can then be used to measure the oxygen concentration at different temperatures and the data recorded in a table and possibly presented in a graph.
   e) There is not necessarily a right answer here. Students should choose several features and present a logical argument to justify their selections e.g. exposure to the Sun, high salinity, wave action.
9. Referring to *Figure 446*:
   a) Regarding these environmental factors:
   - Light: light intensity decreases from very high at the canopy to very low in the forest floor.
   - Temperature: drop in temperature from canopy to forest floor, light does not penetrate and light and heat are required for warming.
   - Humidity: humidity increases from canopy to forest floor. It is cooler at the forest floor and wetter with little evaporation, also more wind that the canopy level to increase evaporation.

   b) It is relatively easy for many organisms living on the forest floor, good availability of food and water and habitat provides shelter. Producers living in the canopy up higher have ample light and warmer temperatures for photosynthesis.
10. Regarding biodiversity:
    a) Species diversity refers to the variety of different species in an ecosystem whereas ecosystem diversity refers to the variety of different ecosystems that exist in a large area or possibly the whole planet.
    b) One relationship is that particular communities of organisms are usually found in specific ecosystems. Ecosystems provide the habitat and environmental conditions necessary for a variety of species to exist.
11. Comparing Desert and Rainforest ecosystems for example: the desert has very harsh environmental conditions e.g. low water availability, high light intensity, low nutrients and low humus. In a rainforest there is high water availability and lower light intensity on the forest floor. Overall much larger trees and greater biodiversity will be found in the rainforest. Only organisms with specific adaptations can survive in the desert ecosystem.

Chapter 4.5 Answers

1. Producers convert light energy into chemical energy through the process of photosynthesis. Consumers can feed on the organic matter.
2. The energy transformation is light energy → chemical energy. This chemical energy is stored in the bonds of organic molecules such as glucose.
3. Energy is transferred by heterotrophs feeding on, or consuming organisms from lower trophic levels.
4. Regarding energy transfer:
   a) Energy is lost as heat as it moves from one level to the next; a byproduct of cellular metabolism.
   b) Organisms use energy for their life processes; movement, reproduction
5. Carbon, water, nitrogen, phosphorus
6. Decomposers such as bacteria and fungi are important in the biogeochemical cycles; consuming and feeding on organic matter and converting the elements into different forms.
7. The processes are:
   a) aerobic respiration
   b) photosynthesis
8. It is taken in as nitrate.
9. With excess phosphate, some of this enters soils and aquatic environments. This excess may be taken up by plants and can lead to large increases in the growth of algae leading in turn to choking of waterways and causing algal blooms and/or eutrophication.
10. This occurs through metabolic reactions breaking down organic molecules, for example to provide energy. As a result of the breakdown, inorganic molecules e.g. CO_2 or nitrate are released.
11. As only about 10% of the energy is passed on to the next trophic level there is less and less energy available at high trophic levels. With less energy these trophic levels cannot be sustained.
12. Biogeochemical cycles involve the cycling of essential nutrients and water in ecosystems. They involve biological (biotic) and geochemical (abiotic) interactions to complete the cycles.
13. As decomposers are essential for nutrient and water recycling the consequences would be severe. Essential inorganic elements and water, necessary to sustain organisms would not be available and many organisms would suffer or die.
14. Energy is not recycled in an ecosystem whereas matter is. Energy is trapped and moves through the trophic levels, matter cycles between biotic and abiotic components.
15. Regarding the carbon cycle:
   a) the removal of trees, less photosynthesis and increased carbon dioxide levels
   b) burning releases CO_2 into the atmosphere again leading to increased CO_2 levels.
16. Wedge-tailed eagles are higher order consumers at high trophic levels and therefore there is not much energy to sustain a lot of these eagles.

Chapter 4.6 Answers

1. Regarding the ecological niche of a River Red gum:
   a) Examples include absorbing carbon dioxide, water and light for photosynthesis, supplies the atmosphere with oxygen, and absorbs light as well as water and nutrients from soil.
   b) Examples include provides food and shelter for insects, birds and lizards as well as competes with other plant populations for light, water and nutrients.
2. Suggestions include:
   - Shelter – warmth and to provide protection from predators.
   - Inorganic materials – depending on whether the organisms is an autotroph or heterotroph may need nitrate, sulphate, phosphate etc.
   - Light – energy source for autotrophs
3. Members of the same species require the same or very similar resources, therefore they compete for those same resources. Individuals from different species are likely to have somewhat different resources that they require.

4. Some species (keystone) are linked to the survival and structure of the whole ecosystem as they interact with many other species and these interactions determine the stability of most species. An example is the bettong whose digging and foraging released spores that are necessary to provide essential nutrients for autotrophs.
5. Regarding the sea otter case study:
   a) The niche of kelp includes providing a source of food for marine organisms, oxygen for them to use for aerobic respiration, and shelter.
   b) The food web with sea otters included relatively low numbers of sea urchins and large populations of kelp. Without sea otters the food web changed to include large numbers of sea urchins and much less kelp. Two species affected by this change included smaller fishes and invertebrates.
6. Regarding the niche overlap graph:
   a) The zone of overlap is where the niche of species is the same; for example, they compete for the same food.
   b) The larger the niche overlap, the more competition between the two species and the more unlikely it will be that the two species will survive in the same environment.
7. Regarding the statement:
   a) The fundamental niche of kangaroos is the range or distribution of them prior to the introduction of sheep. The realised niche of kangaroos is where they are located today.
   b) Examples include introduction of rabbits, human activities like clearing native vegetation to graze sheep, and shooting the kangaroos.
8. If the niches of two species are not sufficiently different competition between them for resources will be so intense one of them will end up being excluded from the habitat.
9. One suggestion is similar species of birds have a similar niche. Therefore, competition between them for resources is quite intense. By occupying different vertical layers up the tree competition between them is reduced.

Chapter 4.7 Answers

1. One example of short-term ecosystem change is change in the activity of populations of herbivores over a 24-hour period. This is mostly due to changes in light intensity and temperature that themselves are caused by the rotation of the Earth.
2. Succession is the change in the mix of species in an ecosystem. Fossil evidence collected from the same location shows this can and does happen over very long periods of time.
3. Regarding changing ecosystems:
   a) Established ecosystems start to change if something significantly alters their abiotic components; for example, a natural disaster like a bushfire or some kind of human activity like clearing of land for agriculture.
   b) In the case of a bushfire changes to the ecosystem include different levels of mineral nutrients in the soil and reduced competition between species. This might lead to the emergence of different populations of plant species. The establishment of these may in turn lead to the arrival of a variety of different populations of animal species.
4. Regarding primary succession:
   a) Autotrophic organisms colonise bare rock. Over time the remains of dead autotrophs contribute to the formation of a simple soil.
   b) Adaptations of autotrophs involved in primary succession might include spores resistant to high temperatures and very low amounts of water. It would be reasonable to expect germinated autotrophs to have small, tough leaves and very short to no stems.
5. Cyclone Yasi triggered secondary succession in far north-east Queensland by blowing down a lot of mature rainforest trees. This increased the intensity of light that could reach the rainforest floor and reduced competition between plants that survived. This allowed different populations of plants to grow in the area and changed to the mix of animal populations.
6. During the Ediacara period in parts of what is now Australia and Canada the abiotic components of marine ecosystems would have been very similar. As a result, they supported similar species of biota; for example, similar species of soft-bodied sponge-like organisms.

7. In the Tasmanian World Heritage Wilderness Area, the abiotic and biotic components of the ecosystems have remained largely unchanged for the last 40 million years. For succession to commence these must change significantly first.
8. Regarding succession:
    a) Small, herbaceous plants often grow in crevices in the rock. As this happens their root systems widen the crevices and the dead remains of them lead to the formation of a richer, deeper soil. While alive, the presence of them is a food source for colonising animal populations.
    b) Spinifex grasses grow in a sand dune. Their roots stabilise the upper surface of the sand dune and dead remains of them contributes to the production of richer, deeper soil. The presence of them while alive provides food and shelter for colonising animal species.
    c) Insects may burrow in the soil and thereby mix organic material with sand and gravel and build up the soil. They may also eat some of the leaves in the litter and assist in the recycling of nutrients.
9. Suggestions include:
    - Certain populations of plants species generally survive the initial ecosystem change.
    - Fire-resistant seeds and adaptations like epicormics buds permit rapid post-fire recovery.
    - Herbaceous plant seeds can quickly grow due to nutrient rich ash and less competition.
    - Rapid emergence of new plant species permits a speedy arrival of new animal species.
10. Regarding possible suggestions to explain observations about succession:
    a) Mature, stable ecosystems are long-lived. This means the mix of species they have has had a long period of time to emerge. Therefore, it is likely that a rich diversity of many different species and plant and animals will have become established.
    b) Ecosystems at a late stage of succession have a much greater biodiversity of species. This means they have many more species that are present to permit the ecosystem to function; in this case, to cycle essential nutrients and chemical elements.
    c) Autotrophs tend to be the first species to inhabit immature ecosystems – they trap the Sun's energy and provide food for the heterotrophs. As the ecosystem matures there is now sufficient food and shelter for the heterotrophs who will appear and start to occupy their various niches.

Chapter 4.8 Answers

1. Organisms belong to trophic levels and interact in a whole range of ways with other species, including competition, predation, symbiosis. Destroying or impacting on one species often disrupts the whole ecosystem.
2. Reasons to maintain natural vegetation include:
    a) it removes carbon dioxide from the air
    b) it contains producers which convert light energy into chemical energy (food) for animals
3. Habitat destruction is the main negative impact by humans. It is the living space for all other organisms and if destroyed, many species are negatively impacted by loss of food, shelter, interactions etc. as such, biodiversity is reduced.
4. Types of data include:
    a) temperature which is a good indication of climate change
    b) carbon dioxide levels in the atmosphere which result from deforestation and burning fossil fuels in particular
    c) the thickness of ice sheets; increased melting of ice is caused by climate change.
5. With regards to carbon dioxide:
    a) an increase in carbon dioxide gives rise to an increase in temperature
    b) this is the 'greenhouse effect', carbon dioxide is a greenhouse gas which prevents some of the heat energy from being radiated from the atmosphere back into space.

6. Effects on communities include:
   a) relocation of animals because of changing abiotic conditions e.g. water temperature
   b) change in breeding patterns and/or behaviour e.g. flowering time for plants and egg laying for animals
   c) changing growth rates of producers e.g. phytoplankton
7. Acidification can destroy the calcium carbonate that is in the shell or protective coating of many organisms e.g. coral, molluscs (sea snails)
8. An example is algae and it's proliferation in algal blooms. Likely to be caused by excess phosphate and/or nitrate flowing into aquatic environments.
9. Regarding lower oxygen levels:
   a) There are a number of such human activities; e.g. excess phosphate and nitrate from fertiliser could cause falls in oxygen levels leading to eutrophication. Eutrophication is when dead and decomposing organic material reduces light penetration, plant growth and oxygen levels due to the action of decomposers.
   b) As this is a very unhealthy ecosystem, lack of oxygen causes death of many species and therefore loss of biodiversity.
10. As the rate of these extinctions is so high compared to past history, there is a greater loss of biodiversity and impacts on many natural ecosystems.
11. There are normally more pests and parasites in agricultural ecosystems because of a lack of natural predators. In addition most agricultural ecosystems are monocultures where there is a lack of biodiversity.
12. Ultimately with more fertilisers and irrigation the costs associated rise dramatically and cannot be easily financed. Also this would impact on the carbon footprint because of the increased use of fertilisers and irrigation.
13. With reference to *figure 487*:
    a) the higher the carbon dioxide levels, the lower the pH. This occurs because when carbon dioxide dissolves in water it forms a weak acid.
    b) Figures are given beyond the present time (2016-2100). These are therefore based on previous data and predictions.
    c) Scientists can use the data to predict what this lower pH would do to oceans and their organisms. This points to the need for lowering atmospheric carbon dioxide levels and therefore slowing the acidification process.
14. If some plants compete more effectively than others, they will increase in number. This may cause some plants to thrive and others to die, thereby decreasing biodiversity.
15. It is more energy efficient to eat plants and plant products because when meat is eaten it is from an organism at a higher trophic level that requires much more energy to sustain life's processes. Recall that there is normally a 90% loss of energy between trophic levels.
16. This is a personal response, however such things could include:
    a) Walking or cycling to schools or shops rather than using a bus or car
    b) Eating more vegetable and less meat
    c) Turning off lights and appliances when not using them
    d) Wearing more clothes in winter instead of burning fuels (directly or indirectly) to keep warm
    e) Using LED light bulbs instead of incandescent
    f) Using less devices with batteries and/or use rechargeable batteries

Introduction

The Laboratory Notes are suggested, particularly for use by Teachers and Laboratory technicians, and again are advisory and not intended to be either comprehensive or exclusive.

SIS 4.1 Laboratory Notes

This activity provides an opportunity to experience a dry-sclerophyll woodland ecosystem and observe some of the populations that make up its community.

- Prior to visiting the woodland, the Biology teacher should have obtained approval, and completed necessary excursion forms. This also applies if students walk from school to an appropriate site.
- Students should have been forewarned by the Biology teacher of the potential for the visit to trigger hay-fever, asthma or related responses. In the environment visited, and depending on the time of year, there may be the added risks of other environmental hazards e.g. sunburn, and stings/bites from bees, hopper ants, and snakes. The risk assessment for the visit should include these hazards as well as make clear appropriate action, especially for those students with severe allergies to bees and hopper ants.
- The Biology teacher will have checked procedures detailing other excursion considerations, and items that should accompany the group e.g. school phone, first aid kit, student medications.
- A good resource to use to identify a suitable woodland is the 2009 work by Todd Berkinshaw:

Berkinshaw, T. 2009. Mangroves to Mallee: The Complete guide to the Vegetation of Temperate South Australia. Greening Australia. Adelaide. Descriptive detail in the above resource for Messmate Stringybark Woodland may be found on p. 66 and 67.

- The Biology teacher will have checked policies regarding student use of mobile phone cameras to record observations e.g. should students take photos that include other students in the photo.
- Student can be introduced to the main plants species typical of this type of community prior to the visit in a variety of ways.
- The webiste in the green box below may be useful. Once in the website, scroll down to Resources and then look for the links listed under Plants and Fungi. Located here are excellent PDF photo documents that display the plants typical in the ground, shrub and tree layer in Grey box woodland, Mallee box woodland and Manna gum woodland. Included in this collection is Stringybark forest which is a good example of the type of dry-sclerophyll woodland the activity is based on.
- Also included in the website is excellent material on birds including a resource called ‘Birds of a Stringybark forest’.
- The Biology teacher will have advised students of an appropriate Conditions of a visit to a Woodland Community Policy. Such a policy should include the following elements:
  - Keep to the path/road at all times.
  - Keep noise to a minimum.
  - Do not pick any flowers or other samples of the plant populations.
  - Do not try to eat any plant material e.g. wild fruit.
  - Do not capture or harm any of the invertebrates or other animals encountered.
  - Leave the community as you entered it e.g. do not leave any litter of any kind.

Helpful Online RESOURCE about the Mt Lofty Ranges

As a start, consult the Natural Resources Adelaide and Mt Lofy Ranges website; access this by using the link below or scan the QR code:

<http://www.naturalresources.sa.gov.au/adelaidemtloftyranges/educate/for-educators/plants-and-animals>

SIS 4.2 Laboratory Notes

This activity provides an opportunity to observe structural features associated with a wide range of animals and to use a dichotomous key.

Method

- Collections of resin embedded specimens of arthropods and/or other animals are suitable to use for this activity. These may be obtained from the usual Educational Science suppliers – see the list at the end of these Appendices.
- Pre-prepared high quality laminated pictures with sufficient necessary detail, and in colour could also be used if needed.
- If students are visiting a zoo/wildlife park, the Biology teacher will have obtained approval, and completed necessary excursion forms.
- Students should have been forewarned by the Biology teacher of the potential for the above visit to trigger hay-fever, asthma or related responses. The risk assessment for the visit should include these hazards as well as make clear appropriate action.
- The Biology teacher will have checked procedures detailing other excursion considerations, and items that should accompany the group e.g. school phone, first aid kit, student medications.
- Note: Specimen 6 in the table provided is a sponge (Porifera) and specimen 9 is a mite (Arthropoda)

SIS 4.3 Laboratory Notes

The DVD *Wild Australasia* may be purchased ($20) from ABC shop online: <https.shop.abc.net.au>

It can also be accessed via Clickview. If *Wild Australasia* is not already on your school accessible system, it can be easily added. Speak to your Resource Centre/Library Staff.

SIS 4.4 Laboratory Notes

This activity provides an opportunity to investigate biological sampling techniques to estimate numbers in a population.

The capture/recapture method

- Use the flatter style of toothpick that has a point at one end and is flat and wider at the other. Alternatively use match sticks. These may be obtained from the usual Educational Science suppliers – see the list at the end of these Laboratory Notes.
- An oval, or similar area, needs to be selected to be able to spread around 1,000 plain toothpicks. It is best if they are semi-camouflaged, and spread fairly evenly, not in large clumps.
- After students have done their tally, spread out the marked toothpicks as above.
- The Biology teacher will have advised students of the following formula to use to estimate the size of the of population:

$$\text{Estimated populations size} = \frac{\text{Number of toothpicks caught in the first capture} \times \text{Number of toothpicks caught in the second capture}}{\text{Number of marked toothpicks caught in the second capture}}$$

- As this activity needs to be conducted outside, students should have been forewarned by the Biology teacher about possible hay-fever, asthma or related responses. The risk assessment for the activity should include these hazards as well as make clear appropriate action.
- This technique should only be used with animals at the Teacher's direction.

The quadrat method

- Make available a quadrat that is 50cm x 50cm square – one of these can be placed by a group of students four times to investigate a 100cm x 100cm area.
- If possible, organise to prefabricate enough 50cm x 50cm quadrats for each group to have a bundle of four. Ideally ensure the quadrats can be pinned down with plastic stakes or tent pegs.
- One way to prefabricate suitable quadrats is to use light weight galvanized steel mesh with mesh size of 10cm x 10cm. The mesh can be cut to produce a square of 50cm x 50cm grid, ensuring there is no overhanging wire. This can then be coated with a zinc spray, to prevent corrosion The materials can be accessed from Steel Supply businesses, or possibly large hardware outlets.
- An alternative is to use 2-2.5 cm diameter PVC pipe, 4 compatible PVC elbow joints, and fluoro coloured bricklayer's string, all available at hardware outlets. The pipe can be cut to allow for the elbow joints and the width of the pipe thus creating an internal area of 50cm x 50cm. The pipe can be marked at 10cm intervals and small holes drilled to pass through both sides of the pipe. A grid can then be produced by threading the frame with the brightly coloured string.
- It may be possible to have Property Maintenance staff make the quadrats up.
- If a location off-site is used, the Biology teacher will have obtained approval, and completed necessary excursion forms. This also applies if students walk from school to an appropriate site.
- Students should have been forewarned by the Biology teacher of the potential for the activity to trigger hay-fever, asthma or related responses. In the environment visited, and depending on the time of year, there may be added risks of other environmental hazards e.g. sunburn, and stings/ bites from bees, hopper ants, and snakes. The risk assessment for the activity should include these hazards as well as make clear appropriate action, especially for those students with severe allergies to bees and hopper ants.
- The Biology teacher will have checked procedures detailing other considerations that must be made, and items that should accompany the group, e.g. phone, first aid kit, student medications.
- If a beach location is selected, the Biology teacher will have assessed the risk of other hazards.

Suppliers catering for Educational Science equipment include:

Livingstone International School Science <www.livingstone.com.au>

Omega Scientific Pty Ltd <www.omegascientific.com.au>

Southern Biological <www.southernbiological.com.au>

Westlab <www.westlab.com.au>

Serrata Pty Ltd <www.serrata.com.au>

Haines Educational <www.haines.com.au>

TOPIC 4 Test Yourself

Answer all of the questions in the spaces provided. The number of marks for each question is shown in brackets. Answers are suggested for all questions at the end of the test. Note that they are not intended to be the only possible answers. Read these carefully after the test and use them as part of an assessment for learning activity.

1. Organisms within a community interact with one another. In the question that follows, which term best describes the interaction described below.

   In this type of interaction generally one species benefits whilst the other is unharmed.

   J Parasitism

   K Commensalism

   L Mutualism

   M Predation

2. Which one of the following correctly matches a type of reproductive isolating mechanism and an example that illustrates this particular type.

	Isolating mechanism	**Example**
J	Pre-zygotic	Different courtship rituals
K	Post-zygotic	Differences in the shape of flowers
L	Pre-zygotic	Infertile offspring
M	Post-zygotic	The inability of sperm to survive in the female reproductive tract

3. Which one of the following best describes a situation in which members of a species are likely to be less well adapted over time in their ecosystem?

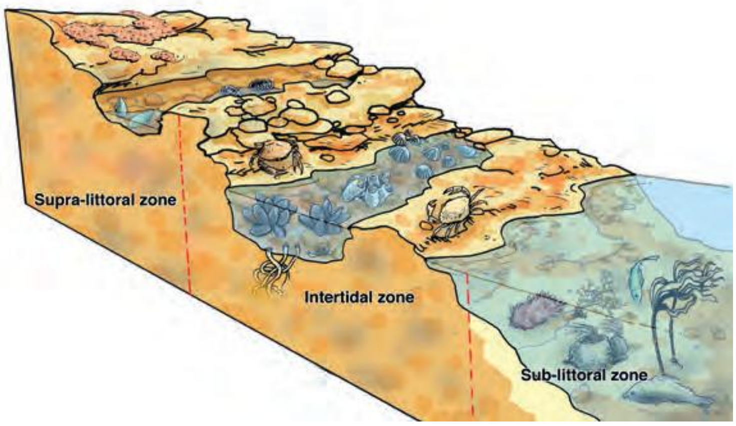
   J Some members of the species are killed in a bushfire.

   K There are changing environmental conditions.

   L Other populations in the ecosystem compete with the species for resources.

   M Some members of the species die before reaching reproductive age.

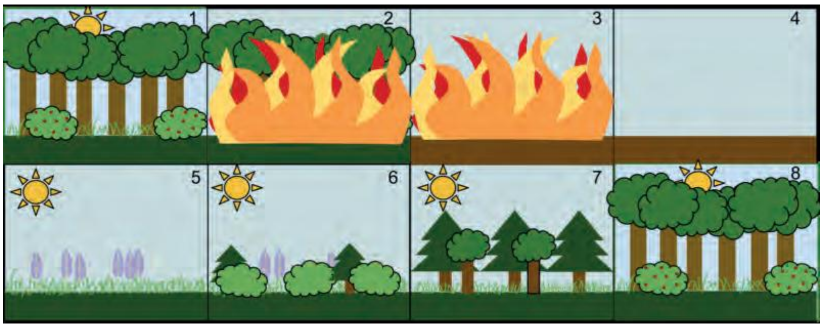
4. *Refer to the diagram below to answer the question that follows.*



Which one of the following is most likely to represent the abiotic conditions influencing the type of community found in the 'sub-littoral' zone compared to the 'supra-littoral' zone?

	Temperature	Oxygen levels	Light
J	Relatively stable	High	High daytime
K	Fluctuating	Low	Reduced
L	Fluctuating	High	High daytime
M	Relatively stable	Low	Reduced

5. *Refer to the numbered diagrams below representing succession in a forest.*



Which one of the following statements is most likely to be correct?

The diagram represents an example of:

J Primary succession with new species colonising the area in *figure 5*.

K Secondary succession where new producers colonise simple soil.

L Primary succession where a mature ecosystem has undergone an extreme event such as a bushfire.

M Secondary succession where a previously mature ecosystem has been destroyed.

6. *Refer to the diagram below showing coral bleaching to answer the question that follows:*

Coral bleaching occurs when coral animals (polyps) expel coloured algae often due to environmental stress. Under ideal conditions the two species, algae and polyp, live together in a symbiotic relationship. Which one of the following statements most likely could lead to coral bleaching as a result of human activities?

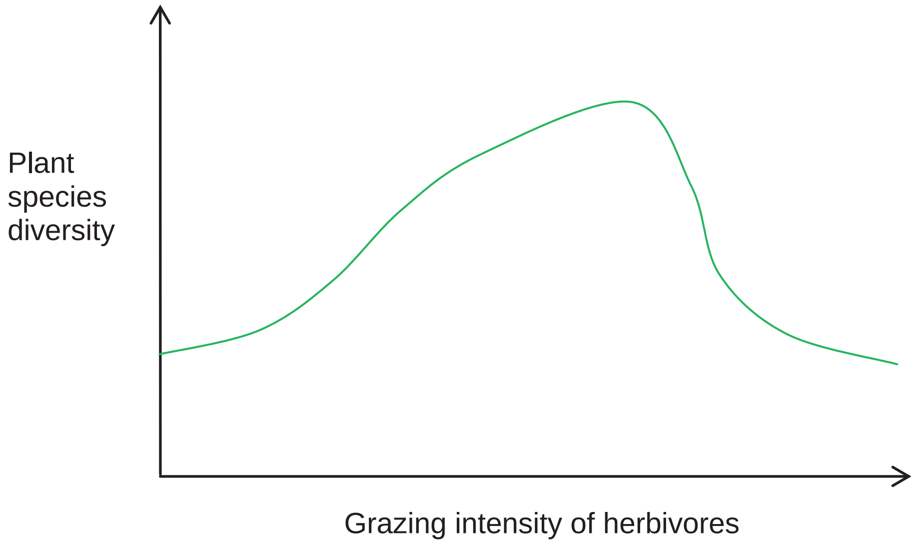
J warming of the oceans

K cooling of the oceans

L an increase in pH levels of the oceans

M rising sea levels

7. *Refer to the graph below which shows the relationship between plant species diversity and grazing intensity by herbivores.*



a) Describe the pattern of results as indicated in the graph.

(2 marks)

b) Describe a possible reason why the increasing amount of grazing may lead to a change in the plant species diversity.

(2 marks)

8. *Refer to the following incomplete table below to answer the questions that follow.* The table shows five different species of plant and some of their hierarchy of classification.

Species	Class	Family	Genus	Species
A	Angiospermae	Proteaceae	Grevillea	robusta
B	Angiospermae	Myrtaceae	Eucalyptus	robusta
C	Angiospermae		Callistemon	citrinus
D			Callistemon	pallidus
E			Adiantum	cunninghamii

a) Using the binomial system of naming, give the scientific name for species B.

(1 mark)

b) From the table, which two plants are mostly related?

(1 mark)

c) From the hierarchy of classification, two higher levels (Kingdom and Phylum) are not included in this table. Name the other level of classification that is missing from the table.

(1 mark)

d) Different species of plant remain reproductively isolated. Describe a method that is used by plants to ensure they remain reproductively isolated and therefore as separate species.

(2 marks)

9. *Refer to the table below showing data collected from two animals living in their natural habitat.* The data relates to methods that the animals use to (a) gain water and (b) lose water.

	Animal A	**Animal B**
Method used to gain water	*mL/day*	*mL/day*
Drinking	0	750
Food	10	225
Metabolic reactions	42	72
Methods of water loss	*mL/day*	*mL/day*
Evaporation	35	250
Urine	14	629
Faeces	3	166

a) Select and explain one piece of evidence that suggests that Animal A is from a drier environment compared to Animal B.

(3 marks)

b) What do you notice about water gained compared to water lost for each animal? Explain the likely reason for this observation.

(3 marks)

c) Organisms have adaptations that enable them to survive dry environments. Name one adaptation in each of the categories below.

Structural

(1 marks

Behavioural

(1 mark)

Physiological

(1 mark)

Science Inquiry Skills

10. *Refer to the data table below, collected during an investigation into the growth of a particular cereal crop.*

	Mineral nutrient levels (arbitrary units)		Cereal crop density kg m^{-2}
Trial	Nitrate	Sulfate	
1	50	25	0.37
2	50	50	0.43
3	100	25	0.62
4	100	50	0.70
5	100	100	0.72
6	200	25	0.47

The problem being investigated was nutrient levels and their impact on the density of the cereal crop. In deconstructing the problem, scientists decided to investigate the effect of varying both nitrate and sulfate levels.

a) Write an investigable question that might have been used to guide this particular investigation.

(2 marks)

b) State one possible conclusion, based on the above data, about the impact of nitrate and sulfate levels on the growth of the crop.

(2 marks)

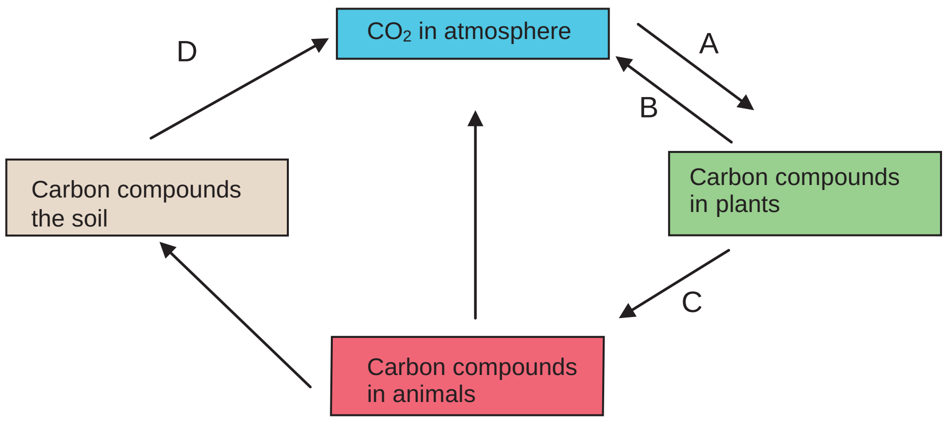
c) Suggest one possible improvement to the design of the experiment, giving a reason for your suggestion.

(3 marks)

d) Name one biotic component that might also affect the growth of the cereal crop and indicate a likely impact.

(2 marks)

11. *Refer to the diagram below of part of the carbon cycle.*



a) Name the chemical reaction or metabolic process labelled:

A ____

(1 mark)

B ____

(1 mark)

C ____

(1 mark)

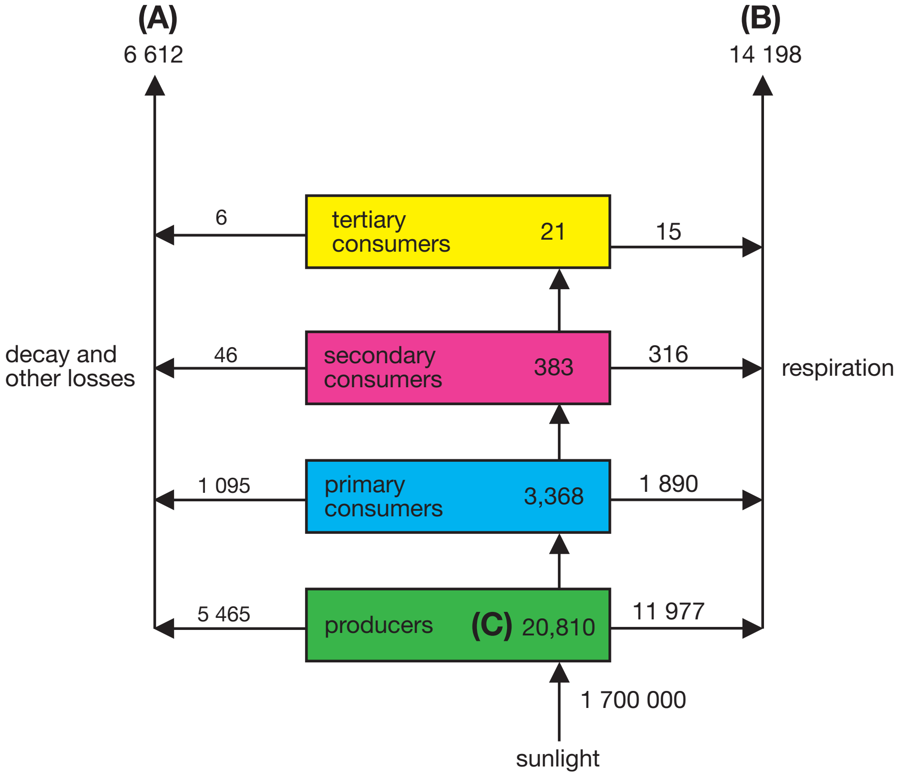
b) Name the group of organisms responsible for the process labelled D.

____

____

(1 mark)

12. *Refer to the diagram below showing energy flow through an ecosystem.* The units are in KJ/m²/yr.



a) Explain why most natural ecosystems cannot support any more than about three or four trophic levels.

(2 marks)

b) Only about 10% of the energy trapped by producers is transferred to the primary consumers. Outline the main reasons for this observation.

(3 marks)

13. *Use the information below to help you answer the questions that follow.*

The Tasmanian bettong is a native marsupial that plays a very important role in its ecosystem. The animals are noted for their foraging and digging, activities which have very beneficial effects on the soil, water and dissolved mineral nutrients. The actions of the bettong increase the soil's capacity to hold and absorb water, and disperse the spores of fungi. The fungal spores are a main food source for the bettong and the actions of the marsupial release and dispense spores throughout the habitat. Plants such as eucalypts and acacias form mutualistic relationships with the fungi which are essential for these plants in obtaining mineral nutrients from the soil in a form that they can use.

a) The bettong can be considered to be a 'keystone species'. Illustrate your understanding of this concept with reference to the bettong.

(3 marks)

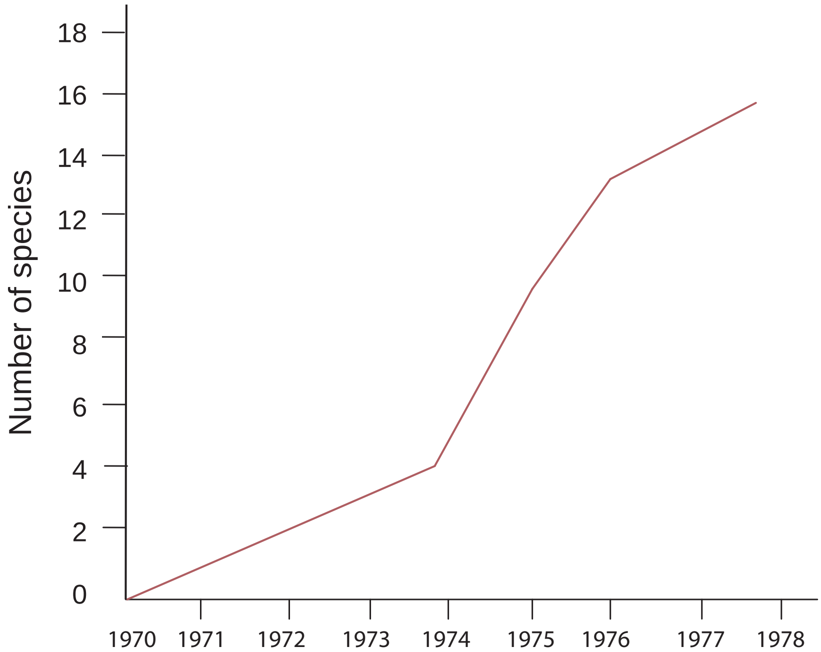
b) Describe the 'ecological niche' of the bettong.

(2 marks)

c) The Tasmanian bettong is considered extinct on the mainland of Australia. In attempts to re-colonise the bettong on the mainland, individuals were sourced from a range of different areas in Tasmania. Explain how sourcing the bettongs from different areas may increase the ability of the relocated population to survive on the mainland.

(3 marks)

14. *Refer to the graph below showing the number of species found on an island immediately following, and for eight years after, a volcanic eruption in 1970.*



a) State the name of the process occurring on the island ecosystem over this nine year period.

____

(1 mark)

b) Name two abiotic components of the habitat that would be challenging for any species trying to colonise the new area.

(i) ____

(ii) ____

(2 marks)

c) Describe an adaptation that one of the early colonisers of the island may have required to survive, explaining the reasons for your choice.

____

____

____

____

____

(2 marks)

15. The Southern bent-wing bat (see pic) is an endangered species in Australia with over 67% of its numbers lost in the last two decades. The remaining populations are prominent in the Naracoorte caves in the south east of South Australia. Human activities including destruction of habitat, use of pesticides and disruption of roosting habits have contributed largely to their decline.

Measuring key aspects of the ecosystem can be useful in making predictions relating to the impact of environmental change.

- Give two examples of such key aspects and describe how such knowledge may assist in protecting the species.
- Describe two strategies that may assist in the recovery of this species over time.

(6 marks)

16. Refer to the table below which compares several components in two lakes over a period of time.

Lake 1 is a natural, unpolluted lake whereas Lake 2 has been polluted by the addition of fertiliser from a farm.

Component being compared	Lake 1	Lake 2
Nitrate concentration (mg/L)	0.05	0.25
Chlorophyll concentration (μg/L)	3.6	9.4
Light penetration (metres)	4.2	1.8
Oxygen used in lower levels (mg/L/day)	3.8	5.6

a) Explain the likely reason for the high concentration of chlorophyll in Lake 2.

(2 marks)

b) Explain why more oxygen would have been used in the lower levels of Lake 2 when compared to Lake 1.

(2 marks)

Assessment Key

Assessment Design Criteria	Questions where this could be assessed
IAE1	10a
IAE2	-
IAE3	7a, b, 9a, b, 10b
IAE4	10c
KA1	1, 2, 3, 6, 8a-d, 9c, 14a, 16a, 16b
KA2	4, 5, 10d, 11a, b, 12a, b, 13a-c, 14b, 14c
KA3	-
KA4	15

Topic 4 Test Yourself - Suggested answers

These answers for each part of each question provided here are suggestions. They are not intended to be the only answer. Read and use them carefully to self-assess your performance in the test. Consider asking someone in your class to peer-assess them as well, then discuss. Make notes of errors for future reference and seek the assistance of your teacher as required.

1. K 2. J 3. K 4. M 5. M 6. J

7. With reference to the graph:
   a) Plant species diversity increases as the grazing intensity increases from a low to moderate level. At high levels of grazing, plant species diversity falls rapidly.
   b) At moderate levels of grazing, it is possible that the numbers of an aggressive species are reduced allowing more species to compete and thrive. At high levels of grazing it is more likely that the herbivores are feeding on more and varied species drastically reducing diversity.
8. With reference to the table:
   a) *Eucalyptus robusta*
   b) C and D
   c) Angiospermae
   d) Order
   e) The two separate species may flower in different seasons or at different times of the year. This would ensure that cross-pollination could not occur and therefore reproductive isolation would be maintained.
9. Referring to the data table:
   a) Animal A loses considerably less water by all methods compared to animal B. This may suggest animal A lives in a drier environment and has evolved strategies to minimise water loss.
   b) They are almost identical for each animal. This is necessary as if one value exceeded the other for an extended period of time, the animal would either gain water or lose water. Water balance is critical for survival and transport of solvents throughout the body.
   c) Examples of adaptations include:
   - Large ears-radiate heat more away from the body in shade or cooler conditions.
   - Nocturnal-only feeding at night avoiding the hot sun during the day.
   - Excreting very little moisture in the body waste and thereby conserving water.
10. With reference to the data table:
   a) The levels of nitrate and sulfate are both equally as important in determining cereal crop density.
   b) It appears that the concentration of nitrate is more important to cereal growth than sulfate.
   c) The experimental design did provide some useful data, particularly at concentrations up to 100 units with nitrate. However there are limitations to any conclusions. Perhaps the following may provide more data: 200 nitrate, 100 sulfate. Also, increasing sulfate levels to 100/200 units could provide some more useful information.
   d) A biotic component could be weeds or grasses competing for water. This factor would reduce the size of the cereal crop and yield.
11. With reference to the diagram:
   a) The reactions and processes are:
   - photosynthesis
   - aerobic respiration
   - feeding/eating by herbivores.
   b) Decomposers e.g. bacteria and fungi
   c) One way is by humans burning fossil fuels e.g. carbon trapped in organic matter in coal, oil etc. This releases large amounts of carbon dioxide into the atmosphere and is causing global warming and climate change.

12. With reference to the diagram:
    a) Higher trophic levels require energy to survive, they obtain this energy from the trophic level below them which they feed on. As only about 10% of the energy trapped by trophic level is passed on, there is not enough energy to support more trophic levels.
    b) Organisms all require energy for such processes as growth, reproduction, synthesis of organic molecules and movement. Also, energy trapped by producers is converted into chemical bonds in organic molecules e.g. carbohydrates, proteins and lipids which make up the structural matter for their tissues. Energy is also lost as heat between each trophic level.
13. Regarding the Tasmanian bettong:
    a) A keystone species is one which is a very important species for the ecosystem, without which, many of the other species may perish. As indicated above, the actions of the bettong are fundamental, through fungi, in providing nutrients for the producers which are the first trophic level.
    b) The ecological niche includes both biotic and abiotic interactions and factors. The main abiotic factor is the soil which is a source of fungal spores. The fungal spores and trees e.g. eucalyptus and acacias are important biotic factors.
    c) Sourcing from different areas is likely to introduce individuals with different genetic make up. This adds genetic diversity to the gene pool and populations that possess this diversity are more robust and likely to survive a range of environmental challenges.
14. With reference to the graph:
    a) Succession (assuming no human intervention)
    b) Such abiotic features include:
    - Lack of suitable soil substrate for producers.
    - Lack of moisture on rough dry rock surfaces.
    c) Possessing the ability to establish a strong hold on a rock surface and withstand the extremes of dehydration. An example could be lichen; secreting acids to break down the rock surface and living in association with fungi which can withstand long periods with no moisture.
15. *Note that although notes have been provided as a guide, your answer requires paragraphs.*

- Examples include
    a) Identify habitat preferences by collecting data regarding preferred dietary requirements, nesting sites, reproductive patterns. Identify habitats and organisms that provide for their requirements.
    b) Make predictions about the sustainability of the population based on their requirements being met in habitats surrounding the caves.
    c) Measure data from blood samples regarding pesticide accumulation, monitor known and unknown outcomes of poisoning.
- Strategies include
    a) Revegetation and/or relocation programs.
    b Working with a range of organisations regarding pesticide reduction and developing alternatives.
    c) Working to increase productivity in already cleared land so that further habitat destruction is prevented

16. With reference to the table:
    a) High levels of nitrate, which is a mineral nutrient required and used by algae and phytoplankton growing in the lake. As the plant material multiplies it will produce chlorophyll as its photosynthetic pigment. All these types of organisms carry out photosynthesis using chlorophyll, so increases in the numbers of them (due to an algal bloom) will lead to a higher concentration of chlorophyll in this lake.
    b) Oxygen is used by organisms that are carrying out the process of aerobic respiration. In the lower levels of the lake these organisms are most likely to be decomposers, feeding on the increased numbers of plants, algae and phytoplankton which die and provide organic matter for them.

Appendix

Section		Page

Capabilities Summary

Topic 1: Cells and Microorganisms

Chapter	Literacy	Numeracy	ICT Capability	Critical and Creative Thinking	Personal and Social Capability	Ethical Understanding	Intercultural Understanding
1.1 **Living things consist of cells**	Cell types Extracting biological information presented in a variety of modes	SIS 1.1 Estimating the diameter of field of view					
1.2 **Two major types of cells**		SIS 1.2 Estimating the size of cells			SIS 1.2 Taking initiative while working independently and collaboratively		
1.3 **Cell division**			My Skin Track UV Using technologies to create new ways to monitor and track exposure to UV light				
1.4 **Cell requirements**							
1.5 **The cell membrane**	Practical activity Critically analysing and evaluating primary and secondary data	Practical activity Carry out an experiment to collect measurable evidence to form and justify a conclusion			Practical activity Managing time, following procedures effectively, and working safely		
1.6 **The importance of microorganisms**	Membrane model Interpreting the work of scientists across disciplines using biological knowledge			Microbial fingerprinting Devising imaginative solutions and making reasonable predictions	Food hygiene Understanding the importance of biological knowledge on health and wellbeing		
1.7 **Microorganisms and food**	Preserving food Communicating appropriately for specific purposes and audiences				Topic 1 test Seeking, valuing and acting on feedback		The world's first bread Being open-minded and receptive to change in light of scientific thinking based on new information

Capabilities Summary   Topic 2: Infectious Disease

Chapter	Literacy	Numeracy	ICT Capability	Critical and Creative Thinking	Personal and Social Capability	Ethical Understanding	Intercultural Understanding
2.1 **Different types of disease**							
2.2 **Disease transmission**	SHE 2.2 Interpreting the work of scientists across disciplines, using biological knowledge	SIS 2.2 Using data collected from a simulation to assess transmission of a pathogen			Disease Understanding the importance of biological knowledge on health and wellbeing		
2.3 **Epidemics and other health issues**		Epidemics Interpreting tables of data and graphs about the onset and spread of epidemics				No jab no play Recognising the importance of participation in social and political decision-making	
2.4 **Disease control**	Controlling disease Using a range of communication formats to express ideas logically and fluently			Dengue wipe out Recognising the significance of creative thinking on developing biological applications	Containing flu Sharing and discussing ideas about biological issues		
2.5 **Adaptations of pathogens**							
2.6 **Physical barriers to disease**	Physical barriers Extracting biological information presented in a variety of modes						
2.7 **The innate immune system**			Wireless wounds Understanding the impact of ICT on biology and its applications in society				
2.8 **The adaptive immune system**					Topic 2 test Seeking, valuing and acting on feedback		Drone delivery of vaccines Understanding that the progress of biology influences and is influenced by cultural factors

Capabilities Summary

Topic 3: Multicellular Organisms

Chapter	Literacy	Numeracy	ICT Capability	Critical and Creative Thinking	Personal and Social Capability	Ethical Understanding	Intercultural Understanding
3.1 **Cell differentiation**	Gene expression Extracting biological information presented in a variety of modes						
3.2 **The organisation of multicellular organisms**						3D mini brains Making ethical decisions based on an understanding of biological principles	
3.3 **Exchange of materials with the environment**	SIS 3.3 Critically analysing and evaluating primary and secondary data	SIS 3.3 Carry out an experiment to collect measurable evidence to form and justify a conclusion			SIS 3.3 Managing time, following procedures effectively, and working safely		
3.4 **Gas exchange in plants**		SIS 3.4 Estimating the density of stomates in leaves					
3.5 **The digestive system in animals**			Food labelling scanner Evaluating the application of ICT to provide more personalised nutrition		Intestines Understanding the importance of biological knowledge on health and wellbeing		
3.6 **The excretory system in animals**		Excretion Analysing data concerning the composition of blood and urine					Purple House Respecting and engaging with different cultural views and customs
3.7 **The circulatory system in animals**	Transport of blood Communicating appropriately for specific purposes and audiences			Tumour nanosensor Envisaging consequences and speculating on possible outcomes	Heart Understanding the importance of biological knowledge on health and wellbeing		
3.8 **Transport of materials in plants**		Transpiration Collecting, displaying and analysing data concerning factors affecting the rate of transpiration			Topic 3 test Seeking, valuing and acting on feedback		

Capabilities Summary

Topic 4: Biodiversity and Ecosystem Dynamics

Chapter	Literacy	Numeracy	ICT Capability	Critical and Creative Thinking	Personal and Social Capability	Ethical Understanding	Intercultural Understanding
4.1 **Biodiversity**					Feral cats Sharing and discussing ideas about biological issues		
4.2 **Biological classification**	Classification Extracting biological information presented in a variety of modes		Cyborg insects Using technologies to create new ways to collect data to help people				
4.3 **Adaptations**							
4.4 **Ecosystem diversity**	SIS 4.4 Critically analysing and evaluating primary and secondary data	SIS 4.4 Estimating the size of populations of animals or plants			SIS 4.4 Taking initiative while working independently and collaboratively		
4.5 **Energy and matter in an ecosystem**							
4.6 **Niche and keystone species**		Competition Interpreting niche overlap graphs					
4.7 **Ecosystems change over time**	Ecosystem change Using a range of communication formats to express ideas logically and fluently	Succession Using secondary data to investigate the effect of fire on an ecosystem					
4.8 **Human impact on ecosystems**	Global warming Synthesising evidence-based arguments	Climate change Using data to analyse and evaluate causes and effects of global warming			Topic 4 test Seeking, valuing and acting on feedback	Climate change Acknowledging the need protect and sustain the biosphere	

Important note to teachers and students: *the following pages are only intended as possible options and resources that may be helpful in teaching and assessing the SACE Stage 1 Biology course. The definitive documents are to be found on the SACE website: <https://www.sace.sa.edu.au/web/biology/stage-1/support-materials>*

Science Inquiry Skills (SIS)

Deconstructing a Problem

Introduction

A Problem is a question that is asked for consideration or inquiry. Problems may be raised because of direct observation or may be prompted by discussion or research.

The investigation of a Problem can take various forms. One is to employ scientific methods to collect data to formulate and justify a conclusion. This involves developing a valid procedure that uses scientific equipment, interpreting and analysing the results, and critically evaluating the evidence obtained in order to justify a conclusion.

The process used to determine the best way to investigate a problem is called Deconstruction. This involves breaking the problem down so that a range of aspects that could possibly affect the outcome of the Investigation can be explored, taken into account, and properly discussed. By Deconstructing a problem, the most appropriate procedure to use to investigate it can then be Designed, and conducted.

It is usual to start with a particular 'Problem', or 'Question'.

For example:

'Does the type of honey affect its antibacterial properties'?

One approach could be to consider questions such as those listed below.

- Research the different types of honey and what makes them different. Can they be classified into any groups?
- Research the types of antimicrobial agents or chemicals found in honey e.g. antioxidants or phenolic compounds.
- Explore the availability of different types of honey that you may wish to investigate e.g. what is Manuka honey?
- Explore the types of bacteria that could possibly be used and the safety requirements.
- Decide how you might make informed decisions about measuring the effect of the type of honey on bacterial growth.
- Explore the healing properties of honey e.g. for wounds, ulcers
- Do darker honey varieties have greater antimicrobial power than lighter varieties.
- Investigate the osmotic and pH effects of honey on microbial growth
- Investigate how to properly culture bacteria.

These and other such questions may be considered to be various 'aspects' related to the problem being considered.

- Brainstorm with others, to record questions and points whilst you consider options about formulating your ideas and what you might be able to test.
- Identify any constraints and other considerations with regard to your investigation.
- Also carefully address the healthy safety considerations.

Evidence of Deconstruction may be presented in a number of ways, for example: Notes, a Concept map, a Table, Answers to directed questions or aspects or some other way.

Once you have completed your Deconstruction you may proceed to the next phase which is 'Designing your own Investigation'. A proposed outline of one way of proceeding is included in this Appendix on the following pages.

Designing an Investigation

Introduction

An Investigation is a process that involves inquiry and exploration. Scientific investigation is the way scientists obtain evidence-based solutions to problems, or answers to questions about the world around us.

A scientific Investigation can be undertaken following an existing set of instructions, or one can be planned from the beginning and then carried out. The process used to put together and document an investigation of a problem is called Design. The Design of an investigation is best done following a process of Deconstruction.

To Design an Investigation of a Problem for which the outcome is uncertain, use the following headings and dot-points as a guide:

Justification

It is important to include a rationale or justification of the procedure based on theoretical and safety considerations, pre-trials and other factors that should be included. In other words, students must justify their plan of action. It is recommended that this can be done for each section using, for example, text boxes or a different colour font.

General

- Deconstruct the problem
- Provide justification of choices made in the Design using annotations or another method.

Variables

- Identify the independent variable (IV) to be explored and the dependent variable (DV).
- Make clear how the IV will be changed, and how many times.
- Include how the IV and DV will measured, and the units of measurement.
- List factors to be held constant, and describe how and why they need to be held constant.
- List factors that may not be able to be held constant or controlled, state why not, and consider the potential impact of this on the data/investigation.

Hypothesis

- Provide a hypothesis expressed with a single IV and DV as a … If … then … statement. This needs to relate to the purpose of the Investigation.

Equipment/materials

- List as dot points all of the equipment/materials required to carry out the investigation, including the quantities and volumes/concentrations as appropriate.

Procedure

- List as numbered steps how the investigation will be carried out.
- Make clear the type and amount of data to be collected e.g. qualitative data (descriptive), quantitative data (numerical), sample sizes, and averages.
- Detail how data will be collected that is reliable, and accurate.

Other considerations

- Include a blank table to show the data to be collected and recorded.
- Provide a description of the expected results.
- Identify safety and/or ethical risks, and describe how they will be managed.
- Include at the end of the Design an overall safety rating /10.

Evidence of Design may be presented in a number of ways. One example of a suggested layout that uses a combination of sub-headings and tables for different parts of the Design is shown below.

Your teacher will provide further direction about what is required.

Problem: ....

Variables

Independent variable ....

Dependent variable ....

Factors to be held constant

5 factors to be held constant	How the factors will be held constant	Why the factors need to be held constant

Factors that may not be able to be controlled

2 factors that cannot be controlled	Why the factors cannot be controlled	Potential effect on the data/ investigation

Hypothesis

....

....

Equipment/materials

....

....

Procedure

....

....

....

....

Safety and/or ethical risks

Safety risks	**Management**
Ethical risks	**Management**

Overall safety rating – circle

1 2 3 4 5 6 7 8 9 10

Science Inquiry Skills (SIS)

Part A: Writing a Practical Investigation Report

Introduction

An important way to study biology is through practical investigation. This may involve using science inquiry skills either to complete an experiment about a problem or Deconsructing a problem to Design a valid procedure to use to investigate the problem, then carrying it out.

There are a number of ways students can present a report of a practical investigation that includes an experiment and a Deconsruction with Design.

General

- One Design practical investigation report has a maximum word count of 1000 words. Only the Introduction, Analysis, Evaluation, and Conclusion are included in this word count.
- Appropriately acknowledge all sources of information in and at the end of the report.

Deconstruction and Design proposal

- Deconstruct a problem for which the outcome is uncertain and attach to the report evidence of the Deconstruction.
- Design of an investigation for which the outcome is uncertain and attach to the report a document that includes the variables, hypothesis, equipment/materials, procedure and ethical/safety risks.
- Provide evidence of Deconsruction and your method chosen
- Justify your plan of action

(Note: This section must be a maximum of 4 sides of an A4 page)

Introduction

- Present biological information/theory relevant to the investigation.

Purpose

- State the aim of the investigation.

Hypothesis

- State the hypothesis used in the experiment.

Results

- Display the results using tables and graphs.
- Support processed data using sample calculations.
- Ensure the format of the tables and graph is consistent with conventions regarding titles, headings, symbols and SI units, and use of significant figures.

Analysis

- Analyse the data to identify a trend or pattern (if any) and discuss the relationship between the independent and dependent variable using biological information/theory.

Evaluation

- Evaluate the procedure and data to identify sources of uncertainty, including sources of random and systematic errors, and factors that cannot be controlled.
- Assess the reliability, accuracy and validity of the results, by discussing sample size, precision, random error, systematic error, and factors that cannot be controlled.

Conclusion

- Form and justify a conclusion that relates to the hypothesis.
- Discuss the limitations of the conclusion based on the procedure and the results.

Part B: A sample Task Sheet for a Deconstruction and Design

Your teacher will provide you with a task sheet to use to prepare a report of a 'Design practical investigation' for summative assessment. Part of one (which has been adapted from SACE) is shown below for illustration.

A guide to approximately how many words for each section is given in brackets. The Purpose, Hypothesis, Results, Deconstruction, Design, and References sections are not in the word count. For the relevant Assessment Design Criteria see the Criteria column.

Note: the word count for Introduction, Discussion and Conclusion in Stage 1 is a maximum 1000 words.

Section	Evidence	Criteria
Deconstruct and Design proposal	An investigable question or hypothesis is formulated that relates to the purpose of the investigation. A method is designed that includes: • a list of all equipment required (with details of sizes and quantities), • describes how the independent variable is varied, • describes how the dependent variable is measured • states the number of trials to be conducted. • procedures to identify how to keep other factors constant • identification of factors that cannot be controlled • procedures to manage ethical and safety considerations. A rationale or justification for the details in the procedure, based on theoretical considerations, safety considerations, student pre-trials or other considerations, should be included. *Note: Evidence of Deconsruction outlining the Deconsruction process, the method chosen as most appropriate, and a justification of the plan of action, must be a maximum of 4 sides of an A4 page. This evidence must be attached to the practical report.*	IAE1
Introduction (~200 words)	• Explanation of relevant science concepts that relate specifically to the hypothesis. • The purpose of the experiment, the hypothesis or investigable question, the independent, dependent and controlled variables are identified.	KA1
Results	• Data is represented in appropriate formats. • Tables with relevant column headings and including units. • The number of significant figures used is appropriate. • Graphs with labelled axes (with units), appropriate scales, an appropriate size, and in a format to suit the type of data.	IAE2
Discussion (i.e. analysis and evaluation) (~600 words)	• Trends in the data are identified and an explanation of these trends in terms of relevant concepts is provided. • An evaluation of the experimental method and its effect on the data is included. • Sources of uncertainty, including random and systematic error, which could have affected the data, are identified and their significance on the validity and reliability of the data is discussed. • The effects of factors that cannot be kept constant on the data obtained are considered.	IAE3 IAE4
Conclusion (~200 words)	• Indicates whether the hypothesis is supported or rejected and states the overall trend indicated by the data. Reasoning based on the data for supporting or rejecting the hypothesis is provided. • Limitations of the conclusion may be discussed and recommendations based upon the conclusion can be made.	IAE3
Communica-tion	• The correct format for the structure of a report is used. • Information is communicated clearly. • Appropriate science terms, equations and conventions are used. • External references (if used) are acknowledged appropriately.	KA4

Science Investigation Skills Summary

Topic 1: Cells and Microorganisms

Chapter	IAE1	IAE2	IAE3	IAE4	KA4
1.1 **Living things consist of cells**		Viewing a specimen **SIS 1.1**	Analysis **SIS 1.1**		Questions **What have you learned?**
1.2 **Two major types of cells**		Observing cells **SIS 1.2**	Estimating sizes of cells **SIS 1.2**		
1.3 **Cell division**		Counting cells **SIS 1.3**	Analysis **SIS 1.3**		Questions **What have you learned?**
1.4 **Cell requirements**					
1.5 **The cell membrane**		Collect and display data **SIS 1.5**	Analysis and conclusion **SIS 1.5**	Evaluate the procedure **SIS 1.5**	Report on the experiment **SIS 1.5**
1.6 **The importance of microorganisms**					
1.7 **Microorganisms and food**	Deconstruction and Design				Questions **What have you learned?**

Topic 2: Infectious Disease

Chapter	IAE1	IAE2	IAE3	IAE4	KA4
2.1 **Different types of disease**			Analysis **SIS 2.1**		
2.2 **Disease transmission**		Performing the simulation **SIS 2.2**	Assessing transmission **SIS 2.2**		Questions **What have you learned?**
2.3 **Epidemics and other health issues**		Antibiotic resistance **SIS 2.3**	Questions **What have you learned?**		
2.4 **Disease control**					Questions **What have you learned?**
2.5 **Adaptations of pathogens**					
2.6 **Physical barriers to disease**		Antimicrobial substances **SIS 2.6**			Questions **What have you learned?**
2.7 **The innate immune system**					
2.8 **The adaptive immune system**	Deconstruction				Questions **What have you learned?**

Science Investigation Skills Summary

Topic 3: Multicellular Organisms

Chapter	IAE1	IAE2	IAE3	IAE4	KA4
3.1 **Cell differentiation**					
3.2 **The organisation of multicellular organisms**		Examine a daffodil flower **SIS 3.2**	Analysis **SIS 3.2**		Questions **What have you learned?**
3.3 **Exchange of materials with the environment**		Collect and display data **SIS 3.3**	Analysis and conclusion **SIS 3.3**	Evaluate the procedure **SIS 3.3**	
3.4 **Gas exchange in plants**		Examine stomata **SIS 3.4**			
3.5 **The digestive system in animals**			Testing starch digestion **SIS 3.5**		Questions **What have you learned?**
3.6 **The excretory system in animals**		Dissecting a kidney **SIS 3.6**			Questions **What have you learned?**
3.7 **The circulatory system in animals**		Dissecting a fish **SIS 3.7**	Analysis **SIS 3.7**		
3.8 **Transport of materials in plants**	Deconstruction and Design	Transport of water in plants **SIS 3.8**			Questions **What have you learned?**

Topic 4: Biodiversity and Ecosystem Dynamics

Chapter	IAE1	IAE2	IAE3	IAE4	KA4
4.1 **Biodiversity**		Describe the environment **SIS 4.1**	Analysis **SIS 4.1**		Questions **What have you learned?**
4.2 **Biological classification**		Using a dichotomous key			
4.3 **Adaptations**		Investigating an ecosystem (multimedia presentation)			Questions **What have you learned?**
4.4 **Ecosystem diversity**		Estimating population size **SIS 4.4**	Discussion and evaluation **SIS 4.4**	Discussion and evaluation **SIS 4.4**	Questions **What have you learned?**
4.5 **Energy and matter in an ecosystem**					Questions **What have you learned?**
4.6 **Niche and keystone species**		Ecosystem stability **SIS 4.6**			
4.7 **Ecosystems change over time**			Using secondary data **SIS 4.7**		Questions **What have you learned?**
4.8 **Human impact on ecosystems**	Deconstruction				A Case Study **Sustainable farming**

Science as a Human Endeavour (SHE)

Introduction

A new direction in biology is one that is unfolding now that includes an emerging technology or application of one. Reports of such developments are common in science magazines/journals as well as in the newspaper and electronic media.

There are a variety of ways to investigate the influence and impact of new directions in biology. One is to use them as contexts to illustrate how science is a product of human endeavour that influences and is influenced by society. By exploring science as a human endeavour, the way new directions in biology develop, influence and rely on systems of communication and collaboration become clear, as do applications and limitations of them.

Part A: About Science as a Human Endeavour

To appreciate better Science as a Human Endeavour, the Biology Subject Outline Stage 1 suggests looking for evidence of it in reports through four key concepts. These are:

Communication and Collaboration

- Science is a global enterprise that relies on clear communication, international conventions, and review and verification of results.
- Collaboration between scientists, governments, and other agencies is often required in scientific research and enterprise.

Development

- Development of complex scientific models and/or theories often requires a wide range of evidence from many sources and across disciplines.
- New technologies improve the efficiency of scientific procedures and data collection and analysis. This can reveal new evidence that may modify or replace models, theories, and processes.

Influence

- Advances in scientific understanding in one field can influence and be influenced by other areas of science, technology, engineering, and mathematics.
- The acceptance and use of scientific knowledge can be influenced by social, economic, cultural, and ethical considerations.

Application and Limitation

- Scientific knowledge, understanding, and inquiry can enable scientists to develop solutions, make discoveries, design action for sustainability, evaluate economic, social, cultural, and environmental impacts, offer valid explanations, and make reliable predictions.
- The use of scientific knowledge may have beneficial or unexpected consequences; this requires monitoring, assessment, and evaluation of risk, and provides opportunities for innovation.
- Science informs public debate and is in turn influenced by public debate; at times, there may be complex, unanticipated variables or insufficient data that may limit possible conclusions.

Useful sources of reports of new directions in biology include:

- Radio/TV announcements that are then located on a website (in text or oral format).
- Articles in scientific magazines (e.g. New Scientist).
- TED talks.
- Newspapers (in either print or digital format).

To investigate science as a human endeavour using a science magazine, use the following as a guide:

- Obtain a print copy of the magazine (school or other library) or access its website.
- Select a recent article that is a report about a new direction in biology.
- Read the article carefully and look for evidence of at least one key concept.
- Annotate the article to display evidence of your understanding of science as a human endeavour it provided.

Part B: Viewing a sample annotation of an article

One recent development in biology was reported in July 2018 in the *New Scientist* magazine. A section of an adapted version annotated to show parts of two key concepts is shown below.

Is a virus causing obesity?
Putting on weight may be catching, finds **Clare Wilson**

Weight gain may be contagious. Evidence is growing that people who are overweight may have a virus to blame. A new study shows for the first time that a virus called *adenovirus-36* is more often found in overweight people. We do not know yet how people catch the virus, but it may spread from person to person.

Nikhil Dhurandhar at Texas Tech University in the United States (US) with a team of scientists looked to see if people who are overweight are more likely to have antibodies (proteins made by white blood cells to kill viruses) to this virus. The Texas Tech team found that they did. Another US study reported that 30% of very overweight people had these antibodies – a clear sign that it had infected their bodies – compared with only 5% of those who were healthy in weight. Wilmore Webley at the US University of Massachusetts went a step further. His team searched for the virus itself in people and found that 81% of tissues samples taken from overweight women contained the virus, while just 19% of samples from healthy-weight women did – a big difference. The findings were presented at a conference of the American Society for Microbiology in Atlanta in the US state of Georgia.

Not everyone is convinced this proves virus-caused obesity. For Keith Godfrey at University Hospital in the United Kingdom (UK) city of Southampton, it may be that overweight people are just more vulnerable to catching this particular virus. However, Richard Atkinson at the University of Wisconsin-Madison in the US has helped to develop a vaccine to prevent infection by adenovirus-36. In very recently published work, the team he worked with demonstrated that the vaccine stopped mice from putting on weight after being exposed to the virus.

Comment [SR1]: Application and limitation
Scientific knowledge and understanding can enable scientists to make discoveries

Comment [SR2]: Communication and collaboration
Collaboration between scientists is required in scientific investigations

Comment [SR3]: Communication and collaboration
Science relies on clear communication

Comment [SR4]: Communication and collaboration
Science is a global enterprise that relies on review and verification of results

Part C: Doing a Science as a Human Endeavour investigation

There are a number of ways to use the key concepts to do a science as a human endeavour investigation. One example is shown below:

- Select a report about a new direction in biology in a science magazine, or another source.
- Make sure it provides evidence of at least one key concept.
- Annotate the report several times to display evidence of at least one key concept.
- Find other related reports to use to provide in-text reference support for the investigation.
- Keep a list of sources of information used in order for them to be properly acknowledged.

Part D: Preparing a formal Science as a Human Endeavour report

1. Use the work done in Part C to prepare a science as a human endeavour report using the new direction in biology you have investigated.
2. Your teacher will advise you of the appropriate format to use and the relevant Assessment Design Criteria.

Guidelines to help you prepare a formal Science as a Human Endeavour Investigation Report and also a sample Task Sheet for a Science as a Human Endeavour Investigation can be found on the following pages.

Science as a Human Endeavour (SHE)

Investigation Reports

Introduction

One way to explore how science interacts with society is through a science as a human endeavour investigation. This involves selecting a report about a new direction in biology, identifying evidence in the report of at least one *Biology Subject Outline Stage 1* key concept, and supporting the points made by using and properly acknowledging other related sources of information.

There are a number of ways students can present a report of a Science as a Human Endeavour investigation. Three options are shown below:

A Science as a Human Endeavour report can be submitted:

- in typed format about a new direction in biology as communicated by a radio/TV announcement.
- in typed format about a new direction in biology as communicated by an article from a science magazine.
- as an oral presentation or multimodal format about a new direction in biology as communicated by a newspaper.

Part A: Writing a SHE Investigation reports

The advice that follows refers specifically to option 2 above, which is referred to here as a 'SHE investigation report'.

General

- One SHE investigation report has a maximum word count of 1000 words. Only the report's text is included – headings, in-text references, and References are not included.
- Appropriately acknowledge all sources of information in and at the end of the report.

Introduction

- Link the new direction in biology to the SHE key concept(s) identified and to a relevant section in the Biology Subject Outline Stage 1.

Relevant science

- Present relevant biology concepts and background information.

Interaction between science and society

- Explain how the new direction in biology and the key concept(s) illustrate the interaction between science and society.

Potential impacts

- Discuss the potential impact of the new direction in biology.
- Include possible future developments.

Conclusion

- Summarise how the SHE key concept(s) has been addressed, including how well.

References

- Ensure the report is supported using in-text referencing.
- List all sources of information acknowledged in the text alphabetically in a References list.

Part B: A sample Task Sheet for a SHE Investigation

Your teacher will give you a task sheet to use to prepare a report of a 'SHE investigation' for summative assessment. Part of one is shown below for illustration.

SHE investigation report: max 1000 words. A guide to approximately how many words for each is given in brackets. Headings, in-text references, and the References list are not in the word count. For the assessment Design criteria see the criterion column.

Headings	SHE skills and requirements	Criterion
Introduction (~200 words)	The new direction in biology is linked to the key concept(s) and to a relevant section in the Biology Subject Outline Stage 1.	KA1
Relevant science (~250 words)	Relevant biology concepts and background is presented.	KA1, KA4
Interaction between science and society (~400 words)	How the new direction in biology and the key concept(s) illustrate the interaction between science and society is explained.	KA3
Potential impacts (~150 words)	The potential impact of the new direction in biology is discussed. Possible future developments are included.	KA3
Conclusion (~100 words)	How the SHE key concept(s) has been addressed, including how well, is clearly summarised.	KA3
References (not incl. in word count)	All sources of information are appropriately acknowledged and are listed correctly using an alphabetical list of References at the end of the report.	KA4

Part C: Possible 'New Directions in Biology' for a SHE Investigation

There is a wide variety of new directions in biology suitable for a SHE investigation. Ideally, these new directions should be biological research and issues that have been unfolding over the last 3 years. Some that can be linked to various Topics in the Biology Subject Outline Stage 1 are listed below:

- Breath test for cancer
- Liquid biopsies for early detection of cancer
- Lab-grown meat
- Earlier detection of malaria
- Scanners to signal the presence of pathogens in food
- Sterile male insect technology
- Superbugs
- Vaccine for tooth decay
- CAR T-cell therapy
- Be My Eyes
- Robotic pills
- Nutraceuticals
- Dialysis anytime, anywhere
- Lab-made blood
- Spider-silk threads
- Alligator (or crocodile) derived antibiotics
- 3D food printing
- DroneSeed

Science as a Human Endeavour Summary (Topics 1-4)

Communication and Collaboration	Development	Influence	Application and Limitation
Clear communication, international conventions and review of results 1.2 Antonie van Leeuwenhoek 3.1 Newborn screening for SMA	Development of models and use of evidence 1.3 Viruses can cause cancer 3.7 Blood circulates	Advances in science in one field influence/ are influenced other areas of STEM 2.2 Earlier detection of malaria	Science understanding/inquiry enables scientists to develop solutions 2.1 Mad cow disease 3.2 Bionic eye
Collaboration between scientists, governments, and other agencies 1.7 Food contamination 2.7 Development of penicillin	New technologies improve procedures and data collection 3.3 Breath test for cancer	Acceptance/use of science is influenced by social and economic considerations 2.8 Immunotherapy treatment of cancer	Science understanding/inquiry enables scientists to make discoveries 1.4 Bionic leaf 4.7 Once upon a time in Winton
	New technologies reveal new evidence that may modify/replace models 1.1 The cell theory 3.5 The cause of stomach ulcers	Acceptance/use of science is influenced by cultural and ethical considerations 3.6 3D printed rib cage	Science understanding/inquiry enables scientists to design sustainable action 4.6 Managing tropical rainforest
			Science understanding/inquiry enables scientists to offer valid explanations/make predictions 2.3 Superbugs
			The use of science knowledge may have beneficial or unexpected consequences 3.4 Green walls 4.5 Polychlorinated biphenyls (PCBs)
			Science informs public debate and in turn is influenced by public debate 2.4 Preventing tooth decay 4.1 Feral cats

Performance Standards for SACE Stage 1 Biology

	Investigation, Analysis, and Evaluation	Knowledge and Application
A	Critically deconstructs a problem and designs a logical, coherent, and detailed biological investigation. Obtains, records, and represents data, using appropriate conventions and formats accurately and highly effectively. Systematically analyses and interprets data and evidence to formulate logical conclusions with detailed justification. Critically and logically evaluates procedures and their effect on data.	Demonstrates deep and broad knowledge and understanding of a range of biological concepts. Applies biological concepts highly effectively in new and familiar contexts. Critically explores and understands in depth the interaction between science and society. Communicates knowledge and understanding of biology coherently, with highly effective use of appropriate terms, conventions, and representations.
B	Logically deconstructs a problem and designs a well-considered and clear biological investigation. Obtains, records, and represents data, using appropriate conventions and formats mostly accurately and effectively. Logically analyses and interprets data and evidence to formulate suitable conclusions with reasonable justification. Logically evaluates procedures and their effect on data.	Demonstrates some depth and breadth of knowledge and understanding of a range of biological concepts. Applies biological concepts mostly effectively in new and familiar contexts. Logically explores and understands in some depth the interaction between science and society. Communicates knowledge and understanding of biology mostly coherently, with effective use of appropriate terms, conventions, and representations.
C	Deconstructs a problem and designs a considered and generally clear biological investigation. Obtains, records, and represents data, using generally appropriate conventions and formats, with some errors but generally accurately and effectively. Undertakes some analysis and interpretation of data and evidence to formulate generally appropriate conclusions with some justification. Evaluates procedures and some of their effect on data.	Demonstrates knowledge and understanding of a general range of biological concepts. Applies biological concepts generally effectively in new or familiar contexts. Explores and understands aspects of the interaction between science and society. Communicates knowledge and understanding of biology generally effectively, using some appropriate terms, conventions, and representations.
D	Prepares a basic deconstruction of a problem and an outline of a biological investigation. Obtains, records, and represents data, using conventions and formats inconsistently, with occasional accuracy and effectiveness. Describes data and undertakes some basic interpretation to formulate a basic conclusion. Attempts to evaluate procedures or suggest an effect on data.	Demonstrates some basic knowledge and partial understanding of biological concepts. Applies some biological concepts in familiar contexts. Partially explores and recognises aspects of the interaction between science and society. Communicates basic biological information, using some appropriate terms, conventions, and/or representations.
E	Attempts a simple deconstruction of a problem and a procedure for a biological investigation. Attempts to record and represent some data, with limited accuracy or effectiveness. Attempts to describe results and/or interpret data to formulate a basic conclusion. Acknowledges that procedures affect data.	Demonstrates limited recognition and awareness of biological concepts. Attempts to apply biological concepts in familiar contexts. Attempts to explore and identify an aspect of the interaction between science and society. Attempts to communicate information about biology.

Health and Safety Information

Often scientists, science teachers and students handle equipment and materials which can be dangerous to their health and safety. Throughout this Workbook you will see a number of symbols and warnings which will represent particular hazards. For each of these, we will briefly describe the hazard and indicate what precautions you should take to avoid damage and/or what responses are appropriate in the event of an accident. In all cases, of course, you should seek advice and assistance from the teacher or laboratory staff.

A biohazard is any organism or body fluid which could possibly cause illness or disease in your body. This particularly includes micro-organisms. Your teacher will give instructions.

Sharp instruments are often used in Science, particularly in Biology, to cut sections through plant or animal tissue. These instruments, which include scalpels and razor blades, are very sharp and will also cut through your tissues. When using these instruments it is essential that you always cut away from your body and preferably onto a cutting board. It is also important to be very careful if you are carrying these instruments and also ensure they are placed on the workbench in a safe place.

It is often necessary to protect your hands from heat, chemicals or animal tissues and gloves will be made available for these situations. The type of glove needed will depend on the particular hazard and your teacher will provide further advice. In some cases you will be advised to dispose of the gloves after use and in other cases to wash and dry them carefully.

Your eyes are the most vulnerable and easily damaged external part of your body. This is why they must be protected if you are using solids and liquids which could get into them. Whenever you are heating things or using corrosive liquids, and in other cases as instructed by a teacher, you should wear safety glasses or goggles. You should also do this, if possible, even if you wear spectacles to correct your vision. In the event that something gets in your eye you should immediately make use of the eyewash facility in the laboratory as instructed and then notify your teacher.

Some chemicals, which are used in a laboratory, are corrosive. This means that they can react with and 'eat away' materials like the bench, your books, clothing and skin. It is essential that you handle these materials, which are usually liquids, with care. Always tip from the container with the label uppermost, never add water to concentrated acid and never have your face anywhere near the container. It is usually advisable to wear both safety glasses and gloves. If protective aprons or lab coats are available your teacher may require that you wear one.

In Science, particularly in Biology, there are situations when ethics and ethical issues need to be considered in experimental work. This is particularly the case when human volunteers are being used, not just for experimental work but also when they are being surveyed to collect personal information. In these cases, a consent form should be used to explain the nature of their involvement and to get their approval. Ethics (particularly bioethics) will also be an issue whenever animals are used in experimentation or when they are collected in the field. They should not be exposed to conditions that are outside their natural range of tolerance and wild animals (e.g. insects) must be released back where they were sampled with minimal disturbance.

Environmental issues become important when hazardous substances are used or produced during an experimen, their disposal must result in minimal impact on the environment, your teacher will advise best practice. During field work the protocol that is used must reflect practices that minimise the impact of the investigation on the site.

Please note: It is a strict condition of sale, that safety in the laboratory is the responsibility of the staff and students doing the laboratory or field work and not, in any way whatsoever, the responsibility of the authors, editor or publisher of this work.

Figure Credits

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TOPIC 1

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Chapter 1.1

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SHE 1.1 http://www.pasteurbrewing.com/spontaneous-generation-and-the-origin-of-life

Chapter 1.2

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Chapter 1.3

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Chapter 1.4

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Chapter 1.5

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Ex 13 http://commons.wikimedia.org/wiki/File:Paramecium_contractile_vacuoles.jpg?uselang=en-gb

Chapter 1.6

Fig 161a https://upload.wikimedia.org/wikipedia/commons/d/da/Anthrax_cells.jpg
Fig 161b https://upload.wikimedia.org/wikipedia/commons/9/97/Aerococcus_urinae_-_microscopy.jpg
Fig 161c https://upload.wikimedia.org/wikipedia/commons/9/9f/Spirillen.jpg
Fig 161d https://upload.wikimedia.org/wikipedia/commons/8/82/Vibrio_vulnificus_01.png
Fig 162a https://commons.wikimedia.org/wiki/File:Sparrige-Sch%C3%BCppling_(Pholiota_squarrosa).JPG
Fig 162b https://upload.wikimedia.org/wikipedia/commons/1/13/Asco1014.jpg
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Fig 163b https://commons.wikimedia.org/wiki/Category:Euglena#/media/File:Euglena_sp..jpg
Fig 163c https://commons.wikimedia.org/wiki/Category:Paramecium#/media/File:Mikrofoto.de-Gruenes_Pantoffeltier_2.jpg
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Fig 164 https://en.wikipedia.org/wiki/Chlorophyta
Fig 165 https://upload.wikimedia.org/wikipedia/commons/7/7d/Lake_Eyre_Floods%2C_South_Australia_-_NASA_Earth_Observatory.jpg
Fig 166 https://commons.wikimedia.org/wiki/Category:Viruses#/media/File:Ebola_Virus_Particle_(16436410472).jpg
Fig 168 SCIENCE PHOTO LIBRARY/F0213537/ KATERYNA KON used under licence
Fig 1610 https://upload.wikimedia.org/wikipedia/commons/e/e7/Pediastrumboryanum.jpg
Fig 1611 https://upload.wikimedia.org/wikipedia/commons/f/f9/Bay_of_Biscay_from_Terra_%282004-05-17%29.jpg
Fig 1612(b) SCIENCE PHOTO LIBRARY/G2000059/DR GOPAL MURTI used under licence
Fig 1614 https://commons.wikimedia.org/wiki/File:Hartkaese_HardCheeses.jpg
CAP 1.6 https://commons.wikimedia.org/wiki/File:US_Army_51869_CID_lab_processes_evidence.jpg

Chapter 1.7

Fig 171 https://upload.wikimedia.org/wikipedia/commons/a/a0/Rotten_Oranges.JPG
Fig 172 https://www.google.com.au/search?q=food+handling+pics&espv=2&biw=1245&bih=1280&source=lnms&tbm=isch&sa=X&ved=0ahUKEwiY8JPH0uXLAhVO8WMKHdjcCPYQ_AUIBigB#tbm=isch&q=rotten+food+copyright+free+pics&imgrc=gTAFfoUni0WLLM%3A
Fig 173 http://www.infobarrel.com/Food_Safety_and_Handling
Fig 174 https://www.google.com.au/search?q=food+handling+pics&espv=2&biw=1245&bih=1280&source=lnms&tbm=isch&sa=X&ved=0ahUKEwiY8JPH0uXLAhVO8WMKHdjcCPYQ_AUIBigB#imgrc=aA4cxH6ua0RgIM%3A
CAP 1.7 https://agrieducate.com.au/2017/05/29/the-first-farmers/
SHE 1.7 https://commons.wikimedia.org/media/File:Frozen_berries_(Unsplash).jpg Firesky studios.com 2015
TTQ7 SCIENCE PHOTO LIBRARY/F0228007/ STEVE GSCHMEISSNER used under licence

TOPIC 2

Title Page	https://upload.wikimedia.org/wikipedia/commons/f/fe/Phlebotomus_pappatasi_bloodmeal_finished.jpg

Chapter 2.1

Fig 212	SCIENCE PHOTO LIBRARY/F02396487/KATERYNA KON used under licence
Fig 213	https://upload.wikimedia.org/wikipedia/commons/b/b1/Salmonella_enteritidis_in_color.jpg / Jean Guard, ARS
Fig 214	https://commons.wikimedia.org/wiki/File:Calf_with_ringworm_infection.JPG?uselang=en-gb
Fig 215	http://www.dddmag.com/sites/dddmag.com/files/ddd1603_malaria_0.jpg
Fig 218	SCIENCE PHOTO LIBRARY/C0456197/ PATRICK LANDMANN used under licence
Fig 219	SCIENCE PHOTO LIBRARY/F023/8116/SCIEPRO used under licence
Fig 2110	https://commons.wikimedia.org/wiki/Category:Prions#/media/File:Prion_trafficking-_scrapie_mouse_(5661846150).jpg / NIAID

Chapter 2.2

Fig 221	SCIENCE PHOTO LIBRARY/M1300492/ LINDA STEINMARK used under licence
Fig 222	SCIENCE PHOTO LIBRARY/F0217360/KATERYNA KON used under licence
Fig 224	SCIENCE PHOTO LIBRARY/C0135950/CLAUS LUNAU used under licence
Fig 225	SCIENCE PHOTO LIBRARY/F0209494/KATERYNA KON used under licence
SHE2.2	https://www.doherty.edu.au/people/professor-stephen-rogerson

Chapter 2.3

Fig 233	https://commons.wikimedia.org/wiki/Ebola#/media/File:Ebola_virus_particles.jpg
Fig 234	https://commons.wikimedia.org/wiki/File:Medical_Team_testing_blood_samples_at_the_training_facility_in_Strensall._MOD_45159008.jpg
Fig 236	https://commons.wikimedia.org/wiki/Monkey#/media/File:Photo_singe_vert_grand.jpg
Fig 237	https://upload.wikimedia.org/wikipedia/commons/e/e6/CSIRO_ScienceImage_1762_Fruit_bats_flying_foxes.jpg
Fig 239	SCIENCE PHOTO LIBRARY/C0404579/STEVE GSCHMEISSNER & KEITH CHAMBERS used under licence_
Fig 2310	https://commons.wikimedia.org/wiki/Category:Antibiotic_resistance#/media/File:AntimcrresUKreview2.jpg
CAP2.3	https://www.health.harvard.edu/blog/why-we-need-to-make-it-harder-for-parents-to-refuse-vaccines-2016090610258
SHE2.3	SCIENCE PHOTO LIBRARY/C0404579/STEVE GSCHMEISSNER & KEITH CHAMBERS used under licence_

Chapter 2.4

Fig 241a	https://upload.wikimedia.org/wikipedia/commons/d/dc/Cox%27s_Bazaar_Refugee_Camp_%288539828824%29.jpg
Fig 241b	https://commons.wikimedia.org/wiki/Category:Refugee_camps_in_Ethiopia#/media/File:Arbeitsbesuch_%C3%84thiopien_(24789938135).jpg
Fig 242	SCIENCE PHOTO LIBRARY/M3120030/ANDY CRUMP, TDR, WHO used under licence
Fig 243	SCIENCE PHOTO LIBRARY/F0243105/KATERYNA KON used under licence
Fig 244	http://www.drugs.com/pro/penicillin-vk.html
Fig 247	SCIENCE PHOTO LIBRARY/C0453823/Ann Ronan Picture Library used under licence
Fig 248	http://www.who.int/csr/disease/ebola/en/
CS 2.4	http://www.who.int/csr/disease/ebola/en/
CAP2.4	https://www.nature.com/articles/d41586-018-05914-3
SHE2.4	https://platinumsmiledental.com.au/conditions/tooth-decay-plaque/

Chapter 2.5

Fig 252	https://commons.wikimedia.org/wiki/File:Aedes_aegypti_biting_human.jpg
Fig 253	https://www.newscientist.com/article/dn20710-grappling-hooks-help-bacteria-slingshot-forward/
Fig 255	SCIENCE PHOTO LIBRARY/C0388305/ HENNING DALHOFF used under licence
Fig 256	https://en.wikipedia.org/wiki/Phagocyte
Fig 257	SCIENCE PHOTO LIBRARY/M0500876/ Russell Kightley used under licence
Fig 258a	https://commons.wikimedia.org/wiki/File:Tomato_late_blight_epidemic_1_(5816171557).jpg
Fig 258b	https://commons.wikimedia.org/wiki/Phytophthora_ramorum#/media/File:Lithocarpus_densiflorus_dead.jpg
2510	https://commons.wikimedia.org/wiki/Category:Pseudomonas_syringae#/media/File:Smart-tomato-speck.JPG
2511	https://upload.wikimedia.org/wikipedia/commons/d/da/Adult_Loa_Loa_Parasite_%288905176106%29.jpg

Chapter 2.6

Fig 265a	SCIENCE PHOTO LIBRARY/C0374926/HENNING DALHOFF used under licence
Fig 265b	SCIENCE PHOTO LIBRARY/P5800141/STEVE GSCHMEISSNER used under licence

Chapter 2.7

Fig 271b	SCIENCE PHOTO LIBRARY/F0173911/Dennis Kunkel Microscopy used under licence
Fig 272	SCIENCE PHOTO LIBRARY/C042/4653/STEVE GSCHMEISSNER used under licence
CAP2.7	https://www.deccanchronicle.com/lifestyle/health-and-wellbeing/170417/new-smart-bandage-tells-doctor-how-wound-is-healing.html
SHE 2.7a	https://commons.wikimedia.org/wiki/File:Penicillium_notatum.jpg
SHE 2.7b	https://upload.wikimedia.org/wikipedia/commons/b/bc/Howard_Florey.jpg
SHE 2.7c	https://commons.wikimedia.org/wiki/File:OIC_adelaide_gh_lord_florey_statue.jpg

Chapter 2.8

Fig 285b	SCIENCE PHOTO LIBRARY/F0161391/JUAN GAERTNER used under licence
Fig 286	SCIENCE PHOTO LIBRARY/C0169057/STEVE GSCHMEISSNER used under licence
Fig 290	https://commons.wikimedia.org/wiki/Category:Breastfeeding#/media/File:Woman_breastfeeding.jpg
SHE2.8	https://www.aspenpublicradio.org/post/living-drug-fights-cancer-harnessing-immune-system-clears-key-hurdle
CAP2.8	https://www.bbc.com/news/world-asia-46616004
TT3 Q5	SCIENCE PHOTO LIBRARY/M0500876/ Russell Kightley used under licence

TOPIC 3

Chapter 3.1

Fig 313b SCIENCE PHOTO LIBRARY/C0299741/ GUNILLA ELAM used under licence
Fig 316 SCIENCE PHOTO LIBRARY/C0148612/Alfred Pasieka used under licence
Fig 318 https://www.flickr.com/photos/nasa2explore/16335632852/ By NASA/Robert Markowitz Public Domain
SHE3.1 https://www.pregnancybirthbaby.org.au/neonatal-screening-test

Chapter 3.2

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Fig 325a SCIENCE PHOTO LIBRARY/F0213518/ KATERYNA KON used under licence
Fig 325b SCIENCE PHOTO LIBRARY/F0087112/PIXOLOGICSTUDIO used under licence
CAP3.2 http://www.melbournepaediatricspecialists.com.au/growing-mini-kidneys/
SHE 3.2 https://www.spaceandintelligence.com/images/bionic-eyes.jpg

Chapters 3.3

Fig 334 modified from SCIENCE PHOTO LIBRARY/ C0167689/ CLAUS LUNAU used under licence
Fig 336b SCIENCE PHOTO LIBRARY/ F0132486/PIXOLOGICSTUDIO used under licence
Fig 337b SCIENCE PHOTO LIBRARY/P57000372/PETER GARDINER used under licence
SIS3.3 https://www.habdirect.co.uk/product/spiropet-spirometer-50-mouthpieces/

Chapter 3.4

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Fig 345b SCIENCE PHOTO LIBRARY/C004/9482/PETER BOND used under licence
SHE3.4 http://www.goodnewsfinland.com/naava-s-smart-green-walls-freshen-air-sweden/

Chapter 3.5

Fig 351 https://upload.wikimedia.org/wikipedia/commons/4/42/Red_Kangaroo_001.jpg
Fig 352b SCIENCE PHOTO LIBRARY/F0244252/KATERYNA KON used under licence
Fig 354b SCIENCE PHOTO LIBRARY/P5200129/EYE OF SCIENCE used under licence
CAP3.5 adapted from: https://appadvice.com/app/food-ingredients-scanner/1459475479
SHE 3.5 http://australia.gov.au/sites/default/files/agencies/culture/library/images/site_images/marshallwarren_web.jpg

Chapter 3.6

Fig 362b SCIENCE PHOTO LIBRARY/ C0131578/ SPRINGER MEDIZIN used under licence
Fig 364b SCIENCE PHOTO LIBRARY C0319774/ DENNIS KUNKEL MICROSCOPY used under licence
CAP3.6 https://www.theguardian.com/australia-news/2018/aug/13/happy-to-be-alive-jack-thompson-garma-and-a-purple-dialysis-truck
SHE3.6 https://newatlas.com/3d-printed-sternum-and-rib-cage-csiro/39369/

Chapter 3.7

Fig 373b SCIENCE PHOTO LIBRARY/F0245788/KATERYNA KON used under licence
Fig 3710 SCIENCE PHOTO LIBRARY/ F0167816/ PIXOLOGICSTUDIO used under licence
CAP3.7 https://www.tedmed.com/speakers/show?id=526463
SHE3.7 https://www.rcplondon.ac.uk/events/ceaseless-motion-william-harveys-experiments-circulation

Chapter 3.8

Fig 381 SCIENCE PHOTO LIBRARY/C0233022/ CARLOS CLARIVAN used under licence
Fig 383a SCIENCE PHOTO LIBRARY/B7050125/ STEVE GSCHMEISSNER used under licence
Fig 383b SCIENCE PHOTO LIBRARY/F0027307/ STEVE GSCHMEISSNER used under licence
TTQ15 adapted from https://www.genomes2people.org/research/babyseq/
TT Q16 http://www.nationalregisterofbigtrees.com.au/listing/35.jpg

TOPIC 4

Title Page https://commons.wikimedia.org/wiki/File:Great_barrier_reef.JPG?uselang=en-gb

Chapter 4.1

Fig 413b https://commons.wikimedia.org/wiki/Ornithorhynchus_anatinus#/media/File:Platypus_BrokenRiver_QLD_Australia.jpg
Fig 413c https://commons.wikimedia.org/wiki/File:B_ashbyi_gnangarra_03.jpg
Fig 416 https://commons.wikimedia.org/wiki/File:Friendly_Male_Koala.JPG
Fig 419b https://commons.wikimedia.org/wiki/File:CSIRO_ScienceImage_21_Predator_Mite_Attacking_a_Red_Mite.jpg
Emojis http://www.freepik.com/free-photos-vectors/icon">Icon vector designed by Freepik</a
Fig 4110a SCIENCE PHOTO LIBRARY/C0126716/DAVID FLEETHAM VISUALS UNLIMITED INC. used under licence
Fig 4110c SCIENCE PHOTO LIBRARY/F0251494/ CHRISTOPH BURGSTEDT used under licence
Fig 4111b SCIENCE PHOTO LIBRARY/C0246912/MIKKEL JUUL JENSEN used under licence
Fig 4113b https://pixabay.com/images/search/great%20barrier%20reef/
Ex 11 https://upload.wikimedia.org/wikipedia/commons/e/e1/Southern_Cassowary_in_rainforest.jpg
SHE4.1 https://www.theland.com.au/story/4477968/war-on-feral-cats-australia-aims-to-cull-2-million/

Chapter 4.2

Fig 421 https://en.wikipedia.org/wiki/Carl_Linnaeus
Examples http://commons.wikimedia.org/wiki/File:Pohlia_nutans.jpeg photographed by Kristian Peters
http://commons.wikimedia.org/wiki/File:Sponge_and_multicolour_sea_fan_at_Bakoven_Rock_DSC11047.JPG
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http://upload.wikimedia.org/wikipedia/commons/f/f1/Escargot_%C3%A0_Grez-Doiceau_001.jpg
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Fig 424 SCIENCE PHOTO LIBRARY/F0068998/ ANDRZEJ WOJCICKI used under licence
Fig 425a https://upload.wikimedia.org/wikipedia/commons/6/65/Eastern_Gray_Kangaroo.jpg
Fig 425b https://commons.wikimedia.org/w/index.php?curid=31109339 by Glen Fergus
https://commons.wikimedia.org/wiki/Macropus_agilis#/media/File:Flinkwallaby.jpg
CAP4.2 https://spectrum.ieee.org/automaton/robotics/industrial-robots/draper-dragonfleye-project

Key Table

SPIDER https://commons.wikimedia.org/wiki/Araneae#/media/File:Sphodros_rufipes_non-crossing_chel.jpg
STARFISH https://commons.wikimedia.org/wiki/File:Reef0296.jpg
SPONGE https://commons.wikimedia.org/wiki/File:Black_sea_fauna_blue_sponge.jpg
WORM https://commons.wikimedia.org/wiki/File:Earthworm_on_the_ground.jpg
SHELLFISH https://commons.wikimedia.org/wiki/Category:Shellfish#/media/File:Pseudocardium_sachalinense.JPG
SNAKE https://commons.wikimedia.org/wiki/Reptilia#/media/File:Couleuvre_collier_62.JPG
CENTPEDE https://upload.wikimedia.org/wikipedia/commons/c/c8/House_Centipede.jpg
MITE https://commons.wikimedia.org/wiki/File:%D0%92%D0%BE%D0%B4%D1%8F%D0%BD%D0%BE%D0%B9_%D0%BA%D0%BB%D0%B5%D1%89.jpg

Chapter 4.3

Fig 431 https://upload.wikimedia.org/wikipedia/commons/8/8c/Macrotis_lagotis_-_bandicut_conejo.jpg
Fig 434 SCIENCE PHOTO LIBRARY/Z2300129/Christian Laforsch used under licence
Fig 436 SCIENCE PHOTO LIBRARY/C0383274/ DR JEREMY BURGESS used under licence
Fig 438 https://commons.wikimedia.org/wiki/File:Delma_nasuta,_Spinifex_Legless_Lizard,_Alice_Springs.jpg
https://commons.wikimedia.org/wiki/File:Simpson17052016.jpg
https://commons.wikimedia.org/wiki/File:Moloch_horridus,_Thorny_Devil,_Alice_Springs.jpg
https://commons.wikimedia.org/wiki/File:Perentie_Lizard_Perth_Zoo_SMC_Spet_2005.jpg

Chapter 4.4

Fig 445 SCIENCE PHOTO LIBRARY/C042/8931/NATURE PICTURE LIBRARY used under licence

Chapter 4.5

Fig 451 https://commons.wikimedia.org/wiki/File:Celestia_sun.jpg
SHE4.5 https://crosscut.com/2018/08/save-orcas-well-have-do-one-radical-thing

Chapter 4.6

Fig 461 https://commons.wikimedia.org/wiki/File:Arctocephalus_pusillus_Colony_Friar_Island.jpg
Fig 462 https://commons.wikimedia.org/wiki/File:Bull_shark_at_unnamed_reef_12-127.jpg
Fig 463 http://www.nationalregisterofbigtrees.com.au/listing/35.jpg
SHE 4.6 https://upload.wikimedia.org/wikipedia/commons/e/e1/Southern_Cassowary_in_rainforest.jpg

Chapter 4.7

Fig 473 a https://commons.wikimedia.org/wiki/File:Forestfire2.jpg
Fig 473 b https://commons.wikimedia.org/wiki/File:Boreal_pine_forest_after_fire.JPG
Fig 473 c,d https://commons.wikimedia.org/wiki/File:Boreal_pine_forest_after_fire.JPG#/media
Fig 474 https://upload.wikimedia.org/wikipedia/commons/0/0f/Close_up_of_dinosaur_tracks.jpg
Fig 475 https://upload.wikimedia.org/wikipedia/commons/8/83/Thylacoleo_vs_Diprotodon.jpg
SHE4.7 http://flamemedia.tv/flame-distribution/catalogue/dinosaurs-in-the-outback

Chapter 4.8

Fig 481 https://upload.wikimedia.org/wikipedia/commons/thumb/d/db/Zrywka_drewna_776.jpg/315px-Zrywka_drewna_776.jpg
Fig 486 SCIENCE PHOTO LIBRARY/C0207071/PETER J. RAYMOND used under licence
Fig 482 https://upload.wikimedia.org/wikipedia/commons/thumb/d/d9/Biodiversity_Hotspots_Map.jpg/800px-Biodiversity_Hotspots_Map.jpg
Fig 483a https://commons.wikimedia.org/wiki/File:Acridotheres_tristis_-Sydney,_Australia-8.jpg
Fig 483b https://upload.wikimedia.org/wikipedia/commons/e/ee/Eolophus_roseicapilla_2010.JPG
Fig 483c https://commons.wikimedia.org/wiki/File:Australian_Magpie.jpg
Coral box http://edition.cnn.com/2012/06/19/world/rio-red-list-extinction-species
Algae box http://en.wikipedia.org/wiki/Algal_bloom
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CAP4.8 http://environmentalprofessionalsnetwork.com/impacts-of-extreme-weather-events-climate-change/
TEST
Q5 https://upload.wikimedia.org/wikipedia/commons/thumb/4/47/Secondary_Succession.png/799px-Secondary_Succession.png
Q6 https://upload.wikimedia.org/wikipedia/en/9/90/Keppelbleaching.jpg
Q13 https://commons.wikimedia.org/wiki/File:Rufous_Bettong_(Aepyprymnus_rufescens)_(9855545873).jpg
Q15 https://commons.wikimedia.org/wiki/File:Southern_bentwing_bat.jpg
Appendix Title Page
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abdominal cavity
the internal part of an animal's body which contains many of the main organs e.g. liver, intestine, kidneys but not the heart and lungs which are in the chest cavity

abiotic
the non-living components of the environment e.g. nutrients, temperature

absorption
taking in substances through cell membranes or layers of cells.

acidification
the process by which carbon dioxide gas in the air dissolves in water to form a weak acid solution which may then damage some organisms e.g. coral

activation energy
the energy necessary for a chemical reaction to proceed

activators
proteins that 'switch on' genes by making them more accessible for transcription

active immunity
immunity due to the production of memory lymphocytes after the organism has been stimulated by antigens

active transport
the process by which materials may be moved across the cell membrane against the concentration gradient, this requires an input of additional energy

adaptation
a characteristic or feature of an organism that increases its chance of survival

adhesion
the force of attraction between atoms or molecules of different substances e.g. water and glass

aerobic respiration
a series of biochemical reactions in which glucose, in the presence of oxygen, is chemically changed into carbon dioxide and water to release energy for life processes. Most stages take place in the mitochondria of cells.

alcohol fermentation
an anaerobic chemical process which occurs in plants, yeast cells and some bacteria. It produces ethanol, carbon dioxide and a small amount of energy.

algae
photosynthesising organisms found mainly in aquatic environments

algal bloom
the rapid growth of algae in water, usually as a result of increased levels of dissolved phosphate and/or nitrate

alimentary canal
a single tube that extends from the mouth to the anus through which food passes, nutrients are absorbed and faeces are egested; also known as the digestive tract

alkaloids
a group of nitrogen compounds produced by plants that bring about a range of effects in humans

alveoli
tiny air sacs in the lungs which provide a very large surface area for the diffusion of gases into and out of the blood (singular: alveolus)

amino acids
molecules consisting of an amino part and an acid part which may be joined together by peptide bonds in long chains to form polypeptides and then 3D proteins

amylase
a type of enzyme which breaks down carbohydrates into simple sugars e.g. starch to maltose

anaphase
the phase in mitotic cell division where the chromatids are separated and dragged towards opposite poles of a eukaryotic cell by spindle fibres

angiotensin
a protein hormone that constricts arterioles, increasing blood volume and pressure

antibiotic
a substance that inhibits the growth or destroys bacteria e.g. penicillin

antibody
a protein molecule made by a plasma cell in response to the presence of an antigen

antidiuretic hormone (ADH)
a hormone that controls the reabsorption of water from the glomerular filtrate in nephrons of the kidneys

antigen
a 'non-self' molecule, usually a protein or carbohydrate that stimulates production of an antibody

antimicrobial substance
a substance which kills or inhibits the growth of microbes

antiseptic
a chemical which can be applied to a wound on the skin to prevent infection due to the growth of microorganisms

archaea
a group of prokaryotic microorganisms that are only distantly related to eukaryotes and the other prokaryotes

arteriole
a small artery with takes blood from arteries to capillaries

artery
a large, elastic blood vessel that transports blood at high pressure away from the heart

athlete's foot
a skin disease, often involving inflammation caused by a fungus

atrio-ventricular (A-V) valve
a valve in the heart between an atrium and a ventricle

atrium
the upper chamber of the heart which receives blood from the body

autotroph
organisms which are capable of making their own food (organic molecules) from inorganic materials using either light, or reactions involving inorganic chemicals as a source of energy. This term is often used for photoautotroph organisms which are able to use light energy to manufacture food molecules in photosynthesis.

axon
the part of a nerve cell or neuron that takes a nerve impulse away from the cell body and towards the dendrites of another neuron

B (and T) memory cells
lymphocytes (white blood cells) which are part of the adaptive immune system

bacteria
very small prokaryotic organisms which do not have a nucleus or any internal membrane-bound organelles

bacterial resistance
a property that bacterial strains can develop whereby they are resistant to and can survive exposure to certain antibiotics

bilateral symmetry
an animal in which one side is the mirror image of the other e.g. humans

binary fission
the method of reproduction of prokaryotic organisms in which one cell divides into two

binomial system
a two-word naming system in which every species has a Latin name made of the genus name, followed by the species name, which is usually written in italics e.g. Homo sapiens for humans

biodiversity
the variety that exists in nature at the gene, species or ecosystem level

biogeochemical cycle
a circuit in which elements and nutrients move between the biotic and abiotic components of an ecosystem e.g. carbon and water.

biota
all organisms living in a particular area including animals, plants and microbes biotic the living components of the environment e.g. producers, consumers, decomposers

bone marrow
the soft central part of a bone which produces white blood cells (lymphocytes)

Bowman's capsule
part of the nephrons in the kidney through which blood is filtered from the glomerulus

bronchiole
small airways which carry air from the bronchi through smaller and smaller tubules to and from the alveoli

bronchus
an airway which carries air from the trachea to each of the lungs

bulb
part of some plants which is able to store sugar and assist with asexual reproduction

cancer
the general name given to cells or groups of cells which undergo rapid and uncontrolled division and may invade and kill other tissues in the body

canopy
the upper layer of branches and leaves in a forest

capillary
tiny blood vessels (about 10 micrometres in diameter) which are very close to cells and transport blood between arterioles and venules. Many substances are exchanged between capillaries and the fluid surrounding cells by diffusion.

carbon footprint
the amount of carbon dioxide produced by certain human activities e.g. mining, transport, food production, heating and cooling

cardiac muscle
a special type of muscle tissue which is found in the heart

carnivore
an animal that only consumes other animals

cell
the smallest unit of an organism which is capable of independent existence. It is the structural and functional unit of almost all living organisms.

cell differentiation
the process by which cells become different

cell division
the process by which one cell divides to become two, and so on

cell membrane
a very thin layer which encloses the contents of a cell. It consists of phospho-lipids and proteins arranged in a fluid mosaic.

cell specialisation
the process by which different cell types develop different structure(s) to perform a specific function(s)

chemical digestion
processes which occur in the alimentary canal of an organism by which food materials are broken-down into smaller molecules which are then able to be absorbed

chemical energy
energy that is stored in the chemical bonds of a molecule. Larger molecules have more chemical bonds and therefore can store more energy.

chemo-autotroph
organisms which are capable of using energy from inorganic chemicals and reactions to make their own food (i.e. organic molecules)

chlorophyll
a green pigment, mainly found in chloroplasts, that can trap the suns energy and enable light energy to be converted into chemical energy trapped in the bonds of organic molecules

chloroplast
organelles which are found in the mesophyll cells of plants. They contain a pigment called chlorophyll which is necessary for the process of photosynthesis.

cholera
a food borne and waterborne bacterial disease of the intestine caused by Vibro cholerae; the symptoms include massive diarrhoea, fluid and electrolyte imbalance, and severe dehydration

chromatids
two identical structures which are formed as a result of DNA replication and which are separated during anaphase as a cell divides

chromatin
the granular material found in the nucleus of a cell during interphase when it is not dividing. It is actually long, loosely packed strands of DNA.

chromosome
structures which are found in the nuclei of eukaryotic cells and in the cytoplasm of prokaryotic cells, they consist of DNA coiled around proteins. Chromosomes store and carry genetic information from cell to cell during mitotic division and from one generation to another during sexual reproduction.

cilia
small hair like structures on the surface of cells that have a range of functions including removing foreign particles

circulatory system
an organ system that consists of the heart and blood vessels and is responsible for circulating blood or a similar fluid throughout the body of many species of animals. Flowering plants circulate a mixture of sugar, certain mineral nutrients and water (sap) in the phloem.

climate change
changes in climate (e.g. temperature, altered patterns of rainfall) that are occurring because of the increasing levels of carbon dioxide and other greenhouse gases in the atmosphere

cloning
the process by which copies of molecules, cells or organisms which have identical genotypes are made. These copies are now able to be formed using modern biological techniques.

closed circulatory system
a transport system in an animal in which the blood is confined to blood vessels

coding DNA
DNA which is transcribed and translated into protein; also called exons

cohesion
the force of attraction between atoms or molecules of the same substance e.g. water

collecting duct
small tubes that collect what remains of the glomerular filtrate from the renal tubules of the nephrons in kidneys. The contents of collecting ducts drain to the bladder as urine.

commensalism
the relationship between two species where one benefits and the other is unharmed

community
the living component of the ecosystem, usually consisting of a very large number of populations of different species

competition
where organisms of the same or different species compete for the same resources e.g. food, water and shelter

complement
a range of proteins that are involved in the innate immune system

complementary
matching, especially the bases Cytosine with Guanine, and Adenine with Thymine in DNA molecules

complementary binding
when two matching shapes fit together and often activate an important biological process e.g. enzyme action, antigen-antibody interaction

concentration gradient
a measure of how quickly the concentration of a particular solute or other substance changes within a certain distance

condensation
the process by which the vapour of a substance becomes liquid e.g. water vapour forming into liquid water

consumer
an organism that feeds on other organisms to obtain its nutritional requirements, it could be a herbivore, carnivore or omnivore

contagious disease
a communicable disease whose agent passes with particular ease among hosts

contractile vacuole
a small vesicle located in the cytoplasm of many freshwater unicellular organisms that pumps out excess water that enters by osmosis

cornea
the transparent surface of the eyeball in front of the lens

coronary artery
an artery which supplies oxygenated blood directly to the heart muscle

cortex (animals)
the outer tissues of several organs, including the kidney and the brain

cortex (plants)
the undifferentiated tissue between the epidermis and the vascular system in the stems and roots of plants

courtship ritual
a series of behaviours of males and female animals, intended to attract a mate for purposes of reproduction

Cretaceous period
a geological period lasting from about 135-65 million years ago

critically endangered species
a species for which the risk of becoming extinct in the wild is extremely high

cuticle
the outermost upper part of a leaf which is waterproof and transparent. It consists of wax which is produced by the epidermis beneath it. The cuticle prevents mesophyll cells from losing too much water.

cyclic
a series of events that are regularly repeated in the same order e.g. day and night, the seasons

cytokines
chemicals of the innate immune system that are released and bring about specific effects in the immune response e.g. interferon

cytokinesis
the process by which a cell membrane and possibly a cell wall form to divide the cytoplasm into two so that one cell becomes two at the end of cell division

cytoplasm
matter in a cell excluding the nucleus and other organelles

decomposer
an organism that breaks down dead and decaying organic matter; they recycle nutrients in the ecosystem, e.g. bacteria and fungi (also saprophyte)

deforestation
the removal of trees and other vegetation, usually for agriculture or forestry

density
a measure of how much mass there is per volume of a substance (e.g. g/cm^3)

deoxygenated blood
blood that has a low concentration of oxygen and a high concentration of carbon dioxide. With the exception of the pulmonary artery, deoxygenated blood is transported by veins.

desert
an area in which there is little rainfall and therefore relatively little vegetation

desiccation
the process of losing water and drying out

dialysis
the process of artificially filtering the blood with a machine because a person's kidneys are not functioning properly

dichotomous key
a method for identifying organisms where each feature chosen to assist with the identification process involves a choice between two alternatives e.g. has antennae, does not have antennae

dicotyledons
plant with seeds that has two leaves (cotyledons) growing from the seed, e.g. rose, dandelion; also called 'dicots'

differential gene expression
the switching on and off of different genes by cells with identical genomes

diffusion
the process by which gas or liquid molecules move to become equally distributed throughout the space available. There will normally be a nett movement from an volume of high concentration to a volume of low concentration.

digestion
the process of breaking down food into smaller pieces and soluble molecules which can be absorbed

digestive system
an organ system in an animal that is responsible for the digestion of food and absorption of the soluble products

diploid
a cell with homologous pairs of each type (i.e. a full set) of chromosome (2n)

disinfectant
a substance that is used on surfaces (e.g. kitchen benches) to kill potential pathogens e.g. bacteria

diuretics
drugs which increase the urine production by the kidney by decreasing the reabsorption of water

DNA
abbreviated name for 'Deoxyribose (or Deoxyribo-) Nucleic Acid' which carries genetic information

DNA nucleotides
the building blocks of DNA molecules. They consist of a base, nucleic acid and phosphate group.

DNA replication
the process in which DNA makes another copy of itself. This occurs prior to cell division during interphase and is said to be 'semi-conservative'.

donor
a person who provides an organ for the purpose of an organ transplantation operation

double circulation system
a system where there are separate circulations from the heart to the lungs and from the heart to the other organs in the body

Ebola
a virulent virus which causes a disease

ecological niche
the way a population of organisms functions in an ecosystem e.g. provides food and shelter for insects and birds

ecological succession
a process that describes the gradual change in the mix of species in an ecosystem

ecosystem
both the living and non- living components that interact in a particular environment, through which matter and energy flow, matter is cycled, energy is not

ectothermic
an organism whose body temperature changes with the temperature of the environment

Ediacara period
a geological period lasting from about 635-542 million years ago

egestion
the process by which undigested food is removed from the body, usually through the anus

embryo
an early stage in the development of an organism that has been produced from a fertilized ovum or zygote

embryonic stem cells
cells produced by mitotic division of the zygote and which form the early embryo. They can be used in the laboratory to grow various sorts of specialised cells.

emphysema
a lung disease in which the walls of alveoli have broken down and cause difficulty breathing

endemic
a species that is restricted to, or originates from, one region e.g. the kangaroo in Australia

endocytosis
the general name for processes which move large molecules and particles of substances, or solutions of them from outside of the cell into the cell by a process of inward folding or invagination of the membrane

endodermis
a cylindrical layer of cells in roots that forms a boundary between the xylem and phloem and the cells of the cortex

endoplasmic reticulum (rough)
a network of membranes in the cytoplasm of eukaryotic cells which is concerned with the synthesis and transport of lipids, and polypeptides, with ribosomes attached to its surface

endoplasmic reticulum (smooth)
a network of membranes in the cytoplasm of eukaryotic cells which is concerned with the synthesis and transport of lipids

endoskeleton
the bony skeleton within an organism e.g. mammals and birds

endothermic
an animal using an internal system to maintain a relatively stable body temperature

epidemic
a widespread outbreak of an infectious disease where many people are infected at the same time

epidemiologist
a medical scientist who studies and deals with the incidence, distribution and control of disease in a population

epidemiology
the scientific study of the cause, spread, control and prevention of diseases

epidermis
the outer layer of cells on an organ e.g. leaf, human skin

epidermis tissue
the outer layer of cells on an organ or organism e.g. leaf, body (skin)

epigenome
a structure of chemicals that covers the chromosomes in human cells; it plays a role in the switching on/off of genes.

epithelium
a particular type of tissue which occurs on the surface of organs e.g. the lining of the alimentary canal and the skin

eukaryotic
a cell that has its internal structure organised into membrane-bound organelles e.g. a nucleus, mitochondria, chloroplasts

eutrophication
the process by which rivers, lakes and other waterways experience excess algal growth which has been stimulated by fertilisers or sewage. It causes reduced levels of oxygen in the water. If left unchecked oxygen levels may fall so low that only bacteria can survive.

exchange of materials
the movement of materials in and out of an organism; from and to the environment

excretion
removal of an organism's waste produced by cells. In animals, this also refers to the removal of excess water and salts from the body.

excretory organ
an organ involved with excretion e.g. kidney, skin

excretory system
an organ system in animals which is able to remove wastes produced by cells and eventually excrete them from the body

exhalation
the process by which air is released from the lungs into the atmosphere

exocytosis
the process by which a cell is able to get rid of large molecules or materials including wastes through its membrane. The process involves a vacuole, containing the material, fusing with the membrane.

exoskeleton
a hard, external skeleton which supports and protects softer tissues e.g. insects

exponential growth
a rapid growth in numbers of a population which can be represented by an equation y=xa

fermentation
an anaerobic process which produces either lactic acid (animals) or alcohol and carbon dioxide (yeast)

filtration
the process by which the blood plasma is filtered from the glomerulus through the Bowman's capsule into the renal tubule in the nephrons of the kidney

flagellum
a whip like tail structure which assists with the locomotion of some unicellular organisms and sperm

Fluid-mosiac model
the current model for the structure of a cell membrane that describes a cell membrane as consisting of two layers (bi-layer) of phospholipid molecules embedded with protein molecules (membrane proteins)

fragmentation
the process by which habitat loss results in the division of an ecosystem into smaller, isolated patches

fundamental niche
the range over which a species occurs in an ecosystem in the absence of interactions with other species e.g. competition

fungi
organisms that lack chlorophyll and act as decomposers; they are heterotrophs

gastric juice
liquid in the stomach consisting of an acid and enzymes which assists in the chemical digestion of protein in food. The acid kills most bacteria in the food eaten.

gene
a particular segment of DNA in a particular chromosome of an organism which carries the information necessary to make a particular protein molecule. It is also referred to as the 'unit of inheritance'.

gene expression
the way in which a segment of DNA, called a gene, can be used to make certain products, usually polypeptides, in an organism

gene switched off
a mechanism by which a gene is inactivated and does not produce a product

gene switched on
a mechanism by which a gene is activated and does produce a product

genetic bottleneck
caused by a drastic reduction in population size and the effect of this on the remaining genes in the gene pool; it reduces biodiversity in the population

genetic drift
changes in the gene pool from one generation to the next

genetic material
the chromosomes of an organism which carry the information necessary to make products, in particular polypeptides and proteins

genital herpes
a sexually transmitted disease caused by the herpes virus

genome
all of the genes present in a cell of an organism

genotype
describes the genes present in an organism, often using using letter for the alleles e.g. Bb where B represents the allele for brown eyes and b represents the allele for blue eyes

global warming
the gradual increase in air and ocean temperatures caused by a change in the composition of the atmosphere, caused mainly by human activities (anthropogenic)

glomerulus
a small ball of capillaries in the Bowman's capsule of the nephron; it is the site of filtration.

glycolysis
the first stage of aerobic respiration and fermentation. During glycolysis, glucose is broken down to smaller molecules to make a small amount of energy available for use (stored in molecules of ATP). Glycolysis takes place in the presence of oxygen (aerobic respiration) as well as in the absence of oxygen (fermentation).

Golgi body
an organelle found in cells involved in the packaging, transport and secretion of molecules

grassland
an ecosystem dominated by grasses with very few shrubs or trees

greenhouse effect
the trapping of heat by the atmosphere resulting in global warming

greenhouse gas
a gas that contributes to the greenhouse effect e.g. carbon dioxide and methane

guard cells
a pair of cells that surround a pore called a stoma. The guard cells and stoma form a stomate (plural stomata). Guard cells regulate the diffusion of water vapour and other gases into and out of the leaf. During the day they inflate which opens stomata and during the night they deflate which closes stomata

habitat
the place or environment where an organism lives

haemolymph
a fluid in insects which is not confined to vessels that is pumped through vessels and spaces (sinuses) by simple 'hearts' to transport substances to and from cells

haploid
a cell that contains only half the usual (diploid) number of chromosomes (n) e.g. gametes

helper T cells
T lymphocytes involved in the adaptive immune response and involved in signalling other lymphocytes and dividing to form other T cells

hemocytes
phagocytic cells in insects which are involved with the immune response

Hendra virus
a deadly virus, transferred from flying foxes to horses and can be passed on to humans

herbaceous plant
species of flowering plants with a green, non-woody stem usually with soft, small leaves

herbivore
an animal that only consumes producers or plants

herd immunity
a form of indirect immunity that occurs when most of the population is immune to the disease

heredity
the scientific study of patterns of inheritance

hermaphroditic
an organism which is able to produce both sperm and ova and able to self fertilise under some conditions

heterotroph
organisms which must take in organic molecules as food to provide them with their essential requirements, otherwise known as consumers e.g. all animals and fungi

hierarchical classification
a system by which all organisms are allocated to a series of smaller and smaller groups starting with a Domain and finishing with a Species

hierarchy
the order of groups used in classification. From largest to smallest these are Domain, Kingdom, Phylum, Class, Order, Family, Genus and Species

histamine
a compound involved in the inflammatory response. Released from mast cells, it increases permeability of blood capillaries.

holdfast
an organ of attachment typically found in algae e.g. seaweeds

homeostasis
a 'steady-state' condition in blood and tissue fluids which exists within the bodies of organisms, to maintain conditions which are more stable than external conditions e.g. temperature

homologous chromosomes
a pair of chromosomes which are the same size and shape and have matching gene positions (loci)

host
an organism that holds a pathogen or parasite providing a nutrient rich environment

hydrophilic
'water loving' or polar molecules which mix with water e.g. dissolved salts

hydrophobic
'water hating' or molecules which do not mix with water e.g. oil

hygienic
meeting certain standards of cleanliness to prevent the spread of microbes and disease

hypersensitivity
a set of responses of the immune system that cause undesirable effects including allergies and acute immune diseases

immune system
a system in the body which usually can identify and remove or destroy foreign particles or organisms

immunity
the ability to resist disease caused by an infectious agent or pathogen

immunodeficiency
where the ability of the host's immune system to fight disease is impaired or deficient

infectious
a property of a disease-causing pathogen enabling it to be transmitted to other organisms

inflammatory response
a response of the innate immune system that helps to fight and destroy invading pathogens

ingestion
a process by which food is taken into an organism, usually through a mouth

inhalation
a process by which air is taken into the body, usually through the lungs

innate
inborn or natural ability to fight pathogenic organisms

inorganic material
the group of chemicals which are not obtained from living cells or organisms, generally they do not contain the element carbon

insect repellent
a chemical that is used to repel insects

insecticide
a chemical that is used to kill insects

interdependence
refers to the way in which different structures, or organisms depend on each other for proper functioning

interferon
one of the cytokines involved in the innate immune response; it interferes with viral reproduction

intermediate host
an additional or secondary host that the pathogen inhabits as part of its life cycle

interphase
a stage of the cell cycle between mitotic divisions. This is when the DNA in the chromosomes replicates and organelles also increase in number.

intertidal
the region between high and low tides on a coastline

intracellular
existing inside a cell

invertebrate
an animal without a backbone

ions
charged atoms that are formed when salts dissolve in water by losing or gaining electrons

karyotype
the complete collection of chromosomes in a particular organism

keratin
a protein often found in hair, feathers, hooves and horns of animals

keystone species
a species whose influence on the stability of an ecosystem is much greater than the number or size of them would suggest

kidney transplant
when a kidney is taken from one person (a donor) and placed into the body of another person (a recipient)

killer T cells
T lymphocytes that work by attacking infected cells and destroying them

lacteal
another name for a lymph capillary, especially in a villus, and involved with the absorption of materials from the alimentary canal

lactic acid fermentation
the process by which animals are able to obtain energy from glucose in the absence of oxygen

lamina
the surface of a leaf

lateral root
roots that grow out sideways from the tap root in a plant that is a dicot

LED lighting
abbreviation for light emitting diode. They are very white, bright lights which produce very little heat and therefore transform energy very efficiently.

lenticel
a tiny pore in the stem of plants that enables gases to be exchanged with the atmosphere

lesion
damage or injury to a part of an organism

lichen
an organism which consists of a fungus and an alga that depend on each other and live together, a very good example of mutualism

lifestyle choices
choices made by people regarding their diet, exercise and interests

lifestyle diseases
diseases which are caused by certain lifestyle choices e.g. poor diet, little exercise

lignin
a carbohydrate found in the xylem of plants that increases the strength of individual xylem vessels. It is also a component of cell walls in plants, usually found together with cellulose fibres.

lipase
a type of enzyme which is involved with the chemical digestion of lipids

lipid
organic molecules that are insoluble in water. The main groups in organisms are fats, oils, steroids and phospholipids.

lower epidermis
a layer of closely packed, protective cells that forms the lower surface of a leaf

lumen
the inside space of a body structure or organ e.g. blood vessel, small intestine

lung cancer
rapid, uncontrolled growth of cells in the lungs, usually in tumours, often as a result of smoking cigarettes or breathing polluted air

lymph
a fluid much like blood plasma which carries white blood cells and assists with the defence of the body against infection

lymph capillary
tiny vessels, much like blood capillaries, but without the red blood cells, which drain fluid into lymphatics or the larger lymph vessels

lymph node
a mass of tissue which occurs at intervals along the lymph system and serves to filter foreign particles and microbes from the lymph fluid; also called a lymph gland

lymphatic system
a separate system of vessels in the human body involved in draining fluid and defending the body against disease

lymphocyte
white blood cells that help defend the body against infection, the two main types are B and T

lysozyme
an enzyme occurring naturally in egg white, human tears, saliva, and other body fluids, capable of destroying the cell walls of certain bacteria and thereby acting as a mild antiseptic

macromolecule
large organic molecules in cells. They include such molecules as nucleic acids, proteins, carbohydrates (or polysaccharides) and lipids.

macrophage
a white blood cell that is capable of carrying engulfing and destroying pathogens by phagocytosis

mallee
a particular type of eucalypt with multiple trunks and a large ligno-tuber or stump

marsupial
mammals where the young are born under-developed and transfer to a pouch to suckle and grow e.g. wallaby, koala, wombat

mast cells
cells involved in the inflammatory response by releasing histamine

maternal chromosome
any of the chromosomes which come from the mother

mature soil
a soil containing large amounts of organic material and is more suitable for the growth of plants

mechanical digestion
the process by which food is broken into smaller pieces prior to chemical digestion. It is also known as physical digestion.

medulla
the inner part of some body organs e.g. kidney and brain

mega-diverse
an ecosystem which shows an unusually large diversity

megafauna
literally means 'large animals' which once inhabited many parts of the world including Australia

mesophyll tissue
the general name given to plant cells which contain a light-absorbing molecule called a pigment, usually chlorophyll. There are two types; spongy and palisade (see separate glossary entries).

messenger RNA
a strand of RNA transcribed from DNA in the nucleus containing information about the sequence of the amino acids in the protein that it codes for

metabolic
a process or biochemical reaction that is related to metabolism

metabolic reaction
a biochemical reaction that contributes to an organism's metabolism

metabolic waste
useless end products of the chemical reactions occurring within an organism

metabolism
all of the biochemical reactions that occur in the body of an organism

metaphase
the phase of cell division in which chromosomes become aligned near the centre of the cell

MHC (Major Histocompatibility Complex)
a system of proteins involved with self and non-self recognition

microflora
the group of normal microbes that inhabit the human digestive system and skin

micrometre
a unit of measurement commonly used in biology (symbol μm). It is one thousandth of a millimetre or one millionth of a metre.

microtubules
a system of tiny tube-like proteins within the cytoplasm of the cell which are part of the cytoskeleton

migration
the seasonal movement of populations of animals from one ecosystem to a different one, usually to find sources of food, shelter or breeding sites e.g. birds, whales

mitochondria
these are organelles which contain the enzymes necessary for aerobic respiration. They are commonly called the 'powerhouse' of the cell (singular mitochondrion)

mitosis
division of the nucleus, which is part of mitotic division, that results in two identical daughter cells

mitotic division
cell division of eukaryotic cells that results in two identical daughter cells. It involves division of the nucleus (mitosis) and the division of the cytoplasm (cytokinesis).

monocotyledon
a plant having only one leaf (cotyledon) growing from the seed e.g. grasses, corn; also called 'monocots'

monoculture
an ecosystem which mainly consists of populations of one species e.g. a crop

monomer
simple building block molecules that when linked together form a polymer e.g. amino acids are linked together to form proteins

monotreme
a species of mammal that can lay eggs e.g. echidna, platypus

morphogenesis
the development, through growth and differentiation of form and structure in an organism

morphology
the visible structure(s) of an organism

mucous
(an adjective) to describe a membrane or tissue secreting mucus

mucus
(a noun) referring to the clear, slimy substance secreted by tissues that is part of the body's innate immune system

multicellular
an organism which is usually made up of many different cells, tissues and organs

mutation
a random and permanent change in the sequence of bases in DNA which may be expressed as a change in the amino acid sequence of a protein. Mutations usually occur at the time of DNA replication. Most of these will be harmful but occasionally it may confer an advantage which could be inherited.

mutualism
a relationship between two different organisms in which both benefit e.g. nitrogen-fixing bacteria in root nodules of plants

mycorrhiza
a symbiotic relationship formed between a fungus and the roots of a plant in which both benefit. The fungus absorbs and transforms essential mineral nutrients, like nitrates and phosphates that it extracts from the soil. These nutrients are then in a form that can be used by the plant. The fungus benefits by receiving food and shelter from the plant.

natural killer cells
white blood cells that are able to recognise non-self cells and viruses and produce cytokines which attack and destroy them

natural selection
a process by which some organisms within a population will live and others will die because some are better suited for survival and reproduction in a particular environment. The selection factors may be biotic or abiotic. The result of this process over many generations is evolution. The theory was first proposed by Charles Darwin in 1859.

nematode
small roundworms often found as parasites and pathogens in plants and animals

nephron
the functional unit of the kidney, responsible for filtering the blood plasma and then reabsorbing most useful materials from the glomerular filtrate

nervous system
an organ system in animals that consists of nerve cells (neurons) in the brain, the spinal cord and other nerves

neuron
a nerve cell which is capable of transmitting tiny electric impulses called nerve impulses

neutrophil
a white blood cell involved in innate immune response and carries out phagocytosis

niche
consists of all of the biotic and abiotic factors of a particular species in its ecosystem

niche overlap graph
a graph used to display to what extent populations of two species have the same niche. The greater the niche overlap the greater the competition between the populations.

nitrate
a soluble form of the element nitrogen that is able to be taken up by plants in solution. Nitrogen is an essential element needed for the synthesis of protein.

nitrogen-fixing bacteria
assist in the process by which atmospheric nitrogen is converted into a soluble form (nitrate) able to be used by plants. Such bacteria are often found in swellings or nodules on the roots of certain plants called legumes.

nocturnal
a species of animal that is mainly active at night

non-coding DNA
DNA which is not transcribed and translated into protein; also called introns

non-infectious
a disease that cannot be transmitted from organism to organism

non-self
cells and molecules that are not part of an organism and are usually recognised by the immune system as foreign and therefore do trigger an immune response

nucleic acids
a macromolecule made up of a sequence of nucleotides joined together. Examples include DNA, mRNA and tRNA.

nucleus
an organelle in a eukaryotic cell which contains the information necessary for the activity and division of the cell. This information is in the form of DNA which is part of the chromosomes.

nutrigenomics
the study of the relationship between diet and the epigenome

nutrition
the process of taking in and making available nutrients in food available to an organism

oesophagus
otherwise known as the gullet, conveys food from the mouth to the stomach

omnivore
an animal that consumes both plants and animals

open circulatory system
a system of circulation in an animal in which blood spends some time outside blood vessels

organ
part of a multicellular organism, consisting of different types of tissues which perform a particular function e.g. the lungs

organ system
part of an organism, consisting of different organs which combine to perform a particular function e.g. the circulatory system consists of the heart and blood vessels

organelle
small structures which exist within the cytoplasm of cells. They each have particular structures and important functions in the cell. Examples include the nucleus, chloroplast and mitochondrion.

organic molecule
substances which are derived from living cells or organisms, generally they are large molecules containing the elements carbon, hydrogen and oxygen

organism
any cell or collection of cells which is capable of independent existence and reproduction

osmoregulation
the process of maintaining the correct balance of water and salts in the blood or cytoplasm of cells

osmosis
the nett movement of water across cell membranes from a region of low solute concentration to a region of higher solute concentration until the two regions have an equal solute concentration

oxygenated blood
blood that has a high concentration of oxygen and a low concentration of carbon dioxide. With the exception of the pulmonary vein, oxygenated blood is transported by arteries.

palisade mesophyll
long, closely-packed cells in the leaf which contain chlorophyll to perform the process of photosynthesis

pancreatic juice
a fluid produced by the pancreas which drains into the small intestine through the pancreatic duct. It contains enzymes to permit chemical digestion in the duodenum and an alkaline fluid to form a pH neutral environment the enzymes need to function.

pandemic
an infectious disease that spreads across continents

parasite
an organism which lives in or on another, usually to the detriment of the host e.g. tapeworm, lice

parasitism
the relationship between two species where one benefits (the parasite) and the other is harmed (the host). The parasite may live in or on the host e.g. tapeworm, lice

parenchyma
plant tissue which consists of relatively undifferentiated cells frequently with airspaces between them; sometimes also referred to as 'cortex'

passive immunity
a form of immunity that provides protection against a disease but does not activate the adaptive immune system

passive transport
the process by which materials may pass from one place to another by diffusion which requires no energy. This includes their passage through a semi-permeable membrane.

pasteurisation
the process by which milk (and some other liquids) are heated and then cooled in order to kill all (or most) of the microorganisms in it

paternal chromosome
any of the chromosomes which come from the father

pathogen
an organism or virus or prion that causes disease when living (or existing) in or on another organism

pathogenicity
the ability of a pathogen to cause disease

pH
the scale to measure how acidic or alkaline a solution is: 7 = neutral, <7 =acid, >7= base (alkali).

phagocytes
white blood cells that are able to engulf (by endocytosis) and destroy foreign cells and particles

phagocytosis
the process used by phagocytes to destroy pathogens

phenols
natural organic compounds released by plants with an important role in cancer prevention and treatment

phenotype
the appearance of an organism which is a result of its genotype and the effect of the environment

phenylketonuria
a disease caused by a mutant gene that leaves a person with an inability to complete the chemical breakdown of the amino acid phenylalanine

pheromones
chemicals used as communicating molecules often to attract mates

phloem
tissue in plants that transports sugar produced by photosynthesis and some mineral nutrients

phloem sap
the solution transported in the phloem tissue in a plant; contains water, sugar and some mineral nutrients

phloem tubes
tube-like cells in a plant through which phloem sap is transported

phosphates
a soluble form of the element phosphorous; an essential component of nucleic acids

phospholipid
organic molecules with phosphate attached to the lipid. Phospholipids are important in cell membrane structure.

photo-autotroph
an organism capable of making its own food by using energy from light in the process of photosynthesis

photosynthesis
a process which occurs in the green cells of a plant whereby carbon dioxide and water are chemically combined in the presence of light to form the sugar glucose and oxygen

physiological
refers to the way that an organism functions internally, sometimes meaning the same as 'functional'

phytoplankton
the microscopic organisms in oceans, lakes and rivers that carry out the process of photosynthesis

pili
tiny, hollow projections made of protein and used to attach bacteria to surfaces

pith
the central tissue of the stem of many large plants

pituitary gland
located in the brain and produces a large variety of hormones that control bodily functions or other endocrine glands, sometimes called the 'master gland'

placental mammal
a mammal that develops in the uterus, attached via an umbilical cord to a placenta

plasma
the liquid part of the blood or lymph, not always confined to vessels

plasma cells
B lymphocytes that produce antibodies

plasmid
a separate, circular piece of DNA in bacteria, capable of independent replication, that can be transferred between individual cells. Plasmids are important in the transfer of genetic information in the process of genetic engineering.

Plasmodium
the parasite that causes the disease malaria

platelets
fragments of white blood cells involved in the process of blood clotting

Pleistocene period
a geological period lasting from about 2 million-10 000 years ago

pneumonia
a disease resulting from the bacterial or viral infection of the lungs, can be fatal if not treated properly

polymer
a substance having large molecules which consist of repeating units called monomers (e.g. polysaccharides consist of monosaccharide monomers)

polypeptide
a long chain of amino acids held together by peptide bonds

polysaccharide
a complex sugar made up of many monosaccharides joined together in a long chain e.g. starch

population
a group of individuals of the one species in a particular place at a particular time

post-zygotic
a type of reproductive isolation in which a zygote is successfully formed but then either fails to develop or develops into a sterile adult

pre-zygotic
a type of reproductive isolation in which organisms of two species never reach the stage of successful mating, and thus no zygote is formed

predation
usually a type of feeding relationship where one organism hunts and kills another for its food

predator
an organism that eats another live organism; includes most animals and some plants

preservatives
chemicals which are added to foods in order to stop or slow down spoilage by microbes

pressure gradient
the change of pressure between two points in relation to their distance apart, especially when considering fluid movement in plants

primary response
the response that occurs when an organism is exposed to a pathogen for the first time. It is generally smaller and slower than the secondary response.

primary succession
the process by which a simple mix of some species gradually emerges in what was previously a virtually lifeless environment e.g. bare rock

prions
an infectious protein particle that has the ability to cause disease e.g. Mad Cow disease

producer
the type of organism that traps the sun's energy in photosynthesis. Plants are producers, as are algae e.g. phytoplankton

prokaryotic
rather primitive and unspecialised cells which do not have membrane-bound organelles or very much genetic material. The most common examples are bacteria and blue-green algae.

promotor
a length of DNA near a gene. If RNA polymerase (the enzyme needed for transcription) can bind to the promotor the gene is 'switched on' and transcription commences.

prophase
the first stage of cell division in which the chromosomes become tightly coiled and visible before the nuclear membrane disappears and the chromosomes become distributed throughout the cytoplasm

protease
a type of enzyme that is involved in the chemical digestion of protein e.g. pepsin

protein synthesis
a two-stage process by which information stored in DNA is used to make messenger RNA (transcription) which, in turn is used to make polypeptides (translation), the folding of these polypeptides then forms functional proteins

proteins
large organic molecules that are made up of one or more long chains of amino acids (or polypeptides) linked together in a 3D shape. They are important structural and functional molecules in living organisms.

protists
the most primitive form of eukaryotic cells and organisms, the most common of these are the protozoa and algae

pulmonary circulation
the circulation of blood in an animal from the heart to the lungs and returning to the heart

pus
a collection of white blood cells, invading cells and other debris that accumulate at the site of an infection

quarantine
the practice of isolating an infected organism from others to prevent the transmission of disease to other organisms

radial symmetry
the property of an organism where the parts seem to extend out from a central point like spokes in a wheel e.g. a starfish, the petals of flowers

radiant energy
a form of electromagnetic energy that is radiated e.g. from the sun

radiation
transmission of energy in the form of waves or particles, this includes electromagnetic radiation, X rays and visible light

reabsorption
the process in the kidney nephrons in which useful substances are returned to the bloodstream from the glomerular filtrate

realised niche
the 'real' niche of an organism that is shaped by interactions with other species

receptor molecules
a protein molecule that is involved in cellular communication; binding to complementary molecules (e.g. hormones) to activate cellular processes

recipient
a person who receives an organ for an organ transplantation operation

recombinant DNA
sections of DNA that do not occur naturally but come from different organisms and have been artificially joined by scientists

renal artery
the artery that transports blood to the kidneys

renal vein
the vein that transports blood from the kidneys

repressors
proteins that 'switch off' genes by making them less accessible for transcription

reproductive isolation
a process where gene flow is prevented between two populations of the same species; achieved by a variety of mechanisms e.g. different mating seasons or calls

reproductive tissue
tissue which comprises reproductive organs that are responsible for the reproduction of the species

residual volume
the volume of air remaining in the lungs after a forced exhalation

respiration (cellular)
a series of metabolic reactions that take place in cells to make energy (stored in food substances) available for use by cells. In aerobic cell respiration, oxygen is involved in the breakdown of glucose, and a large amount of ATP is produced. In anaerobic cell respiration (also called fermentation), oxygen is not involved in the breakdown of glucose and a relataively small amount of ATP is produced. (not to be confused with breathing)

respiratory system
an organ system in animals which enables the organism to move air in and out of the body to enable diffusion of gases into and out of the blood

rhinovirus
common infectious virus in humans and the cause of 'colds'

ribosomes
these organelles are the sites at which translation occurs and polypeptides and proteins are synthesised

RNA polymerase
the enzyme that produces mRNA molecules during transcription

root hair
a microscopic extension of a root epidermis cell which increases the surface area for the absorption of oxygen, water and mineral nutrients

root pressure
the pressure that exists in roots due to the inward flow of water by osmosis

root system
an organ system of a plant, which is normally underground and enables the absorption of oxygen, water and mineral nutrients. It also anchors the plant in the ground to provide stability.

rough endoplasmic reticulum
endoplasmic reticulum with ribosomes attached to the surface. Acts as an internal transport system

saliva
a fluid released by glands in the mouth which contains an enzyme to begin the chemical digestion of starch

Salmonella
a group of bacteria that can cause food poisoning, especially in poultry

salt gland
a gland that can accumulate excess salt and then remove it from the body of the organism. They are present in some plants (e.g. mangroves) and animals (e.g. marine iguanas).

sanitation
usually referring to providing effective means to dispose of human waste and the methods used to reduce the spread of infectious disease

sanitisation
effectively cleaning hands and other surfaces to control the spread of microbes and disease

sclerophyll
species of plants with hardened leaves that contain waxy cuticles to help reduce water loss in hot, dry habitats e.g. species of Eucalyptus

sclerophyll forest
a woodland ecosystem that consists mainly of plants with hardened leaves that contain waxy cuticles to help reduce water loss in hot, dry habitats.

secondary response
the response of the adaptive immune system when a human is exposed to a pathogen for a second or subsequent time. It is bigger and more effective than the primary response.

secondary succession
a change in the mix of species in an ecosystem as a result of a natural disaster or a major human activity e.g. bush fire, clearing of vegetation for agriculture

secretion
the manufacture and discharge of specific substances by cells in to their external medium (e.g. blood)

selectively permeable
the property of the cell membrane which allows some substances to pass in and/or out of the cell whilst not allowing others to do likewise (also semi-permeable)

self
cells and molecules that are part of an organism that are not recognised by the immune system as foreign and therefore do not trigger an immune response

semilunar valve
a valve found at the start of an artery leaving the heart that prevents backflow of blood into the ventricle

shoot system
an organ system of a plant which consists of a stem, branches and leaves

shrubland
an ecosystem consisting mainly of populations of shrubs with relatively few populations of grasses and trees

simple soil
a collection of the remains of dead autotrophs and particles of rock; it is relatively poor in nutrients

soil solution
the solution of water and dissolved mineral nutrients found in the soil

species
the smallest grouping in the biological classification system. A genus is made up of one or more species. A species is a group of organisms that can interbreed with each other to produce fertile offspring. This definition does not apply to those species that reproduce asexually e.g. bacteria.

species richness
a measure of how many different species exist within a community or ecosystem

spindle fibres
microfibres which separate homologous chromosomes and/or chromatids during cell division.

spleen
an organ of the lymphatic system involved in the immune response. Secondary organ where memory lymphocytes (B and T) are stored.

spongy mesophyll
a tissue in a leaf which consists of photosynthetic cells containing chloroplasts separated by air spaces.

spore
small structures involved in asexual reproduction and dispersal; often can survive harsh conditions. They are used in the lifecycles of fungi, ferns etc.

stable ecosystem
a well-established ecosystem with many species that will recover quickly following a disturbance, usually has high levels of biodiversity

stimulus
any event that can be detected by specialized receptors in the body of an organism e.g. sight, sound, touch

stoma
(or stomate) a structure in the epidermis of a leaf which regulates the diffusion of water vapour and other gases into and out of the leaf. It consists of two guard cells and a pore. (plural: stomata or stomates)

stratification
a type of organisation of a community in which populations of species are distributed vertically depending on various biotic and abiotic factors e.g. within a rainforest

succulent
plants that have large fleshy leaves which store water and as a result are able to survive very dry conditions e.g. cactus, pigface

superbug
bacteria that have become resistant to many, if not all, known antibiotics

surface area
the total external area of a structure, particularly a cell membrane

symbiosis
the relationship existing between members of different species; types of symbiosis include mutualism, commensalism and parasitism

synthesis reaction
a chemical process to make or manufacture a particular substance

systemic circulation
the circulation of blood in an animal from the heart to the main organs of the body and back

taproot
the main root of a plant that is a dicot, usually grows straight down into the soil

taxonomic level
one of eight grouping levels that are used to classify all organisms: Domain, Kingdom, Phylum (plural phyla), Class, Order, Family, Genus (plural genera) and Species

telophase
the final stage of mitosis in which two new nuclei are formed

thermophile
microorganisms that grow at high temperature ranges of 40° to 90° Celsius

thoracic duct
the main collecting duct for lymph which drains back into the bloodstream near the vena cava

thymus
an organ of the body which is involved in the maturation of white blood cells, especially T lymphocytes

tidal volume
the volume of air that passes in or out of the lungs during inhalation and exhalation

tissue
a group of similar cells that are organised into a specific structure e.g. muscle cells organised to form a muscle

tissue fluid
the fluid that occurs in between cells in multicellular organisms

toxic
a substance which is poisonous, potentially fatal to living things

toxin
a substance which is a poison and may disrupt the health or threaten the life of an organism. The effects of a toxin are said to be toxic.

trace elements
elements that are needed by living organisms in only very small quantities

trachea
the tube which takes air from the back of the throat to the lungs. It branches to form the two bronchi, one to each lung.

transcription
the process which occurs during protein synthesis in the nucleus of a cell in which DNA is used to make a 'working copy' of mRNA

trangenesis
the process by which genes are taken from the DNA of one organism and incorporated into the DNA of another organism

translation
the process in which mRNA is used to produce a sequence of amino acids that are chemically joined together by peptide bonds (to form a polypeptide). It is the second stage of protein synthesis.

translocation
the process by which the sugar solution (or sap) in the phloem is transported. In leaf-to-root translocation sap is transported from cells in leaves to cells in the roots.

transpiration
the loss of water vapour from leaves as a result of evaporation

transpiration pull
one of the forces in plants that assists in the movement of water and mineral ions from roots to leaves

transpiration stream
the upwards flow of water in the xylem tissue of plants

trophic structure
feeding relationships of a community showing the producers, then first and higher order consumers

tuber
a swollen underground stem or root of a plant in which sugar may be stored. It may also be involved in asexual reproduction.

unicellular
organisms capable of independent existence but consisting of only one cell

unidirectional
a process that only occurs in one direction e.g. ecological succession in which the mix of species gradually changes over time; not cyclic

unstable ecosystem
an ecosystem that will not recover quickly if it is disturbed, usually has low levels of biodiveristy

upper epidermis
a tightly packed layer of transparent cells on the upper surface of a leaf which are normally protected from desiccation by a cuticle

urea
a chemical waste product containing nitrogen. Urea can be excreted from organisms that have sufficient but not an excess of water e.g. most mammals.

urethra
the tube which carries urine from the bladder to the outside of the body

vaccination
an injection that provides a level of immunity against a specific pathogen

vacuole
a membrane-bound organelle in a cell which contains water, which may contain dissolved salts and sugars

vascular bundle
a collection of xylem and phloem tissue in a plant e.g. in dicots the vascular bundles are arranged around the edge of them stem

vascular tissue
in plants the xylem and phloem tissue in roots, stem and leaves; in animals the tissues associated with the vascular (or circulatory) system e.g. tissues of the heart, arteries and veins

vector
an intermediate host involved with the transmission of a pathogen e.g. a tick or mosquito

veins
a blood vessel with valves that transport blood at low pressure back to the heart. Also refers to strands of vascular tissue in the leaves of plants. Dicots have leaves with a network of veins; monocots have leaves with parallel veins.

ventricle
the lower chambers of the heart that pump blood to the lungs and the body tissues

venule
a small vein connecting capillaries to larger veins

villus
a finger-like projection of the wall of the small intestine to increase surface area for absorption (plural villi)

viroids
infectious particle of plants, made of RNA, like a virus

virulent
a term that refers to the ability of a pathogen to cause disease. A highly virulent pathogen causes a high level of disease.

virus
a very tiny infective particle usually with a tough outer wall and containing some nucleic acids. Viruses are not capable of independent existence and are not classified as cells or organisms.

viscosity
the property of a gas or liquid which determines how easily it flows

vital capacity
the total amount of air that can be exhaled after maximum inspiration. In humans this is typically about 4.5 litres.

volume
the total internal space of a structure, particularly a cell

vulnerable species
a species that faces a high risk of going extinct in the wild, often has a gene pool with very little biodiversity

waste
a substance produced by cells that is not required by the organism, sometimes also called 'waste products'. In animals, the term also refers to excess water and salts, faeces are not strictly a 'waste'.

water vapour
water in the gas state that is formed when liquid water evaporates

well-being
a state of good physical and mental health, a term usually applied to humans

xylem
the tissue in a plant that is concerned with the transport of water from roots to leaves

xylem tissue
cells that are involved in the transport of water throughout a plant

xylem vessels
tubular structures which are involved in transporting water and mineral nutrients from the roots to the leaves of a plant

zonation
a type of organisation of a community in which populations of species are distributed horizontally e.g. the different locations of populations of invertebrate species on a coastal rock platform

zygote
a cell which is formed as a result of the fertilisation of the male and female gametes e.g. sperm and ovum (or egg)

Practical Terms

Accurate data
The closer data is to the real value, the more accurate it is. Data from an investigation that was repeated is more accurate because the effect of systematic errors can be minimised.

Analysis
Inspection of the data collected by an investigation to determine if there is a pattern, trend or relationship between changes to the independent variable and measurements of the dependent variable.

Axes headings
The 'x' axis on a hand-drawn graph is labelled with the independent variable and the symbols of the SI unit of measurement e.g. mass (kg). The 'y' axis is labelled with the dependent variable and the symbols of the SI unit of measurement as well.

Collaborative work
Work done, together with other students.

Column heading
The data in a results table is presented in columns that have a heading that includes the quantity the data in the column refers to and the symbols of the SI unit of measurement.

Conclusion
Evidence and biological understanding is used to state whether data supports or refutes the hypothesis and there is detailed justification for this.

Controlled variable
A factor held constant during an investigation.

Deconstruction (of a Problem)
The problem is broken down and discussed in order to design the most appropriate procedure to use to investigate it.

Dependent variable
The variable that may change as the independent variable is changed and can be measured.

Design (of an Investigation)
The process used to put together and document an investigation of a problem. The Design of an investigation is best done immediately following a process of Deconstruction.

Ethical and safety considerations
How the investigation will be conducted that ensure it is the 'right' thing to do (ethical) and how the procedure ensures it minimises risk of harm (safety).

Evaluation
Discussion of the procedure that includes sources of uncertainty and the effect of them on the results.

Factor held constant
A variable kept constant; often also called a 'controlled' variable.

Factor not controlled
A variable that could not be kept constant.

Fair test
An investigation in which only the effect of the independent variable on the dependent variable is measured. All other factors are deliberately held constant.

Hand-drawn graph
A graph of the data drawn by hand on a piece of graph paper. The independent variable is shown on the 'x' axis and the dependent variable on the 'y' axis.

Hypothesis
States what is expected to happen to the dependent variable as the independent variable is increased or decreased. It is often written as an 'If ... then ...' sentence.

Independent variable
The variable that is deliberately changed during an investigation.

Individual work
Work done by students during an investigation, without the assistance of other students.

Introduction
Biological theory relevant to the investigation is outlined and the purpose of the investigation is stated.

Line of best fit
A straight line or curve that is drawn as close as possible to data that has been plotted on a graph.

Materials
All the scientific equipment and materials that are needed to conduct the investigation.

Precision
How close pieces of data are in a set of data. The smaller the scale of a measuring device, the greater the precision of the data it is able to collect.

Primary data
Data collected in an investigation that has not been processed in any way; often also called 'raw' data.

Problem
A question that links the independent and dependent variables; also called an Inquiry Question (IQ).

Procedure
The method that is used to carry out the investigation.

Purpose
The aim of the investigation.

Random error
An error caused by a factor that randomly affects measurement. The effect of random errors on data are minimised by replicating the measurements to increase the sample size.

Reliable data
Data obtained from an investigation in which measurements were replicated.

Repetition
The entire investigation is repeated using an alternative set of materials to gather another set of data to use to detect the effect of systematic errors on measurements.

Replication
The effect of the independent variable on the dependent variable is measured more than once before the independent variable is changed e.g. the time taken to dissolve sugar is measured three times at 20°C before the temperature is changed to 30°C to determine the dissolving time at that temperature.

Results
Data collected by an investigation; often in the form of measurements that are displayed using a table and/or a graph.

Sample size
The number of measurements taken of the dependent variable.

Scatter in the graph
A measure of how far points on a graph are above and below a line of best fit, probably due to the effect of random errors. The more scatter, the less reliable the data.

Secondary data
Data that has not been collected by an investigation, but has been obtained from a published source.

Significant figures
The number of single digits in a measurement e.g. 6.23m has three significant figures while 19.82°C has four significant figures.

SI units and symbols
SI (System of International) units are a collection of internationally agreed units of measurement. These include kilogram, metre and second. Each SI unit is represented by a specific symbol e.g. kg for kilogram, m for metre and s for second.

Source of uncertainty
Any aspect of the investigation that contribute to errors of measurement e.g sources of random and systematic errors, and factors that affect the effective control of variables.

Systematic error
An error caused by a measuring instrument being faulty or incorrectly calibrated. The effect of systematic errors on data are minimised by repeating the investigation.

Table
The data collected is displayed in columns, each one of which have a column heading. The independent variable is listed by the left-most column heading and the dependent variable by the right-most column heading.

Validity
The degree to which an investigation measures what it is designed to measure.

Index

App

L

M

N

O

P

Q

R

S

T

U

V

W

X

Z