4 Systems — living connections

Inside your body is a very complex place and many complex processes need energy. To convert energy into a form you can use requires transport highways to take nutrients where they are needed and carry wastes away. Different parts of your body have different jobs—they may work together and rely on each other. The curiosity, imagination and persistence of humans throughout history has given us our current knowledge about our bodies and how they function. What questions do you have about your body and how it works?

Think about the human body
- What is the function of blood?
- Why do you need a skeleton?
- What are bones made of?
- What makes your bones move?
- Which human blood type is most common?
- How many chambers does a human heart contain?
- What causes the ‘lub dub’ sound that your heart makes?
- What is special about cardiac muscle?
- Why aren’t all of your teeth the same shape?
- In which organ is urine produced?

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YOUR QUEST

Getting below the surface

Have a look at the other students in your classroom. How different from each other are you? Which features do you all have in common? Perhaps there are differences on the outside, but inside you are made up of all of the same bits and pieces organised in the same way.

THINK AND CREATE

Some of the things that you have in common with your classmates are your body systems.

1. Use a mind map to summarise all that you know about human body systems.
2. Compare your mind map with those of at least three team members.
3. Create a new team mind map that combines all your ideas and compare that with the mind map of another team. Add any comments that you think help you learn more about human body systems.

THINK AND INVESTIGATE

4. In your team, make a list of ten questions about human body systems. Select four questions and place these on the class noticeboard with those of other teams to make a ‘class question gallery’. Arrange these questions into groups or themes.
5. Browse the class question gallery and select one question that interests you most. Research your selected question and report back to the class on your findings in an interesting and creative way.
Driven by curiosity?

Imagine if your curiosity was so intense that you spent hour upon hour painstakingly exploring, sketching and recording layer upon layer of a rotting dead body among other decaying and quartered corpses in the ‘dead of night’.

Leonardo da Vinci was one of the best scientific minds of his time. He was intensely curious and painstaking in his observations. He used close observation, repeated testing and precise illustrations with explanatory notes. Using pen, chalk and brush, his scientific illustrations offered visual answers to mysteries that had escaped others for centuries. His volumes of amazing notes of scientific and technical observations in his handwritten scripts led to the birth of a new systematic and descriptive method of scientific study.

Leonardo da Vinci questioned everything. He may have been the most relentlessly curious man in history. He asked questions such as: Why do birds fly? Why can seashells be found in mountains? What is the origin of the wind and clouds? Why do people die? Where is the human soul found?

Dissecting, details and drawing

Leonardo’s anatomical studies of human muscles and bones began around 1490. His exploration of embryology and cardiology came later, with his astonishingly detailed image of a fetus within the womb (around 1505) providing details for obstetric surgery hundreds of years later. His observations were not just of bodies — later generations have been in awe of his sketches of inventions that were centuries ahead of their time.
Challenging ‘knowledge’
Knowledge of the human body was very different in Leonardo’s day from what we accept today. The heart was thought to be made up of two chambers and its function to warm the blood, which was thought to be made in the liver. It was also thought that sperm were produced in the marrow of the spinal column and that the human soul may be located in the spine. Leonardo had questions he wanted to answer. He wanted to find out more. His investigations challenged the accepted knowledge of his day.

Visions and models
Leonardo also emphasised the significance of visual observations and model making — he believed that reality needed to be reconstructed before it could be represented. His models of hands or legs were used to reveal the structural relationships between different layers of arteries, muscles and bones. Leonardo also made a glass model of the heart and used water with different coloured dyes to trace its flow through the heart. His investigations linked anatomy (structure) and physiology (function).
Analogies are sometimes used to help people to connect new learning to previous knowledge. Leonardo used analogies to compare arteries in human bodies to ‘underground rivers in the earth’ and described the bursting of blood from a vein like ‘water rushing out a burst vein of the earth’.

Leonardo’s dissections led to changes in the knowledge and understanding of the structure and function of the heart, including that:
- the heart was a muscle
- the heart did not warm the blood
- the heart had four chambers
- left ventricle contractions were connected to the pulse in the wrist.

To locate cavities around the brain and cranium, Leonardo used innovative techniques, such as injecting molten wax into them. Although Leonardo did not find the location of the human soul, his studies led him to the discovery that the brain and spine were connected.

Leonardo’s curiosity, determination, creativity and persistence did more than make an amazing contribution to our current scientific knowledge of our bodies. These features also helped mould the way in which scientific frameworks were developed to structure our investigations to explore our questions.

Curiosity throughout time and space

Curiosity is one of the features of humans that has contributed to our survival. Some of this curiosity has been about the structure and function of our own bodies. Evidence of this curiosity is woven throughout history and is often found in art. While Leonardo da Vinci provides one example of curiosity driving a search to find out more, he is not the only example. Nor is human curiosity limited to the place or time in which you live.

Knowledge of the internal biology and physiological process in art appears in rock paintings in caves in Australia that are thousands of years old. Examples of Aboriginal X-ray art provide evidence that this type of knowledge dates back more than 6000 years.

The culture and scientific knowledge of the times often determines the types of treatment given for various diseases of the human body. In medieval times, astrology played a key role in medicine and medical prognosis. It was believed that the ‘movement of the heavens’ could influence human physiology, with each part of the body being associated with a different astrological sign. An image of the ‘Zodiac Man’ in the medical texts of the time was used to assist practitioners in their medical treatments.
The 'Zodiac Man' chart was based on astrology and provided advice on when, for example, to 'bloodlet' (a medical treatment involving bleeding the patient), regulated by the position of the moon.

Australian scientists: creative inventors and explorers

Australian scientists have made significant contributions to medical discoveries and inventions. Howard Florey and his team discovered how penicillin could be extracted, purified and produced to be used as an antibiotic to help fight bacterial infections. Barry Marshall and Robin Warren showed that a certain type of bacteria caused stomach ulcers that could be treated with antibiotics. Professor Graeme Clark and his team were involved in the invention of an effective 'bionic ear'. Dr Fiona Wood pioneered a new treatment for burns in her development of spray-on skin that used the patient’s own skin cells. Professor Ian Frazer developed the world’s first vaccine against cervical cancer.

Chinese traditional medicine is an ancient medical system that has been practised for over 5000 years and applies understanding of the laws and patterns of nature to the human body. It views health as the changing flow throughout the body of vital energy (qi) that, if hindered, can lead to illness. Acupressure is an application of this theory that aims to release blocked energy by stimulating specific points along the body’s energy channels.

Scientists are curious

Scientists are also often driven by the thirst to find answers to their questions. With increased technology and knowledge, the answers to these questions often result in even more questions.

Compared with the situation in Leonardo’s day, there are now an amazing number of different types of careers that involve investigations, explorations and applications of science to the human body. Australian scientists are involved in medical research and intervention. They are also involved in the invention and development of medical equipment that assists our understanding of our body systems.
The cochlear implant, also known as the bionic ear, has allowed some people with inner-ear problems to hear sound for the first time. When deafness results from serious inner-ear damage, no sounds are heard at all. Normal hearing aids, which make sound louder, do not help in these cases because the cochlea cannot detect the vibrations. However, the cochlear implant can often help by changing sound energy from outside the ear into electrical signals that can be sent to the brain.

The hearing receptors send message through the auditory nerve to the brain. The sound heard by the user is not completely natural because there are only 22 electrodes replacing the tens of thousands of hair cells in the cochlea of a normal ear.

Electrodes placed inside the cochlea receive the decoded signals. The 22 electrodes allow a range of different pitches to be detected. The electrocodes stimulate the hearing receptors.

The speech processor changes the sound into an electrical code. It can be worn on a belt, or a smaller version can be built into the microphone and worn behind the ear.

The microphone is worn behind the ear.

The receiver–stimulator is implanted in a bone behind the ear. It decodes the signal and sends electrical pulses through wires towards the cochlea.

The electrical code is sent through a cable to the transmitting coil. Radio waves are then used to send the code through the skin.

An enlarged X-ray of the cochlea showing the experimental electrode array inside.

How a cochlear implant works
David Unaipon (1872–1967) has been described as ‘Australia’s Leonardo’. He was born in South Australia, the fourth of nine children of James Ngunaitponi and his wife Nymbulda. Both of David’s parents were Yaraldi speakers from the lower Murray River region.

Interested in Aboriginal mythology, philosophy and science, David was a preacher, author and inventor. He compiled his own versions of Aboriginal legends such as Hungarrrda (1927), Kinie Ger — The Native Cat (1928) and Native Legends (1929). David’s published poetry and legends pre-dated the work of other Aboriginal writers by over thirty years.

Obsessed with discovering the secret of perpetual motion, David made ten patent applications between 1909 and 1944 for inventions including a modified handpiece for shearing, a centrifugal motor, a multiradial wheel and a mechanical propulsion device.

UNDERSTANDING AND INQUIRING

INVESTIGATE

1. Research and construct a model of an invention from one of Leonardo da Vinci’s sketches.
2. Research examples of Leonardo da Vinci’s inventions and make your own variation of one of them, presenting it as a series of annotated sketches.
3. Research an invention sketch by Leonardo da Vinci that is related to something that we use today. Use a tree diagram to show how it may be linked.
4. Find out what the da Vinci® Mitral Valve Repair is and suggest why it is named after da Vinci.
5. Find out about the history behind Treatise on painting and how it relates to science.
6. Find out more about Codex on the flight of birds and summarise your findings in a newspaper article.
7. Research three Australian scientists involved in medical research and intervention, and present your findings as a curricula vitae.
8. Find an example of how Australian scientists have been involved in the development of medical equipment. Produce a brochure to advertise this equipment to prospective buyers.
9. Suggest how scientific understanding of human body systems can determine how we respond to public health issues such as the 2009 swine flu pandemic.
10. Research traditional Chinese medicine and find out about the knowledge of the structure and function of human body systems. Present your findings in a scroll with wooden sticks at each end.
11. Research two of the following applications of traditional Chinese medicine:
   - qigong
   - herbal therapy
   - acupressure
   - healing foods
   - Chinese psychology.
12. Research Aboriginal X-ray art to investigate examples of Aboriginal knowledge of the internal biology and physiological processes of animals.
13. The Warlpiri are one of the largest Aboriginal groups in the Northern Territory. Research and report on their traditional health system and the involvement of ngangkay/kirli (or ngangkari or ngangkay) and Yawulyu ceremonies of the Warlpiri.
Working together?

Like all matter in the universe, you are made up of atoms. Collections of atoms make up molecules, molecules make up organelles, which make up cells, which make up tissues, which make up organs, which make up systems, which make up you. This progression is shown in the diagram below.
All alone? Independent!

Unicellular organisms are made up of only one cell that must do all of the jobs that are required to keep the organism alive. These single-celled organisms are small enough that essential substances (e.g. oxygen) and wastes (e.g. carbon dioxide) can be exchanged with their environment through simple diffusion.

Carbon dioxide out
Oxygen in
Glucose and other useful substances in
Other waste products out

Useful substances (e.g. oxygen) can move into cells and wastes (e.g. carbon dioxide) can move out through a process called diffusion.

One of many?
Better get organised!

Like other multicellular organisms, you are made up of many cells. These cells cannot survive independently of each other. They depend on each other and work together. Working together requires organisation.

Pattern, order and organisation

Multicellular organisms are made up of a number of body systems that work together to keep them alive. Body systems are made up of organs, which are made up of tissues, which are made up of particular types of cells.

Organelles

Within each cell there are structures called organelles. Each organelle has a particular job to do.

Mitochondria, for example, are organelles in which the chemical energy in glucose is transformed into energy that our cells can use.

Cells

Multicellular organisms are made up of many different types of cells, each with a different job to do. Although these cells may have similar basic structures, they differ in size, shape, and in the number and types of organelles they contain. The different make-up of different types of cells and structures within them makes them well suited to their function.

Tissues

Groups of similar cells that perform a specialised job are called tissues. Muscle tissue contains cells with many mitochondria so that the energy requirements of the tissue can be met. Nerve tissue consists of a network of nerve cells with extensions to help carry messages throughout your body. The table below shows some examples of tissues that make up your body, what they look like and what their main functions are.

<table>
<thead>
<tr>
<th>Name of tissue</th>
<th>Description</th>
<th>Main functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Epithelial tissue</td>
<td>Sheets of cells</td>
<td>To line tubes and spaces, and form the skin</td>
</tr>
<tr>
<td>Connective tissue</td>
<td>Tough flexible fibres</td>
<td>To bind and connect tissues together</td>
</tr>
<tr>
<td>Skeletal tissue</td>
<td>Hard material</td>
<td>To support and protect the body and permit movement</td>
</tr>
<tr>
<td>Blood tissue</td>
<td>Runny fluid containing loose cells</td>
<td>To carry oxygen and food substances around the body</td>
</tr>
<tr>
<td>Nerve tissue</td>
<td>Network of threads with long extensions</td>
<td>To conduct and coordinate messages</td>
</tr>
<tr>
<td>Muscle tissue</td>
<td>Bundles of elongated cells</td>
<td>To bring about movement</td>
</tr>
</tbody>
</table>
Organs

Organs are made up of one or more different kinds of tissue and perform one (or sometimes more) main function or job. Examples of your organs include:

- brain
- stomach
- lungs
- heart
- skin
- kidneys

Systems

Multicellular organisms contain organised systems of organs that work together to perform specialised functions. The table on the right provides examples of some of your systems, some organs within them and their main functions.

<table>
<thead>
<tr>
<th>Name of system</th>
<th>Organs in system</th>
<th>Main functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digestive system</td>
<td>Stomach, intestine, liver, pancreas, gall bladder</td>
<td>To digest and absorb food</td>
</tr>
<tr>
<td>Respiratory system</td>
<td>Trachea and lungs</td>
<td>To take in oxygen and get rid of carbon dioxide</td>
</tr>
<tr>
<td>Circulatory system</td>
<td>Heart and blood vessels</td>
<td>To carry oxygen and food around the body</td>
</tr>
<tr>
<td>Excretory system</td>
<td>Kidneys, bladder, liver</td>
<td>To get rid of poisonous waste substances</td>
</tr>
<tr>
<td>Sensory system</td>
<td>Eyes, ears, nose</td>
<td>To detect stimuli</td>
</tr>
<tr>
<td>Nervous system</td>
<td>Brain and spinal cord</td>
<td>To conduct messages between body parts</td>
</tr>
<tr>
<td>Musculoskeletal system</td>
<td>Muscles and skeleton</td>
<td>To support and move the body</td>
</tr>
<tr>
<td>Reproductive system</td>
<td>Testes and ovaries</td>
<td>To produce offspring</td>
</tr>
</tbody>
</table>
Systems need to work together

Body systems within multicellular organisms work together to keep them alive. For example, cells need energy to survive. A process called **cellular respiration** breaks down glucose to release energy in a form that your cells can then use. This process also requires oxygen and produces carbon dioxide, a waste product. Your digestive, circulatory, respiratory and excretory systems work together to provide your cells with nutrients and oxygen, and to remove wastes such as carbon dioxide.

Your **respiratory system** is responsible for getting oxygen into your body and carbon dioxide out. This occurs when you inhale (breathe in) and exhale (breathe out).

Your **circulatory system** is responsible for transporting oxygen and nutrients to your body’s cells, and wastes such as carbon dioxide away from them. This involves **blood cells** that are transported in your **blood vessels** and **heart**. The major types of blood vessels are **arteries**, which transport blood from your heart; **capillaries**, through which materials are exchanged with cells; and **veins**, which transport blood back to the heart.
Your **digestive system** plays a key role in supplying your body with the nutrients it requires to function effectively. You ingest food, digest it, then egest it. Your digestive system is involved in breaking food down, so nutrients are small enough to be transported to, and used by, your cells. Some of the organs of the digestive system are shown in the flowchart below.

Your **excretory system** removes wastes such as undigested food or waste products from a variety of chemical reactions that your body needs to stay alive. The main organs of your excretory system are your skin, lungs, liver and kidneys. Your skin excretes salts and water as sweat and your lungs excrete carbon dioxide when you breathe out. Your liver is involved in breaking down toxins for excretion and your kidneys are involved in excreting the unused waste products of chemical reactions (e.g. urea) and any other chemicals that may be in excess (including water), so that a balance within your blood is maintained.

Your **musculoskeletal system** consists of both your bones and various types of muscles throughout your body. Bones and muscles provide both support and protection for your organs. While the **reproductive systems** of males and females contain different organs in each gender, they both play a key role in continuation of our species. Other systems such as your **nervous system** and **endocrine system** are also involved in coordinating and regulating processes in your body. You will find out more about these later in your studies.
INVESTIGATION 4.1
Mapping your organs

AIM To draw a diagram to map out the positions and shapes of some human body organs

Materials:
- large sheets of paper (e.g. butcher paper)
- pencils and marker pens
- sticky tape
- scissors
- optional: light coloured material, sewing thread and needle (or stapler or craft glue), ‘stuffing’, various other bright coloured materials

METHODS AND RESULTS

1. Use the sticky tape to join the paper together so that it is the size of a student body outline.
2. One member of the team lies down on the paper with their arms away from their body.
3. Compare your diagram to reference materials to judge its accuracy.
4. Using these references as a guide, use different coloured pens to draw in more accurate organ shapes, sizes or locations onto your paper body outline. Optional: Use the final version of your organ body outline as a pattern to make human body organ stuffed toys or a human body organ blanket.

DISCUSS AND EXPLAIN

1. Another team member carefully draws (about 5 cm away from their body) an outline of their partner’s body.
2. Once the outline is drawn, the person on the paper can join the rest of the team for the remainder of the activity.
3. As a team, decide where in the body outline the following organs are located: heart, lungs, small intestine, nose, oesophagus, liver, stomach, ears, kidney, large intestine, pancreas, eyes, bladder, brain, trachea, mouth.
4. Once the location of each organ has been agreed upon, discuss their shape and size.
5. Once consensus is reached within the group, draw each of these organs onto the paper body outline.
6. As an individual learner, identify which organs had a size, shape and location that you expected and which did not. Summarise what you have learnt about human body organs in this investigation.
UNDERSTANDING AND INQUIRING

REMEMBER

1. What do organisms have in common with other matter in the universe?
2. Describe the relationship between:
   (a) atoms, molecules, organelles and cells
   (b) cells, tissues, organs and systems.
3. Identify two ways in which unicellular organisms differ from multicellular organisms.
4. Name an example of an organelle and state its function.
5. Suggest why different types of cells within a multicellular organism may differ in their size and shape.
6. Explain why cells in muscle tissue contain many mitochondria.
7. Identify six:
   (a) types of tissues
   (b) examples of organs
   (c) types of systems.
8. Identify two organs in the:
   (a) respiratory system
   (b) circulatory system
   (c) digestive system.
9. Match the type of tissue with its function in the table below.

<table>
<thead>
<tr>
<th>Tissue</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blood</td>
<td>A Conducts and coordinates messages</td>
</tr>
<tr>
<td>Connective tissue</td>
<td>B Brings about movement</td>
</tr>
<tr>
<td>Muscle tissue</td>
<td>C Binds and connects tissues</td>
</tr>
<tr>
<td>Nervous tissue</td>
<td>D Lines tubes and spaces and forms skin</td>
</tr>
<tr>
<td>Skeletal tissue</td>
<td>E Carries oxygen and food substances around the body</td>
</tr>
</tbody>
</table>

10. Match the system with its organs in the table below.

<table>
<thead>
<tr>
<th>System</th>
<th>Organs</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) Circulatory system</td>
<td>A Liver, kidney, skin, lungs</td>
</tr>
<tr>
<td>(b) Digestive system</td>
<td>B Heart, blood vessels</td>
</tr>
<tr>
<td>(c) Excretory system</td>
<td>C Stomach, liver, gall bladder, intestines, pancreas</td>
</tr>
<tr>
<td>(d) Reproductive system</td>
<td>D Brain, spinal cord</td>
</tr>
<tr>
<td>(e) Respiratory system</td>
<td>E Lungs, trachea</td>
</tr>
</tbody>
</table>

11. Outline the overall function of the:
   (a) digestive system
   (b) respiratory system
   (c) circulatory system.

THINK AND DISCUSS

12. Identify whether the following statements are true or false. Justify your response.
   (a) Cellular respiration involves production of glucose.
   (b) The respiratory system takes oxygen into your body and removes carbon dioxide from your body.
   (c) The circulatory system transports carbon dioxide and nutrients to your body cells, and transports wastes such as oxygen away from them.
   (d) Arteries transport blood to your heart and veins transport blood away from your heart.
   (e) Your kidneys, skin, liver and lungs all play a role in removing wastes from your body.

INVESTIGATE AND CREATE

13. Find out about the different tissues and systems that exist in plants. Present your information using diagrams and lots of colour in a poster or in an electronic format (such as PowerPoint or Animoto presentation). Be as creative as you can.

14. Design and construct a model of one of the following human body systems: respiratory, excretory, digestive or circulatory system.

15. Select one of the following research questions to investigate and present your findings as a labelled model(s), informative animation, picture story book or interesting class presentation. In each question, select either animal (i), (ii) or (iii) to compare it with a human.
   (a) In which ways are the respiratory systems of (i) a fish, (ii) an earthworm OR (iii) an insect and a human similar, and how are they different?
   (b) In which ways are the digestive systems of (i) a starfish, (ii) a snake OR (iii) a bird and a human similar, and how are they different?
   (c) In which ways are the circulatory systems of (i) an insect, (ii) a frog OR (iii) a snake and a human similar, and how are they different?

16. Access the Body systems mind map weblink from your eBookPLUS and save the file of the Body systems mind map to your computer. Then complete the missing sections and add as many more details as you can.
**Digestive system — break it down**

*Digestion* involves the breaking down of food so that the nutrients it contains can be absorbed into your blood and carried to each cell in your body.

**Teeth.** Used to bite and chew your food to break it down into smaller pieces.

**Mouth.** Food and saliva are mixed; teeth mechanically break food into smaller pieces.

**Tongue.** Involved in rolling food into a round ball (bolus) that is then pushed to the back of your mouth to be swallowed.

**Gall bladder.** Bile made in the liver is stored here; bile breaks up fats into droplets small enough to be transported to the rest of the body.

**Pancreas.** Makes pancreatic juice, which is alkaline (base dissolved in water) so it neutralises the stomach acid. Enzymes that break down proteins, fats and carbohydrates are also made here.

**Small intestine.** A tube about 6 m long. Food moves through it by peristalsis. The small intestine makes enzymes that complete the digestion process. The cells in the wall of the small intestine release over 5 litres of mucus and water each day. It is in the small intestine that nutrients from now almost totally digested food are absorbed into your bloodstream. The blood then carries the nutrients to all of the cells of your body.

**Appendix.** Plays no part in digestion in humans. However, it is believed to play a role in fighting some diseases.

**Anus.** The faeces pass through here when you go to the toilet.

**Salivary glands.** Make about 1.5 litres of saliva each day. Saliva contains enzymes that begin breaking down starch in food.

**Epiglottis.** A flap of tissue closes off your trachea (windpipe) so that food doesn’t go down to your lungs and cause you to choke.

**Oesophagus.** Also known as the food-pipe or gullet. It carries the food to the stomach, using involuntary muscular contractions known as peristalsis.

**Liver.** The largest internal organ. It makes bile, which breaks down fats; controls blood sugar; destroys poisons; and stores vitamin A, vitamin D and iron.

**Stomach.** A temporary food storage area, which can expand to hold between 2 and 4 litres of food. Muscle movements in the stomach wall mix the food with gastric juice, which helps to break down proteins. The stomach also contains dilute hydrochloric acid, which kills germs and provides a suitable environment for protein digestion.

**Large intestine (colon).** Undigested material passes into the large intestine. As the material is pushed through it by peristalsis, water, salts, vitamins and any remaining sugars are absorbed so that they can be reused by the body.

**Rectum.** The final part of the large intestine. This is where the faeces are stored.
Five key processes are important in supplying nutrients to your cells. These are:

- **ingestion** — taking food into your body
- **mechanical digestion**
- **chemical digestion**
- **absorption of the broken-down food into your cells**
- **assimilation** — converting the broken-down food into chemicals in your cells

**Mechanical and chemical digestion**

**Mechanical digestion** (also known as physical digestion) involves physically breaking down the food into smaller pieces. Most of this process takes place in your mouth when your teeth bite, tear, crush and grind food. **Chemical digestion** involves the use of chemicals called enzymes to break down food into small molecules. These molecules can then pass through the walls of the small intestine and into the bloodstream.

**The human digestive system**

The key role of your digestive system is to supply your body with the nutrients it requires to function effectively. Your **alimentary canal** (or digestive tract) may be considered as your main digestive highway. It consists of a long tube with coils, large caverns and thin passageways. Other organs that provide chemicals to break down the food or absorb nutrients are attached to the alimentary canal. The alimentary canal begins at the mouth and ends at the anus, where waste products are removed. Excretion of waste products produced by the body's cells can also involve other organs, such as the skin, lungs and kidneys.

**Digestive system — down we go...**

Let's take a journey together to explore the various organs of your digestive system. What do they look like, where are they and what do they do?

**Mouth**

You ingest food, digest it, then egest it. The whole process of digestion starts with you taking food into your mouth. **Enzymes** (such as amylases) in your **saliva** are secreted by your **salivary glands** and begin the process of chemical digestion of some carbohydrates. Your teeth physically break down food in a process called mechanical digestion, then your tongue rolls the food into a slimy, slippery ball-shape called a **bolus**.

**Look at those teeth!**

In many vertebrates, mechanical digestion begins with the teeth. There are four main types of teeth in humans, each type with a different function and position in your mouth as shown below. Your teeth are your very own set of cutlery.

![Four different types of human teeth](image)

**Oesophagus to stomach**

The bolus is then pushed through your **oesophagus** by muscular contractions known as **peristalsis**. From here it is transported to your **stomach** for temporary storage and further digestion.

![Partly digested food is forced along the oesophagus by peristalsis — a wave of involuntary muscular contractions.](image)
**Stomach to small intestine**

Once the food gets from your stomach to your small intestine, more enzymes (including amylases, proteases and lipases) break it down into molecules that can be absorbed into your body. The absorption of these nutrient molecules occurs through finger-shaped villi in the small intestine. Villi are shaped like fingers to maximise surface area, which increases the efficiency of nutrient absorption into the surrounding capillaries. Once absorbed into the capillaries (of your circulatory system), these nutrients are transported to cells in the body that need them.

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**Liver**

Your liver is an extremely important organ with many key roles. One of these is the production of bile, which is transported to your gall bladder via the bile ducts to be stored until it is needed. Bile is transported from the gall bladder to the small intestine where it is involved in the mechanical digestion of lipids such as fats and oils.

**Pancreas**

Enzymes, such as lipases, amylases and proteases, which break down lipids, carbohydrates and proteins respectively, are made by the pancreas and secreted into the small intestine to chemically digest these components of food.

**Large intestine**

On its way through the digestive tract (alimentary canal), undigested food moves from the small intestine to the colon of the large intestine. It is here that water and any other required essential nutrients still remaining in the food mass may be absorbed into your body. Vitamin D manufactured by bacteria living within this part of the digestive system is also absorbed. Any undigested food, such as the cellulose cell walls of plants (which we refer to as fibre), also accumulates here and adds bulk to the undigested food mass.

The rectum is the final part of the large intestine where the faeces is stored before being excreted through the anus as waste.

**Fat stuff**

Breaking down lipids, such as fats and oils, is hard work! Because lipids are insoluble in water, they tend to clump together into large blobs. Bile helps solve this problem. As half of the bile molecule is attracted to water and the other half attracted to lipids, it helps to emulsify or separate the lipids so the lipase enzymes can gain access to them and do their job. This is an example of mechanical digestion (bile) and chemical digestion (lipase) working together to get the job done!

**Enzymes — licensed to speed**

Chemical digestion is usually assisted by compounds called enzymes that increase the rate of the chemical reactions. Without enzymes, a single meal could take many years to break down. Mechanical digestion increases the rate of chemical digestion because it increases the surface area of the food particles. This exposes more of the food surface to the digestive chemicals and enzymes.
Observing villi

**AIM** To investigate the internal structure of the lining of the small intestine

**Materials:**
- prepared slides of the walls of the small intestine
- monocular light microscope

**METHOD AND RESULTS**
- Use a light microscope to observe the prepared slide of the walls of the small intestine.

1. Draw a diagram of your observations. Record the magnification used, label a villus and use descriptive labels to record your detailed observations.

2. Compare your diagram with the photos from the *Observing villi* eBookPLUS weblink.
   - (a) Identify similarities and differences between your diagram and the photos.
   - (b) Suggest reasons for the differences between the images.

3. Describe the function of a villus. (Read through the information previously given in this section if you are unsure.)

4. With reference to your observations, suggest how the shape of a villus suits its function.

Chemical digestion begins in your mouth where enzymes in saliva begin to break down some of the carbohydrates in the food that you eat.

**Not too hot!**

Enzymes are made of protein. That is why it is important that they are not overheated. If they are too hot, they can become denatured. It’s a bit like cooking...
INVESTIGATION 4.3

Does temperature affect enzymes?

Aim To investigate the effect of temperature on enzyme activity

Materials:
- 4 beakers
- 8 test tubes
- milk
- 4 thermometers
- fresh pineapple puree (Fresh pineapple can be pureed using a food processor. If fresh pineapple is not available, use junket powder or a junket tablet dissolved in 10 mL water.)

Methods and Results

1. Copy the table below and complete it with your results.

<table>
<thead>
<tr>
<th>Water bath</th>
<th>Temp. of milk and pineapple mix (°C)</th>
<th>Time taken to set (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iced water</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Room temperature water</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Warm water</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boiled water</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2. Add water to the beakers so that they are two-thirds full. Use cold tap water and ice for beaker 1, cold tap water for beaker 2, hot tap water for beaker 3 and boiling water (from a kettle) for beaker 4. These are the ‘water baths’.

3. Pineapple juice and junket contain an enzyme that causes a protein in milk (casein) to undergo a chemical reaction and change texture; that is why the milk sets. At what temperature did the enzyme work best? Explain.

4. Did the enzyme work well at very high temperatures? Explain your answer.

5. Which variables were controlled in this experiment?

6. Do you think that the same results would be obtained if tinned pineapple puree was used instead of fresh pineapple? Explain your answer.

7. Identify the strengths and limitations of this investigation, and suggest ways to improve it.

8. Propose a research question about enzymes that could be investigated.

Discuss and Explain

Enzymes speed up chemical reactions in the body, but are not changed so can be reused again and again.

Food particle (top) and free enzyme

Enzyme locks onto food particle.

Enzyme is unchanged and can repeat the process on another food particle.

Enzyme breaks the food particle into smaller pieces.

‘Ase’ endings

There are specific enzymes for specific tasks. The substance that they break down is called a substrate. The resulting substance is referred to as the product. As the diagram at right shows, the enzyme remains unchanged at the end of the process.

Enzymes that break down carbohydrates, such as starch, into glucose are called amylases (this process is shown in the diagram at left). Those that break down fats and oils into fatty acids and glycerol are called lipases. Proteases are enzymes that break down proteins into amino acids.

Each enzyme has specific conditions in which it works. For example, amylases that break down carbohydrates in the stomach work in acidic environments, while those in the small intestine work best in alkaline conditions.
Personal explosions

Well, excuse me! Have you burped or passed wind recently? Have you had diarrhoea or vomited? These ‘personal explosions’ are related to the processing of nutrients by your body.

**Burping** occurs when air is swallowed or sucked in. This may happen when you talk while you eat, eat or drink too quickly, or drink fizzy drinks (such as those with carbon dioxide gas dissolved in them). When you eat too fast and don’t chew your food enough, more acid can be produced in your stomach. When you burp, some of this acid can rise up into your oesophagus, resulting in a burning sensation called **heartburn**.

**Flatulence** refers to the release of gases when you ‘pass wind’ through your anus. These gases are produced by bacteria in your large intestine. The odour and composition of the gases depends on

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**INVESTIGATION 4.4**

**Making a burp model**

**AIM** To construct a burp model and to design and construct a model that demonstrates the functioning of a process related to the digestive system

**Materials:**
- vinegar
- baking soda
- medium/large balloon
- funnel

**METHODS AND RESULTS**

1. Pour a small amount of vinegar into the bottom of the balloon ‘stomach’.
2. Add some baking soda to the balloon ‘stomach’ using a funnel.
3. Using your fingers, pinch the balloon closed at its neck.
4. Watch as your ‘stomach’ expands with gas.
5. Unpinch the top of the balloon (or ‘oesophagus/food tube’) to release the gas (or burp).
6. Try to make your model sound like the real thing!

**1** Summarise your observations in a flow chart that includes labelled diagrams or digital/photographic images.

**2** Select an organ belonging to an animal of your choice. Find out more about the structure and function of your selected organ and how it does its job. Summarise your findings.

**3** Summarise your design plans and labelled diagrams or digital images into an advertising brochure or digital multimedia advertisement.

**DISCUSS AND EXPLAIN**

4. Comment on the challenges you experienced during the design and construction of your model, and suggest ways that you could overcome these if you were to do it again.
the foods you have eaten and the amount of air you have swallowed.

**Diarrhoea** is the excessive discharge of watery faeces. It occurs when the muscles of the large intestine contract more quickly than normal, usually in an effort to rid your body of an infection. As a result, the undigested food moves through too rapidly for enough water to be absorbed into your body.

**Diarrhoea** is the excessive discharge of watery faeces. It occurs when the muscles of the large intestine contract more quickly than normal, usually in an effort to rid your body of an infection. As a result, the undigested food moves through too rapidly for enough water to be absorbed into your body.

Green vomit? Messages from your stomach wall travel to the ‘vomiting centre’ of your brain, resulting in forceful ejection of your stomach contents (and occasionally also contents from your small intestine). **Vomiting** can be caused by eating or drinking too much, anxiety, infections or chemicals that irritate your stomach wall. If the vomit is green, it may be due to the colour of food ingested or the presence of bile, which is produced by your liver to help digest food in your small intestine.

**UNDERSTANDING AND INQUIRING**

1. Identify the organs in the figure below.

   - a) Gall bladder
   - b) Liver
   - c) Pancreas
   - d) Small intestine
   - e) Stomach
   - f) Rectum
   - g) Oesophagus
   - h) Large intestine
   - i) Tongue
   - j) Teeth
   - k) Eyes
   - l) Nails

2. Identify four types of teeth and describe their functions.

3. State the name of the:
   (a) type of digestion that involves enzymes
   (b) enzymes that break down fats
   (c) enzymes that break down proteins
   (d) substances that enzymes act on.

4. Describe the process of peristalsis and suggest why it occurs.

5. Describe the relationship between:
   (a) teeth and mechanical digestion
   (b) the pancreas and the small intestine
   (c) the liver, gall bladder and the small intestine
   (d) the villi, small intestine and capillaries
   (e) bile, lipase and fats.

6. Describe what happens to enzymes when they get too hot.

7. Order the following organs into the correct sequence: stomach, large intestine, oesophagus, anus, mouth, small intestine.

8. Match the organ with its function in the table below.

<table>
<thead>
<tr>
<th>Organ</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) Gall bladder</td>
<td>A Where the breakdown of starch and protein is finished and fat breakdown occurs</td>
</tr>
<tr>
<td>(b) Large intestine</td>
<td>B Temporary storage of food and where protein digestion begins</td>
</tr>
<tr>
<td>(c) Liver</td>
<td>C Tube which takes food from mouth to stomach</td>
</tr>
<tr>
<td>(d) Oesophagus</td>
<td>D Stores undigested food and waste while bacteria make some vitamins</td>
</tr>
<tr>
<td>(e) Pancreas</td>
<td>E Stores faeces</td>
</tr>
<tr>
<td>(f) Rectum</td>
<td>F Makes enzymes used in the small intestine</td>
</tr>
<tr>
<td>(g) Small intestine</td>
<td>G Makes bile, stores glycogen and breaks down toxins</td>
</tr>
<tr>
<td>(h) Stomach</td>
<td>H Stores bile made in the liver until needed in the small intestine</td>
</tr>
</tbody>
</table>

9. Explain why it is important to break down food that we eat.

**THINK**

10. Which teeth are used to:
    (a) bite into a pear
    (b) crush and grind nuts?

11. Use Venn diagrams to compare:
    (a) mechanical and chemical digestion
    (b) lipases and proteases
    (c) small intestine and large intestine.

12. Suggest why it is necessary to drink fluids when you suffer from diarrhoea.

(continued)
THINK AND DISCUSS

13 State whether the following statements are true or false. Justify your response.
   (a) Mechanical digestion occurs when chemicals in your body react with food to break it down.
   (b) Ingestion involves taking food into your body, whereas digestion involves breaking food down.
   (c) Many enzymes have names that end with the suffix ‘-ase’.
   (d) ‘Bolus’ is the term used to describe the muscular contractions that push food down your oesophagus to your stomach.
   (e) Plant cell walls make up much of the fibre that accumulates in our large intestines.
   (f) The process of denaturing enzymes kills them.

14 Suggest how you can still swallow food if you were positioned upside down.

15 Take a small piece of bread into your mouth. Although at first you don’t taste much, after a while, it may taste sweet. Suggest reasons why.

INVESTIGATE, THINK AND DESIGN

16 Design an investigation to test the following hypotheses:
   • Fresh pineapple results in a faster enzyme reaction than canned pineapple.
   • The length of time that pineapple puree is kept in ice affects the rate of enzyme reaction.
   • Different coloured junket tablets result in different rates of enzyme reaction.

17 When cows burp, they release methane gas into the air. This gas is believed to be one of the major causes of global warming. It has been suggested that cows could be responsible for about 20 per cent of the methane in the atmosphere. Research these claims.
   (a) On the basis of your findings, do you agree? Justify your response.
   (b) Design an experiment that could be used to test the claim that cows contribute to increased methane gas in the atmosphere.

IMAGINE, INVESTIGATE AND CREATE

18 Cows have four stomachs. Find out the function of each stomach. Construct a model.

19 Research an enzyme of your digestive system. Find out what it does and where, then construct a poster or model to show how it works.

20 (a) Imagine that you are either a cheese and tomato sandwich or a hamburger.
     (b) List the ingredients of the food you chose in part (a).
     (c) Research what happens (and where) to each of these ingredients when eaten.
     (d) Construct a flowchart to show the process of digestion in the human body, including events and locations.

(e) Use this information to write a story in either a cartoon or picture book format.
(f) Convert your story into a play.
(g) Perform your play to the class using animations, team members or puppets.

21 Use information in this section and other resources to relate structural features to the functions of the following parts of the digestive system.

<table>
<thead>
<tr>
<th>Part of system</th>
<th>Structural features</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oesophagus</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stomach</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Small intestine</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Villi</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Large intestine</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

22 Construct a ‘working’ model of the human digestive system.

23 Design and construct a ‘trivial pursuit’-type board game about the digestive system. Include questions in three different categories. Create game pieces that are relevant to the digestive system.

24 Create a picture book or poster that helps explain to primary students how food is digested.

25 Construct a plasticine model (to scale) of the human digestive system, with each organ being a different colour.

26 Find out more about causes, symptoms, treatments and implications of (a) belching (b) flatulence or (c) vomiting. Create a cartoon or poster to summarise your findings.

27 Test your knowledge of the digestive system by completing the Digestive jigsaw interactivity in your eBookPLUS, int-0216.

28 Find out more about the digestion of particular types of food by using the Digestion animation weblink in your eBookPLUS.

29 Practise naming the parts of the digestive system by using the Digestive system drag-and-drop weblink in your eBookPLUS.

From dinner plate to sewerage system
Watch the amazing journey of food through the human body eles-0056
Digestive endeavours

When each part of the digestive system is healthy, your digestion works smoothly without you thinking about it. But things like tooth decay or being a coeliac can cause you problems.

Do you look after your teeth?

Your teeth can decay when bacteria in your mouth turn sugar from your food into acid. This acid can ‘eat’ a hole in your tooth enamel and dentine. Once this hole reaches a nerve, you get a toothache. The illustration at right shows the structure of a tooth and where decay usually occurs — at the top of large back teeth and at the side where one tooth touches another.

If you don’t clean your teeth regularly (at least once a day), they

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**INVESTIGATION 4.5**

**How well do you brush your teeth?**

**AIM** To investigate the effectiveness of brushing teeth

**Materials:**
- 3 nutrient agar plates
- 3 small labels
- 3 cotton buds
- sticky tape
- toothbrush
- toothpaste
- incubator set at 35°C
- dissection microscope

**Note:** This is best done after lunch, prior to cleaning teeth.

**METHODS AND RESULTS**

- Label the three agar plates as ‘Dirty’, ‘Toothpaste’ and ‘Brush only’.
- Repeat the steps above after brushing with no toothpaste and then with toothpaste.
- Incubate the agar plates for 24–48 hours.
- Observe the agar plates using the dissection microscope. Do not open the agar plates. Observe through the plastic dish.
- Record your observations using diagrams with descriptive labels.

**DISCUSSION**

1. Which agar plate showed (a) the most microbial growth and (b) the least microbial growth? What does this suggest?
2. Suggest why we brush our teeth with toothpaste.
3. Suggest improvements to the design of this investigation.
4. Design an experiment that could investigate the effect of different types of toothpaste.
5. Propose a research question related to teeth that could be further investigated.
can become covered with a thin film of food, saliva and bacteria. This is called plaque. As this plaque rots, it causes your gums to swell and bleed. This is known as gum disease.

Our water supply and toothpaste often contain fluoride, which helps prevent tooth decay. Fluoride protects the enamel and helps repair or rebuild the enamel in your teeth. Damaged or missing teeth can make it difficult for you to chew your food properly and therefore may affect digestion of foods.

A future in teeth?

Dentistry is only one example of many different ‘tooth pathway’ careers that you may be aware of. Examples of other dental specialities include oral and maxillofacial surgeons, dental–maxillofacial radiologists, endodontists, oral physicians, oral pathologists, orthodontists, paediatric dentists, periodontists, prosthodontists, public health dentists and special needs dentists.

**How about that!**

Just to whet your appetite ... have you heard the story of Alexis St Martin? In 1822, he was shot in the stomach at close range. Wrong place at the wrong time! His wound healed, but left an open hole that showed the inside of his stomach! By dangling food suspended on a silk thread, his doctor William Beaumont made some breakthrough discoveries on how our stomachs work.
Going up or down?

Gastroscopy and colonoscopy involve the use of endoscopes (from the Greek words meaning to ‘see within’).

A major advantage of these techniques is that they gather important information without needing to cut into the body.

Gastroscopy involves passing a long flexible endoscope through your mouth, down your oesophagus and into your stomach and duodenum. Although it takes only about five minutes, a lot of information can be gathered about the health of this part of your digestive system.

A colonoscopy enables the doctor to look directly at the lining of your colon or bowel. In this case the endoscope is inserted through your rectum. This procedure may take about thirty minutes. The results may be used to investigate abnormalities or detect the presence of colon polyps, which in some cases may turn into cancer.

A colonoscopy can remove small polyps or enable a biopsy to be taken for further testing.
Australian researchers are attempting to develop a vaccine as a new treatment for coeliac disease. In 2009, Dr Robert Anderson and his team at the Walter and Eliza Hall Institute of Medical Research in Melbourne began the world’s first trials of a coeliac vaccine. If this treatment is successful, it could mean the end of gluten-free diets for people with the condition.

Villi alert!

Most nutrients are absorbed into your bloodstream when they get to the last section of your small intestine. The walls of this part of your intestine are lined with finger-like projections called villi.

The shape of villi increases the surface area through which nutrients can diffuse into tiny blood vessels called capillaries. Nutrients are then transported to other parts of your body.

Coeliac disease is an auto-immune disease — that is, one in which your body produces antibodies to attack your own tissues. In this case, it is the villi of the small intestine that are damaged. This interferes with the absorption of nutrients.

People with coeliac disease are intolerant to gluten. This protein is found in wheat, rye, barley and oats. Eating these foods triggers their immune system to damage the villi in their small intestine. Coeliac Australia refers to the condition as a ‘hidden epidemic’. Coeliac disease affects approximately 1 in 70 people in Australia, with many (about 80 per cent) not even knowing that they have it. If left undiagnosed, more severe consequences, such as a variety of nutritional deficiencies, bowel cancer and osteoporosis, may result.
UNDERSTANDING AND INQUIRING

REMEMBER
1 Outline the relationship between diet, coeliac disease and the digestive system.
2 Approximately how many people in Australia are affected by coeliac disease?
3 Use a Venn diagram to compare gastroscopy and colonoscopy.
4 Describe the discovery that led to two Australian scientists winning the 2005 Nobel Prize in Medicine.

THINK AND DESIGN
5 Design an investigation to test the following hypotheses:
   • Drinking fluoridated water reduces tooth decay.
   • Mouthwash prevents the growth of bacteria that cause tooth decay.
   • Drinking bottled water rather than tap water increases tooth decay.

INVESTIGATE AND CREATE
6 Select one of the ‘tooth pathway’ careers in the text ‘A future in teeth’. Find out details of the training required and what a career in this pathway would entail. Present your findings in a brochure and include a section that describes what ‘a day in the life of…’ this career would be like.
7 Imagine that you have invited two friends over for a sleepover. One of them has coeliac disease and the other is lactose intolerant.
   (a) Find out the cause and/or symptoms associated with each of these conditions.
   (b) Find out what sorts of foods you could offer your friends.
   (c) Design a dinner and breakfast menu that includes foods that each of your friends would be able to eat.
8 Research one of the following digestion-related diseases and report on the cause, symptoms, treatment or cure, possible consequences and current research.
   • Heartburn
   • Inflammatory bowel disease
   • Irritable bowel syndrome
   • Appendicitis
   • Constipation
   • Crohn’s disease
   • Diverticulosis
   • Gallstones
   • Haemorrhoids
   • Pancreatitis
   • Peptic ulcer

INVESTIGATE AND REPORT
9 Find out more about one of the following digestion-related scientific careers and report your findings as a diary journal entry.
   • Gastroenterologist
   • Endoscopist
   • Colorectal surgeon
10 Research the symptoms, diagnosis and treatment of coeliac disease and investigate Australian research into the condition. Report your findings in a PowerPoint presentation, a poster or an article. Cite your references and include the Coeliac Society and Australian Gastroenterology Institute weblinks in your eBookPLUS in your research.
11 Find out more about gluten-free diets and coeliac disease using the weblinks in your eBookPLUS. Report your findings to your team.
   (a) Use the Coeliac dietary advice weblink to find out more about gluten-free diets.
   (b) Use the Bob Anderson weblink to find out more about coeliac disease, diet and research.
12 Recently, scientists have suggested a link between the presence of bacteria Helicobacter pylori and cancer protection. Find out more about this research and suggest possible implications that it may have.
Circulatory system – blood highways

If you cut yourself, you bleed. The red liquid that oozes, trickles or bursts from your body is called blood.

What’s in blood?

An average-sized human has about five litres of blood; that’s about a bucketful. Blood is made up of red blood cells (erythrocytes), white blood cells (leucocytes), blood platelets and the straw-coloured fluid they all float in, called plasma.

Ready to carry!

Each drop of blood contains about 300 million red blood cells. These red blood cells travel around the body up to 300 000 times, or for about 120 days. After this they literally wear out and die. Each second you are manufacturing about 1.7 million replacement red blood cells in your bone marrow.

Red blood cells are red because they contain an iron-containing pigment called haemoglobin. Oxygen reacts with haemoglobin in red blood cells to form oxyhaemoglobin, which makes the blood an even brighter red. This change in colour intensity can indicate the amount of oxygen being transported in blood at a particular time.

The shape and size of red blood cells makes them well suited to their function. Their small size allows them to fit inside tiny capillaries. When mature, red blood cells lack a nucleus, increasing space available to carry haemoglobin and hence oxygen. Their biconcave shape means that they have a large surface area for their size, which also assists in their important oxygen transporting role.

Fit to fight!

White blood cells contain a nucleus, and are larger and fewer in number than red blood cells. They are often referred to as the ‘soldiers’ in the blood as they are involved in fighting disease. Some white blood cells produce chemicals called antibodies; others engulf and ‘eat’ bacteria and other foreign matter. When you are ill or fighting an infection, the number of white blood cells in your blood increases for this reason.

Clot and cover...

If you cut yourself, you bleed. This is because a blood vessel has been cut. Platelets in the blood help it to clot and plug the damaged blood vessel. This seal prevents germs getting in.

HOW ABOUT THAT!

The amount of oxygen carried by haemoglobin varies with altitude. At sea level, about 100 per cent of haemoglobin combines with oxygen. At an altitude of 13 000 metres above sea level, however, only about 50–50 per cent of the haemoglobin combines with oxygen.

Insect blood looks a little like raw eggwhite, because it contains no pigment. The blood of crabs and crayfish, however, contains the pigment haemocyanin. This pigment has copper in it and is blue when combined with oxygen. This differs from haemoglobin in humans, which is red when combined with oxygen.
Mix and match?
How much do you know about the red stuff that flows throughout your body? Did you know that your blood might not mix too well with that of your friends?

Blood can be grouped into eight types using the ABO system and the Rhesus (Rh) system. Your blood type is inherited from your parents. These classification systems are based on whether particular chemicals (antigens) are present or absent on your red blood cells. If you are Rh-negative, you do not have the Rhesus factor on your red blood cells; if you do, you are Rh-positive.

The ABO system divides blood into groups A, B, AB and O. If you need a blood transfusion, it is very important to know your blood type and that of the donor because some blood types cannot be mixed. If the wrong types are mixed, the blood cells may clump together and cause fatal blockages in blood vessels.

INVESTIGATION 4.6
Viewing blood cells

AIM To observe blood cells under a light microscope

Materials:
prepared slide of blood smear
microscope

METHODS AND RESULTS
- Place the prepared slide onto the microscope stage.
- Use low power to focus, then carefully adjust to high power.
- Find examples of red blood cells and white blood cells on the slide.

1. Draw diagrams of representative red blood cells and white blood cells. On your diagram, include descriptive labels and the magnification used.
2. Estimate (a) how many red blood cells could fit inside a white blood cell and (b) how many of each cell type could fit across the field of view.
3. Summarise the similarities and differences between the structures of red blood cells and white blood cells.
### Connected pathways

Your **circulatory system** is responsible for transporting oxygen and nutrients to your body's cells, and wastes such as carbon dioxide away from them. This involves interactions between blood cells, blood vessels and your heart.

Blood vessels called **arteries** transport blood from your heart, whereas others, called **veins**, transport blood back to the heart. Materials are exchanged between blood and cells through tiny blood vessels called **capillaries** that are located between arteries and veins.

#### Arteries, veins and capillaries

Arteries have thick, elastic, muscular walls and carry blood under high pressure away from your heart. Veins have thinner walls and possess valves that prevent the blood from flowing backwards as they take blood to your heart.

Capillaries are the most numerous and smallest blood vessels. Your body contains about 100,000 km of capillaries, which penetrate almost every tissue, so no cell is very far away from one. Capillaries are very important because they transport substances such as oxygen and nutrients to cells and remove wastes such as carbon dioxide.

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*Your circulatory system consists of your heart, blood vessels and blood. Arteries, capillaries and veins are the major types of blood vessels through which your blood travels.*
Have a heart

Often linked with emotions, love and courage, the heart has a special meaning for most of us. In a clinical sense, however, it is merely a pump about the size of your clenched fist.

Two pumps in one

To be more precise, the human heart is actually two pumps. One side contains oxygenated blood and the other deoxygenated. Your veins bring ‘used’
deoxygenated blood (stripped of oxygen and bluish in colour) back to your heart. All of these veins join up into a larger vein called the vena cava. Entering the top right chamber of your heart, blood is pumped into the bottom right chamber. It is then pumped out to your lungs where it picks up oxygen and becomes oxygenated and more reddish in colour. It also loses some of its carbon dioxide. The oxygenated blood then returns to the left-hand side of your heart to be pumped out through arteries to your body tissues, where it delivers oxygen and nutrients. The deoxygenated blood then returns to the right-hand side of the heart for the cycle to be repeated.

HOW ABOUT THAT!

If you bump yourself but haven’t cut your skin, a bruise may form. Bruises are caused by burst blood capillaries under your skin. The bruise changes from black to purple to yellow as the blood clears away.
Four chambers

The human heart has four chambers. The upper two chambers are called the left atrium and right atrium (plural = atria), and the lower two chambers are the left ventricle and right ventricle. The two sides of the heart are different. The walls of the left side are thicker and more muscular because they need to have the power to force the blood from the heart to the rest of the body.

Flap-like structures attached to the heart walls, called valves, prevent the blood from flowing backwards and keep it going in one direction. If you listen to your heart beating, you will hear a ‘lub dub’ sound. The ‘lub’ sound is due to the valves between the ventricles and atria shutting. The ‘dub’ sound is due to the closing of the valves that separate the heart from the big blood vessels that lead to the lungs and the rest of the body.

Blood pressure

The heart’s pumping action and the narrow size of the blood vessels result in a build-up of considerable pressure in the arteries. The force with which blood flows through the arteries is called blood pressure. It is affected by different activities and moods. It also goes up and down as the heart beats, being highest when the heart contracts (systolic pressure) and lowest when the heart relaxes (diastolic pressure). A person’s blood pressure is expressed as a fraction. This fraction is the systolic pressure over the diastolic pressure, such as 120/70.
The aortic valve is a semilunar valve. It is located between your left ventricle and your aorta.

The pulmonary valve is a semilunar valve. It is between your right ventricle and your pulmonary artery.

The left atrioventricular (or mitral) valve is a bicuspid valve; it has two cusps. It is located between your left atrium and your left ventricle.

The right atrioventricular valve is a tricuspid valve; it has three cusps. It is situated between your right atrium and your right ventricle.

**INVESTIGATION 4.7**

Heart dissection

**AIM** To observe the structure of a mammalian heart

**Materials:**
- sheep’s heart preferably with the blood vessels still attached
- dissecting instruments
- dissecting board
- newspaper or paper to cover dissecting board

**METHODS AND RESULTS**

1. Place newspaper on the dissection board, then place the heart on top of the paper.
2. Use the diagram on the right to identify the parts of the heart.
3. Try to locate where blood enters and leaves the heart:
   - (a) to and from the lungs
   - (b) to and from the rest of the body.
4. Sketch and label the heart and use arrows to show the direction of blood flow.
5. Cut the heart in two so that both halves show the two sides of the heart (similar to the illustration on the previous page).

**DISCUSS AND EXPLAIN**

1. Right coronary artery
2. Left anterior descending coronary artery
3. Circumflex coronary artery
4. Superior vena cava
5. Inferior vena cava
6. Aorta
7. Pulmonary artery
8. Pulmonary vein
9. Right atrium
10. Right ventricle
11. Left atrium
12. Left ventricle
13. Tricuspid valve
14. Mitral valve
15. Pulmonary valve

3. Suggest reasons for the differences observed.
4. Try to locate the valves in the heart.
5. Describe the valves and suggest their function.
6. Write a summary paragraph about the structure and function of the heart.

**Keeping the pace**

During each minute that you are sitting and reading this, about 5–7 litres of blood completes the entire circuit around your body and lungs. In a single day, your heart may beat about 100 000 times and pump about 7000 litres of blood around your body.

A normal human heart beats about 60–100 times a minute, this rate increasing during exercise or stress. With each heartbeat, a wave of pressure travels along the main arteries. If you put your finger on your skin just above the artery in your wrist, you can feel this pulse wave as a slight throb. Your pulse rate immediately after exercise can be used as a guide to your physical fitness.
The fitter you are, the less elevated your heart rate will be after vigorous exercise.

The regular rhythmic beating of the heart is maintained by electrical impulses from the heart’s pacemaker, which is located in the wall of the right atrium. Some people with irregular heartbeats are fitted with artificial, electronic pacemakers to regulate the heart’s actions and correct abnormal patterns.

Try clenching your fist every second for five minutes. Getting a little tired? The heart is made up of special muscle called cardiac muscle, which never tires. Imagine having a ‘cramp’ or ‘stitch’ in your heart after running to catch the bus! Owing to its unique electrical properties, heart muscle will continue to beat even if it is removed from the body. Scientists have shown that even tiny pieces of this muscle cut from the heart will continue to beat when they are placed in a test tube of warm salty solution.

### UNDERSTANDING AND INQUIRING

**REMEMBER**

1. Match the circulatory system term with its description in the table below.

<table>
<thead>
<tr>
<th>Term</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) Artery</td>
<td>A The bottom two chambers of the heart</td>
</tr>
<tr>
<td>(b) Atria</td>
<td>B Cell involved in transporting oxygen around the body</td>
</tr>
<tr>
<td>(c) Capillary</td>
<td>C Blood vessel that takes blood to the heart</td>
</tr>
<tr>
<td>(d) Heart</td>
<td>D Cell involved in protection against infection</td>
</tr>
<tr>
<td>(e) Red blood cell</td>
<td>E Blood vessel that takes blood away from the heart</td>
</tr>
<tr>
<td>(f) Vein</td>
<td>F The top two chambers of the heart</td>
</tr>
<tr>
<td>(g) Ventriles</td>
<td>G Organ that pumps blood around the body</td>
</tr>
<tr>
<td>(h) White blood cell</td>
<td>H Blood vessel that exchanges substances with cells</td>
</tr>
</tbody>
</table>

2. Outline what blood is, and what it does.
3. Name and describe the types of blood vessels in which blood travels around your body.
4. Compare red blood cells, white blood cells and blood platelets.

**THINK**

11. Use information in this section and other resources to relate structural features to the functions of the following parts of the circulatory system.

<table>
<thead>
<tr>
<th>Part of system</th>
<th>Structural features</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arteries</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Veins</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capillaries</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Red blood cells</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Think of other ways that information about the components of blood could be organised visually. Organise the material in one of these ways.

Think and Discuss

(a) Some people have religious grounds for disagreeing with the use of blood transfusions. Imagine a four-year-old child with a life-threatening condition. Her parents will not allow her to have the blood transfusion that she needs. What should the doctors do? Discuss this with your team and report your decision to the class. If there are any differences of opinion, organise a class debate on the issue.

(b) Would your response be different if the child was 18 years old and wanted the blood transfusion, but her parents would not allow it?

A day after donating blood, a person finds that they have an infectious disease that can be transmitted by blood. What should they do? Discuss this with your team, giving reasons for your opinions.

Using Data

Which blood type is the most common? Which is the least common?

Which blood group(s), A, B, AB or O, can be accepted by:

(a) all blood groups?

(b) blood group AB?

(c) blood group A?

INVESTIGATE, THINK AND DISCUSS

The higher the altitude, the less oxygen there is in the air. Propose a reason living at high altitudes usually have more red blood cells than people living at low altitudes.

Find out more about how blood circulates in insects and lobsters.

Construct a bar graph to show the proportions of the different parts of blood.

Find out what happens when people donate their blood at a blood bank. How often can you donate blood, how long does it take and how much blood do they take? Prepare a brochure, storyboard, PowerPoint presentation or cartoon to share your findings.

Use the internet to research waste removal and excretion for an animal of your choice. Present your findings in PowerPoint or as a poster.

Imagining that you have a friend who is anaemic. She is constantly tired and very pale.

(a) Using the internet and other resources, find out what you could do to help her improve her health.

(b) Report back to your team, sharing your ideas and any other relevant information. Have your team scribe summarise your ideas in a cluster map or mind map.

(continued)
(c) As a team, decide on a strategy for helping your anaemic friend.
(d) Share your strategy with other teams as a mind map, flowchart, concept map or another visual tool.
(e) Reflect on what you have learned during this activity. How might it influence your future behaviour or thinking? Could any of the strategies designed by the groups be used to solve any other problems? If so, which ones?

26 With a partner, construct a PMI chart for a law that makes it compulsory for everyone over 16 to donate blood at least once a year.

**INVESTIGATE, THINK AND CREATE**

27 (a) Copy the ‘connected pathways’ diagram on page 110 into your workbook.
(b) Use a coloured pencil to show the path taken for a red blood cell to travel from the pulmonary vein to the pulmonary artery, if it goes via the intestines.

28 Mark the following sites (a, b, c, d) on your diagram. In which blood vessel(s) would you expect the highest:
(a) blood pressure
(b) blood glucose levels
(c) blood carbon dioxide level
(d) oxygen level?

29 List the following in the order that a red blood cell would reach them after leaving the aorta: pulmonary artery, left ventricle, right atrium, intestine, lung, pulmonary vein, left atrium, liver, right ventricle.

30 Convert your classroom or sports oval into a ‘circulatory highway system’. Pretend to be a red blood cell and travel along the route it would take around the body.

31 Divide the class into groups, with each group making a model of a type of blood cell or vessel. Combine all of the models to convert the room into a circulatory system. In teams, write a play to use your circulatory system. Act it out for the class or get the class to act it out for you.

32 (a) Construct a model of the human heart using clay or bread dough.
(b) Use information in this section and other resources to relate the structural differences between the atria and ventricles of the heart to their function.

33 Make up a rhyme or poem to describe the flow of blood through the heart. Use as many of the bold blue words in this section as possible.

34 Construct a ‘working’ model of a human heart that shows the movement of blood through the various chambers and blood vessels.

35 Use the Heart surgery weblink in your eBookPLUS to complete the animation activity and find out more about heart surgery and the anatomy of a human heart.

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**eLesson**

Heart valve

Watch this video eLesson to learn more about replacing heart valves without the substantial trauma of open heart surgery, a procedure set to revolutionise cardiovascular medicine for patients.

**eBookPLUS Interactivity**

Test your ability to label the parts of the heart by completing the Beat It! interactivity in your eBookPLUS.
Transport technology

Our understanding of the circulatory system has been built by scientists and physicians throughout human history. With new observations and evidence, some theories have been discarded and others developed or modified. New technologies have enabled new observations to be made, which have resulted in new ways of thinking about the structure and functioning of the human body.

Scientific theories can change over time

Claudius Galen (c.129–c.199 AD)
For over a thousand years, the key training books used for doctors were based on the ideas of the Greek physician Claudius Galen. Galen’s ideas were based on his observations of dissections of animals (other than humans). Galen described the human heart as being made up of two chambers and also being the source of the body’s heat. He believed that blood was made by the liver and travelled to the right chamber of the heart and that the left chamber made ‘vital spirits’ which were then transported by arteries to body organs.

Andreas Vesalius (1514–1564)
Hundreds of years later another physician, Andreas Vesalius, began to transform medical knowledge — by questioning all previous theories. He believed that it was necessary to dissect bodies to find out how they worked. As the Church did not allow this, he took bones from graves and even stole a body from the gallows. His drawings showed the position and working of the muscles and organs in the body. Vesalius’s observations proved that some of Galen’s theories were wrong and he discovered anatomical structures previously unknown. His findings helped establish surgery as a separate medical profession.
Heart technology

Heart and blood vessel diseases are a key cause of death for many Australians. Medical research and new technologies strive to minimise the effects of diseases and disorders of the circulatory system.

Faulty heart and vein valves
The heart, like many other pumps, depends on a series of valves to work properly. These valves open and close to receive and discharge blood to and from the chambers of the heart. They also stop the blood from flowing backwards. If any of the four heart valves becomes faulty, the function of the heart may be impaired.

Veins throughout the body may also contain valves that keep the blood flowing in one direction. Defective valves in leg veins can cause blood to drain backwards, and to pool in the veins closest to the skin surface. These veins can become swollen, twisted and painful, and are called varicose veins.

A faulty heart valve may be replaced by an artificial valve. Why are the heart valves so important to the functioning of the heart?

William Harvey (1578–1657)

Although Vesalius had assisted in revising the structure of the human heart, there was still confusion about its function. About 100 years later, William Harvey, an English physician, published his work on blood circulation which led to another change in how we think about the heart and our circulatory system.

‘If I only had a heart…’
The tin man from The Wizard of Oz would have been very happy with the development of an artificial heart. This mechanical device is made of titanium and plastic. Surgeons also implant a small electronic device in the abdominal wall to monitor and control the pumping speed of the heart. An external battery is strapped around the waist and can supply about 4–5 hours of power. An internal rechargeable battery is also implanted inside the wearer’s abdomen. This is so they can be disconnected from the main battery for about 30–40 minutes for activities such as showering.
A heart – but no pulse?
If only the left ventricle is damaged, and the rest of the heart is in good working order, a backup pump may be implanted alongside the heart. One model of these devices results in its wearers having a gentle whirr rather than a pulse. This is the sound of the propeller spun by a magnetic field to force a continuous stream of blood into the aorta.

Getting the beat!
An electrocardiogram (ECG) shows the electrical activity of a person’s heart. ECG patterns are valuable in diagnosing heart disease and abnormalities.

![Electrocardiograms](image)

**INVESTIGATION 4.8**

**Check your heart**

**AIM** To investigate the short-term effects of exercise on heart rate and blood pressure

**Materials:**

- stopwatch
- blood pressure monitor

Optional: data logging or digital measuring devices

**METHOD AND RESULTS**

1. Copy the table below into your workbook and enter your own results.

<table>
<thead>
<tr>
<th>Test</th>
<th>Heart rate (bpm)</th>
<th>Blood pressure (mm Hg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before exercise</td>
<td></td>
<td></td>
</tr>
<tr>
<td>After walking</td>
<td></td>
<td></td>
</tr>
<tr>
<td>After running up stairs</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Find your pulse, either on the inside of your wrist or in your neck (see the illustrations). Make sure you use two fingers, not your thumb, to find your pulse.

2. Measure and record your heart rate in beats per minute (bpm) by counting the number of times your heart beats in 15 seconds and then multiplying this number by 4.

3. Measure and record your blood pressure using the blood pressure monitor.

4. Go for a walk in the playground or around the school oval. Measure and record your heart rate and blood pressure again.

5. Run up and down a flight of stairs. Measure and record your heart rate and blood pressure again.

**DISCUSS AND EXPLAIN**

6. What effect does exercise have on heart rate and blood pressure?

7. Identify strengths and limitations of this investigation and suggest improvements.

8. Design and carry out an experiment to test the following hypothesis: ‘There is a link between a person’s resting heart rate and the number of hours the person spends exercising each week’.
Artificial blood

A current wave of interest in vampire movies and books has brought with it discussion about the merits of artificial blood sources. The interest in artificial blood, however, is not new; people have thought about its use in blood transfusions for hundreds of years. William Harvey’s description in 1628 of how blood circulated through the body prompted a variety of unsuccessful investigations into the use of alternative fluid substitutes. Shortage of blood supplies during war and disease epidemics has fired up the quest for an artificial blood substitute. Currently, the two most promising red blood cell substitutes are haemoglobin-based oxygen carriers (HBOCs) and perfluorocarbon-based oxygen carriers (PFCs).

PFCs are usually white, whereas HBOCs are a very dark red. Although PFCs are entirely synthetic, HBOCs are made from sterilised haemoglobin. The haemoglobin may be from human or cow blood, human placentas or bacteria that have been genetically engineered to produce haemoglobin. As the haemoglobin doesn’t have a cell membrane to protect it, various techniques such as cross-linking and polymerisation are used to make it less fragile. Some scientists are even investigating the idea of wrapping it in an artificial membrane.

Transplant pioneer

If your heart or lungs were not working properly and you had needed a heart or lung transplant in the 1980s, the doctor to see was Victor Chang.

Victor Chang was an Australian doctor who was awarded a Companion of the Order of Australia for his contribution to medicine. Dr Chang played an important role in establishing the heart transplant unit at St Vincent’s Hospital in Sydney. He set up a team of 40 health professionals who were the finest in their field and developed new procedures and techniques that led to an improved rate of success. Of his patients, 92 per cent were still alive one year after their heart or lung transplant operation and 85 per cent were still alive five years later.

The first heart transplant operation that Victor Chang carried out at St Vincent’s Hospital was in 1984 on a young girl called Fiona Coote. Fiona is now an adult and, although she has since needed a second heart transplant, she owes her life to Dr Chang.

Dr Victor Chang also developed an artificial heart valve, called the St Vincent heart valve, and was working on developing an artificial heart. Unfortunately, his life was tragically cut short in 1991 when he was murdered by gunshot.
Artificial blood vessels?
Will the artificial blood vessels of the future be made by bacteria? Molecular biologist Helen Fink, working in Sweden, has suggested this may be the case. The cellulose produced by *Acetobacter xylinum* bacteria is strong enough to cope with blood pressure and function within our bodies, and could be used for artificial blood vessels in heart bypass operations in the future.

**UNDERSTANDING AND INQUIRING**

**REMEMBER**
1. What are varicose veins and what causes them?
2. What is an electrocardiogram and when is it useful?
3. Explain why valves are important to the functioning of the heart.
4. Describe how an ECG is used to detect heart abnormalities.
5. Outline how heart valves are similar to the valves in veins.
6. Construct a matrix table to show the differences between red blood cells, HBOCs and PFCs.

**THINK**
7. Look at the electrocardiograms on page 119.
   (a) At “P”, are the muscle cells of the atria contracted or relaxed?
   (b) After the ‘QRS’ wave, is the ventricle relaxed or contracted?
   (c) How does the normal electrocardiogram differ from the abnormal electrocardiogram?
   (d) Suggest what might be wrong with the heart activity shown on the abnormal electrocardiogram.

**INVESTIGATE**
8. What are artificial hearts made of and how do they work?
9. How can blood loss cause death?
10. Use the internet to research one of the following: stroke, heart murmur, ‘hole in the heart’, atherosclerosis, angina, heart attack, arrhythmias, pericarditis, hypertension. Present your findings as a PowerPoint presentation or a poster.
11. Find out more about Dr Victor Chang and report your findings to others in the class.
12 There are a number of issues surrounding the development and use of artificial blood. Find out what these are and then construct a PMI chart as a summary. What is your opinion about artificial blood? Provide reasons for your opinion.

13 Find out and report on ‘transport technology’ research that Australian scientists are currently involved in.

14 (a) Which organs are most successfully transplanted into humans?
(b) List sources of the organs for transplant and identify associated issues.
(c) Describe how donors and organ recipients are matched.
(d) Organ recipients can require specific treatment after the operation. Outline what this involves and why it is needed.

15 If you required a new heart, would you prefer an artificial one or one from a human or other natural source? Provide reasons for your response.

16 Outline your opinion on being an organ donor yourself.

17 Find out issues related to organ transplants and construct a PMI summary.

18 Research one of the following circulation topics and report your findings to the class: blood transfusions, rhesus babies, varicose veins, leukaemia, haemophilia, thrombosis, embolisms, aneurisms.

19 Plasma is the liquid part of blood. It can be used to make a number of products to help others in need. Report back on the uses of some of the following: Intragram, Anti D, Albumex 20, Factor VIII, Monofix, Prothrombinex, Thrombrotol VF, normal immunoglobulin, hyper-immunoglobulin.

INVESTIGATE, THINK AND DISCUSS

20 Dr Mary Kavurma and Dr Seana Gall are Tall Poppy Science Award winners. This award recognises young scientists who excel at research, leadership and communication. Dr Kavurma is a scientist at the University of New South Wales involved in research into atherosclerosis and cardiovascular disease. Dr Gall is based at the Menzies Research Institute, University of Tasmania, and her research field is cardiovascular epidemiology.
(a) Find out more about their research and that of other scientists in this field of science.
(b) Find out more about Australia’s Tall Poppy Science Awards and other winners.

21 Find out more about Galen, Vesalius and Harvey, and their work and discoveries. Suggest how they were influenced by the times in which they lived. Why didn’t they just accept the ideas of their times? Why did they ask questions? Propose a question or hypothesis that you may have asked if you lived in each of their times.

22 Find examples of how developments in imaging technologies have improved our understanding of the functions and interactions of our body systems. Share your findings with others.

23 Investigate how technologies using electromagnetic radiation are used in medicine; for example, in the detection and treatment of cancer of the circulatory or respiratory system.

24 (a) Identify issues associated with organ transplantation.
(b) As a team, select one of these issues and find out why it is an issue.
(c) What is your opinion on the issue?
(d) Share your opinion and reasons for it with other members of your team.
(e) Construct a team PMI on the organ transplant issue.

INVESTIGATE, THINK AND CREATE

25 In your team, design and perform an experiment to investigate the effect of different types of activities on your heart rate.

26 Doctors use a stethoscope to listen to heartbeats. Make and test your own stethoscope using rubber tubing and a plastic funnel.

27 What does a cardiologist do? Find an example of an Australian cardiologist and write a ‘diary entry’ for a day at work for them.

28 Find articles in the media that advertise foods or drinks that can reduce heart disease. In a team, research the claims and summarise your findings in a SWOT diagram. As a class, be involved in a debate that includes members from different interest groups or with different perspectives or biases.

29 Can diet, exercise or lifestyle choices change the chances of you having a heart attack? Research this question, summarising your findings in a PMI chart. On the basis of your data, what is your personal answer to this question? Give reasons for your opinion.

30 (a) Find examples of scientific research on the circulatory system.
(b) Create a poster, PowerPoint presentation or podcast on the research and present your findings to the class.

31 (a) Use the internet to identify problems relating to the circulatory system.
(b) Select one of these problems and construct a model or animation to demonstrate its effect on normal body function.

32 Use the Electrocardiogram game weblink in your eBookPLUS to simulate performing ECGs on patients referred to you by medical doctors.

33 Use the Interviews with Australian scientists weblink in your eBookPLUS to find out more about the work of vascular biologist Professor Julie Campbell.
Respiratory system — breathe in, breathe out

Breathe in deeply... now breathe out. You have exchanged gases with your environment. You have supplied your body with some essential oxygen and removed some unwanted carbon dioxide. You do this about 15–20 times a minute without even having to think about it. Where does this oxygen go and where did the carbon dioxide come from?

Cells need energy!

Your cells need **oxygen** as it is essential for **cellular respiration**. This process involves breaking down **glucose** so that energy is released in a form that your cells can use. This reaction produces **carbon dioxide** as a waste product that needs to be removed.

\[
\text{glucose + oxygen} \rightarrow \text{carbon dioxide + water + energy}
\]

Respiratory system

The main role of your **respiratory system** is to get oxygen into your body and carbon dioxide out. This occurs when you inhale (breathe in) and exhale (breathe out). The respiratory system is made up of your **trachea** (or windpipe) and your **lungs**.

Getting oxygen to your lungs

When you breathe in, air moves down your **trachea**, then down into one of two narrower tubes called **bronchi** with **alveoli**.
bronchi (bronchus). After that, the air moves into smaller branching tubes called bronchioles, which end in tiny air sacs called alveoli (alveolus). It is at the alveoli that gases (such as oxygen and carbon dioxide) are exchanged between the respiratory system and the circulatory system.

**Working together to get oxygen from lungs TO cells**

Your circulatory and respiratory systems work together to get oxygen to your cells. Once you have breathed in and oxygen has reached your alveoli, oxygen diffuses into red blood cells in capillaries that surround the alveoli.

The oxygen diffuses into the red blood cells because there is a higher concentration of oxygen inside the alveoli than inside the blood cells. Once inside the red blood cells, oxygen binds to haemoglobin to form oxyhaemoglobin. It is in this form that oxygen travels throughout your body. The blood that it travels in is referred to as oxygenated blood.

The oxygenated blood travels from your lungs via the pulmonary vein to the left atrium of your heart. From here, it travels to the left ventricle where it is pumped under high pressure to your body through a large artery called the aorta. The oxygenated blood is then transported to smaller vessels (arterioles) and finally to capillaries through which it diffuses into body cells for use in cellular respiration.

In an alveolus, oxygen diffuses into the blood and carbon dioxide diffuses out of the blood.

The pathway oxygen travels to your lungs when you inhale.

The pathway oxygen travels from your lungs to your body cells.

The pathway carbon dioxide travels from your body cells to your lungs.
Working together to get carbon dioxide FROM cells

Carbon dioxide is a waste product of cellular respiration and needs to be removed from the cell. When carbon dioxide has diffused out of the cell into the capillary, the blood in the capillary is referred to as **deoxygenated blood**. This waste-carrying blood is transported from the capillaries to small veins (**venules**) to large veins called vena cava, then to the **right atrium** of your heart. From here it travels to the **right ventricle** where it is pumped to your lungs through the **pulmonary artery** (the only artery that does not contain oxygenated blood).

Exhaling carbon dioxide from lungs

Once the deoxygenated blood reaches the alveoli of the lungs, carbon dioxide diffuses out of the capillaries. This occurs because there is a higher concentration of carbon dioxide inside the capillaries than in the alveoli. Carbon dioxide is then transported into the bronchiole, then bronchi and trachea, until it finally exits through your nose (or mouth) when you exhale.

**HOW ABOUT THAT!**

Phew ... garlic breath! Have you ever heard someone say this? Garlic or onion breath comes from further down than your mouth! It has travelled through a number of your body systems. After you have eaten food containing either of these, and it has been digested, it is absorbed through the walls of your intestines and then into your blood. When the smelly onion or garlic blood reaches your lungs through your circulatory system, you breathe out the smelly gas.
Brain AND muscle?
The respiratory system also relies on organs from other systems. When you breathe in, a muscle beneath your rib cage called the diaphragm tightens. This allows the lungs to expand and air to be pulled into them. When you breathe out, the diaphragm relaxes, which reduces the size of the lungs and pushes air out. The largest volume of air that you can breathe in or out at one time is called your vital capacity.

Breathing involves muscle movements that are automatic and controlled by the respiratory centre in the brain.

INVESTIGATION 4.9

Hands on pluck

AIM To investigate the trachea, lungs, heart and liver of mammal

Materials:
sheep’s pluck (heart and lungs) with part of the liver and trachea attached
newspaper and tray to place the pluck on
plastic disposable gloves
balloon pump and rubber tubing

METHOD AND RESULTS

1 Copy the table below into your workbook.

<table>
<thead>
<tr>
<th>Organ</th>
<th>Shape (sketch)</th>
<th>Approx. size (cm)</th>
<th>Colour</th>
<th>Texture</th>
<th>Other comments</th>
<th>System to which the organ belongs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trachea</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lung</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heart</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Liver</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2 Carefully observe and record the shape, size, colour and texture of the sheep’s trachea, lungs, heart and liver. Include notes on how they are connected. Can you see any blood vessels?

- Push a piece of rubber tubing down the trachea to the lungs and use a balloon pump to blow some air into the trachea.

CAUTION For hygiene reasons, it is not recommended that you use your mouth to blow into the tube inserted in the trachea.

3 Cut through the lung, heart and liver tissue. Make a record of your observations describing how they are similar and how they are different. Discuss possible reasons for the differences with your team members.

4 Using a scalpel or scissors, cut off a small piece of heart, lung and liver. Place each piece into a beaker of water and observe what happens. Discuss possible reasons for your observations with your team members.

DISCUSS AND EXPLAIN

5 Could you see any blood vessels? Try to find out their names and what sort of blood they carry.

6 Suggest why there are rings of cartilage around the trachea.

7 Suggest reasons for the differences in texture between the heart and lungs.

8 Suggest reasons for the differences in the shapes of the organs that you observed.

9 Comment on something that you learned or found particularly interesting from this investigation. Share your comment with others.

10 Research and report on the following points for each of the organs in this investigation:
- its function and how it carries this out
- the system to which it belongs
- a disease relevant to it.

(a) Breathing in
(b) Breathing out

When you breathe in, your diaphragm tightens; when you breathe out, it relaxes.
INVESTIGATION 4.10
Measuring your vital capacity

AIM To investigate the vital capacity of lungs

Materials:
balloon
ruler

METHOD AND RESULTS
眭 Blow up a balloon to about 20 cm in diameter two or three times to stretch it. Release the air each time.
眭 Take the biggest breath you can, then blow out all the air into the balloon. Tie up the end of the balloon to hold in your ‘blown out’ air.

1 Use a ruler to measure and record the diameter of the balloon as shown below.
2 Use the table at the bottom of this page to determine your approximate vital capacity in litres.
3 Release the air from the balloon and repeat your measurement of vital capacity three more times. Average your results to get your best estimate of the maximum ‘blow-out’ of your lungs.

DISCUSS AND EXPLAIN

5 Collect results from all the students in your class and complete the table.
6 Calculate the average lung capacity for all the females and for all of the males in your class.
7 Calculate the average lung capacity for all students in your class who play a wind instrument.

8 Suggest why were asked to stretch the balloon first.

9 Suggest why you measured your vital capacity four times.
10 With reference to your results, do females have a bigger or smaller lung capacity than males in your class?
11 Compare the average lung capacity for students who play a wind instrument with the average value for students who do not. Do your results suggest that playing a wind instrument has an effect on lung capacity? Explain.
12 Suggest another way of measuring the amount of air exhaled with each breath.

<table>
<thead>
<tr>
<th>Balloon diameter (cm)</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
<th>16</th>
<th>17</th>
<th>18</th>
<th>19</th>
<th>20</th>
<th>21</th>
</tr>
</thead>
<tbody>
<tr>
<td>Approx. vital capacity (litres)</td>
<td>0.3</td>
<td>0.4</td>
<td>0.5</td>
<td>0.7</td>
<td>0.9</td>
<td>1.2</td>
<td>1.4</td>
<td>1.8</td>
<td>2.1</td>
<td>2.6</td>
<td>3.0</td>
<td>3.6</td>
<td>4.2</td>
<td>4.8</td>
</tr>
</tbody>
</table>
UNDERSTANDING AND INQUIRING

REMEMBER
1 Match the terms associated with the respiratory system with their description in the table below.

<table>
<thead>
<tr>
<th>Term</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) Alveoli</td>
<td>A blood vessel that carries deoxygenated blood from the heart to the lungs</td>
</tr>
<tr>
<td>(b) Bronchiole</td>
<td>One of two narrower tubes that leads off the trachea</td>
</tr>
<tr>
<td>(c) Bronchus</td>
<td>A muscle that allows the lungs to expand so that air can be pulled in</td>
</tr>
<tr>
<td>(d) Diaphragm</td>
<td>A red pigment that binds to oxygen</td>
</tr>
<tr>
<td>(e) Haemoglobin</td>
<td>A blood vessel that carries oxygenated blood from the lungs to the heart</td>
</tr>
<tr>
<td>(f) Pulmonary artery</td>
<td>A tube through which air moves from your mouth to your lungs</td>
</tr>
<tr>
<td>(g) Pulmonary vein</td>
<td>A tiny air sac through which oxygen diffuses into capillaries</td>
</tr>
<tr>
<td>(h) Trachea</td>
<td>A small branching tube with alveoli at its end</td>
</tr>
</tbody>
</table>

2 Use flowcharts to identify the pathway that:
(a) oxygen travels to get from the air outside your body to the alveoli of your lungs
(b) oxygen travels to get from your lungs to your body cells
(c) carbon dioxide travels to get from your body cells to the alveoli of your lungs
(d) carbon dioxide travels to get from your lungs to the air outside your body.

USING DATA
3 The table below shows approximate percentages of various gases breathed in and breathed out.

<table>
<thead>
<tr>
<th>Gas</th>
<th>Oxygen (%)</th>
<th>Carbon dioxide (%)</th>
<th>Water vapour (%)</th>
<th>Nitrogen (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air breathed in</td>
<td>21</td>
<td>0.04</td>
<td>1</td>
<td>78</td>
</tr>
<tr>
<td>Air breathed out</td>
<td>15</td>
<td>4</td>
<td>5</td>
<td>76</td>
</tr>
</tbody>
</table>

(a) (i) Compare the percentage of oxygen breathed in to that breathed out.
(ii) Suggest a reason for this pattern.
(b) (i) Compare the percentage of carbon dioxide breathed in to that breathed out.
(ii) Suggest a reason for this pattern.
(c) The percentages in the table can vary in different weather conditions and at different heights above sea level. Research these variations and the possible implications this may have on humans.

THINK AND DISCUSS
4 Describe how oxygen gets from the alveoli of your lungs into blood cells in your capillaries.
5 Differentiate between the terms ‘cellular respiration’, ‘respiratory system’ and ‘breathing’.

THINK AND INVESTIGATE
6 Use information in this section and other resources to relate structural features to the functions of the following parts of the respiratory system.

<table>
<thead>
<tr>
<th>Part of system</th>
<th>Structural features</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trachea</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alveoli</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lungs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capillaries</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

7 Some people describe the structure of the lungs as an upside-down hollowed-out tree. Which parts of the lungs might be the following parts?
(a) Trunk
(b) Branches
(c) Twigs
(d) Leaves

8 Give reasons for the following pieces of advice.
(a) It is better to breathe through your nose than your mouth.
(b) You should blow your nose when you have a cold rather than sniff it back.
(c) You should not talk while you are eating or drinking.

9 Find out what a spirometer is.

10 Did you know that mountain climbers often find it difficult to breathe? Some wear oxygen tanks to allow them to climb very high mountains. Research the effects of high altitude on breathing and report your findings.
11 Some singers can hold a musical note for a very long time — investigate what muscles and techniques they use to be able to do this.

THINK AND CREATE

12 Construct a model lung as shown in the diagram below. You can use the following items:
- two clear 1-litre plastic bottles with tops
- four balloons
- two plastic drinking straws
- rubber bands or very sticky tape
- plasticine or Blu-Tack
- scissors.

13 Carefully observe the lung model shown below.

(a) Identify which body parts are represented in the model by the:
(i) straw
(ii) rubber sheet at the bottom of the bottle
(iii) balloon connected to the straw
(iv) plastic bottle.

(b) Pull the rubber sheet at the bottom of your model downwards. Record your observations. Release the rubber sheet. Record your observations. Discuss how your observations relate to how a lung works. Suggest how the model could be improved.

14 Use the Anatomy of breathing weblink in your eBookPLUS to view an animation that outlines how the respiratory system works.

A model lung. When the rubber sheet at the bottom is pulled down, the pressure inside the jar drops and air is sucked into the balloon. The balloon inflates (blows up).
Short of breath?

Have you suffered an asthma attack? If not, have you ever struggled to breathe after intense exercise? Not being able to take a full breath can be a scary thing.

Asthma

If you do not suffer from asthma, it is very likely that you know someone who does. Asthma is a very common condition and the number of people who suffer from it has increased over the years.

What is asthma?

Asthma is a narrowing of the air pipes that join the mouth and nose to the lungs. The pipes most affected are the bronchi. They become narrower as:

- the muscle wall of the air pipes contracts
- the lining of the air pipes swells
- too much mucus is produced.

The narrow pipes make breathing difficult and can result in wheezing, coughing and a tight feeling in the chest. The coughing is usually worse at night.

What causes asthma?

It is not known why some people get asthma and others do not. It seems that it can be inherited, but many people from families without a history of asthma are affected. Asthma is certainly the result of sensitive airways. An asthma attack occurs when those sensitive airways are ‘triggered’. If the sufferer has a cold, the airways are already inflamed and are more likely to be triggered.

Some of the common triggers of an asthma attack are:

- vigorous exercise
- cold weather
- cigarette smoke
- dust and dust mites
- moulds
- pollen
- air pollution
- some foods and food additives
- some animals.

Not all asthma sufferers are affected by the same triggers. Some people suffer attacks only as a result of exercise. Others might be affected by any one or more of the triggers. It is important that those who get asthma try to find out what triggers the attacks. Many of the triggers can be avoided.

Controlling the triggers

The best way to control asthma is to avoid the triggers. While this is not always possible, it is worthwhile to recognise the triggers, so that you can minimise them.

Pollen and moulds

Pollen from some grasses and trees is very light and becomes airborne on even slightly windy days. The inhaling of pollen can be reduced by avoiding outdoor activities and keeping windows and doors closed on breezy spring days. Moulds live in warm, humid conditions and thrive in bathrooms, kitchens and bedrooms. Their spores are easily breathed in, triggering attacks in some asthma sufferers. Moulds can be reduced by airing the house regularly.

Air pollution

Those asthma sufferers whose attacks are triggered by air pollution are warned to remain indoors as much as possible and avoid vigorous activity on smoggy days. If tobacco smoke is a trigger, the cigarette smoke of others needs to be avoided.
**Dust mites**

Dust mites are a common trigger of asthma attacks. Dust mites are microscopic animals that live in their thousands in warm, moist and dark places like doonas, sheets, pillows, carpets and curtains. Dust mite droppings float in the air and are easily inhaled.

Since you share so much of yourself and where you live with this fellow Australian, you should probably know its name. It is the most common dust mite (a relative of spiders and ticks) in Australia, *Dermatophagoides pteronyssinus*. The good news is that it is half a millimetre long and doesn’t bite. The bad news is that there may be thousands of them living in your pillow, each defecating about 20 faecal pellets a day, reproducing (each female laying about 30 eggs in her lifetime), dying and decomposing. The fact that dust mites mate for 24 hours at a time (perhaps because their penis is only about as wide as their sperm) may make this particularly disturbing!

Our skin scales are the main food source for these dust mites, so wherever we are, they are. Dr Janet Rimmer (a respiratory physician and Director of the National Asthma Council Australia) also suggests that, of the 45 per cent of Australians who are affected by allergies, about 80 per cent are allergic to dust mites. But not all researchers have bad news about dust mites. Dr Matthew Colloff, a CSIRO researcher, has found them so interesting that he wrote a book (called *Dust mites*) about them.

Even the cleanest house has dust mites, but their numbers can be reduced by:
- exposing your mattress to the sun, because dust mites are susceptible to drying out
- washing bedding materials and bedclothes in tea-tree or eucalyptus oil or in hot water (above 55°C)
- removing soft toys that collect dust or hot washing them weekly
- regularly vacuuming curtains and carpets
- airing the bedroom by keeping doors and windows open
- replacing carpets with hard flooring.

**A house dust mite**

**HOW ABOUT THAT!**

Dust mites thrive best in bedding and carpets because these contain plenty of dead human skin cells. Humans shed a complete layer of dead skin cells every month. That amounts to about 1 kilogram of skin cells each year. In fact, most of the dust in your house consists of dead skin cells.

**Asthma medication**

Asthma medications can be divided into two main groups: preventers and relievers. Preventers make the lining of the airways less sensitive and therefore less likely to be triggered. Relievers open up the airways once an attack has commenced. Most asthma medications are applied with inhalers or ‘puffers’, which direct the medication straight into the air tubes for fast action. Severe attacks of asthma require other drugs and sometimes extra oxygen needs to be supplied.
Up in smoke
Asthma is not the only condition that can interfere with your lungs functioning as they should. Some human activities can damage not only your lungs, but also those of others around you. Smoking is one example of such an activity. About 15,000 Australians die each year as a result of diseases caused by smoking. Smoking is actually the largest preventable cause of death and disease in Australia.

There are some more obvious effects such as bad breath, body odour and watery eyes. After several cigarettes, your teeth and fingers become stained. Your sense of taste is reduced. Even your stomach is affected as acid levels increase.

Smoking and your lungs
Lung cancer is the most well-known disease caused by smoking. Chemicals that cause cancer are called carcinogens. Cigarette tobacco contains a number of carcinogens. The chemicals in cigarettes also clog up the fine hairs in your air tubes with a mixture of mucus and foreign chemicals.

Cough it up
Coughing is the body’s way of trying to clear the air tubes. However, not all of the clogging can be cleared by coughing. A dirty mixture remains in the air tubes, causing swelling, making them sensitive and slowing down the passage of air. Eventually, the sticky mixture sinks down into the lungs, where it blocks some of the pathways to the alveoli, where freshly breathed air should deliver oxygen to the blood.

The diseases caused by this blocking process are called chronic obstructive pulmonary diseases, or COPD. Emphysema is the worst of these diseases and results in the eventual destruction of the alveoli.
1. **What is your current science-related title?**

   I am a Professor of Medicine, with particular responsibilities for allergy, clinical immunology and respiratory medicine, at Monash University, Melbourne. I am also the Director of the Department of Allergy, Immunology and Respiratory Medicine at the Alfred Hospital in Melbourne.

2. **What field of science are you in?**

   Allergy, cellular immunology and respiratory medicine. I was appointed to the first Chair in Allergy and Clinical Immunology in Australia.

3. **Describe some science that you are involved in at the moment.**

   Millions of people around the world suffer from allergies. I am sure you know several friends who have asthma or hay fever, or you may even have them yourself. Asthma and hay fever are usually triggered by proteins called allergens, from house dust mites or grass pollens. Allergies to peanuts and shellfish are less common but often more serious, because they can trigger life-threatening allergic reactions called anaphylaxis. Allergies are caused by reactions between white blood cells (‘T cells’) and environmental proteins that are usually harmless. My research group is trying to find ways to damp down the allergic T-cell responses.

   Allergen immunotherapy (allergy shots) is the only treatment that can prevent allergic diseases, but currently it can’t be used for peanut allergies, even though this is one of the most serious allergens. To develop a safe and effective vaccine against peanut allergies, we are identifying parts of critical peanut proteins that can build up tolerance in allergic patients without risking anaphylaxis.

4. **What do you enjoy about being a scientist?**

   I enjoy the fact that my research not only is laboratory-based, exploring novel methods for switching off allergic responses, but also lets me see patients and train other doctors in how to do research from bench to bedside to the community. I head an active clinical department, still carry out clinics with patients, and am actively engaged in national and international tests of new preventions and treatments for allergies. My combined research and clinical duties allow translation of our research findings into better clinical practice.

5. **What triggered your interest in science?**

   I decided to specialise in allergy and respiratory medicine, focusing on asthma, following my experiences as a young trainee physician at the Alfred Hospital in Melbourne. Asthma was a huge problem in Australia at that time, and many times I resuscitated young adults in the hospital emergency room — and I watched them return, with appropriate medication and careful education, to confident, full lives. Some remain my patients today. The ability to dissect underlying mechanisms of disease and then work towards new therapeutics and practices to benefit patients is a great excitement and honour. The diversity of patients and their needs ensures that every day is quite different.

6. **Do you have any other comments that may be of interest to Year 8 Science students?**

   A career in science combined with medicine may take a bit longer in terms of training, but it gives you a fantastic ability to do interesting work that is intellectually demanding and also involves working with lots of people who need your help. I am very glad that I chose a career in science and medicine.
UNDERSTANDING AND INQUIRING

REMEMBER
1 What happens to the air pipes to the lungs during an asthma attack to make breathing difficult?
2 Why is an asthma attack more likely to be triggered in a person with a cold?
3 What is an asthma trigger?
4 What are the two major types of asthma medication and how are they different from each other?

THINK AND DISCUSS
5 (a) In your team, brainstorm ideas about the common triggers of asthma that can be controlled. Summarise your discussion in a bubble map.
(b) Construct a table similar to the one below.
(c) Again as a team, add suggestions to your table of ways that the trigger could be controlled.

<table>
<thead>
<tr>
<th>Trigger</th>
<th>How the trigger can be controlled</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moulds</td>
<td>Air the house regularly.</td>
</tr>
</tbody>
</table>

6 (a) If you suffer from asthma, prepare a talk for the rest of your class explaining:
(i) what it is
(ii) how it affects you
(iii) how you control it or try to prevent attacks.
(b) If you do not suffer from asthma, write a set of at least five questions that you could ask an asthma sufferer in an interview. If possible, conduct the interview and record the answers in writing, or as audio or video.

THINK
7 Draw up a two-column table. The first column should be headed ‘Reasons for smoking’; the second column should be headed ‘Reasons for not smoking’. With at least one other person, complete the table. Then compare your table with others. You might be able to construct a large table for the whole class.

8 Smoking-related diseases cost taxpayers many millions of dollars because hospitals are mostly paid for by governments. Write down your opinion of each of the proposals below. Give reasons for your opinion.
(a) The cost of hospital treatment for diseases caused by smoking should be paid for by the patient because it was their fault that they got sick.
(b) Cigarettes should cost more. The extra money made from them could then be given to hospitals to help pay for treating smoking-related diseases.
(c) Cigarette companies who make profits from smoking should be made to pay for hospital treatment of patients with diseases caused by smoking.

INVESTIGATE AND DISCUSS
9 Propose a series of questions to find out more about each of the areas below, investigate them, and then share your findings with others.
(a) Allergies
(b) Asthma
(c) Anaphylaxis
(d) Allergen immunotherapy
(e) Clinical immunology and respiratory medicine
10 (a) Find out more about Anaphylaxis Australia Inc.
(b) Outline the topics covered in a first aid course for management of anaphylaxis.
(c) What is an EpiPen and how is it used?
The table above shows how the popularity of smoking has changed over the past 70 years or so.

(a) Draw a line graph of the data in the table. Use ‘Year’ on the x-axis and ‘% of adult Australians who smoke’ on the y-axis. Draw lines for males and females in different colours.

(b) Why do you think that the percentage of females who smoke has changed little while the percentage of males who smoke has declined greatly?

(c) Use dotted lines to show your prediction of the trends up to the year 2020. What percentage of males and females do you predict will be smoking in 2020?

Study graph 1 on the right.

(a) Copy and complete the following statements.
   (i) People who smoke 10 cigarettes a day are _________ times more likely to develop lung cancer than non-smokers.
   (ii) People who smoke 30 cigarettes a day are _________ times more likely to develop lung cancer than people who smoke 10 cigarettes a day.

(b) If a packet of cigarettes costs $15 and contains 20 cigarettes, calculate how much a person smoking 40 cigarettes a day spends on smoking:
   (i) each day
   (ii) each week
   (iii) each year.

Study graph 2 on the right.

(a) Describe how the incidence of lung cancer deaths changed between 1900 and 1980.

(b) Identify when the number of male smokers peaked.

(c) Identify when the number of deaths from lung cancer peaked.

(d) Explain why there is a 20-year gap between the two numbers.

(e) The graph shows data for male smokers only. Predict when the number of cases of lung cancer deaths in women peaked (use the graph you drew for question 13 to answer this).

(a) Research the structure and function of an alveolus.

(b) Suggest how the structure of an alveolus is related to its function.

(c) Suggest how smoking affects the ability of an alveolus to perform its function.
Excretory system — taking out the trash!

Being alive requires energy and nutrients. It also results in the production of wastes that need to be removed.

Excretory system

Excretion is any process that gets rid of unwanted products or waste from the body. The main organs involved in human excretion are your skin, lungs, liver and kidneys. Your skin excretes salts and water as sweat, and your lungs excrete carbon dioxide (produced by cellular respiration) when you breathe out. Your liver is involved in breaking down toxins for excretion, and your kidneys are involved in excreting the unused waste products of chemical reactions (e.g. urea) and any other chemicals that may be in excess (including water) so that a balance within our blood is maintained.

Kidneys

If you put your hands on your hips, your kidneys are close to where your thumbs are. You have two of these reddish-brown, bean-shaped organs. Without them you would survive only a few days.

Organs, tubes and urine

Your kidneys play a key role in filtering your blood and keeping the concentration of various chemicals and water within appropriate levels. Each of your kidneys is made up of about one million nephrons. These tiny structures filter your blood, removing waste products and chemicals that may be in excess. Chemicals that your body needs are reabsorbed into capillaries. The fluid remaining in your nephrons travels through tubes called ureters to your bladder for temporary storage. As it fills, your bladder expands like a balloon. It can hold about 400 mL of this watery fluid which contains unwanted substances called urine. Urination occurs when urine moves from your bladder through a tube called the urethra and out of your body.
Nephrons — how their structure suits their function

Each nephron is made up of a long tubule (very fine tube) that forms a cuplike structure at one end called the Bowman's capsule. This structure surrounds a cluster of capillaries called the glomerulus (from an ancient Greek word meaning ‘filter’).

Blood containing wastes travels to the glomerulus within each nephron in your kidneys, where the blood is filtered. Wastes and excess water move into the surrounding Bowman’s capsule. As this ‘waste’ fluid moves along the tubules, any useful substances are reabsorbed back into capillaries that are ‘twisted’ around the tubules, and hence back into circulation. The remaining fluid becomes urine, which eventually travels in your ureters to your bladder prior to urination.

Have a drink!

Both blood and urine are mostly made up of water. Water is very important because it assists in the transport of nutrients within and between the cells of the body. The concentration of substances in blood is also influenced by the amount of water in it.

Water helps the kidneys do their job because it dilutes toxic substances and absorbs waste products so that they can be transportation out of the body. If you drink a lot of water, more will be absorbed from your large intestines and your kidneys will produce a greater volume of dilute urine. If you do not consume enough liquid, you will urinate less and produce more concentrated urine.
**Haemodialysis**

People with kidney disease may not be able to remove the waste materials from their blood effectively. They may be linked up to a machine that does this job for them. Their blood is passed along a tube that lets wastes, such as urea, pass out of it. However, useful substances, such as glucose, proteins and red blood cells, stay in the tube and are kept in the blood. This process is called **haemodialysis**.

**Liver**

**Livers are busy places!**

Over a litre of blood passes through your liver each minute. Your liver is like a chemical factory, with more than 500 different functions. Some of these include sorting, storing and changing digested food. The liver removes fats and oils from the blood and modifies them before they are sent to the body’s fat deposits for storage. It also helps get rid of excess protein, which can form toxic compounds dangerous to the body. The liver converts these waste products of protein reactions into urea, which travels in the blood to the kidneys for excretion. It also changes other dangerous or poisonous substances so that they are no long harmful to the body. Your liver is an organ that you cannot live without.

**Too much alcohol?**

The liver is also involved in breaking down alcohol. Alcohol is converted into a substance called acetaldehyde, then to acetate and finally into carbon dioxide and water. The carbon dioxide is transported from the liver to the lungs, and then exhaled out of the body. The water may be removed as vapour in breath, sweat on skin or as urine.

Alcohol can also affect the amount of urine produced by the kidneys. Reabsorption of water may be reduced in the kidneys, resulting in the production of more urine. Increased urination can result in dehydration and consequently impair other body functions.

**HOW ABOUT THAT!**

The human kidneys remove excess salt from the blood to help keep levels constant. Different types of animals have other ways of removing excess salt from their bodies. Turtles, for example, have salt-secreting glands behind their eyes. Hence you may see a turtle ‘shedding tears’. On the other hand, penguins and some other seabirds, such as the Southern Giant Petrel, may appear to have runny noses because that is where their salt-secreting glands are located.
UNDERSTANDING AND INQUIRING

REMEMBER

1. Match the terms associated with the excretory system with their description in the table below.

<table>
<thead>
<tr>
<th>Term</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) Bladder</td>
<td>A Watery fluid produced by kidneys that contains unwanted substances</td>
</tr>
<tr>
<td>(b) Kidney</td>
<td>B Transports urine from bladder to outside body</td>
</tr>
<tr>
<td>(c) Ureter</td>
<td>C Stores urine</td>
</tr>
<tr>
<td>(d) Urethra</td>
<td>D When urine moves from the bladder, through the urethra and out of the body</td>
</tr>
<tr>
<td>(e) Urination</td>
<td>E Transports urine from kidneys to bladder</td>
</tr>
<tr>
<td>(f) Urine</td>
<td>F Filters the blood and produces urine</td>
</tr>
</tbody>
</table>

2. Define the term ‘excretion’.
3. Draw and label a diagram of the kidneys showing the following attachments: renal arteries, renal veins, ureters, bladder.
4. Outline what happens when you drink a lot of water.
5. Describe one way in which excess salt is removed from your body.
7. Describe the relationship between:
   (a) a kidney and a nephron
   (b) kidneys and urine
   (c) alcohol, lungs and kidneys.
8. Distinguish between:
   (a) the ureter and the urethra
   (b) a Bowman’s capsule and a glomerulus
   (c) the bladder and the kidney.

THINK AND DISCUSS

9. Carefully observe the haemodialysis diagram on page 138. Suggest reasons the following are included in the process:
   (a) blood pump
   (b) bubble trap
   (c) constant temperature bath.
10. Suggest what you would expect to find in used dialysing solution.
11. Suggest why red blood cells don’t pass through the dialysis tubing.
12. Use a Venn diagram to compare haemodialysis with real kidneys.

ANALYSE AND EVALUATE

13. Use the table above right and the other information in this section to answer the following questions.
   (a) Draw two bar graphs to show the quantity of water, proteins, glucose, salt and urea in blood and in urine.
   (b) Which substance is in the greatest quantity? Suggest a reason for this.
   (c) Which substances are found only in blood?
   (d) Which substances are found in urine in a greater quantity than in blood? Suggest a reason for this.
   (e) When would the amount of these substances in the urine become greater or less than in the blood?

<table>
<thead>
<tr>
<th>Substance</th>
<th>Quantity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>In blood</td>
</tr>
<tr>
<td>Water</td>
<td>92</td>
</tr>
<tr>
<td>Proteins</td>
<td>7</td>
</tr>
<tr>
<td>Glucose</td>
<td>0.1</td>
</tr>
<tr>
<td>Chloride (salt)</td>
<td>0.37</td>
</tr>
<tr>
<td>Urea</td>
<td>0.03</td>
</tr>
</tbody>
</table>

INVESTIGATE AND CREATE

14. Research and report on one of these conditions: urinary incontinence, kidney stones, kidney transplants, cystitis, blood in urine, proteinuria, nephritis.
15. Find out and report on:
   (a) the differences between the urethra in human males and females
   (b) why pregnant women often need to urinate more frequently
   (c) how the prostate gland in males may affect urination in later life
   (d) which foods can change the colour or volume of urine
   (e) which tests use urine in the medical diagnosis of diseases.
16. Find out more about nephrons and how they work. Construct a model of a nephron that shows how it is linked to blood vessels and how urine gets to your bladder from it.
17. Research the nephrons of animals that live in different environments (for example, deserts, oceans and rivers). Comment on similarities and differences in their structure. Suggest reasons for the differences.
Your **musculoskeletal system** consists of your **skeletal system** (bones and joints) and your **skeletal muscle system**. Working together, these two systems protect your internal organs, maintain posture, produce blood cells, store minerals and enable your body to move.

**Bones**

Did you know that an adult human skeleton contains over 200 separate bones? Without a skeleton we may resemble jelly-like blobs! Not only does it provide a structure for our muscles to attach to, allowing us to move, but it also provides support, protects vital organs (e.g. brain and heart) and forms a frame that gives our body shape.

Your bones have many different shapes and sizes, depending on the job that they have to do. They can be short, thick, round or flat. The longest bone in your body is the femur, or thigh bone. The smallest bone, the stapes, or stirrup bone is in your ear and is about 3 mm in length. A feature that all bones have in common, however, is that they are all light and strong. Why do you think they share this feature?

**It’s hard being a bone**

Bones are alive. If bones were not alive, how would you grow taller? How would a broken arm or leg mend? Bones contain living cells and need a blood supply to provide them with oxygen and other nutrients.

Not only are bones busy providing you with support and movement, they are also busy inside. Bones contain soft tissue called **bone marrow**. This is very important because it is where blood cells are made.

Throughout the first twenty years of your life, most of the soft and rubbery **cartilage** that made up your skeleton is gradually replaced with bone. Your trachea, nose and ears, however, are made mostly of cartilage and the ends of your bones remain covered in cartilage.

Compact bones, such as the long bone of your femur, have a strong and hard outer layer that contains **calcium** and **phosphorus**. This is why you need an adequate supply of these minerals. Investigation 4.11 shows what could happen to your bones without a supply of these important **minerals**.

The hardening of your bones as you get older is called **ossification**. After ossification, the bone is made up of about 70 per cent non-living matter and 30 per cent living matter. As you get even older, your bones may get dry and brittle, which is why older people break their bones more easily.

**Joints**

A **joint** is the region where two bones meet. Your knees and elbows are examples of joints. Bones at a joint are held together by bundles of strong fibres called **ligaments**. The cartilage that covers the end of each bone is itself covered with a liquid called **synovial fluid**. The cartilage and synovial fluid work together to stop bones from scraping against each other.
Most joints allow your bones to move. The amount and direction of movement allowed depends on the type of joint. Twist your neck. The joint between your skull and spine is a **pivot joint**, which allows this twisting type of movement (figure a). Bend your elbow. Your elbows and knees are **hinge joints**, like those of a door. They allow movement in only one direction (figure b). Roll your shoulder. Your hip and shoulder joints are **ball and socket joints**, allowing movement in many directions (figure c).

Some joints, such as those that join the plates in your skull, do not move. These are called **immovable joints**. While not allowing movement, these joints provide a thin layer of soft tissue between bones. Their job is to absorb enough energy from a severe knock to prevent the bone from breaking.
Muscles

Muscles are tough and elastic fibres. The movement of muscles is controlled by the brain, which sends signals through your nerves. Muscles such as those that make your heart pump and those that control your breathing rate are called **involuntary muscles** — they work without you having to think about it. The muscles that are connected to bones are called **voluntary muscles** because you have to choose to use them.

**All pull, no push!**

Muscles are connected to the bones of your skeleton by bundles of tough figures called **tendons**. Muscles pull on bones by contracting or shortening. Muscles never push.

Broken bones

**Breaks and fractures**

When a bone breaks, the ends of the bone need to be put back into place (set) so that they can grow together. If a bone is shattered into several pieces, it is sometimes possible to use pins or wire to hold the pieces in place while the bone heals. A **greenstick fracture** occurs when the bone cracks but does not break. This type of **fracture** is common in children because their bones are more flexible.

**On the mend?**

New technologies are being researched and developed to help fix broken bones. Some of these involve special cells called **stem cells**, while others involve the use of special ‘glues’ that hold bones together and aid the healing process. Scientists at CSIRO are currently working on a liquid gel called NovoSorb that glues the fractured bone together so that it is supported while it heals. As this gel degrades naturally, it does not require follow-up surgery to remove pins as is needed with older technologies.

Osteoporosis

Osteoporosis is a loss of bone mass that causes bones to become lighter, more fragile and easily broken. It occurs in middle-aged or elderly men and women. In Australia, about 60 per cent of women and about 30 per cent of men are affected by osteoporosis at some stage. It is believed to be caused by lack of calcium in the diet.

In your teenage years, you can help protect yourself from getting osteoporosis later in life by having a healthy diet and exercising. Your diet should include dairy products such as milk, cheese and yoghurt and other foods high in calcium. Such a diet will help ensure that your bone mass is adequate as an adult.

Ouch! Torn or swollen?

**Sprains**

Sprains occur when ligaments joining bones at a joint are torn or stretched. Sprains usually happen when you fall onto a joint, such as an elbow or an ankle, and twist it.
**Arthritis**

Arthritis is a swelling of the joints that makes movement difficult. Osteoarthritis occurs mainly in elderly people and is caused by wear and tear of the joints. The cartilage gradually breaks down, thus allowing bare bones to grate against each other instead of sliding or turning smoothly. Rheumatoid arthritis is a swelling of the tissue between the joints. The swelling causes the joints to slip out of place, which then causes great pain and deformities.

**Tennis elbow**

Tennis elbow occurs when the lining of the elbow joint swells and produces too much synovial fluid. The joint becomes swollen and painful. This occurs when the joint is used a lot and is most common in tennis players.

**Torn hamstrings**

Torn hamstrings are a common sporting injury. The hamstring muscle joins the pelvis to the bottom of the knee joint, running along the back of the thigh. It controls the bending of the knee and straightening of the hips. A sudden start or turn in sport often stretches the hamstring muscle too far. It tears, causing great pain. Cold and unprepared muscles are more likely to tear. Proper warming up before strenuous sporting activity is one way to reduce the chances of tearing a muscle.

### INVESTIGATION 4.11

**Rubbery bones**

**AIM**

To investigate the effect of calcium and phosphorus deficiency on bone

**BACKGROUND INFORMATION**

Vinegar is an acid that dissolves minerals such as calcium and phosphorus, removing them from bones.

**Materials:**

- 2 chicken or turkey bones
- water
- 2 jars (or beakers)
- vinegar

**METHOD**

- Clean the two chicken or turkey bones and leave them to dry overnight.
- Observe the bones and then place one bone in a jar of vinegar and the other in a jar of water.
- Allow the bones to soak for at least three days. Then remove the bones and observe any changes.
- Return the bones to their previous jars for another week, then remove and observe any further changes in the bones. Can you tie either bone into a knot?

**RESULTS**

1. Construct a table to record your observations.
2. Record your observations of the bone:
   - (a) before placing them in the solutions
   - (b) after soaking for three days
   - (c) a week after your observation in part (b).

**DISCUSS AND EXPLAIN**

3. Suggest a reason for the inclusion of the jar of water in the investigation.
4. Describe changes that you observed for each bone.
5. Provide reasons for the changes that you observed.
6. Relate this investigation to your bones and your diet.
7. Propose a conclusion for your findings.
INVESTIGATION 4.12
Chicken wing dissection

AIM To investigate the structure of a chicken wing

BACKGROUND INFORMATION:
Take special care when using scissors and scalpels.

Materials:
- chicken wing
dissection tray or board
newspaper
disposable gloves
scalpel
scissors

METHOD
- Sketch one of the joints in the chicken wing. Label the bones, the tendons and the muscles. Show clearly where the muscle inserts (attaches to the bones). Use arrows to show how the bones move when the muscle is shortened.
- Feel the cartilage with a gloved hand. Does the cartilage feel rough or slippery? Why does it need to be slippery?
- Is cartilage harder or softer than bone?

RESULTS
1 Sketch one of the joints in the chicken wing. Label the bones, the tendons and the muscles. Show clearly where the muscle inserts (attaches to the bones). Use arrows to show how the bones move when the muscle is shortened.
2 Feel the cartilage with a gloved hand. Does the cartilage feel rough or slippery? Why does it need to be slippery?

DISCUSS AND EXPLAIN
3 Describe differences that you observed between cartilage, tendons, muscles and bones.
4 Relate this investigation to your own joints, muscles, tendons and bones.
5 Propose a conclusion for your findings.

UNDERSTANDING AND INQUIRING

REMEMBER
1 Match the common name with the scientific term in the table below.

<table>
<thead>
<tr>
<th>Common name</th>
<th>Scientific term</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) Breastbone</td>
<td>A Mandible</td>
</tr>
<tr>
<td>(b) Knee cap</td>
<td>B Cranium</td>
</tr>
<tr>
<td>(c) Lower jaw</td>
<td>C Vertebrae</td>
</tr>
<tr>
<td>(d) Shin bone</td>
<td>D Tibia</td>
</tr>
<tr>
<td>(e) Skull</td>
<td>E Sternum</td>
</tr>
<tr>
<td>(f) Spine</td>
<td>F Femur</td>
</tr>
<tr>
<td>(g) Thigh bone</td>
<td>G Patella</td>
</tr>
</tbody>
</table>

2 Describe the job done by each of the following parts of a joint.
(a) Ligament
(b) Cartilage
(c) Synovial fluid

3 Some joints are referred to as immovable joints. What is the use of having joints that don’t move?

4 Write down an example of each of the following types of joint.
(a) Hinge
(b) Ball and socket
(c) Pivot
(d) Immovable

5 Ligaments and tendons are bundles of tough fibres. What is the major difference between a ligament and a tendon?

6 Describe the action of the biceps and triceps muscles as you bend your elbow to raise your forearm.

THINK AND INVESTIGATE

7 Your musculoskeletal system consists of your skeletal system (bones and joints) and your skeletal muscle system (voluntary or striated muscle). Working together, these two systems protect your internal organs, maintain posture, produce blood cells, store minerals and enable your body to move.

Use information in this section and other resources to relate structural features to the functions of the following parts of these systems.

<table>
<thead>
<tr>
<th>Part of system</th>
<th>Structural features</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bones</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cartilage</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Joints</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Skeletal muscles</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

8 Find out more about the structure and function of skeletal, smooth and cardiac muscle tissue.

9 What is dietary rickets and how is it caused?
10 Look carefully at each of the skeletons above. Three of them are incomplete. Identify the incomplete skeletons and name the missing parts.

11 Apart from warming up just before a game, how do the best basketball and netball players reduce the likelihood of torn muscles and tendons?

12 What would happen if the cartilage in your knee joint wore out?

13 Research and report on one of the following science careers: orthopaedic surgeon, physiologist, physiotherapist, occupational therapist, rheumatologist, fitness trainer.

INVESTIGATE AND DISCUSS

14 (a) In teams of four, use a ‘lucky dip’ system to match each member of the team with one of the following topics.
   - Deviated septum
   - Broken nose
   - Nose cancer
   - Rhinoplasty
   (b) Each member should investigate their topic and report their findings to their team.
   (c) As a team, construct a cluster map or mind map to summarise the key points of your team findings.
   (d) As a team, select one of the four topics for further research. Brainstorm questions for your selected topic and research these questions.
   (e) Report your team’s findings to the class.

CREATE

15 Make a skeleton mobile to hang from the ceiling.
   (a) Trace the skeleton diagram on page 140 (or a larger one from another resource), colour it and cut it into a number of sections.
   (b) Paste each section onto cardboard and thread the sections together to make a skeleton mobile.

16 Use a cut-out human skeleton to make a new, imaginary animal by rearranging the bones. Suggest a name and describe the lifestyle of your animal.

17 Make a working model of an arm to show how the biceps and triceps work. Use the illustration on page 66 as a guide. Materials you might use include icy-pole sticks or stiff cardboard (for bones), split pins (for ligaments), string or rubber bands (for muscles), polystyrene foam (for cartilage) and glue. Draw a labelled diagram of your model.

Identify the incomplete skeletons and name the missing parts.
Same job, different path

Similar, but different? While organisms can have different solutions to life’s challenges, these differences share similar patterns, order and organisation.

Patterns, order and organisation

Organisms possess a variety of structures that help them to obtain the resources that they need to survive. While there are similarities and patterns in some of these structures, there are also differences. These differences provide examples of wonderful, creative solutions to the continual challenge of staying alive.

Shaping clues

The structures of cells and tissues often provide clues to their function. For example, structures that are involved in absorption often have shapes that increase their surface area to volume ratio. Intestinal villi in humans and plant root hairs are examples of this. Can you see the similarities in the figures below? Can you think of other cells or tissues that also share this pattern?

Respiratory routes

\[ \text{glucose} + \text{oxygen} \rightarrow \text{carbon dioxide} + \text{water} + \text{energy} \]

Cellular respiration is essential for life. Organisms require a supply of oxygen and a way to remove the carbon dioxide that is produced as waste. Although this gaseous exchange is essential, different types of organisms achieve it in different ways.

Unicellular organisms are small enough that gases such as oxygen and carbon dioxide can simply diffuse in and out of their cell. Likewise, some very thin multicellular organisms have many of their cells in direct contact with their environment. These organisms rely simply on diffusion for their exchange of gases. Flat worms, for example, do not need a respiratory system, as they use their whole body surface to obtain the oxygen they require from the water in which they live. Some other small animals, such as worms living on land, can exchange gases through their mucus-covered skin. Oxygen from the air dissolves in the mucus, while carbon dioxide seeps out. Tiny blood vessels in their skin transport the gases to and from the rest of the worm’s body.
Other animals may have specialised gas exchange organs. Three main kinds of these organs are lungs in mammals and amphibians, gills in fish, and tracheae in insects. Examine the figure below to compare the structure of these organs. How are they similar? How are they different?

What do they eat?

Animals can be classified on the basis of their diet. Herbivores eat plants; carnivores eat other animals; omnivores eat both plants and animals. An animal’s teeth can provide hints to the types of food that it eats. Observe the teeth in the skulls of the vertebrates shown below. Based on your observations, predict the types of food that they may eat.

Wombats are herbivores. They have large incisors for biting and cutting, but no canines. They also have large premolars and molars because the fibrous plant materials they eat need a lot of grinding. Tasmanian devils are carnivores. Because their prey is alive and moving, they possess large canines for stabbing and holding on to it. Their incisors are used for tearing meat. The molars and premolars in carnivores have cutting edges. Insectivores are carnivores that eat only insects. Their teeth are small and pointed so that they can crush the exoskeleton of the insect, which they then swallow whole. Even if you are a vegetarian, as a species, humans are considered to be omnivores. We possess all of the different types of teeth needed to break down both meat (from animal tissue) and plants.
Digestive differences

Although most vertebrates possess a digestive system that has a similar pattern, order and organisation, there may be differences that are related to nutritional needs and diet. Consider, for example, differences in the digestive systems of herbivores with diets that are high in plant material with lots of cellulose compared with those of carnivores with lots of animal flesh, high in protein. How would these compare with the digestive system of an organism that ate only nectar and pollen?

Heart count?

Two, three or four? Not all animals have a four-chambered heart like you. Fish have a heart with two chambers and blood passes through the heart only once each time around the body. The hearts of amphibians and most reptiles are three chambered and allow oxygenated and deoxygenated blood to mix. Birds and mammals are similar to amphibians and most reptiles in that blood flows through the heart twice in each circulatory trip, but they possess a heart with four chambers that does not allow the mixing of blood. What do they share? How are they different?

Notice any similarities or differences in these digestive systems?
Throwing out the trash!

Have you seen a penguin ‘cry’ or a turtle with a ‘runny nose’? While humans use their kidneys to remove excess salt from their blood, other animals can have different strategies. Turtles, for example, have salt secreting glands behind their eyes. Hence you may see a turtle ‘shedding tears’. Penguins and some of their seabirds, such as the southern Giant Petrel, may appear to have runny noses because that is where their salt-secreting glands are located.

Different types of fish, living in different environments, can also differ in how they maintain their salt balance. Saltwater fish, such as snapper, drink sea water constantly and produce a small volume of urine. Freshwater fish, such as Murray cod, however, rarely drink, but make lots of urine.

Proteins are involved in a variety of different chemical reactions that keep animals alive. Ammonia is formed when proteins break down. Ammonia is toxic to cells and requires either lots of water to release it into, or conversion into a less toxic form (such as urea or uric acid). Conversion into other forms costs the animal energy. Whichever form these nitrogenous wastes are in, they need to be removed from the animal’s body.

Different types of animals use different strategies to remove nitrogenous wastes. This is linked to the amount of water available in the environments in which they live. Fish, for example, have a ready supply of water, so most fish release their nitrogenous waste as ammonia. The main nitrogenous waste excreted by humans is urea. Uric acid requires the least water for excretion. Insects, spiders and birds excrete their wastes as uric acid.
Have you noticed the pattern? The environment in which an organism lives, in this case, the amount of water available, can play a role in how different species have evolved different strategies to the same problem of removal of their wastes.

**Inside or out?**

Are you wearing your skeleton on the inside or outside? Vertebrates (such as humans) have an internal backbone. They also have an internal skeleton called an **endoskeleton**. You can read more about our endoskeleton on the previous pages. Invertebrates, however, do not possess a backbone. Some invertebrates, such as grasshoppers and ants, have their skeleton on the outside of their bodies.

Their external skeleton is called an **exoskeleton**. Other invertebrates, such as worms and jellyfish, do not have any skeleton at all.

Due to their different body structures, invertebrates can use their muscles in different ways to achieve movement. Worms and slugs, for example, can stretch and shorten muscles in certain parts of their body to bring about movement. Even though the muscles of jellyfish have no bones or other hard parts to attach to, they propel themselves through water by pumping water into their body cavities and releasing it suddenly. The muscles in insects, such as grasshoppers, are attached to their exoskeleton. They can extend their legs by contracting the extensor muscles and relaxing their flexor muscles.

The muscles in insects are attached to the exoskeleton, the outer covering of the body. This grasshopper can extend its leg by contracting the extensor muscle and relaxing the flexor muscle.
INVESTIGATION 4.13
Inside or out?

AIM
To use models to investigate the differences between how muscles join to bones in animals with endoskeletons and exoskeletons

Materials:
2 cardboard tubes, each at least 30 cm long
sticky tape
rubber bands
large nail or other pointed object

METHOD
» Cut each cardboard tube into two pieces about 15 cm long.
» Using the nail, make two holes on opposite sides of each tube. These should be about 5 cm from the end of each piece.
» Label two pieces ‘Endo A’ and ‘Endo B’ and the other two pieces ‘Exo A’ and ‘Exo B’.
» Tape Endo A and Endo B together on one side, so that they form a hinge at the ends with the small holes.

RESULTS
1 When one rubber band contracts, what happens to the one on the opposite side?
2 Draw sketches of each and record your observations when the joint is moved.

DISCUSS AND EXPLAIN
3 Describe how the two skeletons are different.
4 Identify the strengths and limitations of the method and how you could improve it.
5 Research and construct models that demonstrate how two different types of organisms have developed different strategies to solve the same ‘problem’ that is related to their survival.

Congratulations!
The survival of a species depends on its members surviving the challenges related to both their internal and external environments. Over many generations, the selection of ‘what works’ and ‘what doesn’t work’ has led to the diversity of organisms on our planet. Every organism is a celebration of the creative variety of solutions to challenges of survival.

UNDERSTANDING AND INQUIRING

REMEMBER

1 Place the following terms in order of simplest to most complex: cell, organ, system, multicellular organism, tissue.
2 Provide an example of how structure can give clues about function.
3 Write the word equation for cellular respiration.
4 Describe two key functions of gaseous exchange.
5 Suggest why there are differences between herbivores and carnivores in the structures of their digestive systems.
6 Construct a table to summarise similarities and differences between the hearts and circulation of fish, amphibians and mammals.
7 Name two organs belonging to each of the following systems.
   (a) Respiratory system
   (b) Circulatory system
   (c) Excretory system

(continued)
8 Construct a matrix table to compare the diets and teeth of herbivores, carnivores, omnivores and insectivores.

THINK

9 Why don’t herbivores have canine teeth?
10 How do we know what different types of dinosaurs ate, even though they haven’t existed for about 65 million years?

INVESTIGATE AND DISCUSS

11 (a) In terms of three, use a ‘lucky dip’ system to match each member of the team with one of these organisms: earthworm, grasshopper, fish.
   (b) Each member should investigate the respiratory system of their matched organism and report their findings to their team.
   (c) As a team, construct a cluster map that summarises the key details and features of the respiratory systems of each of these organisms.
   (d) As a team, construct a matrix table that summarises the similarities and differences between the respiratory systems of humans, earthworms, grasshoppers and fish.

12 Select an animals of your choice.
   (a) Find out how it:
      (i) detects stimuli
      (ii) supports itself and moves
      (iii) takes in oxygen and removes carbon dioxide
      (iv) conducts messages from one part of its body to another.
   (b) Construct a model or animation to demonstrate one of the functions above.

13 There are differences in the form in which groups of animals excrete nitrogenous wastes. Find out the differences between humans, freshwater fish, saltwater fish and insects. Communicate your findings using models or in a puppet play, documentary or animation.

INVESTIGATE, DESIGN AND CREATE

14 Research and prepare a poster on the hearts of different types of animals.

15 (a) Outline the key differences between the structures of the digestive systems of a cow, a koala, a Tasmanian devil and a honey possum.
   (b) Suggest reasons for the differences.

16 Complete the following table.

<table>
<thead>
<tr>
<th>Feature</th>
<th>Mammal</th>
<th>Fish</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of chambers in the heart</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Times blood travels through heart in each circulatory trip</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Name of gaseous exchange respiratory organ</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

17 Find out about the different tissues and systems that exist in plants. Present your information, using diagrams and lots of colour, on a poster or PowerPoint presentation. Be a creative as you can.

18 (a) Select one of the systems in the mind map on page 12 and find out more about what it does and how it works.
   (b) Use your findings to write a brief play that other students in the class can act out.

19 In a small team, formulate scientific questions about how the structure of the heart, kidney or lungs is related to the function of that organ. Research these questions and present your findings to the class.

20 Select an organ (for example, heart, lungs or stomach) and find out the answers to the following questions.
   (a) What is the function of the organ?
   (b) Which system does it belong to?
   (c) What other organs are in the same system?

21 Design and construct a model of one of the following systems: respiratory, excretory, reproductive, digestive.

22 Some animals that live in water, such as sea anemones, have a digestive sac which acts both as a mouth and an anus.
   (a) Find out more about the digestive system of sea anemones and construct a model to demonstrate your understanding of how it works.
   (b) Describe how this digestive system is similar to that of humans and how it is different.
   (c) Suggest reasons for the differences.
### MULTICELLULAR ORGANISMS
- state the relationship between cells, tissues, organs, systems and multicellular organisms
- describe the key functions of the following body tissues: connective, epithelial, skeletal, blood, muscle, nerve
- identify the organs and overall function of a system of a multicellular organism
- describe the structure of each organ in a system and relate its function to the overall function of the system
- compare similar systems in different organisms

### MUSCULOSKELETAL SYSTEM
- describe the structure of a human bone
- describe the relationship between bones, joints, ligaments and muscles

### CIRCULATORY SYSTEM
- identify the components that make up blood
- compare red blood cells and white blood cells
- state the relationship between blood, heart, arteries, veins and capillaries

### DIGESTIVE SYSTEM
- sequence the structures of the digestive system and state the function of each
- describe how the structure of the teeth, oesophagus and villi in the small intestine assist their function
- describe how the tongue, gall bladder, pancreas and liver are involved in the digestive process
- outline the importance of peristalsis
- distinguish between the processes of ingestion, mechanical digestion, chemical digestion, absorption of nutrients, assimilation and egestion

### EXCRETORY SYSTEM
- explain how wastes are removed from the human body

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### DIGITAL RESOURCES

#### ANSWERS
For this chapter can be found online in your eBookPLUS.

#### Online section
This section of the chapter can be found online in your eBookPLUS.

#### Individual pathways

<table>
<thead>
<tr>
<th>Activity 4.1 Systems</th>
<th>Activity 4.2 Investigating systems</th>
<th>Activity 4.3 Analysing systems</th>
</tr>
</thead>
<tbody>
<tr>
<td>doc-6081</td>
<td>doc-6082</td>
<td>doc-6083</td>
</tr>
</tbody>
</table>

#### FOCUS activity
Access more details about focus activities for this chapter in your eBookPLUS.

#### eLesson
From dinner plate to sewerage system
This video lesson explains the amazing journey of food through the human body, from dinner plate to sewerage system. Learn how our bodies release chemicals to break down food and absorb energy-giving nutrients, all without us even being aware of the process. A worksheet is attached to further your understanding.

Searchlight ID: eles-0056

Heart valve
This video lesson shows a revolutionary way of replacing heart valves.

Searchlight ID: eles-0858

#### INTERACTIVITY

- **Digestive jigsaw**
  This interactivity looks at the jigsaw puzzle that is the digestive system. Test your knowledge by re-creating the human digestive system. Instant feedback is provided.
  Searchlight ID: int-0216

- **Beat it!**
  The heart is one of the most important organs in the human body. This interactivity tests your ability to label the parts of the heart. Instant feedback is provided.
  Searchlight ID: int-0210
In this chapter you have seen the importance of your transport system.

(a) With your team, create mind or concept maps that summarise what you know about the following.

- Blood
- Blood vessels
- Heart
- Lungs
- Kidneys
- Liver

(b) For each of the six parts of your body listed above, brainstorm in your team as many questions as you can. Then select one question for each body part to do your own research. Report your findings back to the group.

(c) Summarise your group findings in a creative way — this could be as a cartoon, song, poem, play, model or simulation.

2

(a) In a pair, select one of the statements from the cartoon below and continue the conversation, taking turns asking relevant questions and answering them.

(b) Find a new partner and repeat activity (a) with the same statement or another one.

(c) In a team, create at least five other statements that could have been made on:
   (i) animal transport systems
   (ii) transport technology
   (iii) transport system disorders or diseases.

3

In a team, brainstorm ideas to come up with the following for transport systems.

(a) Words for an alphabet key

(b) Five ‘what if’ keys

4

(a) Drinking of any alcohol in Australia should be illegal.

(b) Smoking in public should be punishable by a 10-year prison sentence.

(c) Donating blood at least four times a year should be compulsory for all over the age of 16.

(d) Only people under the age of 40 should be allowed to have a heart transplant.

(e) Smokers should not be allowed to have surgery.

(f) Blood transfusions should be illegal.

(g) Everyone should have the right to a blood transfusion.

(h) Organ donation should be compulsory.

(i) Overweight people should not be allowed to have surgery on their circulatory system.

5

Using the cartoon on the right as a beginning, write a story that tells of the life of a red blood cell.

6

Make a copy of the diagram below for your workbook.

(a) Label the lettered parts (A to J) of the human circulatory system and blood vessels on your diagram.
(b) Use a red pencil to colour in the blood vessels with oxygenated blood, and a blue pencil for those with deoxygenated blood.

(c) State whether the blood in the following blood vessels is deoxygenated or oxygenated.
   (i) Aorta
   (ii) Pulmonary artery
   (iii) Pulmonary vein
   (iv) Vena cava
   (v) Carotid arteries

(d) Draw up a table that shows the differences in structure and function of the arteries, veins and capillaries.

7 Outline the purpose of digestion.

8 Construct a Venn diagram to show similarities and differences between mechanical and chemical digestion.

9 Label this diagram of the human digestive tract.

10 (a) Using the links and ideas in the two visual thinking maps on this page (as well as your own), construct a board for the game 'Nutridigest', which you will create.

(b) In a team of four, brainstorm as many questions as you can that could be placed on each of the squares. Creatively write these onto your Nutridigest cards.

(c) As a team, discuss the rules for your Nutridigest game. Write down those you agree on.

(d) Make a brochure that explains how to play your game.

(e) Trial playing the game with your team.
(f) Make any alterations to your game that you think would improve it.
(g) Play the game that has been created by another team.
(h) In a team of eight, discuss the good things (strengths) and not-so-good things (limitations) of each game. Also, suggest ways that they could be improved in the next ‘edition’.

11 (a) Have a lucky dip with names of parts of the digestive system and three different nutrients inside.
(b) As a class, make your selections from the lucky dip.
(c) Think about the function of your selection. Also, think about what sorts of actions or sounds it might have.
(d) As a class, act out your roles in digestion.

12 (a) Construct a mind or concept map to summarise what you have learned during your study of ‘living connections’.
(b) Share your map with others in your team.
(c) Create another mind or concept map that incorporates the learning of all of your team members.

13 As a team, create a song, poem, cartoon or play about something that you have learned.

14 (a) Discuss in your team what you have learned or found interesting in this chapter.
(b) On sticky notes, write down other questions that you or your team may have about areas related to those in this chapter. Place the questions on a class question gallery board with those of other class members.
(c) Once all of the questions are on the board, organise them into groups or themes.
(d) In pairs, select one of the questions in the gallery.
(e) Research the question and report your findings to the class.

15 The process of replacing oxygen with carbon dioxide is called gas exchange. Some animals exchange gases through lungs or gills. Some other animals exchange gases through their skin, and yet others through rows of air holes along both sides of their bodies.
Investigate how animals and insects exchange gases to create a mind map and answer the following questions.
(a) Construct a mind map, poster or PowerPoint presentation that summarises your findings on how at least five different animals achieve their exchange of gases.

(b) Why do frogs need lungs when they can exchange gases through their skin?
(c) Why can’t fish survive in the air?
(d) Why can’t humans breathe under water without air tanks?
(e) How is gas exchange in insects similar to that in humans?
(f) What are two major differences between gas exchange in insects and humans?

16 (a) In teams, construct mind maps about each of the circulatory, respiratory and excretory systems.
(b) Use the information in these mind maps to construct matrix grids to summarise the key information for each system.

17 (a) Name the organs in each of the following systems.
(i) Circulatory system
(ii) Respiratory system
(iii) Excretory system
(b) Create a word-find with these terms and then swap it with another team member to see how many words each of you can find.

18 Carefully observe the diagrams of the digestive systems of the animals below. Construct a matrix table that shows the similarities and differences between birds, earthworms, insects and humans.
Use spread 4.12 flowcharts and cycle maps from your eBookplus to help you answer questions 19–23.

19  (a) Read through the information in section 4.5 to refresh your memory on the structure and function of your heart.
(b) Use a flowchart to show the movement of blood through your body using the following labels: left atrium, right atrium, right ventricle, left ventricle, pulmonary artery, pulmonary vein, lungs, aorta, vena cava, from body, to body.

20  (a) Use the cardiac cycle diagram below to answer the following questions.
(i) In which stage do the atria contract?
(ii) In which stage do both the atria and ventricles relax?
(b) Construct flowcharts to help you summarise the information in the diagram.

21 Systole is the contraction of your heart muscle and diastole is the relaxation of your heart muscle. What do you think the following mean?
(a) Atrial systole
(b) Ventricular systole
(c) Atrial diastole
(d) Ventricular diastole

22  (a) Construct a cycle map to outline the over all movement of blood through the heart.
(b) Use this information to design a working model of a human heart.
(c) Use a flowchart to plan the construction of your heart model.

23  (a) Find out more about Leonardo da Vinci’s models of the human heart.
(b) Use a flowchart to map changes in scientific ideas about the heart throughout history.

One complete cardiac cycle can take about 0.8 seconds in an adult human with a pulse of about 75 beats per minutes.

Fig. 42.6, p. 876 from Biology, 6th ed. by Neil A. Campbell and Jane B. Reece. Copyright © 2002 by Pearson Education Inc. Reprinted with Permission.