3 Living systems

HAVE YOU EVER WONDERED…

- why your stomach makes so many embarrassing noises?
- why your heart beats faster when you run?
- why you have a skeleton?
- how your body gets rid of wastes?

After completing this chapter students should be able to:

- identify the organs and overall function of a system of a multicellular organism in supporting the life processes
- describe the structure of each organ in a system, relating its function to the overall function of the system
- describe the specialised cells and tissues involved in the structure and function of particular organs
- compare similar systems in different organisms
- describe how advances in technology have enabled medical science to replace or repair organs
- discuss ethical issues that arise from organ transplantation.

3.1 Digestion

Food is something you probably think about often during the day. You look forward to eating some foods, and hope that your favourite foods are served up for dinner. Food provides your body with all its building materials and the energy you need for all your activities. However, you cannot use food until after your digestive system has been to work on it.

The need for body systems

Your body is made up of trillions of tiny building blocks called **cells**. These are so small that you cannot see them without the help of a microscope. Your cells are where most of your body's work is carried out. Cells need raw materials to work with. Your body is organised in a way that makes sure that the cells are supplied with the raw materials they need.

In your body there are different levels of organisation. Cells come in many types, such as skin cells and muscle cells. Cells of the same type that carry out the same job in the body are grouped together to form **tissues**, such as muscles and nerves. At the next level of organisation, tissues are grouped to form organs, such as the stomach or brain. An **organ** is a structure that contains at least two different types of tissue that work together to complete a task. Organs are arranged into organ systems that have two or more different organs that work together (Figure 3.1.1).

The systems of your body all have their own jobs to do.

- The respiratory system takes in oxygen.
- The digestive system makes food available in a form the body can use.
- The circulatory system carries the food and oxygen to the cells where it is needed.
- The excretory system gets rid of the wastes.
- The skeletal system supports the body and enables it to move.

Figure 3.1.1 In both the jockey and the horse, cells are organised into tissues, tissues into organs, and organs into systems.

The digestive system

The food you eat tastes good but is not in a form that can be used by your cells. Bread, meat, fruit and vegetables, like those in the bun in Figure 3.1.2, are made of complex chemicals. These have to be broken down, or digested, into simple, soluble chemicals that can be used by your cells. Your body needs the chemicals in food for energy, growth and repair. These chemicals are known as nutrients. **Digestion** is the process of breaking down food into a useable form and making the nutrients available.

Figure 3.1.2 The bun looks good and probably tastes good, but it has to be digested before you can use the nutrients it contains.

science 4 fun

Where's the sugar?

Is there sugar in bread?

Yes

Collect this…

- 3 cm x 3 cm piece of bread or water cracker biscuit (not a sweet biscuit)

Do this…

1. Chew the bread or biscuit so that it is broken up and well moistened with saliva.
2. Keep it in your mouth for about a minute—don't swallow it.

Record this…

Describe any change you observed in the tastes.
Explain why you think this happened.

Digestion takes place in your **digestive system**. Your digestive system consists of:

- a digestive tract, the pathway that the food takes though a series of organs. The first part of the digestive tract is the mouth.
- organs off to the side of the digestive tract that produce chemicals that assist with digestion.

The human digestion system is shown in Figure 3.1.3.

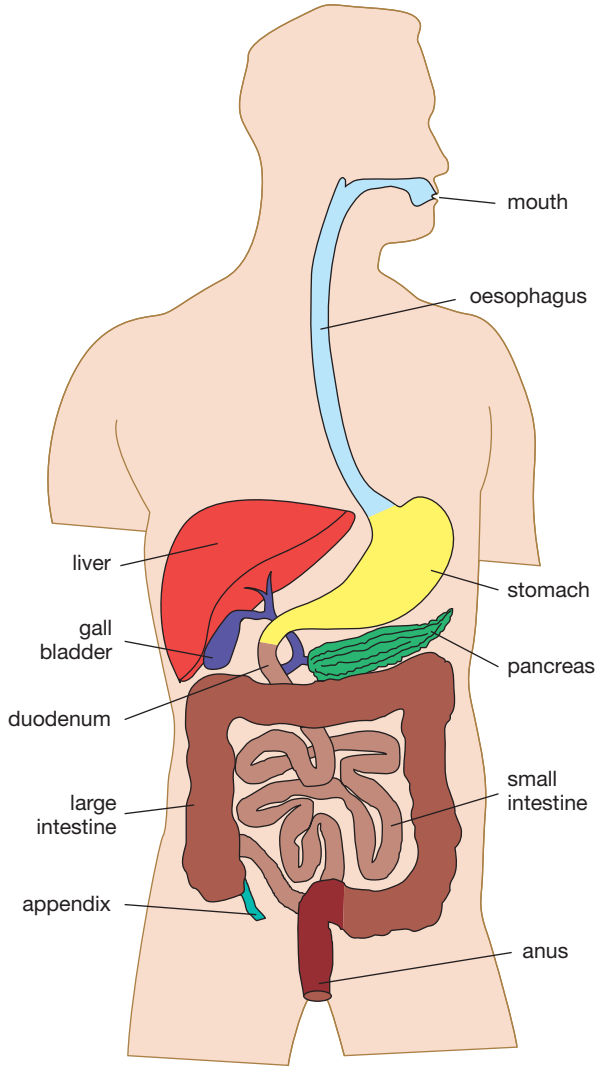

Figure 3.1.3 The human digestive system

3.1

Types of digestion

There are two different types of digestion: mechanical digestion and chemical digestion. Mechanical digestion is when the food is broken down into smaller pieces, as shown in Figure 3.1.4. It is like cutting a slice of bread or piece of meat into smaller pieces. Mechanical digestion is a physical change because no new substances are made.

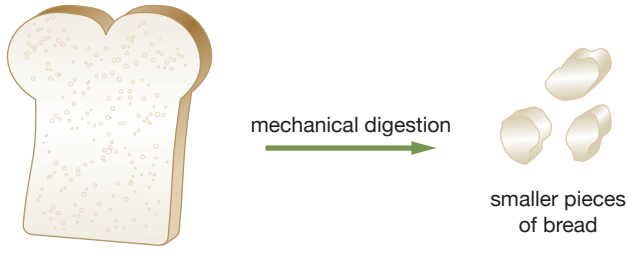

Figure 3.1.4 Mechanical digestion happens when you tear and chew food with your teeth.

In chemical digestion the large, complex substances in the food are broken down into simpler chemicals. You can see this in Figure 3.1.5. This produces new, smaller chemicals that the body can absorb. Chemical digestion is a chemical change because new substances are produced.

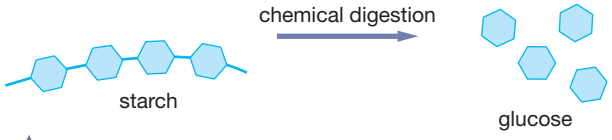

Figure 3.1.5 Chemical digestion happens when saliva in your mouth and gastric juice in your stomach break down your food.

3.2

In the mouth

The process of digestion starts with your teeth. You have four types of teeth: incisors, canines, premolars and molars. These are shown in Figure 3.1.6. The incisors are the four pairs of teeth at the front and their job is to bite off pieces small enough to chew. The tongue then pushes the food back to the premolars and molars. These teeth grind the food into smaller and smaller pieces as you chew.

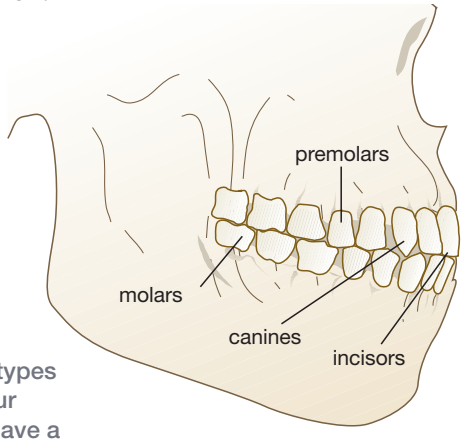

Figure 3.1.6 The different types of teeth in your mouth each have a specific job to do.

In humans, the canine teeth do not have a significant function or job. However, in animals such as lions or wolves that catch live prey, the long canines are used to hold onto the food as it is torn apart.

Biting and chewing food is a form of mechanical digestion but chemical digestion also takes place in the mouth. As the food is being digested mechanically, it is mixed with saliva. Saliva is a watery liquid produced by your salivary glands. Saliva contains a chemical that starts to change any starch (a complex sugar) in the food into glucose (a simple and easily absorbed sugar). Saliva also moistens the food, making it slippery, slimy and easy to swallow. The tongue rolls the food into a ball (called a **bolus**), which is pushed down into the next part of the system, the oesophagus.

Swallowing

SciFile

Tongue tied

The tongue is the only muscle in the human body that is attached at only one end.

Your **oesophagus** is a long muscular tube that has the mouth at one end and the stomach at its other end. The muscles of the oesophagus push the ball of food down the tube by contracting behind the ball. The muscles then relax. This process is called **peristalsis**. It is as though you are trying to push the air into the end of a long thin balloon. Persistalsis can be seen in Figure 3.1.7.

A flap of skin called the **epiglottis** closes the end of the windpipe as you swallow. This makes sure that the food goes into your stomach and not into your lungs via the windpipe. If food does get into the windpipe, you start to choke. You then cough to force the food back up into your mouth so that it can be swallowed correctly.

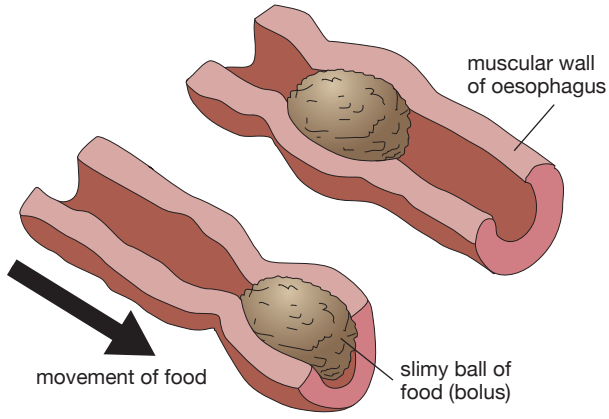

Figure 3.1.7 Peristalsis is the rhythmic contracting and relaxing of the muscles of the oesophagus that keeps food moving through the oesophagus and other parts of the digestive system.

A circle of muscle (called a **sphincter**) separates the oesophagus from the stomach. The sphincter opens and the food passes into the stomach. It then closes to stop food or stomach juices from flowing back up.

Stomach

The stomach is shaped like a bag. It is the big red shape in the middle of Figure 3.1.8. Food is stored in the stomach for 1–6 hours. Once in the stomach, the food really begins to change. The muscular walls of the stomach contract and relax, churning up the food. This further digests the food mechanically as well as mixing it with gastric juice. It is this churning of food as the muscles in the stomach wall contract and relax that creates the gurgling noises in your stomach.

Gastric juice is produced by special cells in the stomach wall. Gastric juice contains:

- hydrochloric acid—a strong acid that kills many of the bacteria that may have entered the body with the food
- mucus—creates a layer on the lining of the stomach and prevents the stomach digesting itself
- digestive juices—contains chemicals that start the digestion of protein, the main nutrient found in meat.

1 p87

Figure 3.1.8 In the stomach, food is digested both mechanically and chemically. The food is turned into a thick, acidic soup.

Small intestine

The **duodenum** is the first part of your small intestine. Two tubes entering the duodenum carry chemicals important for digestion. These tubes come from the pancreas and the liver.

The **pancreas** is not part of the digestive tract. It is an organ that is connected to it that produces pancreatic juice. Pancreatic juice contains chemicals that help digest carbohydrates (starches and sugars), fats and protein.

The **liver** is the body's largest internal organ and performs over 500 different chemical processes. It is a vital organ, meaning that you cannot survive without it. The process in the liver that is important for digestion is the production of bile. **Bile** is a greenish liquid responsible for chemical digestion of fats. It acts in a similar way to dishwashing detergent. In the washing up water, detergents break the fats and oils on dishes into tiny droplets that can easily be washed away. Bile causes large pieces of fat in the food to be broken down into tiny pieces so that they can be digested more easily. Figure 3.1.9 shows the liver and adjacent organs.

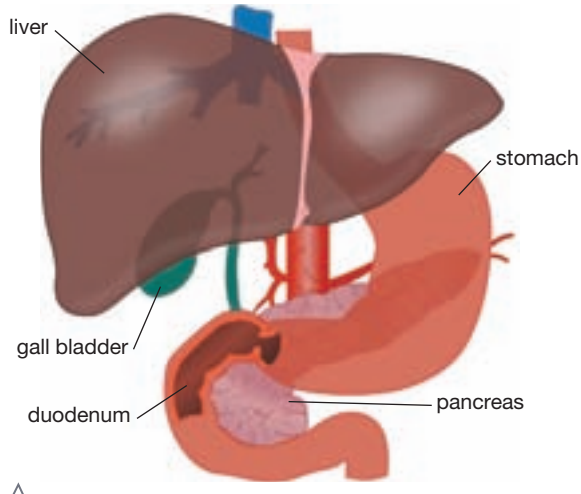

Figure 3.1.9 Blood carrying nutrients from the digestive system travels to the liver before it goes anywhere else. The liver removes toxins such as alcohol from the blood and also acts as a short-term store for glucose. Glucose is a simple sugar produced by the digestion of carbohydrates.

The walls of the duodenum are muscular. They continue to squeeze and churn the food, breaking it down and making sure that the digestive chemicals are mixed through. The digestive chemicals change the remaining foods into forms that can be used by the body. When it passes into the lower part of the small intestine, the food is in the form of very tiny particles that can be absorbed by (taken into) the body.

The part of the **small intestine** after the duodenum is a very long, narrow tube. It is the longest part of your digestive tract—up to 6 metres long. The 'small' intestine gets its name because of its diameter, which is only 3 cm.

It is in this part of the small intestine that the digested food is absorbed into the body. On the inner lining of the small intestine are **villi** (singular: villus). These are microscopic 'fingers' that greatly increase the surface area of the intestine wall and through which the nutrients can pass. Within the villi are tiny blood vessels called capillaries. The walls of the villi and the walls of the capillaries are only one cell thick. This means that the nutrients have to travel a very tiny distance (about one-hundred-thousandth of the diameter of a full stop) as they move from the digestive system into the blood system. Figure 3.1.10 shows the detailed structure of villi.

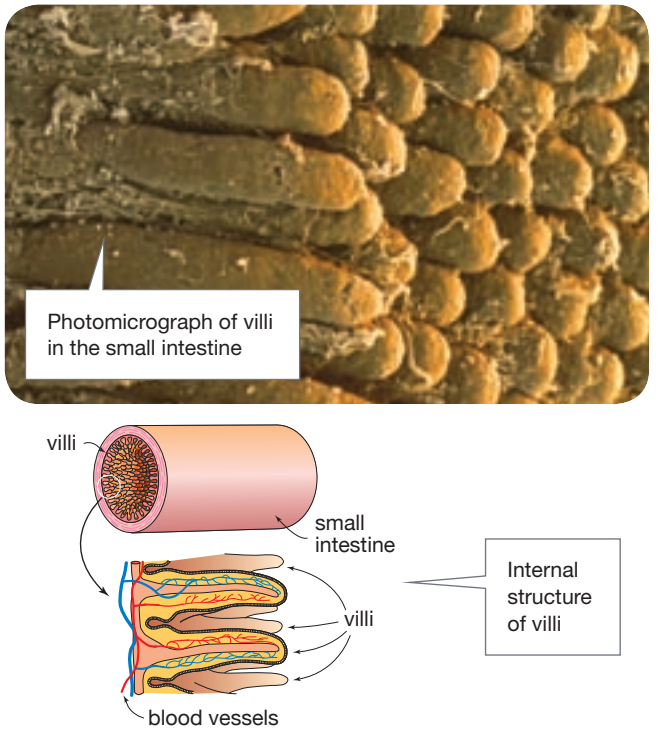

Figure 3.1.10 Villi greatly increase the surface area through which nutrients can be absorbed from the small intestine.

3/3

The nutrients that pass from the small intestine are:

- fatty acids and glycerol produced from digestion of fats
- amino acids from the digestion of proteins
- glucose from the digestion of carbohydrates.

Your body uses glucose as its main source of energy. Figure 3.1.11 summarises the major changes that occur in the digestive system.

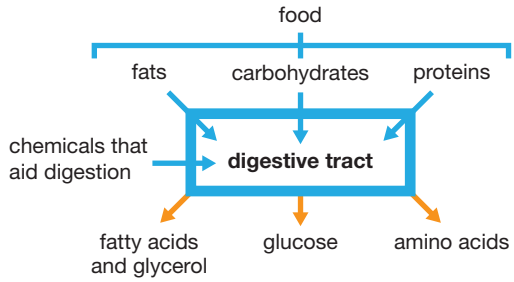

Figure 3.1.11 A lot of different things happen to food in the digestive system.

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Large intestine

The **large intestine** is the final section of your digestive tract. At 1.5 metres, it is shorter than the small intestine, but it is wider, being 6–7 cm in diameter. The large intestine can be seen in red in Figure 3.1.12. In the large intestine, water is reabsorbed into the body from what is left of the food, along with any remaining nutrients. The waste forms lumps of faeces (known as stools). These are later expelled from the body through the **anus**—a sphincter muscle at the end of the digestive tract. As Figure 3.1.13 on page 84 shows, about one-third of the solid material in faeces is bacteria from the intestine. Most of these helped your body digest the food but they are passed out and contribute to the smell of the faeces.

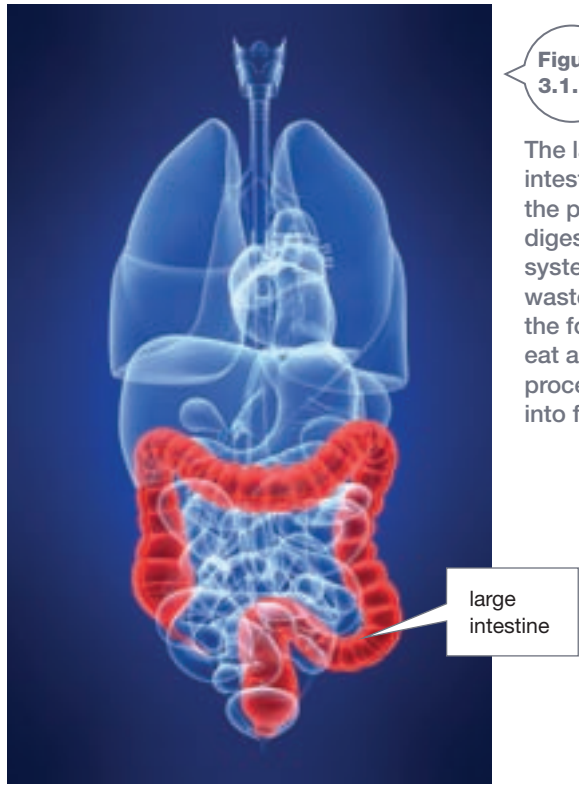


Figure 3.1.12 The large intestine is the part of the digestive system where wastes from the food you eat are processed into faeces.

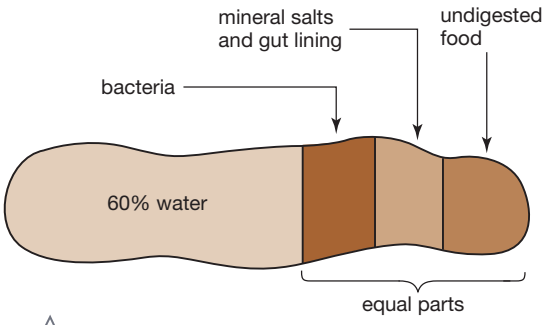


Figure 3.1.13 A large percentage of faeces is water. If the proportion of water decreases too much, then stools become dry, very firm and difficult to expel from the body.

Digestive disorders

Vomiting

Vomiting is a quick way of getting rid of unwanted bacteria in the digestive tract. Stress or infections such as gastroenteritis can cause the muscular wall of the stomach and small intestine to contract. The sphincters at the top and bottom of the stomach open, and the contents of the stomach are forced along the oesophagus and out of the mouth. Vomit is partly digested food mixed with stomach acid and bile.

Diarrhoea

Diarrhoea is another quick way of getting rid of harmful bacteria and viruses. These cause the lining of the small intestine to become inflamed so that it can no longer absorb water from the faeces. Instead of a firm stool passing through the anus, the faeces are loose and watery. The body is at risk of dehydration so people with diarrhoea should drink plenty of fluids to replace what is being lost.

Heartburn

Heartburn is a burning sensation that rises up the oesophagus from your stomach. Peristalsis pushes food down your oesophagus to your stomach. Pressure on the stomach wall can cause the stomach contents to be pushed back up. Lying down or bending over can cause this type of pressure.

Unlike the stomach, your oesophagus does not have mucus protecting the lining from stomach acids. The burning sensation of heartburn is the acid attacking the lining of the oesophagus.

Appendicitis

The appendix is a blind-ended tube connected to the large intestine. If the opening into the appendix is blocked, then the appendix fills with mucus. It becomes inflamed and swollen, causing the pain of appendicitis. The only treatment is an operation to remove the appendix before it bursts and causes even more severe infection.

SciFile

The appendix

It was once thought that the appendix had no function in humans but now it is believed that the appendix may house useful bacteria and be important in the development of the immune system in babies. It is your immune system that helps you fight disease.

Comparing digestion

Humans, dogs and cows eat different food and they also have a different pattern of eating. Working dogs are very active for a large part of the day and may spend only 10–15 minutes each day eating. The food they eat is mostly meat. In contrast, cows spend a very large part of their day chewing and eating grass. Humans eat both plants and meat. We spend about one and a half hours eating each day.

The teeth and digestive systems of these three animals are different to suit their different diets. Most of a cow's teeth are designed to grind up grass and other plant material. It takes more time to digest plant material than meat. A cow's intestines are much longer than those of a dog. The teeth at the front of a dog's mouth are designed to hold meat and tear it into small pieces. Dogs do not chew their food. The teeth at the back of their mouths are designed for cutting rather than chewing. These different types of teeth can be seen in Figure 3.1.14.

Figure 3.1.14 The dog has long canine teeth for holding prey. The teeth at the back have sharp edges that can cut though meat. They are not designed for grinding and chewing.

The human digestive system is shorter than that of a cow and longer than that of a dog. Humans eat both plants and meat. Human teeth are designed for both cutting and chewing.

3.4

3.1 Unit review

Remembering

1 **List** the organs of the digestive tract in order from the start to the finish.

2 a **List** the organs that are part of the digestive system but not part of the digestive tract.
b **State** how each organ contributes to digestion.

3 **Name** three disorders of the digestive system.

Understanding

4 **Describe** the process of peristalsis and how it keeps food moving through the digestive tract.

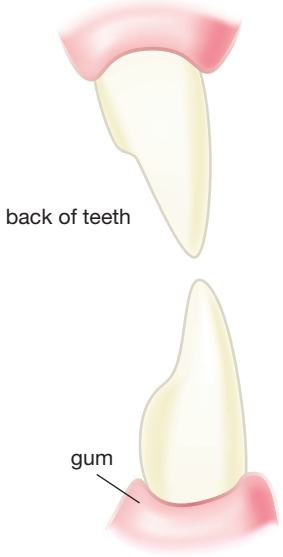
5 **Explain** how the structure of the following organs makes them well suited for the job they do.
a stomach
b small intestine

6 **Explain** what happens to most of the harmful bacteria that enter the digestive system.

7 **Describe** what can happen if too many harmful bacteria enter the system.

8 Figure 3.1.15 illustrates the shape of the incisor teeth.

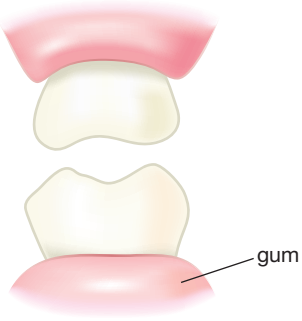
Figure 3.1.15



a **Describe** the shape of the teeth.
b **Explain** why this is an ideal shape to bite off small pieces of food.

9 Figure 3.1.16 illustrates the shape of the molars.

Figure 3.1.16



a **Describe** the shape of the teeth.
b **Explain** why this is an ideal shape for grinding food.

10 **Explain** why it is important that you keep your teeth strong and healthy.

Applying

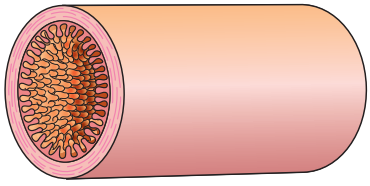
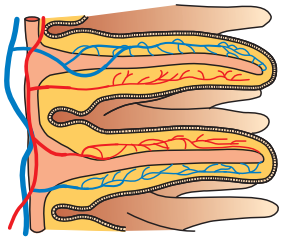


Figure 3.1.17



11 a **Identify** the part of the digestive system shown in Figure 3.1.17.
b Use the diagram to **demonstrate** by how much these structures increase surface area.

3.1 Unit review

Analysing

12 **Compare** mechanical digestion and chemical digestion.

13 **Classify** these descriptions of digestion as mechanical or chemical.

- a The slices of apple were ground to a pulp by his back teeth.
- b Adding the digestive juice caused the mass of oil to break up into tiny droplets.
- c At the end of the experiment we tested the food for the complex compound starch and didn't find any. A test for the simple sugar glucose showed that it was present. There was no glucose at the beginning of the experiment.
- d She nibbled at the biscuit.

Evaluating

14 **Propose** what would happen if the length of the small intestine was halved.

15 Figure 3.1.18 shows the digestive system of a snake.

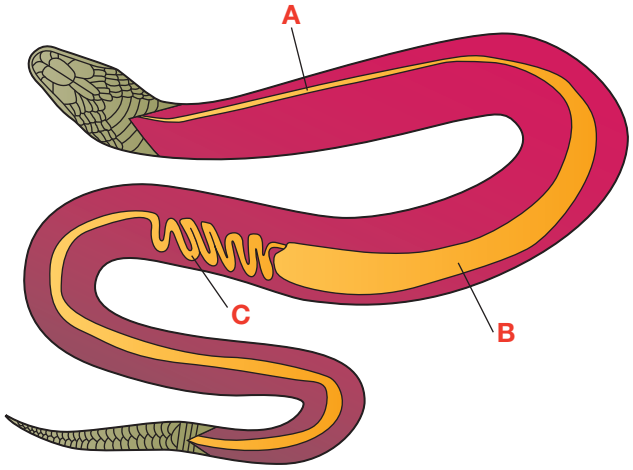


Figure 3.1.18

- a Using the human digestive system as a model, **propose** the names of the parts labelled A, B and C.
- b **Justify** your answer.

Creating

16
- a **Construct** a diagram of the digestive system.
- b Label the parts and **identify** the function of each part.

17 Imagine that you have been miniaturised and placed in a capsule that has been swallowed. You are in the human stomach. **Construct** an annotated diagram or write a short paragraph describing the conditions around you.

18 Digestive enzymes can be purchased for use in experiments. Write a method for a prac that would **demonstrate** that mechanical digestion makes chemical digestion more efficient.

Inquiring

1 Research what effect the eating disorder bulimia has on the digestive system.

2 Before modern technology, scientists had great difficulty finding out what happened inside the body. Alexis St Martin contributed a great deal of knowledge of the human digestive system. Research his work.

3 Investigate the structure of teeth and why problems develop if plaque is allowed to build up on them.

Figure 3.1.19 Plaque can lead to tooth decay. Plaque-disclosing tablets from a pharmacy will show you if you are cleaning the plaque off your teeth.

3.1 Practical activities

1 Breaking down fats and oils

A model is a way of demonstrating how a real system works.

Purpose

To model the effect of bile.

Materials

- 4 × 250 mL beakers
- 10 mL vegetable oil
- 1 cm^3 block of animal fat
- 20 mL detergent
- warm water at about 38°C
- 10 mL measuring cylinder
- 200 mL measuring cylinder
- 4 stirrers
- 4 labels

Method

1. Label the beakers 'Fat', 'Fat and detergent', 'Oil', and 'Oil and detergent'.
2. Cut the block of animal fat in half and add one piece to each of the beakers labelled 'Fat' and 'Fat and detergent'.
3. Using the 10 mL measuring cylinder, add 5 mL of oil to each of the beakers labelled 'Oil' and 'Oil and detergent'.
4. Wash the measuring cylinder carefully or use a clean cylinder to add 10 mL of detergent to each of the beakers labelled 'Fat and detergent' and 'Oil and detergent'.
5. Using the 200 mL measuring cylinder, add 150 mL of warm water to all four beakers.
6. Using a clean stirrer for each beaker, stir the contents gently to mix them together.
7. Stop stirring and after 3 minutes observe any changes in the beakers.

Results

Copy the following table into your workbook. Record all your observations in it.

Beaker contents	Observations after 3 minutes
Oil	
Oil and detergent	
Fat	
Fat and detergent	

Discussion

1. **Explain** why the temperature of the water used was close to 38°C.
2. **Compare** the changes in the two beakers containing vegetable oil.
3. **Compare** the changes in the two beakers containing fat.
4. **Compare** the changes to the fat and oil in the beakers also containing detergent.
5. Based on the observations you made, **propose** what happened to the fat and oil.

2 A model intestine

Tes-Tape tests for the presence of glucose in a solution.

Purpose

To investigate how the small intestine works.

Materials

- 2 × 500 mL beakers
- 2 × 20 cm lengths of dialysis tubing
- 2 × 10 cm lengths of thin string
- starch solution
- glucose solution
- iodine solution
- Tes-Tape
- water

SAFETY

Iodine stains. Avoid contact with skin and clothes.

Procedure

1. Two-thirds fill both of the beakers with water.
2. Add 10 mL of iodine solution to one beaker. Label this beaker 'Starch'.
3. Label the other beaker 'Glucose'. Test the water in this beaker with Tes-Tape to demonstrate that there is no glucose present.
4. Run both pieces of dialysis tubing under the tap to soften them.
5. Tie a knot in one end of each tube and rub the other end to open up the tube.
6. Fill one tube with starch solution and tie the open end firmly with string. Carefully rinse the outside of the dialysis tubing to ensure that there is no starch solution on the outside. Place this tube into the beaker labelled 'Starch'. This is summarised in Figure 3.1.20.
7. Fill the other tube with glucose solution and tie the open end firmly with string. Carefully rinse the outside of the dialysis tubing to ensure that there is no glucose solution on the outside. Place this tube into the beaker labelled 'Glucose'.

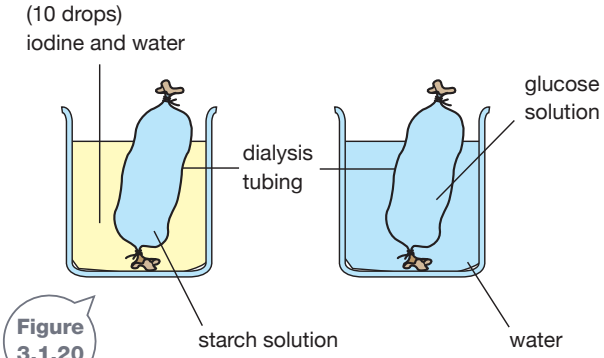


Figure 3.1.20

Results

1. After 15 minutes, observe the beakers and record any changes.
2. Test the water in the 'Glucose' beaker with Tes-Tape. Record the result.

Discussion

1. **Explain** how you know when starch is present in a solution.
2. **Explain** how you know when glucose is present in a solution.
3. **Describe** the changes that took place in the beaker labelled 'Starch'. **Infer** what happened to cause the changes.
4. **Describe** the changes that took place in the beaker labelled 'Glucose'. **Infer** what happened to cause the changes.
5. **Compare** what happened in this experiment with what happens in the small intestine.
6. **Explain** why starch cannot be used by the body until it has been digested.