Unit

2A

Chapter 7
Input and output: the lungs and alimentary canal

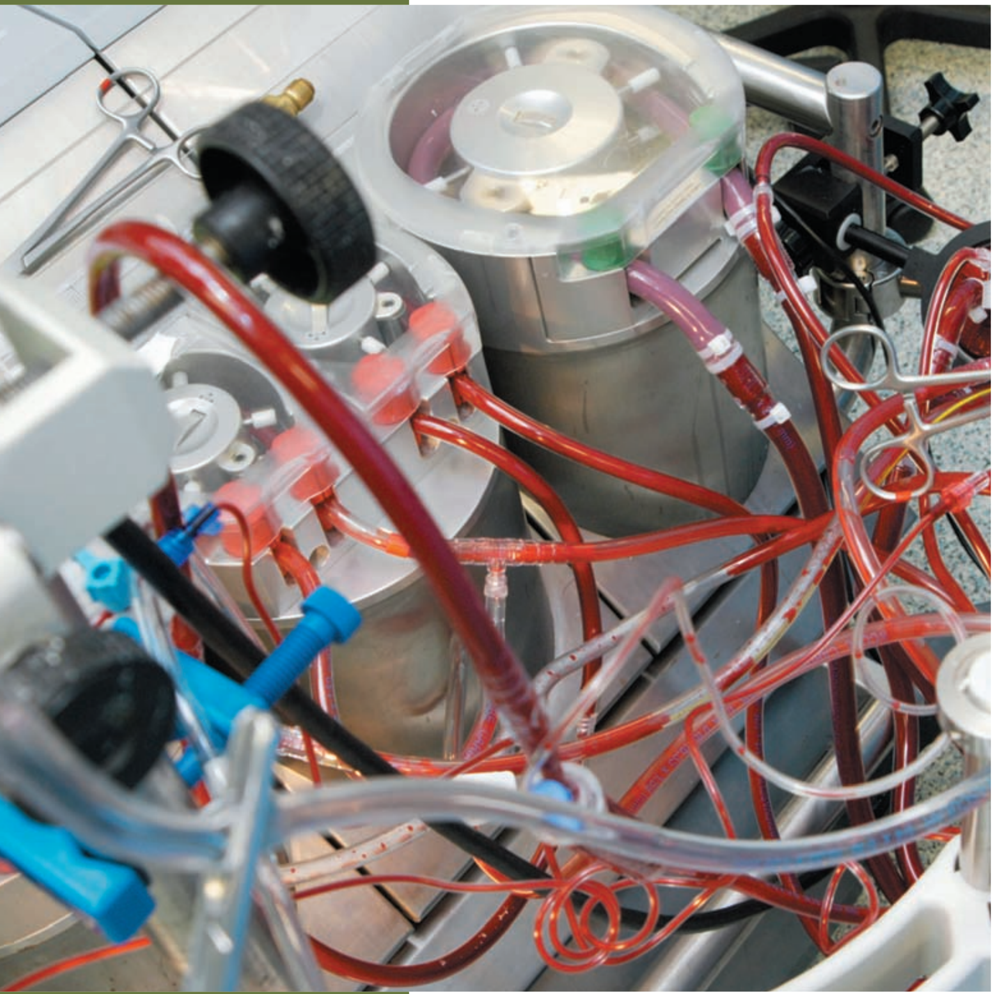


Figure 7.1 Heart–lung machines take over the role of the heart and lungs during an operation. The machine adds oxygen to the blood and removes carbon dioxide

Unit content

Body systems
The respiratory, circulatory, digestive and excretory systems are specialised to control inputs and outputs in supporting metabolism.

Respiratory system
Structure and function related to:
- gas exchange including characteristics of respiratory surfaces
- maintenance of concentration gradients in lungs, including breathing and blood flow.

Digestive system
Structure and function related to:
- mechanical digestion including teeth, bile, process of peristalsis
- chemical digestion of carbohydrates, lipids and proteins including enzymes and the associated glands
- absorption of nutrients
- elimination

The relevance of human biology to everyday life
Lifestyle choices can compromise body functioning in the short term and affect future health.

Lifestyle choices that compromise health:
- active or sedentary lifestyle;
- use of drugs including alcohol and smoking
- diet.

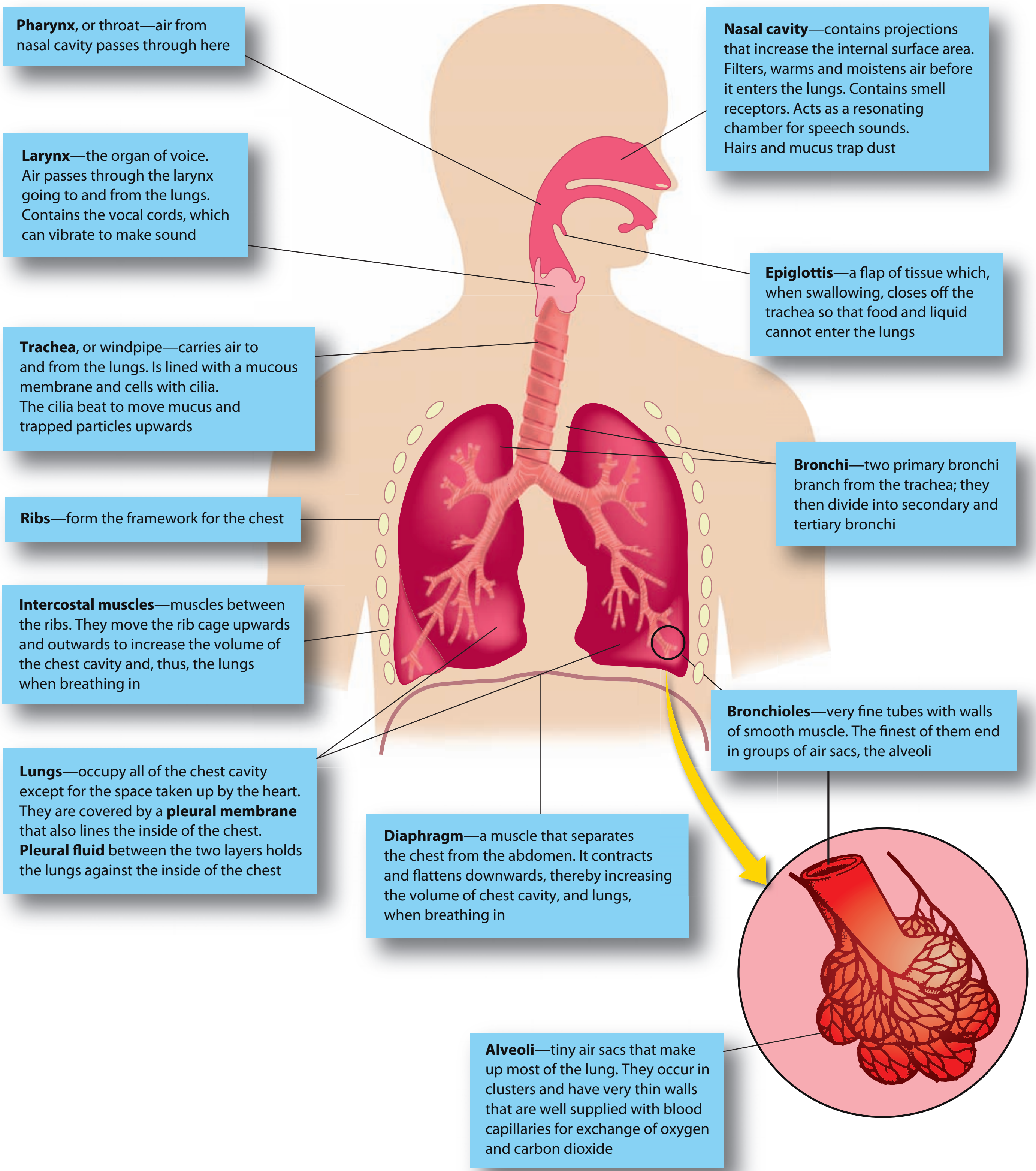


Figure 7.2 The structure and functions of the parts of the respiratory system

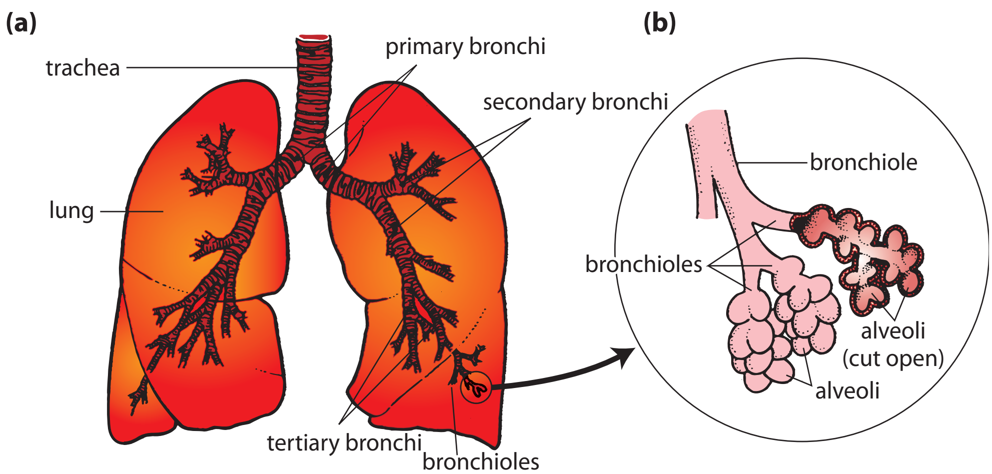
The oxygen and nutrients that body cells require for metabolism come from the external environment. Metabolism produces wastes that must be passed out of the body into the external environment. This chapter and Chapter 8 examine the special surfaces, and the mechanisms for exchange of materials, that enable our bodies to take in essential materials from outside and to pass out unwanted materials.

The **respiratory system** is specialised for the intake of oxygen and passing out of carbon dioxide; the **digestive system** extracts nutrients from the food we eat and absorbs them into the body; the **excretory system** removes waste and passes it to the exterior. As we saw in Chapter 6, the link between these body systems is the **circulatory system**, the body's transport network.

Respiratory surfaces and the exchange of gases

Air enters and leaves the lungs through a system of branching tubes. At the ends of the very smallest tubes, the **bronchioles**, are clusters of tiny air sacs called **alveoli** (Figs 7.2 and 7.3). It is the alveoli that allow the blood to take up oxygen from the air and allow carbon dioxide to pass from the blood into the air. The alveoli are the exchange surface for respiratory gases.

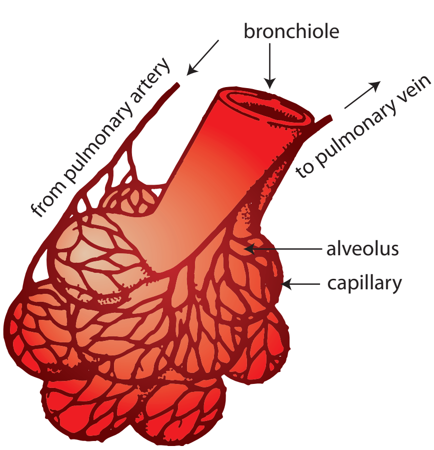
Figure 7.3 The lungs: **(a)** air passages; **(b)** the alveoli



The lungs are well suited to their gas exchange function for the following reasons:

- The alveoli give the lungs a huge internal surface area, so that large amounts of gases can be exchanged in a relatively short time. Estimates of the number of alveoli in the lungs vary considerably but there are hundreds of millions of them; they probably have a total surface area of 50–80 square metres (m^2)—about one-third the area of a tennis court.
- Each alveolus is well supplied with blood vessels, so that as much blood as possible is close to the air in the alveolus (Fig. 7.4). The continuous flow of the blood helps to maintain a difference in concentrations of oxygen and carbon dioxide in the blood and in the air in the lungs.
- The membrane that forms the wall of the alveolus is very thin, so that gas molecules do not have far to travel to move into or out of the blood. The wall has only one layer of cells and is only 1 micrometre (1 μm or 1/1000 of a millimetre) thick (Fig. 7.5).
- The lungs are positioned deep inside the body to prevent excessive evaporation of the fluid that covers the respiratory surfaces. It is important that the membrane of the alveolus be covered by a thin layer of moisture because gases can diffuse into and out of the blood only when they are dissolved in fluid.

Figure 7.4 Blood capillaries surrounding the alveoli



- The lung volume can be changed by movements of the respiratory muscles, so that air is made to flow into and out of the lungs. Constant changing of the air in the alveoli helps to ensure that there is always a difference in the concentrations of oxygen and carbon dioxide in the air and in the blood.

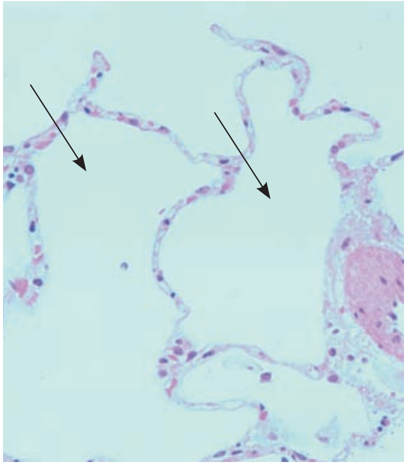


Figure 7.5 Photomicrograph of a section of lung tissue. The areas arrowed are the air spaces inside the alveoli

The mechanics of breathing

For the efficient exchange of gases between the blood and the air in the alveoli, the air in the lungs must continually change. The process by which air is moved into and out of the lungs is called **ventilation**, or breathing. Air flows from places of higher pressure to places of lower pressure, thus air flows into and out of the lungs due to differences in air pressure.

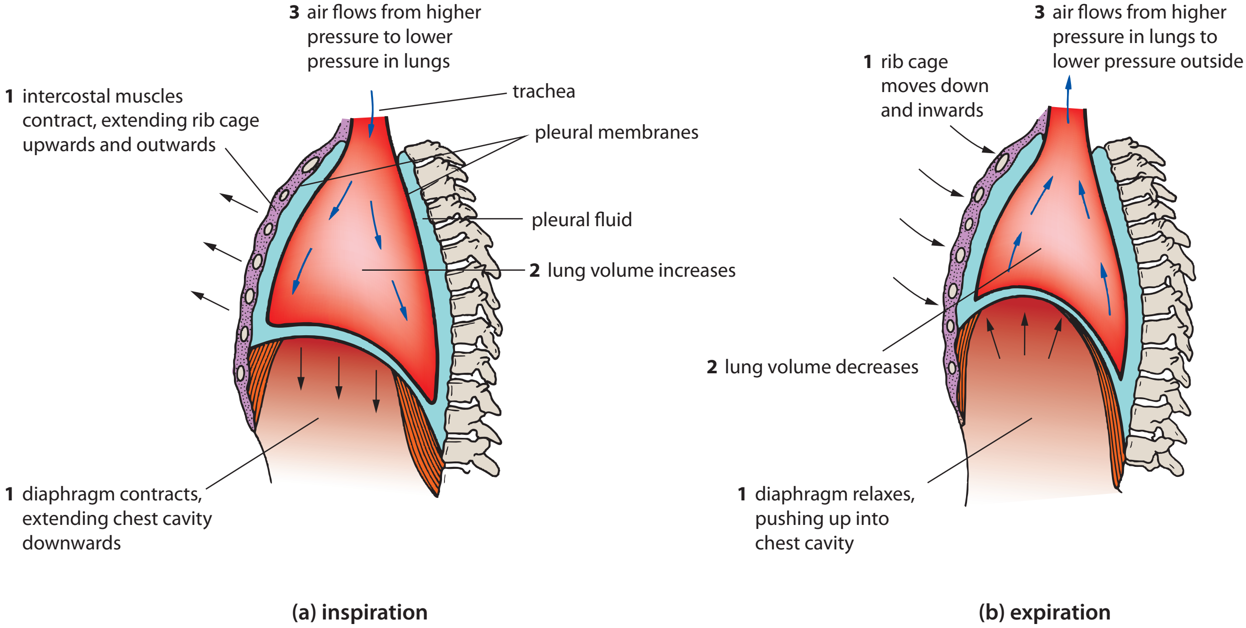
Inspiration

The process of taking air into the lungs is called **inspiration**, or inhalation. For air to flow into the lungs, the pressure of air in the lungs must be less than the atmospheric pressure outside the body. Decreasing the pressure of air in the lungs is achieved by increasing the volume of the lungs. To increase the volume of the lungs, the diaphragm and external intercostal muscles contract. The diaphragm thus becomes flatter and the rib cage moves upwards and outwards, increasing the volume of the chest cavity. As the **pleura** (the membrane around the lungs) adheres to the internal wall of the chest cavity, the lungs expand with the expanding chest cavity. Increased lung volume means that air pressure inside the lungs is slightly lower than pressure outside. Air flows in through the nose and trachea until the pressure becomes equal (Fig. 7.6a). During normal, quiet breathing the diaphragm is mainly responsible for the changes in chest volume. Movements of the rib cage become more important during heavier breathing.

Expiration

Breathing out is called **expiration**, or exhalation. It occurs in the opposite way to inspiration. The diaphragm and external intercostal muscles relax so that the diaphragm bulges more into the chest cavity and the rib cage moves downwards. This reduces the volume of the chest cavity and, hence, that of the lungs. Air pressure in the lungs is now greater than pressure outside the body. Air flows out through the trachea and nose until the pressures are equal (Fig. 7.6b).

Figure 7.6 The sequence of events that occur during **(a)** inspiration and **(b)** expiration



When a person is breathing quietly at rest, expiration is a passive process, involving relaxation of the muscles that have contracted during inspiration. Heavier breathing involves more forceful expiration, and intercostal muscles contract to actively lower the rib cage. The same sort of contraction occurs when forcibly exhaling, as when blowing up a balloon.

Gas exchange

The blood in capillaries surrounding the alveoli is brought to the lungs by the pulmonary arteries. This blood has been through the capillaries of the body, where much of the oxygen has been taken up by the body cells. Thus, the blood that comes into the capillaries around the alveoli has a low concentration of oxygen—lower than the concentration in the air in the alveolus. Oxygen therefore dissolves in the moisture on the inside of the alveolus and diffuses through the membrane, through the walls of the capillaries and into the blood (Fig. 7.7).

You can view an animation of gas exchange at http://www.bmu.unimelb.edu.au/examples/gasxlung

The blood arriving at the capillaries of the alveoli has a higher concentration of carbon dioxide. It has come from the body circulation where it has picked up carbon dioxide produced by respiration in the cells. The concentration of carbon dioxide in the alveolar capillaries is therefore higher than the concentration in the air in the alveolus. Carbon dioxide diffuses out of the blood, into the air in the alveolus. Thus, the expired air contains less oxygen, and more carbon dioxide, than inspired air (Table 7.1).

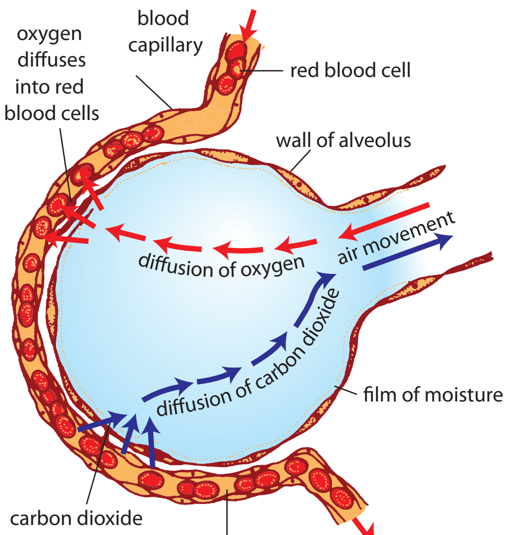


Figure 7.7 Gas exchange between alveolar air and blood

Table 7.1 Oxygen and carbon dioxide concentrations in expired and inspired air

	Inspired air	Expired air
Oxygen	20.95%	15.80%
Carbon dioxide	0.04%	4.30%

Note: The other 79% of the inspired air is made up mainly of nitrogen, with varying amounts of water vapour.

For diffusion of gases into and out of the blood there must be a **concentration gradient**, that is, a difference in gas concentration between the air in the alveoli and the blood in the capillaries. The concentration gradient for oxygen and carbon dioxide is maintained by:

- the constant flow of blood through the capillaries. As the blood flowing through the capillaries around each alveolus picks up oxygen and loses carbon dioxide it is replaced by more blood pumped into the capillaries. This 'new' blood is low in oxygen and high in carbon dioxide so that the concentration gradient is maintained.
- the movement of air in and out of the alveoli as we breathe in and out. The air which has picked up carbon dioxide from, and lost oxygen to, the blood is replaced by 'new' air with each breath. The 'new' air is low in carbon dioxide and high in oxygen.

EXTENSION

The activities of the circulatory system and respiratory system are closely related.

Find out:

- why rate and depth of breathing change when we exercise
- why heart rate also changes
- how the activities of the circulatory and respiratory systems are coordinated.

The alimentary canal and absorption of nutrients

The **alimentary canal** is the continuous tube that runs from the mouth to the anus (Fig. 7.8 and Table 7.2). Together with associated organs like the pancreas and the gall bladder the alimentary canal makes up the **digestive system**. The lining of the alimentary canal is the surface through which nutrients are absorbed.

Body cells require simple sugars, amino acids, fatty acids, vitamins, minerals and water if they are to function normally. Vitamins, minerals and water are in the form of small molecules that are able to pass through the differentially permeable membrane surrounding each cell. Simple sugars, amino acids and fatty acids are eaten as complex carbohydrates, proteins and fats. The molecules of these substances are large and must be broken into smaller units before they can be absorbed into cells. The process in which carbohydrate, protein and fat molecules are broken down to products small enough to be absorbed into the blood and into the cells is called **digestion**.

The organs of the digestive system are structured and arranged so that they can carry out six basic activities:

1. ingestion of food and water
2. mechanical digestion of food
3. chemical digestion of food
4. movement of food along the alimentary canal
5. absorption of digested food and water into the blood and lymph
6. elimination of material that is not absorbed.

Each part of the alimentary canal is specially structured to carry out one or more of these basic activities.

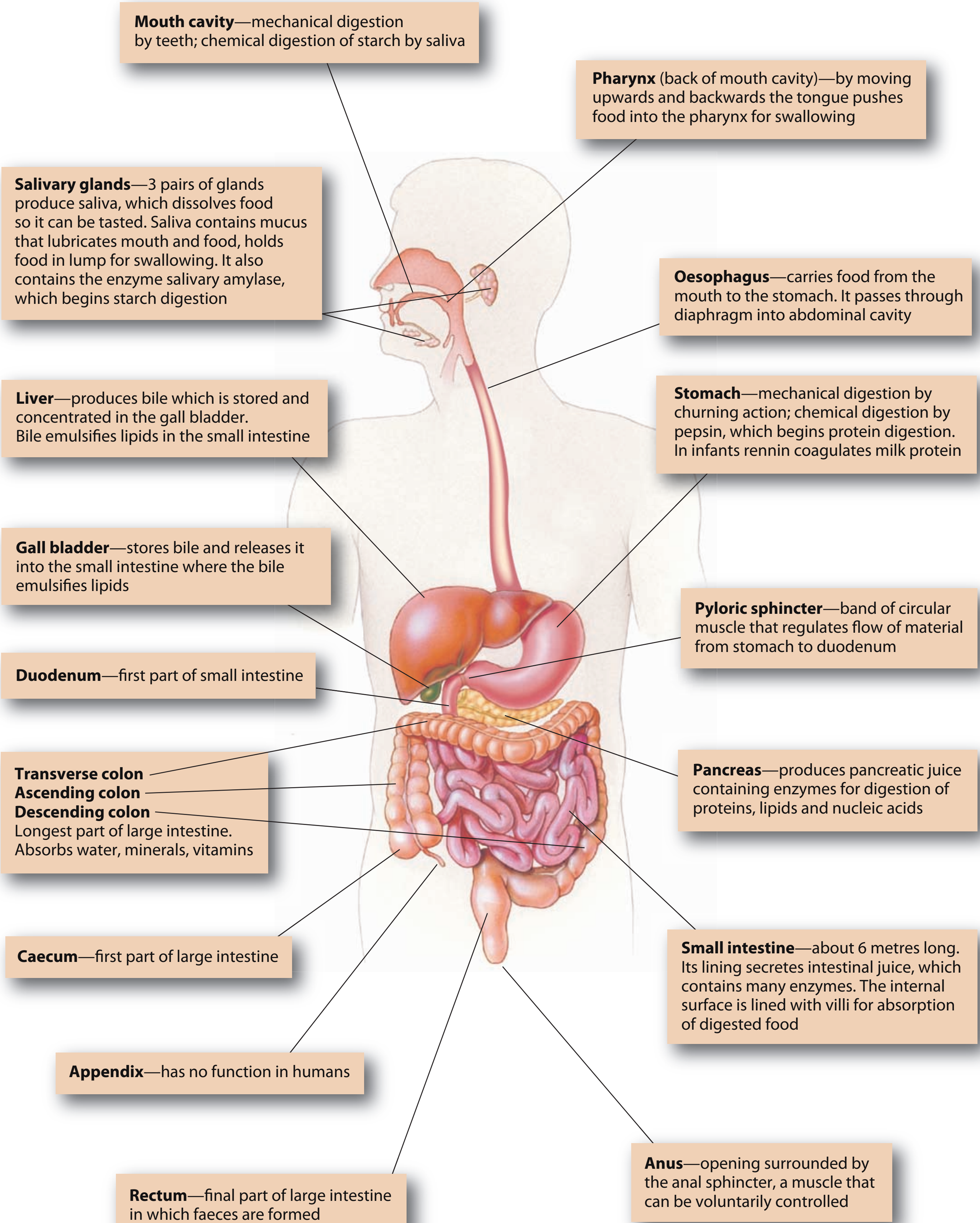


Figure 7.8 The structure and functions of parts of the digestive system

Table 7.2 Functions of parts of the digestive system

Organ	Mechanical digestion	Chemical digestion	Other functions
Mouth	Breaks food into smaller particles by chewing	**Saliva**, which contains *salivary amylase*, begins starch digestion	Food is dissolved in saliva so that it can be tasted
Oesophagus			Carries food from the mouth to the stomach
Stomach	Waves of contraction churn food	**Gastric juice**, which contains *pepsin*, breaks down proteins to polypeptides	Stores large quantities of food as it is eaten; absorbs certain drugs, including some alcohol
Small intestine	Muscular contractions churn food; bile salts emulsify lipids	**Pancreatic juice** contains: *pancreatic amylase*, which breaks starch into disaccharides; *pancreatic protease*, which breaks proteins and polypeptides into peptides; *pancreatic lipases*, which break lipids into fatty acids and glycerol; and *nucleases*, which digest DNA and RNA. **Intestinal juice** contains *amylases* to break down disaccharides to simple sugars; *peptidases* to break down peptides to amino acids; and *lipases* to break down lipids to fatty acids and glycerol	Absorbs simple sugars, amino acids, fatty acids, glycerol, vitamins, mineral nutrients and water
Large intestine			Absorbs water and vitamins; stores faeces; defecation

The mouth

Intake of food, **ingestion**, occurs at the mouth. The action of the jaw and teeth begins **mechanical digestion** where the food is broken up into smaller pieces. As the food is chewed it is mixed with **saliva**, a fluid which is secreted into the mouth cavity by three pairs of **salivary glands**. It contains mucus and a digestive enzyme, salivary amylase, which begins the **chemical digestion** of starch, breaking down the large starch molecules into smaller molecules.

The teeth and mechanical digestion

There are four types of teeth, and each has a different function in mechanical digestion. Figure 7.9 shows the teeth in the lower jaw. A full adult set of teeth consists of:

- four **incisors**. These are chisel-shaped teeth used for biting or cutting, such as when one takes a bite out of an apple;
- two **canines**, one on each side of the incisors. These are conical teeth used for tearing. Human canines are the same length as the other teeth. In carnivorous animals, such as dogs and cats, the canines are much longer than the other teeth and the tearing role is more important than in humans;
- four **premolars**, two on each side of the jaw;

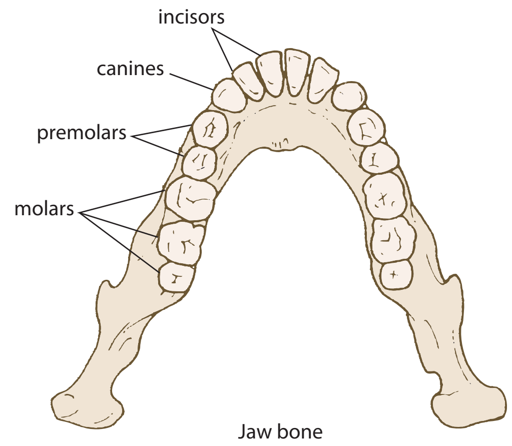


Figure 7.9 Permanent teeth in the lower jaw

- six **molars**, three on each side of the jaw. The premolars and molars have broad crowns with rounded cusps. The cusps of the teeth of one jaw fit into depressions on the surface of teeth on the other jaw, making the premolars and molars ideal for crushing and grinding food.

After chewing, the food is formed by the tongue into a rounded lump. To swallow, the tongue moves upwards and backwards, pushing the food lump into the back of the mouth, the **pharynx**. The pharynx leads into the **oesophagus**, a tube about 23–25 cm long that connects the pharynx to the stomach.

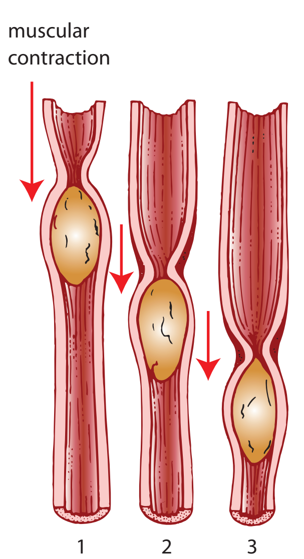


Figure 7.10 Food is moved along the alimentary canal by peristalsis, a wave of muscular contraction that pushes the food along

The oesophagus

The wall of the oesophagus, like the rest of the alimentary canal, has a double layer of muscle, made up of **circular muscle**, with muscle fibres arranged in a circle around the alimentary canal, and **longitudinal muscle**, with fibres arranged along the length of the canal.

As the lump of food enters the pharynx and oesophagus, the circular muscle behind it contracts to form a constriction. By contraction of successive bands of circular muscle the constriction moves in a wave along the oesophagus, pushing the food in front of it. This wave of constriction is called **peristalsis** (Fig. 7.10). Movement of food along the oesophagus is lubricated by the secretion of mucus from the inner lining of the oesophagus.

The stomach

From the oesophagus food enters the stomach. The lining of the stomach, the **mucosa**, is specialised for the secretion of **gastric juice**, a digestive juice that is responsible for digestion in the stomach. Gastric juice is secreted by **gastric glands**, which are located in narrow, tube-like structures called gastric pits. Gastric juice contains hydrochloric acid, mucus and digestive enzymes. Each of these is secreted by a different type of cell in the gastric pits (Fig. 7.11). Chemical digestion is brought about by the digestive enzymes contained in the gastric juice. Most of the chemical activity in the stomach is concerned with the start of protein digestion.

Mechanical digestion in the stomach is achieved by waves of muscular contraction that move along the stomach wall. Unlike the rest of the alimentary canal, the stomach has an oblique muscle layer as well as a circular and longitudinal layer. This enables the stomach to contract in a variety of ways to churn the food and mix it with the gastric juice until the food is converted to a thick, soupy liquid.

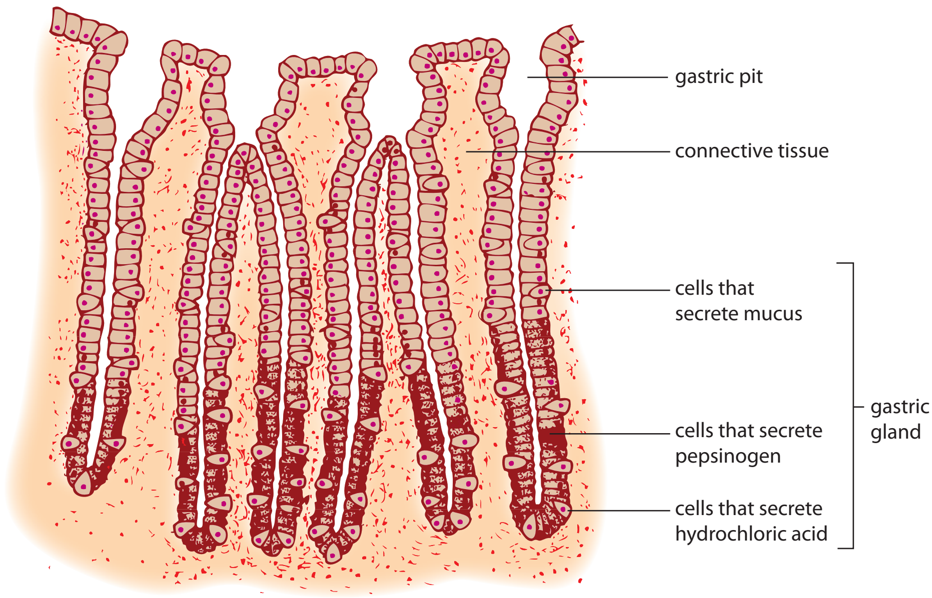


Figure 7.11 The mucosa of the stomach as seen in a transverse section

Nutrients are not absorbed into the blood through the stomach because the internal surface is covered by a thick layer of mucus. Some alcohol and a few other drugs such as aspirin are absorbed in the stomach.

At the lower end of the stomach there is a thickening of the circular muscle, which results in a constriction called the **pyloric sphincter**. The constriction is sufficient to prevent the stomach contents moving through unless pushed along by peristalsis. After 2–8 hours the stomach contents are gradually pushed into the next part of the alimentary canal, the small intestine.

You can see peristalsis in action at http://pennhealth.com/health_info/animationplayer/peristalsis.html

The small intestine

The **small intestine** is approximately 6 metres long, the longest part of the alimentary canal. It receives material pushed through the pyloric sphincter from the stomach. The first part of the small intestine is called the **duodenum**. It is about 25 cm long and extends from the bottom end of the stomach in a curve around the pancreas (see Fig. 7.8).

Digestion continues in the small intestine under the influence of **intestinal juice**, which is secreted by glands in the lining, **pancreatic juice**, which is secreted by the pancreas, and **bile**, which is secreted by the liver but stored in the gall bladder.

Pancreatic juice enters the duodenum and helps to neutralise the acid that has come with the material from the stomach. Many of the enzymes involved in the digestion of food are contained in pancreatic juice. These include:

- **pancreatic amylase**, which breaks down starch
- **trypsin** (or **pancreatic protease**), which splits proteins into much smaller units
- **ribonuclease** and **deoxyribonuclease**, enzymes that digest RNA and DNA
- **pancreatic lipases**, enzymes that break down fats into fatty acids and glycerol.

Bile does not contain any digestive enzymes, but **bile salts** are very important in the digestion of fats. They act like a detergent and emulsify the fat, breaking it into tiny droplets. This is a form of mechanical digestion, increasing the surface area on which the lipases can act to bring about the chemical breakdown of fat.

Intestinal juice contains many enzymes that complete the digestion of carbohydrates, proteins and lipids (see chemical digestion in the small intestine in Table 7.2).

When chemical digestion is complete the complex carbohydrates will have been broken down to simple sugars, the proteins to amino acids and the lipids to fatty acids and glycerol.

The products of digestion, along with substances such as vitamins, minerals and water, are then absorbed through the wall of the small intestine into the blood. Nutrients are absorbed through the internal surface of the small intestine, so efficient absorption requires a large surface area. A large internal surface area is achieved in a number of ways:

- the small intestine is very long—about 6 metres
- the inner lining, known as the **mucosa**, has folds that extend into the interior (Fig. 7.12a)
- the mucosa has small, finger-like projections called **villi** that extend from the folded surface (Fig. 7.12b)
- the cells covering the outside of the villi have tiny microscopic projections from their external surfaces. These are the **microvilli** (Fig. 7.13).

The structure of a villus is ideally suited to its function of nutrient absorption. Each villus is about 1 mm long and is covered by a single layer of cells. Inside the villus is a lymph capillary, called a **lacteal**, which is surrounded by a network of blood capillaries (Fig. 7.14). Absorption is further enhanced by a continual movement of the villi brought about by the muscular movements of the intestinal wall. This constantly brings the villi into contact with different parts of the intestinal contents. These contents are constantly changing as new material is emptied into the small intestine from the stomach.

Some absorption occurs through simple diffusion, as there is a higher concentration of nutrient materials in the interior of the small intestine than in the cells lining the villi. Absorption also occurs through **active transport**, which involves the cells of the villi using energy to take in nutrients against a concentration gradient—that is, taking in molecules from a lower concentration to a higher concentration.

From the walls of the villi simple sugars, amino acids, water and water-soluble vitamins are absorbed into the blood capillaries. Fatty acids and glycerol recombine in the cells of the villi to form fats and, along with the fat-soluble vitamins, enter the lacteals. The

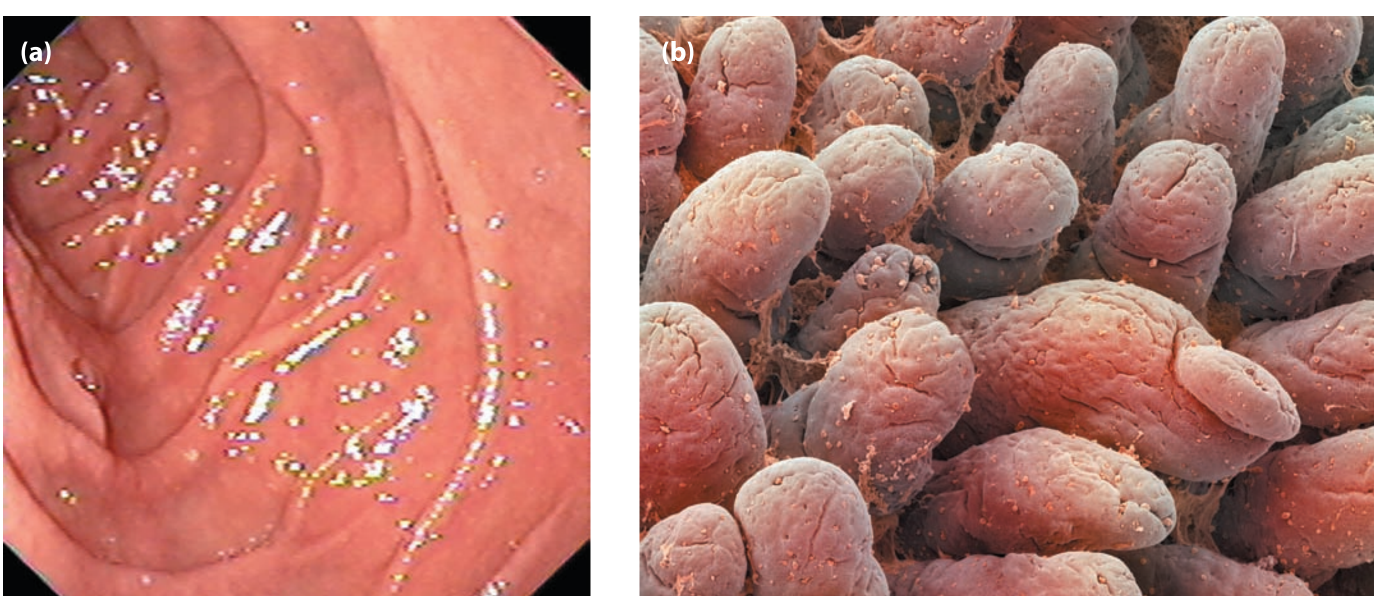


Figure 7.12 (a) Folds of the mucosa on the inside of the small intestine. **(b)** Villi cover the internal surface of the small intestine, as shown in this scanning electron micrograph

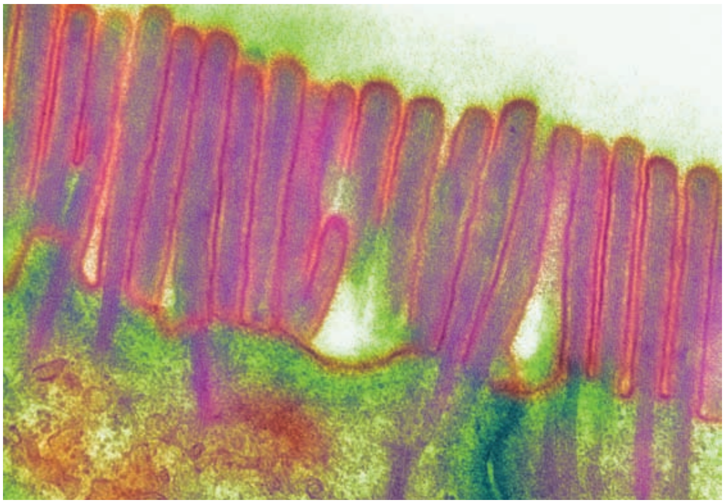


Figure 7.13 Electron micrograph showing microvilli that cover the surface of each villus

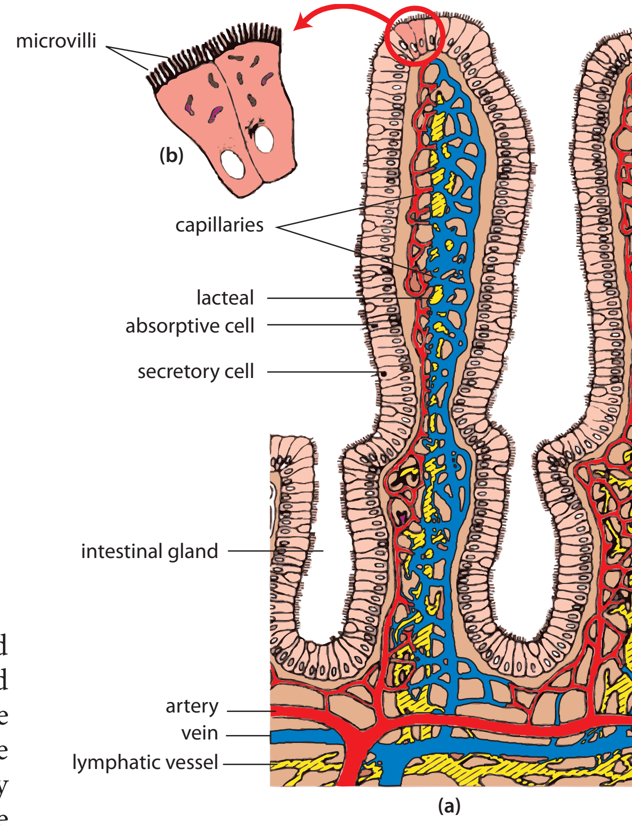


Figure 7.14 Diagram showing: **(a)** the structure of a villus; **(b)** an enlarged view of the cells covering the outside of the villus, including the microvilli

substances that are absorbed into the blood capillaries are carried by the hepatic portal vein to the liver. Here they may be removed for further processing, or they may remain in the blood to be carried to other body cells. Substances that are absorbed into the lacteals are transported in the lymph system, which eventually empties into the blood through veins in the upper part of the chest (see Fig. 9.9, p. 123).

The large intestine

The **large intestine** is about 1.5 metres long, and is so named because it is larger in diameter than the small intestine. There are no villi in the large intestine, and no digestive juices are secreted, although the lining does secrete a large amount of mucus. Movement of material through the large intestine is fairly slow. It may take 18–24 hours for material to pass through. During this time most of the remaining water is absorbed, so that the contents become more solid.

Bacteria in the large intestine break down much of the remaining organic compounds. Some bacteria produce vitamins, which are then absorbed through the walls into the blood. Mineral nutrients are also absorbed.

The semi-solid material left after water absorption and bacterial action makes up the faeces. **Faeces** contain water; undigested food material, particularly cellulose; bacteria; bile pigments, which give the faeces their colour; and the remains of cells that have broken away from the internal lining of the alimentary canal. Many people refer to defecation as excretion. Excretion is the removal of metabolic waste, waste that has been produced by chemical activity of the body cells. Except for the bile pigments the contents of the faeces are not metabolic waste so defecation is better referred to as **elimination** rather than excretion.

Environment and lifestyle affect input and output surfaces

The way in which we live and the environment in which we work and spend our leisure time can have profound effects on the efficiency of the surfaces through which materials are taken in and passed out of our bodies.

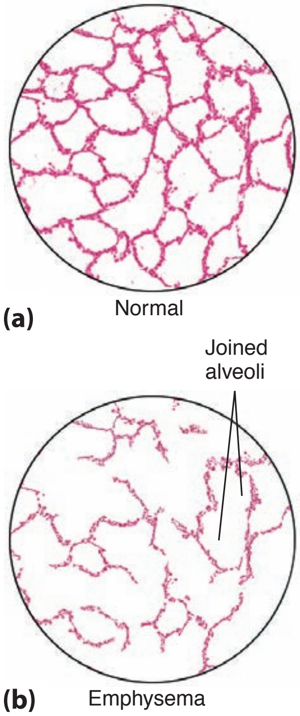


Figure 7.15
(a) Photomicrograph of a section of lung tissue showing normal alveoli.
(b) Photomicrograph of a section of lung tissue from a patient with emphysema showing how alveolar walls have broken down forming larger, fewer alveoli with reduced total surface area

Gas exchange in the lungs

Emphysema

Emphysema is a disease usually caused by long-term exposure to irritating particles in the air taken into the lungs. No-one can avoid inhaling particles, as there are particles of matter in the air at all times. Some people, however, are exposed to excessively high levels. Smokers constantly inhale irritants in tobacco smoke; those who work in situations where a lot of dust is produced are also at risk. In cities with continually high air pollution there is a greater risk of emphysema.

The irritating particles cause damage to the alveoli. They lose their elasticity, are often replaced with fibrous tissue, and may break down, reducing the internal surface area of the lung (Fig. 7.15). Because of the loss of elasticity of the lung tissue, the lungs are constantly inflated, and breathing out no longer occurs passively but requires voluntary effort. Thus, the emphysema sufferer has two problems—inadequate surface area for gas exchange, and difficulty in ventilating the lungs. Emphysema cannot be cured, and once lung damage begins the progression of the disease cannot be stopped.

Lung cancer

Lung cancer is similar to other cancers in that it involves the development of a tumour, a mass of cells that divides in an uncontrolled way. Evidence shows clear links between lung cancer and tobacco smoking, and exposure to asbestos fibres and other pollutants. Smoking poses by far the greatest risk for lung cancer and, if smoking is combined with other risk factors, the chances of contracting lung cancer are even greater. For example, asbestos workers who smoke have a 20–90 times greater risk of contracting lung cancer than similar workers who do not smoke. Some chemical substances seem to initiate cancerous growths; others seem to promote the growth of the tumour. Tobacco smoke contains both initiators and promoters of lung cancer.

The most common form of lung cancer begins in the walls of the air passages, usually the bronchi. Inhaled smoke particles constantly irritate the mucous membrane that lines the air passages. This results in excessive production of mucus. Cells at the base of the membrane begin to divide more rapidly and accumulating mucus cannot be removed. This results in 'smoker's cough'. The trapped mucus causes rupture of the alveoli. Emphysema has then developed. Ultimately a cancerous growth develops in an air passage and may spread to other parts of the body.

Lung infections

Pneumonia is an infection of the lungs caused by bacteria, viruses, fungi or other organisms. The inflammation resulting from the infection causes secretion of fluid and mucus into the alveoli, thus reducing the amount of air that they can contain. The surface area available for exchange of gases is also reduced and breathing difficulty is a symptom of many types of pneumonia.

Tuberculosis (TB) is an infection of the lung by the bacterium *Mycobacterium tuberculosis*. As a cause of death, tuberculosis, along with HIV/AIDS and malaria, is one of the top three infectious diseases in the world. Fortunately, in Australia, there is a very low incidence of tuberculosis—about 1000 cases per year, most of them in people born overseas.

Most lung infections, such as tuberculosis and pneumonia, are spread by droplets. When infected people cough, sneeze or spit, tiny droplets of moisture containing the bacteria, viruses or fungi may be inhaled by others, so spreading the infection. Good hygiene practices, such as coughing and sneezing into a handkerchief and not spitting, help to reduce the spread of lung infections.

Asthma

Asthma is an allergic response to foreign substances that enter the body. Some of the more common sources of such foreign particles are animal skins, feathers, bird excreta, house dust mites and pollen grains. Substances in food may also trigger an asthma attack. During such an attack the muscles that surround the bronchioles go into spasm—sudden involuntary contractions. This causes narrowing of the air passages and difficulty in breathing.

Usually the irritation of the membranes lining the air passages causes secretion of excessive mucus and this also restricts movement of air. The reduced volume of air going in and out of the lungs means that the exchange of gases is impaired and the blood does not carry the usual amount of oxygen.

Diet affects absorption in the alimentary canal

The speed with which material is moved through the alimentary canal depends on the size and contents of a meal. A *large meal* causes greater stretching of the stomach and material is pushed into the small intestine much more quickly than when the stomach is less distended. *High protein and/or high fat content* in a meal slow the movement from stomach to small intestine. *Alcohol* and *caffeine* both stimulate movements of the stomach.

Constipation

Constipation occurs if the movements of the large intestine are reduced and the contents remain there for long periods of time. As water is absorbed, the faeces become drier and harder than usual. Defecation becomes difficult and possibly painful, a condition known as **constipation**. Constipation may be caused by a lack of roughage in the diet. Roughage is cellulose, or insoluble fibre, a major component of plant foods. We have no enzymes to digest cellulose but it is important because it stimulates the movements of the alimentary canal. Other causes of constipation may be lack of exercise or emotional problems.

Diarrhoea

Diarrhoea is characterised by frequent defecation of watery faeces. It is caused by an irritation of the small or large intestine, which increases peristalsis so that the contents of the intestines move through before there is adequate absorption of water. Such an irritation may be the result of a bacterial or viral infection. Bacteria that produce food poisoning may cause diarrhoea. Cholera bacteria cause such severe diarrhoea that death often results from dehydration through loss of water from the intestines.

Bowel cancer

Research suggests that cancer of the large intestine may be linked to diet. It is thought that a diet high in animal fat and protein, and low in fibre (fruit and vegetables), may increase the risk of developing bowel cancer.

The importance of soluble fibre in the diet

Both soluble and insoluble fibre are found only in foods derived from plants. Soluble fibre includes pectins, gums and mucilage. Soluble fibre intake has been linked to lower cholesterol levels in the blood, decreased risk of heart disease and cancer, and beneficial effects on blood glucose levels. Fats in the intestines are trapped by soluble fibre, thereby helping to prevent their absorption by the body. This is thought to be the reason that soluble fibre helps to lower blood cholesterol levels. Good sources of soluble fibres are fruits, vegetables, oat bran, barley and soy products.

Coeliac disease

People with coeliac disease are unable to tolerate a protein called gluten, which is found in wheat, rye and barley. If such people eat food containing gluten, their immune systems respond by damaging or destroying the villi in the small intestine. Without healthy villi nutrients cannot be absorbed and the patient becomes malnourished no matter how much food is eaten.

The symptoms of coeliac disease are many and vary from person to person. Symptoms such as muscle cramps, joint pain or tingling in the legs may appear to have nothing to do with nutrition or digestion. Some people may not have symptoms but are still in danger of becoming malnourished. The variety of symptoms makes the condition very difficult to diagnose.

Coeliac disease is inherited. There is no cure and the only treatment is to follow a gluten-free diet.

EXTENSION

Find out:

- why vigorous exercise after a large meal may cause discomfort and cramps in the abdomen
- what is meant by the glycaemic index of a carbohydrate
- which carbohydrates are most beneficial—those with a high or a low glycaemic index.

Working scientifically

Activity 7.1 Investigating breathing

Working on your own, or with a partner, think of a factor that could influence breathing.

- Propose a hypothesis that links the two variables—some aspect of breathing and the factor that you have selected.
- Design an experiment to test your hypothesis.
- Your teacher may want you to carry out your experiment and present a report in some appropriate format.

Activity 7.2 Alexis St Martin

Alexis St Martin was a French–Canadian fur trader. In 1822, at a trading post in what is now Michigan in the United States, St Martin was shot at point-blank range by a shotgun. The blast left a hole in his upper left abdomen and stomach that was described as being 'larger than the palm of a man's hand'. St Martin was treated by a US Army surgeon, Dr William Beaumont. Under Beaumont's treatment the wound healed but the hole in the stomach and wall of his abdomen never entirely closed over. If St Martin ate too much, food would come out of his stomach through the hole.

At the time of St Martin's accident doctors did not know what happened to food in the stomach. Some thought that food was ground up, others believed that it was cooked and some thought it was chemically reduced. Beaumont was an exceptional doctor and scientist. He realised that the hole into his patient's stomach gave him an ideal opportunity to study what happened to food in the stomach.

One of the experiments that Beaumont did was to compare the action of stomach juices in a test tube with their action in the stomach. He extracted juice from St Martin's stomach and placed it in a test tube with a piece of meat. At the same time he suspended a piece of meat, on a string, in the man's stomach. Beaumont found that the stomach completely digested the meat in 2 hours; the stomach juice in the test tube took 10 hours.

1. What variables should Beaumont have controlled in order to draw valid conclusions from his experiment?
2. Suggest why the meat in the stomach was digested more quickly than the meat in the test tube (assuming that Beaumont controlled all the relevant variables).
3. Would Beaumont have obtained the same result if he had used a vegetable such as cabbage instead of meat? Explain.
4. Suggest some other investigations that Beaumont could have performed using St Martin as his subject (remember that St Martin's injury occurred over 180 years ago).

William Beaumont published the results of his investigations in 1833 in a book called *Experiments and Observations on the Gastric Juice and the Physiology of Digestion*. It was the foundation for what we know about digestion today and Beaumont became known as 'the father of gastric physiology'. Alexis St Martin died in 1880 at the age of 86.

REVIEW QUESTIONS

1. List the characteristics of the lungs that make them well suited for gas exchange.
2. Why is it that, in the lungs, oxygen diffuses into and carbon dioxide out of the blood, whereas in other body tissues oxygen diffuses out of and carbon dioxide into the blood?
3. **(a)** Draw a diagram showing inspiration. As labels for your diagram, list the sequence of events that occur in inspiration.
   (b) Draw a diagram showing expiration. As labels for your diagram, list the sequence of events that occur in expiration.
4. **(a)** Why is a concentration gradient important for the exchange of gases?
   (b) Explain how a concentration gradient for oxygen and carbon dioxide is maintained between the blood and the air in the alveoli.
5. What are the basic activities that the digestive system must carry out?
6. Draw up a table with three columns. In the first column list the parts of the alimentary canal that are discussed in this chapter; in the second column describe the role of each part in digestion and absorption; and in the third column explain how the structure of the part is suited to its functions. Remember to put an appropriate heading on each of your columns.

7. Explain the digestive function of each of the following:
   (a) gastric juice
   (b) bile
   (c) pancreatic juice
   (d) intestinal juice.
8. (a) How does the absorption of fatty acids and glycerol differ from the absorption of amino acids and simple sugars?
   (b) How does the absorption of water differ from the absorption of simple sugars?
9. Describe precautions that you can take to reduce your risk of developing emphysema or lung cancer.
10. Why does pneumonia often cause difficulty in breathing?
11. (a) Explain the difference between constipation and diarrhoea.
    (b) What precautions can you take to make sure that you do not suffer from constipation?
12. What are the advantages of consuming a diet that is high in both soluble and insoluble fibre? List foods that would be high in soluble and insoluble fibre.
13. Why are people who suffer from coeliac disease likely to become malnourished?

APPLY YOUR KNOWLEDGE

1. To be effective, any surface where materials are taken into the body, or passed out of the body, must have a very large surface area. For the exchange surfaces discussed in this chapter explain how a large surface area is achieved.
2. The exchange surfaces of the lungs and the alimentary canal rely on concentration differences so that substances diffuse across the surface. For the lungs and the alimentary canal explain how the concentration difference is maintained.
3. Explain how the respiratory and digestive systems are involved in maintaining substances in the body at a constant level.
4. Explain why the small intestine has a much larger surface area than the large intestine.
5. The faeces contain the remains of cells. Refer to Table 5.1 and suggest why cell remains should be in the faeces.
6. Although alcohol is absorbed in the stomach, it is absorbed much more rapidly in the small intestine.
   (a) Suggest why alcohol is much slower to affect a person's mood when consumed with a meal.
   (b) Would the nature of the meal, for example, a meal high in carbohydrate compared with a meal high in fat, have any influence on alcohol absorption? Explain.
7. List five occupations in which people could be at risk of contracting emphysema. What precautions could be taken to reduce the risk of workers contracting the disease?
8. In expired air resuscitation (mouth-to-mouth resuscitation) air from the rescuer's lungs is blown into the patient's lungs. How is expired air able to keep the patient alive? (Refer to Table 7.1.)