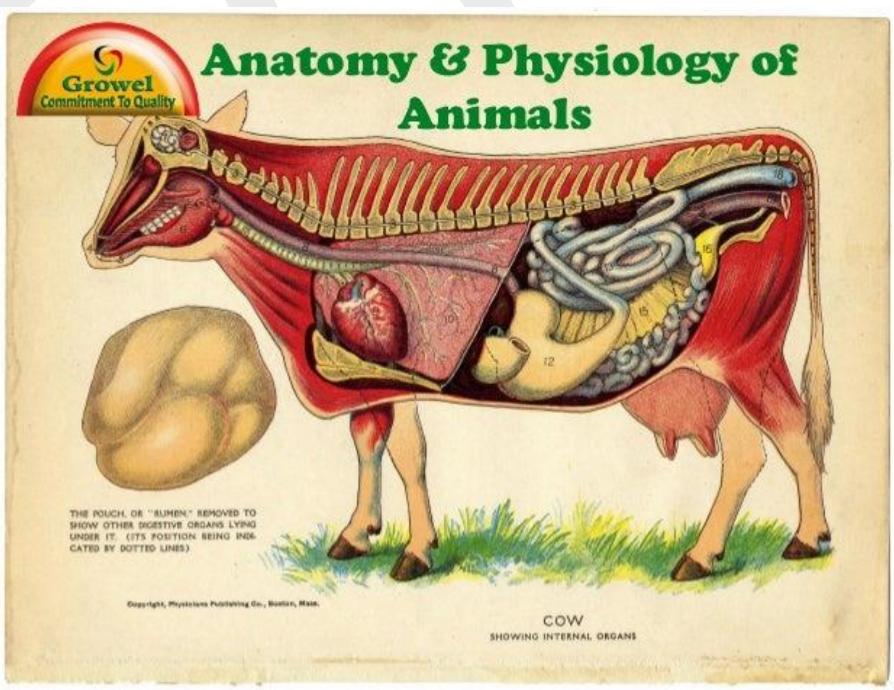
Edexcel

IGCSE

Biology

CODE: (4BI1)

Unit 02



2.3 Breathing and gas exchange

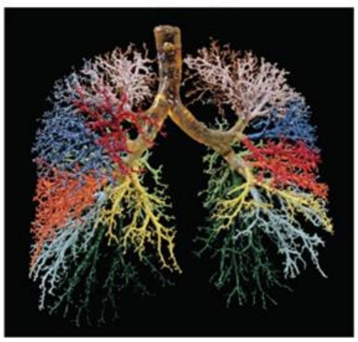
Cells get their energy by oxidising foods such as glucose, during the process called **respiration**. If cells are to respire aerobically, they need a continuous supply of oxygen from the blood.

Respiration and breathing

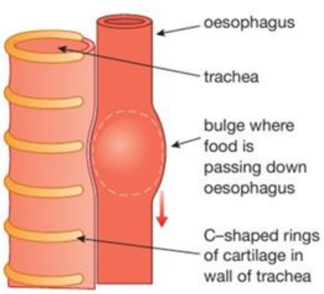
Respiration is the oxidation reaction releasing energy from food, while breathing moves air into and out of the lungs for gas exchange, often referred to as the gas exchange system, not the respiratory system.

The structure of the gas exchange system

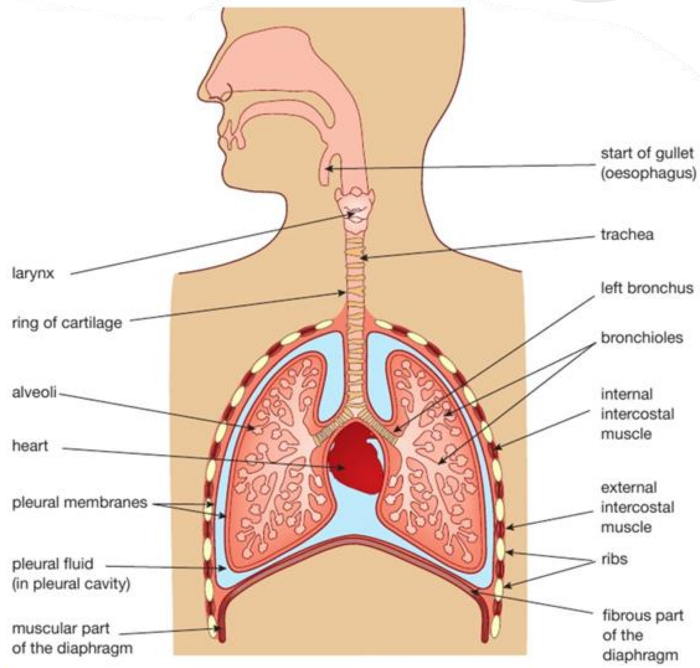
The lungs are enclosed in the chest or **thorax** by the ribcage and a muscular sheet of tissue called the **diaphragm** (Figure 3.1). Joining each rib to the next are two sets of muscles called **intercostal muscles** ('costals' are rib bones).



▲ Figure 3.2 This cast of the human lungs was made by injecting a pair of lungs with a liquid plastic. The plastic was allowed to set, then the lung tissue was dissolved away with acid.



▲ Figure 3.3 C-shaped cartilage rings in the trachea.



▲ Figure 3.1 The human gas exchange system

The air passages of the lungs form a highly branching network (Figure 3.2). This is why it is sometimes called the **bronchial tree.**

When we breathe in, air enters our nose or mouth and passes down the windpipe or **trachea**. The trachea splits into two tubes called the **bronchi** (**singular bronchus**), one leading to each lung. Each bronchus divides into smaller and smaller tubes called **bronchioles**, eventually ending at microscopic air sacs, called **alveoli** (**singular alveolus**). It is here that gas exchange with the blood takes place.

The walls of trachea and bronchi contain rings of gristle or **cartilage**. These support the airways and keep them open when we breathe in.

The inside of the thorax is separated from the lungs by two thin, moist membranes called the **pleural membranes.** They make up a continuous envelope around the lungs, forming an airtight seal. Between the two membranes is a space called the **pleural cavity,** filled with a thin layer of liquid called **pleural fluid**.

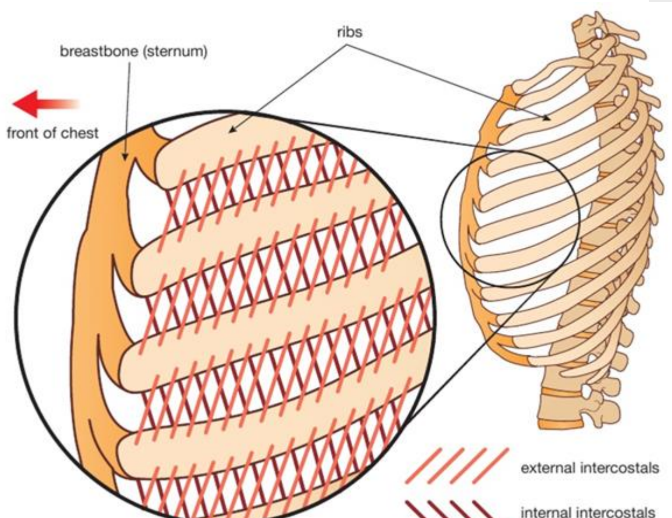
▲ Figure 3.4 This electron microscope picture shows cilia from the lining of the trachea.

Keeping the airways clean

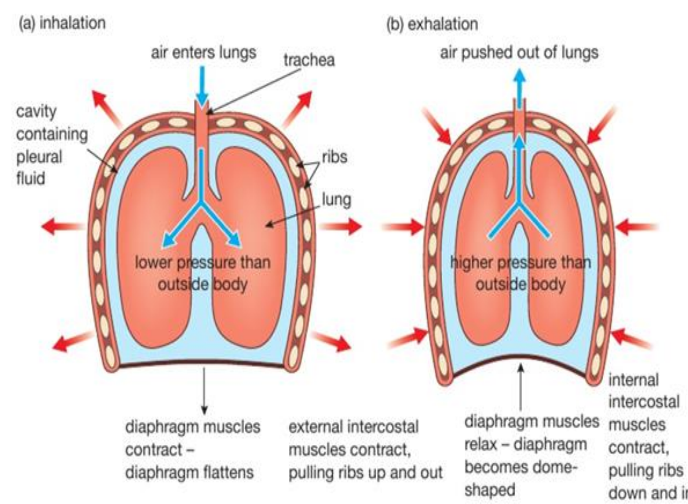
The trachea and larger airways are lined with a layer of cells that have an important role in keeping the airways clean. Some cells in this lining secrete a sticky liquid called **mucus**, which traps particles of dirt or bacteria that are breathed in. Other cells are covered with tiny hair-like structures called **cilia** (Figure 3.4).

Ventilation of the lungs

Ventilation is the process of moving air in and out of the lungs, requiring a difference in air pressure. It is dependent on the thorax being an airtight cavity, and changes in the volume of the thorax alter the pressure inside it. Two movements that bring about ventilation are the ribs and the diaphragm. When breathing in, the ribs move upwards and outwards, while when breathing out, the ribs and diaphragm contract, causing a slight drop in pressure and forcing air out of the lungs.



▲ Figure 3.5 Side view of the chest wall, showing the ribs. The diagram shows how the two sets of intercostal muscles run between the ribs. When the external intercostals contract, they move the ribs upwards. When the internal intercostals contract, the ribs are moved downwards.



▲ Figure 3.6 Changes in the position of the ribs and diaphragm during breathing. (a) Breathing in (inhalation). (b) Breathing out (exhalation).

Gas exchange in alveoli

You can tell what is happening during gas exchange if you compare the amounts of different gases in atmospheric air with the air breathed out (Table 3.1).

Gas	Atmospheric air / %	Exhaled air / %
nitrogen	78	79
oxygen	21	16
carbon dioxide	0.04	4
other gases (mainly argon)	1	1

Exhaled air, saturated with water vapor, is warmer than atmospheric air and helps the lungs absorb oxygen into the blood and remove carbon dioxide from it. The alveoli, which contain 700,000 tiny air sacs, have a total surface area of 60 m2, larger than a classroom floor area.

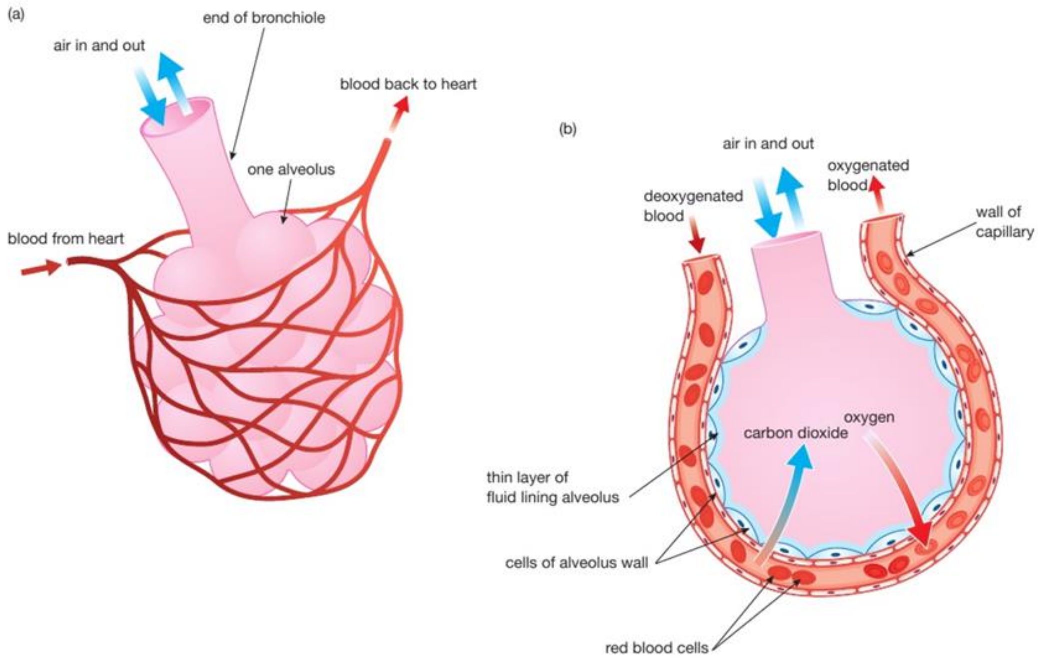


Figure 3.7 (a) Alveoli and the surrounding capillary network. (b) Diffusion of oxygen and carbon dioxide takes place between the air in the alveolus and the blood in the capillaries.

The effect of smoking

Smoking disrupts the proper exchange of gases in the lungs, leading to lung cancer, bronchitis, emphysema, coronary heart disease, stomach and intestine ulcers, and underweight babies in pregnant women. It also contributes to other medical conditions such as coronary heart disease, which will be discussed in Chapter 5.

Effects of smoke on the lining of the air passages

Bronchitis is a lung disease caused by reduced cilia and irritated airway lining, leading to'smoker's cough'. Infections from mucus bacteria and irritation of the bronchial tree cause bronchitis, causing difficulty breathing.

Emphysema

Emphysema, a lung disease causing approximately 20,000 deaths in Britain annually, is caused by smoking. It damages alveoli walls, causing irregular air spaces and reduced oxygen supply. Patients often require constant oxygen supply, and there is no cure, often leading to long and distressing illness.

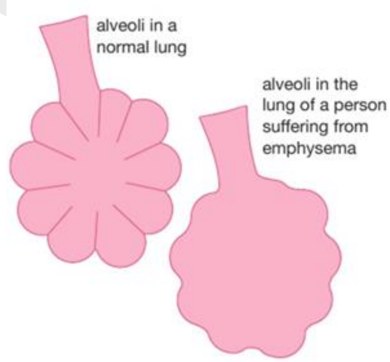


Figure 3.9 The alveoli of a person suffering from emphysema have a greatly reduced surface area and inefficient gas exchange.

Figure 3.10 Patients with emphysema often need to breathe air enriched with oxygen in order to stay alive.

Lung cancer

The 1950s study revealed a link between smoking and lung cancer. Patients in the hospital were compared to a control group, which had various illnesses but not lung cancer. The **control** group had a higher proportion of smokers, indicating a connection between smoking and lung cancer.

Table 3.2 Comparison of the smoking habits of lung cancer patients and other patients.

	Percentage of patients who were non-smokers	Percentage of patients who smoked more than 15 cigarettes a day
lung cancer patients	0.5	25
Control patients (with illnesses other than lung cancer)	4.5	13

Cigarette smoke contains a strongly addictive drug - **nicotine**. Smoke contains over 7000 chemicals, including carbon monoxide, arsenic, ammonia, formaldehyde, cyanide, benzene, and toluene. More than 60 of the chemicals are known to cause cancer. These chemicals are called **carcinogens** and are contained in the tar that collects in a smoker's lungs. Cancer happens when cells mutate and start to divide uncontrollably, forming a **tumour** (Figure 3.11).

If you smoke you are not bound to get lung cancer, but the risk that you will get it is much greater. In fact, the more cigarettes you smoke, the more the risk increases (Figure 3.12).

The obvious thing to do is not to start smoking. However, if you are a smoker, giving up the habit soon improves your chance of survival (Figure 3.14).

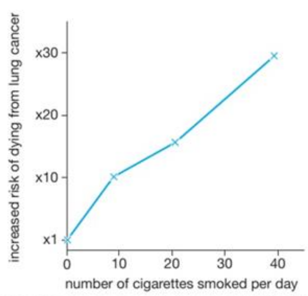


Figure 3.12 The more cigarettes a person smokes, the more likely it is they will die of lung cancer. For example, smoking 20 cigarettes a day increases the risk by about 15 times.

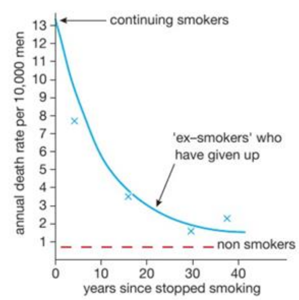


Figure 3.13 Death rates from lung cancer for smokers, non-smokers and ex-smokers.

Carbon monoxide in smoke

One of the harmful chemicals in cigarette smoke is the poisonous gas **carbon monoxide**. When this gas is breathed in with the smoke, it enters the bloodstream and interferes with the ability of the blood to carry oxygen. Oxygen is carried around in the blood in the red blood cells, attached to a chemical called **haemoglobin** . Carbon monoxide can combine with the haemoglobin much more tightly than oxygen can, forming a compound called **carboxyhaemoglobin**.

If a pregnant woman smokes, she will be depriving her unborn **fetus** of oxygen (Figure 3.14).

Some smoking strategies

■It is estimated that there are over 1 billion smokers worldwide. In 2014 they consumed 5.8 trillion cigarettes.

■Every year nearly 6 million people are killed by tobacco-related illnesses. If the current trend continues, by 2030 this will rise to 8 million deaths per year and 80% of these premature deaths will be in developing countries.

■Smoking causes almost 80% of deaths from lung cancer, 80% of deaths from bronchitis and emphysema, and 14% of deaths from heart disease.

■More than a quarter of all cancer deaths are attributable to smoking. These include cancer of the lung, mouth, lip, throat, bladder, kidney, pancreas, stomach, liver and cervix.

■While demand for tobacco has steadily fallen in developed countries like the UK, cigarette consumption is being increasingly concentrated in the developing world.

■9.6 million adults in the UK smoke cigarettes, 20% of men and 17% of women. However, 22% of women and 30% of men in the UK are now ex-smokers. Surveys show that about two-thirds of current smokers would like to stop smoking.

■It is estimated that worldwide, 31% of men and 8% of women are smokers.

■In China alone there are about 350 million smokers, who consume about one-third of all cigarettes smoked worldwide. Large multinational tobacco companies have long been keen to enter the Chinese market.

■In China there are over a million deaths a year from smoking-related diseases. This figure is expected to double by 2025.

■In developing countries, smoking has a greater economic impact. Poorer smokers spend significant amounts of their income on cigarettes rather than necessities like food, healthcare and education.

■Tobacco farming uses up land that could be used for growing food crops.

Giving up smoking

Smokers often desire to quit their habit due to the addictive nature of nicotine, which causes withdrawal symptoms like cravings, restlessness, and weight gain. Alternative methods include vaping, nicotine patches, or chewing gum, which provide nicotine without the harmful tar of cigarettes, reducing cravings and gradually reducing the dose until weaning off the habit.

2.4 Food and digessive

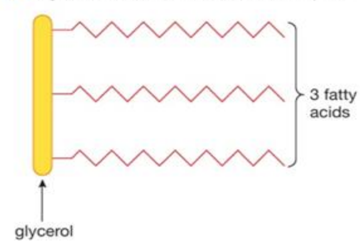
▲ Figure 4.1 A balanced diet contains all the types of food the body needs, in just the right amounts.

We need food for three main reasons:
■To supply us with a 'fuel' for energy
■To provide materials for growth and repair of tissues
■To help fight disease and keep our bodies healthy.

A balanced diet

The food that we eat is called our diet. No matter what you like to eat, your diet must include the following five groups of food substances if your body is to work properly and stay healthy - **carbohydrates, lipids, proteins, minerals** and **vitamins** - along with **dietary fibre** and water. Food should provide you with all of these substances, but they must also be present in the right amounts. A diet that provides enough of these substances and in the correct proportions to keep you healthy is called a **balanced diet** (Figure 4.1).

▲ Figure 4.3 These foods are all rich in lipids.



▲ Figure 4.4 Lipids are made up of a molecule of glycerol joined to three fatty acids. The many different fatty acids form the variable part of the molecule.

Carbohydrates

Carbohydrates only make up about 1% of the mass of the human body, but they have a very important role. They are the body's main 'fuel' for supplying cells with energy. Cells release this energy by oxidising a sugar called **glucose**,

Glucose is found naturally in many sweet-tasting foods, such as fruits and vegetables. Other foods contain different sugars, such as the fruit sugar called

fructose, and the milk sugar, **lactose**. Ordinary table sugar, the sort of some people put in their tea or coffee, is called **sucrose**.

We can get all the sugar we need from natural foods such as fruits and vegetables, and from the **digestion** of starch. In fact, we get most of the carbohydrate in our diet not from sugars, but from **starch**. Starch is a large, insoluble molecule. Because it does not dissolve, it is found as a storage carbohydrate in many plants, such as potato, rice, wheat and millet.

Starch is only found in plant tissues, but animal cells sometimes contain a very similar carbohydrate called **glycogen**.

Cellulose, a glucose-polymer in plant cell walls, is not digestible by humans due to the lack of enzymes in the gut. Despite this, it plays a crucial role in our diet by providing **dietary fiber.**

Lipids (fats and oil)

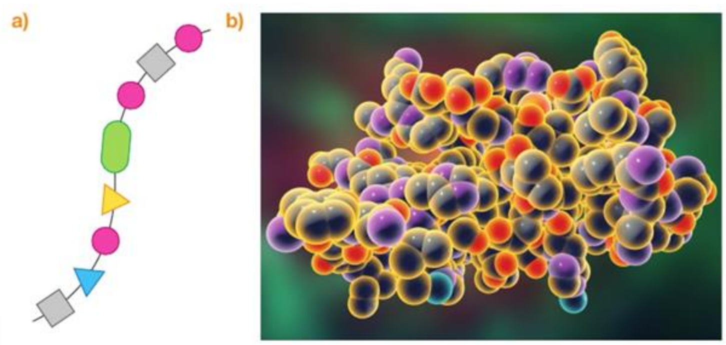
The chemical 'building blocks' of lipids are two types of molecules called **glycerol** and **fatty acids**. Glycerol is an oily liquid. It is also known as glycerine and is used in many types of cosmetics. In lipids, a molecule of glycerol is joined to three fatty acid molecules. There are many different fatty acid molecules, which give us the many kinds of lipid found in food (Figure 4.4).

Although lipids are an essential part of our diet, too much lipid is unhealthy, especially a type called saturated fat, and a lipid compound called **cholesterol**.

Proteins

we don't need much protein in our diet to stay healthy. Doctors recommend a maximum daily intake of about 70g. In more economically developed countries, people often eat far more protein than they need, whereas in many poorer countries a protein-deficiency disease called **kwashiorkor** is common (Figure 4.5).

Like starch, proteins are also polymers, but whereas starch is made from a single molecular building block (glucose), proteins are made from 20 different sub-units called **amino acids.**



▲ Figure 4.6 (a) A chain of amino acids forming part of a protein molecule. Each shape represents a different amino acid. (b) A computer model of the protein insulin. This substance, like all proteins, is made of a long chain of amino acids arranged in a particular order and folded into a specific shape.

Minerals

Foods consist of five chemical elements: carbon, hydrogen, oxygen, nitrogen, and sulfur. Our bodies contain minerals or ions, such as calcium for teeth and bones, and iron, essential for oxygen transport in our blood, present in smaller amounts.

Table 4.1 shows just a few of these minerals and the reasons they are needed.

Table 4.1 Some examples of minerals needed by the body.

Mineral	Approximate mass in an adult body / g	Location or role in body	Examples of foods rich in minerals
calcium	1000	making teeth and bones	dairy products, fish, bread, vegetables
phosphorus	650	making teeth and bones; part of many chemicals, e.g. DNA and ATP	most foods
sodium	100	in body fluids, e.g. blood	common salt, most foods
chlorine	100	in body fluids, e.g. blood	common salt, most foods
magnesium	30	making bones; found inside cells	green vegetables
iron	3	part of haemoglobin in red blood cells, helps carry oxygen	red meat, liver, eggs, some vegetables, e.g. spinach

Vitamins

Experiments in the early 20th century revealed that pure carbohydrates, lipids, and protein led to illness and death in rats, while milk supplemented these foods allowed normal growth and health.

These chemicals are called **vitamins**. The results of one of these experiments are shown in Figure 4.8.

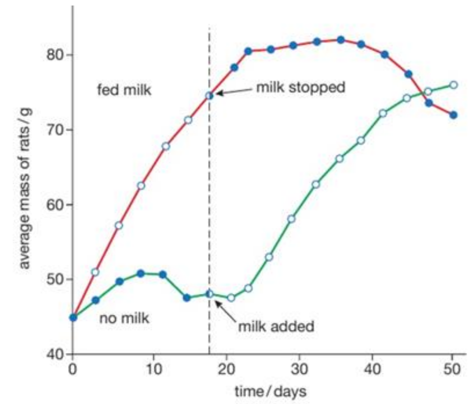


Figure 4.8 Rats were fed a diet of pure carbohydrate, lipid and protein, with and without added milk. Vitamins in the milk had a dramatic effect on their growth.

Vitamin C, found in blood vessels and skin, is essential for connective tissue fibers and acts as a glue, but deficiency can lead to scurvy, causing wound failure and bleeding.

This is especially noticeable in the gums (Figure 4.9).

Vitamin B, a group of vitamins B1 (thiamine), B2 (riboflavin), and B3 (niacin), is crucial for cell respiration and can cause deficiency diseases like **beri-beri**, muscle weakness, and paralysis.

The main vitamins, their role in the body and some foods which are good sources of each, are summarised in Table 4.2.

Food tests

Chemical tests can determine a food's content of starch, glucose, protein, or lipid. Practical 8 uses pure substances, but normal foods can be tested. Small pieces of food are ground, then shaken with water to extract components.

Table 4.3 Energy content of some common foods

Food	kJ per 100g	Food	kJ per 100g
margarine	3200	white bread	1060
butter	3120	chips	990
peanuts	2400	grilled beef steak	930
samosa	2400	fried cod	850
chocolate	2300	roast chicken	770
Cheddar cheese	1700	boiled potatoes	340
table sugar	1650	milk	270
cornflakes	1530	baked beans	270
rice	1500	yoghurt	200
spaghetti	1450	boiled cabbage	60
fried beefburger	1100	lettuce	40

Energy from food

Food energy content is determined by the proportion of carbohydrates, lipids, and proteins. Carbohydrates produce 17 kJ, lipids 39 kJ, and proteins 18 kJ per gram. Food labels display energy content and nutrient amounts. High-lipid foods like butter or nuts have a high energy content.

Others, like fruits and vegetables, which are mainly composed of water, have a much lower energy content (Table 4.3).

Digestion

Enzymes play a crucial role in **digestion**, a process where food components are broken down into building blocks for absorption through the gut wall. These molecules, including sugars, fatty acids, glycerol, amino acids, minerals, vitamins, and water, are

Table 4.2 Summary of the main vitamins. Note that you only need remember the sources and functions of vitamins A, C and D.

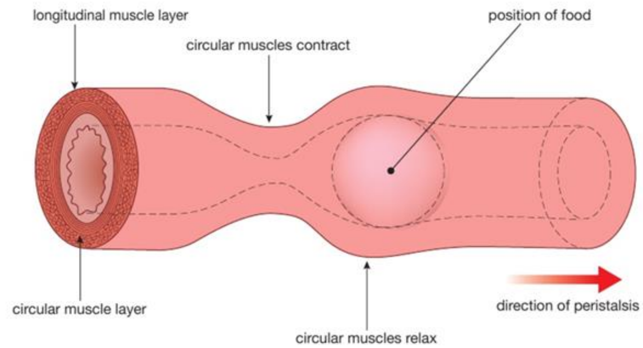
Vitamin	Recommended daily amount in diet[1]	Use in the body	Effect of deficiency	Some foods that are a good source of the vitamin
A	0.8 mg	making a chemical in the retina; also protects the surface of the eye	night blindness, damaged cornea of eye	fish liver oils, liver, butter, margarine, carrots
B1	1.1 mg	helps with cell respiration	beri-beri	yeast extract, cereals
B2	1.4 mg	helps with cell respiration	poor growth, dry skin	green vegetables, eggs, fish
B3	16 mg	helps with cell respiration	pellagra (dry red skin, poor growth, and digestive disorders)	liver, meat, fish.
C	80 mg	sticks together cells lining surfaces such as the mouth	scurvy	fresh fruit and vegetables
D	5 μg	helps bones absorb calcium and phosphate	rickets, poor teeth	fish liver oils; also made in skin in sunlight

[1]Figures are the European Union's recommended daily intake for an adult (2012). 'mg' stands for milligram (a thousandth of a gram) and 'μg' for microgram (a millionth of a gram).

carried around the body in the blood and reassembled into cells. Digestive enzymes, made by gut tissues and glands, speed up this chemical digestion, which is assisted by mechanical digestion, which occurs in the mouth and other parts of the gut.

Parietals

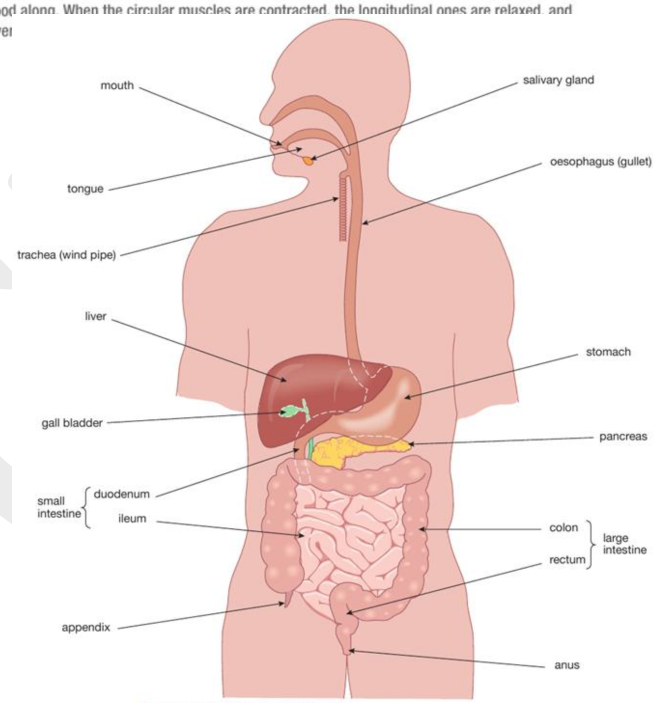
Muscles in the intestine, consisting of two layers, act to push food along the wall. Circular and longitudinal muscles contract and relax, causing the gut to narrow or widen. This process, called peristalsis, allows food to move in the gut without relying on gravity, allowing us to eat standing on our heads.



▲ Figure 4.14 Peristalsis: contraction of circular muscles behind the food narrows the gut, pushing the food along. When the circular muscles are contracted, the longitudinal ones are relaxed, and vice ver

The digestive system

The mouth, stomach and the first part of the small intestine (called the **duodenum**) all break down the food using enzymes, either made in the gut wall itself, or by glands such as the **pancreas**. Digestion continues in the last part of the small intestine (the **ileum**) and it is here that the digested food is absorbed. The last part of the gut, the large intestine, is mainly concerned with absorbing water out of the remains and storing the waste products (**faeces**) before they are removed from the body.



▲ Figure 4.15 The human digestive system

The three main classes of food are broken down by three classes of enzymes. **Carbohydrates** are digested by enzymes called carbohydrases. Proteins are acted upon by **proteases**, and enzymes called **lipases** break down lipids. Some of the places in the gut where these enzymes are made are shown in Table 4.5.

Digestion begins in the mouth. **Saliva** helps moisten the food and contains the enzyme **amylase**, which starts the breakdown of starch. The chewed lump of food, mixed with saliva, then passes along the **oesophagus** (gullet) to the stomach.

The stomach holds food for several hours for protein digestion, with hydrochloric acid secreted to kill bacteria in the gut. **Pepsin**, a stomach protease enzyme, works in these acidic conditions, with an optimal pH of 2. The semi-digested food is held back by a **sphincter muscle**, which releases it into the duodenum.

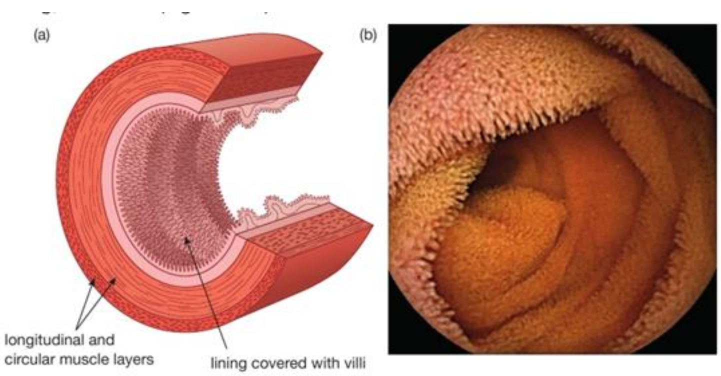
Table 4.5 Some of the enzymes that digest food in the human gut. The substances shown in bold are the end products of digestion that can be absorbed from the gut into the blood.

Class of enzyme	Examples	Digestive action	Source of enzyme	Where it acts in the gut
carbohydrases	amylase amylase maltase	starch → maltose[1] starch → maltose maltose → **glucose**	salivary glands pancreas wall of small intestine	mouth small intestine small intestine
proteases	pepsin trypsin peptidases	proteins → peptides[2] proteins → peptides peptides → **amino acids**	stomach wall pancreas wall of small intestine	stomach small intestine small intestine
lipases	lipase	lipids → **glycerol** and **fatty acids**	pancreas	small intestine

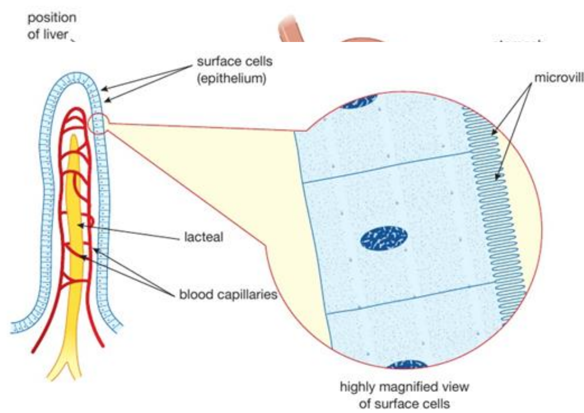
Several digestive enzymes are added to the food in the duodenum. These are made by the pancreas, and digest starch, proteins and lipids (Table 4.5). As well as this, the **liver** makes a digestive juice called **bile**. Bile is a green liquid that is stored in the **gall bladder** and passes down the **bile duct** on to the food. Bile does not contain enzymes but has another important function.

Absorption in the ileum

The villus, a small, 1-2 mm long lining in the digestive system, is called a **villus**. Its surface cells have hundreds of minute projections called **microvilli**, increasing absorption surface area. Each villus contains blood capillaries, with most digested food entering these vessels. Fat digestion products and droplets enter a **lacteal** tube, transporting lymph.



▲ Figure 4.18 (a) The inside lining of the ileum is adapted to absorb digested food by the presence of millions of tiny villi. (b) Photo of the inside a patient's ileum, taken using a camera attached to an endoscope. You can see thousands of tiny villi covering the lining.



▲ Figure 4.19 Each villus contains blood vessels and a lacteal, which absorb the products of digestion. The surface cells of the villus are covered with microvilli, which further increase the surface area for absorption.

The hepatic portal vein connects blood vessels from the ileum, leading to the liver. The liver functions like a food processing factory, breaking down and storing molecules like glucose, glycogen, and glucose.

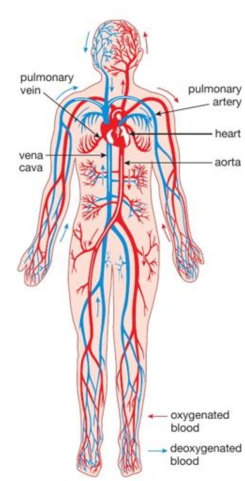
The large intestine – elimination of waste

The gut's contents reach the small intestine's end, absorbing most digested food and water, leaving waste materials like cellulose, indigestible remains, water, dead bacteria, and cell loss.

The function of the first part of the large intestine, called the **colon**, is to absorb most of the remaining water from the contents, leaving a semi-solid waste material called **faeces**. This is stored in the rectum, until expelled out of the body through the **anus**.

2.5 The need for circulatory system

Figure 5.1 shows the circulatory system of a mammal.



▲ Figure 5.1 The human circulatory system.

Blood is pumped around a closed circuit made up of the heart and blood vessels. As it travels around the body, it collects materials from some places and unloads them in others. In mammals, blood transports:
oxygen from the lungs to all other parts of the body
■Carbon dioxide from all parts of the body to the lungs
■Nutrients from the gut to all parts of the body
■Urea from the liver to the kidneys.
Hormones, antibodies and many other substances are also transported by the blood. It also distributes heat around the body.

Single-celled organisms, like the ones shown in Figure 5.2, do not have circulatory systems.

Single-celled organisms lack a circulatory system, allowing materials to move freely. They obtain oxygen through diffusion through the cell's surface membrane, with the supply rate determined by the cell's surface area and demand rate determined by its volume.

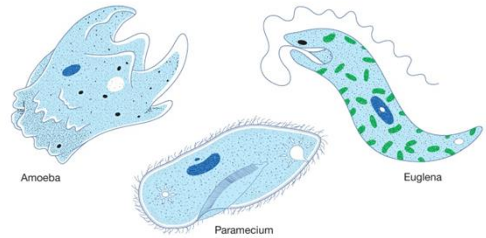


Figure 5.2 Unicellular organisms do not have circulatory systems.

The ratio of supply to demand can be written as: $\frac{\text{surface area}}{\text{volume}}$

The'surface area to volume ratio' is a crucial aspect of an organism's size, affecting its ability to supply oxygen and nutrients. Single-celled organisms have a high ratio, while larger animals have a lower ratio due to insufficient surface area. To overcome this, organisms have evolved special gas exchange organs and circulatory systems, distributing oxygen and nutrients throughout the body.

The circulatory system of different animals

One of the main functions of a circulatory system in animals is to transport oxygen. Blood is pumped to a gas exchange organ to load oxygen. It is then pumped to other parts of the body where it unloads the oxygen. There are two main types of circulatory systems in animals.

■In a single circulatory system, the blood is pumped from the heart to the gas exchange organ and then directly to the rest of the body.

■In a double circulatory system, the blood is pumped from the heart to the gas exchange organ, back to the heart and then to the rest of the body. Figure 5.3 shows the difference between these systems.

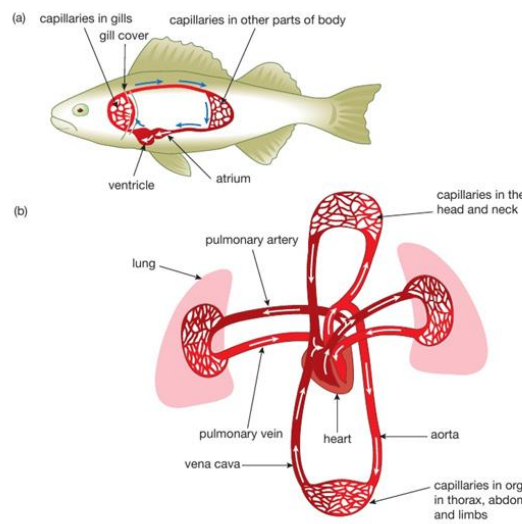


Figure 5.3 (a) The single circulatory system of a fish. The blood passes through the heart only once in a complete circuit of the body. (b) The double circulatory system of a human (and other mammals). The blood passes through the heart twice in one complete circuit of the body.

There are two parts to a double circulatory system:

■**The pulmonary circulation.** Deoxygenated blood leaves the heart through the pulmonary arteries, and is circulated through the lungs, where it becomes oxygenated. The oxygenated blood returns to the heart through the pulmonary veins.

■**The systemic circulation.** Oxygenated blood leaves the heart through the aorta and is circulated through all other parts of the body, where it unloads its oxygen. Deoxygenated blood returns to the heart through the vena cava.
system of a fish, blood loses pressure as it passes through the gills. It then travels more slowly to the other organs.

The human circulatory system comprises:

■The heart - this is a pump

■blood vessels - these carry the blood around the body; arteries carry blood away from the heart and towards other organs, veins carry blood towards the heart .

■blood - the transport medium.

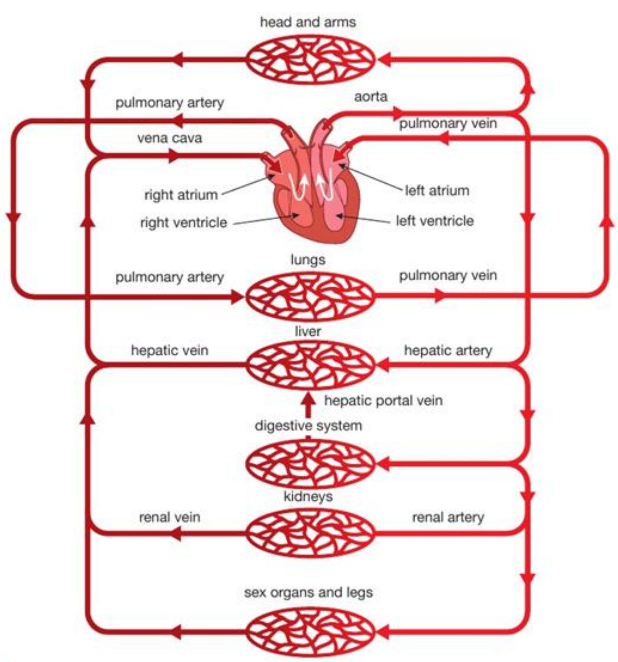
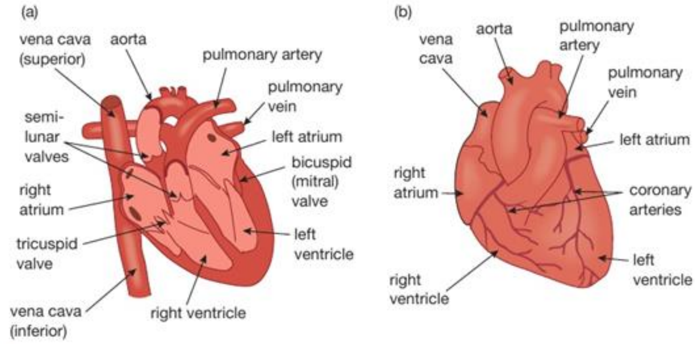


Figure 5.4 The main components of the human circulatory system

Figure 5.4 shows the main blood vessels in the human circulatory system.

The structure and function of the human heart

The human heart is a pump (Figure 5.5). It pumps blood around the body at different speeds and at different pressures according to the body's needs.



▲ Figure 5.5 The human heart: (a) vertical section; (b) external view

The structure of the heart is adapted to its function in several ways:

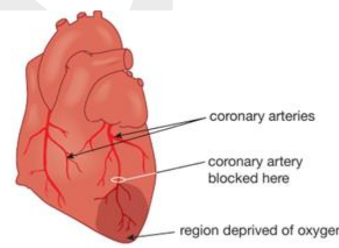
■It is divided into a left side and a right side by a wall of muscle called the **septum**. The right **ventricle** pumps blood only to the lungs while the left ventricle pumps blood to all other parts of the body.

■Valves ensure that blood can flow only in one direction through the heart.

■The walls of the **atria** are thin. They can be stretched to receive blood as it returns to the heart but can contract with enough force to push blood through the bicuspid and tricuspid valves into the ventricles.

■The walls of the heart are made of **cardiac muscle,** which can contract and then relax continuously without becoming fatigued.

■The cardiac muscle has its own blood supply - the coronary circulation. Blood reaches the muscle via **coronary arteries.** These carry blood to capillaries that supply the heart muscle with oxygen and nutrients. Blood is returned to the right atrium via **coronary veins.**



▲ Figure 5.7 A blockage of a coronary artery cuts off the blood supply to part of the heart muscle.

The coronary heart disease

The coronary arteries, narrow and easily blocked by fatty substances like cholesterol, can cut off blood supply to cardiac muscle, preventing oxygen and glucose delivery, leading to heart attacks. This is called **coronary heart disease** (CHD). It can lead to severe health problems and is often fatal.

Several factors make coronary heart disease more likely:

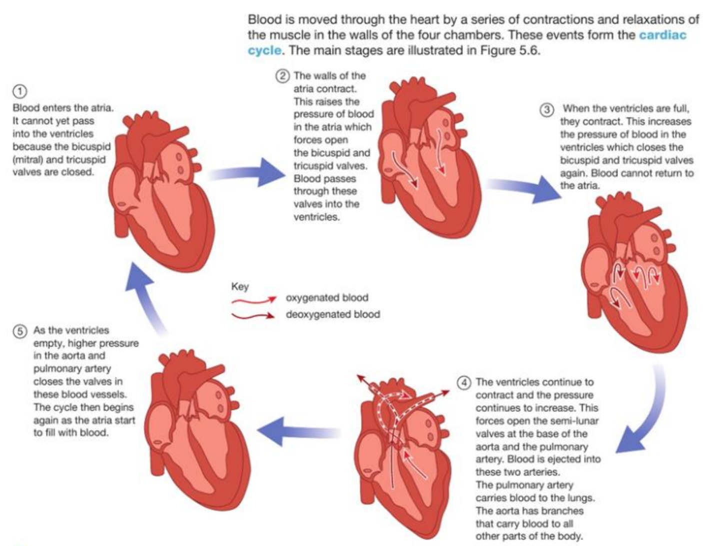
■Heredity - some people inherit a tendency to develop coronary heart disease

■High blood pressure - puts more strain on the heart

■Diet - eating large amounts of saturated fat is likely to raise cholesterol levels

■Smoking - raises blood pressure and makes blood clots more likely to form stress - raises blood pressure

■Lack of exercise - regular exercise helps to reduce blood pressure and strengthens the heart.



▲ Figure 5.6 The cardiac cycle.

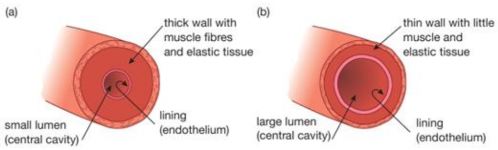


Figure 5.9 The structure of (a) an artery and (b) a vein as seen in cross section.

Veins also have **semilunar** (half-moon shaped) **valves**, which prevent the backflow of blood. The action of these valves is explained in Figure 5.10.

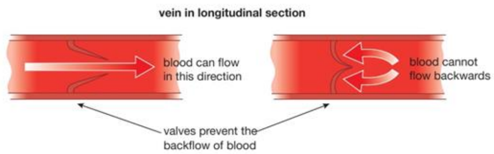


Figure 5.10 The action of semilunar valves in veins

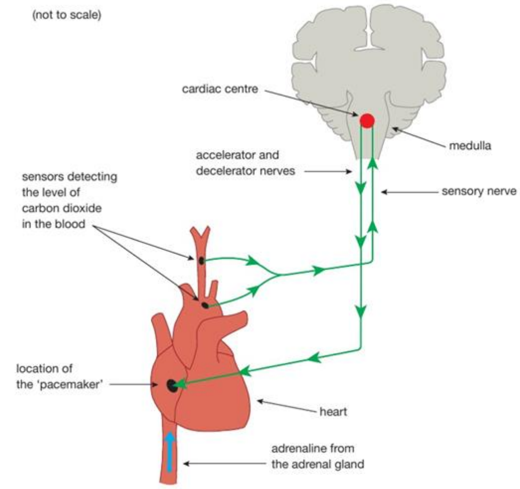


Figure 5.8 How the heart rate is controlled.

Heart rate

When we are angry or afraid our heart rate again increases.
The increased output supplies extra blood to the muscles, enabling them to release extra energy through aerobic respiration. This allows us to fight or run away and is called the 'fight or flight' response. It is triggered by **secretion** of the hormone **adrenaline** from the adrenal glands

These changes in the heart rate are controlled by nerve impulses from a part of the brain called the medulla (Figure 5.8).

The accelerator nerve increases the heart rate. It also causes the heart to beat with more force and so increases blood pressure. The decelerator nerve decreases the heart rate. It also reduces the force of the contractions. Blood pressure then returns to normal.

Arteries, veins and capillaries

Arteries - Arteries transport blood from the heart to body organs, pumped out by ventricles at high pressure. Elastic tissue and muscular walls maintain blood pressure and control flow.

Veins - Veins carry blood from organs to the heart, with lower pressure than arteries. They are thinner and contain less elastic tissue and muscle, as shown in Figure 5.9.

Capillaries - Capillaries transport blood through organs, bringing blood close to every cell. They facilitate substance transfer by being small enough to fit between cells and allowing materials to pass easily through their walls. Red blood cells fit through these capillaries, allowing oxygen to diffuse quickly.

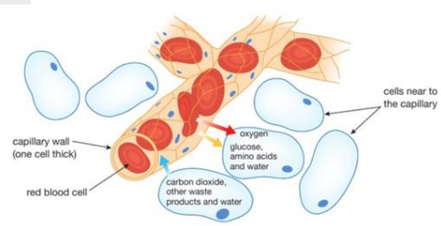


Figure 5.11 How capillaries exchange materials with cells

Figure 5.12 The lumen of the artery is the same size as the lumen of the vein – but note the difference in the thickness of the walls of these two vessels.

The composition of blood

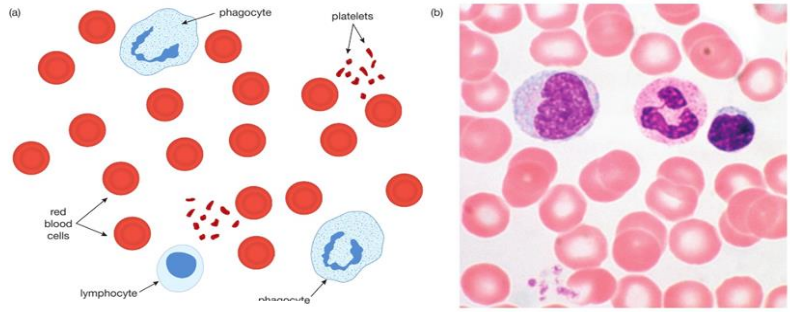
Blood is a lot more than just a red liquid flowing through your arteries and veins! In fact, blood is a complex tissue. Figure 5.13 illustrates the main types of cells found in blood.

Red blood cells

The red blood cells or **erythrocytes** are highly specialised cells made in the bone marrow. They have a limited life span of about 100 days after which time they are destroyed in the spleen. They have only one function - to transport oxygen. Several features enable them to carry out this function very efficiently.

Red blood cells contain **haemoglobin**. This is an iron-containing protein that associates (combines) with oxygen to form **oxyhaemoglobin**.

As red blood cells pass through the lungs, they load oxygen. As they pass through active tissues they unload oxygen.



m of the different cells. (b) A blood smear seen through a light microscope. The smear shows blood cell.

$$\text{haemoglobin} + \text{oxygen} \underset{\text{in the tissues}}{\overset{\text{in the lungs}}{\rightleftharpoons}} \text{oxyhaemoglobin}$$

White bloods cells

Table 5.1 Functions of the different components of blood.

COMPONENT OF BLOOD	DESCRIPTION OF COMPONENT	FUNCTION OF COMPONENT
plasma	liquid part of blood: mainly water	carries the blood cells around the body; carries dissolved nutrients, hormones, carbon dioxide and urea; also distributes heat around the body
red blood cells (erythrocytes)	biconcave, disc-like cells with no nucleus; millions in each mm^3 of blood	transport of oxygen – contain mainly haemoglobin, which loads oxygen in the lungs and unloads it in other regions of the body
WHITE BLOOD CELLS:		
lymphocytes	about the same size as red cells with a large spherical nucleus	produce antibodies to destroy microorganisms – some lymphocytes persist in our blood after infection and give us immunity to specific diseases
phagocytes	much larger than red cells, with a large spherical or lobed nucleus	digest and destroy bacteria and other microorganisms that have infected our bodies
platelets	the smallest cells – are really fragments of other cells	release chemicals to make blood clot when we cut ourselves

There are several types of white blood cell. Their main role is to protect the body against invasion by disease-causing microorganisms (pathogens), such as bacteria and viruses. They do this in two main ways: **phagocytosis** and production of **antibodies.**

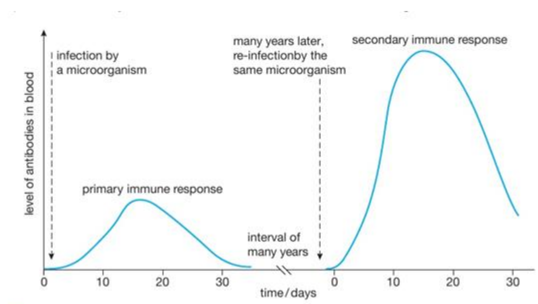
About 70% of white blood cells can ingest (take in) microorganisms such as bacteria. This is called **phagocytosis,** and the cells are phagocytes. They do this by changing their shape, producing extensions of their cytoplasm, called **pseudopodia.**

Approximately 25% of white blood cells are **lymphocytes**. Their function is to make chemicals called **antibodies.** Antibodies are soluble proteins that pass into the plasma. Pathogens such as bacteria and viruses have chemical 'markers' on their surfaces, which the antibodies recognise. These markers are called **antigens.** The antibodies stick to the surface antigens and destroy the pathogen.

Immunity

Some lymphocytes do not get involved in killing microorganisms straight away. Instead, they develop into **memory cells.** These cells remain in the blood for many years, sometimes a lifetime.

This secondary **immune response** is much faster and more effective than the primary response. The number of antibodies in the blood quickly rises to a high level, killing the microorganisms before they have time to multiply to a point where they would cause disease. This is shown in Figure 5.15.



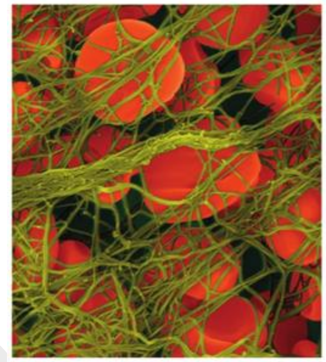
▲ Figure 5.15 The primary and secondary immune responses

Vaccination is a method of artificial immunity to a disease-causing organism without contracting the disease itself. It involves injecting an agent with the same antigens, which lymphocytes recognize and multiply. This secondary immune response, if present, may prevent the pathogen from reproducing and causing the disease.

Some agents used as vaccines are:

■A weakened strain of the actual microorganism, e.g. vaccines against polio, tuberculosis (TB) and measles
■Dead microorganisms, e.g. typhoid and whooping cough vaccines
■Modified toxins of the bacteria, e.g. tetanus and diphtheria vaccines just the antigens themselves,

■Harmless bacteria, genetically engineered to carry the antigens of a different, disease-causing microorganism,



▲ Figure 5.16 Red blood cells trapped in fibres of fibrin, forming a blood clot.

Platelets

Platelets, bone marrow fragments, are stimulated by air exposure to skin damage, causing the soluble plasma protein **fibrinogen** to transform into fibrin. This **fibrin** forms a network across the wound, trapping red blood cells and forming a clot to prevent further blood loss and pathogen entry. The clot develops into a scab, protecting damaged tissue while new skin grows.

Chapter 06

2.6 Coordination

Stimulus and response

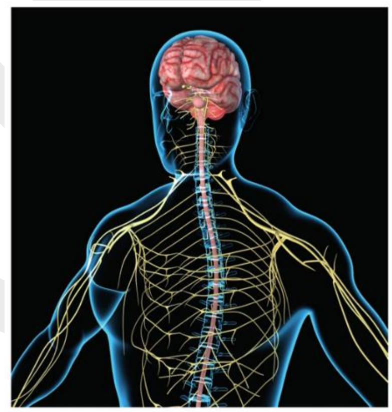


Figure 6.2 The brain and spinal cord form the central nervous system. Cranial and spinal nerves lead to and from the CNS. The CNS sorts out information from the senses and sends messages to muscles.

When walking, a high-speed football approaching your head may prompt you to move or duck to avoid contact. In a hungry situation, your mouth may water, causing saliva to be secreted.

Each of these situations is an example of a **stimulus** and a **response**. A stimulus is a change in an animal's surroundings, and a response is a reaction to that change. The change in your environment was detected by your eyes, which are an example of a **receptor** organ. The response was brought about by contraction of muscles, which are a type of **effector** organ (they produce an effect).

The nervous system links the two and is an example of a coordination system. A summary of the sequence of events is:

stimulus → receptor → coordination → effector → response

The nose acts as a receptor for food smell, triggering saliva secretion from glands. Glands release chemical substances, and the nervous system links the stimulus and response. The information in the nerve cells is transmitted in the form of tiny electrical signals called **nerve impulses.**

Receptors

The role of any receptor is to detect the stimulus by changing its energy into the electrical energy of the nerve impulses. For example, the eye converts light energy into nerve impulses, and the ear converts sound energy into nerve impulses (Table 6.1).

Table 6.1 Human receptors and the energy they receive.

Receptor	Type of energy received
eye (retina)	light
ear (organ of hearing)	sound
ear (organ of balance)	mechanical (kinetic)
tongue (taste buds)	chemical
nose (organ of smell)	chemical
skin (touch/pressure/pain receptors)	mechanical (kinetic)
skin (temperature receptors)	heat
muscle (stretch receptors)	mechanical (kinetic)

The central system

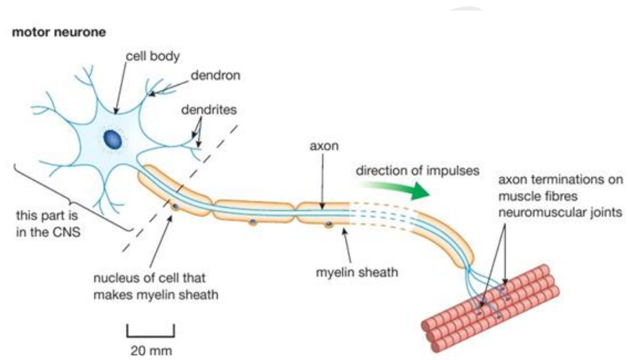
The biological name for a nerve cell is a **neurone**. The impulses that travel along a neurone are not an electric current, as in a wire.

Impulses from receptors pass along nerves **containing sensory neurones,** until they reach the brain and spinal cord. These two organs are together known as the **central nervous system, or CNS** (Figure 6.2).

Other nerves contain **motor neurones,** transmitting impulses to the muscles and glands. Some nerves contain only sensory or motor cells, while other nerves contain both - they are 'mixed'. A typical nerve contains thousands of individual neurones.

The structure of neurons

The cell body of a motor neurone is at one end of the fibre, in the CNS. The cell body has fine cytoplasmic extensions, called **dendrons**. These in turn form finer extensions, called **dendrites**. There can be junctions with other neurones on any part of the cell body, dendrons or dendrites. These junctions are called **synapses**.
This is the fibre that carries impulses to the effector organ and is called the **axon**. At the end of the axon furthest from the cell body, it divides into many nerve endings. These fine branches of the axon connect with a muscle at a special sort of synapse called a **neuromuscular junction.**



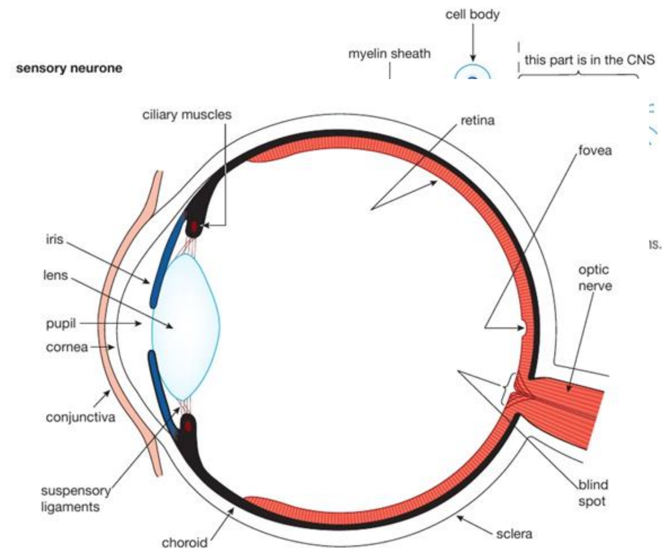
The signals from nerve impulses are transmitted across the neuromuscular junction, causing the muscle fibres to contract. The axon is covered by a sheath made of a fatty material called **myelin**. The **myelin sheath** insulates the axon, preventing 'short circuits' with other axons, and speeds up the conduction of the impulses.

A **sensory neurone** has a similar structure to the motor neurone, but the cell body is located on a side branch of the fibre, just outside the CNS.

▲ Figure 6.3 The structure

The eye

The tough outer coat of the eye is called the **sclera,** which is the visible, white part of the eye. At the front of the eye the sclera becomes a transparent 'window' called the **cornea**, which lets light into the eye. Behind the cornea is the coloured ring of tissue called the **iris**. In the middle of the iris is a hole called the **pupil**, which lets the light through. It is black because there is no light escaping from the inside of the eye.



▲ Figure 6.4 A horizontal section through the human eye

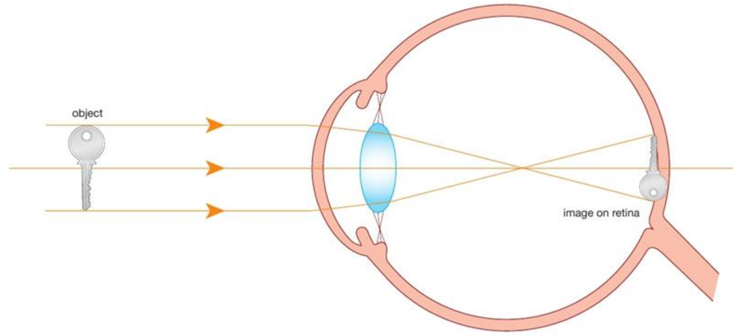
The innermost layer of the back of the eye is the **retina**. This is the light- sensitive layer, the place where light energy is converted into the electrical energy of nerve impulses. The retina contains receptor cells called **rods** and **cones**. These cells react to light, producing impulses in sensory neurones. The sensory neurones then pass the impulses to the brain through the **optic nerve.**

Rod cells work well in dim light but cannot distinguish colors, resulting in black and white images. Cones, responding to red, green, and blue wavelengths, work in bright light, allowing us to see all visible light colors due to different stimulation levels.

For example, if red, green and blue are stimulated equally, we see white. Both rods and cones are found throughout the retina, but cones are particularly concentrated at the centre of the retina, in an area called the **fovea**.

Forming an image

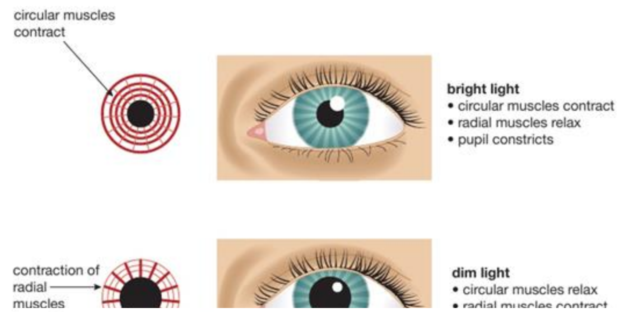
To form an image on the retina, light needs to be bent or refracted. Refraction takes place when light passes from one medium to another of a different density. In the eye, this happens first at the air/cornea boundary, and again at the lens (Figure 6.5). In fact the cornea acts as the first lens of the eye.



▲ Figure 6.5 How the eye forms an image. Refraction of light occurs at the cornea and lens, producing an inverted image on the retina.

The iris reflex

The iris controls light intake by altering the pupil size. It contains circular and radial muscles. In bright light, the pupil is constricted, while in dim light, it widens due to the contraction of radial muscles.



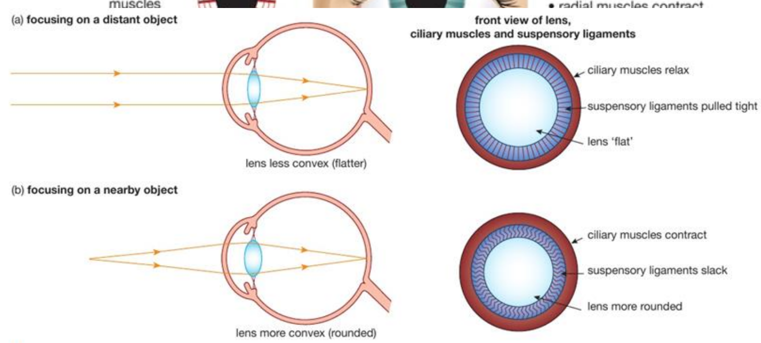
Whenever our eyes look from a dim light to a bright one, the iris rapidly and automatically adjusts the pupil size. This is an example of a **reflex action.**

The blind spot

The **blind spot** is an area of the retina where the optic nerve leaves the eye, without rods or cones. Both eyes have blind spots, but the brain cancels them out. The optic nerve leaves the eye towards the edge, where vision is less sharp. To see your own blind spot, cover or close your right eye and read numbers from left to right.

Accommodation

The changes that take place in the eye which allow us to see objects at different distances are called **accommodation.**



▲ Figure 6.7 Accommodation: how the eye focuses on objects at different distances

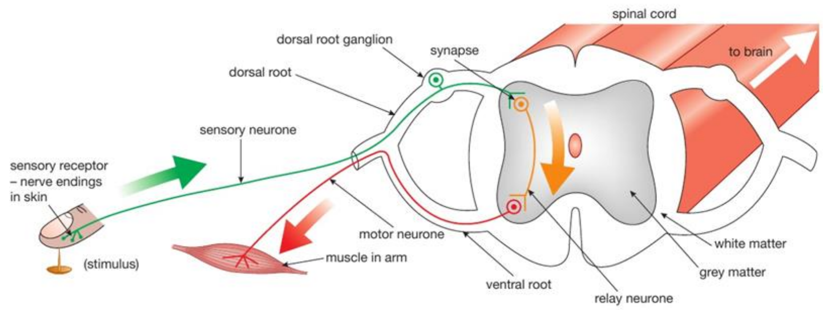
Figure 6.4 shows that the lens is held in place by a series of fibres called the **suspensory ligaments.** These are attached like the spokes of a wheel to a ring of muscle, called the **ciliary muscle.**

Reflex actions

The nerve pathway of a reflex is called the **reflex arc**. The 'arc' part means that the pathway goes into the CNS and then straight back out again, in a sort of curve or arc (Figure 6.8).

The impulses enter the CNS through a part of the spinal nerve called the **dorsal root.** In the spinal cord the sensory neurones connect by synapses with short **relay neurones,** which in turn connect with motor neurones. The motor neurones emerge from the spinal cord through the **ventral root** and send impulses back out to the muscles of the arm.

The middle part of the spinal cord consists mainly of nerve cell bodies, which gives it a grey colour. This is why it is known as **grey matter.** The outer part of the spinal cord is called **white matter** and has a whiter appearance because it contains many axons with their fatty myelin sheaths.



▲ Figure 6.9 A reflex arc in more detail

Synapses

Synapses are crucial for the functioning of the nervous system, connecting billions of nerve cells in the CNS. Each neuron may form synapses with thousands of others, forming between 100 and 1000 million million synapses in the brain. Synapses are gaps between nerve cells, crossed by chemicals, causing neurotransmitters to diffuse and attach to the second neurone's membrane, initiating impulses.

2.7 Chemical coordination

Glands and hormones

A gland is an organ that releases or secretes a substance. This means that cells in the gland make a chemical which leaves the cells through the cell membrane. The chemical then travels somewhere else in the body, where it carries out its function. There are two types of glands - exocrine and **endocrine glands. Exocrine glands** secrete their products through a tube called a duct. Instead, their products, **the hormones,** are secreted into the blood vessels that pass through the gland (Figure 7.1).

▲ Figure 7.1 Exocrine glands secrete their products though a duct, while endocrine glands secrete hormones into the blood.

Hormones only affect tissues or organs if the cells of that tissue or organ have special chemical receptors for the hormone. For example, the hormone **insulin** affects the cells of the liver, which have insulin receptors.

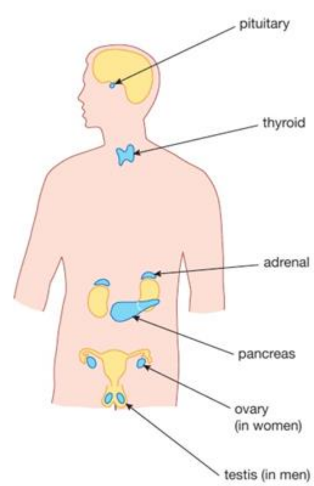
The differences between nervous and endocrine control

Although the nervous and endocrine systems both act to coordinate body functions, there are differences in the way that they do this. These are summarised in Table 7.1.

The endocrine glands

The **pituitary gland** (often just called 'the pituitary') is found at the base of the brain. It produces several hormones, including **antidiuretic hormone (ADH**), which acts on the kidneys, controlling the amount of water in the blood. The pituitary also releases hormones that regulate reproduction

Just above the pituitary is a part of the brain called the **hypothalamus**.



▲ Figure 7.2 The main endocrine glands of the body.

Table 7.1 The nervous and endocrine systems compared.

Nervous system	Endocrine system
works by nerve impulses transmitted through nerve cells (although chemicals are used at synapses)	works by hormones transmitted through the bloodstream
nerve impulses travel fast and usually have an 'instant' effect	hormones travel more slowly and generally take longer to act
response is usually short-lived	response is usually longer-lasting
impulses act on individual cells such as muscle fibres, so have a very localised effect	hormones can have widespread effects on different organs (although they only act on particular tissues or organs if the cells have the correct receptors)

The **pancreas** is both an endocrine and an exocrine gland. It secretes two hormones involved in the regulation of blood glucose, and is also a gland of the digestive system, secreting enzymes through the pancreatic duct into the small intestine (see Chapter 4). The sex organs of males (**testes**) and females (**ovaries**) are also endocrine organs.

Adrenaline the "fight or flight" hormone

When you are frightened, excited or angry, your adrenal glands secrete the hormone **adrenaline**.

Adrenaline acts at several target organs and tissues, preparing the body for action. In animals other than humans this action usually means dealing with an attack by an enemy, where the animal can stay and fight or run away - hence 'fight or flight'. This is not often a problem with humans, but there are plenty of other times when adrenaline is released (Figure 7.3).

If an animal's body is going to be prepared for action, the muscles need a good supply of oxygen and glucose for respiration. Adrenaline produces several changes in the body that make this happen (Figure 7.4) as well as other changes to prepare for fight or flight.

Insulin control of blood glucose

Adrenaline raises blood glucose from liver stores, which contain **glycogen**, a good storage product. When the body lacks glucose, glycogen is broken down into glucose, which enters the bloodstream. Insulin, made by pancreatic cells, controls glucose levels by stimulating liver cells to convert glucose into glycogen.

Table 7.2: Some of the main endocrine glands, the hormones they produce and their functions.

Gland	Hormone	Some functions of the hormones
pituitary	follicle stimulating hormone (FSH)	stimulates egg development and oestrogen secretion in females and sperm production in males
	luteinising hormone (LH)	stimulates egg release (ovulation) in females and testosterone production in males
	antidiuretic hormone (ADH)	controls the water content of the blood
thyroid	thyroxine	controls the body's metabolic rate (how fast chemical reactions take place in cells)
pancreas	insulin	lowers blood glucose
	glucagon	raises blood glucose
adrenals	adrenaline	prepares the body for physical activity
testes	testosterone	controls the development of male secondary sexual characteristics
ovaries	oestrogen	controls the development of female secondary sexual characteristics
	progesterone	regulates the menstrual cycle

Figure 7.4 Adrenaline affects the body of an animal in many ways.

Diabetes

Diabetes is a condition where the pancreas cannot produce enough insulin to maintain blood glucose levels, leading to high concentrations. Symptoms can be detected through urine tests, which show glucose excretion in the blood.

Chapter 08

Homeostatic and excretion

Inside our bodies, conditions are kept relatively constant. This is called **homeostasis**. The kidneys are organs which have a major role to play in both homeostasis and in the removal of waste products, or excretion.

The inside of the body is known as the **internal environment**. You have probably heard of the 'environment', which means the 'surroundings' of an organism. The internal environment is the surroundings of the cells inside the body. It particularly means the blood, together with another liquid called **tissue fluid.**

Table 8.1 Some of the main solutes in urine.

Substance	Amount / g per dm^3
urea	23.3
ammonia	0.4
other nitrogenous waste	1.6
sodium chloride (salt)	10.0
potassium	1.3
phosphate	2.3

Urine

An adult human produces about 1.5 dm3 of urine every day, although this volume depends very much on the amount of water drunk and the volume lost in other forms, such as sweat. Every litre of urine contains about 40 g of waste products and salts (Table 8.1).

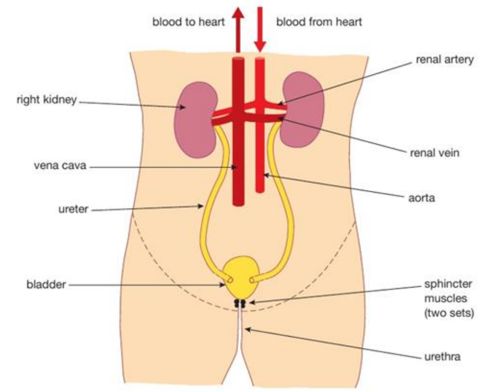


Figure 8.2 The human urinary system

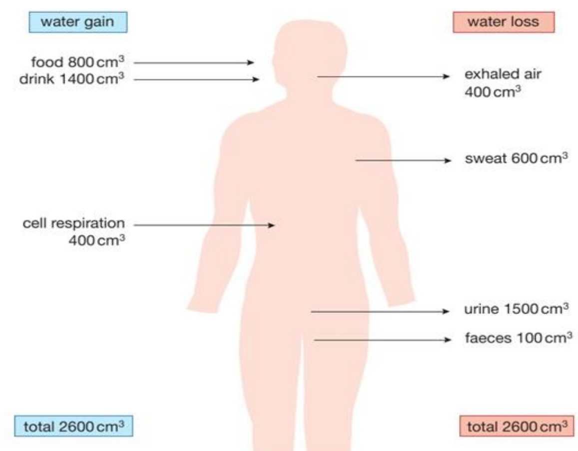


Figure 8.1 The daily water balance of an adult

The kidneys

There is not much that you can make out without the help of a microscope. The darker outer region is called the **cortex**.. They are the filtering units, called kidney tubules or **nephrons** (from the Greek word nephros, meaning kidney). The tubules then run down through the middle layer of the kidney, called the **medulla**. The tubules in the medulla eventually join up and lead to the tips of these pyramids, where they empty urine into a funnel-like structure called the **pelvis**. The pelvis connects with the ureter, carrying the urine to the bladder.

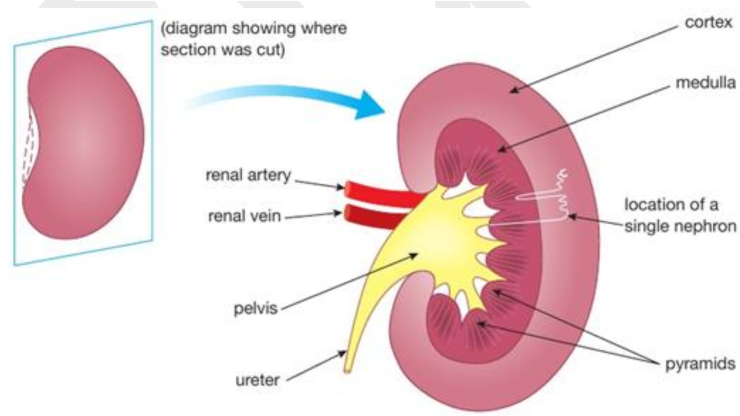


Figure 8.3 Section through a kidney cut along the plane shown.

Structure of the nephron

By careful dissection, biologists have been able to work out the structure of a single tubule and its blood supply (Figure 8.4). There are about a million of these in each kidney.
Ultrafiltration in the bowman's capsule
At the start of the nephron is a hollow cup of cells called the **Bowman's capsule**. It surrounds a ball of blood capillaries called a **glomerulus** (plural glomeruli).The smallest arteries (arterioles) supply the capillaries of the glomerulus (Figure 8.5).

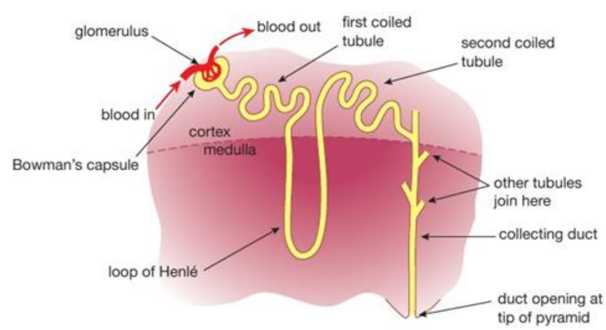


Figure 8.4 A single nephron, showing its position in the kidney. Each kidney contains about a million of these filtering units.

Between the two cell layers is a third layer called the **basement membrane**, which is not made of cells. These layers act like a filter, allowing water, ions, and small molecules like glucose and urea to pass through, but holding back blood cells and large molecules such as proteins. The fluid that enters the capsule space is called the **glomerular filtrate**. This process, where the filter separates different- sized molecules under pressure, is called **ultrafiltration.**

Changes to the filtrate in the rest of the nephron

There are two coiled regions of the tubule in the cortex, separated by a U-shaped loop that runs down into the medulla of the kidney, called the **loop of Henlé**. After the second coiled tubule, several nephrons join up to form a **collecting duct**, where the final urine passes out into the pelvis.

Samples 1-4 analyze blood before entering the glomerulus and at three points inside the tubule. The flow rate measures water content in the tubule, with a decrease from 100% to 50% indicating water has passed back into the blood. Concentrations of dissolved protein, glucose, urea, and sodium are shown by different letters. In the blood, protein is zero, while other substances are at the same concentration. Sample 3 shows a 20% flow rate, indicating 80% of water has been reabsorbed back into the blood. Glucose concentration remains zero, as glucose is taken back into the blood. Sample 4 shows a 1% flow rate, indicating 99% of water has been reabsorbed. Other solutes, like ammonium ions, are concentrated in urine by different amounts.

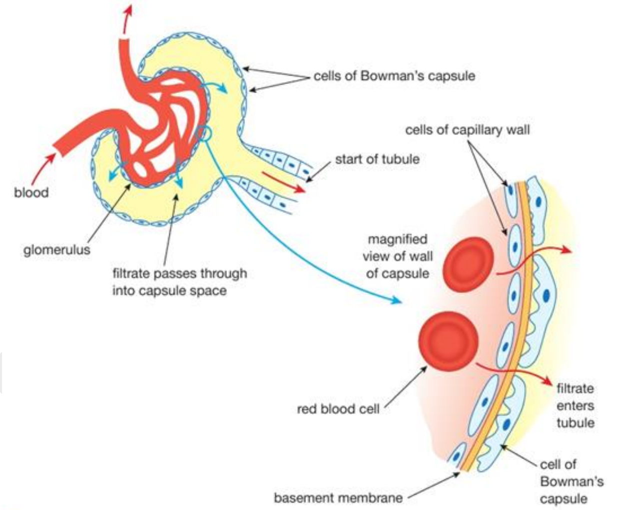


Figure 8.5 A Bowman's capsule and glomerulus

The loop of Henle

The loop of Henlé is a complex biological mechanism that concentrates fluid in the tubule by reabsorbing more water into the blood. Mammals with long loops produce more concentrated urine, while those with short loops conserve water. Desert animals have many long loops, while otters and beavers have short loops.

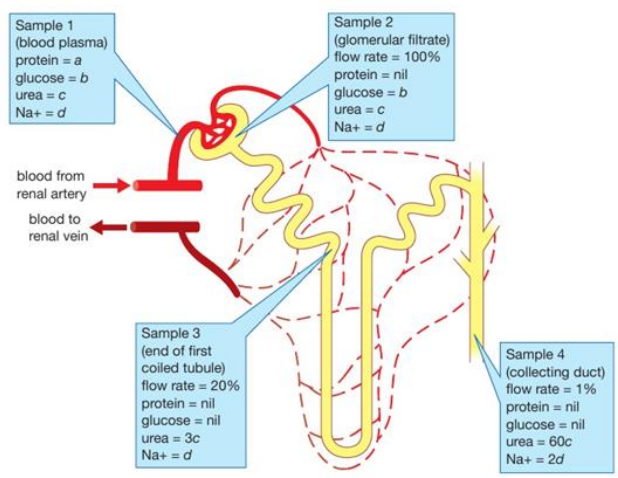


Figure 8.6 A nephron and its blood supply. Samples 1–4 show what is happening to the fluid as it travels along the nephron.

The control of body water content

The kidneys can produce more concentrated urine than the blood and regulate the water content of the blood. When the body loses too much water, it causes the blood's concentration to increase, causing the pituitary gland to release more antidiuretic hormone (ADH). This hormone travels to the kidneys, making the collecting ducts more permeable to water, resulting in more water being reabsorbed back into the blood. This makes the urine more concentrated, causing the body to lose less water and the blood to become more dilute. This action illustrates the principle of negative feedback, where a change in conditions in the body is detected and starts a process to return to normal. When the blood's water content returns to normal, ADH release is switched off, resulting in less water reabsorption.

Control of body temperature

Homeothermic animals maintain their body temperature constant despite changes in their surroundings, such as humans maintaining a constant 37°C. Endotherms, on the other hand, use physiological changes to generate or lose heat, such as sweating and blood flow through the skin. They also use behavioral methods to control their temperature, such as penguins huddled together or humans wearing extra clothes in winter. The advantage of maintaining a body temperature of 37°C is that all chemical reactions in the body can continue at a steady, predictable rate. This allows metabolism to continue in cold environments, and enzymes work best at 37°C. Endotherms have evolved a body temperature around 40°C and enzymes that work best at this temperature.

Monitoring body temperature

The **thermoregulatory centre**, located in the hypothalamus, is responsible for monitoring the core body temperature in humans and other mammals. It sends electrical impulses to the brain when exposed to warm or cold environments, causing changes in behavior. If these changes are insufficient, the centre detects blood temperature changes and sends signals to other organs.

The skin and temperature control

The human skin has a number of functions related to the fact that it forms the outer surface of the body. These include:

- Forming a tough outer layer able to resist mechanical damage
- Acting as a barrier to the entry of pathogens
- Forming an impermeable surface, preventing loss of water
- Acting as a sense organ for touch and temperature changes
- Controlling the loss of heat through the body surface.

Figure 8.9 shows the structure of human skin. It is made up of three layers: the epidermis, dermis and hypodermis.

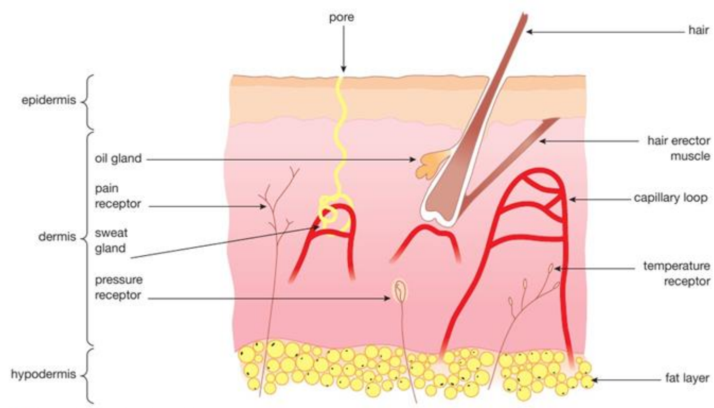


Figure 8.9 A section through human skin

The outer **epidermis** consists of dead cells that stop water loss and protect the body against invasion by microorganisms such as bacteria. The **hypodermis** contains fatty tissue, which insulates the body against heat loss and is a store of energy. The middle layer, the **dermis**, contains many sensory receptors.

First, the **sweat glands** produce greater amounts of sweat. This liquid is secreted onto the surface of the skin. When a liquid evaporates, it turns into a gas. This change needs energy, called the latent heat of vaporisation.

Secondly, hairs on the surface of the skin lie flat against the skin's surface. This happens because of the relaxation of tiny muscles called **hair erector muscles** attached to the base of each hair.

Lastly, there are tiny blood vessels called capillary loops in the dermis. Blood flows through these loops, radiating heat to the outside, and cooling the body down. If the body is too hot, arterioles (small arteries) leading to the capillary loops dilate (widen). This increases the blood flow to the skin's surface (Figure 8.10) and is called **vasodilation.**

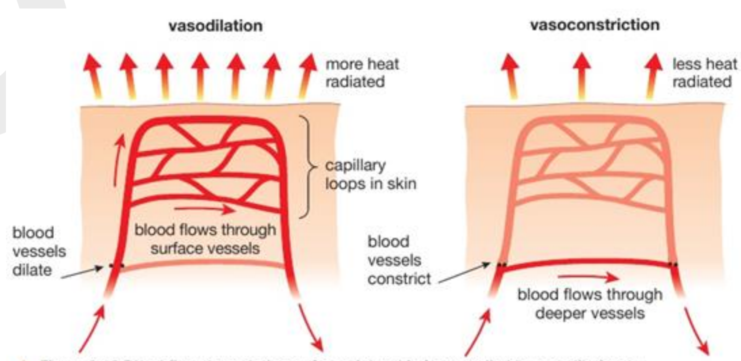


Figure 8.10 Blood flow through the surface of the skin is controlled by vasodilation or vasoconstriction.

In cold conditions, the opposite happens. The arterioles leading to the surface capillary loops constrict (become narrower) and blood flow to the surface of the skin is reduced, so that less heat is lost. This is called **vasoconstriction.**

There are other ways that the body can control heat loss and heat gain. In cold conditions, the body's metabolism speeds up, generating more heat. The liver, a large organ, can produce a lot of metabolic heat in this way. The hormone adrenaline stimulates the increase in metabolism. Shivering also takes place, where the muscles contract and relax rapidly. This also generates a large amount of heat.

Unit 09

Sexual and asexual reproductive compared

In any method of reproduction, the result is the production of more organisms of the same species. Humans produce more humans; pea plants produce more pea plants and salmonella bacteria produce more salmonella bacteria. However, the way in which they reproduce differs. There are two types of reproduction: **sexual reproduction** and **asexual reproduction.**

In sexual reproduction, specialised sex cells called **gametes** are produced. There are usually two types, a mobile male gamete called a **sperm**, and a stationary female gamete called an egg cell or **ovum** (plural **ova**).

The sperm must move to the egg and fuse (join) with it. This is called **fertilisation** (Figure 9.1). The single cell formed by fertilisation is called a **zygote**. This cell will divide many times by mitosis to form all the cells of the new animal.

▲ Figure 9.2 *Hydra* reproducing asexually by budding

All the offspring produced from Hydra buds are genetically identical - they have the same genes. This is because all the cells of the new individual are produced by **mitosis** from just one cell in the body of the adult.

Sexual reproduction

There are four stages in any method of sexual reproduction.

■Gametes (sperm and egg cells) are produced.

■The male gamete (sperm) is transferred to the female gamete (egg cell).

■Fertilisation must occur - the sperm fuses with the egg.

■The zygote formed develops into a new individual.

The offspring produced by sexual reproduction show a great deal of genetic variation because of both gamete production and fertilisation.

Production of gametes

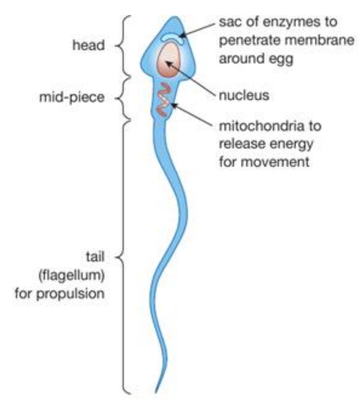
Sperm are produced in the male sex organs - the testes. Eggs are produced in the female sex organs - the ovaries. Both are produced when cells inside these organs divide. These cells do not divide by mitosis but by **meiosis**.

KEY POINT

Cells that have the full number of chromosomes are called **diploid** cells. Cells that only have half the normal number of chromosomes are called **haploid** cells.

Transfer of the sperm to egg.

Sperm, with a tail-like **flagellum**, are specialized for swimming and are used in external fertilisation. Male animals release sperm into water, while females release eggs. Mating behavior ensures male, and female are in the same place, allowing fertilisation to occur before water currents sweep sex cells away.



▲ Figure 9.3 The structure of a sperm

Other male animals, such as those of birds and mammals, **ejaculate** their sperm in a special fluid into the bodies of the females. Internal fertilisation then takes place inside the female's body. Fertilisation is much more likely as there are no external factors to prevent the sperm from reaching the eggs. Some form of **sexual intercourse** precedes ejaculation.

Fertilization

Sperm enters the egg, fuses with the egg nucleus, forming a zygote with 46 chromosomes. In humans, each sperm and egg have 23 chromosomes, forming a zygote.

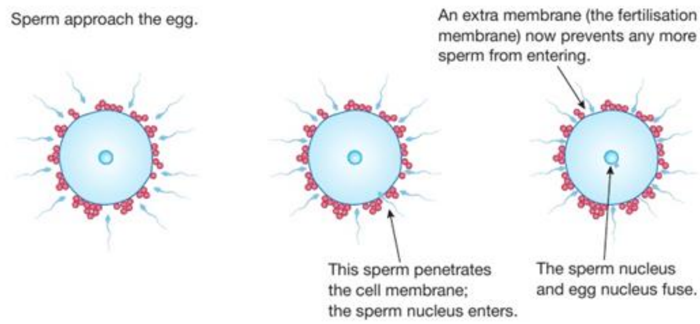


Figure 9.4 The main stages in fertilisation

Summary of the human life cycle

Mitosis is not the only process involved in development, otherwise all that would be produced would be a ball of cells. During the process, cells move around, and different shaped structures are formed. Also, different cells specialise to become bone cells, nerve cells, muscle cells, and so on (the process called **differentiation**.

Reproductive in humans

Humans reproduce sexually and fertilisation is internal. Figures 9.6 and 9.7 show the structure of the human female and male reproductive systems.

The sperm are produced in the testes by meiosis. During sexual intercourse, they pass along the sperm duct and are mixed with a fluid from the seminal vesicles. This mixture, called **semen**, is ejaculated through the urethra into the vagina of the female. The sperm then begin to swim towards the oviducts.

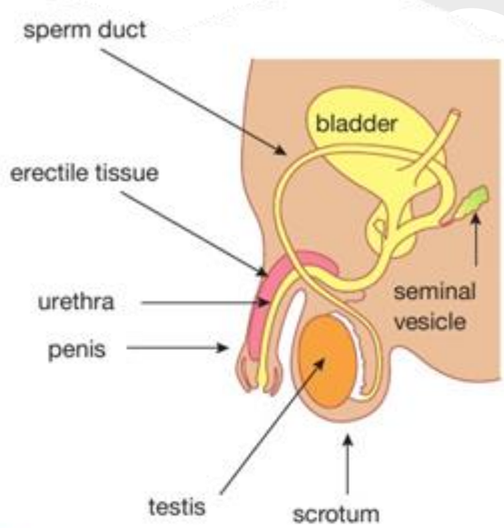


Figure 9.7 The human male reproductive system.

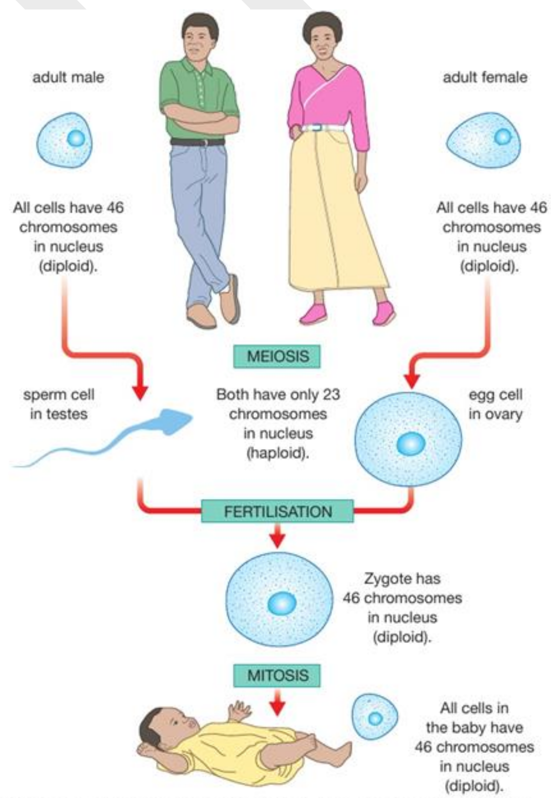


Figure 9.5 The importance of meiosis, mitosis and fertilisation in the human life cycle.

Each month, an egg is released into an **oviduct** from one of the ovaries. (The oviduct is also known as the Fallopian tube.) This is called **ovulation**. If an egg is present in the oviduct, then it may be fertilised by sperm introduced during intercourse. The zygote formed will begin to develop into an **embryo**, which will implant in the lining of the uterus. Here, the embryo will develop a **placenta**, which will allow the embryo to obtain materials such as oxygen and nutrients from the mother's blood.

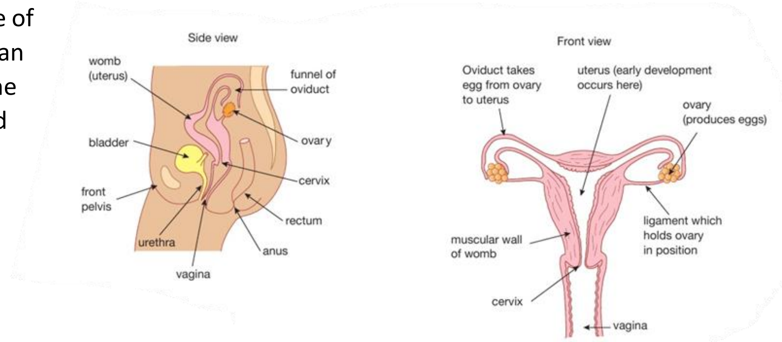


Figure 9.6 The human female reproductive system

During pregnancy, a membrane called the **amnion** encloses the developing embryo. The amnion secretes a fluid called **amniotic fluid**, which protects the developing embryo against sudden movements and bumps. As the embryo develops, it becomes more and more complex. When it becomes recognisably human, we no longer call it an embryo but a **fetus**.

Figure 9.8 also shows the position of a human fetus just before birth.

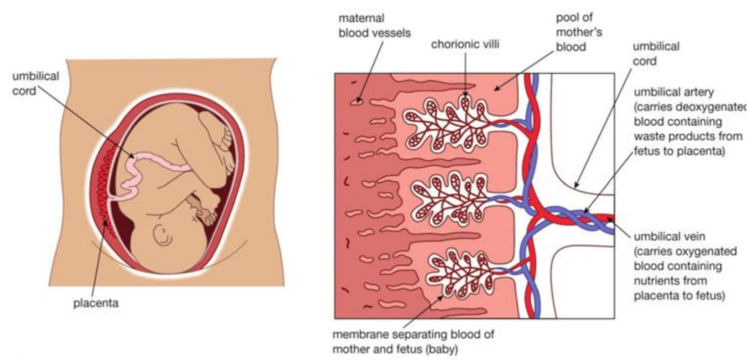


Figure 9.8 The position of the fetus just before birth, and the structure of the placenta.

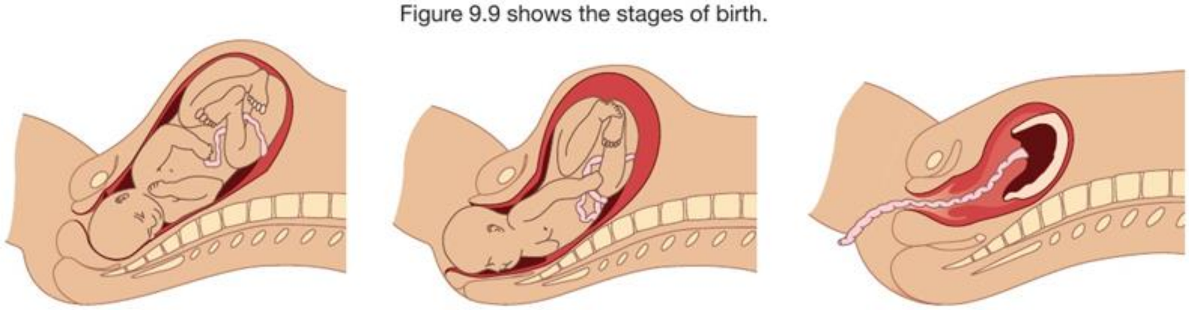
There are three stages to the birth of a child.

1. **Dilation of the cervix**. The cervix is the 'neck' of the uterus. It gets wider to allow the baby to pass through. The muscles of the uterus contract quite strongly and tears the amnion, allowing the amniotic fluid to escape. (In some countries the woman describes this as 'her waters have broken'.)

2. **Delivery of the baby.** Strong contractions of the muscles of the uterus push the baby's head through the cervix and then through the vagina to the outside world.

3. **Delivery of the afterbirth.** After the baby has been born, the uterus continues to contract and pushes the placenta out, together with the membranes that surrounded the baby. These are known as the afterbirth.

Figure 9.9 shows the stages of birth.



1 Baby's head pushes cervix; mucous plug dislodges and waters break.

2 Uterus contracts to push baby out through the vagina.

3 The placenta becomes detached from the wall of the uterus and is expelled through the vagina as the afterbirth.

Figure 9.9 The stages of birth

Hormones controlling reproduction

During their teens, changes happen to boys and girls that lead to sexual maturity. These changes are controlled by hormones, and the time when they happen is called **puberty**. The second is that the bodies of both sexes adapt to allow reproduction to take place. These events are started by hormones released by the pituitary gland called **follicle stimulating hormone (FSH)** and **luteinising hormone (LH).**

In boys, FSH stimulates sperm production, while LH instructs the testes to secrete the male sex hormone, **testosterone.** Testosterone controls the development of the male **secondary sexual characteristics.**

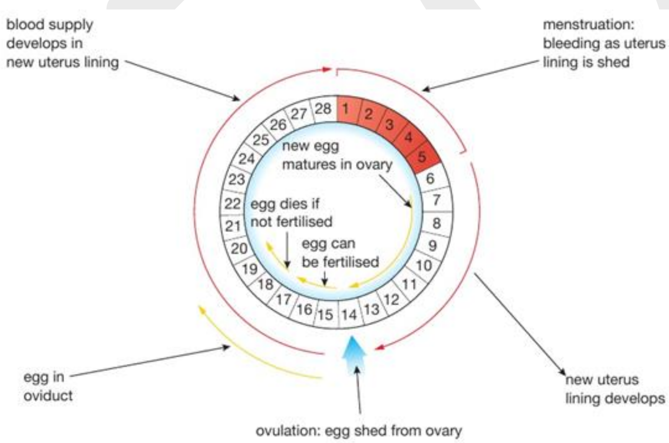
In girls, the pituitary hormones control the release of a female sex hormone called oestrogen, from the ovaries. **Oestrogen** produces the female secondary sexual characteristics.

Table 9.1 Changes at puberty.

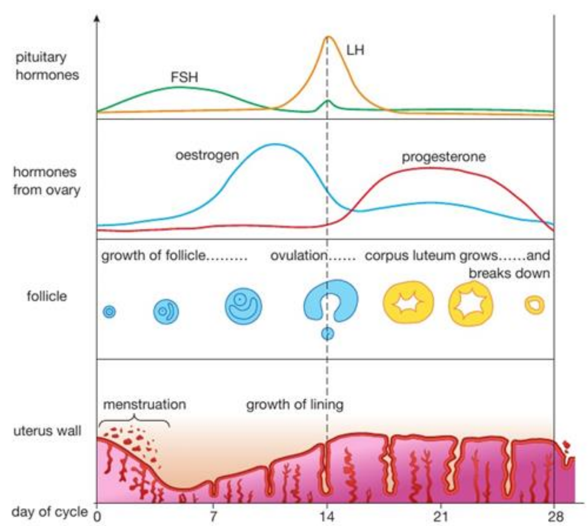
In boys	In girls
sperm production starts	the menstrual cycle begins, and eggs are released by the ovaries every month
growth and development of male sexual organs	growth and development of female sexual organs
growth of armpit and pubic hair, and chest and facial hair (beard)	growth of armpit and pubic hair
increase in body mass; growth of muscles, e.g. chest	increase in body mass; development of 'rounded' shape to hips
voice breaks	voice deepens without sudden 'breaking'
sexual 'drive' develops	sexual 'drive' develops
	breasts develop

Hormones and the menstrual cycle

'Menstrual' means 'monthly', and in most women the **menstrual cycle** takes about a month, although it can vary from as little as two weeks to as long as six weeks (Figures 9.10 and 9.11). In the middle of the cycle is an event called **ovulation**, which is the release of a mature egg cell, or egg.



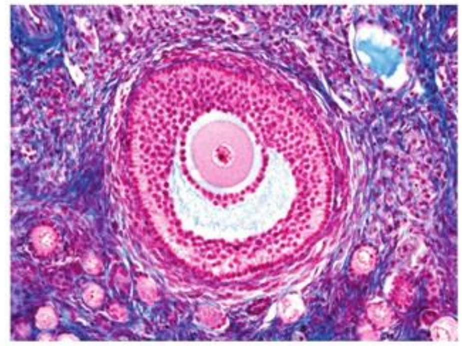
▲ Figure 9.10 The menstrual cycle



▲ Figure 9.11 Changes taking place during the menstrual cycle

One function of the cycle is to control the development of the lining of the uterus (womb), so that if the egg is fertilised, the lining will be ready to receive the fertilised egg. If the egg is not fertilised, the lining of the uterus is lost from the woman's body as the flow of menstrual blood and cells of the lining, called a **period.**

A cycle is a continuous process, so it doesn't really have a beginning, but the first day of menstruation is usually called day 1.



▲ Figure 9.12 Eggs developing inside the follicles of an ovary. The large follicle contains a fully developed egg ready for ovulation.

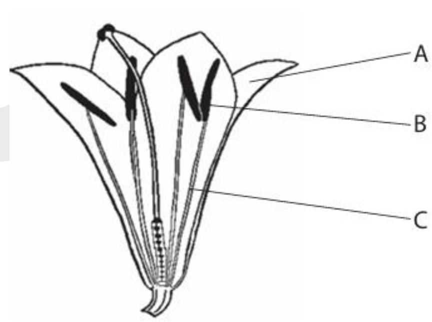
Inside a woman's ovaries are hundreds of thousands of cells that could develop into mature eggs. Every month, one of these grows inside a ball of cells called a **follicle** (Figure 9.12)

After the egg has been released, it travels down the oviduct to the uterus. It is here in the oviduct that fertilisation may happen, if sexual intercourse has taken place. What's left of the follicle now forms a structure in the ovary called the **corpus luteum**. The corpus luteum makes another hormone called **progesterone.**

If, however, the egg is fertilised, the corpus luteum carries on making progesterone, the lining is not shed, and menstruation doesn't happen. The first sign that tells a woman she is pregnant is when her monthly periods stop. Later in pregnancy, the **placenta** secretes progesterone, taking over the role of the corpus luteum.

Revision questions

(1) Plants can reproduce sexually or asexually. Plants that reproduce sexually can be pollinated by insects or by wind. (a) State three ways in which the structure of insect-pollinated flowers differs from the structure of wind-pollinated flowers.



(b) The diagram shows a flower from a plant.
Name the structures labelled on the diagram.
(c) The flower in the diagram is insect pollinated.
An insect carrying pollen lands on the flower.
Describe the events that lead to seed formation

(2) The diagram shows an insect pollinated flower called a lily.

(a) Describe the features of an insect pollinated flower that help it to attract insects.
(b) Sexual reproduction in flowering plants and mammals involves the process of gamete formation by meiosis followed by fertilisation.

Use the words from the box to complete the table about sexual reproduction in flowering plants and mammals.

Each word can be used once, more than once or not at all

anther	copulation	fallopian tube	ovary	ovule
placenta	penis	pollination	seed	testes
uterus	vagina	zygote		

(c) Cell division in an organism can take place by mitosis or by meiosis. Give three ways in which mitosis differs from meiosis.

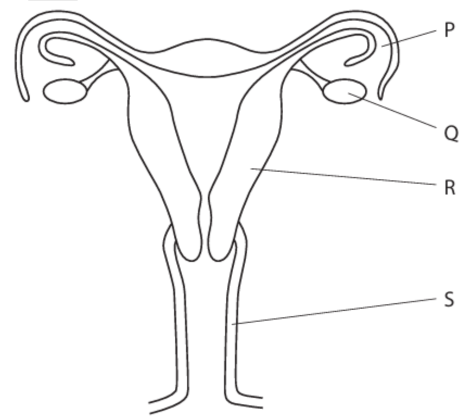
(d) Suggest why a flower grower may want his coloured flowers to reproduce asexually.

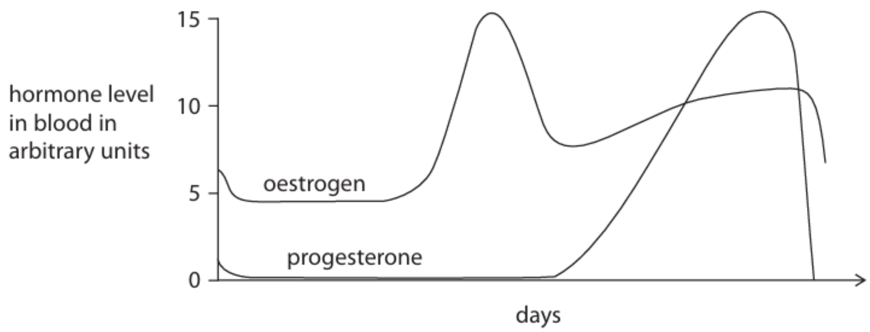
	In flowering plants	In mammals
female gametes are made in the		
male gametes are made in the		
gametes are brought together by		
fertilisation takes place in the		
embryos develop in the		

(3) The diagram shows the structure of the female reproductive organs.

(a) Name the structures labelled in the diagram.

(b) The graph shows changes in the hormones oestrogen and progesterone during a woman's menstrual cycle.





On the graph indicate using

(i) a letter O, the day when ovulation is most likely to occur.

(ii) a letter M, the day when menstruation is likely to start.

(iii)Describe the changes that take place in structure R during the menstrual cycle.

(c) Some women only have sexual intercourse at certain times of their menstrual cycle in order to avoid pregnancy. Explain why this may not be a reliable method of birth control.

(d)Describe the role of oestrogen at puberty.

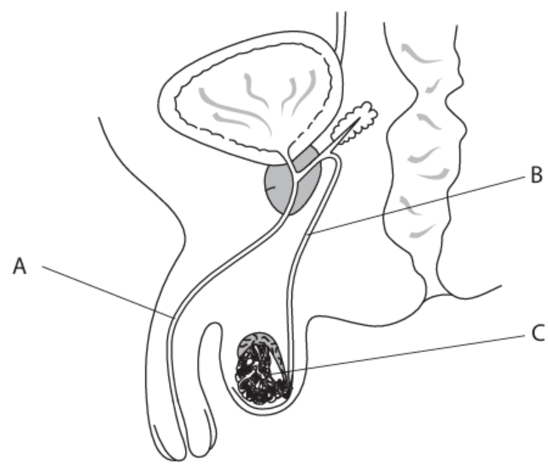
(4) (b) The crosses between the dogs are examples of sexual reproduction.

(i) Name the gametes produced by males in sexual reproduction.

(ii) Name the gametes produced by females in sexual reproduction.

(iii)Give the term used to describe the fusion of gametes.

(iv)In which organ of a female parent do offspring develop?



(5) The diagram shows the male reproductive organs.

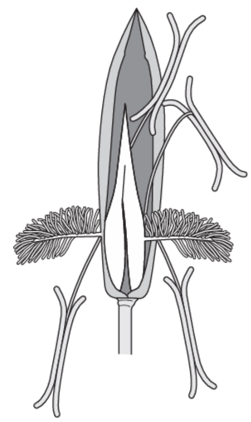
(a) Name the structures labelled A, B and C

(b)A couple want to control their fertility. The man has an operation to cut tube B. Explain how this operation would prevent his partner from becoming pregnant.

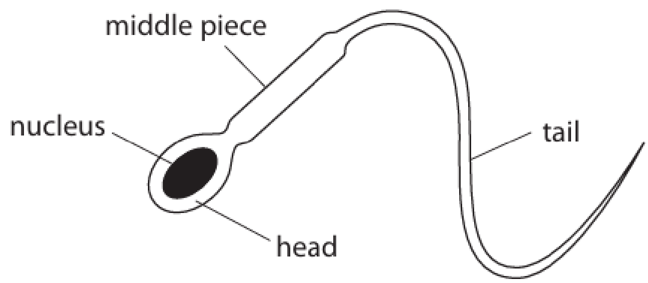
(c) The woman could also have an operation to cut her oviducts to prevent pregnancy. Suggest why the operation to cut tube B in males is much more common than the operation to cut the oviducts in females.

(d) Structure C produces a hormone. Name this hormone and describe its functions.

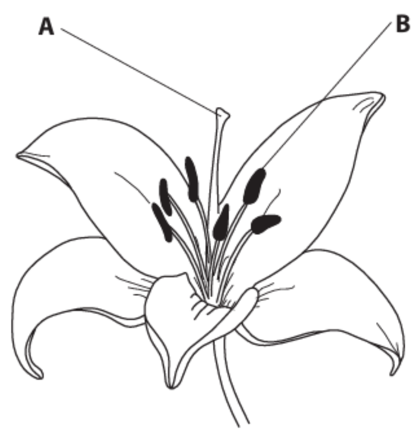
(6) Flowers are reproductive organs. They help flowering plants with sexual reproduction.
(a) Suggest how sexual reproduction makes it more likely that a species can adapt to a changing environment
(b) Some flowering plants transfer their male gametes (pollen) by using insects and others use wind. The diagram shows a plant that is wind-pollinated.
(i) Give two ways you can tell from the diagram that this plant is wind-pollinated
(ii) Suggest why insects rarely visit wind-pollinated flowers.
(c) Some people have an allergy to pollen produced by flowering plants. This is known as hay fever.
(i) Suggest why hay fever tends to be caused by wind-pollinated plants rather than insect pollinated plants.
(ii) Suggest why people only show symptoms of hay fever at certain times of the year.



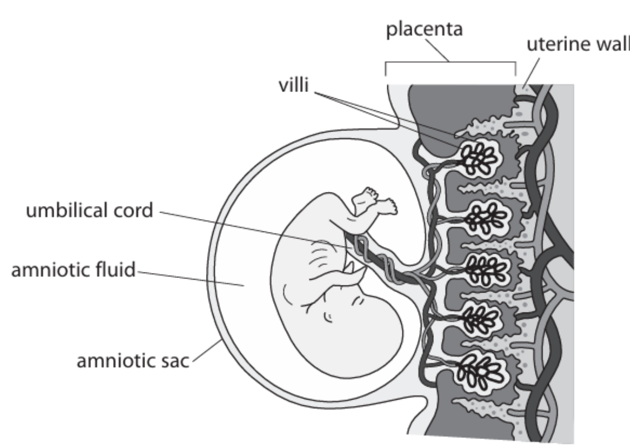
(7) The diagram shows a human sperm cell.
(a) How many chromosomes are there in the nucleus?
(b)Respiration takes place in the middle piece of the sperm cell. Explain why respiration is important to a sperm cell.
(2) (c) A sample of semen contains 40 million sperm cells. Only sixty percent of these sperm cells are capable of swimming. Calculate how many sperm cells in this semen sample are capable of swimming. Show your working



(8) The diagram shows part of a lily. A lily is an insect-pollinated flower.
(a)Name the structures labelled A and B
(b)Describe what is meant by the term insect-pollination.
(c)Give two ways in which the structure of a wind-pollinated flower would differ from the lily flower shown in the diagram
(d)Describe the events that follow pollination and how they lead to seed formation.



(9) The diagram shows a human fetus developing in the uterus.
(a) Describe the function of the amniotic fluid surrounding the fetus.
(b) The placenta functions as an organ of exchange.
(i) Name two substances, required by the fetus, that move from the mother's blood into the blood of the fetus.
(ii) Name two waste substances that move from the blood of the fetus into the mother's blood.
(c) Use information from the diagram to help explain how the placenta is adapted for the efficient exchange of substances.

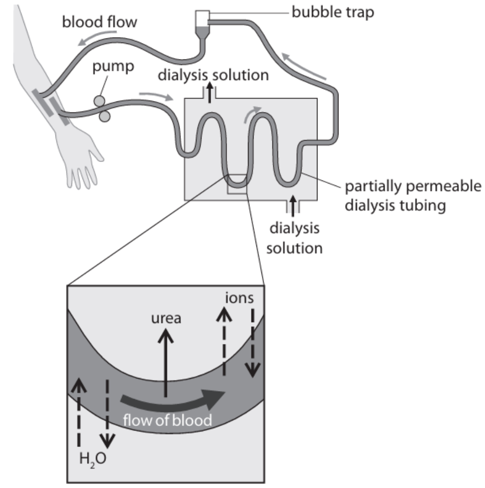


Revision questions

(1) The human kidney removes urea from the blood.

(a) Name two other substances the kidney removes from the blood

(b) The diagram shows a simple kidney machine that uses dialysis to remove urea from the blood.



(i) Give one way in which dialysis is similar to diffusion.

(ii) Give one way in which dialysis is similar to osmosis.

(iii)Describe how the kidney machine removes urea from the blood

(iv)Another function of the kidney machine is to maintain normal blood glucose concentration.

Suggest how the concentration of glucose in the dialysis solution helps to maintain a normal glucose concentration in the blood.

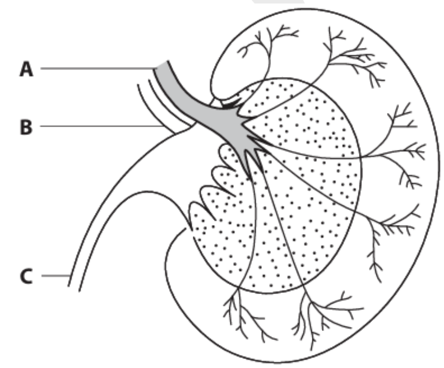
(v) Describe two processes that take place in the kidney but not in the kidney machine.

(2) Kidney failure can be treated by transplanting a healthy donor kidney into the patient.

(i) The procedure involves connecting two blood vessels and a tube to the transplanted kidney. Name the two blood vessels and the tube.

(ii) Suggest why the transplanted kidney is placed in the lower abdomen instead of in the kidney's usual location.

(3) The diagram shows the human kidney with tubes labelled A, B and C.



(a)Which letter shows the tube that would contain urine?

(b) The table shows the concentration of plasma proteins and glucose in the blood entering the kidney and in the urine.

Name of substance	Concentration of substance in mg per 100 ml	
	blood entering the kidney	urine
plasma proteins	740	0
glucose	90	0

(i) Explain why there are no plasma proteins in the urine

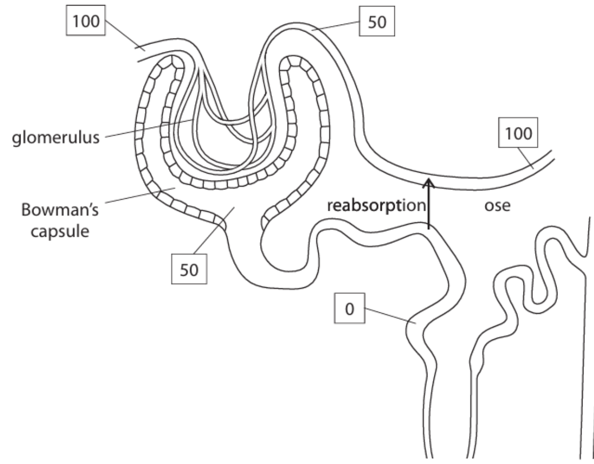
(ii) Explain why there is no glucose in the urine.

(iii)Water is found in the urine. Name two other substances you would also find in the urine

(c) Some people do have glucose in their urine. These people have diabetes. Suggest why a person with diabetes has glucose in their urine.

(d)On a hot day there is less water in urine. Explain how the kidney is able to reduce the water content of urine produced on a hot day.

(4) The diagram shows some of the blood vessels and a nephron in the human kidney. The numbers represent the concentration of glucose at various places in the blood vessels and in the nephron, in arbitrary units.



(a) Explain how the structure of the blood vessels entering and leaving the glomerulus help to move glucose into the Bowman's capsule

(b)What type of blood vessels are found in the glomerulus?

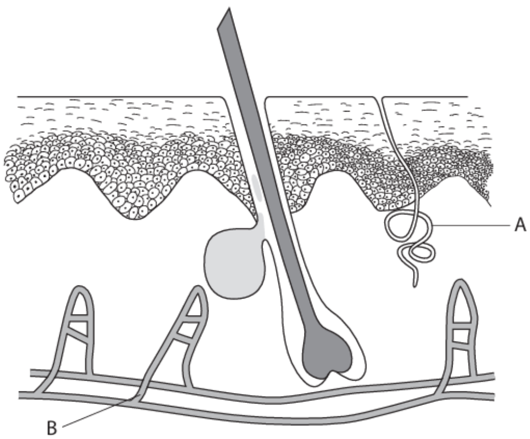
(5) (i) Describe how glucose is reabsorbed from the nephron back into the blood

(ii) Suggest why glucose needs to be returned to the blood.

(6) The skin is an organ of homeostasis and excretion.

(a) Describe what is meant by the term excretion.

(b) The diagram shows a section through the skin with two structures labelled A and B.



The structures labelled A and B play a part in homeostasis when a person enters a very warm environment.

(i) Explain the role of structure A.

(ii) Explain the role of structure B.

(7) Some hormones are involved in homeostasis.

(i) Explain the role of insulin in homeostasis.

(ii) Explain the role of ADH in homeostasis

(8) (a)Some plants lose their leaves in cooler months. This can be described as an excretory mechanism. Suggest two other reasons why some plants lose their leaves in cooler months.

(b) Name one excretory organ in humans and name the substance it excretes.

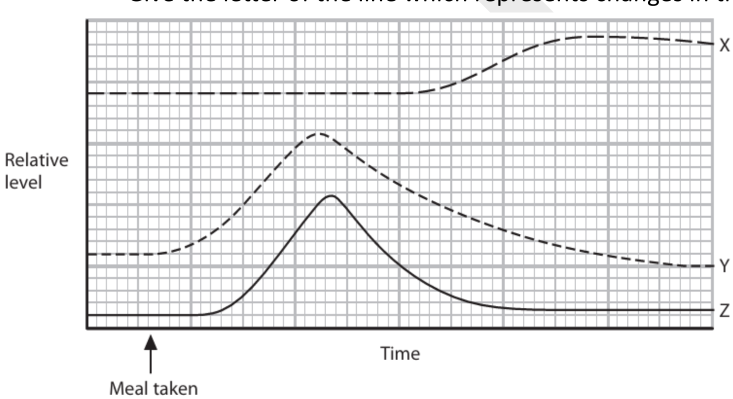
Revision questions

(1) (a) The table lists the effects of some hormones. Complete the table by naming each hormone and its source. The first one has been done for you.

(b)Cells do not store glucose. Instead it is converted into glycogen to be stored. Suggest why cells do not store glucose.

(c) The graph shows changes in the relative level of glucose, glycogen and insulin before and after a meal

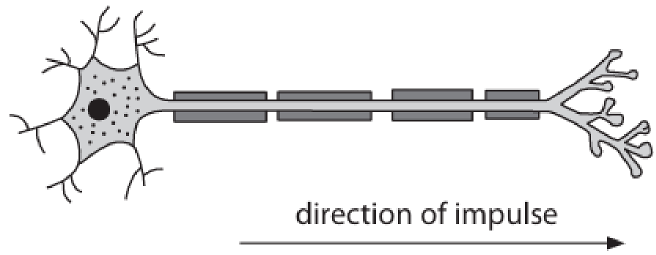
Give the letter of the line which represents changes in the relative level of glycogen.



Effect	Name of hormone	Source
converts glucose to glycogen	insulin	pancreas
stimulates male secondary sexual characteristics		testis
increases permeability of the collecting duct		
repairs the uterus lining		

(2)The diagram shows an animal cell called a neurone.

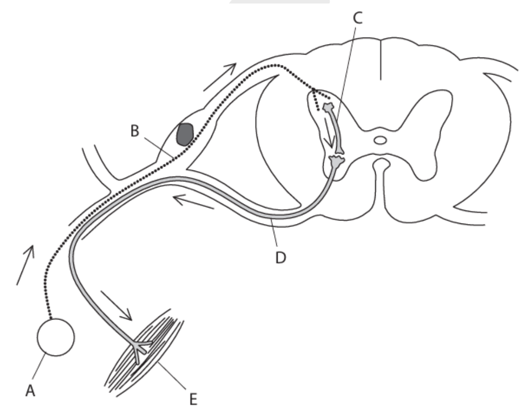
(a) Name the three structures found in a plant cell that are not found in a neurone.



(b)Neurones are involved in the reflex arc that helps humans respond to stimuli. The diagram shows a reflex arc with parts labelled A, B, C, D and E. The arrows show the direction of the nerve impulse.

(i) Complete the table by naming each part of the reflex arc. One has been done for you

Part	Name
A	
B	sensory neurone
C	
D	
E	



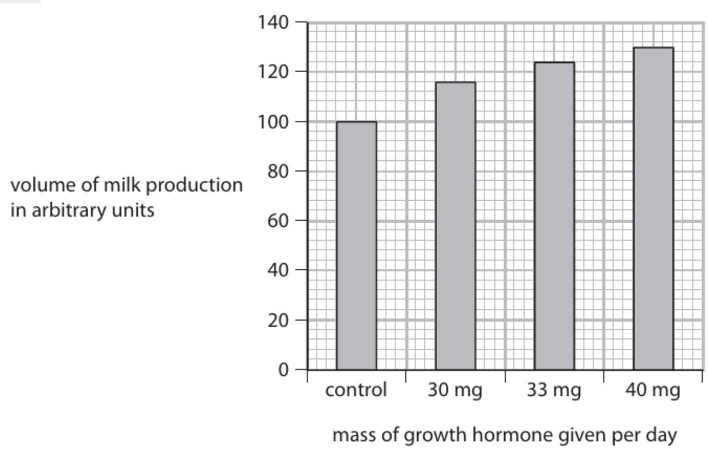
(ii) There is a small gap between neurone B and neurone C. What is the name of the small gaps between neurones?

(c) Nerve impulses can travel along neurones at 120 m/s. The distance between the spinal cord and the foot of a human is 90cm. Calculate the time, in seconds, that it would take a nerve impulse to travel from the spinal cord to the foot of this human. Show your working.

(3) An investigation was carried out to find out the effect of a growth hormone on milk production.

Groups of cows were given different masses of a growth hormone.

The volume of milk the cows produced was then measured. The graph shows the results.



(a) (i) How much growth hormone should have been given to the control group?

(ii) Describe the effect of growth hormone on milk production.

(b) Farmers want to make reliable comparisons about the effect of different doses of growth hormone.

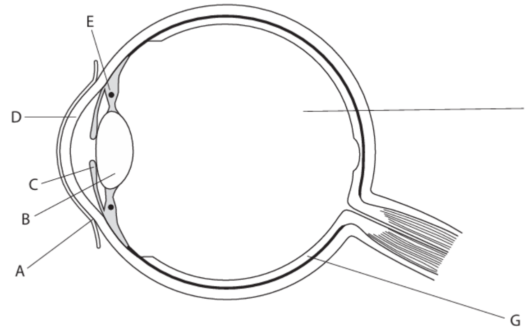
(i) What was done in this investigation to make the results reliable?

(ii)Many variables that affect milk production need to be kept the same for each group of cows. This allows a valid comparison to be made between each group. Give two variables that need to be kept the same

(4) (a) Growth hormone is a protein.

It might be present in the milk produced by the cows and then be consumed by humans.
Some people are worried that this may harm humans. Other people say that this is not a problem for two reasons. Firstly, the milk is pasteurised (heated to high temperatures).
Secondly, the growth hormone is destroyed in the human stomach.
(i) Suggest what happens to the growth hormone when milk is pasteurised
(ii) Describe how the growth hormone could be destroyed in the stomach.
(b) The growth hormone used in this investigation was obtained from genetically modified bacteria. Describe how bacteria can be genetically modified and used to produce growth hormone.

(5) The diagram shows a section through the human eye. Different parts of the eye have been labelled A to G.



The table lists some health problems that affect the eye and describes how they are caused.

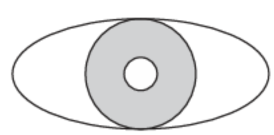
Complete the table by choosing the correct label letter for the part of the eye linked with each health problem. The first one has been done for you.

Health problem	Description	Label letter
conjunctivitis	infection of the conjunctiva	A
cataract	a cloudy lens	
blindness	a detached retina	
glaucoma	increased fluid pressure	
myopia	a change in the shape of the cornea	

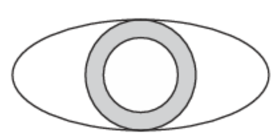
(6) (a) Describe the stages that are used to genetically modify a bacterium that is able to manufacture human growth hormone.
(b)BST is a hormone that increases milk yield in cows.
(i) Explain what is meant by the term hormone.
(ii) In some countries BST from genetically modified bacteria has been injected into cows to improve milk production.

In other countries selective breeding has been used to improve milk production.
Describe how selective breeding could be used to increase milk production.

(7) The eye can respond to changes in light intensity. The diagram below shows how pupil size changes in different levels of light
(a) Use a ruler to measure the change in pupil diameter between bright light and a dark room
(b)Where in the eye are the cells that detect the change in the stimulus to cause this response?
(c) Explain the changes that take place in the pupil as a person moves from bright light into a dark room.

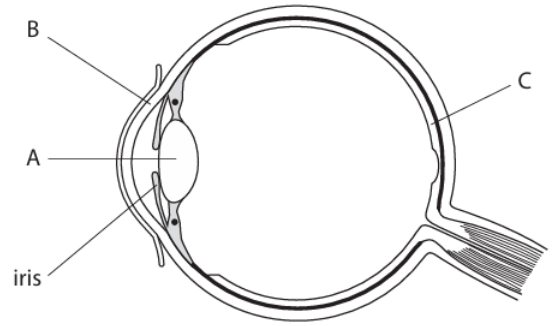


bright light



dark room

(8) The diagram shows a section through an eye with the iris and parts A, B and C labelled.



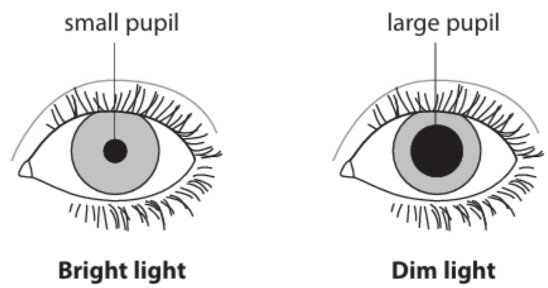
(a) Name parts A, B and C.

(b)When you move from a bright room into a dark room you cannot see very well for a while. After a brief time, a change in the iris helps you to see more clearly.

(i) The iris contains muscle tissue. What is meant by the term tissue?

(ii) Describe the changes that take place in the iris when moving into the dark room and explain how they help you to see more clearly.

(9) The diagram shows the difference in the pupil diameter of the eye in bright light and after moving into dim light. The difference is caused by a reflex action.



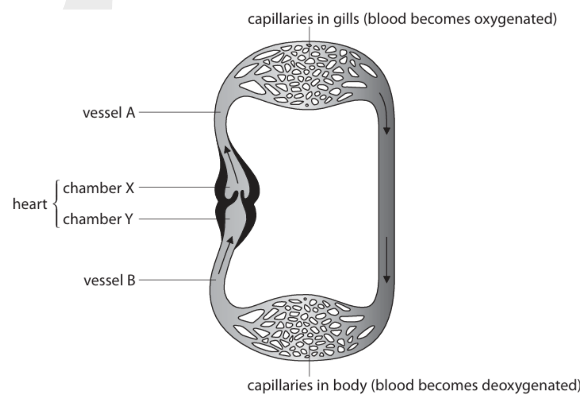
(a) The table gives descriptions of parts of the reflex arc involved with the reflex action. Complete the table by naming each part. One has been done for you.

(b) Explain how the lens changes whe

Description of part	Name
contains light receptor cells	
neurone that sends impulses into the brain	
microscopic gap between neurones	
contains muscle effector cells	iris

Revision questions

(1) The diagram shows the heart and circulation system of a fish



(a) The circulation system and heart structure of a fish have similarities and differences to those of a human. Use your knowledge of human circulation and heart structure to answer these questions.

(i) What type of blood vessel is vessel A?

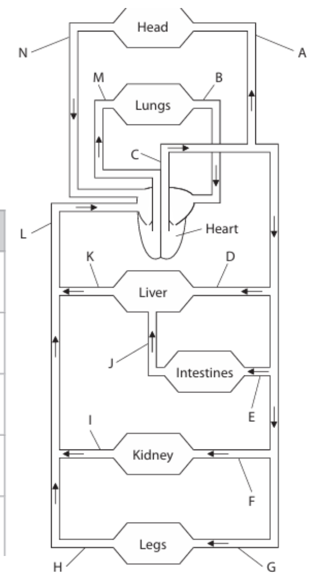
(ii)What type of heart chamber is chamber Y?

(iii)Describe how the structure of a fish heart differs from that of a human heart.

(b) The concentrations of the gases in the blood leaving the fish heart are different from the concentrations of the gases in the blood leaving the human heart in the aorta. Explain the differences in the concentrations of gases.

(c) Explain why the pressure of the blood returning to the fish heart is lower than the pressure of the blood returning to the human heart.

(2) Arteries and veins are important blood vessels in the circulatory system.
(a) Describe two ways in which the structure of an artery differs from the structure of a vein.
(b) The diagram shows the human circulatory system. The blood vessels are labelled with letters.



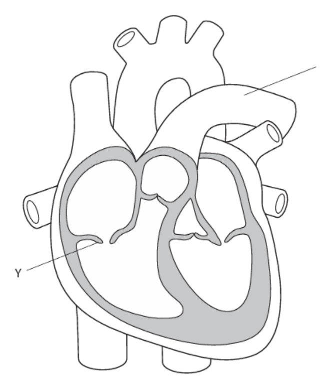
(i) The table names some of the blood vessels in this circulatory system. Complete the table by giving the letter for each blood vessel. The first one has been done for you.

Name of blood vessel	Letter
vena cava	L or N
aorta	
pulmonary vein	
hepatic artery	
renal vein	

(ii) The plasma in the blood vessels can contain different concentrations of substances. Complete the table by giving the letter for the blood vessel that matches the contents

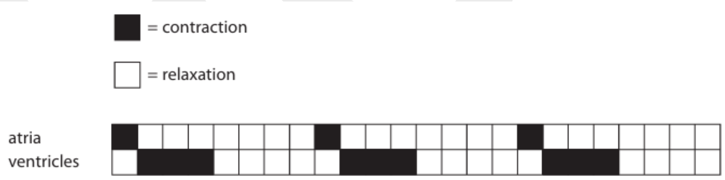
Contents of blood vessel	Letter of blood vessel
contains the most glucose after a meal	
contains the least urea	
contains the least oxygen	

(3)The diagram shows a section through a human heart.



(a) The blood in vessel X is transported to an organ.
(i) Name the organ.
(ii) State two changes to the blood in this organ
(b) What is the function of the part labelled Y?
(c) The diagram shows the contraction and relaxation of the atria and ventricles during several heartbeats.
Each square represents a time of 0.1 second

(i) For how long do the ventricles contract during one heartbeat?
(ii) How many heartbeats does the diagram show?
(iii)Use the diagram to calculate the heart rate of this person in beats per minute. Show your working.



(4) The table gives statements about blood cells. Some apply to red blood cells and some to white blood cells.
(a) Complete the table by using a tick or a cross to show if each statement applies to red blood cells or to white blood cells. The first statement has been done for you.

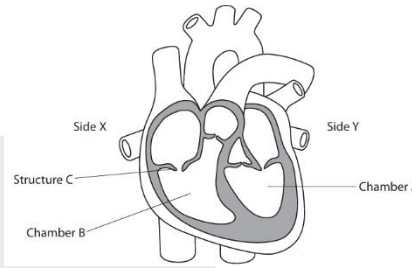
Statement	Red blood cells	White blood cells
transport oxygen	✓	×
contain a nucleus		
produce antibodies		
biconcave shape		
ingest pathogens		
numbers may increase following infection		

(b) Some athletes preparing for a long-distance race train at high altitude for several weeks. The availability of oxygen at high altitude is lower so the body responds by increasing the number of red blood cells. The number of red blood cells remains high when the athletes return to lower altitude to compete.

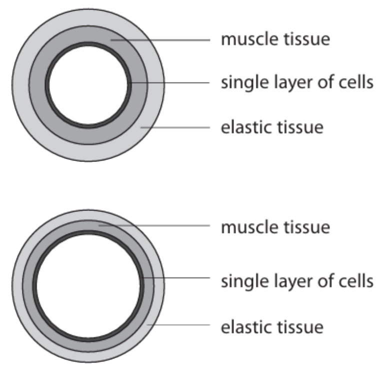
Explain how more red blood cells an advantage to athletes having is who take part in long distance races.

(c) A 100 m sprint race takes less than 10 seconds to complete. Suggest why sprint athletes gain no advantage from training at altitude.

(5) The diagram shows the structure of the human heart.



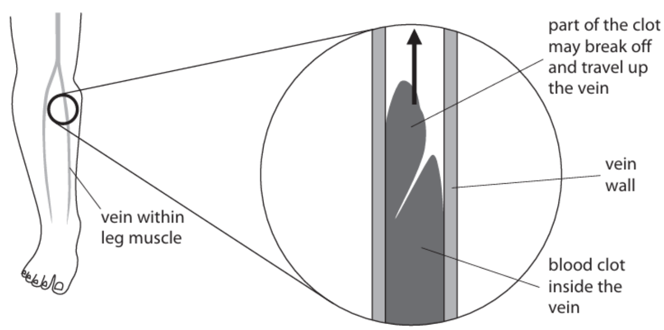
(a) (i) Explain how you know that X is the right side of the heart.
(ii) Give the name of chamber A.
(iii)On the diagram, label the pulmonary artery.
(iv)Explain the difference in the structure of the walls of chamber A and chamber B.
(b) (i) Give the name of structure C.
(ii) Describe the function of structure C.
(c) Sometimes a baby is born with a hole between chambers A and B. Suggest the effects that this condition may have on the baby
(6) The diagrams show sections through an artery and a vein.



(a) Use the information in the diagrams and your own knowledge to give three ways in which the structure of an artery differs from the structure of a vein

(b) Lack of movement by sitting still for long periods of time makes blood flow very slowly in a vein. Blood that flows slowly is more likely to clot than blood that flows normally. This problem is known as deep vein thrombosis (DVT). In DVT, the clot usually occurs in a leg vein as shown in the diagram

DVT is dangerous because sometimes part of the clot breaks off and travels to the lung, blocking small blood vessels and causing death.
(i) Suggest why blood flow in a leg vein is slow when there is lack of movement.
(ii) Name the blood cells responsible for transporting oxygen
(iii)Suggest why a clot that blocks the small blood vessels in the lungs can cause death.



(7) The box shows the names of three blood vessels

aorta	**capill y**	**ena cava**

(a) The table gives information about these blood vessels. Complete the table by writing the name of the correct blood vessel in each empty box

Name of blood vessel	Diameter of the lumen in mm	Thickness of the vessel wall in mm
	30.0	1.5
	0.006	0.001
	25.0	2.0

(b) (i) Which of these blood vessels carries blood containing the most oxygen?
ii)Which of these blood vessels carries blood at the lowest pressure?
(iii)Which of these blood vessels is most suite

Revision questions

(1) A group of students investigate the effect of exercise on breathing rate.
They measure their breathing rate at rest by counting breaths per minute.
They then exercise by running on the spot.
After exercise they measure their breathing rate by counting breaths per minute.
These are their results.

At rest 14, 13, and 14

After exercise 27, 25, 26.

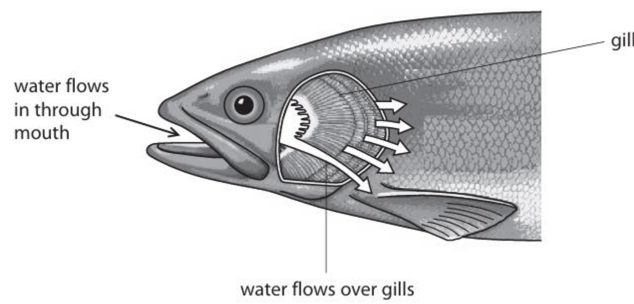
(a) Display these results in a table.
(b) Explain why breathing rate is higher after exercise.
(c) Explain how the students could improve their investigation.

(2) This warning appears on the side of a cigarette packet.

Smoking seriously damages your health and those around you

(a) Describe how smoking damages the lungs.
(b) If a pregnant woman smokes cigarettes it will increase the risk of her producing a smaller baby. This is because cigarette smoke contains carbon monoxide.
Suggest how carbon monoxide will increase the risk of producing a smaller baby.

(3) Fish breathe by opening their mouths to allow water containing oxygen to pass over their gills. This is shown in the diagram.



(a) (i) Gas exchange takes place in the gills. What is meant by the term gas exchange?
(ii) Fish use their gills as a gas exchange surface. Suggest three ways in which fish gills are adapted for efficient gas exchange.

(b) Students investigated the effect of temperature on the breathing rate of fish. They put fish of the same size in tanks of water at different temperatures. They measured the breathing rate by counting the number of times the fish opened their mouths in a minute. The results are shown in the table.

Water temperature in °C	Breathing rate in breaths per minute				
	Trial 1	Trial 2	Trial 3	Trial 4	Average
2	2	3	3	4	3
8	30	33	27	30	30
14	54	52	53	53	53
20	80	75	81	84	80
26	101	98	102	101	101

(i) Plot a line graph to show the effect of water temperature on the average breathing rate of the fish. Join the points with straight lines
(ii) Suggest how the results support the hypothesis that warm water contains less oxygen than cold water.
(iii)The students controlled the size of fish. Explain why this is needed to make it a valid investigation.
(iv)Give two other factors the students should have controlled.

(4) The diagram shows some structures in the human breathing system

(a) Name structures A and B

(b) The table shows the level of two gases, X and Y, in blood entering and leaving the lungs during the process of gas exchange

Gas	Level of gas in cm^3 per 100 cm^3 of blood	
	Blood entering lungs	Blood leaving lungs
X	10.6	19.0
Y	58.0	50.0

(i) Name the two gases.

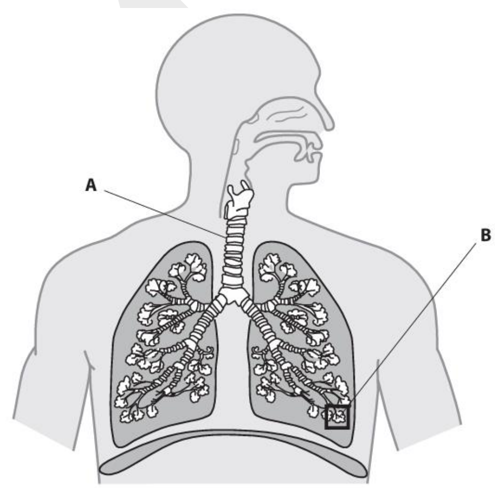
(ii) How much of gas X enters 100 cm^3 of blood, before the blood leaves the lungs?

(iii) What term is used to describe how the process of gas exchange takes place?

(5) Doctors use X-rays to produce images of structures inside the body. The image shows an X-ray of a normal human thorax.

(a) Identify the structures labelled A, B, C and D

(b)Describe how structures B and D help a person to breathe in.

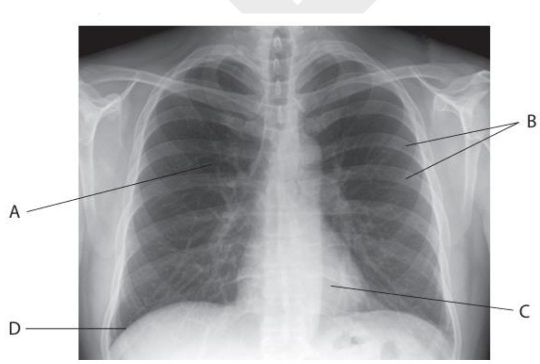


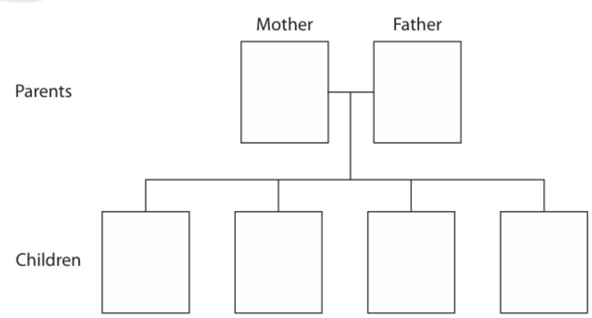
(c) Some cells lining the bronchioles in the lung produce mucus. Cystic fibrosis is an inherited condition in which these cells produce very sticky mucus which blocks the bronchioles. The allele for producing very sticky mucus, f, is recessive to the allele for producing normal mucus, F.

(i) In the boxes below give the genotypes of the parents, and all the possible children, for a cross between a heterozygous mother and a heterozygous father.

(ii) Suggest why people with cystic fibrosis often have lung infections.

(iii)Suggest why gas exchange is reduced in someone with cystic fibrosis

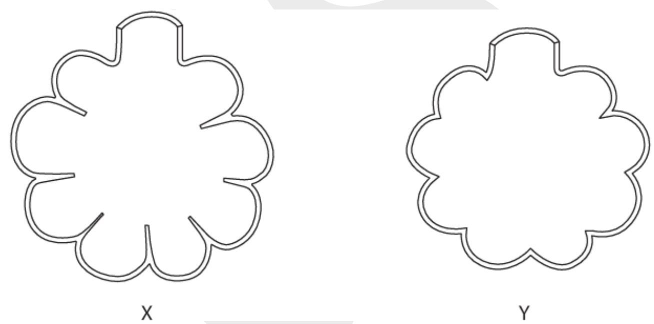




(6) The table shows the number of deaths in the United Kingdom in 2010 caused by cancer, lung diseases and circulatory diseases. The table also shows the number of these deaths caused by smoking.

Cause of death	Total number of deaths	Number of these deaths caused by smoking
cancer	66 000	38 000
lung diseases	46 000	22 000
circulatory diseases	138 000	20 000

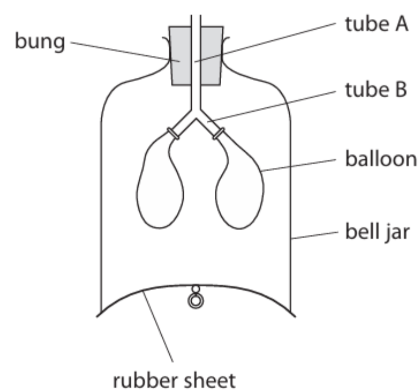
(a) (i) What is the total number of deaths caused by all three diseases?
(ii) Calculate the percentage of the total number of deaths that are caused by smoking. Show your working.
(b)Chemicals in cigarette smoke cause mutations in cells which can lead to cancer. What is meant by the term mutation?
(c) Emphysema is a lung disease that is usually caused by smoking. The diagram shows a cross section through two alveoli X and Y. Alveolus X is from a non-smoker and alveolus Y is from a smoker suffering from emphysema.



Use the diagram to suggest and explain the effect of emphysema on gas exchange.

(d) Smoking can increase the risk of developing coronary heart disease. Explain how coronary heart disease can cause death.

(7) The diagram shows a model that can be used to demonstrate how the lungs inflate.



(a) Suggest which part of the human thorax is represented by
(i) the balloons
(ii) the rubber sheet
(iii) tube A
(iv) tube B
(b)Describe and explain what happens to the balloons as the rubber sheet is pulled down
(c) Explain why the model does not fully show the mechanism of breathing in the human thorax.
(d)Describe an experiment you could carry out to investigate the effect of exercise on breathing in humans.