Human biology and health

Unit 3

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Section	Learning competencies
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3.1 The nervous system

By the end of this section you should be able to:

- Name the parts of the nervous system.
- Explain the structures and functions of the human nervous system.
- List the three types of neurons, indicate their structures and explain their functions.
- Describe an action potential and the passage of a nerve impulse along a neuron with examples.
- Describe a synapse and how an action potential crosses it.
- Describe neurotransmitters with examples.
- Explain how the brain is protected and compare the functions of the fore, mid and hind brain.
- Describe the reflex arc, mention the structures involved and compare simple and conditioned reflexes.
- Demonstrate at least two examples of reflex actions such as knee jerks and blinking.
- Define substance abuse, explain its effects, its status in Ethiopia and possible preventative measures.
- Give examples of drugs abused in the locality.
- Express willingness to conform to a drug-free lifestyle.

Figure 3.1 *Human beings not only control our own bodies, we expect our co-ordination systems to control fast and complicated machines as well.*

KEY WORDS

spinal cord *column of neurons within the backbone*

neurons *nerve cells*

sensory receptors *nerve endings that can sense stimuli, e.g. pressure, pain, temperature, and start a nerve impulse that sends this information back to the brain*

affector (afferent) *neuron that sends impulses from organs to the spinal cord and brain*

effector (efferent) *neuron that sends impulses from the brain and spinal cord to organs*

The human sense organs

All living organisms need some level of awareness of their surroundings so they can avoid danger, find food and, in some cases, find a mate. Whatever the level of awareness, it requires co-ordination and control within an organism to respond to changes in the surroundings. In large and complex organisms like ourselves it is also very important that the different systems within our body are co-ordinated and work together.

Awareness of changes in our surroundings is only useful if the reactions of our body can be co-ordinated and controlled to take advantage of the information. It is no good if an antelope smells or sees a lion stalking if it cannot run away! We need to pick up all sorts of changes in the environment, and respond to them. Your body has two very different ways of bringing about this co-ordination and control.

The nervous system is involved in all the most rapid responses. It involves the passage of electrical impulses around the body. The endocrine (hormonal) system involves the movement of chemical messages around the body. It is rather slower than the nervous system but is responsible for the co-ordination of much of the functioning of the body.

Nervous co-ordination

Single-celled organisms do not have nervous systems or any type of nervous co-ordination and control and neither, as far as we know at the moment, do plants. But most other living multicellular organisms have some sort of nervous system, even if it is very simple.

In human beings our nervous system is a highly complex system that provides us with rapid, co-ordinated responses to the situations we meet in our lives. It allows us to react to our surroundings and co-ordinate our behaviour. The nervous system has two main parts. The central nervous system (CNS) is made up of your brain and **spinal cord**. The peripheral (body) system is made up of the **neurons** (nerve cells) and the **sensory receptors**.

How nervous co-ordination works

Once a stimulus is picked up by a sensory receptor, the information is passed along special nerve cells, **affector** or **afferent** neurons, to the central nervous system (CNS), made up of your brain and spinal cord. Once the information has been processed in the CNS, instructions are sent out to the body along more neurons called **effector** or **efferent** neurons. These stimulate the effector organ, usually muscles or a gland.

sense organ → afferent neuron → central nervous system → efferent neurons → muscles

These neurons are the basic unit of your nervous system, with millions of them working together in your body. Neurons are

extremely specialised for the transmission of electrical impulses. They have a cell body that contains the cell nucleus, mitochondria, and other organelles. They also have slender finger-like processes called **dendrites** that connect to neighbouring nerve cells. The most distinctive feature of all nerve cells is the **axon** or nerve fibre, which is extremely long and thin. The nerve impulse travels along the axon from one place to another (see figure 3.2). Neurons are also irritable – which means they react to the world around them – and they can conduct electricity. This is the result of the structure of the axon. The axon membrane changes its permeability to sodium ions to create an electrical impulse (see the action potential below), while the **myelin sheath** provides a layer of insulating material so the nerve impulse travels as fast as possible.

So, to recap, afferent neurons carry information from your receptors to your central nervous system (CNS). In the brain the information is added to the vast amounts of other information arriving from all over the body. The brain co-ordinates all this information and then sends messages out along efferent neurons. These effector neurons carry messages from the CNS to different parts of the body to make muscles contract and/or organs respond to the changes in the surroundings. The huge network of nerves running all over your body carrying information to and from the CNS is called your peripheral nervous system. The muscles or organs of the body that bring about the response to the original stimulus are known as effectors.

KEY WORDS

dendrites *tree-like branches from nerve cell bodies that receive signals from other nerve cells at synapses*

axon *long process from nerve cell that carries the nerve impulse*

myelin sheath *fatty insulating sheath that grows around many nerves*

DID YOU KNOW?

The average axon is only 10 µm in diameter but in a large animal like an elephant or a giraffe they can be up to 4 m in length.

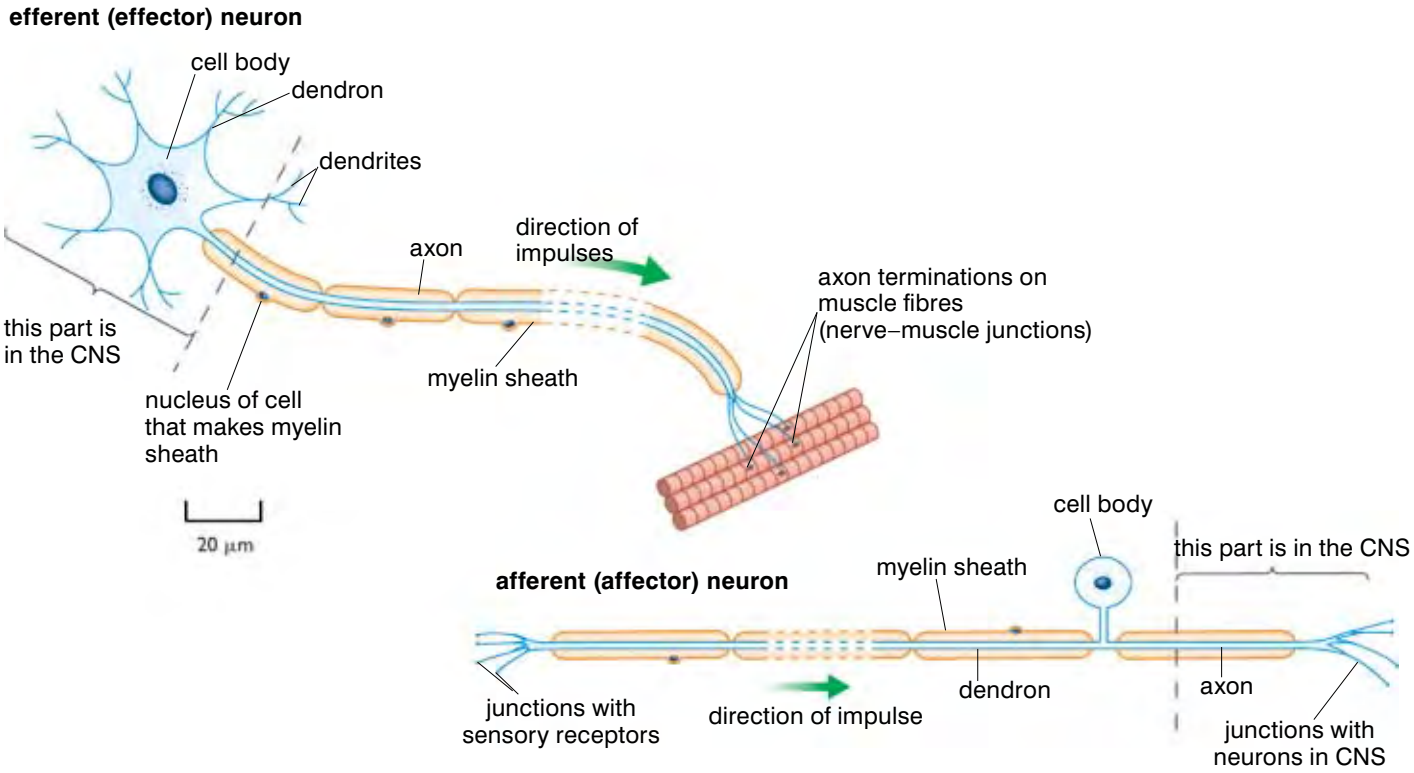


Figure 3.2 *The afferent (affector) neurons and efferent (effector) neurons carry messages to and from your central nervous system and are vital for the co-ordination of your body.*

KEY WORDS

action potential *a short-term change in the electrical potential on the surface of a cell when it is stimulated*

synapse *the junction between two neurons (axon-to-dendrite) or between a neuron and a muscle*

neurotransmitters *chemicals that transmit nerve impulses across synapses*

neuromuscular junctions *the junction between an axon terminal of a motor neuron and a muscle fibre*

cranium *the part of the skull that encloses the brain*

Nerves are bundles of neurons. Some carry only effector neurons and are known as effector nerves, some carry only affector neurons and are known as affector nerves, whilst others carry a mixture of effector and affector neurons and are called mixed nerves.

Your nervous system relies on nerve impulses travelling along the neurons. Each nerve impulse is a minute electrical event that is the result of charge differences across the membrane of the axon. The wave of positive charge inside the axon when the neuron is stimulated is known as the action potential.

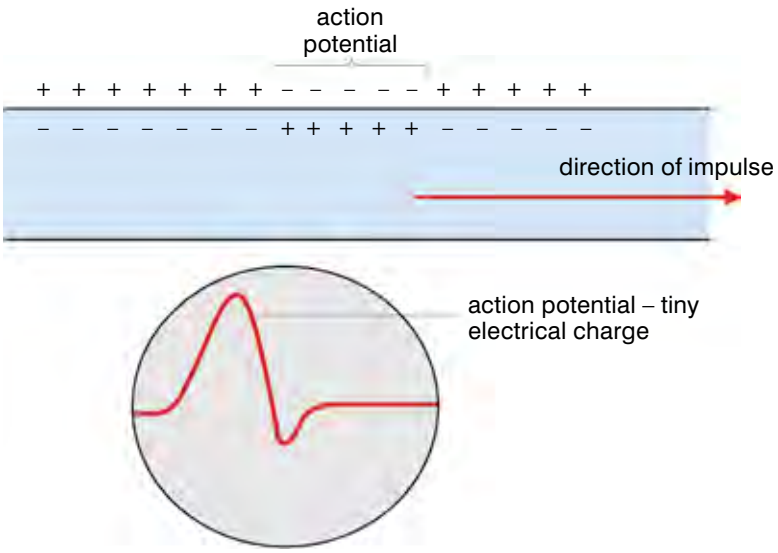
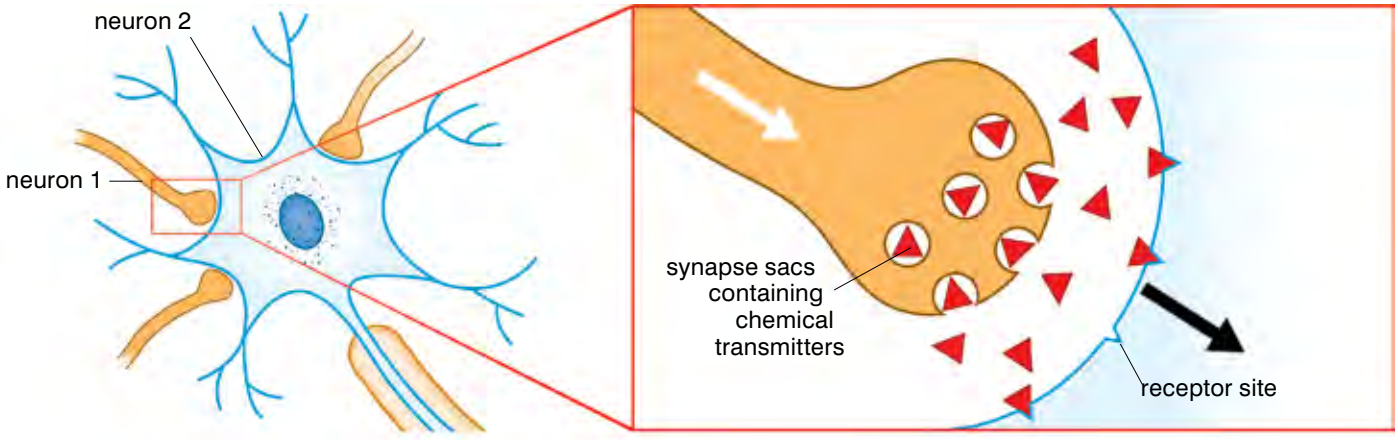


Figure 3.3 *The action potential is the basis of all the electrical signals in the nervous system of your body.*

Neurons are not continuous 'wires' running about your body. Whenever one neuron ends and another begins there is a gap known as a **synapse**. The electrical impulses that travel along your neurons have to cross these synapses, but an electrical impulse cannot leap the gap. So when an impulse arrives at the end of a neuron, chemicals are released. These chemical transmitters (**neurotransmitters**) cross the synapse and are picked up by special receptor cells in the end of the next neuron. In turn this starts up an electrical impulse, which then travels along your next neuron. This is how impulses pass from one neuron to another all over your body.

Figure 3.4 *A synapse – the junction between one neuron and another. The electrical impulse cannot cross the gap – it relies on chemical transmission across the synapse.*



Every neuron – and particularly the neurons in your brain – will have thousands of synapses, each one connecting it to other neurons. So synapses are very important for the co-ordination of information in your central nervous system, information that is coming in from many different areas of your body. There are special synapses between effector neurons and the muscles they stimulate. These are known as **neuromuscular junctions** and they work in the same way as a normal synapse, except the chemical crossing the gap causes the muscles to contract.

The chemical transmitters produced by different cells are not always the same. Sometimes one neurotransmitter will cancel out another. Some medicines – and some poisons – work by blocking chemical transmission across a synapse or by speeding it up.

Review questions

1. What are the differences between a neuron and a nerve?
2. What makes up the central nervous system?
3. What is an effector organ?
4. How do synapses work?

The central nervous system

You have seen how the neurons carry messages around the body in the form of electrical impulses, and have considered the sense organs that respond to changes in both your internal and external environments. But the affector inputs and the impulses are no use without some sort of co-ordination – and this is where the central nervous system comes into its own.

The central nervous system consists of two main regions – the brain and the spinal cord.

Your brain is a delicate mass of nervous tissue with the consistency of thick yoghurt. It is enclosed in membranes and protected by the bones of your skull in a space known as the **cranium**. The spinal cord runs out from your brain down your body. It is encased and protected by the vertebrae making up your spine.

As you have seen, the nerves that run to and from the CNS make up your peripheral nervous system. The nerves that come out of the brain are known as the **cranial nerves**. They go mainly to structures in your head and neck, like your eyes, tongue and jaws. The majority of the nerves come out of the spinal cord and these are known as the **spinal nerves**. They go to the arms, the legs and the trunk (the rest of your body).

KEY WORDS

cranial nerves *12 pairs of nerves that emerge directly from the brain stem*

spinal nerves *mixed nerves containing both sensory and motor neurons*

DID YOU KNOW?

One of the most common chemical transmitters found in synapses is a chemical called acetylcholine. A number of well-known poisons work by affecting synapses with this neurotransmitter:

- **Botulinus toxin** affects the first membrane and stops the release of acetylcholine. No transmission of impulses across synapses prevents the nervous system from working and causes death.
- **Strychnine** and **organophosphorus compounds** (sometimes used as weedkillers and insecticides) deactivate the enzymes on the second membrane and so prevent the breakdown of acetylcholine. The nerves fire continuously and the muscles contract all the time causing rigid paralysis.
- **Curare** (used on arrow tips by South American Indians) stops the second membrane from responding to the chemical transmitter. This causes paralysis as the muscles can no longer be stimulated by the nerves.

DID YOU KNOW?

An average human brain weighs 1300–1400 g (about 3 lb) yet the cerebral cortex, which controls most of our conscious thought and action, is only about 3 mm thick.

KEY WORDS

grey matter *areas in the brain and spinal cord that consist of unmyelinated nerve cells*

fore brain *the large frontal area of the human brain*

Your brain is a very complex structure that carries out an amazing variety of functions. The different areas of the brain carry out very different functions, from the basic reflexes that keep us breathing to the complex ideas needed to create a story or write and play music. Our understanding of how the brain works is based partly on observations of people who have suffered injuries to different areas of the brain through accidents or disease. The impact of damage in a certain area on abilities to speak and think can give us clear clues as to the working of the brain. More recently, new technology has enabled us to see inside the living brain – but we still have a lot to learn about how this most complex organ works.

The bulk of your brain is made up of **grey matter** – the cell bodies of neurons and the synapses that connect them. Inside the brain is the white matter – the axons that lead into and out of the brain.

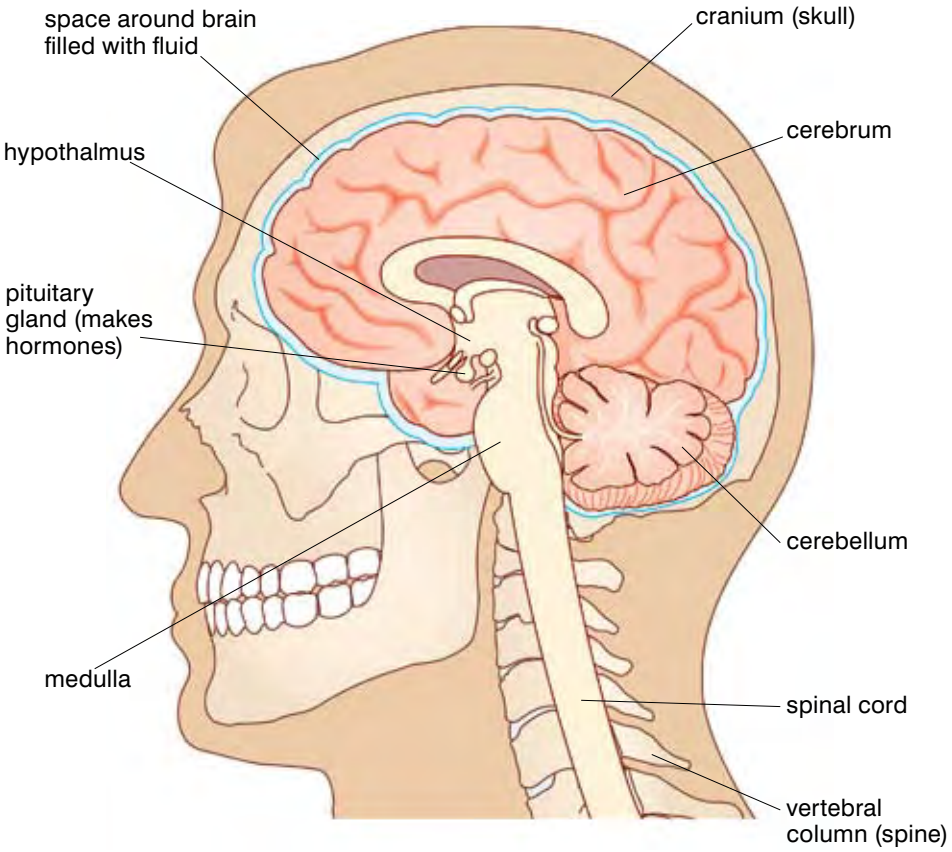


Figure 3.5 *The fore, mid and hind brain are the three main areas as the brain develops.*

As an embryo develops in the womb, the brain starts off as a tube in the head with three main areas. The **fore brain** develops into the olfactory lobes, which deal with smell, and the cerebral hemispheres that are involved in all the higher levels of thought. Some areas of the cerebrum (cerebral hemispheres) are involved in the co-ordination and interpretation of affector input from your sense organs. Other areas are involved in sending out effector impulses to control the actions of your body in response to the affector information.

The mid brain develops into the areas of your brain that deal with vision (the optic lobes) while the hind brain forms the areas of the brain that deal with balance and orientation (the cerebellum) and the most fundamental reflexes of life (the medulla). Even if all of your higher brain is damaged and destroyed, you may continue to breathe if your medulla is intact.

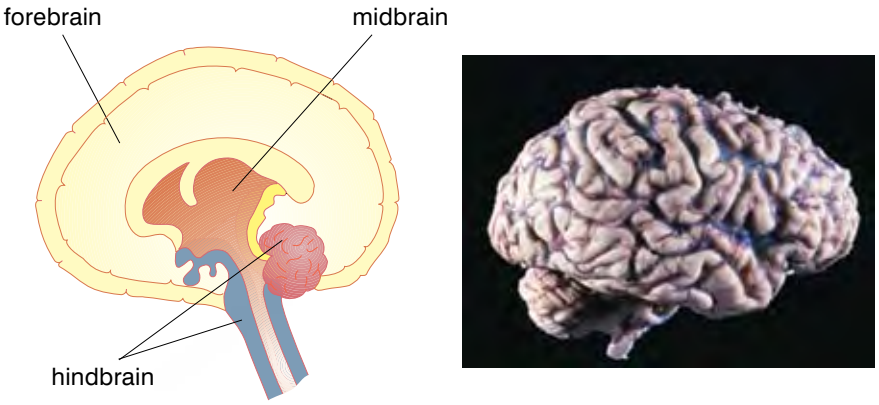
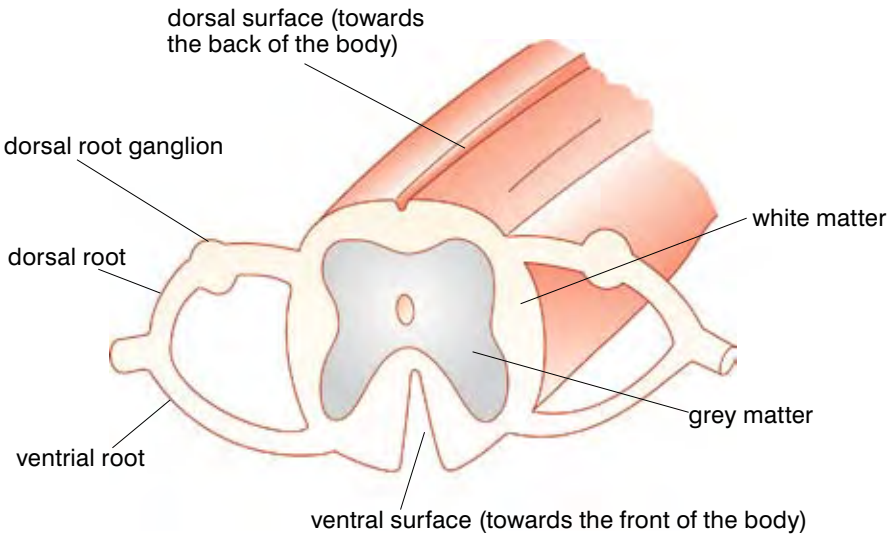


Figure 3.6 *The human brain – its appearance may not be spectacular but it is capable of the most amazing things.*

The spinal cord has a much simpler structure than your brain. The grey matter (cell bodies and short **relay neurons**) are in the middle and the white matter (axons) are on the outside. At regular intervals along the spinal cord there are entrance points for affector nerves bringing information into the CNS and exit points for effector nerves carrying instructions from the CNS.



The way in which the human brain works to make each of us who we are is still not understood very well. So it is perhaps not surprising that we don't fully understand what happens when things go wrong. Sometimes the processes in the brain don't work as they should. **Mental illness** is a very general term that is difficult to define. It is the term we use to describe a wide variety of disorders and diseases, which are diagnosed as mental illnesses because they involve thought processes, emotional disturbances and/or behaviour that are considered abnormal. Mental illness may range from mild depression, when someone feels low and sad for no apparent

KEY WORDS

relay neurons *neurons which are activated by other neurons*

mental illness *general term referring to psychological, emotional, or behavioural disorders*

DID YOU KNOW?

Each side of your body is controlled by the opposite side of your brain – so what you see with your right eye goes to the left-hand side of your brain. The left-hand side of your brain is good at processing information and largely controls your speech, while the right-hand side is better at spacial awareness and recognising faces. If the right-hand side of your brain is damaged you may be unable to recognise even your closest family. It is often only when parts of the brain are damaged that we appreciate just what an amazing organ it is.

Figure 3.7 *The structure of your spinal cord. If your spinal cord is damaged you may lose all sensation below the damaged area, or lose effector control – or both.*

reason and cannot lift their mood, to conditions such as psychosis, when your ability to distinguish between what is real and what is imaginary becomes seriously affected in a way that can completely take over your life.

Mental illness can be the result of an imbalance of the chemical transmitters in your brain, and so for some conditions there are effective treatments. However, scientists and doctors have a great deal of research to do before all of these conditions are fully understood and can be treated. One growing concern is that the use of illegal drugs, which affect the chemistry of the brain, is leading to an increase in mental illness in young people. You will look at the effect of drugs in more detail on pages 64–74.

Voluntary and reflex control

Sense organs such as the eye, which you will look at in detail later in this unit, respond to changes in the world around you, and to changes in your internal environment. However, a change in a sense organ alone is simply not enough. The information needs to reach your central nervous system and you need to process the information and then respond. Many of the activities you carry out are voluntary – you choose to do them. So how do they come about? For example, if you see a mango or a banana that looks ripe on a market stall, you may well pick it up, feel it and smell it before deciding if it is as good as it looks and buying it.

- When you see the mango the information from your eyes travels along affector neurons to your spinal cord.
- From the spinal synapses the electrical signal continues up affector neurons in the spinal cord until it reaches the brain.
- The information is assimilated along with other information that places you in a market and links into memories of buying unripe or over-ripe mangos in the past as well, and the pleasure of a ripe mango.
- Electrical messages are sent back along from the brain along the effector nerves down your spinal cord.
- At more spinal synapses the message is transferred to effector nerves running to the muscles of your arm and hand that enable you to make a voluntary movement, reaching out to take hold of the mango, feel it and bring it to your nose to smell it.
- Another flood of information from stretch receptors in your muscles, olfactory (smell) receptors in your nose, pressure receptors in your skin and many more goes back to your brain, all in a very short space of time, to be processed again before you make your next voluntary movement.

Think of a different situation – crossing a road, greeting a friend, eating a meal – and work out what is happening in your nervous system.

Figure 3.8 *Buying fresh food from a local stall – just one of the millions of voluntary actions we carry out each day.*

To summarise the situation, the nervous system is involved in rapid responses by the human body to changes in the world around it and within the body as well. Receptor cells collect information about a particular stimulus and electrical impulses transmit the information from the receptor cells along affector neurons to the central nervous system (CNS). Here the information is processed and another electrical impulse is sent out along the effector nerves to a muscle or gland (effector) that will then cause the appropriate body response. Muscles contract whilst glands release chemical substances.

Activity 3.1: Investigating reaction times

The length of time it takes you to recognise a stimulus and react to it is your reaction time. These are very important in many situations – for example, when you are driving, or at the start of a race. Some people react more quickly than others – and you can train yourself to speed up. In this investigation you will be looking at reaction times by measuring how quickly your partner catches a metre ruler when you let it fall. If you collect all the data for the class, you can produce a graph to show the range of reaction times for your science group, and also do some statistical analysis to find the average, median and mean reaction times for your class.

You will need:

- A metre ruler (or a stick and a ruler)

Method

1. Work in pairs, with one partner holding the ruler and recording the distance and the other catching.
2. Hold the ruler so that your partner's hand is level with the 10 cm mark. They should be able to see the ruler and your hand.
3. Warn them that you will soon be dropping the ruler and, after a few seconds, let go.
4. Repeat this three times and calculate the average distance the ruler travelled before your partner caught it.
5. Reverse roles.
6. Draw up a table and collect the results for the whole class.
7. Write up your investigation, including a graph to show the distribution of reaction rate across the class.
8. How could you develop or refine this investigation?

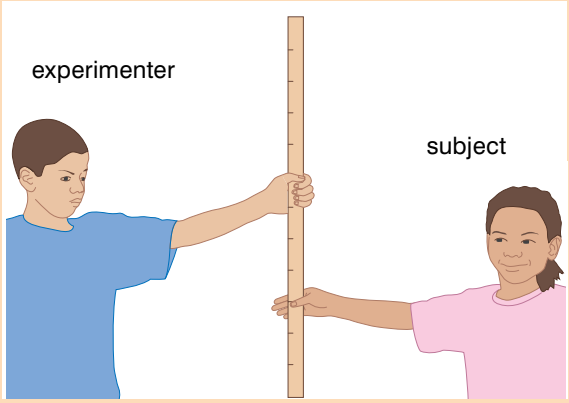


Figure 3.9 *Testing reaction times using a metre ruler*

In a normal conscious action we are in control – we see a book, reach out and pick it up or hear an approaching car and stop moving. But some of the actions of our body are so rapid that there is no time for conscious thought. Others take place without any awareness on our part – when was the last time you realised your pancreas was producing insulin or that your gastric pits were filling up with digestive enzymes? So what is happening in these involuntary or **reflex** actions?

KEY WORDS

reflexes *automatic, instinctive, unlearned reactions to stimuli*

KEY WORDS

reflex arc *neural path of a reflex*

reflex action *automatic, instinctive, unlearned reaction to a stimulus*

A reflex action

Some of our responses to stimuli are purely automatic. When we touch something very hot we withdraw our hand before we are consciously aware of the sensation of pain. If an object approaches our face we blink. We breathe and the muscles of our gut churn our food. Reactions such as these are known as reflexes.

Reflexes occur very fast. They are usually involved in helping us to avoid danger or damage. We also have lots of reflexes taking care of basic bodily functions, leaving the brain free for thinking about other things. Breathing is a good example. You don't consciously instruct your diaphragm to flatten and your intercostal muscles to contract yet your breathing movements continue, because breathing is a reflex action. Not only does gaseous exchange take place constantly, but you don't have to waste precious thinking time making sure it keeps going. The pupil reflex, where the pupil of your eye dilates or constricts depending on the light levels, is another example of a protective reflex action that you don't have to think about. It protects your retina from damage from too much light, and enables you to see as well as possible in low light levels. The blink reflex, where you blink your eyes if something comes towards your face, protects your eyes from physical damage. The key point about a reflex action is that the messages do not reach a conscious area of your brain before instructions are sent out to take action. Many reflexes involve the spinal cord while others involve the brain. They involve three types of neuron – affector neurons, relay neurons and effector neurons. Relay neurons connect the affector and effector neurons directly in the CNS, without input from other areas. The receptors, neurons and effectors involved are referred to as a **reflex arc**. The brain and spinal cord together act as co-ordinators that process the information coming from sensory receptors and neurons and instruct effector neurons and effectors to react.

A **reflex action** is a sudden, automatic and uncontrolled response of parts of the body or the whole body to external stimuli.

The reflex jerk of your knee is used by doctors to check that your reflexes are working properly – but it normally works if you stumble and the tendon is stretched. The reflex helps to straighten your leg and stop you falling.

Activity 3.2: The knee jerk reflex

You can demonstrate a simple spinal reflex used by doctors.

1. Work in pairs.
2. One person sits down with one leg loosely crossed over the other.
3. The other hits the crossed leg just below the knee cap (patella) gently but firmly. Use the edge of the hand, a special hammer or the edge of a ruler to do this. It should not hurt!
4. This hits a ligament which stretches a muscle. This is picked up by stretch receptors setting up a reflex arc. The impulse travels to the spinal cord and back to the quadriceps muscles in the thigh. These contract, causing the lower leg to jerk upwards and outwards as the leg straightens. It drops straight back into its normal position.
5. Change places and repeat.

How reflexes work in detail

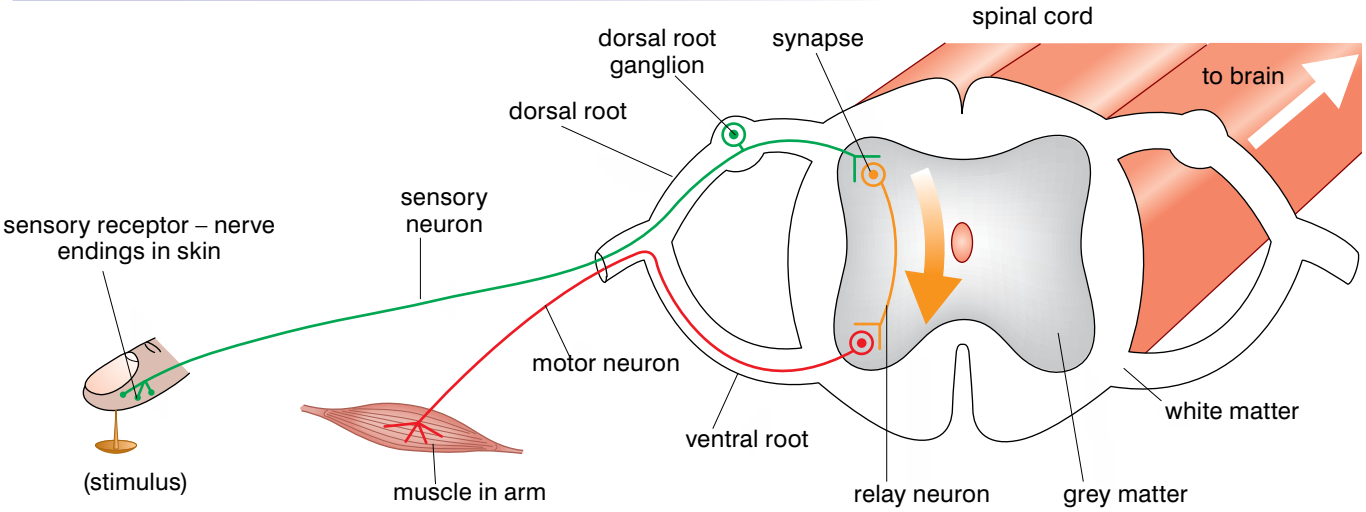


Figure 3.10 *This reflex action moves your hand away from the pin before you hurt yourself too much.*

In the example shown in Figure 3.10, when you put your finger on a sharp pin:

- Impulses from a sensory receptor in the skin pass along an affector neuron to the central nervous system – in this case the spinal cord.
- The neuron enters the spinal cord through the **dorsal root**.
- When an impulse from the affector neuron arrives in the synapse with a short relay neuron a transmitter is released (see earlier in the section), which causes an impulse to be sent along the relay neuron.
- When the impulse reaches the synapse between the relay neuron and an effector neuron returning to the arm again another transmitter chemical is released.
- This starts impulses travelling along the effector neuron to the organ (effector), which brings about change. The effector neuron leaves the spinal cord by the **ventral root**. In this example the impulses arrive in the muscles of the upper arm, causing them to contract and move your hand upwards sharply.

KEY WORDS

dorsal root *root at the back of the spinal cord*

ventral root *root at the front of the spinal cord*

Most reflex actions can be analysed as follows:

stimulus → receptor → afferent neuron → co-ordinator → efferent neuron → effector → response

This is very similar to a normal conscious action, except that in a reflex the co-ordinator is a relay neuron either in the spinal cord or in the unconscious areas of the brain.

If you put your hand down on something hot this analysis would show:

hand on hot plate → temperature and pain receptors in skin → afferent neuron → relay neuron in spinal cord → efferent neuron → muscles of arm → moving hand away from hot object

By missing out the process of conscious thought the whole action is speeded up. However, even as the impulse is moving through the

DID YOU KNOW?

Action potentials can travel along axons at speeds of 0.1–100 m/s. This means that nerve impulses can get from one part of a body to another in a few milliseconds. This is why reflexes can happen so quickly. It is the processing of information and decision making in your brain that tends to take the time.

Activity 3.3: Reflex action

Notice how much saliva you make. You probably make more when you smell food cooking or expect a meal.

List as many conditioned reflexes as you can think of.

reflex arc, other neurons have also been stimulated at the synapses in the CNS and these carry information up to the conscious brain so that you know what has happened after the event.

Conditioned reflexes

However, not all reflexes are simple. Some of them can be learnt. In 1902, a Russian scientist called Ivan Pavlov investigated conditioned reflex action using a dog. He noticed that a dog produces a lot of saliva at the sight of food. The production of saliva is a reflex action in response to the sight of food. In this experiment, a bell was rung every time food was supplied to a dog. After the experiment was repeated several times he noticed that when the bell was rung the dogs salivated, even if there was no food present.

Usually the sound of a bell does not cause a dog to salivate. In the experiment, however, the dog had learnt to associate the sound of the bell with the presence of food. Thus, the sound of the bell started the secretion of saliva in the same way as the sight of food. Salivation at the sound of the bell thus became a reflex action. Since this reflex action was not innate (there at birth), it is a result of experience or learning. This learned reflex action is called a conditioned reflex action.

It is possible to change an animal's behaviour in this way. This helps an animal to learn new ways of behaving. Conditioned reflexes also produce responses which are favourable. For example, a child is usually attracted to anything that moves, especially animals. This is an automatic behaviour. If, however, a safari ant happens to bite the child it is almost certain that in future, instead of being attracted to it, the child will fear to move towards a safari ant. Thus the child's behaviour has been changed or conditioned. So reflexes are important both for keeping us safe, and for helping us to learn.

Review questions

1. What is a reflex action?
2. What is a voluntary action and how does it differ from a reflex action?
3. If you touch something hot, you withdraw your hand very quickly in a reflex action. Draw a diagram to show this reflex arc and label it carefully.

Drug abuse

Almost every person reading this book will have taken a drug – and not just medicine from the doctor or healer. Most of you will have had a cup of coffee at some point in your lives – and so you have taken caffeine, a legal stimulant drug! What do we mean by a drug? A drug is a substance which alters the way in which your mind, or body, or both, works. In every society there are certain drugs which are used for medicine and others which are used for pleasure. Usually some of these substances are socially acceptable and others

are illegal. In Ethiopia caffeine, nicotine, khat and alcohol are the legal recreational drugs. The status of a drug may be related to its effect on people, or it may be simply down to the history of its use.

Most of the drugs which we use for medicine affect our bodies. The drugs we use for pleasure tend to have a distinct effect on our minds.

Drug (or substance) use is when you choose to take a substance that affects your brain and/or body function and mental activity. It is done for a variety of reasons. Legal drugs are used for the mild pleasure they bring, to be sociable and because using them becomes a habit. People start to use illegal drugs for much the same reasons – because everyone else does and because you like the effect – but as many of these drugs are highly addictive, they can soon lead to many problems.

Drug (or substance) abuse is when you use a substance to the point of excess and/or dependence. When you take an excess of a drug you risk serious side effects and even death. Drug dependence is when you use a drug again and again and become **addicted**. Drugs change the chemical processes in your body and this is why you can become addicted to them (dependent on them). If you are addicted to a drug you cannot manage or function properly without it. This may be psychological – the need to keep using it becomes a craving or compulsion. On the other hand it may be a physical dependence where your body no longer works properly without added chemical extras. Once addicted to a drug, you cannot manage without it and you generally need more and more of it to keep you feeling normal. When an addict tries to stop using their drug they will feel very unwell, often experiencing combinations of aches and pains, shaking, sweating, headaches, cravings for the drug and even fevers as the body reacts – these are known as **withdrawal symptoms**.

Drug abuse, of both legal and illegal substances, is becoming more of a public health problem in Ethiopia because the numbers of people involved is growing. School surveys have shown that alcohol, khat, tobacco, cannabis (marijuana) and solvents are the substances most widely used in Ethiopia. Alcohol, khat and tobacco are legal drugs in Ethiopia – you can buy them easily in shops and bars, but cannabis is illegal. Solvents like gasoline are legal but are not meant for humans to inhale. Drugs such as LSD, ecstasy, cocaine and heroin are illegal but rarely used in Ethiopia.

Khat, alcohol and tobacco are linked to a wide range of health problems. The health issues linked to these legal drugs are mainly the result of their effect on the systems of your body. However, illegal drugs also affect the health, in two quite different ways. Firstly, like any other drug, they cause changes in your body and can damage vital systems. But also, because these drugs are both illegal and addictive, people need to find considerable sums of money to feed their addiction. They may spend all of their cash on drugs, not feed themselves properly because they are buying drugs with the money, turn to crime or prostitution to raise the money

Figure 3.11 *We use legal drugs such as alcohol as part of our normal social life. No one at this party will be thinking of themselves as drug users – but that is what they are doing!*

DID YOU KNOW?

Alcohol is highly intoxicating and extremely poisonous. If it was a newly discovered substance it would almost certainly be illegal and regarded as highly dangerous. But because in many countries alcohol has been used for centuries, the drug is widely accepted as part of normal social life.

KEY WORDS

addicted *compulsively or physiologically dependent on something habit-forming*

withdrawal symptoms *a set of unpleasant effects upon the body caused by a sudden stopping of using a drug*

they need and take part in risky activities such as sharing needles, which increases the risk of becoming infected with HIV/AIDS or hepatitis. So the lifestyle associated with illegal drug use also has a major impact on health. However, these behaviours are relatively rare in Ethiopia, as you will see.

In the next part of this chapter you are going to look at some of the most commonly used recreational drugs in Ethiopia. They all have the following features in common:

- They are addictive.
- They affect brain function and alter behaviour.
- They damage health, resulting in lower productivity and absence from school/work.
- They adversely affect the individual, families, community and country.

You will explore all of these in this section.

Smoking

Figure 3.12 *Smoking is expensive, very addictive and causes many health problems.*

Smoking is not as common in Ethiopia as it is in many parts of the world. However, the evidence suggests that more and more young people are taking up smoking across the whole of Africa. The addictive drug in cigarette smoke is nicotine, which affects the brain and produces a sensation of calm well-being and being able to cope. However, it is very physically addictive. Unfortunately cigarette smoke also contains many very harmful chemicals, and these are linked to a number of very serious health conditions. Smoking increases your risk of the following diseases:

- **Coronary Heart Disease** – the chemicals in the tobacco smoke affect the walls of your arteries. They make the blood vessels supplying oxygen to the heart narrow. This reduces the blood supply to the heart and other areas of the body. They also tend to damage the smooth lining of the arteries, which makes it much more likely that atherosclerosis will occur.
- **Strokes** – the blood vessels taking blood to the brain suffer the same damage as the vessels going to the heart described above. If the blood vessels going to the brain become blocked you suffer a stroke. An area of your brain is damaged which may lead to paralysis, memory loss and even death.
- **Lung Disease** – tar and other chemicals in tobacco smoke damage the tissues of the lungs and lead to a greatly increased risk of developing chronic obstructive pulmonary disease (COPD) and lung cancer.
- **Cancers (lip, mouth, throat, pancreas, bladder and kidney)** – many of the chemicals in cigarette smoke are carcinogenic (cancer causing) and smoking has been shown to increase the risk of all these listed cancers. The mouth, lips and throat are obvious, but no one is quite sure exactly why the pancreas, bladder and kidney are particularly affected by cigarette smoke.

In recent years scientists have realised that smoking does not just affect the person who smokes. Passive smoking (inhaling smoke from those around you) can be equally dangerous to your health, and smoking while pregnant has been shown to affect the unborn child.

Review question

1. When a pregnant woman smokes, how does it affect her baby?

Because nicotine is so addictive it can be very difficult to give up smoking once you have started. You have to break the addiction. There are a number of ways which people use – some more successful than others! Will power and determination are needed whichever method you chose. Some people rely on this alone. Others give up smoking but use nicotine patches or gum to help wean themselves gradually off the drug. At least then they are not taking in all the chemicals from the cigarette smoke and get used to being without a cigarette in their hands or mouth. Other people cut down on their cigarettes gradually, cutting out one or two at a time until they can give up entirely. Each individual has to find their own way to give up! It is easier not to start smoking at all!

Activity

Look at the representation of smoking in the media: newspapers, magazines, films, advertisements, and anything else you can think of. Collate examples and discuss with the rest of the class.

Alcohol

Alcohol is one of the drugs most commonly used by people of all ages in Ethiopia, but we still drink far less than many other countries. For many people alcohol is part of their social life. They like to share a drink with friends and don't think of themselves as drug users. In small amounts, alcohol makes people feel relaxed and cheerful. It makes you less inhibited. So shy people can feel more confident when they've had an alcoholic drink.

But alcohol has a powerful effect on your body. It is very addictive and it is also very poisonous. Although some religions ban the use of alcohol, it is accepted all over the world. Perhaps this is because alcohol has been around for thousands of years. We also see that many important and famous people like a drink!

Review question

1. Why is alcohol described as a drug?

How does alcohol affect your body?

Alcohol is poisonous. However, your liver can usually break it down. It gets rid of the alcohol before it causes permanent damage and death. Alcohol acts quickly because it is readily absorbed into the bloodstream from the stomach. When you have an alcoholic drink, the alcohol passes through the wall of your gut and goes into your bloodstream. From your blood, the alcohol passes easily into nearly every tissue of your body.

It dilates blood capillaries near the skin surface producing a feeling of warmth and well-being. It increases the heart rate as well as

DID YOU KNOW?

It takes your liver at least one hour to break down the alcohol in an average drink of tella.

increases hunger. It gets into your nervous system and brain. This slows down your reactions. It can make you lose your self-control. It contributes to poor muscular co-ordination, resulting in slurred speech and a lack of balance. Alcohol is a diuretic, which means that it makes you lose water through increased urination.

As the effects of the alcohol wear off, it can cause headaches, due to dehydration, and nausea. When you have had too much to drink, you lack judgement.

Research has shown that young people who drink alcohol are more likely to have unprotected sex. This means they are more likely to become pregnant, and also much more likely to become infected with HIV/AIDS. Young people who drink every day are three times more likely to have unprotected sex than those who do not drink. Alcohol can cause you to make stupid or dangerous decisions, decisions you might regret for the rest of your life. And if you drink large amounts of alcohol, like a whole bottle of spirits, your liver simply cannot cope. You suffer from alcohol poisoning. This can quickly lead to unconsciousness, coma and death.

KEY WORDS

alcoholics *people who are addicted to alcohol*

cirrhosis of the liver *endstage liver disease*

Review question

1. Give an example of a poor decision that someone under the influence of alcohol might make.

Some people drink heavily for many years, becoming **alcoholics**. They are addicted to the drug. Their liver and brain suffer long-term damage and eventually the drink may kill them.

They may develop **cirrhosis of the liver**. This disease destroys your liver tissue. They can also get liver cancer, which spreads quickly and can be fatal. In some heavy drinkers their brain is so damaged (it becomes soft and pulpy) that it can't work any longer. This causes death.

Short bouts of very heavy drinking can cause the same symptoms to develop quite quickly.

The effects of drinking on society

Alcohol can also put you at risk because of the way you behave under the influence of the drug. Because alcohol slows down your reactions, you are much more likely to have an accident. This is very dangerous if you drive after drinking. As car ownership increases in Ethiopia, so do the number of deaths and injuries in car accidents.

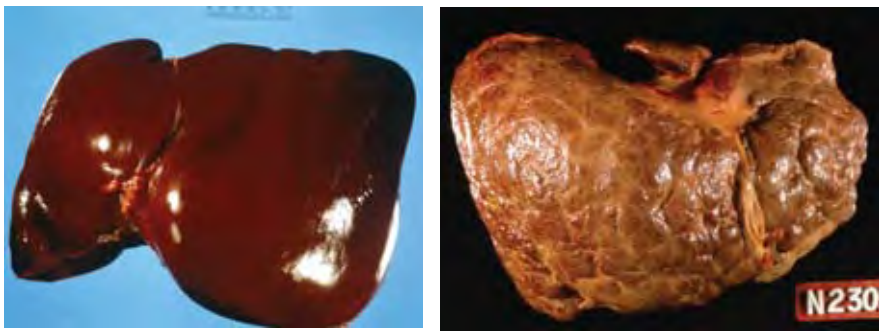


Figure 3.13 *Your liver deals with all the poisons you put into your body. But if you drink too much alcohol, even your liver can't cope. The difference between the healthy liver on the left and the liver with cirrhosis shows just why people are warned against heavy drinking!*

We need to make sure that people are aware of the dangers of drinking and driving. For example, alcohol is a factor in a high percentage of all fatal road accidents in the Caribbean. In fact, a survey in Trinidad a number of years ago showed that almost 50% of the men admitted to hospital had alcohol-related conditions. Let us make sure that here in Ethiopia we avoid these problems from the start!

Alcohol abuse affects personal lives as well. Domestic violence is often linked to patterns of heavy drinking. Many crimes take place when people are under the influence of alcohol, often mixed with other drugs.

Binge drinking is a recent problem. This often involves young people. They go out and get very drunk several nights a week. They can become violent and abusive, damage property and put their own health at risk both in cars and from HIV/AIDS through unprotected sex.

KEY WORDS

binge drinking *consuming excessive amounts of alcohol in a short period of time*

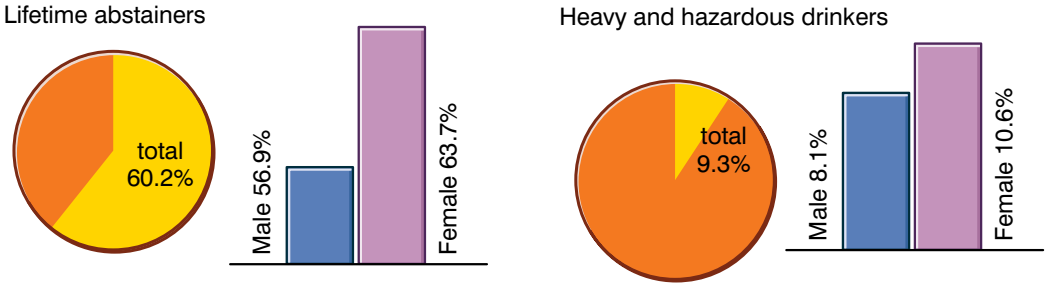


Figure 3.14 *This data is based on information collected by the World Health Organisation. It shows that while many people in Ethiopia do not drink alcohol at all, over 9% of our population drink very heavily indeed.*

Khat

Khat is the leaves of the khat shrub. People chew fresh khat leaves which contain a drug which affects the brain. It can also be made into a tea. It is a mild stimulant, makes people feel happy and also reduces your appetite. It is often used in social situations. In Ethiopia, khat use is growing fast among young people. It is a legal drug in our country. A survey showed that over 30% of our population use khat regularly.

The drug cathinone from the khat leaves is absorbed into the bloodstream through the membranes lining the mouth and the stomach as the leaves are chewed. It acts quickly, within 30 minutes of starting to chew, before it is broken down and removed by the liver. People can become addicted to khat, and when they cannot get the drug feel depressed, tired and unable to concentrate.

Surveys have shown that young people who are in school are much less likely to use khat than young people who are not in education. Khat use is linked to unprotected sex, putting young people at risk of pregnancy and HIV/AIDS infection. Young men who use khat have been shown to be more likely to use a sex worker, and more likely to have many different sexual partners. All of these

Figure 3.15 *Khat – a local drug that causes harm in our society, but has been used for centuries.*

behaviours increase their risk of becoming infected with HIV/AIDS and of passing that infection on to someone else. Using khat also makes people more likely to be injured in accidents, more likely to be involved in crime, less likely to have a job and more likely to have problems in their family lives.

Khat has been a part of our Ethiopian culture for centuries, but now there are growing concerns about its use. It is an important part of our economy – in 1999–2000 sales of khat brought around $60 million into the economy. Khat is relatively easy to grow and it creates jobs in the harvesting, packing and transporting of it as well as in selling it. What is more, it stops you feeling hungry. If people have little food to eat, it helps them to cope if they can chew leaves which make them feel good and stop them feeling hungry.

But the negative effects of the drug may be damaging the economy even more. People spend hours chewing and dreaming when they could be working. If people spent less time chewing khat and more time cultivating the fields there might be more food to eat. Khat affects the health of the population directly and indirectly by the behaviour it causes. For many young people, khat is destroying their chances in life. Many people in Ethiopia need to work together to find the best way to deal with the problem of khat. It might seem impossible, but in the UK 50 years ago smoking was widespread. Hundreds of thousands died from smoking-related diseases. Some people still smoke in the UK, but numbers have fallen dramatically and it is now against the law to smoke in public buildings. The numbers of people dying from smoking-related diseases has fallen steadily. This shows that it is possible to reduce the use of familiar local drugs.

The final commonly used drug in Ethiopia is **cannabis**, also known by many other names including **marijuana**, **ganja** and **weed**.

KEY WORDS

cannabis/marijuana *drug made from the cannabis plant*

ganja/weed *drug made from the cannabis plant*

hallucinogens *psychotoxic drugs that affect the mind in a way that produces distorted sensations abnormal in content*

Cannabis (marijuana)

Cannabis is a plant that contains 400 known chemicals, 60 of which, called the cannabinoids, are unique to the plant. The most potent is delta-9-tetrahydrocannabinoid (THC). THC is known to affect the brain cells responsible for memory, emotion and motivation. Cannabis is usually smoked but it can also be eaten, when it has a much stronger effect because your liver converts it into a much more powerful drug. It can make you feel a great sense of well-being and relaxation, happy and euphoric – and this is why people use it. It is a mild hallucinogenic drug. **Hallucinogens** are drugs that produce vivid waking dreams, where the user sees or hears things that are not really there, or has a distorted view of the world. However, some people find the effect of the drug a very unpleasant and disturbing experience.

The effect of cannabis is very variable. It affects different people in different ways, and even the same person can react very differently depending on how it is used.

Review question

1. Why do you think people use cannabis?

Many people mix cannabis with tobacco, so they have all the health problems linked to tobacco smoke as well as the problems cannabis can bring. Finally, because cannabis is illegal, people have to buy their supplies from illegal drug dealers. This means it can have a 'gateway' effect, putting people in touch with dealers who will later try to sell them harder and more expensive drugs.

Cannabis is illegal in Ethiopia, but in spite of this there is a long tradition of using it. It is currently used in a number of social contexts. As well as personal enjoyment with friends, it is used in folk medicine – and it seems to be very effective in pain relief for diseases such as multiple sclerosis.

It is difficult to see a way forward to reduce the use of the drug. It is already illegal but this has not stopped people. Better education so that people understand the health risks of using the drug can only help.

Most drugs carry risks. A survey showed that 43% of the people in mental hospitals in Ethiopia had abused alcohol, khat or cannabis. All of these drugs increase the risk of becoming infected with HIV/AIDS and other sexually transmitted diseases through unprotected sex. They make people less able to work.

There are many other illegal drugs but they are not widely used in Ethiopia, although in some places they are becoming more common. They include:

- **LSD (lysergic acid diethylamide)**. This is a very strong hallucinogenic drug made in the laboratory. It has such a powerful effect on the brain that many people who have used the drug for some time – and even first time users – develop severe mental illness as a result. Its effects can be so powerful that people believe they can fly, and there have been many cases of young people high on LSD (an LSD trip) leaping from buildings and falling to their deaths.
- **Cocaine**. When you take cocaine you get a rush of energy and a high where you feel very powerful. The downside is that you can end up feeling paranoid and depressed afterwards. It is an extremely addictive drug – your body quickly craves more and more of it. As a result people get addicted very quickly. It is also quite expensive, so people end up spending all their money to get enough fixes to satisfy their craving. Cocaine raises your blood pressure, causes your heartbeat to become fast and irregular and increases your body temperature. It can kill you the first time you use it, as some people have complete heart failure as a reaction to the drug. Every time you use the drug you are putting your mental and physical health at risk.

Figure 3.16 *Different types of cannabis plants produce different amounts of the hallucinogenic drug. Even the same type of plant, grown in different conditions, will produce more or less of the drug.*

Activity: Role Play

Divide into pairs and plan and act out a role play between a person who is abusing drugs and a friend or neighbour concerned about his or her behaviour and the effects on other people.

- **Heroin**. Heroin is one of a family of drugs known as the opioids formed from the opium poppy. People have used opiates, both medically as very good painkillers and as recreational drugs, for centuries. Heroin is usually found as a white or brownish powder, which is dissolved in water and injected either under the skin or directly into a muscle or vein. It can also be 'snorted' into the nose, smoked, eaten or inserted as a suppository into the rectum. The heroin molecules interact with receptors in the brain to create strong sensations of pleasure and to block pain. Most heroin users do not feel hunger, pain or sexual feelings when they are under the influence of the drug. A high dose of heroin kills very easily. Many heroin addicts get ill through sharing needles. They run a high risk of getting HIV/AIDS. They also risk abscesses, liver diseases such as hepatitis and even heart and brain damage.

The social effects of drug abuse on individuals, families and communities

The excessive and wrong use of drugs is considered drug abuse. Often this excessive use arises because what was initially a liking becomes an addition. As you have seen, most drugs tend to be habit-forming, if not physically addictive. The sensation that accompanies the use of drugs is often very appealing and satisfying and as a result this 'high' is sought after. This great high, however, is usually followed by depression and an extreme craving for another 'hit' just to feel better again. Many people spend a lifetime chasing that high and it becomes very difficult to break the cycle. The effects of drug abuse are many and varied. The excessive use of drugs significantly affects the individual user, the family and the wider community.

Effects on individuals

Because most drugs affect the nervous system, someone who abuses drugs usually displays an unusual sense of relaxation on one hand and a superhuman energy and strength on the other. Drug use is sometimes accompanied by aggressive and abusive behaviour, especially when someone wants some of the drug and can't get it.

Figure 3.17 *People who use drugs often become isolated from their families and the community.*

Using drugs reduces your ability to concentrate, to pay attention and to think logically and clearly; your judgement is impaired, which results in poor decision making. People often suffer from insomnia, anxiety, depression and acute panic reactions. These reactions inevitably affect other people as well. People who are experiencing paranoia and hallucinations are not easy to live with! Drug users often become suspicious of others, which can lead them into arguments and fights. Some drugs lead to an increase in appetite and weight gain, others to lack of appetite and weight loss. All these changes have a big impact on work as well as social and family life.

Many drug users turn to crime to fund their drug habit. Often this involves prostitution, so drug users are particularly prone to

sexually transmitted diseases including HIV/AIDS. The lifestyle linked to drugs often leads users to neglect their personal hygiene and fail to feed themselves properly. They often suffer ill health as a result. Drug users who inject themselves often share needles, which leads to a greatly increased risk of catching blood-borne diseases such as hepatitis and HIV/AIDS. Finally, some drugs can have a direct effect on your health. They may trigger mental illness, and they can kill you or leave you brain damaged.

Effects on family and friends

Very often relationships at home are affected and regular friendships are seriously damaged. The drug user may lose his/her job due to poor-quality work, regular absences or the inability to function. Loss of employment means a loss of income, creating serious financial problems. Drugs often impair sexual function, which will affect the relationship between the drug user and their partner. Many drug users crave attention and affection, often leading to an increasingly promiscuous lifestyle. Divorce is often the outcome of continued drug use.

Some people use drugs to help them cope with problems in their family. But often, it is drug use that causes a family to break up under the strain. People who become long-term, regular drug users often become isolated from their families and community. This isolation can make it harder for friends and family to keep in touch with the drug user to encourage them to break the habit.

The family of the drug abuser can often feel defeated, helpless and hopeless; they can experience a range of emotions such as anger, depression, fear, aggression, loneliness, hostility and embarrassment. This in turn affects the other relationships in the family. The family is often divided on how to address the problem and how to relate to the drug user, which creates its own conflict within the family.

In many cases in order to maintain their habit, drug users will steal and sell items from home, creating further distress to the family. Even where the drug abuser is not in the family home there is the emotional and psychological pain from being uncertain of his or her whereabouts and state. Children in these families become lonely in their confusion, depressed, aggressive and disruptive and often become a drugs user themselves to manage their pain – so the cycle continues.

Effects on the community

The wider community is severely challenged by the presence of those who have become abusers of drugs. One of the main social issues surrounding drug use is theft to finance the addiction – this could be through burglary, car theft or mugging. Violence, theft, sexual abuse and assault, murder, damage to property and violent crimes plague many communities where drug usage is high. Because drug use affects vision, sense of timing and co-ordination, many accidents can be attributed to drug use. Consequently,

Activity

Work in groups to research the prevalence of drug abuse in your own area, and write a report to present to the class. Identify the most commonly used drug, and assess why this is, and look at the effects on the individuals and wider community'.

communities where there is a high number of drug users are often gripped by fear, anxiety and grief as a result of accidents. People cannot work effectively, families break up – the impact of drug use on a community can be huge in both economic and personal terms.

What is more, the community has to pay for the health care of addicts, for the education programmes, for hostels and to help support the families left in despair. The cost of drug abuse is a very high one indeed.

To overcome the problems of drug abuse you need to be strong and prepared to avoid the use of drugs within your own life, and help others to avoid them too. Ethiopia will grow stronger and be a better place in the future if we all use alcohol sensibly and try to prevent the use of khat, cannabis and other illegal substances in our communities.

Summary

In this section you have learnt that:

- Living organisms need systems of co-ordination and control.
- Many multicellular organisms including human beings have both nervous and hormonal co-ordination and control systems.
- The nervous system is the most rapid. Nervous control involves:

  stimulus → receptor → co-ordinator → effector → response
- A nerve cell or neuron consists of a cell body, dendrites and an axon.
- Sensory neurons carry information from the sense organs to the central nervous system (CNS).
- Motor neurons carry instructions from the CNS to the effector organs (muscles and glands).
- The central nervous system is the brain and spinal cord. Information is assimilated and co-ordinated in the CNS.
- Neurons carry electrical impulses known as the action potential.
- In any pathway the junctions between neurons are called synapses. When an impulse arrives in one neuron chemicals are released in the synapse to trigger an impulse in the next neuron.
- A nerve contains many neurons. There are sensory nerves, motor nerves and mixed nerves.
- The spinal cord carries information from all over the body to and from the brain.
- Mental illnesses describe a wide variety of disorders and diseases that involve thought processes, emotional disturbances and/or behaviour that are considered abnormal.
- Cranial nerves come from the brain, while spinal nerves are from the spinal cord.
- Reflex actions avoid danger and run mundane bodily functions – they avoid conscious thought.
- Reflex actions involve:

  stimulus → receptor → co-ordinator → effector → response

  but the co-ordinator is the relay neuron in the spinal cord and there is no conscious thought involved.
- The knee jerk reflex is a common example of a reflex. It is used by doctors to test reflexes and in ordinary life to prevent stumbling.
- **Drug abuse** is when you use a substance to the point of excess and/or dependence. When you take an excess of a drug you risk serious side effects and even death.

- **Drug dependence** is when you use a drug again and again and become **addicted**.
- Drugs change the chemical processes in your body so you can become **addicted** to them (dependent on them). This means you cannot manage or function properly without the drug. This may be psychological – the need to keep using it becomes a craving or compulsion – or a physical dependence where your body no longer works properly without the drug.
- Alcohol, tobacco, khat and cannabis are the most widely used substances in Ethiopia.
- Other drugs which can be misused include prescription sedatives, cocaine, LSD, ecstasy and heroin.
- Drug abuse and dependence can hurt the individual user, their family and the entire community.

Review questions

1. Which of these statements correctly explains the relationship between neurons and nerves?
   A A neuron is a bundle of nerves.
   B They are the same thing.
   C Neurons carry messages to the brain and nerves carry messages away from the brain.
   D A nerve is a bundle of neurons.
2. Which of the following is NOT part of a nerve cell?
   A cilia
   B dendrites
   C cell body
   D axon
3. A nerve impulse crosses a synapse by means of:
   A electricity
   B vibration
   C chemical transmitters
   D light rays
4. One of these actions is NOT a reflex. Which one?
   A blinking
   B moving your foot away when you tread on a pin
   C driving
   D a new-born baby gripping your finger
5. Which of the following drugs is not legal in Ethiopia?
   A nicotine
   B alcohol
   C khat
   D cannabis
6. a) What is the main difference between a voluntary action and a reflex action?
   b) What is the value of reflex actions to the body?
   c) Analyse the following reflex actions using the sequence:
   stimulus → receptor → co-ordinator → effector → response
   i) A doctor hits you just below the knee cap with a rubber hammer.
   ii) You put your bare foot down on a drawing pin.
   iii) Someone claps their hands near your face.
7. a) Define the terms 'drug use', 'drug abuse' and 'drug dependence'.
   b) List the three most commonly abused substances by young people in Ethiopia.
   c) Explain the impact of substance abuse on the family and community.

3.2 Sense organs

By the end of this section you should be able to:

- Indicate the structures of the human eye, ear, skin, tongue and nose using diagrams or models, and describe their functions and methods of caring for them.
- Show the structures of the eye using a sheep's or cow's eye.
- Describe image formation and accommodation.
- Demonstrate the blind spot.
- List common eye defects in humans and explain their causes and the available corrective measures.
- Explain how balance is maintained by the inner ear.
- Identify the taste areas of the tongue.
- Conduct an experiment to prove that the actual taste of food is a mixture of taste and smell.
- Draw and label the smelling organ.
- Draw and label the structure of the skin.

Figure 3.18 *Different parts of the body contain different numbers of sensory receptors – this is what we would look like if our body parts reflected how sensitive they are.*

For any nervous system to work there must be sensory receptors that respond to stimuli. Stimuli are the changes in the environment that you need to know about to decide whether they are useful, dangerous or neutral – and what you need to do about them. In the human body there are many different types of sensory receptors that respond to different stimuli. In every case sensory receptors change the energy of the stimulus into electrical energy in a nerve impulse. Some of the most important include:

Table 3.1: *Table to show the main sense organs of the body and the type of stimulus they respond to*

Receptor	Energy
Eye (retina, provides vision)	Light
Ear (cochlea, organ of hearing)	Sound
Ear (semi-circular canals, organ of balance)	Movement (kinetic)
Tongue (taste buds, enable us to taste)	Chemical
Nose (olfactory organ or organ of smell)	Chemical
Skin (touch, pressure and pain)	Movement (kinetic)
Skin (temperature receptors)	Heat
Muscles (stretch receptors)	Movement (kinetic)
Arteries and brain (chemoreceptors responding to pH and carbon dioxide levels)	Chemical

The human eye

You are going to look in detail at one of our most important sense organs – the eye. Although the detailed anatomy of your other sense organs is very different, the same basic principles for transferring energy apply.

Sight is an important sense for human beings. The reason we can see so well is largely due to the very complicated sense organs that we use to pick up light stimulation – our eyes.

A **sensory organ** is an organ that contains a large number of sensory receptor cells and the human eye is a good example. Our eyes enable us to see in clear focus, in three dimensions and in colour. Not many other animals can manage all three. Let's take a look at the structure of the human eye and find out exactly how it works.

KEY WORDS

sensory organ *an organ that receives and relays information about the body's senses to the brain*

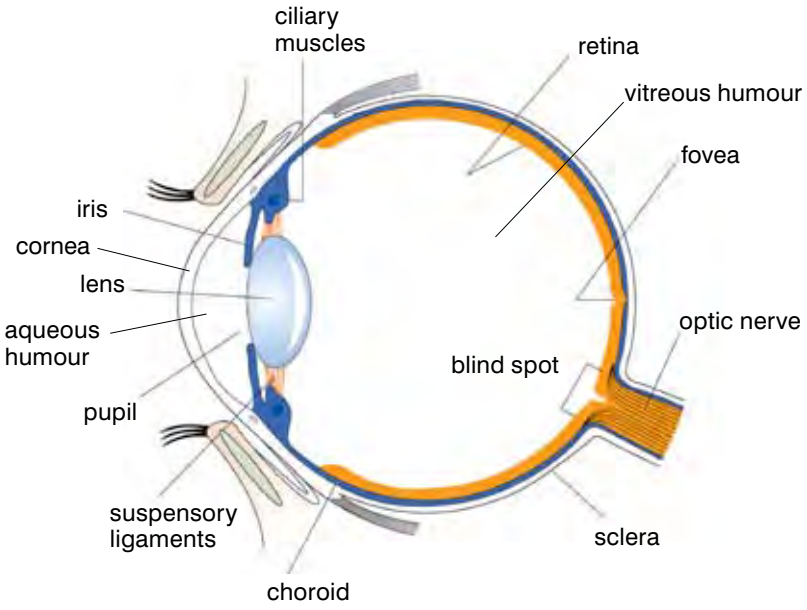


Figure 3.19 *This vertical section shows the main structures of the human eye – a very effective sense organ.*

Activity 3.4: Investigating the structure of the human eye

In this investigation you are going to look at eyes – your own and one from another animal.

You will need:

- a mirror
- a white tile
- sharp dissecting scissors
- eye of a sheep, cow or other mammal

Method

1. Look at your eyes in a mirror. How many of the features shown in figure 3.19 can you see? Draw and label your eyes.
2. Move your eyes from side to side or up and down to see the whites of your eyes – which part of the eye is this?
3. Look at the animal's eye provided by your teacher. Draw the external appearance of this eye and label it clearly. Can you see any of the muscles that are used to move the eyeball in the socket?
4. Using your scissors CAREFULLY cut a hole in the side of the eyeball. What comes out? How does this affect the eyeball?
5. Open the eyeball up more fully. Find the lens, the retina and as many other features from figure 3.19 as you can – NB you won't be able to see them all. Draw and label what you can see once you have opened the eyeball up fully.

KEY WORDS

sclera *the tough, opaque tissue that serves as the eye's protective outer layer*

cornea *transparent structure over the front of the eye that allows light to enter. A cornea resembles a contact lens in size and appearance*

choroid *the middle layer filled with blood vessels that nourish the retina*

pupil *a hole in the centre of the iris that changes size in response to changes in lighting*

iris *a membrane in the eye, responsible for controlling the amount of light reaching the retina*

dilated *becomes wider*

constricted *becomes smaller*

Your eyes are set in eye sockets in your skull that protect them. You also have eyelids that close over your eyes to protect them from the entry of material like dust, sand and insects, which might injure or irritate them. The eyelids also sweep tear solution regularly over the surface of your eye, which contains enzymes that destroy bacteria that might infect your eye.

The white outer layer of the eye, the **sclera**, is very tough and strong so the eyeball is not easy to damage. It has a transparent area at the front known as the **cornea**, which lets light into the eye. The curved surface of the cornea is also very important for bending the light coming into the eye to make sure it enters the eye and is focused on the retina. The rest of the sclera has many blood vessels, which supply your retina with food and oxygen, and a dark layer underneath – the **choroid**. This layer is dark because it contains pigmented cells that absorb light and stop it being reflected around the inside of the eye. Your eyeball is filled with a jelly-like fluid that helps to hold its shape.

Once the light has travelled through the cornea it has to pass through the **pupil** in the centre of the **iris**. The iris is the coloured part of the eye, but it is not there simply to look pretty. It is made up of muscles that contract or relax to control the size of the pupil and so to control the amount of light reaching the retina. The circular muscles run around the iris, while the radial muscles run across it like the spokes of a bicycle wheel. When the light is relatively dim, the radial muscles contract and the circular muscles relax and the pupil is pulled open wide (it **dilates**). When the pupil is dilated, lots of light can get into the eye and so you can see even in relatively low light levels. In bright light, however, the circular muscles of the iris contract and the radial muscles relax, which makes the pupil very small (it **constricts**). This reduces the amount of light that goes into the eye, so that the delicate light-sensitive cells are not damaged by too much bright light. The change in the size of the pupil in response to light is a reflex action – you don't have to think about it. You have already learnt about reflex actions earlier in this chapter.

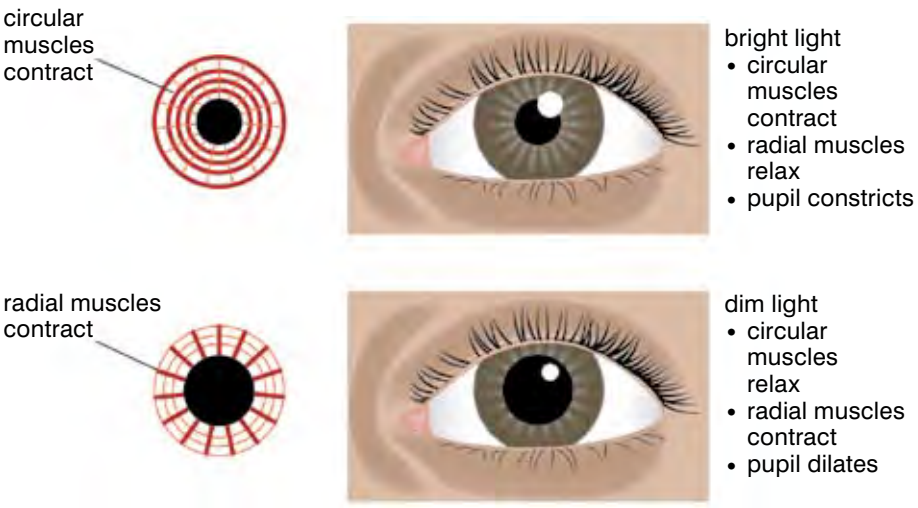


Figure 3.20 *The eyes have been described as the windows of the soul. They are certainly the windows of the body, letting the right amount of light in to fall on the sensitive cells of the retina.*

Activity 3.5: Investigating the effect of light on the size of the pupil

You can observe the way the size of the pupil changes in response to light in two simple ways – either work with a partner or use a mirror and observe your own eyes.

1. Observe the size of your partner's/your own pupils in the normal working light of your classroom.
2. Cover your eyes with your hands, or with a piece of cloth, for a minute or so – but keep your eyes open normally (you can blink).
3. Remove the cover from the eyes and observe the pupils closely. Note down what you see both immediately after removing the cover and as the eye adjusts to normal light levels (diagrams may help).
4. Now increase the light intensity – move outside into the sunlight or just move nearer to the windows. Again watch and record what happens to the pupils in the brighter light – and when you return to normal classroom levels of light.

KEY WORDS

lens *a flexible disc that helps focus light on the retina*

suspensory ligaments *elastic-like structures that suspend the lens and pull it into shape for focusing distant objects onto the retina*

ciliary muscles *eye muscles that automatically contract or relax the shape of the lens of the eye to help focus light on the retina*

Once light has entered your inner eye through the pupil it passes through the **lens**, a clear disc made up largely of proteins. The lens is held in place by **suspensory ligaments** and the **ciliary muscles**. It is the lens of the eye that 'fine-tunes' the focusing of the light, bending it to make sure that it produces an image on the retina (see How the retina works – Focusing the light).

All of the light-sensitive cells are arranged together in a special light-sensitive layer at the back of the eye known as the **retina**. When an image is produced on the retina, the light-sensitive cells are stimulated. They send impulses to the brain along affector (sensory) neurons in the optic nerve. When the brain receives these messages it interprets the information and we understand the impulses as an awareness of a visual image – in other words, we see something.

At the point where your optic nerve leaves your eye there is no retina. You have a blind spot. But take a look around your classroom – there are no missing bits in your field of vision. Your brain does a very good job of filling in the missing bits from your blind spots with information from the other eye. The only way you can prove that it is there is to use a bit of trickery yourself.

Activity 3.6: Demonstrating the blind spot

1. Look at the picture below. Hold the book so it is 30 cm from your eyes, with the pictures below level with your eyes.
2. Close your left eye completely and focus on the person with your right eye.
3. SLOWLY bring the book towards your face, keeping your right eye focused on the person all the time.
4. What happens to the lion as you move the picture towards you? How do you explain what happens?
5. What happens if you repeat the investigation with both eyes open? Explain any differences you observe.

KEY WORDS

retina *a light-sensitive tissue lining the inner surface of the eye*

rods *cells in the retina that perceive light and movement and work well in dim light*

cones *cells in the retina that perceive light and movement and only work in bright light*

DID YOU KNOW?

The pigment in the rods that responds to light is based on vitamin A. This is why a lack of vitamin A in your diet causes **night blindness**. You can't make the visual pigment you need to see in low light levels if you are short of vitamin A.

Review questions

1. What are sense organs?
2. What is the role of the iris, the ciliary muscles and the retina in your eye?

How the retina works

The light energy that falls on your retina is changed into electrical energy by the light-sensitive cells known as the **rods** and **cones** that make up your retina. Rods and cones contain chemicals that change when light falls on them. This change triggers an impulse in the affector neurons that make up the optic nerve. The impulses travel along the optic nerve to the visual areas of the brain (see page 59). The rods and cones then use energy to restore the chemicals to their original form.

Rods respond to relatively low light levels, but they do not give a very clear image and they do not respond to different colours. This explains why, when light levels fall in the evening, the colour drains away and everything looks black and grey. Rods are spread across your retina except over the fovea (the small area of your retina which contains ONLY cones).

Cones only work properly in bright light – but they respond to colours and give very clear, defined images. There are fewer cones than rods, and there are very few of them around the edges of the retina. This is why the edges of your visual field are blurred – but very sensitive to movement. The closer you get to the fovea the more cones there are, and the fovea itself has only cone cells. When light falls on your fovea you see clearly and in colour. Each cone responds to red, green or blue light. The colours you see depend on which combination of cones is stimulated – if all three are stimulated equally, you see white.

Some people cannot see all the colours because they are missing one or more type of cone. This is known as colour blindness. It is not a major problem although there are a few jobs you can't do easily if you are colour-blind.

Focusing the light

If you are going to see clearly, light from an object must be focused on your retina. For this to happen the light must be bent or refracted. Light rays are refracted when they pass from one medium to another – for example, from air into water.

a light-sensitive pigments
b mitochondria to supply energy
c nucleus
d dentrites synapse with optic nerve

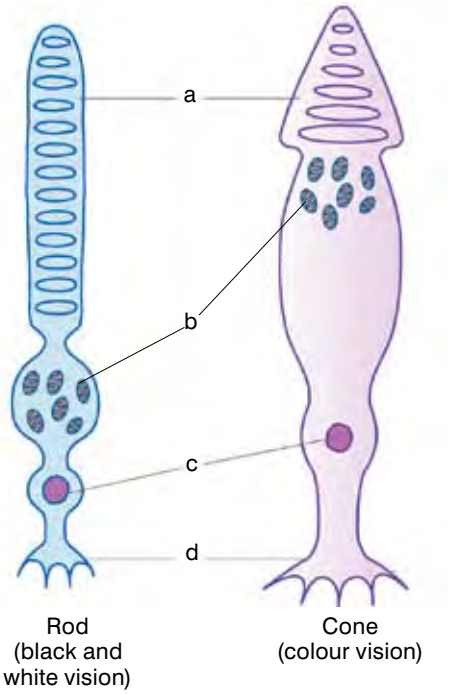


Figure 3.21 *The rods and the cones in the retina of your eye are efficient energy transducers that enable you to see in black-and-white and colour.*

Activity 3.7: Investigating refraction

This is a very simple exercise to remind you of the way light can be refracted as it changes medium.

You will need:

- a beaker or glass of water
- a glass rod, ruler or your finger

Method

Look carefully at your rod, ruler or finger. Then dip it into the water in the beaker or glass and observe what appears to happen. Any changes you see are due to the rays of light bending as they pass from water to air.

In your eye, the light coming in is bent (refracted) twice – once as it passes from the air through the cornea and then again as it passes through the lens. As a result of this refraction the image is focused onto your retina – and it is also upside down. The optical areas of the brain interpret this inverted image so that you are aware of the world the right way up.

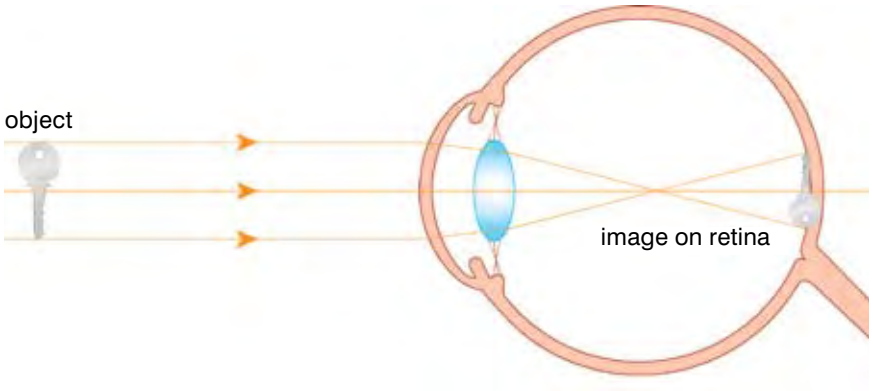


Figure 3.22 *When an inverted image falls on the light-sensitive cells of the retina and a message is sent through the optic nerve to the brain, you can see.*

Sometimes we look at objects close to us – for example, when we are reading or studying. At other times we are gazing into the distance, looking at objects a long way away. The light arriving at our eyes in these circumstances is travelling differently. The light from a distant object reaching our eyes will be travelling in almost parallel rays, whilst the light from close objects will be spreading out or **diverging** very strongly.

The cornea bends all of the light entering the eyes towards the retina, but it is the lens that makes sure that we can see both close and distant objects equally well. It does this by changing shape. Light from **distant** objects needs little further bending once it has passed through the cornea, so the lens is stretched long, thin and relatively flat and has little effect. However, light from close objects still needs some considerable bending to bring it into focus on the

DID YOU KNOW?

There are around 100 million light-sensitive cells in each of your retinas.

KEY WORDS

diverging *spreading apart*
distant *far away*
convex *curving or bulging outwards*
converging *two or more things coming together*
concave *curving or bulging inwards*

DID YOU KNOW?

In an investigation a group of people were given special goggles that inverted the image going into their eyes. As a result, the image on their retina was the right way up – so they perceived the world as upside-down! In time their brains adapted, and eventually they 'saw' the world as completely normal, even though they were still wearing the goggles. The only problem was, when they removed the goggles, everything looked upside down again… until their brains readjusted yet again.

retina. The lens of the eye needs to be much thicker to focus light from near objects. It becomes shorter, fatter and much more convex (rounded) so that it bends the light much more. These changes in the shape of the lens are brought about by the contraction and relaxation of the ciliary muscles that surround them, which in turn pull – or don't pull – on the suspensory ligaments that hold the lens in place. Ability of the human eye to focus on objects at different distances is known as accommodation.

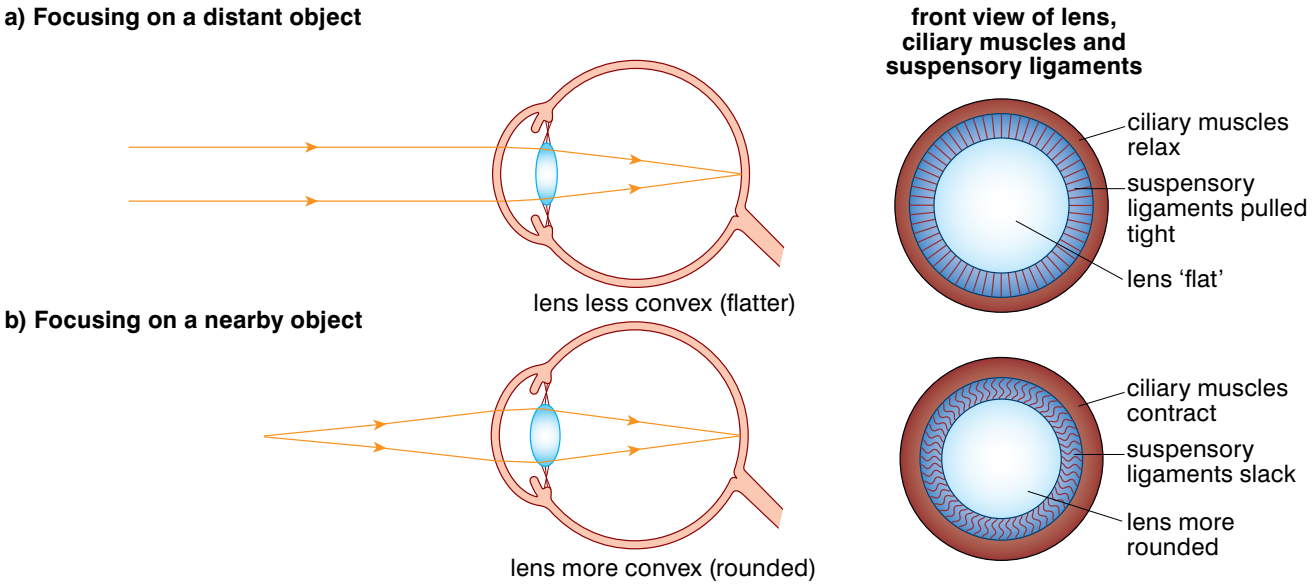


Figure 3.23 *Accommodation in the eye. It is the relaxation and contraction of the ciliary muscles that change the shape of the lens and allow distant and close objects to be focused equally clearly on the retina.*

Activity 3.8: Bending light rays

For this investigation you will need to raid the stores of the physics department.

You will need:

- light boxes or small, bright light sources
- lenses

Method

Switch on the light box and observe the light emerging. Try putting the different lenses in the light and make drawings to show how they affect the light rays.

Common eye defects

As people get older the lens of the eye may begin to harden, so accommodation becomes more difficult and they cannot focus so easily on close objects. This can make reading a problem, for example.

However, it isn't only older people who can have problems with their vision. There are a number of common eye defects that can and do affect many people of all ages. There are a number of ways in which these problems can be treated – but they all involve the use of extra lenses to bend the light. A lens is a piece of transparent material (usually glass or plastic) that has one or more curved surfaces. An outward curve makes a **convex** lens and this will bend the light rays towards each other (a **converging** lens). An inward curve makes a **concave** lens and this will spread the light rays out (a diverging lens).

In some people the normal method of accommodation in the eye that enables them to see close-up and distant objects with equal clarity just doesn't work properly:

Short sight: A short-sighted person can focus clearly on things that are close to them but has much more difficulty with objects in the distance, which appear blurred. This may be as a result of a lens

that is effectively 'too strong' – it is too curved even when the ciliary muscles are fully relaxed and so the light from distant objects is focused in front of the retina, making the image that actually lands on the retina spread out again and blurry. Another cause of short sightedness is when the lens is normal but the eyeball is particularly long – and again this means light is focused in front of the retina.

This problem can be corrected using concave (diverging) lenses that spread the light out more before it gets into your eye. This means that the thicker lens can bring the rays of light into perfect focus on the retina – or there is room in the long eyeball for the light rays to be focused on the correct point.

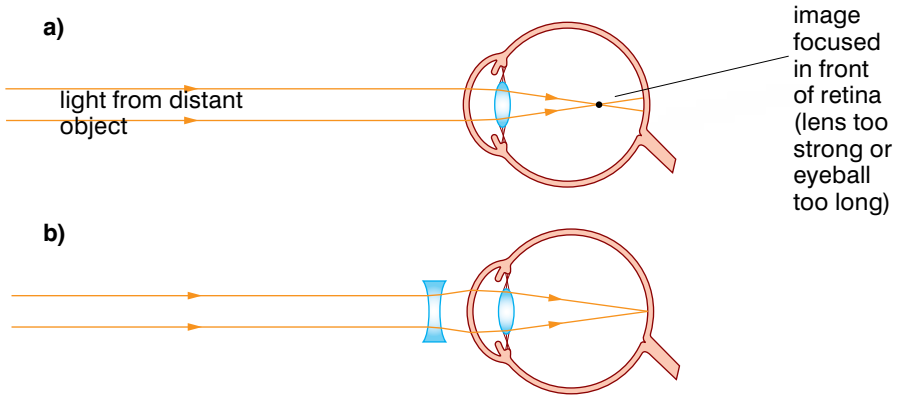


Figure 3.24 *The eyes of short-sighted people focus light from distant objects in front of the retina, which makes it difficult to see clearly. A simple concave lens makes all the difference.*

Long sight: A long-sighted person can focus clearly on things that are at a distance but has much more difficulty with objects close to them, which appear blurred. This may be as a result of a lens that is effectively 'too weak' – it is too flat even when the ciliary muscles are fully contracted and so the light from close objects is focused behind the retina, so the image that actually lands on the retina is spread out and blurred. Another cause of long sightedness is when the lens is normal but the eyeball is particularly short – and again this means light is focused behind the retina.

This problem can be corrected using convex (converging) lenses that bring the light rays together more before they reach your eye. Now the thinner lens can bring the rays of light into perfect focus on the retina – or the short eyeball becomes the right length for the light rays to be focused on the correct point.

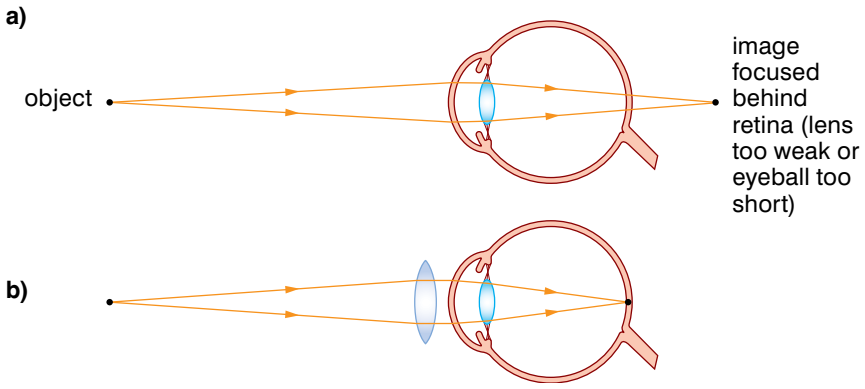
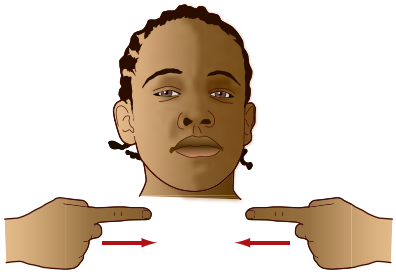
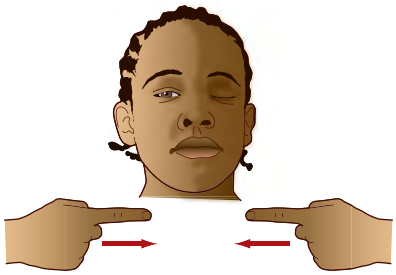


Figure 3.25 *The eyes of long-sighted people focus light from close objects behind the retina, which makes it difficult to see clearly and makes tasks such as reading very difficult. In this case a simple convex lens makes all the difference.*

Astigmatism: Astigmatism is another fairly common eye defect. The shape of the eye is irregular – more egg-shaped than round – so the cornea is curved asymmetrically and this affects the way light is focused on your retina. In some people it is the lens rather than the eyeball itself that is an unusual shape, but the end result is the same. Astigmatism can also be corrected by the use of lenses, but the situation is more complex than for long and short sight.



move fingers together so they touch with your eyes open



move fingers together so they touch with just one eye open

3-D vision

We not only see in colour and in clear focus – we also see in three dimensions. Our view of the world gives us enough information to build up a 3-D picture of the world around us. This 3-D vision is vital for giving us the judgement of distances that we need to do so many things, from threading a needle to driving a car. This amazing spatial awareness comes from the overlapping of the visual field from our two eyes. If you look at the world through one eye it appears flat. You may not notice particularly – but try this. Hold out both hands, with one finger pointing on each. Bring your fingers together with the tips meeting in one smooth movement. Now close one eye and repeat the manoeuvre – it isn't so easy!

Seeing in depth depends on you using both eyes. Each eye sees a slightly different view of the same object. Your brain combines the two images and uses all the information to give you a 3-D view of the object.

Review questions

1. How are lenses used to correct sight defects?
2. Why is 3-D vision so useful to us?

The ear as a sense organ

Your ears are specialised organs which enable you to hear sound. They are also concerned with the balance and position of the body.

The ear is divided into three regions: the **outer ear**, **middle ear** and **inner ear**. Look at figure 3.27 to see the structure of the ear as you read about how it works.

The outer ear consists of a flap called a pinna. Leading from the pinna is a tube, the ear canal. In humans this is about 2 cm long. The pinna helps to trap and funnel sound into the ear. This is particularly important in animals with longer ears than humans, which can move the pinna to pick up sounds.

At the end of the ear canal is a sheet of very thin membrane called the **eardrum** or tympanum that closes the tube.

The pinna, ear canal and the eardrum form the outer ear. At the entrance of the ear canal are a number of small hairs. These filter out dust particles from the air entering the ear canal. The cells lining the ear canal produce waxy material which traps dust and germs, and lubricates the eardrum.

KEY WORDS

astigmatism *an optical defect in which vision is blurred due to the inability of the optics of the eye to focus a point object into a sharp focused image on the retina*

outer ear *the part of the ear visible externally*

middle ear *the main cavity of the ear, between the eardrum and the inner ear*

inner ear *a complex system of interconnecting cavities, concerned with hearing and equilibrium*

eardrum *the membrane in the ear that vibrates to sound*

Behind the eardrum is a cavity filled with air. This cavity contains three tiny bones and forms the middle ear. The three tiny bones – called the **malleus** (**hammer**), the **incus** (**anvil**) and the **stapes** (**stirrup**) because of their shape – are the smallest bones in your body. They form joints with one another, with the malleus attached to the eardrum and the stapes to the oval window. The cavity of the middle ear is connected to your throat by a tube called the Eustachian tube. This is usually closed but when the pressure in the middle ear increases – when you are flying, for example – the tube opens until the air pressure in the middle ear is equal to that in the throat and therefore to the atmosphere.

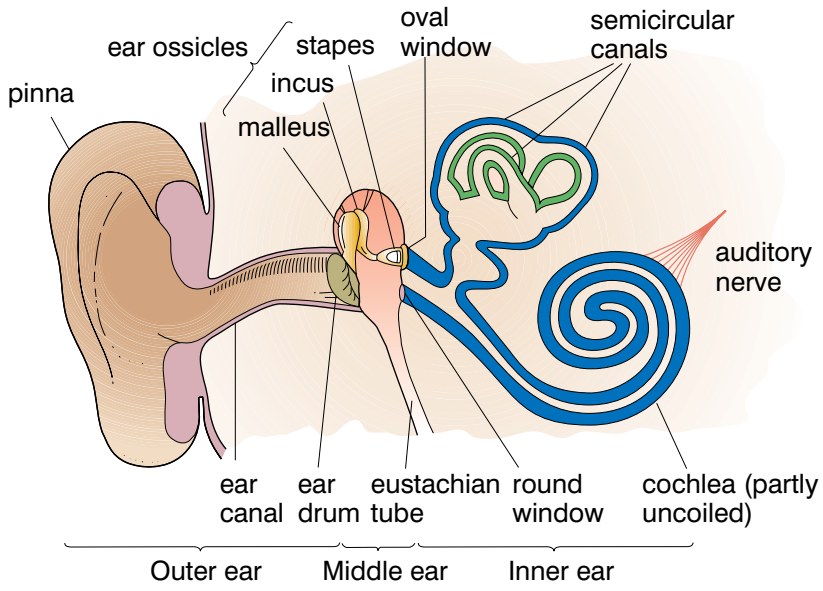
At one end of the middle ear, opposite to the eardrum, there are two openings: one of them is oval in shape and hence it is called the oval window. The other is round and is called the round window. The openings are covered by very thin membranes.

The inner ear consists of a cavity filled with a fluid, two sac-like structures called the sacculus and utriculus, three semicircular canals and a coiled tube called the cochlea.

The sacculus, utriculus, semicircular canals and the cochlea are filled with a liquid. A cross section of the cochlea reveals that it is made up of three tubes in one (figure 3.28). The floor of the middle tube is lined with sensory cells linked to affector neurons. These nerve fibres join to form the auditory nerve which leads to the brain.

Review question

1. How can you use your ears to help you find where a sound is coming from?



The mechanism of hearing

You have had a look at the structure of the ear. Now you need to look at how the ear works. The pinna collects sound waves and directs them to the eardrum through the ear canal. When sound waves hit the eardrum, it vibrates. This magnifies the vibrations,

Figure 3.26 *The pinna plays an important role for these antelopes, allowing them both to pick up sounds very easily and also to find out which direction the sound is coming from.*

Activity 3.9: Examination of the human ear

You will need:

- a model of a mammalian ear

Method

1. Examine the external part of the ear of your neighbour. Note its shape and texture.
2. Examine a model of a mammalian ear. Note the shape of the various parts.
3. Make a drawing of the model.
4. Compare your diagram with that in figure 3.27.

Figure 3.27 *The structure of the human ear.*

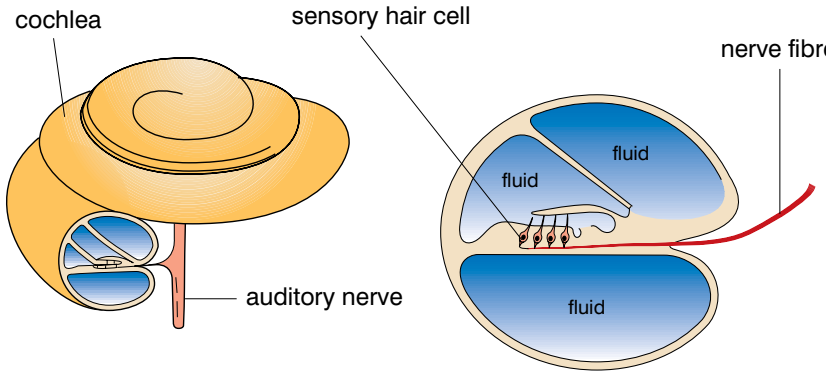


Figure 3.28 *This cross section through a cochlea shows how the movement of the fluid in the inner ear affects the sensory hair cells – and the impulses they send to your brain are interpreted as sounds.*

which are then transmitted through the ear ossicles (the small bones) to the oval window. The ear ossicles also amplify the vibrations (make them bigger).

The vibrations of the stapes make the membrane at the oval window vibrate. The vibrations of the oval window are transmitted to the fluid and then spread to the cochlea. Vibrations of the fluid cause the hair-like sensory cells to move. These movements in turn cause production of nerve impulses in the affector nerve fibres. These impulses are transmitted to the brain for interpretation.

The human ear is sensitive to vibrations ranging from those of a very low note of about 20 vibrations per second, to a very high note of about 30 000 vibrations per second. High notes are detected in the first part of the cochlea and low notes are recorded in the last part of the cochlea.

KEY WORDS

malleus (hammer) *the ossicle attached to the eardrum*

incus (anvil) *the ossicle between the malleus and the stapes*

stapes (stirrup) *the stirrup-shaped ossicle that transmits sound from the incus to the cochlea*

ampullae *the swelling at the base of each semicircular canal, containing sensory cells which detect movement of the fluid within the canals*

The senses of balance and movement

The semicircular canals in your inner ear are concerned with the detection of motion. The swellings on each of the semicircular canals (the **ampullae**) contain sensory cells attached to sensory nerve endings. The sensory cells have hairs which are enclosed in a core of jelly substance called a cupula (figure 3.29). Whenever the body or the head moves, the semicircular canals move with the head. The fluid in the semicircular canals also starts to move but it lags behind in its motion and so it apparently moves in the opposite direction. The moving fluid causes the cupula to tilt, thus pressing the hairs of the sensory cells. The pressing of the sensory hairs creates nerve impulses in the sensory nerve endings. The nerve impulses are transmitted to the brain. The brain then interprets the direction and speed of motion of the body or head.

The semicircular canals are all at right angles to each other, so each one is sensitive to movement in a different plane. One canal responds when you nod your head, one when you shake it and one when you tilt your head to the side. If you spin round and round fast and then stop, you will feel dizzy. This is because the fluid in your semicircular canals keeps on moving after you have stopped. Your ears are telling your brain that you are moving round, but your eyes and other senses are saying you are standing still – and these mixed messages result in the dizzy sensation.

The utriculus and sacculus are concerned with your sense of balance and posture. The inner surfaces of these structures contain sensory cells with protruding hairs embedded in a jelly-like substance containing tiny particles of chalk called **otoliths**. When your head is tilted on one side, the otoliths move in the opposite

direction, pulling or pressing the sensory hairs. This initiates nerve impulses which are transmitted to the brain. The brain then detects the angle of tilt and sets of reflexes are initiated, which tend to return the body to its normal posture.

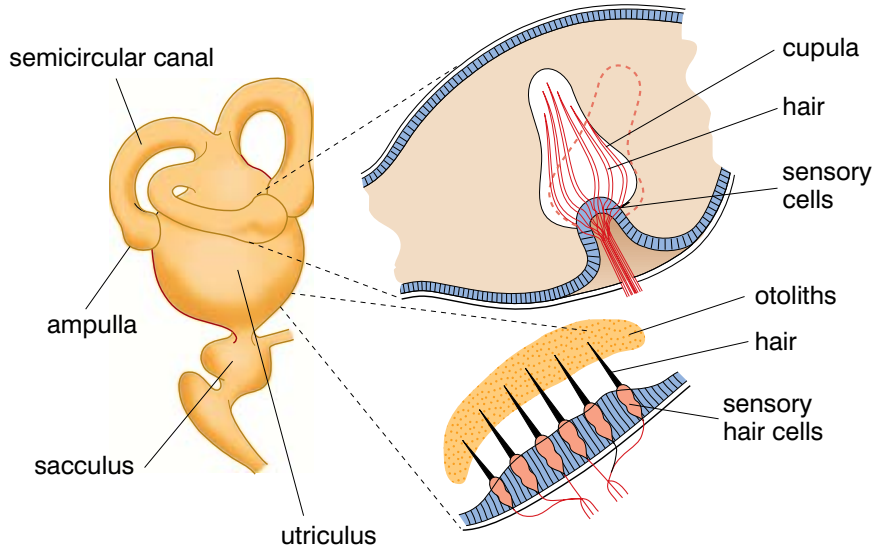


Figure 3.29 *The balance organs of the ear.*

Your ear is not the only part of your body involved in giving you a sense of balance. The sense of balance is also affected by your vision and by stretch receptors in the muscles, which constantly help you to be aware of your position. Someone trying to stand on their toes with their eyes closed will invariably begin to fall forward. This is much less likely to happen if the same exercise is performed with the eyes open!

Common disorders of the ear

Deafness, or the inability to hear, is one of the most common disorders of the ear. Deafness may be temporary or permanent. It can be caused in many ways. If the eardrum is damaged, by a blow or by a very loud noise, deafness will result. This may be temporary or, if the eardrum fails to heal, it can be permanent. If the tiny bones of the middle ear become damaged or fused by infection, or crumble away with age or disease, you will be permanently deaf. Damage to the auditory nerve is another cause of deafness, and once the nerve is damaged it cannot be restored.

Hearing loss can also be the result of infection, when the middle ear becomes full of thick infected mucus. This type of hearing loss can be reversed if the infection is cleared with antibiotics. However, if the infection lasts too long, permanent hearing loss may result.

Taste and smell

The sensory receptors of your tongue and those found in the nostrils are sensitive to solutions of certain chemical substances. The sensory receptors of taste are located on the upper surface of the tongue, and to a lesser extent on the surface of the throat. The receptors for smell are located in the upper parts of the nasal passages.

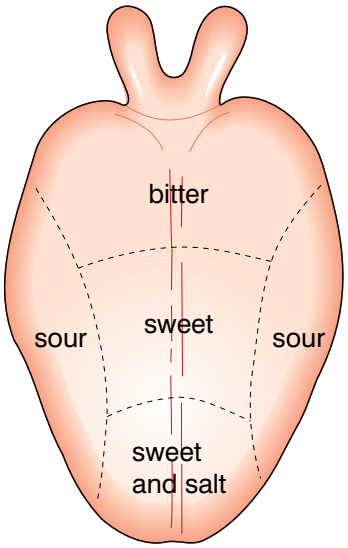


Figure 3.30 *This 'map' of the main taste areas of the tongue has been taught for many years. Scientists have discovered that in fact there are five different types of taste buds spread evenly across the tongue – and the idea for the map comes from a German text which was translated wrongly many years ago!*

There are five basic taste sensations. The first four are sweet, sour, bitter and salt. We have known about these for many years. Very recently scientists have discovered a fifth taste called umami (a very savoury flavour found in foods such as meat, cheese, broth and mushroom). For many years it was thought that the receptors for the four known senses had their areas of greatest concentration on different parts of the tongue. It has now been clearly shown that in fact all of the five different taste organs are spread out all over the tongue, although some of them may seem to be in a greater concentration in certain places.

Activity 3.10: Investigating the sense of taste

You will need:

- sugar solution
- salt solution
- vinegar
- rhamnus
- cotton buds or clean pieces of cotton wool or cloth

Method

1. Draw a blank map of your tongue.
2. Work in pairs.
3. One person dips a cotton bud in the sugar solution and touches it in several places on the tongue of their partner.
4. Each time the tongue is touched, the subject says what they can taste (if anything). Mark the taste on the map.
5. Throw away that cotton bud. Dip another in salt solution and repeat.
6. Do this for all four solutions.
7. Then exchange roles and repeat the experiment.
8. What sort of map did you get – and is everyone's tongue map the same?
9. The tongue can only taste chemicals that are in solution. Design an experiment to demonstrate this.

Figure 3.31 *The taste of your food is partly the result of information from the taste buds on your tongue and partly from the sense of smell in your nose.*

A few substances stimulate only one of the five types of receptors, but most stimulate two, three, four or five types to varying degrees. The taste sensations you experience are produced by a blending of the five basic sensations in different relative intensities along with the input of smell from your nose.

The sensation experienced by different people in response to the same stimulus may not be the same. The same substance can give rise to a sensation of sweet in one person if it stimulates primarily the sweet receptors. It can give rise to a sensation of bitter in a second person if it stimulates primarily the bitter receptors. There can be no sensation at all to a third person if it fails to stimulate any

of the receptors. This is why the same food can taste delicious to one person and disgusting to another!

It is possible for someone to have particularly sensitive sweet receptors and particularly insensitive sour receptors. Such a person might not like sugary food, because it would stimulate the sweet receptors excessively and arouse a sickening sweet sensation. But they might be very fond of lemons so sour that most people would reject them. This is because the sour receptors in this person, being unusually insensitive, would be hardly stimulated by the lemon juice.

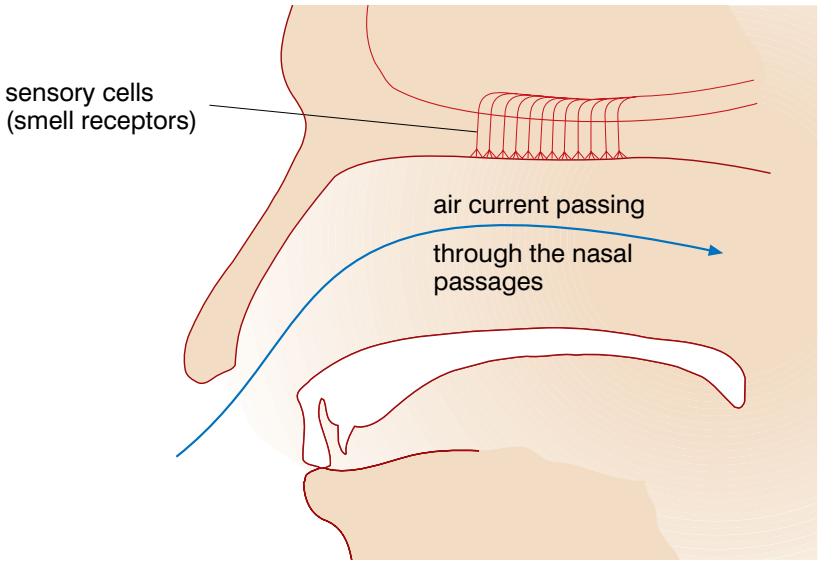


Figure 3.32 *You are aware of the sense of smell as air is drawn through your nasal passages over the smell receptors in your nose.*

The receptors of taste and smell are essentially similar in function. In fact much of what is called taste is in fact a function of the sense of smell. When a person speaks of taste sensation they are referring to a compound sensation produced by stimulation of both taste and smell receptors. One reason why hot foods often have more 'taste' than cold foods is because they vaporise more. The vapour passes from the mouth up into the nasal passages, where it stimulates smell receptors (figure 3.32). The reason why you cannot 'taste' foods well when suffering from a cold is that, with your nasal passages inflamed and coated with mucus, your smell receptors cannot work. In other words, much of what is called taste is really smell.

For you to be able to taste and smell, chemicals must go into solution in the film of liquid coating the membranes of receptor cells before they can be detected. The major functional difference between the two kinds of receptors is that smell receptors are more specialised for detecting vapours coming to the organism from distant sources. Taste receptors are specialised for detection of chemicals present in the mouth itself. Furthermore, smell receptors are much more sensitive than taste receptors.

The skin as a sense organ

The skin is a remarkably complex organ which carries out a number of important functions in your body. Some of these you will be looking at in section 3.5 on homeostasis, but the skin also contains very many sense organs, which give you your senses of touch, temperature and pain:

- It contains a huge variety of sense organs (touch, temperature, pressure, pain).
- It forms a waterproof layer around your body tissues, which protects you against the loss of water by evaporation and prevents you gaining water by osmosis every time you swim in the river or wash.

Activity 3.11: Conduct an experiment to prove that the actual taste of food is a combination of taste and smell

How can you prove that the taste of everyday food is a combination of information from the sense of taste on your tongue and the sense of smell from your nose?

Plan a simple investigation to prove that people cannot tell what they are eating when their eyes are closed unless they can both taste and smell the food.

Show your plan to your teacher and then carry out your investigation.

Write up your experiment carefully so that other students could repeat the experiment and check your results.

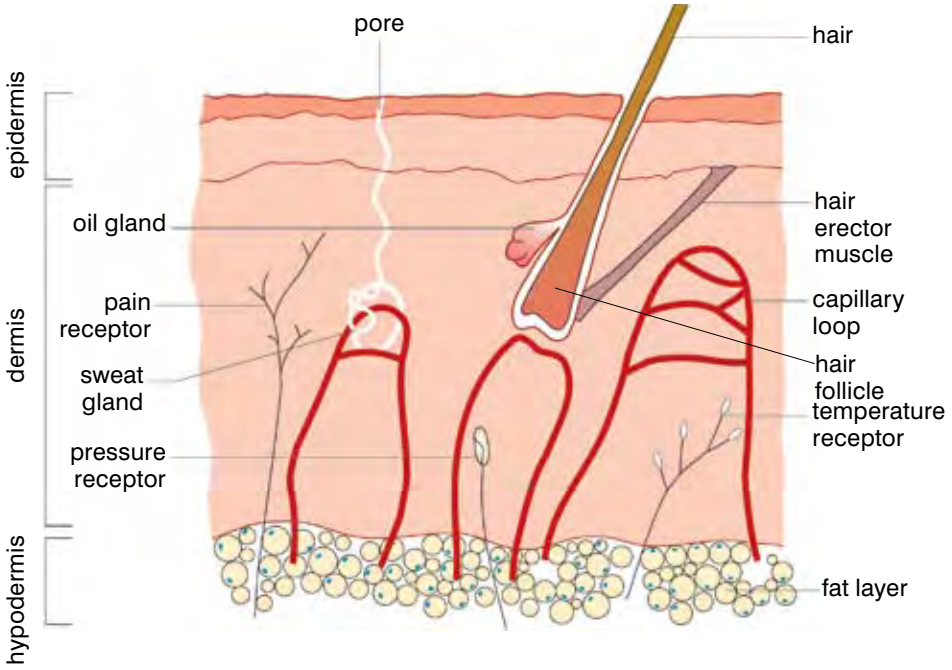


Figure 3.33 *This cross section through the human skin helps you to understand how the structure of the skin is related to its functions.*

KEY WORDS

hypodermis *the lower fatty layer of skin which helps to insulate the body against heat loss*

dermis *the middle layer of skin, which is made up of blood vessels, lymph vessels, hair follicles, and sweat glands*

epidermis *the outermost layer of skin, comprising dead cells which protects against water loss and entry of pathogens*

- It protects you from the entry of bacteria and other pathogens.
- It protects you from damage by UV light from the sun.
- It is an excretory organ (nitrogenous wastes are lost in your sweat).
- It is vital in controlling your body temperature.

Your skin has three main layers. The lower layer, the **hypodermis**, contains fatty tissue which is both an energy store and acts as an insulation layer, protecting you against heat loss. The middle layer or **dermis** contains the blood vessels, the sweat glands, the sensory receptors and the hair follicles. This layer is closely involved in temperature control in homeostasis and in your sense of touch. The upper layer or **epidermis** is made up of dead cells. These stop water loss and also protect against the entry of pathogens. It is the dermis which is particularly involved in the homeostatic mechanisms of the skin.

Activity 3.12: Identifying the parts of the skin

You will need:

- a light microscope
- a prepared slide of skin

Method

1. Using the techniques for using a light microscope which you have met in grade 9, examine your slide of the skin and identify as many features as possible.
2. Draw and label your section through the skin.
3. Identify and draw higher magnification details of particular tissues such as the sweat gland, any sense organs, etc.

Activity 3.13: Investigating the senses of touch and temperature

1. Touch:

You are going to investigate the sense of touch in different areas of skin.

You will need:

- a fine ballpoint or felt pen
- a bristle mounted on wooden holder or blunt seeker or fine piece of wire or very sharp pencil

Method

1. Work in pairs. Take it in turns to carry out the investigation.
2. With the pen, draw a grid of 25 squares on the back of your partner's hand. Each square should be 2 mm x 2 mm.
3. Draw an identical grid on paper and label it with the name of the subject and the area of the body.
4. The subject should close their eyes or look away – they must rely on the sense of touch alone. Ask them to say YES when they feel a touch.
5. Press the tip of the bristle against the skin in one of the squares until it just bends, or touch the skin with the blunt seeker as gently as possible. Touch each of the squares in turn, marking on your paper each one that gives a positive response.
6. Now try other areas of the skin that you might expect to be more or less sensitive, e.g. the palm of the hand, the arm, the leg, the foot, etc.
7. Once you have tested three different areas, swap roles.
8. Are some parts of the skin more sensitive than others? Write up your experiment along with the results and explain your observations as well as you can.

2. Temperature:

Is your sense of temperature absolute – or comparative? In other words, are your temperature receptors working like mini-thermometers or do they measure temperature relative to your body?

You will need:

- three bowls of water – one containing ice-cold water, the second hot water (but not too hot – you have to put your hand in it) and the third water at approximately room temperature.
- a watch, stopwatch or clock

Method

1. Place your left hand in the hot water and your right hand in the cold water for one minute.
2. Once the minute is up, place both hands in the water at room temperature.

   What does each hand feel like?
   What does this tell you about your sense of temperature?
3. Write up your method, observations and explanations.

Summary

In this section you have learnt that:

- Sense organs detect changes in the internal or external environment.
- The human eye includes: sclera, cornea, iris, pupil, lens, ciliary muscle, suspensory ligament, retina and optic nerve.
- The light-sensitive cells – the rods and the cones - are found in the retina.
- The iris controls the amount of light entering the eye.
- The cornea bends the light into the eye.
- The lens controls the fine focus of the image onto the retina.
- Short sight, long sight and astigmatism are three common defects of the eye.

- The ear is an organ of hearing and of balance.
- Hearing involves the outer, middle and inner ear. Balance involves the semicircular canals.
- Identify the taste areas of the tongue.
- Conduct an experiment to prove that the actual taste of food is a mixture of taste and smell.
- Draw and label the smelling organ.
- Draw and label the structure of the skin.

Review questions

1. Which of the following is not part of the eye?

   A lens

   B retina

   C pinna

   D eyelid

2. Imagine you have been out on the beach looking at some friends in the sea. You walk into the shade of a palm tree and begin to read a book. What changes would take place in your eyes?

   A Your pupils would constrict and your lens would become flatter and less convex.

   B Your pupils would constrict and your lens would become rounder and more convex.

   C Your pupils would dilate and your lens would become flatter and less convex.

   D Your pupils would dilate and your lens would become rounder and more convex.

3. Which is the correct order of the bones in the middle ear, from the eardrum inwards?

   A hammer, anvil, stirrup

   B anvil, hammer, stirrup

   C stirrup, anvil, hammer

   D none of these

4. Which is the most recently discovered sense of taste?

   A sweet

   B bitter

   C sour

   D umami

3.3 The endocrine glands

By the end of this section you should be able to:

- Define glands as structures that produce hormones or other secretions and distinguish between exocrine and endocrine glands.
- Locate the position of the main endocrine glands and describe their functions.
- State the cause and treatment of goitre.
- State the cause and treatment of diabetes mellitus.
- Describe the menstrual cycle and the associated changes.

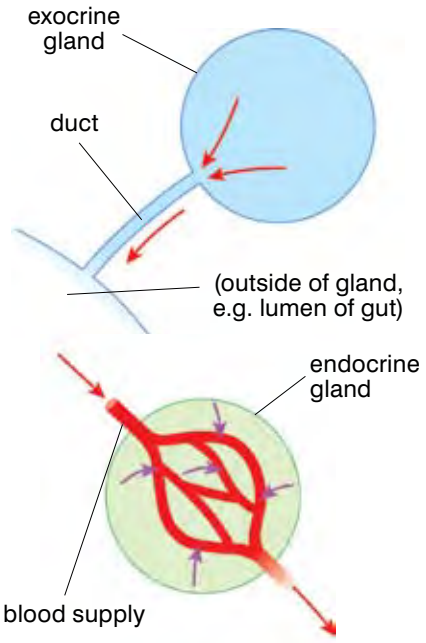


Figure 3.34 *The secretions of an exocrine gland can only go as far as the duct reaches – but the hormones produced by your endocrine glands travel all around your body in your blood.*

It is very important that our bodies are co-ordinated not just from minute to minute, but from day to day and from year to year throughout our lives. Many processes in the body are co-ordinated by chemical substances known as **hormones**. Hormones act as chemical messages, produced in one part of the body but having an effect somewhere entirely different. Glands are structures which produce hormones and other useful substances. Hormones are produced (secreted) by special endocrine glands found around the body. Many glands in your body are exocrine glands. This means they have a special tube or duct that carries the secretion from the gland where it is made to the place where it is needed. Sweat glands, salivary glands and mammary glands are all examples of exocrine glands. The endocrine glands that produce your hormones have no ducts, so they are sometimes known as ductless glands. They secrete hormones directly into your blood, and the chemicals are carried from the glands all around your body in the bloodstream. Most hormones only affect certain tissues or organs – their target organ – and the hormone is picked up from the blood by receptors in the cell membranes. They can act very rapidly, but often their effects are slower and longer lasting than the results of nervous control. This will be discussed in the next section.

The pituitary gland, found in the brain and about the size of a pea, is sometimes described as the controller of the endocrine orchestra. The hormones made in this tiny gland control the secretion of many other hormones. Because of its position in the brain, it is also involved in co-ordination between the nervous and hormonal systems of control.

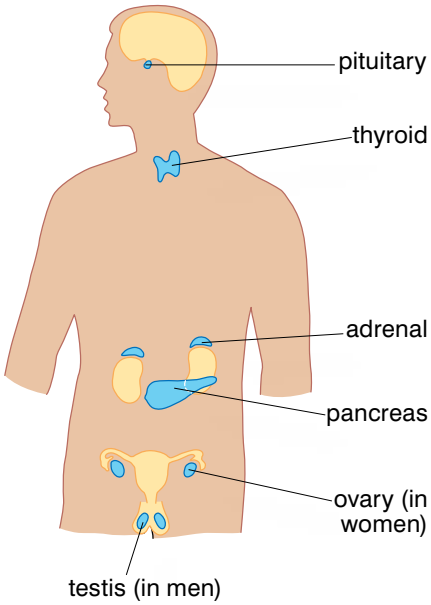


Figure 3.35 *These endocrine glands control many things about us, including the way we grow, our sexual development, reproduction and the sugar levels in our blood.*

Iodine deficiency and goitre

The thyroid gland in your neck uses iodine from your diet to produce the hormone **thyroxine**. Thyroxine is one of the hormones involved in the long-term chemical control of your body. It controls the metabolic rate of your body – how quickly substances are built up and broken down, how much oxygen your tissues use and how the brain of a growing child develops. If someone has an overactive

KEY WORDS

hormones *chemicals produced in one part of an organism which produce specific effects on a different part of the organism*

thyroxine *hormone produced by the thyroid glands to regulate metabolism by controlling the rate of oxidation in cells*

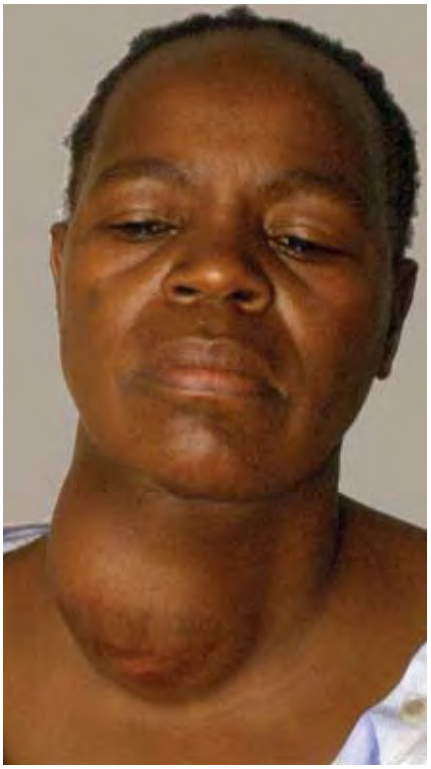


Figure 3.36 *The thyroid gland is very important for the normal control of your metabolic rate and growth. When things go wrong, as in this picture of a woman with goitre, it is important to treat the situation as soon as possible to prevent permanent damage.*

thyroid that makes too much thyroxine, their metabolism starts to go very fast – the symptoms include losing a lot of weight, sweating a lot and becoming irritable. If the thyroid doesn't make enough thyroxine, people feel tired and lack energy. They may gain weight. Low levels of thyroxine can cause problems in getting pregnant, miscarriages and still births. If small children do not make enough thyroxine, their growth is stunted and they do not develop normally, and this damage can be permanent. They have difficulties in learning. This is called cretinism.

The most common reason for not making enough thyroxine is a lack of iodine in the diet. Without iodine, the thyroid gland works very hard to try and make enough thyroxine but it cannot do it. The gland will grow and enlarge in an attempt to make the right amount of thyroxine. This is known as goitre. The enlarged gland can be felt in the neck. Eventually the goitre gets so big it can be seen as a swelling in the neck. Many people do not like the appearance of a goitre in their neck.

Iodine deficiency disorders such as goitres are very common in Ethiopia. Several scientific studies have shown that between 30 and 40% of our population are affected by iodine deficiency to some extent. Women and children tend to be more affected than men. This may be because women have big demands on their bodies with pregnancy and breastfeeding, while children are growing. The problem is worse in rural areas, particularly in the mountainous regions where any iodine tends to be washed away out of the soil. In some areas up to 90% of school children show some level of iodine deficiency. Iodine deficiency affects the health of millions of people in Ethiopia.

There is a simple solution for most of the problems of iodine deficiency and goitre. We need to include more iodine in our diet. There is a simple way to do this. Iodine can be added easily to the salt we use to season our food. Just that tiny amount of extra iodine is all we need to overcome all the problems that goitre and IDD (iodine deficiency disease) can bring! In areas where the iodine levels are very low, special iodised capsules can be used to help people overcome the deficiency. In the year 2000 about 28% of all households in Ethiopia used iodised salt. The Government and the Department of Health are working with other agencies to try and make sure that everyone in Ethiopia can get iodised salt by 2015. This would mean all of the disorders linked to iodine deficiency would go. Our goitres would disappear. Our women would suffer far fewer losses during pregnancy and birth. Our children would not fail to develop and become cretins. Every child would benefit and be able to learn more effectively. People would have more energy and be able to work more effectively. Adding more iodine to our diet in this simple way can have major effects on the well-being of millions of people in our country. It has worked elsewhere in the world – now it is our chance to overcome this simple but devastating disease.

Table 3.2 *Goitre rate of women by regional states (1997)*

The different areas	Percentage of women with goitres
Amhara	28.8%
Oromia	31.3%
Tigray	35.6%
SNNPR	59.9%
Addis Ababa	22.3%
Afar	15.6%
Benshangul Gumuz	37.3%
Dire Dawa	12.4%
Harari	6.7%
Gambella*	1.4%
Total goitre rate (weighted)	35.8%

*Under-represented because of insufficient data.

Figure 3.37 *Iodised salt made and sold in Ethiopia can help us prevent all the problems caused by iodine deficiency diseases including goitre.*

Insulin, controlling the blood sugar levels and diabetes mellitus

It is very important that your cells have a constant supply of the glucose they need for cellular respiration. Glucose is transported around your body to all the cells by your blood. However, you don't spend all of your time eating to keep your blood sugar levels high and provide a constant source of glucose for your cells. Instead the level of sugar in your blood is controlled by hormones produced in your pancreas.

When you digest a meal large amounts of glucose pass into your blood. Without a control mechanism your blood glucose levels would vary wildly. After a meal they would soar to a point where glucose would be removed from the body in the urine. A few hours later the levels would plummet and cells would not have enough glucose to respire.

This internal chaos is prevented by your **pancreas**. The pancreas is a small pink organ found below your stomach. It constantly monitors your blood glucose concentration and controls it using two hormones known as **insulin** and **glucagon**. When your blood glucose concentration rises above the ideal range after you have eaten a meal, insulin is released. Insulin stimulates your liver to remove any glucose which is not needed at the time from the blood.

KEY WORDS

pancreas *a gland that produces digestive enzymes and manufactures hormones, including insulin and glucagon*

insulin *a hormone that lowers the blood glucose level*

glucagon *a hormone that raises the blood glucose level*

glycogen *a form of carbohydrate stored primarily in the liver and broken down into glucose when needed by the body*

The soluble glucose is converted to an insoluble carbohydrate called **glycogen** and stored in your liver.

When your blood glucose concentration falls below the ideal range, the pancreas monitors it and secretes glucagon. Glucagon stimulates your liver to break down glycogen, converting it back into glucose and so releasing stored sugar back into the blood. By using these two hormones and the glycogen store in your liver, your pancreas keeps your blood glucose concentration fairly constant at about 90 mg glucose per 100 ml of blood (4–6 millimoles per litre).

Review questions

1. Why are the levels of glucose in your blood so important?
2. Which two hormones are involved in the control of your blood sugar levels?

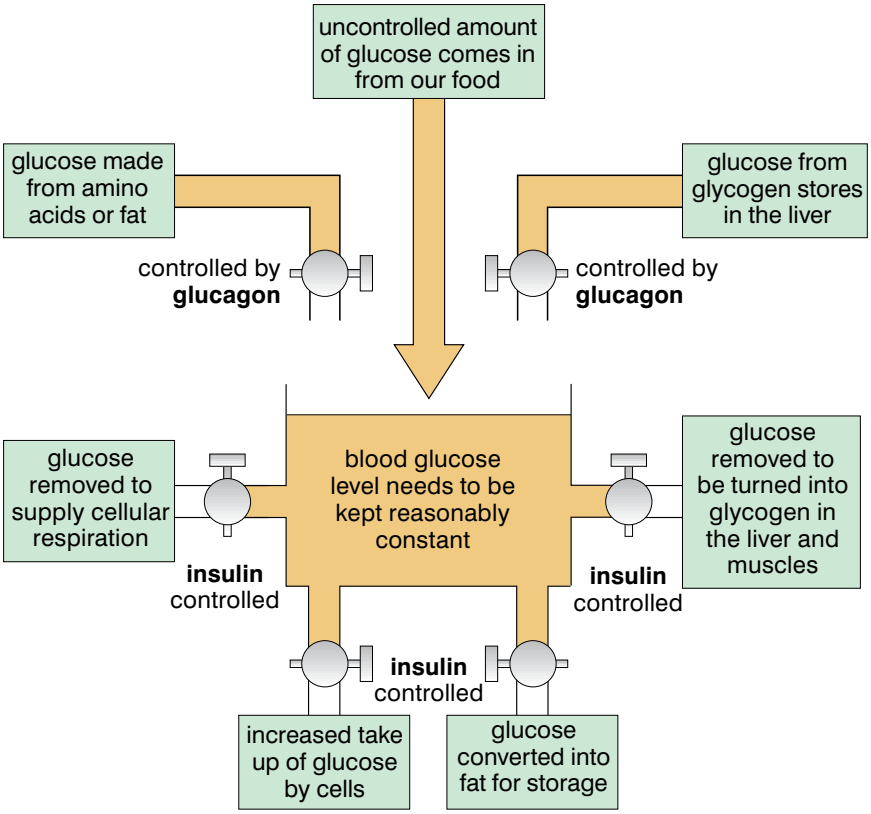


Figure 3.38 *This model of your blood glucose control system shows the blood glucose as a tank. It has both controlled and uncontrolled inlets and outlets. In every case the control is given by the hormones insulin and glucagon.*

The causes and treatment of diabetes

Most of us never think about our blood sugar levels because they are perfectly controlled by our pancreas. But for some people life isn't quite this simple, because their pancreas does not make enough – or any – insulin. Without insulin your blood sugar levels get higher and higher after you eat food. Eventually your kidneys produce glucose in your urine. You produce lots of urine and feel thirsty all the time. Without insulin glucose cannot get into the cells of your body, so you lack energy and feel tired. You break down fat and protein to use as fuel instead, so you lose weight. Type 1 diabetes appears in children and young people. It is inherited and you cannot avoid it. Type 2 diabetes appears later in life and it can be linked to being

obese or possibly very underweight as well. Before there was any treatment for diabetes, people would waste away, fall into a coma and die. Fortunately there are now some very effective ways of treating diabetes. However, not everyone in Ethiopia knows about the treatment, and it can be difficult to get the treatment you need.

If you have a mild form of diabetes, managing your diet is enough to keep you healthy. Avoiding carbohydrate-rich foods keeps the blood sugar levels relatively low so your reduced amount of insulin can cope with them. Getting regular exercise also helps your body cope with diabetes.

However, many people with diabetes need replacement insulin before meals. Insulin is a protein which would be digested in your stomach, so it is usually given as an injection to get it into your blood. This injected insulin allows glucose to be taken into your body cells and converted into glycogen in the liver. This stops the concentration of glucose in your blood from getting too high. Then as the blood glucose levels fall, natural glucagon makes sure glycogen is converted back to glucose. As a result your blood glucose levels are kept as stable as possible. Insulin injections treat diabetes successfully but they do not cure it. Until a cure is developed, someone with diabetes has to inject insulin several times every day throughout their life.

DID YOU KNOW?

In 2005 doctors in Japan performed a successful living transplant of pancreas tissue. Cells from a mother were given to her daughter who had severe diabetes. Within three weeks the daughter no longer needed insulin injections – her new cells were controlling her blood sugar.

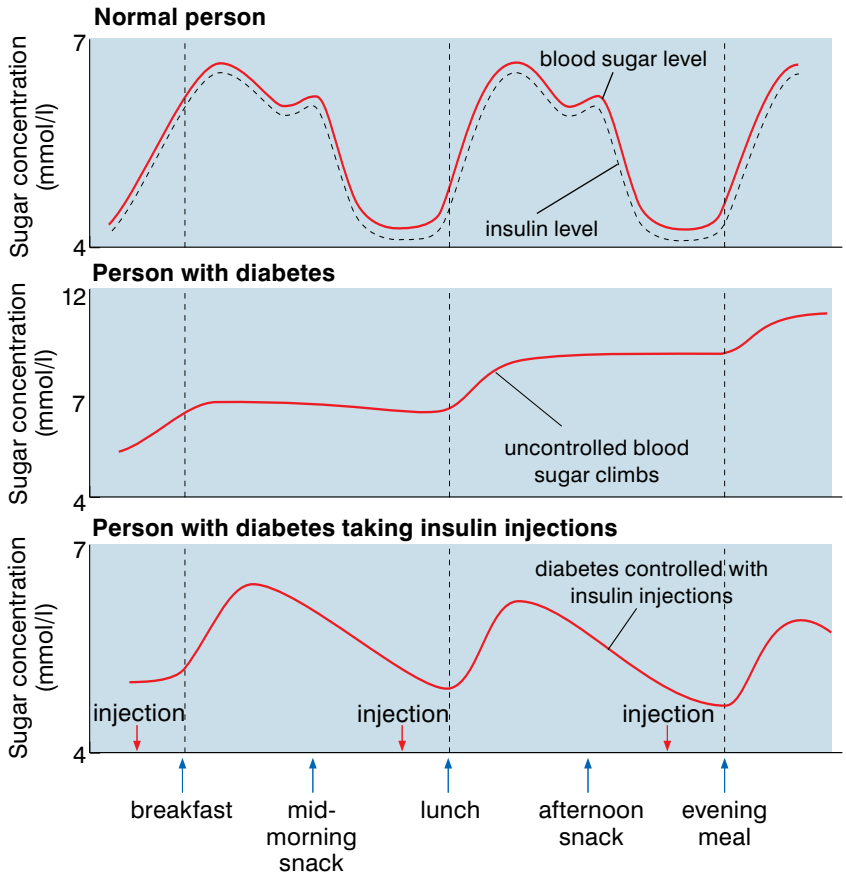


Figure 3.39 *Insulin injections keep the blood sugar level within safe limits. They cannot mimic the total control given by the natural production of the pancreas – but they work well enough to let people lead a full and active life.*

Figure 3.40 *The treatment of diabetes involves regular blood sugar tests and insulin injections. These could become a thing of the past if some of the new treatments being developed work as well as scientists hope!*

DID YOU KNOW?

In 2005 research scientists produced insulin-secreting cells from human stem cells which cured diabetes in mice. More research is needed but the scientists hope that before long diabetes will be a disease which can be cured instead of treated.

The treatment of diabetes has changed a great deal over the years. For centuries nothing could be done. Then in the early 1920s Frederick Banting and Charles Best realised that extracts of animal pancreas could be used to keep people with diabetes alive. For many years insulin from pigs and cows was used to treat affected people. This saved millions of lives.

In recent years bacteria have been developed using genetic engineering which produce pure human insulin. This is now used by the majority of people affected by diabetes. It means that a regular, reliable supply of exactly the right chemical is always available. Now scientists are trying to find easier ways – like nasal sprays – to get insulin into the body. If the regular injections could be replaced it would certainly improve the quality of life for diabetics. But it is still a miracle of medicine that this potentially devastating condition can be managed and controlled effectively, and homeostasis restored.

KEY WORDS

adrenaline *a hormone produced by the adrenal glands that elevates heart and respiration rates; also called 'epinephrine'*

In Ethiopia there are relatively low rates of reported diabetes but it often causes many problems. It is thought that many people suffering from diabetes are not diagnosed and so may suffer symptoms and die without ever having treatment. Even when people are diagnosed with diabetes it can be difficult to keep under control. This is because in Ethiopia many people do not have a hospital or doctor close to their home. People may have to travel many kilometres to collect their insulin and the testing kits they need. Also these medications can be expensive. Hopefully more doctors and nurses will be found working in the countryside in the future, providing the insulin that is needed to keep people with diabetes healthy and well.

Adrenaline is a well-known hormone – we talk of things 'getting the adrenalin running'. It is produced by your adrenal glands, which sit on top of your kidneys and it is the hormone of 'fight or flight'. If you are stressed, angry, excited or frightened your adrenal glands will secrete lots of adrenalin. Carried rapidly round in your blood, adrenalin affects many different organs from the pupils of your eyes (it dilates them) to the beating of your heart (it speeds it up). Adrenalin basically prepares your body for action, so that you can run fast to escape or fight successfully if you need to. The main changes produced by adrenalin are:

- Increased heart rate, sending more blood carrying food and oxygen to the muscles.
- Increased breathing rate to increase the amount of oxygen coming into the blood and to get rid of excess carbon dioxide produced.
- Stored carbohydrate in the liver is converted into glucose in the blood, and the muscle cells absorb more glucose for cellular respiration to provide extra energy.
- Your pupils dilate, allowing more light into your eyes and making you oversensitive to movement.

- Your body hair stands on end – not much use to us, but it makes other animals like cats look much bigger.
- Increased mental awareness and speed of reaction times.
- Blood diverted away from your gut and into your big limb muscles – you don't need to digest food but you do need a good blood supply to the muscles.

There are some concerns that when people are stressed in their lives they will produce adrenalin. Their heart and the rest of their body will be affected, but they don't get involved in physical activity. Eventually this may have a damaging effect on their health.

Other hormones

Growth hormones produced by the pituitary gland have a long, slow effect on you throughout childhood, and then when you reach puberty, the sex hormones are produced, which lead to long-term physical development and growth. You will be looking at these hormones in more depth next.

KEY WORDS

testosterone *the primary male hormone responsible for the development of masculine traits*

secondary sexual characteristics *distinguish between the two sexes; includes facial hair of the human male and enlarged hips and breasts of the female*

The gonads

The gonads are the endocrine glands which produce some of the sex hormones. These are the testes in boys and the ovaries in girls. They become active at the time of puberty when the big physical changes which make boys and girls look very different take place and the body takes on its adult form. The changes come about in response to hormones released by the brain and by the gonads themselves.

The role of the testes

Puberty in boys usually begins somewhere between the ages of 9 and 15 years old. It may happen very rapidly, over the space of a year or so, or it may take place much more slowly over a number of years. A general sequence of events is described here, but the order and speed in which changes occur is very much an individual thing – no two people experience puberty in exactly the same way.

The chemical changes which trigger puberty are unseen, another important example of hormonal co-ordination and control. The pituitary gland in your brain starts to produce increasing amounts of FSH. This in turn stimulates the male gonads or testes to begin developing and producing the male sex hormone **testosterone**. The rising levels of testosterone trigger the many changes which affect the body during puberty, causing the development of the **secondary sexual characteristics**. The main ones are listed below:

- The whole body undergoes the adolescent growth spurt, so you get taller.
- Pubic hair, body hair and facial hair begin to grow. Some men are naturally smooth and develop little body hair. Others are much hairier. The full development of facial and body hair can take many years.

- The larynx enlarges so the voice deepens. This is known as the voice 'breaking' and it can happen very slowly over a period of months or very suddenly, almost overnight!
- The shoulders and chest broaden as you develop more muscle.
- The testes grow larger, become active and start producing sperm and the other chemicals necessary to produce semen, the nutritious sperm-containing fluid which is ejaculated into the female reproductive system.
- The penis enlarges and the skin of the penis and the scrotum may darken.
- The brain changes too as you make the transition from boy to man. Adolescents become more independent, more questioning and start to look out beyond their families. They can also feel young and insecure, confused or angry for no real reason. It is all part of growing up and changing hormone levels are at least partly to blame.

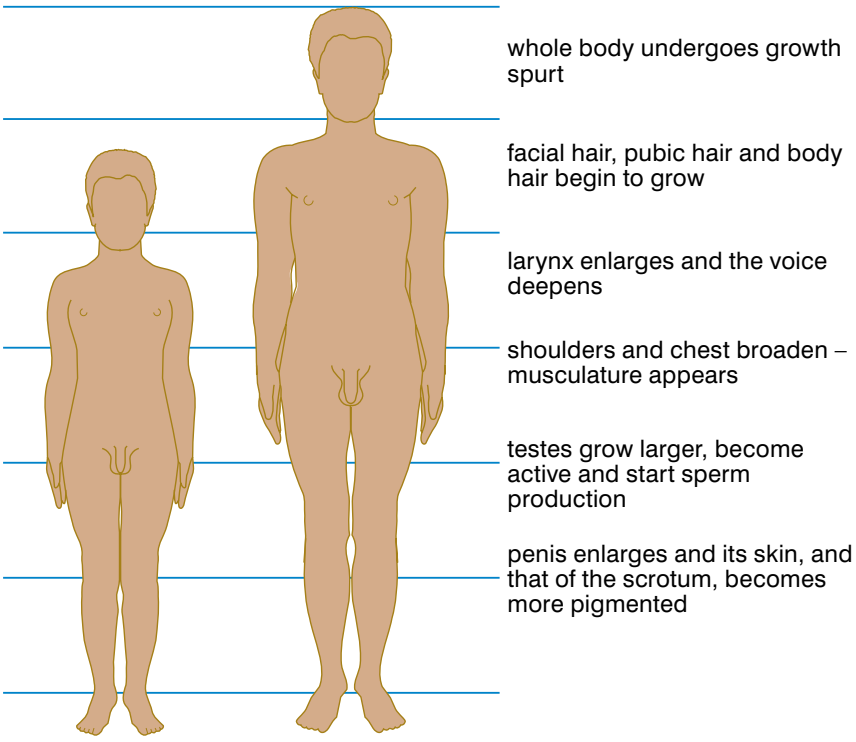
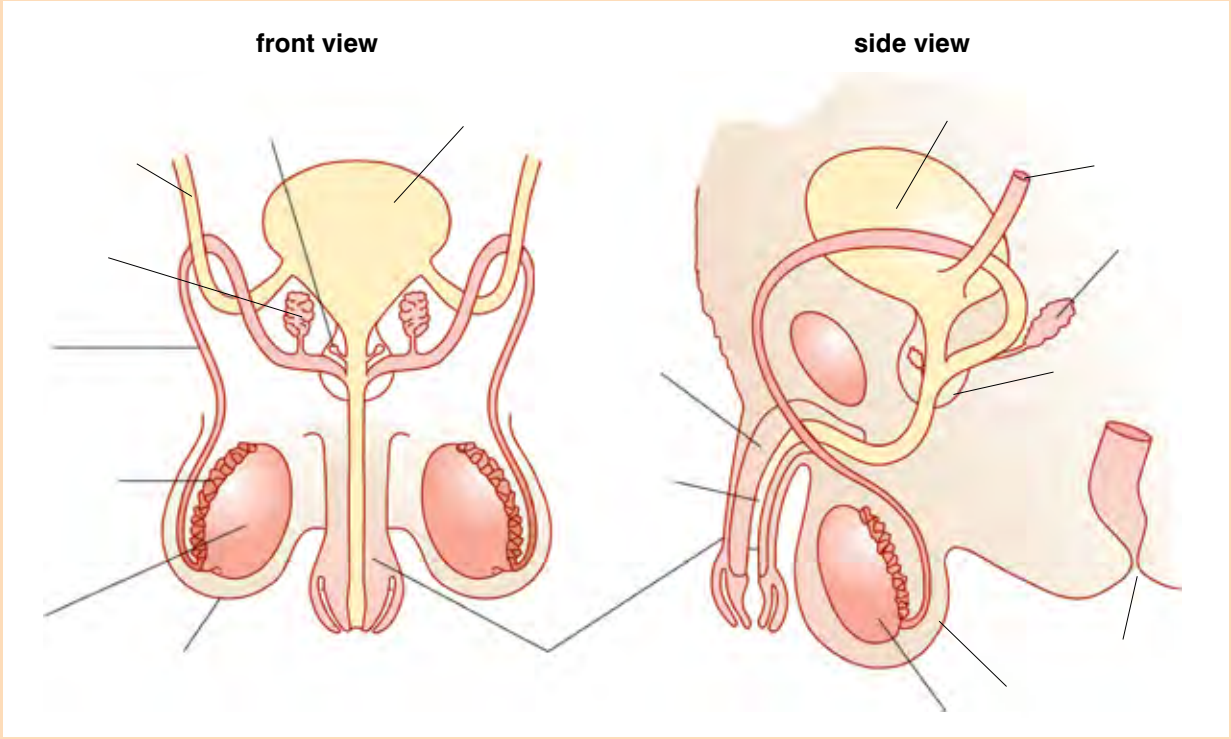


Figure 3.41 *The changes which take place during puberty result in a fully mature and functioning male reproductive system.*

ACTIVITY 3.14: Remembering the male reproductive system

You learnt about the male reproductive system when you were in grade 8. These are the organs that are particularly affected by the hormones produced by the gonads. See how much of the system you can remember – copy and label this diagram.



The role of the ovaries

The role of a woman in human reproduction is to produce a relatively small number of large gametes or ova, to provide the developing embryo with food and oxygen, remove its waste products and, after delivering a baby into the world, to provide it with a continued supply of food for a period of time.

The female gonads are the ovaries, two walnut-sized organs found low in the abdomen. They are closely associated with the uterus and the Fallopian tubes, but are not actually attached to them.

Girls often go into puberty slightly earlier than boys, and so between the ages of 8–14 most girls begin the changes which will take their bodies into sexual maturity. As with boys, the time and speed of puberty varies greatly from one person to another. Although it is different for everyone – and everyone ends up a slightly different shape and size – the basic changes which take place are the same.

Just as in boys, puberty is controlled by hormones from the pituitary gland in the brain and from the gonads themselves – in this case the ovaries. FSH from the brain stimulates the ovaries to become active and start producing the female sex hormone oestrogen. As the levels of oestrogen rise and the body responds, all kinds of changes are triggered and the female secondary sexual characteristics develop.

DID YOU KNOW?

By the time a baby girl is born, her ovaries contain all the eggs she will ever have – several hundred thousand of them in each ovary! But only about 450 of those eggs will ever be released, and a tiny fraction of those will become babies.

- The whole body undergoes the adolescent growth spurt, so you get taller.
- Pubic hair and body hair (underarms) begin to grow.
- The breasts develop.
- The external genitalia become larger and the colour of the skin darkens.
- The female pattern of fat deposits on the hips, buttocks and thighs develops.
- The ovaries begin the production of mature ova and menstruation begins.
- The uterus grows and begins to produce a thickened lining each month in response to hormones from the ovary.
- The brain changes too as you make the transition from girl to woman. Just like boys, as girls become adolescents they become more independent, more questioning and start to look out beyond their families. They can also feel young and insecure, confused or angry for no real reason. It is all part of growing up and changing hormone levels are at least partly to blame.

The female reproductive system is adapted so that a mature ovum is released each month. It provides for an embryo to develop and grow into a baby which is then delivered. As you look at the menstrual cycle you will see how closely it is controlled by hormones.

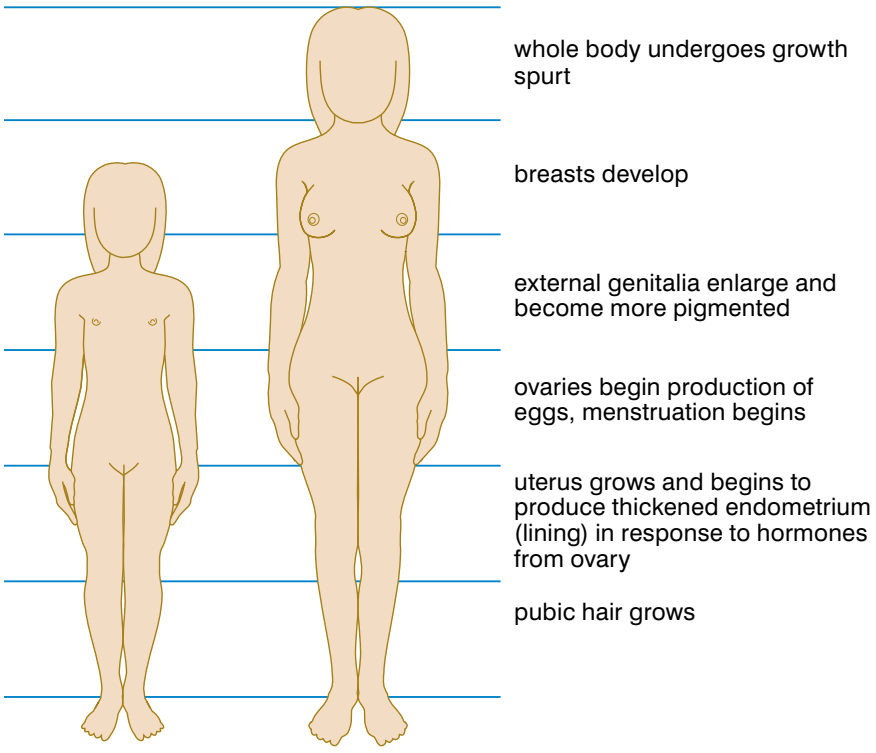
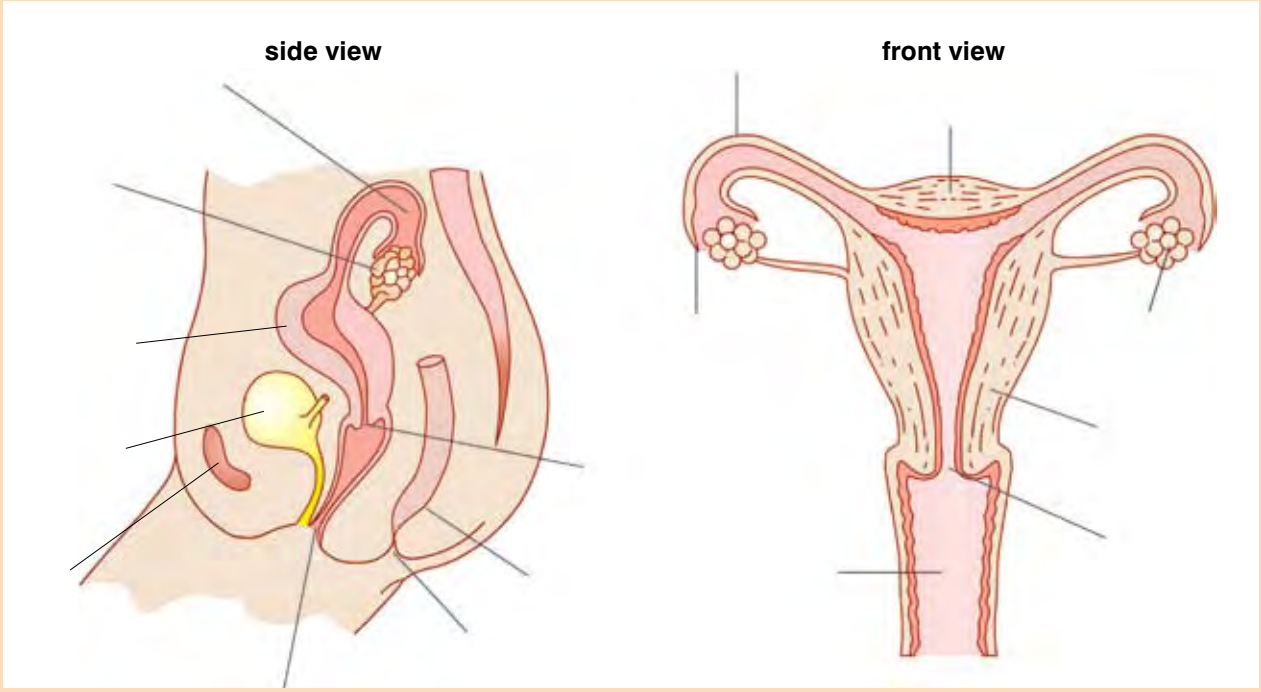


Figure 3.42 *The changes which take place during puberty result in a fully mature and functioning female reproductive system.*

ACTIVITY 3.15: Remembering the female reproductive system

You learnt about the female reproductive system when you were in grade 8. These are the organs that are particularly affected by the hormones produced by the gonads. See how much of the system you can remember – copy and label this diagram.



Review question

1. What are the similarities and differences between the changes which take place at puberty in boys and girls? Make a table to help you with your summary.

The menstrual cycle

Chemical control by hormones is vital in the female reproductive system. Hormones control the whole process of menstruation and pregnancy. The menstrual cycle is a sequence of events which takes place approximately every four weeks throughout the fertile life of a woman, from the age of puberty to around 50 years of age.

A baby girl has ovaries full of immature ova, but they do nothing until after puberty. Then, once a month, a surge of the hormone FSH from the pituitary gland in the brain starts a few of the ova developing.

FSH also affects the ovary itself which starts making the female hormone oestrogen. This in turn stimulates the uterus to build up a thick, spongy lining with lots of blood vessels ready to support a pregnancy. About 14 days after the ova start ripening, one of them bursts out of its follicle. This is called ovulation and when it happens the hormone levels from the pituitary begin to drop dramatically.

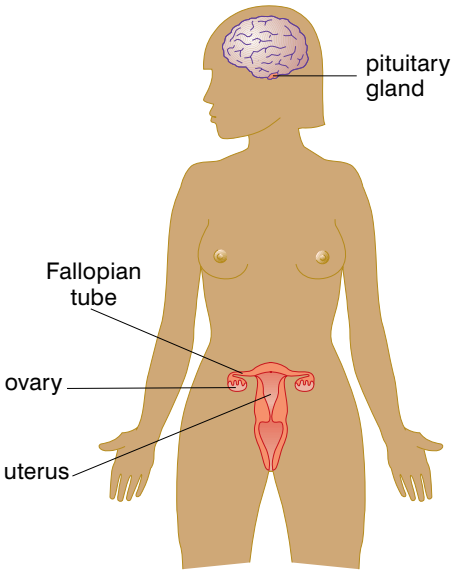


Figure 3.43 *The action of hormones from the pituitary gland and the ovary makes it possible for women to produce fertile eggs and become pregnant.*

KEY WORDS

corpus luteum *the cell mass that remains after the release of an egg. It secretes both progesterone and oestrogen*

progesterone *a hormone that prepares the uterus for the implantation of a fertilised ovum and to maintain pregnancy*

implant *fix or set securely*

After ovulation the remains of the follicle forms the **corpus luteum** (which means yellow body because it is filled with a yellowish fat) and this secretes a different hormone (**progesterone**). Progesterone makes sure that for some days the uterus lining stays thick and spongy and stimulates the growth of more blood vessels, ready to receive a fertilised ovum. If a pregnancy occurs the embryo will immediately get a rich supply of food and oxygen. But most months the ovum is not fertilised and the woman does not become pregnant.

About ten days after ovulation (when no pregnancy has occurred) the ovary reduces the levels of both oestrogen and progesterone. As the chemical messages change again the blood vessels which are supplying the thick spongy lining of the uterus close down. The lining detaches from the wall of the uterus and is lost through the vagina as the monthly period or bleeding.

However, if the ovum has been fertilised it will reach the uterus and sink into the thick, spongy lining, attach itself (**implant**) and start to develop.

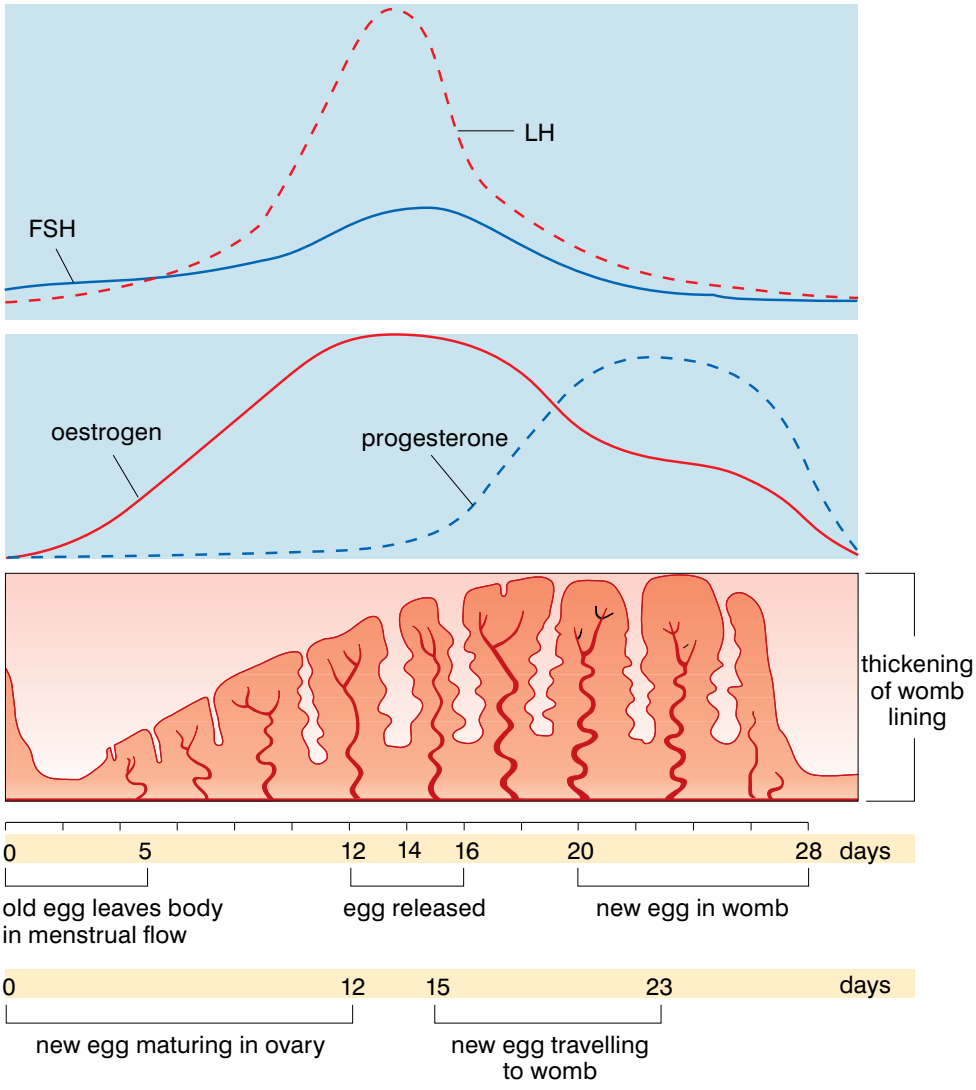


Figure 3.44 *How changes in hormone level influence the events of the menstrual cycle*

The hormones of the menstrual cycle

Remember, there are four main hormones which have an effect on the female reproductive system and between them control the menstrual cycle and female fertility.

Produced by the pituitary gland in the brain:

FSH (**follicle stimulating hormone**) stimulates the development of a follicle in the ovary, and within the follicle the egg matures and ripens. FSH also stimulates the ovaries to produce hormones, particularly oestrogen.

LH (**luteinising hormone**). stimulates the release of the egg from the ovary in the middle of the menstrual cycle and also affects the ovary so that it produces another hormone (progesterone) to keep the uterus lining in place.

Produced by the ovaries:

Oestrogen stimulates the lining of the uterus to build up in preparation for pregnancy. It also affects the pituitary gland. As the oestrogen levels rise, the production of FSH by the pituitary gradually falls – which in turn means the oestrogen levels fall. The rise in oestrogen levels has the opposite effect on the levels of the other pituitary hormone, LH. As oestrogen rises, the production of LH goes up. When LH reaches its peak in the middle of the menstrual cycle it stimulates the release of a ripe egg from the ovary.

Progesterone maintains the thickened lining of the uterus and stimulates the growth of blood vessels in the lining to prepare for a pregnancy – and if a fertilised ovum arrives in the uterus, progesterone helps to maintain the pregnancy.

By the end of the cycle, when the menstrual bleeding is about to start, all of the hormones are at a low ebb.

Because the ovaries only contain a limited number of ova, women do not have periods throughout their lives. Eventually the ova in the ovaries run out. The hormone levels drop, the ovaries and uterus shrink and the woman stops having periods. She is no longer fertile. This change, which takes place around the age of fifty, is known as the menopause.

Nervous and hormonal systems in co-ordination

So as you have seen, some hormones do bring about rapid responses – adrenaline, insulin and glucagon are examples of these. But many others such as thyroxine, growth hormone and the sex hormones have a much longer, slower impact on the body – but they are no less important for co-ordination and control.

Both the nervous system and the hormone system are important for co-ordination and control. They both have features in common, but in many ways they are very different.

Nervous system:

- Electrical messages travel along neurons.
- Chemical messages travel across synapses.

KEY WORDS

FSH (follicle stimulating hormone) *a hormone produced by the pituitary gland that stimulates the growth of eggs in the ovaries*

LH (luteinising hormone) *a hormone that triggers the onset of ovulation. Works in concert with FSH*

oestrogen *the primary female hormone responsible for the development of feminine traits*

DID YOU KNOW?

An average girl loses around 50 cm^3 of blood in each menstrual period, and will have approximately 450 periods during her fertile lifetime, although this will depend on how many times she is pregnant. This means she will lose around 22.5 litres (39 and a half pints) of blood before she goes through the menopause!

- Messages travel fast.
- Messages usually have rapid effect.
- Usually a short-lived response.
- Nerve impulse affects individual cells, e.g. muscle cells, so have a very localised effect.

Hormonal control:

- Messages transported slightly more slowly in the blood – minutes rather than milliseconds.
- Only chemical messages involved.
- Often take longer to have an effect.
- Effect often widespread in the body – affect any organ or tissue with the correct receptors.
- Effects often long lasting.

The combination of nervous and hormonal control enables your body to work as a co-ordinated whole – and plays a vital role in the homeostasis you will be looking at in section 3.5.

Review questions

1. Which of the following endocrine glands secretes a hormone that directly affects the metabolic rate of the body?

   A pituitary gland

   B ovary

   C thyroid

   D pancreas

2. Which of the following reproductive hormones is produced by the pituitary gland?

   A oestrogen

   B testosterone

   C follicle stimulating hormone

   D progesterone

3. Which of the following changes takes place at puberty ONLY in boys?

   A growth spurt

   B larynx enlarging and voice deepening

   C body shape changes

   D mature gametes produced

Table 3.3 *Table to show the main hormones produced in the body, the endocrine organ that produces them and the function in the body*

Gland	Hormone	Functions of the hormones
Pituitary	Growth hormone	Controls the growth rate of children
	Thyroid stimulating hormone (TSH)	Stimulates the thyroid gland to secrete thyroxine
	Anti-diuretic hormone (ADH)	Controls the water content of the blood by its effect on kidneys (see homeostasis)
	Follicle stimulating hormone (FSH)	Stimulates egg development and oestrogen production in women and sperm production in men
	Luteinising hormone (LH)	Stimulates egg release in women and testosterone production in men
Thyroid	Thyroxine	Controls the metabolic rate of the body
Pancreas	Insulin	Lowers blood sugar levels
	Glucagon	Raises blood sugar levels
Adrenal glands	Adrenaline	Prepares the body for stressful situations – 'fight or flight'
Ovaries	Oestrogen	Controls development of female secondary sexual characteristics Involved in menstrual cycle
	Progesterone	Involved in menstrual cycle
Testes	Testosterone	Controls development of male secondary sexual characteristics Involved in sperm production

Summary

In this section you have learnt that:

- Chemical co-ordination and control of the body is brought about by hormones secreted by special endocrine glands.
- The hormones are secreted directly into the blood and are carried around the body in the blood.
- They may affect a single target organ or a range of organs and tissues. They have their effect through special receptor molecules on the cell membranes of the target organs and tissues.
- Hormonal control may be rapid but is often relatively slow and long term.
- Important endocrine organs include the pituitary gland, the thyroid gland, the adrenal glands, the pancreas, the ovaries and the testes.
- Insulin produced by the pancreas controls the blood sugar levels. If the insulin metabolism goes wrong you have diabetes.
- Hormones from the pituitary and the ovary control the menstrual cycle.

3.4 Reproductive health

By the end of this section you should be able to:

- List the different birth control methods and explain how each one works.
- Describe the symptoms and incubation period of HIV/AIDS.
- Explain how AIDS is currently treated.
- Describe female genital mutilation as a harmful traditional practice.
- Demonstrate life skills that will help you prevent the spread of HIV/AIDS.

KEY WORDS

sexual intercourse *the erect penis of the male entering the vagina of the female*

ejaculation *the release of semen from the penis*

DID YOU KNOW?

Sperm can live for up to three days inside a woman's body, waiting for an ovum. But once an ovum is released from the ovary, it is fertile for only a few hours – 24 at most.

DID YOU KNOW?

Sometimes two ripe ova will be released during the same monthly cycle. If they are both fertilised by sperm, two babies may develop in the uterus and the mother will deliver **non-identical twins**. The babies may be the same or different sexes, and are really normal siblings born at the same time.

More rarely, the fertilised ovum splits completely in two as the early embryo forms. Again two babies develop – but these are **identical twins**. Because they come from the same fertilised egg they are genetically identical – they are human clones!

You are going to be looking at the different ways in which we can control our fertility and limit our family size to the number of children we can feed and care for. To understand how these birth control methods work, you need to understand how pregnancy comes about. For human reproduction to be successful the sperm made in the man's testes must meet up and join with an ovum released from the woman's ovary. The sperm gets inside the body of the woman during **sexual intercourse**. The erectile tissue in the penis fills with blood so that it becomes erect and can be placed inside the vagina. The sperm move from the testes through the urethra, and semen containing millions of sperm is released inside the vagina in a process known as **ejaculation**. The sperm move through the cervix into the uterus. They then make their way through the uterus and into the Fallopian tubes. It is here that the sperm will meet a ripe ovum, if the woman is at the right stage of her menstrual cycle. Out of the millions of sperm which set off, only a few hundred to a few thousand actually reach the ovum – and only one of those will actually fertilise it. Yet in spite of all the difficulties they face, sperm manage to reach the Fallopian tubes only around half an hour after they are released.

The ovum which bursts from the follicle at the moment of ovulation has no way of moving itself. The end of the Fallopian tube moves across the surface of the ovary to pick up the ovum. It is then moved along the tube by the beating of the cilia, which carry the ovum towards the uterus.

When a single sperm joins with the ovum this is the moment of **fertilisation**, which in humans is also known as **conception**. The nucleus from the sperm, containing the chromosomes from the father, fuses with the nucleus from the ovum, containing chromosomes from the mother, and a potential new life begins. The new cell (known as the **zygote**) has a unique set of chromosomes. If all goes well, it will develop into a baby.

Sadly here in Ethiopia we have a very high rate of maternal deaths in childbirth – 871 women for every 100 000 births. This is partly because in our large and rural country, many women do not have

health professionals with them to help when they are giving birth. But some of the problems we can do something about ourselves. Girls' bodies do not stop growing and maturing until they are at least 18. If a girl becomes pregnant before she is 18–19 years old, she is much more likely to be damaged as she gives birth, and there is a higher chance that she and her baby might die. Sensible use of contraception (see below) means that women need not become mothers while they are still children themselves. If a wife is young, the couple can be careful and use contraception until the girl is older and can bear a baby safely. Women are also more likely to die in childbirth if they have many children close together. Again we can do something about this. If couples use contraception to help them space their children further apart, this gives the mother's body time to heal and get strong again. She is less likely to die giving birth, and her children will be stronger and healthier too. Healthy women have healthy babies, so the more we can do to prevent diseases such as goitre and HIV/AIDS in our country, the healthier our families will be.

Controlling fertility – contraception

Many people do not wish to risk pregnancy whenever they have sex. People have tried for thousands of years to control their fertility and to have babies exactly when they wanted them. Methods of avoiding pregnancy have included vinegar-soaked sponges and mixtures of camel dung and various herbs placed in the vagina before intercourse, and reusable condoms made from animal intestines. Many of these traditional methods of contraception were harmful and did not work, they were not scientific at all.

In the 21st century we have a wide range of **contraceptive** choices. Contraception means 'against pregnancy' and it describes ways in which pregnancy can be avoided. There are several different types of contraception. The effectiveness of contraceptive methods is measured per '100 woman years' – in other words, if a hundred women use a method of contraception for a year, how many of them would end up pregnant? By choosing to use contraception, men can protect their wives from having too many children too quickly, or from having a baby too young. By using condoms, men cannot only avoid unwanted pregnancies but protect themselves and their partners from HIV/AIDS and other sexually transmitted diseases. Women can protect themselves by insisting men use condoms, or by using female methods of contraception such as the pill. When couples work together, the reproductive health of both of them can be protected.

Natural methods of contraception are based on understanding the menstrual cycle and accurately predicting the moment of ovulation. Ovulation can be detected by the increase in temperature associated with it, by changes in the vaginal mucus or by using a monitor which detects changes in the chemicals in the urine around ovulation. If sexual intercourse is avoided around the fertile time, pregnancy can be avoided.

KEY WORDS

fertilisation *a single sperm combining with an ovum*

conception *a single sperm combining with an ovum*

zygote *a fertilised ovum*

contraceptive *the prevention of conception*

DID YOU KNOW?

60–70% of fertilised ova never make it to be a baby – in fact about 50% of all fertilised eggs are lost before a woman even realises she is pregnant. This is usually because there is something wrong with the embryo and it cannot develop normally.

Figure 3.45 *The arrival of a healthy full-term baby is the hoped-for outcome of every planned pregnancy.*

Advantages: there are no side effects and this method is permitted by most religions. Carried out with care and scientific precision about recording techniques it can be very effective.

Disadvantages: it depends on full co-operation of both partners and it is not always easy to pinpoint ovulation so pregnancy can result.

Effectiveness: 10 pregnancies per 100 woman years.

Natural methods are considered to be birth control because they use the natural cycles of the body to space out the number of children born and simply avoid sexual intercourse to ensure that the ovum and the sperm do not meet. Breastfeeding a baby also helps to space a family as a woman often does not ovulate while she is fully breastfeeding a baby. However, most methods of contraception set out to prevent conception or the implantation of the embryo whilst sexual activity continues whenever the couple desire it. Community-based reproductive health programmes can give help, advice and contraception.

a

b

c

Figure 3.46
(a) Male condoms; (b) Female condom; (c) Diaphragm: all physical barriers to conception.

Physical or barrier methods of contraception involve physical barriers which prevent the meeting of the ovum and the spermatozoa.

- **Condoms** – a thin latex sheath is placed over the penis during intercourse to collect the semen and so prevent ovum and sperm meeting. Gives better protection against pregnancy when combined with spermicide.

Advantages: no side effects, don't need medical advice, used every time you have sex offers protection against sexually transmitted diseases such as syphilis and HIV/AIDS.

Disadvantages: can interrupt intercourse. Sheath may tear or get damaged during intercourse, allowing semen to get through.

Effectiveness: 2.5 pregnancies per 100 woman years.

- **The female condom** – a thin sheath worn by a woman during sex. It lines the vagina so that sperm cannot enter the cervix.

Advantages: no side effects, don't need medical advice, used every time you have sex it protects from infection with HIV/AIDS or other sexually transmitted diseases.

Disadvantages: can only be used once, can be expensive, gives better protection against pregnancy when used with spermicide, takes practice to insert it properly.

- **The diaphragm or cap** – a thin rubber diaphragm is inserted into the vagina before intercourse to cover the cervix and prevent the entry of sperm.

Advantages: no side effects, offers some protection against cervical cancer.

Disadvantages: must be initially fitted by a doctor. May be incorrectly positioned or damaged and allow sperm past. Gives better protection against pregnancy when combined with spermicide.

Effectiveness: 2.5 pregnancies per 100 woman years.

Hormonal methods use variations on your natural hormones to prevent conception.

- **The mixed pill** – one of the most reliable methods of contraception. The pill contains the female hormone oestrogen. This raises the level of oestrogen in the blood which is detected by your pituitary gland, which in turn slows the production of FSH. Without rising FSH levels no follicles develop in the ovary and no eggs mature to be released. Without mature ova there can be no pregnancy. The pill also contains progesterone, so the mucus in the vagina and cervix change as if a pregnancy has occurred to stop more sperm getting in. The pill must be taken regularly – if the artificial hormone levels drop the body's own hormones can take over and an egg can be released unexpectedly. The **progesterone only pill** (**mini-pill**) doesn't contain oestrogen so it does not inhibit ovulation and needs to be taken at very precise time intervals to be effective.

Figure 3.47 *A tiny pill containing a mixture of female hormones can trick the body and prevent the release of any further eggs.*

Advantages: the combined pill particularly is very effective at preventing pregnancy. The pill is taken at regular daily intervals and so does not interfere with intercourse. It may offer some protection against certain tumours.

Disadvantages: the pill may increase the risk of certain tumours. It can cause raised blood pressure and an increased tendency for the blood to clot.

Effectiveness (combined pill): 0.5 pregnancies per 100 woman years (due to human error in taking the pill).

- **Hormone injections** – in this method of contraception a woman is given an injection of hormones which prevents pregnancy for up to three months. The injections stop ovulation, cause changes in the mucus of the cervix to prevent sperm getting through and reduce the lining of the uterus so a fertilised ovum would not be able to implant.

Advantages: very effective at preventing pregnancy. Only need an injection every three months.

Disadvantages: you can't change your mind once you have had the injection – you can't get pregnant for about 3 months. There are some side effects – it can affect your periods and may give you headaches.

Effectiveness: 1 pregnancy per 100 woman years (because sometimes women don't get their injections regularly enough).

- **Hormone implants** – this method involves implanting small silicone capsules containing female hormones very like those in the contraceptive pill under the skin. They release small doses of hormone and prevent pregnancy for up to five years. If a woman wants to become pregnant the implant can be removed.

Advantages: the implant is very effective at preventing pregnancy and can last for up to five years.

Disadvantages: there can be side effects including changes to your periods, headaches and depression.

Hormone implants being implanted under the skin.

Effectiveness: 0.5–1 pregnancy per 100 woman years.

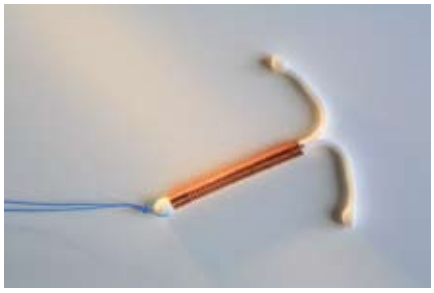
Sterilisation or surgical contraception is the ultimate form of contraception. By cutting or tying the tubes along which eggs or sperm travel conception is rendered almost impossible. This has the additional benefit of removing the human element of contraception, which is the major cause of failure in the other methods.

- **Vasectomy** – in men the sperm ducts (vas deferens) are cut, preventing sperm from getting into the semen.
- **Female sterilisation** – in women the Fallopian tubes are cut or tied to prevent the ovum reaching the uterus or the sperm reaching the ovum.

Advantages: almost 100% guaranteed to prevent pregnancy. Permanent control of fertility. Removes the problem of human error in contraception.

Disadvantages: for women in particular it involves a general anaesthetic. Not easily reversible.

Effectiveness: 0.05 pregnancies per 100 woman years.



An IUD

The IUD or **intrauterine device** does not prevent conception – the ovum and the sperm may meet – but it interferes with and prevents the implantation of the early embryo. An IUD is a device made of plastic and a metal, frequently copper, which is inserted into the uterus by a doctor and remains there all the time.

Advantages: once inserted, no further steps need to be taken. Relatively effective at preventing implantation and pregnancy.

Disadvantages: can cause pain and heavy periods. Can cause uterine infections which may lead to infertility. If pregnancy does occur it has a high chance of being in the Fallopian tubes (ectopic pregnancy).

Effectiveness: 2.5 pregnancies per 100 woman years.

Effective family planning using a reliable method of contraception can have a big impact on individuals and on society. If every child is a wanted child, born when the parents feel ready both financially and emotionally to support a baby, then everyone benefits. Couples who have children when they want them can enjoy those children. Having the number of children you choose, and spacing the births to give the mother time to recover from one pregnancy before she is pregnant again, makes for healthier women, healthier children, less poverty and generally happier families. This in turn means society functions better. Less money needs to be spent supporting children who are unwanted or uncared for by their families or on dealing with the health problems which result from too many pregnancies too close together. This frees up money for other things. Regular use of condoms can also reduce all the problems which come from HIV/AIDS.

Human Immunodeficiency Virus and Acquired Immune Deficiency Syndrome (HIV/AIDS)

Acquired Immune Deficiency Syndrome (AIDS) is the medical term for a combination of illnesses that result when the immune system is weakened or destroyed. It is the advanced form of an infection caused by Human Immunodeficiency Virus (HIV), a virus that attacks the immune system, making the sufferer susceptible to other diseases.

Introduction

HIV/AIDS is a big problem in Ethiopia. Between 60 000–70 000 people die of AIDS every year, at the moment, and well over a million people are infected with the virus.

HIV attacks the your immune system so you cannot fight off infections such as TB or even a cold.

HIV, the virus that leads to AIDS, can be spread through four bodily fluids – blood, semen, vaginal secretions and breast milk. The virus can only be spread from an infected person if his or her bodily fluids enter the bloodstream of an uninfected person. It is most commonly spread through unprotected sex with an infected partner (without using a condom). In Ethiopia more people are infected through heterosexual sex than any other way.

Figure 3.48 *Practising life skills such as assertiveness, decision making and problem solving, will help young people avoid infection with HIV/AIDS.*

An HIV-infected mother can infect her baby during pregnancy, at birth or through breastfeeding. HIV can also be passed on by an infected blood transfusion or by sharing non-sterilised needles, syringes or razors. It is a particular problem with drug addicts who share needles.

An individual can become infected from only one exposure. You only need to take a risk once – but once you are infected with HIV you can infect others. How would you know if you have HIV/AIDS – what are the symptoms?

Symptoms of HIV/AIDS

The symptoms of HIV/AIDS are different at different stages of the disease. After about three months some people start to feel unwell – early symptoms include fevers, headaches, tiredness, and swollen glands, but not everyone infected with HIV feels ill. These symptoms are very mild and easily mistaken for an ordinary infection. But after about three months, HIV antibodies appear in your blood – you become HIV-positive

As the immune system weakens, an infected person may develop more symptoms (relatively mild at first), including swollen lymph glands, night sweats, fever, cough, diarrhoea, and/or weight loss. As the disease progresses the symptoms become more noticeable and more severe.

Figure 3.49 *Because there is no cure yet, everyone who becomes HIV-positive will eventually die of AIDS. However, with a healthy lifestyle and with modern retroviral medicines, some people are living for longer before the disease reaches its final stages.*

The symptoms of the final stages of AIDS include:

- extreme fatigue
- rapid weight loss
- appearance of swollen or tender glands in the neck, armpits or groin
- unexplained shortness of breath, frequently accompanied by a dry cough
- infections such as TB and pneumonia
- persistent diarrhoea
- intermittent high fever
- appearance of one or more purple spots on the surface of the skin, inside the mouth, anus or nasal passages caused by a rare cancer, Karposi's sarcoma
- whitish coating on the tongue, throat or vagina as fungal infections take hold
- forgetfulness, confusion and other signs of mental confusion

The incubation period

The first symptoms appear 3–12 weeks after you have become infected. This is the initial incubation period of the virus. Before this you can't even detect the infection with a test because your body has not produced enough antibodies. People who think they may have been infected and receive a negative test result should do a second test three months later to be absolutely sure of their HIV status. During the waiting period they should either not have sex or use a condom properly at all times. **People who look healthy can infect you with HIV/AIDS**.

After the first mild symptoms the disease incubates again. In Ethiopia many people will progress from HIV infection to full-blown AIDS in 2–3 years, because they are already suffering from other diseases or just from a shortage of food. During this time the virus reproduces rapidly, infecting the cells of the immune system and destroying them. However, in very healthy, well-fed people with the best medicines available the incubation period is much longer. It can take 20 years or more before all the symptoms of the disease appear.

Treatment

There is no cure for HIV/AIDS, and there is as yet no effective vaccine either. Antiretroviral medications are used to control the reproduction of the virus and slow the progression of HIV-related disease. Some of the early symptoms of HIV can be treated – the secondary infections can be treated with antibiotics, the fungal infections with antifungal drugs and any anaemia with iron and transfusions.

Some of the factors that affect how quickly HIV infection can develop into AIDS can be controlled by the infected person. A healthy lifestyle, with a good balanced diet, regular exercise, no smoking or illegal drug use, and drinking alcohol in moderation if at all can help you to stay well for longer. By carefully managing your lifestyle and so keeping your immune system healthy you can help your body cope with the effects of the virus for as long as possible.

Anti-HIV medications do not cure HIV infection and individuals taking these medications can still transmit HIV to others. They can, however, lengthen the period of healthy, active life available to an infected individual. The earlier they are started, the more effective they are at lengthening the lifespan of an HIV-positive individual.

Life skills for responsible sexual behaviour

The most effective ways of reducing or halting the spread of HIV/AIDS involve changing the way people – and young people in particular – behave.

It is vitally important to be aware of the risk of HIV/AIDS in any sexual relationship.

Using condoms is very effective at reducing the risk of the infection spreading – although it is not risk free as condoms can break. Ideally everyone would have an HIV test at the onset of establishing a new relationship.

Abstinence from extra-marital sex and being faithful within marriage or a relationship is by far the safest option. The more partners you have, and the more times you have unprotected sex, the more you put yourself at risk. If people avoid the use of substances, such as alcohol, which can affect their judgement and make you more likely to take part in risky behaviour, fewer mistakes will be made.

There are other ways in which you can protect yourself. You should never use drugs that are non-medicinal, especially those that require needles. Sharing needles between drug users is very dangerous, so setting up needle exchanges where intravenous drug users can get clean, sterile needles on a regular basis is another way of preventing the spread of HIV/AIDS.

It is important to practice precautions when handling blood and the body fluids as well as body refuse. This has important implications for hospitals and doctors. What's more, blood for transfusions needs to be thoroughly screened for HIV antibodies – a precaution already taken in Ethiopia.

Pregnant women need to be screened, and if found to be at risk, given drugs to reduce the risk of infecting their unborn child. Caesarean deliveries are advised, and HIV-positive mothers should bottle feed their babies if at all possible as the virus can pass through to the baby in the breast milk. Without this intervention, 25–30% of all babies born to HIV-positive mothers will be infected with the

Figure 3.50 *Posters like this are used to help educate people about the risk of HIV/AIDS.*

Activity 3.16: Don't pass it on

Anyone who might be infected with HIV/AIDS must act carefully to prevent the virus from spreading. Make a list of behaviours which should be followed to prevent the spread of HIV/AIDS by people who may be incubating the virus. The title of your list is:

You may have HIV – Don't pass it on!

Activity 3.17: Family support

Discuss the problems for a family affected by HIV/AIDS, and how your school community can help affected families and change attitudes in the community.

Activity 3.18: Role play

Sometimes it can be difficult to behave sensibly, but young people must be careful when they have sexual relations. They need to be assertive and sensible. Plan and act out one of these role plays:

a) A young girl and her boyfriend
The boy wants them to have sex. The girl wants to abstain.

b) A nurse/village elder has a discussion with some young pregnant women on how they can reduce the risk of their baby contracting HIV/AIDS

virus. At the moment only about 1% of pregnant women who are HIV-positive in Ethiopia are given the antiretroviral drugs needed to protect their unborn child.

Most of all, people around the world need to be educated about the risks of HIV/AIDS, how it is passed on and how to avoid it.

It is very important that you, our young people, develop the personal skills which will help you reduce the risk that HIV/AIDS poses both to you as individuals and to our society. It is important to be assertive. Girls and young women must be able to insist that their sexual partners use a condom for sex. Boys and young men must learn to respect their partners and to take responsibility for their own sexual health and that of others by using condoms. Young people need to make decisions about their own behaviour and that of their local community about how to care for and support people who are already living with HIV/AIDS, and how to reduce the risk of this terrible disease for future generations.

Female genital mutilation and reproductive health

In Ethiopia, we are leading the way in recognising that some of our traditional practices, carried out with the best of intentions, can in fact cause great damage and are part of the reason for our high rates of HIV/AIDS infections. One of these harmful traditional practices is female genital mutilation (FGM) also known as female genital excision (FGE) or more locally as 'removing the dirt'.

Female genital mutilation is a process which is carried out across Ethiopia. There are various forms of FMG. All of them involve removing part of the external genitalia of young girls in surgery which is carried out without any anaesthetic, using blades or sharpened obsidian. In some forms of the process almost all of the external genitalia are removed, and the whole region is sewn together leaving a single small opening for the passage of urine and menstrual blood. Sometimes FGM is carried out on babies, but more often it is performed when girls are aged from six up until just before marriage. Traditionally people believed that FGM keeps girls pure and is necessary for them to be accepted by men in marriage.

Women were traditionally completely dependent on men, and so anything which helped them to marry successfully was done.

In some regions of our country almost every girl will undergo FGM. In other areas, numbers are lower. For example, about 54% of girls in SNNPR experience FGM, with 92% in Amhara and up to 100% in Somali.

In Ethiopia, with great wisdom and understanding, many people have begun to understand that this traditional practice causes harm rather than good. Bogaletch Gebre is a shining example of this. Not only was she the first Ethiopian woman to join the science faculty at the University of Addis Ababa, she has also established the Kembatta Women's Self-Help Centre, Kembatti Mentii Gezzima-Tope (KMG). This organisation aims to help women and men throughout Ethiopia understand the best way forward for a strong and healthy population in our country.

Our government has set up a national committee known as the Eradication of Harmful Traditional Practices (EHTP). This committee is working with leaders of Islam, Christianity and other religions and with many other organisations to help everyone in our country change their minds and make different choices. People often do not understand all of the problems which can result from cutting a young girl in this way.

Unfortunately FGM, rather than protecting our girls, puts them at great risk in many different ways.

- The process of FGM when a girl is cut can result in serious bleeding and infections which can kill. In Ethiopia today, with our high rates of HIV/AIDS, it can put our girls at risk of HIV infection too. The traditional practitioners who carry out the process may carry out 20 FGMs a day. If one of those girls was infected as a baby, her blood could infect all of the other girls cut that day.
- When the genital region is sewn closed, girls are at constant risk of infection. This can make them infertile (unable to have children). It can also affect their kidneys and kill them.
- Because the process of FGM leaves much scarring, this means that sexual intercourse is often very painful for women. This does not help them to feel close and loving towards their husbands. It also means that sexual intercourse often causes bleeding on the damaged scar tissue of the genitalia. This makes it very easy for them to become infected with HIV/AIDS if their partner carries the disease. FGM is one of the reasons why HIV/AIDS levels are so high in Ethiopia. It is also part of the reason why our women – and so, very often, our children – are so badly affected by this killer disease.
- The terrible scarring and narrow vaginal opening often left by FGM means that cut women often have big problems giving birth. The stitching and scarring can tear open, so the woman loses a great deal of blood. Sometimes the baby cannot be delivered alive, and in many cases the woman may die.

Figure 3.51 *Bogaletch Gebre is internationally recognised for the work she has inspired in Ethiopia in supporting the right of women to be freed from harmful traditional practices such as FGM.*

Figure 3.52 *A sign warning about the dangers of FGM.*

EHTP and others are helping people across the country to understand just how damaging FGM can be and that the alternatives are very positive for the country as a whole. When girls are not cut they remain healthier. They are less likely to become infected with HIV/AIDS which also means they are more likely to have healthy children. They are more able to have a full and happy relationship with their husbands. Because they are healthier, they can work harder and bring more prosperity to the family. And they are much less likely to die in childbirth or to lose their baby. Of course women want to be married, but as more and more girls become educated they can be equal partners with their husband and they do not need to be cut to be married.

To help people around the country understand the choices that can be made there are films of a young girl being cut. Many men realise for the first time what a terrible thing is done to their daughters and wives. They recognise how damaging FGM really is.

Organisations such as the EHTP show people how positive marriage can be when girls remain uncut, and how much healthier those girls remain.

The Government wants to make full use of the women of Ethiopia to help our country grow. To do that it needs them to be healthy and whole and so FGM is against the law. Our Government recognises that people need to feel good about their decisions and is working hard to help people see the advantages of leaving girls uncut. Education for both boys and girls is very important in this.

Religious leaders have made it clear that FGM is against the principles of both Islam and Christianity and is not part of the Koran or the Bible. They too are working to make their communities healthier for everyone and protect the girls under their care from this harmful practice.

The traditional practitioners who carry out the cutting are very influential in the community. The money they earn for cutting girls increases their income and it gives them high status. However, more and more traditional practitioners are giving up cutting girls. They are using their knowledge and status in the local communities to explain to parents why it is better to leave their daughters uncut. They are becoming very valuable advisers on the prevention and treatment of HIV/AIDS. They are paid for this work and become more important in the community than ever before. They will play a big part in maintaining the future health of Ethiopia.

Activity 3.19: Campaign against FGM

Work in groups and plan a campaign to help people in your area understand the dangers of the traditional practice of female genital mutilation and the benefits of keeping girls uncut.

Think about why people do this to their children, and make sure you make the benefits very clear.

Design a poster or a leaflet which could be used in your local community to help people understand the problem and the solution.

Around the world many people admire the way that the Government and people of Ethiopia have recognised that modern knowledge and the arrival of HIV/AIDS means that some long-held traditional practices are now very harmful. The way our country is changing its traditions to keep our women healthy and reduce the spread of HIV/AIDS is an example to many other countries in Africa and beyond.

Ethiopia is not alone in trying to tackle this harmful traditional practice. In December 2009, female genital mutilation was made illegal in Uganda, punishable by 15 years in jail.

Summary

In this section you have learnt that:

- There are a number of different birth control methods which can be used to control the size and the spacing of a family. They include natural methods, physical or barrier methods such as condoms, chemical methods such as the contraceptive pill or implants and surgical methods such as sterilisation.
- HIV is the virus that causes AIDS. It is spread through blood, semen, vaginal secretions and breast milk. The most common way in which it is transmitted is by unprotected sex. Patients often do not have any symptoms to begin with but deteriorate and eventually show many signs and symptoms of a weakened immune system.
- Treatment options include use of antiretroviral drugs, healthy lifestyle practices and strong support systems.
- Female genital mutilation is a traditional practice which people are now realising causes much harm. It increases the spread of HIV/AIDS and means many girls and women suffer and die in childbirth unnecessarily.

Review questions

1. In which part of the female reproductive system does fertilisation of the ovum take place?

   A uterus

   B cervix

   C fallopian tube

   D vagina

2. How long is the average human pregnancy?

   A 30 weeks

   B 35 weeks

   C 40 weeks

   D 45 weeks

3. Which of the following is NOT a way to help prevent the spread of HIV/AIDS?

   A washing your hands after using the toilet.

   B using a condom when you have sex.

   C having only one sexual partner.

   D not sharing needles for intravenous drug use.

3.5 Homeostasis

By the end of this section you should be able to:

- Define homeostasis as maintenance of a constant internal environment and explain its significance.
- Define poikilotherms as organisms whose temperature is governed by the external temperature.
- Define homoiotherms (homeotherms) as organisms with constant body temperatures.
- Explain the physiological methods of temperature regulation in homoiotherms.
- Explain the behavioural methods of temperature regulation in homoiotherms and poikilotherms.
- Label the structures of the kidney.
- State the functions of the structures of the kidney.
- Explain how the kidney regulates water and ionic balance.
- Explain how the skin helps in water and salt balance.
- Explain the role of the liver in regulation of the body.

KEY WORDS

homeostasis *the body's ability to maintain normal function and stability*
homoios *like, or the same*
stasis *state*

Just stop and think for a moment about the different conditions in which people live around the world. From the warmth of Africa to the cold of the Arctic tundra, from the arid dryness of the Sahara desert to the risk of flooding in the Nile delta – there are few areas of the planet where people have not settled, survived and thrived. What is more, think about the different conditions your own body finds itself in during a single day. You may eat lots of food, or you may eat very little, you may spend time training for sport in the sun, or swim in the river, or sit in the shade. You may be ill and have a fever. You may even take a flight to a country with a very different climate from your own land. But, however much your external environment may change, things inside your body need to stay the same.

DID YOU KNOW?

The word **homeostasis** comes from the Greek words **homoios**, which means 'like' or 'the same', and **stasis**, which means 'state'. So the word tells you exactly what it means – keeping the conditions in the inside of your body (the internal environment) in the same state all the time.

Figure 3.53 *The beautiful countryside of Ethiopia and our thriving cities bring pleasure to local people and tourists alike – and everyone maintains a constant internal environment, regardless of the external conditions they are familiar with.*

Figure 3.54 *In warm sunny weather like this, or cold snowy weather, and whatever clothes we wear, homeostasis makes sure conditions inside our bodies stay the same.*

Here are some of the main threats to a stable state inside your body.

- You eat several times a day, so sometimes products of digestion are flooding into your blood and at other times little or no food is available from the gut, yet your cells need a constant supply of glucose for respiration.
- When you respire, you produce a poisonous waste product – carbon dioxide. If levels build up in your body they change the pH of your tissues. This in turn could denature your enzymes and so stop your cell chemistry completely.
- As you break down the products of digestion, poisonous wastes are produced, such as the urea which comes from the breakdown of amino acids in your liver. A build-up of urea could poison and kill you.
- Whenever you exercise you produce heat from your muscles. This can increase your core body temperature, as can spending too much time in the sun or having a fever. If your body temperature gets too high, your enzymes will denature and so all your cell chemistry will come to a halt and you may die.
- If you lose too much heat from your body because the external conditions are very cold, or you lose a lot of body heat, the cellular reactions slow down and you may die.
- The amounts of water and salt you take in vary greatly throughout the day and from day to day, and so does the amount of water and salt you lose through sweat and urine – yet the water balance inside your body needs to stay the same to keep the cells in osmotic balance.

As you can see, keeping your internal conditions in a stable state isn't easy – yet this is what your body manages to do 24 hours a day, every day of your life. The nervous and hormonal systems which you discovered in sections 3.1, 3.2 and 3.3 play an enormous role in maintaining this important balance. Feedback mechanisms involving both the nervous system and hormonal systems play a very important part in maintaining homeostasis. Most of these control systems in the body are examples of negative feedback. This

means that when levels of a substance in your body rise, changes are made which *lower* the levels again. Similarly, when levels of a substance fall, changes are made so that it *rises* again to the original levels. Look out for these feedback mechanisms as you learn about homeostasis.

Controlling temperature

One of the most important factors which animals need to control is the internal or core body temperature.

Heat is a form of energy which is produced in a number of ways including by the sun and by artificial heating systems. It is also generated by the chemical reactions which take place in your own body. Temperature is a way of measuring hotness or coldness (the effect of heat energy) on a relative scale.

It is vitally important that wherever we go and whatever we do our body temperature is maintained at the temperature (around 37 °C) at which our enzymes work best. It is not the temperature at the surface of an organism which matters – the skin temperature can vary enormously without causing harm. It is the temperature deep inside the body, known as the internal or core body temperature, which must be kept stable. We can get a good measure of our human core body temperature by taking the temperature in the mouth, in the anus or on the surface of the eardrum.

Living organisms are continually gaining heat from cellular respiration and by conduction, convection and radiation from their surroundings. They are also constantly losing heat by the evaporation of water from the body surfaces and by conduction, convection and radiation to their surroundings. It is the balance of these gains and losses that gives the core temperature. Organisms use a number of different ways to shift the balance and allow themselves to gain or lose heat as they need to.

Not all animals need to control their core body temperatures. Protista and small animals living in big bodies of water like the sea have no means of temperature regulation because they do not need them.

Larger animals living in many different habitats must be able to regulate their body temperatures so they can avoid cell damage from overheating, but also gain enough heat to have an active way of life. There are two types of animals:

Poikilotherms – organisms whose body temperature is governed by the external temperature. They rely largely on the environment for their body heat. Their body temperature can vary over a wide range, for example, fish and reptiles.

Homoiotherms – organisms with a relatively constant internal body temperature which is usually higher than the external temperature, for example, birds and mammals.

Humans are a well-known example of homoiotherms.

Figure 3.55 *People can live in conditions of extreme heat and extreme cold and still maintain a constant internal body temperature.*

KEY WORDS

poikilotherms *animals whose internal temperature varies along with that of the ambient environmental temperature*

homoiotherms *animals whose internal temperature is relatively constant and independent of the environmental temperature*

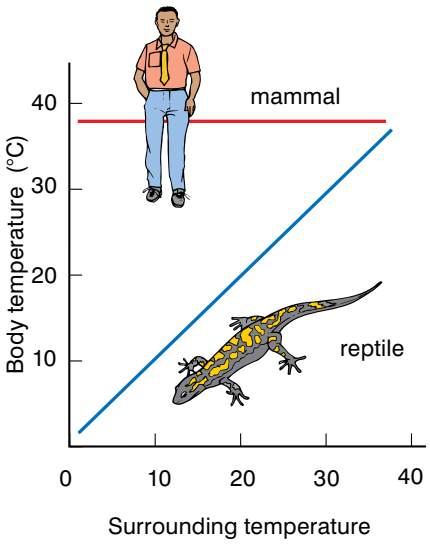


Figure 3.56 *The difference between homoiotherms like us and poikilotherms like this lizard can be seen very clearly when you look at the comparison between the internal and external temperatures of both organisms if they are not allowed to move or use behaviour to control their temperature.*

DID YOU KNOW?

A liquid evaporating to become a gas is a physical state change which needs energy to take place – **the latent heat of vaporisation**. So when your sweat evaporates, the energy required is supplied by the heat of your body. As your body loses heat, it cools down.

KEY WORDS

dilate *to become wider or larger; expand*

Temperature control in poikilotherms

Poikilothermic animals have to rely on changes to their behaviour and their body structures to use the heat in their environment to maintain a reasonably steady and useful body temperature.

When they are cold they may:

- bask in the sun
- press their bodies close to a warm surface
- erect special sails or areas of skin which will allow them to absorb more heat from the sun

When they are getting too hot they may:

- move into the shade
- move into water or mud

Temperature control in homoiotherms

Human beings are good examples of homoiotherms. Our body temperature is controlled by a number of physiological mechanisms which work together to allow us to gain or lose heat as we need to.

Physiological methods of temperature regulation in homoiotherms

- **Sweating** – when you are hot sweat oozes out of the sweat glands and spreads over the surface of the skin. Sweat is made up mainly of water and salt but also contains a small amount of nitrogenous waste. As the water evaporates it cools the skin, taking heat from the body. Because water and salt are lost in the sweat, when you sweat a lot this can affect your water and ion balance so you need to take more water and ions in through drink or food to replace the water and ions which are lost. It is important to remember that sweat itself is not cool, and it can only cool you down if it evaporates. In hot, humid conditions you may sweat a lot – but it won't cool you down because the water can't evaporate! In cold weather, little or no sweat is formed so that as little heat as possible is lost by evaporation.
- **Vasodilation** – if the body temperature starts to go up, the blood vessels supplying the capillaries in your skin **dilate**, so that more blood flows through the capillaries. Your skin flushes and more heat is lost through radiation from the surface. This is known as vasodilation and it is particularly obvious in pale-skinned people. Less blood flows through the slightly deeper vessels in your skin as a result.
- **Panting and licking** – many mammals have thick, furry coats and so cannot evaporate sweat easily from the skin surface even when they are getting hot. Some animals, such as dogs and cats, only have sweat glands in small areas of the skin such as the feet. So to increase the amount of heat lost through evaporation, these animals may lick themselves, coating parts of their bodies with

saliva which evaporates and cools them down. They also pant, which allows water to evaporate from the moist surfaces of the mouth and this also cools them down.

- **Vasoconstriction** – if your core temperature begins to fall the blood vessels which supply your skin capillaries **constrict** (close up) to reduce the flow of blood through the capillaries. This reduces the heat lost through the surface of the skin, and makes you look paler. This is known as **vasoconstriction** and it works to keep you as warm as possible. More blood flows through the deeper blood vessels of your skin as a result.
- **Piloerection** (**pulling the hairs upright**) – human beings, like other mammals, have a layer of hair over their bodies. Our hair is very light compared to a dog or a cat, for example, but our bodies still react as if we are furry. The hair erector muscles contract. In furry animals this pulls the hairs upright, trapping an insulating layer of air which is very effective at conserving heat. Our hairs are also pulled upright, but we have so little body hair that it has little or no effect on heat conservation. The most obvious effect is that we get goosebumps on our skin – each bump is the contracted muscle pulling on a hair. When the core temperature starts to climb, the hair erector muscles which move our body hair all relax and our hair lies very flat against our skin. Again in humans this has very little effect, but in hairy animals this reflex action is important because it reduces the layer of insulating air trapped in the fur and so makes it easier to lose heat by convection.
- **Shivering and metabolic responses** – if your core body temperature drops your metabolic rate speeds up, producing more heat energy so your body temperature starts to go up. Your liver in particular is involved in this because it is a very large organ which carries out many different metabolic reactions. As part of this response you may start to shiver. When you shiver your muscles contract rapidly, which involves lots of cellular respiration. This releases some energy as heat which is used to raise the body temperature. As you warm up, shivering stops. But if your core body temperature starts to rise, the metabolic rate drops so less heat is produced.
- **Fat layer under the skin** (**subcutaneous fat**) – it is important that homoiotherms only lose or gain heat when they really need to. So under the surface of the skin is an insulating layer of fat. This prevents unwanted heat loss. It is particularly noticeable in animals which live in very cold conditions, for example, seals and whales. The very thick layer of fat under their skin is known as blubber.

Homoiotherms do not only rely on physiological methods to control their internal body temperature. Like poikilotherms, they use **behavioural methods of temperature control**. Some of these methods are similar to those used by poikilotherms, some are only seen in homoiotherms and some are unique to human beings.

Figure 3.57 *Panting is another physiological way to lose heat by evaporation.*

KEY WORDS

constrict *squeeze, or press together*

vasoconstriction *constriction of a blood vessel*

Behavioural methods of temperature regulation

- **Clothing** – people choose suitable clothes for the weather as we do not have fur or feathers to keep us warm. We wear warm clothes when the weather is cold and fewer, cooler clothes when the external temperature is hot.
- **Seeking shade or shelter** – like many other animals, people look for shade to keep them cool when it is hot and sunny, and look for shelter from cold, wet or windy conditions to help prevent excess heat loss and keep themselves warm, for example, native male rats live underground in burrows all the time in arid deserts.
- **Taking high-calorie food** in cold conditions. We need to use more metabolic energy to keep warm so we eat high-calorie food in cold conditions. Birds and other mammals do the same.

Figure 3.58 *In countries such as the UK small animals like this hedgehog cannot cope with the cold winters so they hibernate through them.*

- **Hibernation** – in countries which have very cold winters, some homoiothermic animals will hibernate. They cannot eat enough to keep their body temperature stable through the cold winter, so they sleep through the bad conditions. These animals eat a lot and gain a lot of fat before hiding away in a warm nest or burrow and going into a very deep sleep. Their metabolic rate falls and so does their body temperature. They do not wake up until the warmer weather of spring arrives with more food for them to eat, for example, dormice and hedgehogs in the UK.
- **Aestivation** – in hot countries, some animals 'hibernate' through the hottest weather as they cannot keep their bodies cool enough. These animals usually hide themselves underground or under a layer of mud and go into a deep sleep until conditions cool down again, for example, East African land snails can aestivate for up to three years in times of extreme drought.
- **Wallowing or bathing** – some animals cannot lose enough heat through sweating alone to keep their bodies cool enough in hot weather. This is a particular problem for some larger animals. By wallowing in mud or bathing in water, the animals cover themselves in water and the water evaporates from the surface of their skin, cooling them down, for example, elephants and pigs.
- **Burning fires, central heating, air conditioning, etc**. – people can change the temperature of their environment. By burning a fire or turning on the heating we can warm things up and reduce the heat we lose, keeping us warmer. Air conditioning is used in some buildings and vehicles to cool the air down if it gets too hot, so the people inside can lose more heat and keep themselves cool.

Controlling the core body temperature

At only a few degrees above or below normal body temperature our enzymes cannot function properly. If this goes on for any length of time the reactions in our cells cannot continue and we die. As you have seen, all sorts of things can affect your internal body temperature, including heat generated in your muscles during exercise, fevers caused by disease and the external temperature rising or falling.

Human beings have an internal control mechanism, a system of homeostasis which enables us to lose excess heat if our core temperature starts to rise, yet generate and conserve heat when our core temperature starts to fall. How does this temperature control mechanism work? Control of the temperature relies on the thermoregulatory centre in the brain. This centre contains receptors which are sensitive to the temperature of the blood flowing through the brain itself. Extra information comes from the temperature receptors in the skin, which send impulses to the thermoregulatory centre giving information about the skin temperature. These receptors are so sensitive they can detect a difference of as little as 0.5 °C. When the **thermoregulatory centre** detects changes in temperature, our first responses are conscious – we put more clothes on, or take clothes off, move outside or light a fire. But if the core temperature starts to move in one direction or the other, automatic body responses take over. The control of the body temperature is an example of a negative feedback loop. The feedback control of the body temperature involves the thermoregulatory centre in the brain and the skin.

KEY WORDS

thermoregulatory
centre area of the brain responsible for controlling body temperature

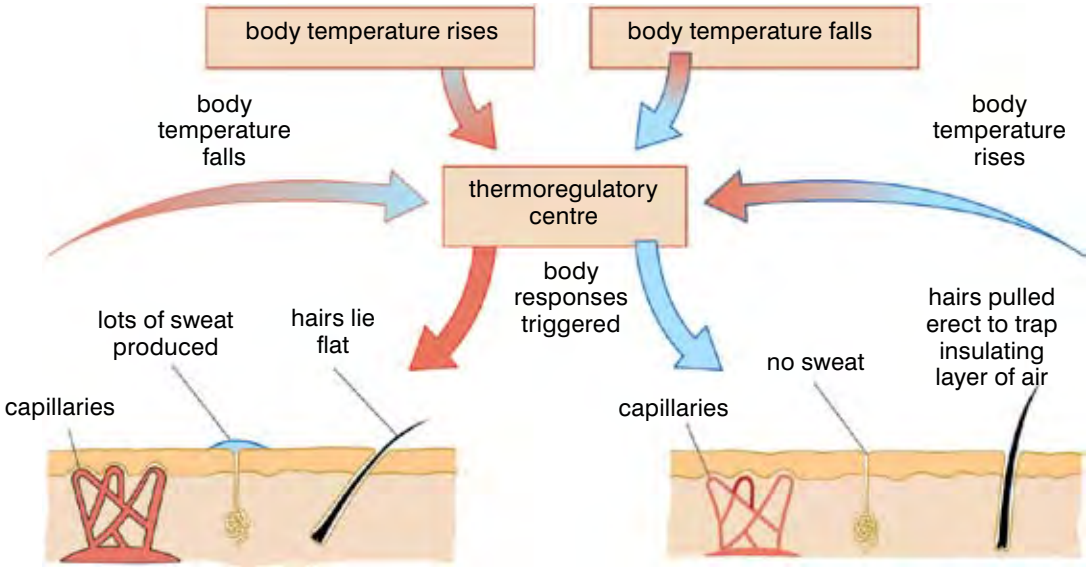


Figure 3.59 *The thermoregulatory centre in the hypothalamus of your brain acts as your body thermostat. As a result of all these sensitive control mechanisms, the core temperature of your body is usually kept the same with only about 1 °C variation.*

When things go wrong

The homeostatic mechanisms of temperature control in your body usually work very effectively. However, if conditions become too extreme and things go wrong with your temperature control mechanism, the need for this homeostasis quickly becomes very clear indeed.

For example, when the weather becomes extremely hot and humid, and when people undertake exceptionally challenging physical activity like running a marathon, the normal homeostatic mechanisms may not cope. For example, eventually there is not enough spare water in the body to produce sweat. The salt and water balance is destroyed and then the core temperature will rise to dangerous levels. Once this happens people may die.

On the other hand, if your core body temperature falls too low you suffer from hypothermia. In Ethiopia hypothermia can be seen sometimes in new-born infants if they are small and have little body fat, or if they are not dried and wrapped up warm to be cuddled by their mother as soon as possible after birth. In cooler climates such as the UK this silent killer claims around 30 000 lives every year.

People with hypothermia have greyish-blue, puffy faces and blue lips. Their skin feels very cold to the touch, and they will be drowsy with slurred speech. As it gets worse, they will stop shivering. If the body temperature falls too low the sufferer will become unconscious and may die.

Activity 3.20: Investigating factors which affect heat loss

Different factors affect how quickly a person loses heat – surface area to volume ratio, insulation, whether they are wet, etc. You can mimic these situations in a number of ways using beakers or conical flasks, and use this to investigate factors which affect heat loss. You can use all of the different suggestions in the equipment list in one large investigation, or different groups can investigate different factors and then the whole class share and compare results.

You will need:

- a 250 cm^3 beaker or conical flask (your control)
- a 100 cm^3 beaker or conical flask
- a 250 cm^3 beaker or conical flask wrapped in cotton wool or fabric
- a 250 cm^3 beaker or conical flask wrapped in wet cotton wool or fabric
- for each container you use, a cardboard lid with a thermometer poking though it. If you have cotton wool or wet cotton wool around your container, cover the lid with it as well
- hot water – 60–70 °C is hot enough – be very careful how you handle it
- a stopwatch or clock with minute hand

Method

1. Arrange your containers – work with a control and at least one other container each time.
2. Add the same volume of hot water – e.g. 75 cm^3 – to each container and gently place the lids on. Make sure the bulb of the thermometer is in the water.
3. Take and record the temperature in each container.
4. Repeat the temperature readings at 1-minute intervals for 20 minutes.
5. If you have time, repeat the experiment using the same control but a different combination of containers – or vary the conditions, placing all the containers in a draught or outside in the sun, for example.
6. Record your results on a graph, plotting temperature against time. Use the same axes for all your results – use different colours or clear labels to identify the different containers. This allows you to compare your results very easily.
7. Write up your experiment and explain the results you have obtained. Which container loses heat fastest? Which retains the most heat? How does this relate to temperature control in humans? Do you think these containers are good models? How could you improve or extend this investigation?

Your surface-area-to-volume ratio is an important factor here. Smaller people – such as children – have a much bigger surface area to volume ratio than larger people. You lose heat through the surface of your body – so small people lose heat relatively faster than larger people. As a result babies, children and small adults are more at risk of becoming too cold than larger people. Big people, on the other hand, have a greater risk of overheating as their relatively small surface area to volume ratio means they cannot lose large amounts of heat effectively.

Review questions

1. Explain the feedback system which is used to control your body temperature within narrow limits.
2. Why is it so important to control your body temperature?

Homeostasis and the kidney

Excretion – getting rid of the waste products which could build up in your body and damage your cells – is one of the most important aspects of homeostasis. There are two main metabolic waste products which would cause major problems in your body if the levels rise – carbon dioxide and urea. Your body deals with them both very differently. Metabolic wastes are materials which are produced by the metabolic processes of life. The organs which are involved in getting rid of these metabolic wastes are known as **excretory organs**. The main excretory organs in your body are your lungs, your kidneys and your skin.

The carbon dioxide produced during cellular respiration is almost all removed from the body via the lungs when you breathe out. So the lungs are not only the site of gas exchange for respiration, they are also an excretory organ removing carbon dioxide waste very effectively from your body. If the levels of carbon dioxide increase as you exercise, the level is picked up by sensory receptors in your arteries and brain, which send electrical impulses to stimulate the breathing centres in your brain. In turn, these send impulses to make you breathe faster and deeper. As a result, the carbon dioxide levels fall. This is picked up by the same receptors and so the stimulation of the breathing centres is reduced, and in turn the breathing rate falls. This is an example of a feedback mechanism – as the carbon dioxide levels go up, the breathing rate goes up which makes the carbon dioxide levels fall, so the breathing rate returns to normal as well.

Another metabolic waste which can cause serious problems is urea. Urea is produced in your liver when excess amino acids are broken down. These excess amino acids come from protein in the food you have eaten and from the breakdown of worn-out body tissue. If you eat too much carbohydrate or fat, you can store it (as glycogen or fat) until you need it. However, your body cannot store excess protein or amino acids, so any excess is always broken

KEY WORDS

excretion *the bodily process of discharging waste matter*

excretory organs *organs involved in excretion*

Activity 3.21: Surface area: volume ration

Sort this list of animals in order of their surface area: volume ratio. Put the ones with the biggest surface area: volume ratio first, and the ones with the smallest ratio last.

elephant	dik dik
mouse	rat
gelada baboon	camel
ethiopian wolf	giraffe

KEY WORDS

nitrogenous waste *nitrogen-rich chemical waste of several cellular processes, excreted via urine*

osmoregulation *control of the water and electrolyte balance in the body*

down. The amino acids are converted into carbohydrate (which can be stored or used) and ammonia. The ammonia is then combined with carbon dioxide (getting rid of another metabolic waste) to make urea. The urea which is produced is a form of **nitrogenous waste** and it leaves your liver via the blood. The urea is then filtered out of the blood by the kidneys and removed in the urine. Your kidneys are one of your main excretory organs, and also one of your main organs of homeostasis. They play a vital role in the removal of urea from the body, but their role in homeostasis is even more important, because they also play a major part in regulating the water and salt balance of your body.

Controlling the internal concentration

If the concentration of the body fluids changes, water will move into or out of the cells by osmosis and they could be damaged or destroyed. Yet some days you may drink several litres of liquid and other days much less. How is the balance maintained?

We gain water when we drink and eat. We lose water constantly from the lungs when we breathe out – water evaporates into the air in the lungs and is breathed out. This water loss is constant. Whenever we exercise or get hot we sweat and lose more water.

The water balance is maintained by the kidneys. They remove any excess water and it leaves the body as urine. If we are short of water we produce very little urine and most water is saved for use in the body. If we have too much water then our kidneys produce lots of urine to get rid of the excess.

The ion concentration of the body – particularly ordinary salt – is also important. We take in mineral ions with our food. Some are lost via our skin when we sweat. Again the kidney is most important in keeping an ion balance. Excess mineral ions are removed by the kidneys and lost in the urine. The balance of water and salts in your body is very important because of the osmotic impact on your cells if the balance is wrong so controlling this balance is known as **osmoregulation**. Your kidneys are vitally important in two aspects of homeostasis, both in excretion and in osmoregulation. Let's take a look at how they work.

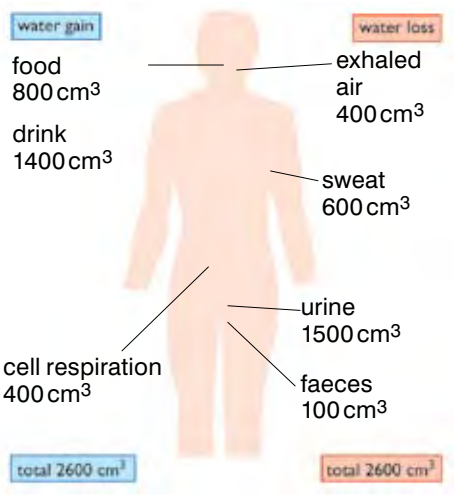


Figure 3.60 *The daily water balance of an adult*

DID YOU KNOW?

Your kidneys are vital – if they fail you will die unless you can use a special 'artificial kidney' known as a **dialysis machine**. Patients have to be connected to the machine several times a week, for several hours each time to clean and balance the blood. They have to be very careful what they eat as well. The only other alternative is a kidney transplant.

Review questions

1. What is meant by the term 'internal environment'?
2. What is homeostasis?
3. What is excretion and why is it so important?

The kidneys

How do the kidneys remove urea and control the levels of water and ions in your body? Blood flows into the kidney along the renal artery. The blood is filtered, so fluid containing water, salt, urea, glucose and many other substances is forced out into the kidney tubules. Then everything the body needs is taken back (reabsorbed), including all of the sugar and the mineral ions needed by the body. The amount of water reabsorbed depends on the needs of the body. The waste product urea and excess ions and water not needed by the body are released as urine. Each kidney has a very rich blood supply and is made up of millions of tiny microscopic tubules (nephrons) which are where all the filtering and reabsorption takes place.

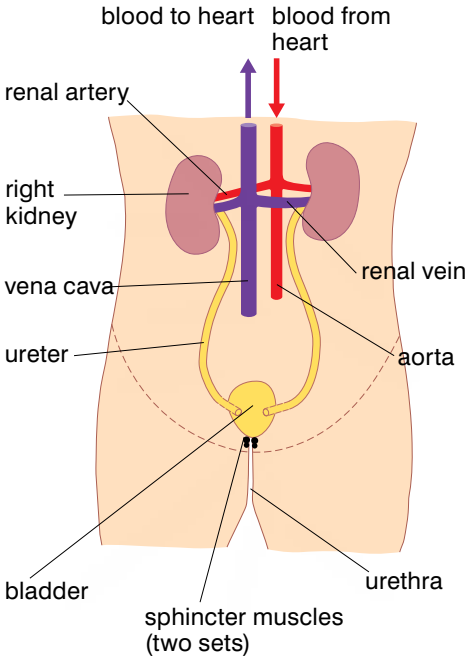


Figure 3.61 *Our kidneys are very important organs of homeostasis, involved in controlling the loss of water and mineral ions from the body as well as getting rid of urea.*

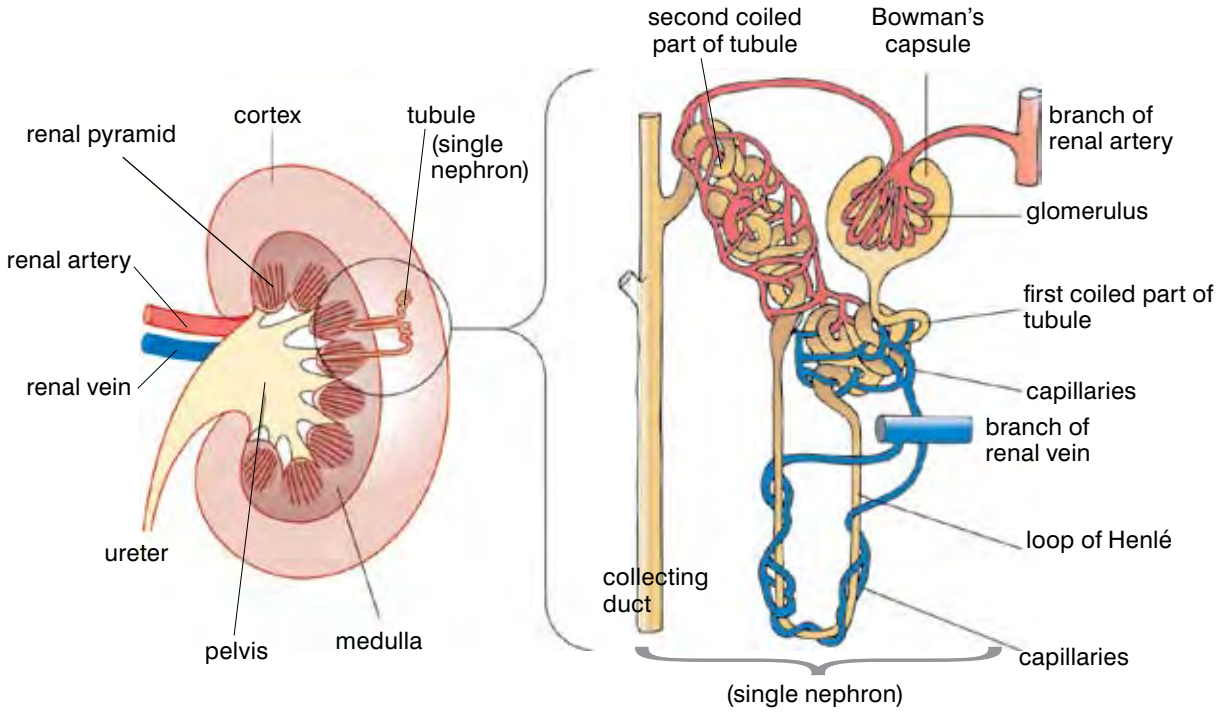


Figure 3.62 *The kidney filters the blood and removes materials which are not needed to form the urine. The kidney tubules or nephrons are the units which carry out the work.*

DID YOU KNOW?

Each nephron is 12–14 mm long, but only about 10 microns wide, and there are around 1.5 million of them in each kidney!

Activity 3.22: Investigating kidney structure

By dissecting a kidney you can see the way the different tissues are arranged. Remember to indicate the magnification of your drawing each time – if it is life size, it is × 1.

You will need:

- a kidney (lamb or pig) from the butcher, preferably with the fat surrounding the kidney in place
- dissecting instruments – a scalpel, forceps and a seeker
- dissecting board

Method

1. Observe the outer appearance of the kidney with the fat on, if possible. Draw and label what you see.
2. Carefully remove the fat, clearing the tubes leading into and away from the kidney carefully. Again draw and label what you see.
3. Slice the kidney in half longitudinally (along its length) and open it out to see the internal structure. Again draw and label the regions carefully – use figure 3.62 to help you identify them.
4. You may have the opportunity to look at prepared slides of kidney tissue under the microscope – if so, keep the drawings you make with these drawings from a fresh kidney to build up a record of the whole organ from your own observations.

KEY WORDS

Bowman's capsule *the expanded end of a kidney tubule or nephron that acts as a filter to produce urine*

ultrafiltration *the removal of excess water and other substances from the blood*

glomerular filtrate *the liquid resulting from filtration in the Bowman's capsule*

The roles of the different areas of a single kidney tubule in the production of urine are described below:

- **Bowman's capsule**: the site of the **ultrafiltration** of the blood. The blood vessel feeding into the capsule is wider than the vessel leaving the capsule, which means the blood in the capillaries is under a lot of pressure. Several layers of cells – the wall of the blood capillaries and the wall of the capsule – act as a filter and the blood cells and the large blood proteins cannot leave the blood vessels as they are too big to fit through the gaps. However, water, salt, glucose, urea and many other substances are forced out into the start of the tubule – in fact the concentration of substances in the liquid in the capsule is the same as that in the blood itself. This process is known as ultrafiltration – filtration on a very small scale.
- **Glomerulus**: the knot of blood vessels in the Bowman's capsule where the pressure builds up so that ultrafiltration occurs. The volume of blood leaving the glomerulus is about 15% less than the blood coming in – which is a measure of the liquid which has moved into the capsule as a result of ultrafiltration.
- **First coiled (convoluted) tubule**: the liquid which enters this first tubule is known as the **glomerular filtrate**. The first tubule is where much of the reabsorption takes place. All of the glucose is actively taken back into the blood along with around 67% of the sodium ions and around 80% of the water. It has many microvilli to increase the surface area for absorption.
- **Loop of Henlé**: where the urine is concentrated and more water is conserved.
- **Second coiled (convoluted) tubule**: where the main water balancing is done. If the body is short of water, more is

reabsorbed into the blood in this tubule under the influence of the **anti-diuretic hormone** or **ADH**. (Diuresis means passing urine, so anti-diuresis means preventing or reducing urine flow.) See below for more details of this mechanism. Also ammonium ions and some drugs (if they have been taken into the body) are secreted from the blood into this tubule to get rid of them. By the end of this second coiled tubule all of the salt which is needed by your body has been reabsorbed, leaving the excess in the filtrate along with most of the urea.

- **Collecting duct**: where the liquid (essentially urine) is collected. It contains about 1% of the original water, with no glucose at all. The level of salt in the urine will depend on the amount of salt in your diet and the water content of the urine. There is also a much higher concentration of urea in the urine than in the blood – about 60 times more, in fact. But if your body badly needs more water, more may be reabsorbed along the collecting duct – again under the influence of ADH – until the urine passes into the pyramid of the kidney and on into your bladder.

Urine is formed constantly in your kidneys, and it drips down to collect in your bladder. The bladder is a muscular sac which can hold between 600 and 800 cm^3 urine, although we usually empty it when it contains only 150–300 cm^3. We can control the opening of the bladder thanks to a strong ring of muscle known as a **sphincter** at the entrance to our **urethra**, the tube that leads from the bladder to the outside world. We can open and close this sphincter voluntarily, although it also opens as a reflex action if the bladder is too full – or if we are very frightened! When we are young, we have to learn to control our bladder sphincter voluntarily.

The amount of water lost from the kidney in the urine is controlled by a sensitive feedback mechanism involving the hormone ADH.

If the water content of the blood is too low (so the salt concentration of blood increases) special sense organs known as **osmoreceptors** in your brain detect this. They stimulate the pituitary gland in the brain to release ADH into the blood. This hormone affects the second coiled tubules of the kidneys, making them more permeable so more water is reabsorbed back into the blood. This means less water is left in the kidney tubules and so a more concentrated urine is formed. At the same time the amount of water in the blood increases and so the concentration of salts in the blood returns to normal.

If the water content of the blood is too high, the pituitary gland releases much less ADH into the blood. The kidney then reabsorbs less water back into the blood, producing a large volume of dilute urine. Water is effectively lost from the blood and concentration of salts returns to normal.

This system of osmoregulation is an example of negative feedback. As the water concentration of the blood falls, the level of ADH produced rises. Then as the water concentration of the blood rises again, the level of ADH released falls.

KEY WORDS

antidiuretic hormone (ADH) *hormone produced by the pituitary gland that reduces the production of urine in the kidneys and thereby prevents water loss*

sphincter *a ring of muscle that contracts to close an opening*

urethra *a duct through which urine is discharged*

osmoreceptors *specialised nerve cells responsible for monitoring the osmotic pressure of the blood and extracellular fluid*

DID YOU KNOW?

How do we know so much about how the kidney tubules work when they are so tiny? As well as using electron microscopes, which have revealed many details about the tubule cells, scientists have developed microscopic micropipettes which they have used to sample the liquid inside the different regions of an individual nephron.

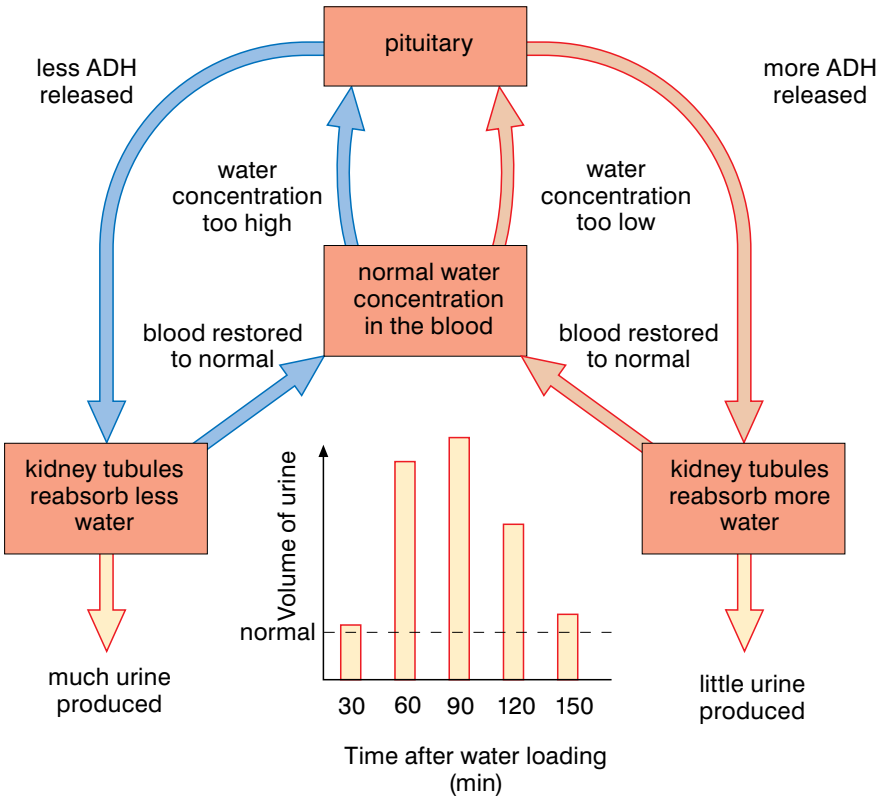


Figure 3.63 *The negative feedback system which operates to control the amount of water which the kidney removes from the blood means that we can cope with temporary shortages or loading of water surprisingly well.*

On an average day your kidneys will produce around 180 l (that's about 50 gallons) of liquid filtered out of your blood in the glomerulus (**glomerular filtrate**) – but only about 1.5 l (just over 2.5 pints) of urine. So more than 99% of the liquid filtered out of your blood is eventually returned to it. You can observe the way in which your kidney works to maintain water balance in your own body. If you drink a lot of water, you will quickly notice that you need to urinate more often, and that you produce large quantities of very pale coloured, dilute urine. If, on the other hand, you are in a situation where you cannot get enough to drink, you will urinate much less frequently and produce a small volume of dark coloured, concentrated urine. This is a very elegant example of homeostasis in action.

DID YOU KNOW?

Your blood passes through your kidneys at the rate of 1200 cm^3 per minute, which means all the blood in your body passes through your kidneys and is filtered and balanced approximately once every five minutes.

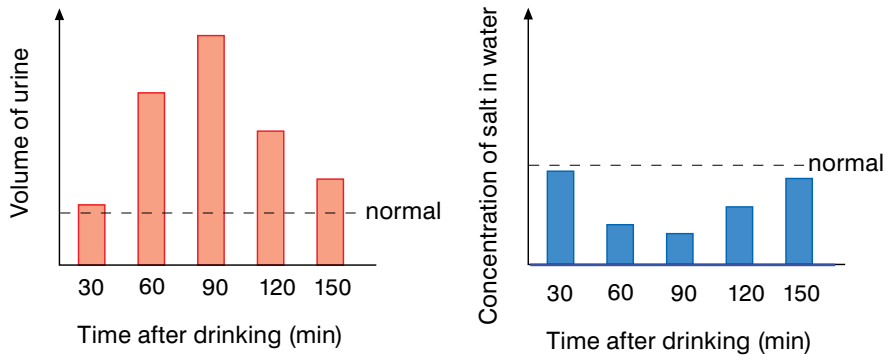


Figure 3.64 *The graphs show the effect of drinking a given volume of water on both the volume and the salt concentration of the urine produced. Urine was collected at 30-minute intervals after the drink was given and it clearly shows how sensitive the response of the body is. The water load is removed, but without losing much-needed salt.*

Your skin also plays a part in the salt and water balance of the body. It forms a waterproof layer around the body tissues which protects us from the uncontrolled loss of water from our body tissues by evaporation. It also prevents you from gaining water by osmosis every time you go swimming in the river! The skin also loses salt and water through the process of sweating. This can affect the ion and water balance of your body when you sweat a lot. But this is a relatively uncontrolled loss. You sweat to help the body cool down, not to control the ion and water balance of the body. The kidneys have to work to support the changes to the concentration of the body fluids that result from sweating excessively.

The liver and homeostasis

Your kidneys and skin are not the only organs of homeostasis. The liver also plays a large role in maintaining a constant internal environment. It is the largest individual organ in your body – in fact it makes up around 5% of your body mass. Your liver cells are very active – they carry out a wide range of functions, many of which help to maintain a constant internal environment. The liver has a very special blood supply. As well as the usual artery and vein (the hepatic artery and vein) there is another blood vessel which comes to the liver directly from the gut. This is the hepatic portal vein and it brings the products of digestion to the liver to be dealt with.

A large number of reactions take place in the liver. Many of them are involved in homeostasis in one way or another. It plays a part in all of the following functions:

- Control of the sugar levels in the body (through stored glycogen in the liver itself).
- Controlling and balancing the fats that you eat and the cholesterol levels in your blood.
- Protein metabolism – your liver breaks down excess amino acids and forms urea. If you eat more carbohydrate or fat than you need in your diet your body simply stores the excess energy as fat. If you eat too much protein, it isn't so easy. Your body cannot store the excess amino acids or simply convert protein to fat. Instead the amino acids which make up the protein are broken down in your liver. The amino (nitrogen containing) part of the amino acid molecule is removed and converted into ammonia and then urea in the liver. The rest of the amino acid can be used in cellular respiration or converted to fat for storage. The process of removing the amino group from excess amino acids is known as **deamination** and it is a very important function of the liver.
- The breakdown of worn-out red blood cells – in particular the red pigment haemoglobin.
- The formation of bile which is made in the liver and stored in the gall bladder before it is released into your gut to emulsify fats and help in their digestion.

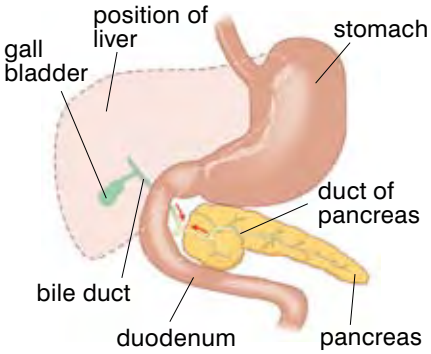


Figure 3.65 *The liver is one of the most active organs in your body – it carries out over 500 different functions!*

KEY WORDS

deamination *the removal of an amine group from a molecule*

- Control of toxins – your liver breaks down most of the poisons you take into your body, including alcohol. This is why the liver is so often damaged when people drink heavily.
- Temperature control. Around 500 different reactions take place in the liver at any time. For many years it has been believed that as a result of all these reactions the liver generates a lot of heat which is then spread around the body by the bloodstream. Increasingly scientists think that the reactions which generate heat are cancelled out by reactions which use heat, so that in fact the liver produces very little excess heat. Any that is produced is used around the body.

The liver is a very important organ and we need to look after the health of our livers. The best way to do this is to avoid drinking too much alcohol, which can cause cirrhosis of the liver. The liver tissue is destroyed which can eventually kill you. Heavy drinkers also often develop liver cancer which spreads quickly and can be fatal.

As you have seen, homeostasis is a delicate balance throughout your body as all of the changes which come with everyday life are resisted by your body to maintain the constant internal environment that cells need to work properly.

Summary

In this section you have learnt that:

- Living organisms need systems of co-ordination and control.
- Many multicellular organisms including human beings have both nervous and hormonal co-ordination and control systems.
- The nervous system is the most rapid. Nervous control involves:

  stimulus → receptor → co-ordinator → effector → response
- A nerve cell or neuron consists of a cell body, dendrites and an axon.
- Sensory neurons carry information from the sense organs to the central nervous system (CNS).
- Motor neurons carry instructions from the CNS to the effector organs (muscles and glands).
- The central nervous system is the brain and spinal cord. Information is assimilated and co-ordinated in the CNS.
- Neurons carry electrical impulses known as the action potential.
- In any pathway the junctions between neurons are called synapses. When an impulse arrives in one neuron chemicals are released in the synapse to trigger an impulse in the next neuron.

- A nerve contains many neurons. There are sensory nerves, motor nerves and mixed nerves.
- The spinal cord carries information from all over the body to and from the brain.
- Mental illnesses describe a wide variety of disorders and diseases that involve thought processes, emotional disturbances and/or behaviour that are considered abnormal.
- Cranial nerves come from the brain, while spinal nerves are from the spinal cord.
- Reflex actions avoid danger and run mundane bodily functions – they avoid conscious thought.
- Reflex actions involve stimulus → receptor → co-ordinator → effector → response but the co-ordinator is the relay neuron in the spinal cord and there is no conscious thought involved.
- The knee jerk reflex is a common example of a reflex. It is used by doctors to test reflexes and in ordinary life to prevent stumbling.
- Drug abuse is when you use a substance to the point of excess and/or dependence. When you take an excess of a drug you risk serious side effects and even death.
- Drug dependence is when you use a drug again and again and become addicted.
- Drugs change the chemical processes in your body so you can become addicted to them (dependent on them). This means you cannot manage or function properly without the drug. This may be psychological – the need to keep using it becomes a craving or compulsion – or a physical dependence where your body no longer works properly without the drug.
- Alcohol, tobacco, khat and cannabis are the most widely used substances in Ethiopia.
- Other drugs which can be misused include prescription sedatives, cocaine, LSD, ecstasy and heroin.
- Drug abuse and dependence can hurt the individual user, their family and the entire community.

Review questions

1. Which of the following is not an example of homeostasis?

   A control of the blood sugar levels

   B control of the body temperature

   C control of the water content of the blood

   D control of the length of the limbs

2. Which of the following areas is NOT part of the nephron (kidney tubule)?

   A Bowman's capsule

   B urinary bladder

   C loop of Henlé

   D first coiled tubule

3. Which of the following statements is true about ADH?

   A ADH is a hormone produced in the brain which affects the second coiled tubules of the kidneys, making them more permeable so more water is reabsorbed back into the blood and little, concentrated urine is formed.

   B ADH is a hormone produced in the brain which affects the first coiled tubules of the kidneys, making them more permeable so more water is reabsorbed back into the blood.

   C ADH is a hormone produced in the kidney which affects the coiled tubules of the kidneys, making them more permeable so more water is reabsorbed back into the blood.

   D ADH is a hormone produced in the brain which affects the second coiled tubules of the kidneys, making them less permeable so less water is reabsorbed back into the blood and much dilute urine is formed.

4. Here is a jumbled list of the events by which your body temperature is controlled when it starts to go up. Which sequence of events is correct?

   I Tilahun exercises hard and his body temperature starts to rise.

   II Tilahun takes a long, cool drink to replace the liquid he has lost through sweating.

   III His temperature returns to normal.

   IV Tilahun's skin reddens and he sweats heavily so the amount of heat lost through his skin goes up.

   A I, II, III, IV

   B I, III, IV, II

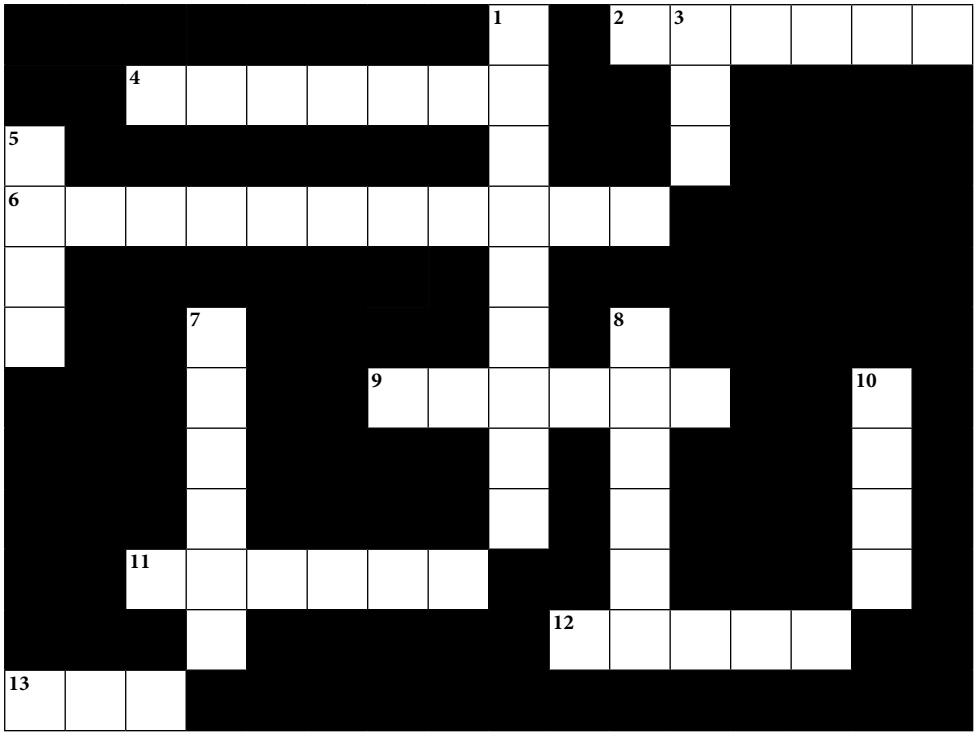
   C I, IV, III, II

   D I, III, IV, II

End of unit questions

1. Explain what happens in the Bowman's capsule of a kidney tubule.
2. What happens to the filtrate as it passes through the kidney tubule?
3. How does urine differ from the original filtrate?
4. a) What is a hormone?
   b) Where are the main human hormones produced? (Make a table to show the main hormones produced in the body, where they are produced and what they do.)
   c) How is control by hormones different from control by the nervous system?
5. There are two main metabolic waste products which have to be removed from the human body: carbon dioxide and urea.
   a) What is meant by the term 'metabolic waste'?
   b) For each waste product named above describe:
      i) how it is formed
      ii) why it has to be removed
      iii) how it is removed from the body
6. a) What does the word contraception mean?
   b) Describe the main available forms of contraception.
   c) The biggest cause of failure of contraception is usually human error. What does this mean?
7. a) Hormones can be used to control fertility artificially. Explain how hormones can be used to prevent pregnancy in the contraceptive pill.
   b) What are the benefits of family planning to:
      i) the individual and
      ii) to society?
8. HIV/AIDS is a sexually transmitted disease which is a major problem in Ethiopia. Describe the disease and explain both why it is such a problem in Ethiopia and how the disease may be controlled.
9. a) What is female genital mutilation?
   b) What are the health risks caused by FGM?
   c) How are the people of Ethiopia changing opinions and removing this harmful traditional practice?

Copy the crossword puzzle below into your exercise book (or your teacher may give you a photocopy) and solve the numbered clues to complete it.



ACROSS

2 The light sensitive layer of the eye (6)

4 The gap between two neurons (7)

6 The maintenance of a constant internal environment (11)

9 A nerve cell (6)

11 Rapid response that does not involve conscious thought (6)

12 The most recently discovered taste (5)

13 The human sense organ that responds to sound (3)

DOWN

1 --------- cycle – the fertile cycle in women (8)

3 Human sense organ that responds to light (3)

5 Legal drug that is commonly used in Ethiopia (4)

7 An important organ of homeostasis which balances water and salt and excretes urea (6)

8 A form of barrier contraceptive used by men which can also prevent the spread of HIV/AIDS (6)

10 Long extension from motor nerve that carries the nerve impulse (4)