Practical activity 10.3
To examine the structure of skin

1 Examine the skin on your arm for what you see and feel.

2 With a hand lens examine a microscopic section of the skin.

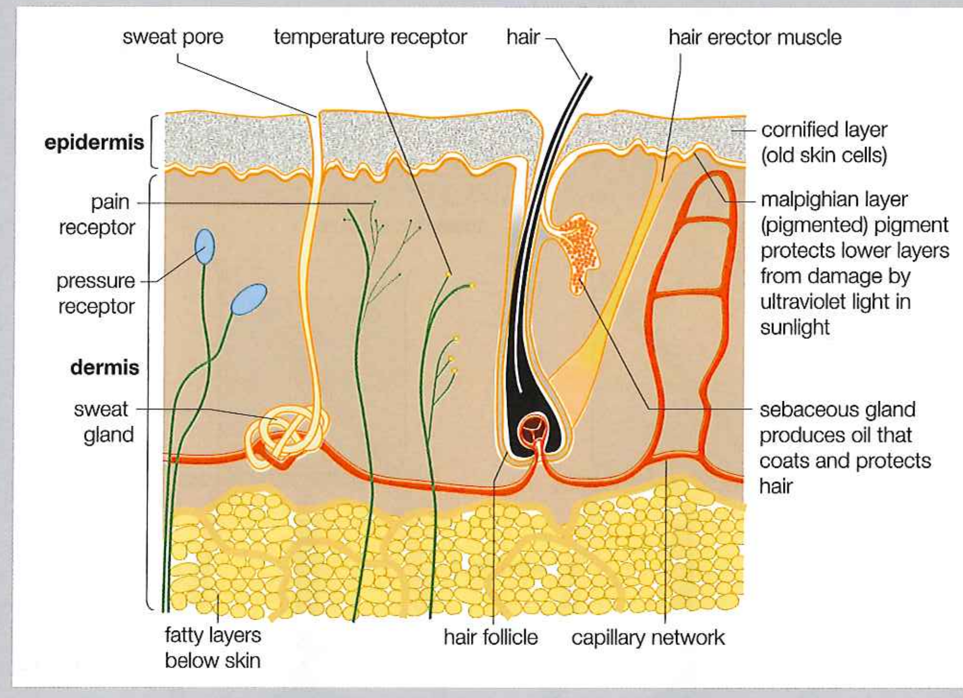


Figure 10.9 A vertical section through the human skin.

Questions

1 Describe what you see and feel and try to consider their functions.

2 Draw and label your section, comparing it with figure 10.9.

3 What major parts are more numerous on the skin of most other mammals?

4 What are fingerprints?

sebum ▶ Opening into the hair follicles are sebaceous glands, which secrete an oily substance called sebum. This keeps the hair and the epidermal cells flexible and prevents the skin from cracking. Washing the hair more than once daily can remove all the sebum and make the hair brittle.

Excretion of sweat	salts, water, trace of urea
Protection	covering reduces mechanical injury
Prevents water loss	by covering tissues
Disease organisms	cannot enter the complete thick layer
Sense organ	detects temperature change, pressure and pain
Vitamin D	synthesised from ultraviolet light
Temperature	regulates the heat in the body – see below

Table 10.4 Functions of the skin.

• List all the functions of the skin.

Heat and temperature measurement

Practical activity 10.4
To find the difference between heat and temperature

1 Put 25 cm^3 of tap water in a beaker.

2 Record the temperature of the water with a thermometer and then heat it over a Bunsen burner for exactly 2 minutes before again recording the temperature of the water.

3 Repeat this with 50 cm^3 of the same tap water using the same size Bunsen flame.

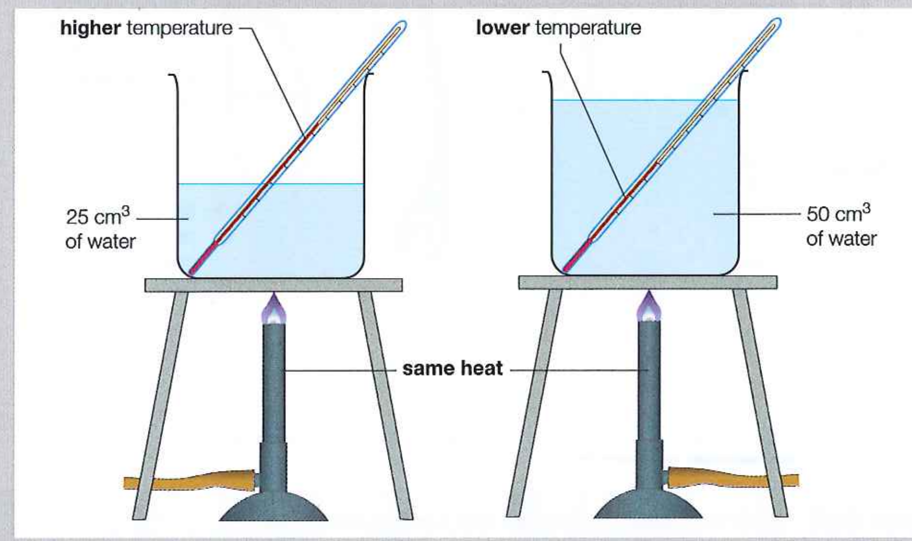


Figure 10.10 Apparatus to show the difference between heat and temperature.

Questions

1 What remains the same and what differs in the two experiments (1 and 2) and the repeat experiment 3?

2 State how heat and temperature are different.

ITQ5
Calculate which contains more heat, (a) 1 cm^3 of water at 20°C or (b) 100 cm^3 of water at 19°C?

In this experiment both beakers have been given the same amount of heat. The same Bunsen burner was used for the same length of time. The temperature after 2 minutes of heating, however, is not the same. The 50 cm^3 of water is at a lower temperature. Thermometers are used to record temperature differences.

heat ▶ **temperature ▶** **heat capacity ▶**

Heat, you will remember, is measured in joules. Heat is a form of energy, while temperature is a degree of hotness. The quantity of heat needed to raise the temperature of a substance through 1°C is called the heat capacity. 1 g of water has a heat capacity of 4.2 J/°C.

clinical thermometer ▶

The body temperature is taken with a clinical thermometer usually placed under the tongue. It has a constriction in the capillary tubing that contains the mercury, which prevents the mercury from falling back after removal to read the temperature. After the reading has been taken, the thermometer has to be shaken to return the mercury to the bulb.

Practical activity 10.5
Taking your temperature

1 Wash the bulb of a clinical thermometer in warm water in which a crystal of potassium permanganate has been dissolved. This sterilises the thermometer.

2 Shake and examine to check that the mercury has all returned to the bulb.

3 Place the bulb of the thermometer under your tongue. After 1 minute, remove it and read it.

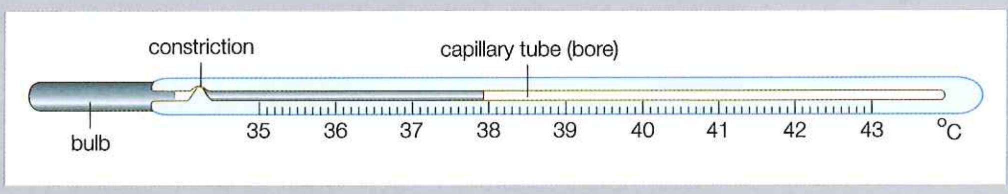


Figure 10.11 A clinical thermometer.

Questions

1 What is the purpose of the constriction in the mercury tube?

2 What is your body temperature?

3 Does your body temperature change after exercise?

4 Why does a doctor sometimes take your body temperature?

5 What other way could you sterilise the thermometer?

Regulation of body temperature

Large numbers of bacteria or viruses in the body cause a rise in the body temperature. This rise in temperature is used as an indication that an infectious disease organism may be present in the body.

Detection and control of body temperature

Many structures in the skin are concerned with maintaining a constant body temperature in man. These structures are controlled by messages from the brain via nerves. The messages received depend on the temperature of the blood passing over the temperature receptors in the hypothalamus of the brain.

hypothalamus ▶

Hence the importance of blood in distributing heat throughout the body. It is the hypothalamus that acts as a thermostat to keep the body temperature constant. A thermostat is a heat-regulating device to control a particular temperature.

thermostat ▶

Temperature receptors in the skin also detect body and environmental temperatures so that we feel hot or cold. As a result we may make voluntary actions, such as exercise, to generate heat in cold weather. These receptors do not control the involuntary body temperature regulating mechanisms, which are controlled by the hypothalamus.

- Where are the receptors that detect the blood temperature to maintain homeothermy?

Heat production to warm the body

respiration ▶

The origin of most heat in the body is from the oxidation of food during respiration in the body cells. Heat may also be absorbed from the surroundings when they are above body temperature. Any increased activity, or muscle action in exercise that increases respiration, will increase the production of heat. Hence shivering makes heat. The liver is an important source of heat. This is because it is large and many metabolic activities in it produce heat.

Heat loss to cool the body

Sweating is a response made by the body to excessive heat in the surroundings. Also, it can be our own body temperature that is raised due to infection or strenuous activity.

evaporation of sweat ▶
specific latent heat ▶

- What type of heat is used to change liquid sweat to a vapour?

Evaporation of sweat cools the body, as the water in sweat evaporates from the surface of the skin. The heat required for evaporation to take place is specific latent heat. Such heat energy changes liquid to vapour instead of causing a temperature rise. Hence heat is taken from the body to change liquid sweat to vapour, so causing cooling.

Note that sweating itself does not cool the body. It is the evaporation of the sweat which has this effect.

Thus under conditions where sweat cannot evaporate, i.e. in badly ventilated rooms, or in humid air, great discomfort can be caused. Fans can help by blowing the water vapour away from the skin surface and so increase the rate of evaporation. Air conditioning units in the tropics also remove water from the air, so that the evaporation of sweat can take place more quickly.

Practical activity 10.6
To show how evaporation of fluid produces cooling

1 Put out all naked flames and avoid breathing in the vapour when doing this exercise.

2 Dip your finger into a liquid, such as 90% alcohol, which evaporates very rapidly. (It has a low boiling point.)

Questions

1 What do you feel when you remove your finger?

2 Blow on the liquid on your finger, record and explain any further changes.

3 Why does this experiment not work so well with water?

4 Is the alcohol before use in this experiment at room temperature?

vasodilation ▶

ITQ6
What is wrong with the statement 'sweat cools the body'?

ITQ7
Explain vasodilation.

Another major way in which the body is cooled is by the blood capillaries near the surface of the skin. The arterioles can enlarge in diameter and so carry more blood. This enlargement is called vasodilation. The larger volume of blood carried in the skin capillaries will be carrying more heat, which can be lost through the skin. This is why white-skinned people appear red, in hot weather, or after exercise. This flush is due to the blood in the expanded capillaries.

A certain amount of heat is also lost from the lungs during breathing. Water from the lungs evaporates to produce cooling.

Keeping the body warm

When the body cools, contraction of muscles in the arterioles reduces their diameter so that they carry less blood. This is the opposite of vasodilation and

vasoconstriction ▶

is called vasoconstriction. When less blood is carried in the skin capillaries, less heat is lost through the skin. The contraction and relaxation of the muscles in the arterioles is controlled by nerve impulses from the blood temperature receptors in the hypothalamus of the brain.

heat exhaustion ▶

Overheating, in conditions where the amount of water vapour in the air is high, can cause heat exhaustion. This is dangerous because the high temperature can cause fainting and even death. Continual sweating at high temperatures, due to physical effort, can cause the more severe heat stroke. Stress is put on the heart to pump blood around the body and the supply of liquid for sweating may cease. This causes the temperature to rise even further, so that fainting occurs.

The patient should be placed in cool surroundings with plenty of moving air. Drinks to replace the lost water should be given.

hyperthermia ▶

The condition where the body temperature rises and the regulatory mechanisms fail to cool it is called hyperthermia. This is more common in the high temperatures of the Caribbean. This causes heat exhaustion.

hypothermia ▶

- What is the name of the condition where the body temperature rises rapidly and the regulatory mechanisms fail to correct this?

When the body temperature is uncontrollably lowered and regulating mechanisms fail, a condition caller hypothermia develops. A cold environment and/or rapid evaporation of water from the body surface may be responsible. Hypothermia may develop in old age when the body temperature regulating mechanisms are less efficient. In cold climates, the elderly may remain inactive in cold homes, particularly if heating fuel is expensive. Their body temperature is lowered, they become weak and may lose consciousness and die, unless they receive treatment to raise temperature steadily.

shivering ▶

- Why does shivering keep us warm?

Shivering is a response made by the body to cold. When the body cools, the muscles under the skin quickly contract and relax. The muscles are doing work and so heat is released as respiration increases.

subcutaneous fat ▶

The layer of subcutaneous fat also acts as an insulating layer against cold. Fat is a poor conductor of heat so this subcutaneous layer holds heat within the body. The fat also serves as a source of nutrient to produce heat during respiration.

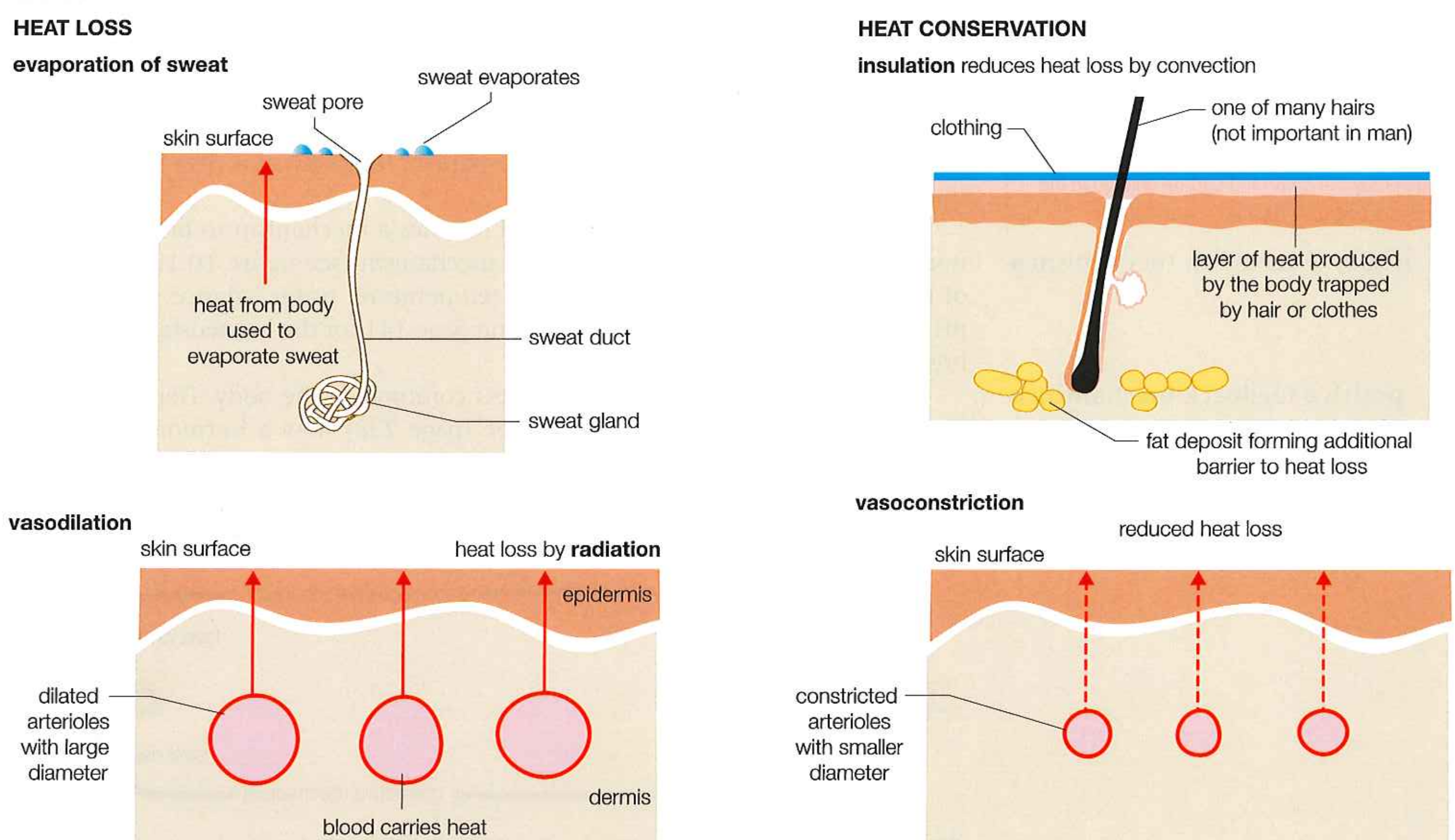


Figure 10.12 Parts of skin that help regulate body temperature.

clothing ▶

Clothing acts as an insulator to keep the body warm. Warm clothing such as wool has large air spaces between the fibres. Air is a very good insulator and so traps heat over the surface of the body. White clothing is preferable in hot climates because it absorbs less heat than darker colours (e.g. cricketers' 'whites').

ITQ8
Why is white silk preferable to dark wool for clothing in the Caribbean?

hair ▶

Fur in animals acts as an insulator, trapping air to keep them warm. However, man does not have enough hair to keep him warm in this way. Some warmth may be retained by hair on the head, although this may be more important to act as an insulator against hot sunlight.

Heat production	respiration of body cells metabolism as in the liver shivering and exercise
Heat retention	vasoconstriction fat insulation
Cooling	evaporation of sweat vasodilation
Heat transport	blood circulation
Heat detection	receptors in hypothalamus

Table 10.5 The control of body temperature.

Homeostasis

homeostasis ▶

- What term describes the maintenance of constant conditions in the body in spite of changes from the surroundings?

Homeostasis is the way constant conditions in the body are maintained in spite of changes from the surroundings. These mechanisms work to maintain normal conditions in the body. It is important that constant conditions exist, particularly when so many events in the surroundings try to change them. Should these homeostatic mechanisms fail, illness results.

Homeostasis is controlled by self-regulatory processes in the body. Too much of a substance in the body triggers a mechanism to get rid of it. Too little causes a mechanism to get more of it.

ITQ9
Explain why the control of carbon dioxide in the blood is a negative feedback mechanism.

negative feedback mechanism ▶

When the body detects changes and initiates a mechanism to bring it back to normal, it is called a negative feedback mechanism (see figure 10.13). Examples of this include the control of the body temperature, water balance, blood sugar, pH and cell contents. See pages 120–2 and page 141 for the homeostatic control of breathing by carbon dioxide.

positive feedback mechanism ▶

A positive feedback mechanism is less common in the body. Here a stimulus initiates more of the same. We shall see (page 238) how a hormone, oxytocin, initiates childbirth. This stretches the birth canal, stimulating the production of even more oxytocin.

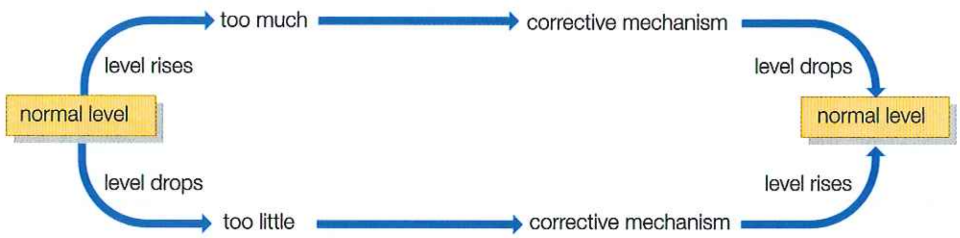


Figure 10.13 A typical negative feedback mechanism. A change detected by a stimulus causes a response to return to the normal.

Homeothermy

body temperature ▶ **homeothermy ▶**

Our body temperature remains constant even if the surroundings are hot or cold. This is called homeothermy and the skin, as we have shown, is mainly responsible. The control is due to the blood temperature as it passes over the receptors in the hypothalamus. These initiate either heat loss, or heat gain with heat retention actions, in the skin. Hence the body maintains a constant temperature of about 37°C.

Homeostasis of water balance

Our body fluids remain constant whether we drink a little or a lot of water. As we have seen, the kidneys are largely responsible for the water balance in the body.

We know that an important function of the kidney is to control the correct amount of water and salts in the body fluids. This in turn affects the water and salt content of the cells. This control of water balance by osmosis is called osmoregulation.

osmoregulation ▶

Water that enters the cells blows them up, rather like an inflated balloon. The cells are said to be turgid (see page 30). It is important to maintain an osmotic balance between the body cells and the body fluids.

turgid ▶

If the body fluids became less concentrated than the body cells, then water would enter the cells. The cells may take in so much water that they burst open. Should water leave the cells then they lose this support and deflate. This would occur if the body fluid were more concentrated than the cell contents. The correct water balance of the cells can only be kept constant if the surrounding body fluids have roughly the same water potential as the cell fluids.

If we drink more water, then more has to be eliminated. In hot weather more sweat is produced, so less water is excreted as urine. These are good examples of different organs of the body working together.

Water is taken into the body in variable amounts by the alimentary canal, particularly through the ileum and colon. It is excreted in sweat, urine and expired air, but the kidney actually maintains the correct proportion. This is why the proportions of the parts of urine may vary. We have seen (page 102) how loss of water in faeces, when suffering from diarrhoea, causes the body to become dehydrated and then the urine becomes concentrated.

ITQ10

List the methods by which water (a) enters and (b) leaves the body.

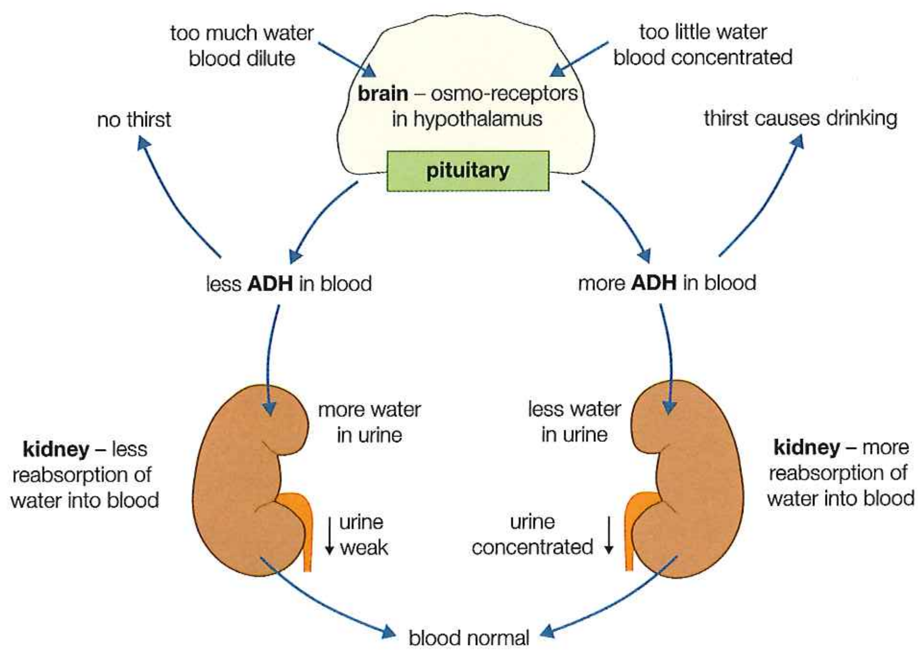


Figure 10.14 Control of the water potential (concentration of water to solutes) in blood by ADH.

control of water content ▶

antidiuretic hormone ▶

Control of the water content by ADH in the blood is maintained by the hypothalamus of the brain. This contains osmoreceptors, which detect a high blood concentration and stimulate the posterior pituitary gland to secrete antidiuretic hormone (ADH). On arrival at the kidney, ADH acts to stimulate increased reabsorption of water from the filtrate into the blood. ADH increases the permeability to water of the distal kidney tubule and collecting ducts. Pores open so that water can pass through the tubule wall. Hence more water passes back into the blood. The blood is diluted to normal and the urine becomes more concentrated.

Homeostasis of the blood sugar content

Mechanisms also keep the level of sugar constant in the blood, whether we eat a lot of, or little, carbohydrate. The hormones insulin and glucagon from the pancreas mainly regulate the blood sugar concentration.

The liver stores glycogen and helps to regulate the blood sugar concentration. Up to 100 g of glycogen may be stored in the liver and more is stored in the muscles.

Excess sugar in the blood is converted to glycogen by the action of insulin, secreted by the pancreas.

islets of Langerhans ▶

insulin ▶

When the blood sugar concentration rises, receptors in the islets of Langerhans, which are special cells in the pancreas, detect an increased concentration of blood sugar. Beta (β) cells in the islets of Langerhans then secrete the hormone, insulin. This may occur after a large meal containing carbohydrate. This insulin causes the liver to convert the excess sugar to glycogen. The uptake of glucose by the body cells is increased. Insulin also converts some sugar to fat and increases the oxidation of sugar.

ITQ11

Explain what happens to all the glucose after a heavy meal.

glucagon ▶

Less blood sugar causes alpha (α) cells of the islets of Langerhans to secrete the hormone, glucagon. Glucagon then acts on liver cells to cause the breakdown of glycogen into glucose, thus restoring normal sugar concentrations in the blood. This is another example of a negative feedback mechanism.

Insulin lowers the blood sugar concentration and glucagon raises it.

A low concentration of glucose in the blood causes a loss of consciousness. A high concentration of glucose, above 160 mg in 100 cm³ of blood, results in

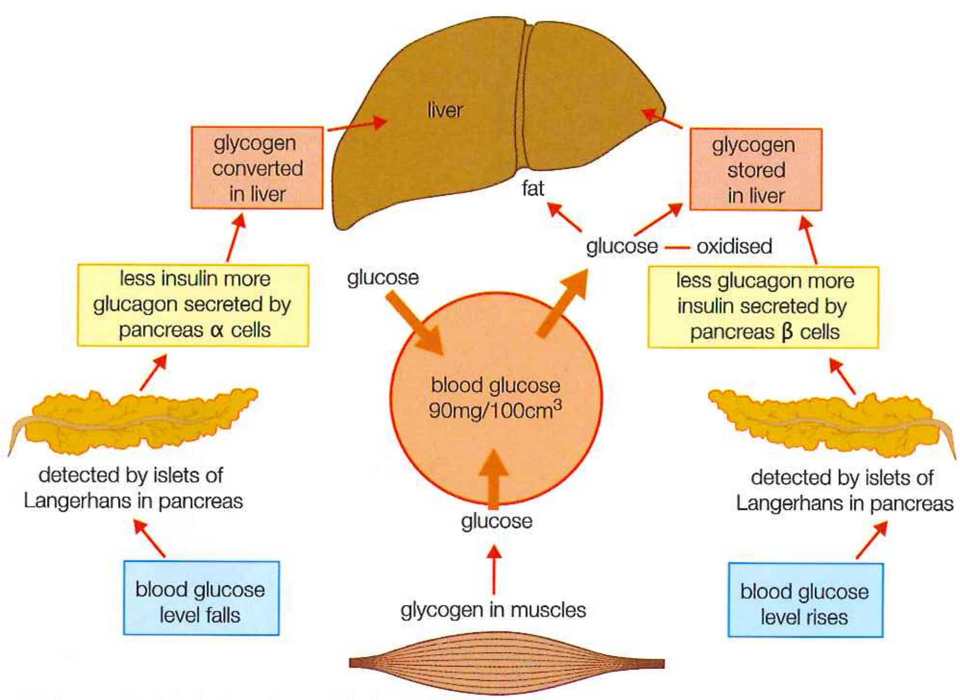


Figure 10.15 Control of blood glucose concentration by insulin and glucagon.

its excretion in the urine. Hence it is important to maintain the blood glucose concentration within the range of 80 to 150 mg/100 cm^3.

adrenaline ▶ Adrenaline, secreted from the adrenal glands when the body is responding to the need for vigorous activity (the 'fight or flight' response), also speeds up the conversion of glycogen to glucose.

Diabetes

diabetes type 2 ▶ Diabetes type 2 occurs in about 90% of the diabetic population. In type 2 diabetes the target cells containing glucose do not respond to insulin, so causing the diabetes. Sugar accumulates in the body and is excreted because the concentration of glucose in the blood is greater than the kidney can deal with. The kidney tubules fail to reabsorb all the glucose. The glucose can be detected in the urine by tests (practical activity 10.2).

Diabetes is often a complication associated with obesity (see page 72). Diabetes is becoming more common in the Caribbean among people who overeat and lack exercise. The excess of stored carbohydrate to be metabolised leads to the insulin all being used up. Extra water is required to excrete sugar in the blood, so more urine is made. This makes the patient become dehydrated and thirsty. The excretion of glucose lowers its concentration in the blood, causing unconsciousness.

hyperglycaemia ▶ When the concentration of glucose in the blood is above normal it is called hyperglycaemia. This can end in death.

Other complications include the blood becoming acidic, which causes tiredness, vomiting and reduced fat metabolism. Renal failure, eye defects, pain in the limbs, atherosclerosis and mental confusion may all occur in untreated cases.

diabetes type 1 ▶ Diabetes type 1 is less common, occurring in about 10% of the cases, mainly developing in young children. The β cells of the pancreas completely fail to make insulin.

Fortunately, insulin from the pancreas of cattle can be prepared and injected, so that sugar metabolism functions normally. The insulin stops the glucose being excreted by converting it to glycogen for later use. More recently, insulin has been produced by biotechnology (see page 408).

ITQ12
How do insulin injections prevent diabetes?

ITQ13
A health inspector finds minute traces of urea in peanuts in a bar where customers help themselves. What two unhygienic practices of the customers could account for this?

Hormone	Secreted by	When	Action
Glucagon	pancreas	blood sugar is low	converts glycogen to glucose
Insulin	pancreas	blood sugar is high	converts glucose to glycogen
Adrenaline	adrenal glands	fright or flight	converts glycogen to glucose

Table 10.6 Control of blood sugar.

- Explain how glucagon and insulin maintain a constant concentration of glucose in the blood.
- What is present in the urine of a diabetic and why?

Summary

- Excretion is the elimination of the waste products of metabolism from the body.
- The kidneys excrete urine containing urea, water and salts.
- The skin excretes sweat containing water, salts and traces of urea.
- The lungs excrete expired air containing carbon dioxide and water vapour.
- The alimentary canal excretes water, bile, salts and mucus.

- Undigested food in faeces is not excreted (it is not a metabolic product) but egested.
- The kidney is made up of many nephrons that, by ultrafiltration, osmosis and selective reabsorption, maintain the blood at a constant composition.
- The skin is concerned with protection, sensitivity and maintaining a constant body temperature.
- Metabolism, exercise and shivering produce heat, fat insulation and vasoconstriction retain heat, while the evaporation of sweat and vasodilation make for cooling.
- A thermometer measures temperature but the amount of heat depends on the volume at a particular temperature.
- Homeostasis is the way constant conditions in the body are maintained in spite of changes in the surroundings.
- Negative feedback mechanisms control the body's temperature, the blood sugar concentration and the water and salt balance.
- Insulin converts glucose to glycogen; glucagon converts glycogen to glucose.
- Diabetes is where people lack sufficient insulin so that they are unable to oxidise glucose, which accumulates, causing hyperglycaemia, and is excreted from the body.

Answers to ITQs

ITQ1 In the faeces, undigested food (never part of metabolism) is egested, and bile, salts, excess enzymes, mucus and metabolic water are excreted.

ITQ2 High blood pressure is created by contraction of the left ventricle combined with the efferent arteriole having a smaller diameter than the afferent arteriole in the glomerulus. This forces plasma and all but large proteins and corpuscles into the Bowman's capsule to form glomerular fluid.

ITQ3 Selective reabsorption is when active transport and other secretory mechanisms select particular chemicals to pass them across the tubule membranes, e.g. glucose reabsorption in the tubule.

ITQ4 Table showing the composition differences between blood in the renal artery and renal vein.

Renal artery	*Renal vein*
oxygenated blood	deoxygenated blood
more O_2, less CO_2	less O_2, more CO_2
high urea concentration	little or no urea
more other nitrogenous waste	less other nitrogenous waste
more salts	less salts
more water	less water

ITQ5 (a) contains $1 \times 20 \times 4.2 = 84$ J

(b) contains $100 \times 19 \times 4.2 = 7980$ J

So the answer is (b). Although at a slight lower temperature, the larger volume contains the most heat.

ITQ6 No amount of sweating can cool the body unless it also evaporates. Hence the statement should add 'when it evaporates'.

ITQ7 Vasodilation occurs when warm blood stimulates the receptors of the hypothalamus to send nerve impulses to dilate the arterioles supplying the skin. More blood passes through the capillaries, taking more heat to the surface to be lost, so cooling the body.

ITQ8 White silk is cool, because white reflects heat, while silk lacks air spaces to act as an insulator.

ITQ9 Control of carbon dioxide in the blood is a negative feedback because more carbon dioxide triggers a mechanism (increased breathing) to remove it. Too little would (decrease breathing) cause more of it.

ITQ10 Water enters the alimentary canal in drinks and food. This is also the source of metabolic water produced. Water leaves the body in urine, expired air, sweat and faeces.

ITQ11 After a heavy meal excess glucose is converted to glycogen, stored mainly in the liver and muscles. The glucose is detected by islets of Langerhans in the pancreas that secretes insulin, converting the glucose to glycogen.

ITQ12 Diabetes occurs when glucose accumulates in the blood, and is detected in urine excreted. Insulin injections convert the glucose to glycogen for storage.

ITQ13 The two sources of a minute trace of urea in the peanuts: (1) from sweat from unwashed fingers, (2) after urination not washing the hands before dipping in to the peanuts.

Examination-style questions

Multiple choice questions

(Write down the number of the question followed by the letter of the correct answer. You can check your answers on page 417.)

1 Which is *not* an excretory product?
- **A** carbon dioxide
- **B** sweat
- **C** undigested food in faeces
- **D** urine

2 What causes water to pass from the glomerulus to the Bowman's capsule during ultrafiltration?
- **A** blood pressure
- **B** diffusion
- **C** osmosis
- **D** secretion

3 Loss of heat from the body is increased by:
- **A** evaporation of sweat
- **B** blood storage in the liver
- **C** subcutaneous fat insulation
- **D** vasoconstriction

4 What is the major source of body heat?
- **A** blood circulation and metabolic activities
- **B** metabolic activities and contracting muscles
- **C** contracting muscles and vasodilation
- **D** vasodilation and production of sweat

5 Which detects changes in the temperature of the blood to control body temperature?
- **A** hypothalamus
- **B** islets of Langerhans
- **C** skin temperature receptors
- **D** skin blood capillaries

6 Which is *not* kept constant by a homeostatic mechanism?
- **A** blood sugar concentration
- **B** body temperature

C carbon dioxide in blood
D urine concentration

7 What is the effect of insulin on the liver?
A deamination increases
B more glucagon is secreted
C glucose is converted to glycogen
D glycogen is converted to glucose

8 Which occurs when too much water is drunk, making the blood dilute?
A more ADH secreted, increases reabsorption of water
B more ADH secreted, decreases reabsorption of water
C less ADH secreted, decreases reabsorption of water
D less ADH secreted, increases urine concentration

9 What would happen to body cells if the blood supplying them became very concentrated?
A burst
B lose salts
C lose water
D become turgid

10 What stimulates the breakdown of glycogen in the liver?
A ADH
B diabetes
C glucagon
D insulin

Short answer and essay type questions

11 Copy Fig 10.16 showing a kidney tubule into your book and label parts A to D.

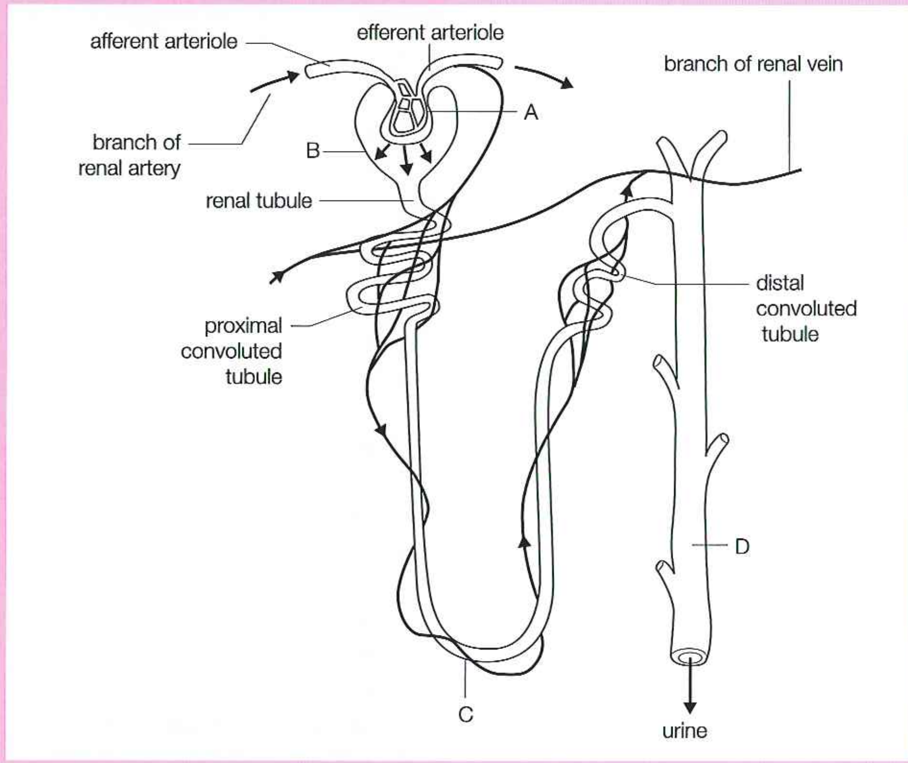


Figure 10.16 A kidney tubule.

12 On your diagram place the letter:
W where ultrafiltration takes place
X where most glucose is reabsorbed into the blood
Y where most water is reabsorbed into the blood
Z where ADH affects the tubule permeability

13 Why is the diameter of the afferent arteriole to the glomerulus larger than the efferent arteriole?
(*Note*: *afferent* means leading into, *efferent* means leading away from.)

14 Define the process of homeostasis.

15 Explain one example of a homeostatic mechanism in the body.

16 Why does sweating sometimes not cool the body in a badly ventilated room?

17 How can you explain why the skin of white-skinned people turns red in hot conditions?

18 Name three excretory organs in the body and the excretions they produce.

19 Make a large labelled diagram to show the structure of the skin. How is a constant body temperature maintained and what is the source of the heat?

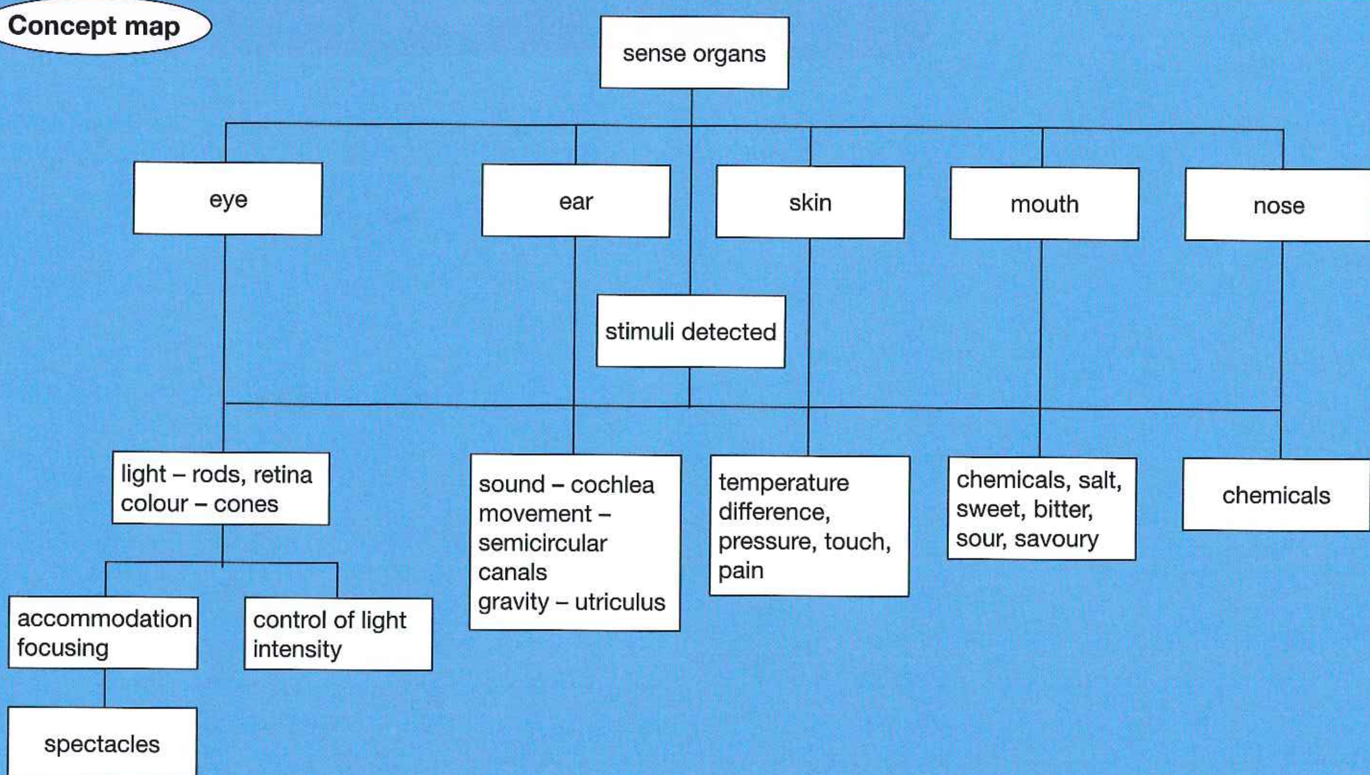
20 Why does a diabetic person sometimes need to:
(i) eat a lump of sugar?
(ii) inject insulin?

11 Sense organs

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

- ☑ name all the human sense organs and the stimuli they detect;
- ☑ describe the structure and functions of the eye;
- ☑ explain the control of light entering the eye;
- ☑ understand the formation of images and accommodation;
- ☑ know how to correct common eye defects, long- and short-sightedness and astigmatism;
- ☑ explain the structure and function of the ear;
- ☑ understand the detection of gravity, movement and balance;
- ☑ understand the detection of pressure, pain and temperature difference by the skin;
- ☑ explain the mechanisms of taste and smell in the mouth and nose.

Concept map



Receptors

stimuli ▶
sense organs ▶
receptors ▶

All around us in our surroundings there are stimuli, which affect our behaviour. These stimuli include light, sounds, gravity, movement, touch, temperature and chemical tastes. Sense organs contain receptors, which detect these stimuli. The human sense organs are the eyes, ears, skin, nose and mouth. These organs detect stimuli to keep us informed about the events in our surroundings.

ITQ1

Complete a table for the five sense organs with headings **sense organ** and **all stimuli detected**. Name the types of stimuli detected.

The eye

retina ▶

The eye receives light that it brings to focus on a layer of light-sensitive cells, called the retina. All the cells in the retina detect light and some detect colour. The brain interprets the impulses passed to it from the eyes. The optic centre in the cerebral cortex of the brain produces the picture seen from the nerve impulses sent to it.

- What are the structures called that contain receptors to detect stimuli?

Practical activity 11.1
To investigate the external structure of the eye

1 Either look into a mirror, or the eye of another person.
2 Note the parts of the eye you can see and make a drawing.
3 Note the names of the structures visible as shown in figure 11.1.

Questions

1 Why does the pupil appear black? (see page 192)
2 What colour is the iris and what is its function?
3 Make a drawing and list the functions of all the parts visible.

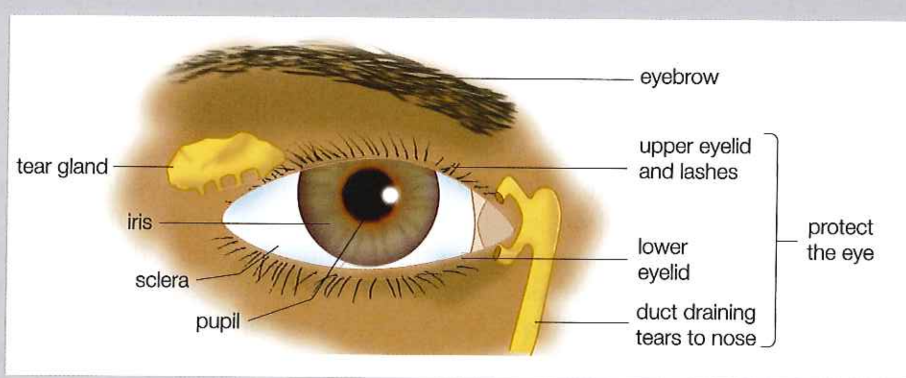


Figure 11.1 Front view of eye.

Protection of the eye

eyebrows ▶
eyelids ▶

From the front view we see several structures protecting the eye. The eyeball is in a cavity (socket) of the skull that protects it from knocks. The eyebrows prevent sweat from the brow from entering the eye. The eyelids prevent the entry of substances such as windblown grit. They also help lubricate the surface of the eye with tears, when blinking occurs.

- What is the purpose of tears in the eyes?

tears ▶

These tears are made in glands and pass down ducts entering at the inner end of each eyelid. Further ducts drain the fluid away into the nasal cavity. Tears are slightly antiseptic (capable of killing bacteria). The eyelashes also help to prevent the entry of grit and dust into the eye.

ITQ2
In what ways are the eyes protected from a 'punch with a fist' and 'windblown dust'?

Practical activity 11.2
Dissection of a fresh ox's eye

This dissection will be done only as a teacher demonstration, provided it does not contravene safety regulations.

An eye can be obtained from the suppliers or butchers.

1 Push scissors firmly through the eyeball and cut around the circumference so that the front part can be lifted off.
2 Remove the jelly-like aqueous and vitreous humours.
3 Remove and examine the lens.
4 Examine all the other structures.
5 The section of the eye can also be examined on a prepared slide. This may be best viewed with a magnifying glass.
6 Alternatively, an eye frozen solid can be cut in half with a hacksaw to examine a section.
7 Examine a model of the human eye and note the parts.

Questions

1 Why was it so difficult to insert the scissors at the start?
2 Name the 'white' of the eye and the parts attached to its outside.
3 What 'should' happen to the lens if it is squeezed, and why?
4 Name each part visible on the dissection, describe it and state its function.

Structures of the eye

sclera ▶ **conjunctiva ▶** **cornea ▶** **iris ▶** **pupil ▶**

The white of the eye is the tough outer fibrous sclera that helps retain the almost spherical shape of the eyeball (see figure 11.2). At the front it is covered with a very thin membrane called the conjunctiva, which then folds back under the eyelids. This prevents substances such as grit from getting right behind the eyeball.

The front part of the sclera is transparent and is known as the cornea. This is slightly more convex than the rest of the eyeball. Through this we can see the coloured iris, which encircles a central pupil. This is the hole through which light passes.

- Name the coloured part of the eye controlling the amount of light entering.

The sclera is attached to the skull socket by six muscles. These six muscles work against each other to move the eye in its socket. These muscles contract when you 'roll your eyes'.

vitreous humour ▶ **aqueous humour ▶** **lens ▶** **suspensory ligaments ▶** **ciliary muscles ▶**

- Name the layer in the eye that converts light energy into nerve impulses.

The jelly-like fluid in the posterior chamber of the eye is called vitreous humour. In the anterior chamber is a similar fluid called aqueous humour. These fluids help maintain the shape of the eyeball. Most of the refraction occurs in the cornea. The lens, held in position by suspensory ligaments behind the iris, also helps to refract light on to the retina at the back of the eye. These suspensory ligaments are supported by ciliary muscles, which can change the shape of the lens by changing the tension in the suspensory ligament.

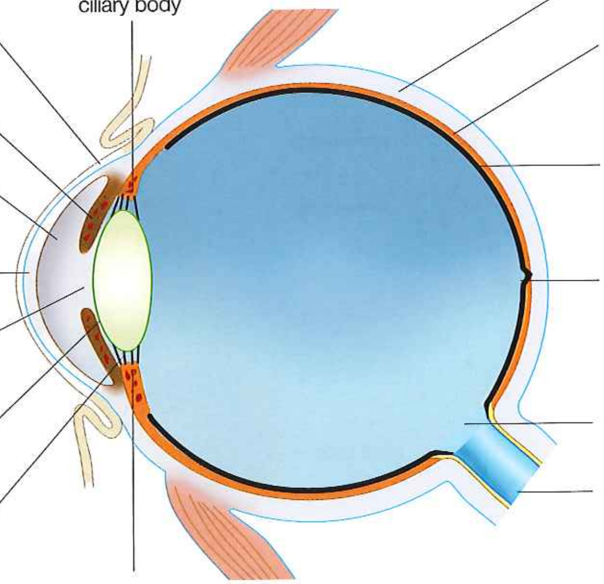


Figure 11.2 The parts of the right eye as seen in horizontal section.

ITQ3

Why is figure 11.2 not a vertical section?

- What is the function of the aqueous and vitreous humours?
- What parts of the eye refract the light passing through it?

blind spot ▶

The retina

The retina is a thin layer, which contains light-sensitive cells. These cells convert light energy to nerve impulses. When stimulated, these cells send impulses to the brain via the optic nerve at the back of the eyeball. The nerve fibres from the light-sensitive cells pass in front of the cells so that the light has to pass through them. These nerves then all pass out of the eye at a point where light-sensitive cells are absent. This is called the blind spot.

Practical activity 11.3
To investigate the presence of the blind spot

1 Close the right eye.
2 Hold this book 35 cm from the eyes and look hard at the cross.
3 If necessary move the book until the spot disappears.

Questions

1 Explain why the spot disappears.
2 Why is a blind spot not normally dangerous for vision?

Figure 11.3 To detect the blind spot.

ITQ4

When not looking directly at a black cat in a dimly lit room, it can be seen. How do you explain why it is not seen when directly looking at it?

ITQ5

What do you think is the significance of several rods supplying one neurone, while each cone has a separate neurone?

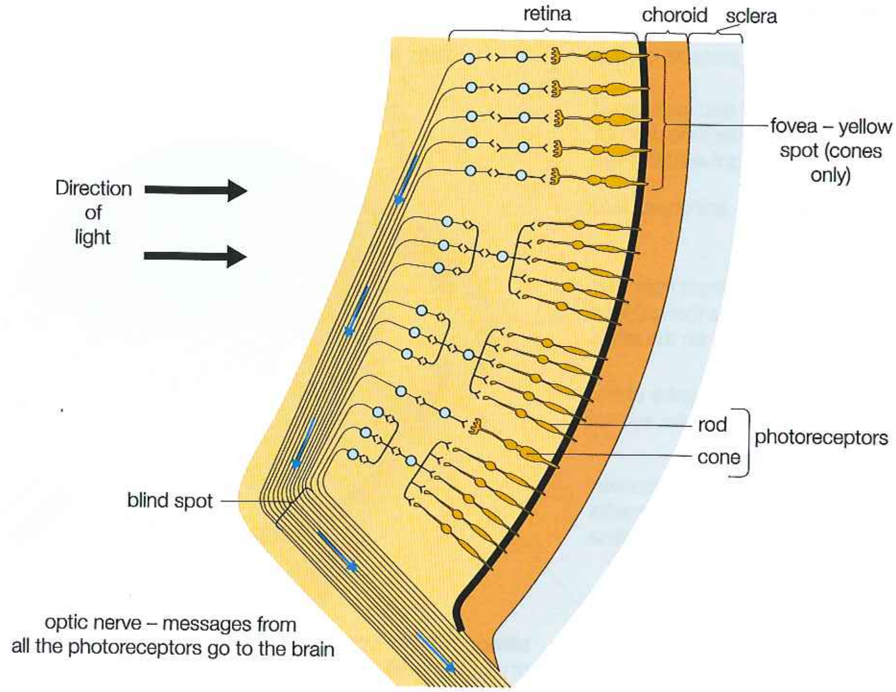


Figure 11.4 Section through part of retina to show rods, cones, blind spot and fovea.

In practical activity 11.3, light from the spot is falling on the blind spot and not stimulating any cells in the retina.

cones ▶ **colour ▶** **rods ▶** **yellow spot (fovea) ▶** **good resolution ▶**

Light-sensitive cells within the retina are of two kinds (see figure 11.4). The cones are sensitive to colour and are only affected at high light intensity. This is why colours are not so obvious at dusk. The rods only distinguish black and white, but detect light at lower intensities. The yellow spot (fovea) is the centre of the retina, which is thus in the centre of our field of vision. It only contains cones but these are closer together than elsewhere, to give really good resolution. (Resolution means the ability to distinguish detail.) You will now see why it is so difficult to distinguish detail in poor lighting conditions.

- What is detected by (a) rods (b) cones?

ITQ6

In figure 11.5, why can you clearly see the colour of the red sunset, but not the green colour of the trees?

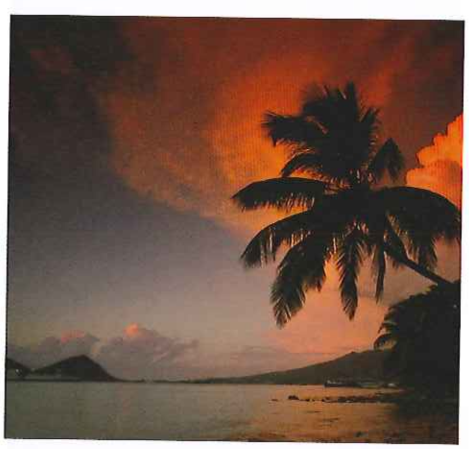


Figure 11.5 An evening scene.

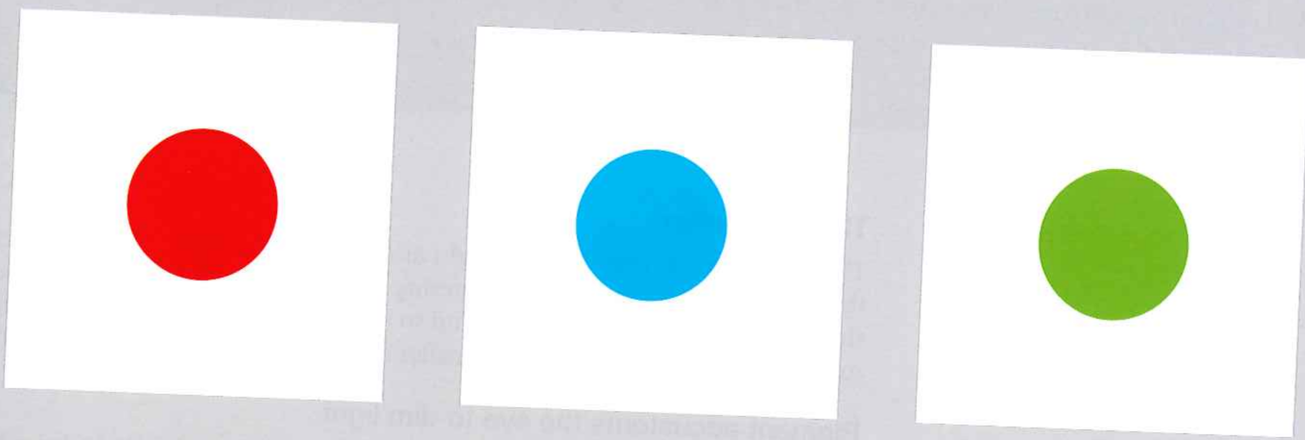
Structure	Function
External eye muscle	moves eyeball in socket (4 rectus and 2 oblique)
Sclera	tough fibrous layer keeps spherical shape
Choroid	well supplied with capillaries provides nutrients
Conjunctiva	thin membrane stops entry of grit and protects the eye
Cornea	transparent window, refracts (bends) light rays
Aqueous humour	refracts light, helps maintain shape
Lens	becomes more or less convex to focus light on retina
Suspensory ligament	supports lens
Ciliary muscle	contracts and relaxes to alter the shape of the lens
Vitreous humour	refracts light, helps eyeball keep shape
Retina	converts light energy to nerve impulses
Optic nerve	transmits nerve impulses to brain
Blind spot	lacks retina, no vision at this point
Yellow spot	provides detailed vision at the centre, cones only
Pupil	hole through which light passes
Iris	controls the amount of light passing through the pupil

Table 11.1 Structure and function of the parts of the eye.

Practical activity 11.4
A possible explanation of how cones detect colours

1 Cover the green and blue spots with white paper.
2 Close one eye and stare for a minute at the bright red coloured spot. Do not move your eye, even though it will tire.
3 Next look at a white background. The colour green may be seen.
4 After resting the eyes, try this with the other colours.

It is thought that the cones sensitive to red light are tired by overuse, so that white light stimulates the other two types of cone only. These combine to produce a complementary colour. Green is therefore seen after staring at red.



Questions

1 Which three colours make up white light?
2 What colour do you see when looking at (i) green (ii) blue in this experiment?
3 For each colour, explain which cones are being stimulated.

How the eye actually works to see colour is not fully understood. One theory suggests that there are cones sensitive to the three primary colours, red, blue and green. A mixture of these produces all the other colours and these will depend on the number of cones of each sort that are stimulated. Support for this hypothesis comes from practical activity 11.4.

Colour blindness

colour blindness ▶ Complete colour blindness when a person only sees black, greys and white is very rare. Failure of all types of cones or their nerve supply would cause this condition.

red/green colour blind ▶ However, many more people cannot distinguish reds from greens and are said to be red/green colour blind. The information from two types of cone or their nerve supply may be faulty. Colour-blind people may not do certain jobs such as being a pilot, where safety depends on the ability to see colours. We shall see later (page 267) how red/green colour blindness is a sex-linked inherited disease, which means it is more common among males than females.

choroid ▶

• Which layer in the eyeball supplies the oxygen and nutrients?

Between the retina and the sclera is the choroid layer. This is well supplied with blood capillaries providing nutrients for the eye. This layer also contains black pigment that cuts down unwanted internal reflection in the eye.

Control of light entering the eye

Practical activity 11.5
To investigate the control of light intensity entering the eye

1 Examine the pupil of a partner's eyes in dim light.
2 Shine a light in the eye and note the effect.
3 Look into a mirror at your right eye, then put your hand over your left eye and remove the it.

Questions

1 Explain the changes in pupil size in each case.
2 What does step 3 tell you about the mechanism controlling pupil size in both eyes?

The pupil reflex

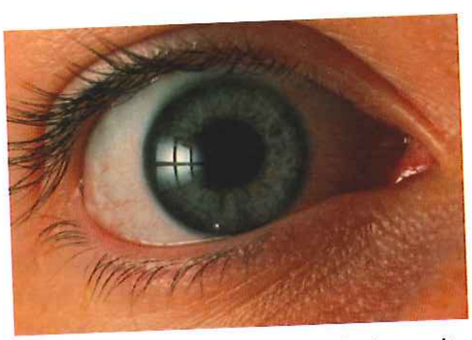
The pupil size is smaller in bright light and larger in dim light. This is a reflex action that controls the amount of light entering the eye. In bright light, circular muscles in the iris contract, enlarging the iris and so reducing the pupil size. In dim light, radial muscles contract to make the iris smaller and enlarge the pupil (see figure 11.6).

Pigment accustoms the eye to dim light

eyes become accustomed ▶

Over a longer period the eyes become accustomed to dim light by adaptation of a pigment, visual purple (rhodopsin), in the rods of the retina. This pigment is bleached in bright light and takes time to recover or regenerate to be able to trigger further impulses in the dark. When a person moves from bright light to dim conditions, it may take 30 minutes before all the pigment in the rods is regenerated. The rods become more sensitive and so they are stimulated to allow seeing in very dim light. Until this time relatively few rods are able to trigger nerve impulses, and light falling on 'bleached' rods is not detected. This accounts for the difficulty in seeing at first on entering a dark room.

ITQ7
A boy goes from bright light into a cinema. Explain the control of light mechanism, which initially allows him to see his seat and then later on recognise a friend.



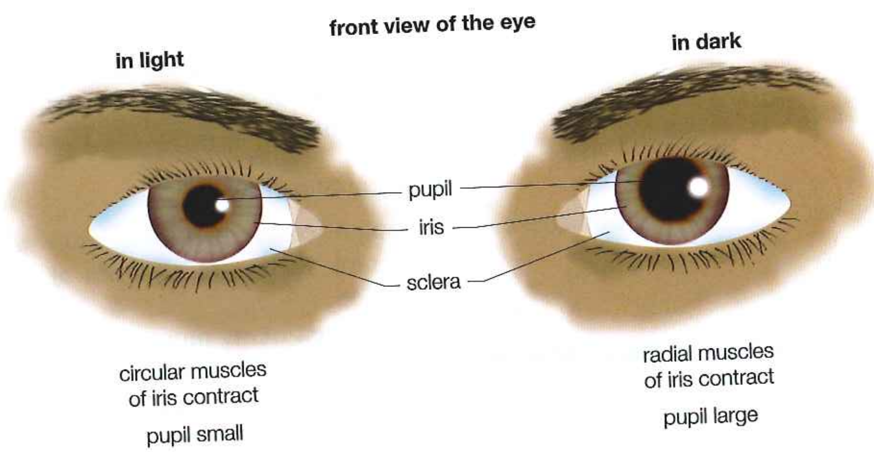


Figure 11.6 The effect of light intensity on the size of the pupil.

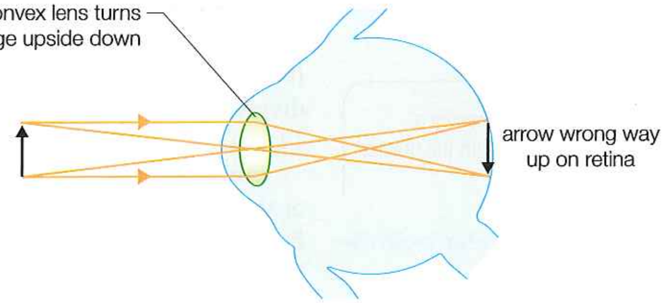


Figure 11.7 Images turned upside down on the retina are changed by the brain to the right way up.

Images inverted on the retina

light is refracted ▶

Figure 11.7 shows how the image on the retina is formed the wrong way up (upside down). The brain interprets the image so that it is the right way up. Light is refracted as it enters the denser medium of the cornea. The transparent humours allow the passage of light to the retina. The lens refracts the light to give fine focusing.

Accommodation

focusing ▶

viewing distance objects ▶

- Name the muscles and ligaments that support the eye lens.

The way the lens brings about fine focusing is called accommodation. The lens is elastic and its shape and focal length can be changed.

The focal length of the lens is made longer for viewing distant objects, by the lens becoming thinner. The suspensory ligament holding the lens becomes tight, stretching it, due to the relaxation of the ciliary muscles. The ciliary muscles form a ring around the suspensory ligament so that as they relax the ring enlarges. This is why the eye is in focus for distant objects when it is relaxed (see figure 11.8a).

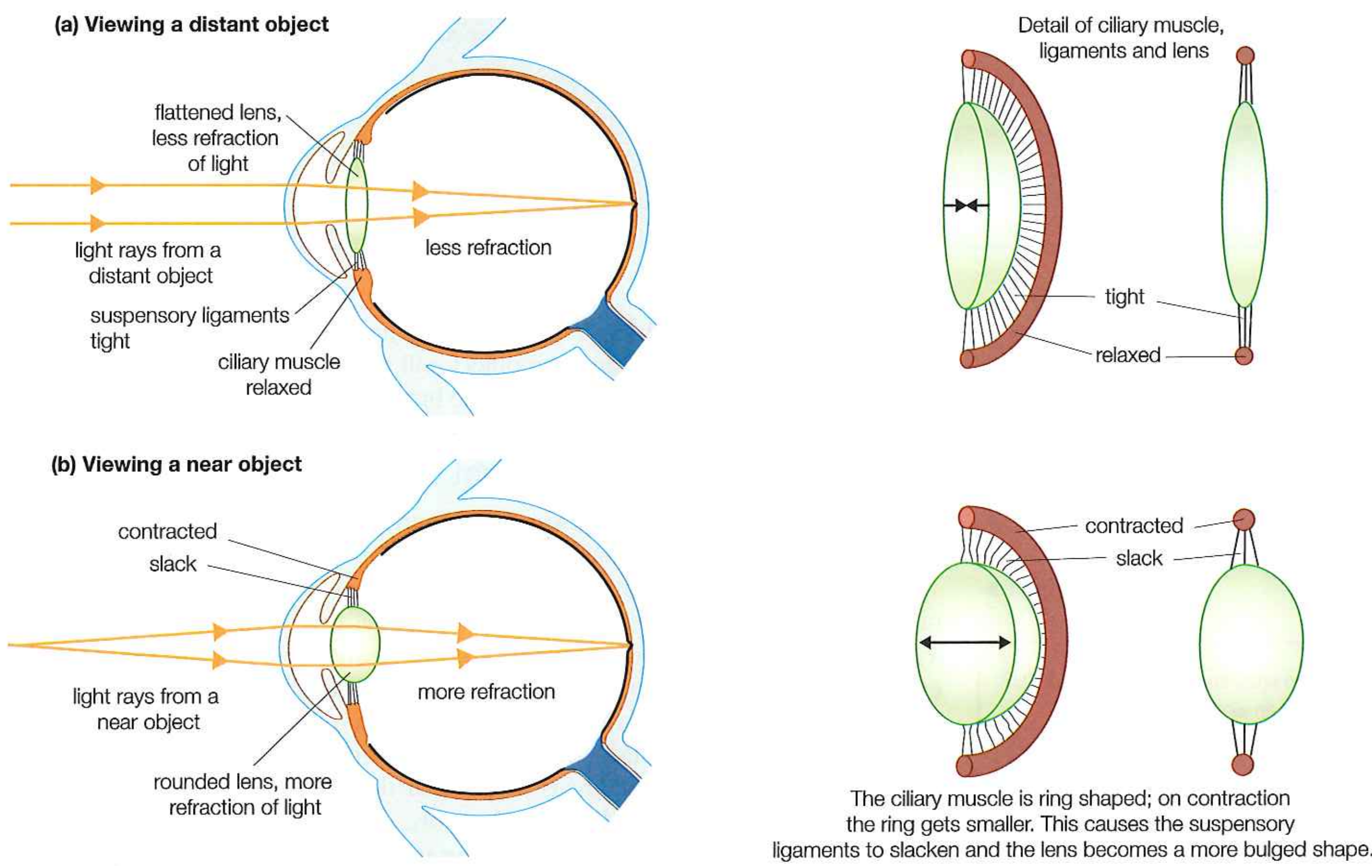


Figure 11.8 Accommodation: the way the lens adjusts to view near and distant objects.

viewing near objects ▶

To view near objects the ciliary muscles contract. This removes the tension on the suspensory ligaments so that the lens, due to its elasticity, becomes more convex (converging). This shortens its focal length so that near objects that produce more diverging rays of light are refracted to bring them to focus on the retina (see figure 11.8b).

ITQ8

Explain the accommodation of the eye by a batsman while watching the ball from the bowler hit his bat.

near point ▶

For a normal eye, objects nearer than about 25 cm cannot be focused, since at this distance the lens cannot become any more convex to refract the light rays further. This distance is called the near point. Measure your near point with a ruler by bringing an object slowly nearer to the eyes until it just goes out of focus. As you get older so this distance increases.

fine detail ▶

When viewing distant objects or looking at fine detail, the pupil contracts slightly by a similar mechanism to that in bright light. The smaller pupil improves the resolving power. This is why some people who need glasses screw up their eyes. This is also why good cameras have an iris diaphragm, so that the aperture is made small when fine detail is needed.

Practical activity 11.6
Vision test and investigate stereoscopic vision

1. Use an optician's chart to test the vision in each eye of pupils in the class.
2. With one eye open *only*, and with a pencil in each hand, bring them together so that the points touch.
3. Alternative activity: Place a coin overlapping the edge of a table. With one eye closed and the arm slightly bent, walk up to the coin and try to knock it off with one downward strike.
4. Now repeat with both eyes open.

Questions

1. From the chart write down the smallest line you can read. Compare with others.
2. For activities 2 and 3, were you most successful with one eye open or both?
3. How do you account for your results?
4. Why do you think the alternative activity is a better experiment with the arm bent?

stereoscopic vision ▶

Stereoscopic vision allows a distance to be judged more accurately. The angle between the two eyes looking at an object will decrease as the object moves away into the distance. This angle is used by the brain to judge the distance.

ITQ9

To what extent is a person with one eye limited from judging the distance away of a car along a road?

Causes and correction of sight defects

defects in vision ▶

Defects in vision where objects cannot be clearly seen can be made better by using glasses. The lenses of these glasses refract the light before entering the eye.

long sight ▶

Long sight occurs when near objects cannot be focused because the diverging rays of light are not sufficiently refracted. Parallel rays from distant objects need less refraction and so can be seen clearly. Long sight may be caused by a short eyeball or weak lens. A convex lens in glasses will refract the light sufficiently to focus the diverging rays from near objects onto the retina (see figure 11.9).

ITQ10

Explain why and what sort of lenses are needed by a person with an elongated eyeball.

short sight ▶

Short sight makes distant objects appear blurred because parallel light rays are refracted too much and focus in front of the retina. Near objects are visible since the diverging rays need more refraction. A long eyeball causes short sight. A concave lens that will diverge the light rays will allow the eye to refract them onto the retina (see figure 11.10).

- What shaped lens corrects the inability to see near objects clearly?

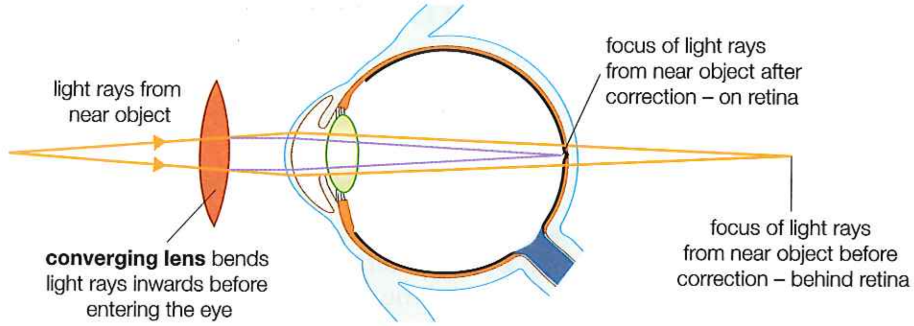


Figure 11.9 Long sight and its correction with glasses.

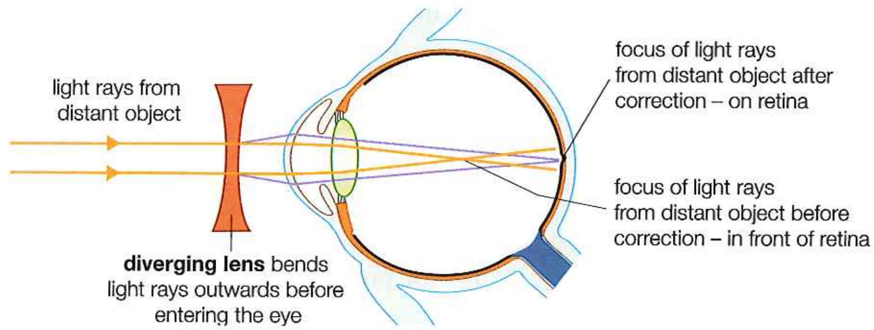


Figure 11.10 Short sight and its correction with glasses.

With age, the natural elasticity of the lens is lost so that accommodation is reduced. It generally means that convex lenses are needed for near vision. Bifocals may be needed which have lenses for both near and distant vision.

astigmatism ▶ Should the cornea become uneven, then vision becomes distorted. Parallel vertical or longitudinal bars appear to bend. This is called astigmatism and correction by lenses has to compensate for the uneven cornea.

glaucoma ▶ Glaucoma is a most common cause of blindness in the Caribbean. It is caused by an increase in pressure in the aqueous humour, due to its increased secretion in front of the lens. It results in poor vision, weeping, and inflamed and painful eyes. Severe pressure may damage the optic nerve, causing blindness so that surgery may be necessary. It is a degenerative disease with age, while heredity, myopia, a stroke and some other diseases may cause it. Treatment with eye drops is sometimes successful.

cataracts ▶ Another degenerative disease is cataracts, where the lens becomes opaque. Reduced vision, then blindness, occurs as it slowly develops. It may also occur in babies if the fetus receives certain drugs, or pathogens such as the German measles virus during pregnancy. Laser surgery is used to remove the lens and spectacles, or contact lenses, are used to compensate for their loss.

Figure 11.11 A cataract

The ear

The ear is a receptor for sound vibrations as well as an organ for detecting gravity and assisting balance.

Detection of sound

outer ear ▶
external auditory canal ▶
tympanum ▶
oval window ▶
middle ear ▶
eustachian tube ▶

ITQ11
Explain why it is important (a) not to remove wax from your ear with a pencil and (b) to swallow when you appear to go deaf when climbing up a mountain.

The outer ear helps collect the sound waves and pass them down the ear passage or external auditory canal. The two ears help you detect the source of the sound, by the relative loudness heard by each ear. The structure of the ear is best seen by means of a model because it is buried in the bone of the skull and is small and difficult to dissect (see figure 11.12).

The eardrum or tympanum separates the outer ear from the middle ear. Sound waves cause the eardrum to vibrate. These vibrations are transmitted across the middle ear by the movements of three small bones called ossicles.

These vibrations cause the oval window to move and pass them to the inner ear. The middle ear is an air-filled cavity and the pressure is kept equal on either side of the eardrum by air passing into the middle ear through the eustachian tube. This tube leads to the back of the pharynx and it opens during swallowing.

As changes in atmospheric pressure may occur daily, it is important that the pressure is kept equal on either side of the drum to prevent it from bursting. People who fly in aircraft find that more frequent swallowing, or yawning, can balance the pressure changes that occur.

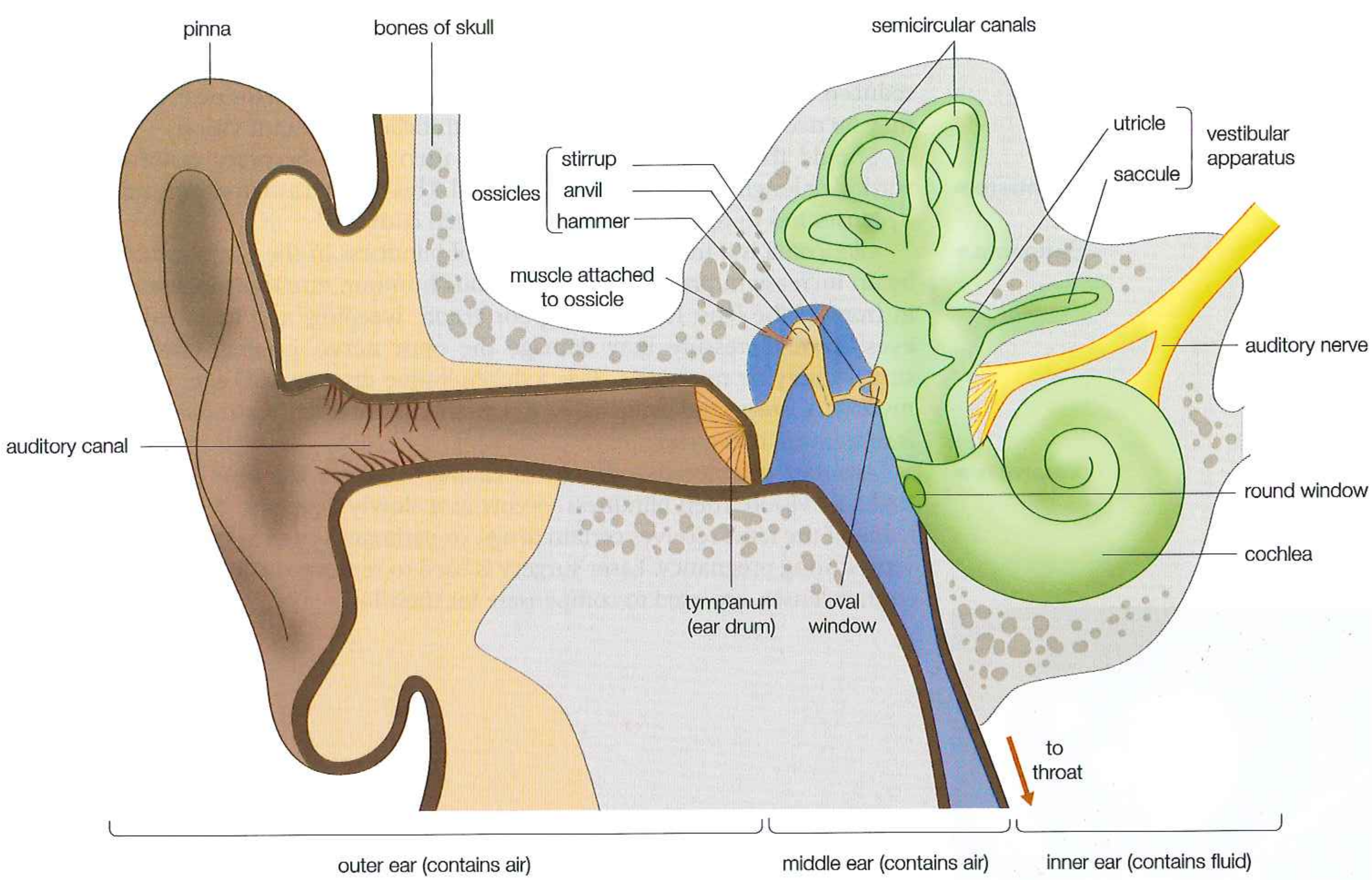


Figure 11.12 Sectional view of the human ear.

inner ear ▶ **cochlea ▶**

The inner ear is filled with a fluid. Vibrations are passed to this fluid by the movements of the oval window. This fluid passes the vibrations around the spirally coiled tube of the inner ear, called the cochlea. Lengthways along the cochlea are sensory cells that are stimulated to send impulses to the brain.

The auditory centre of the cerebral cortex in the brain interprets the impulses as known sounds. Loudness will be detected by the degree of stimulation of the cells. Different cells along the length of the basilar membrane detect pitch.

- Name the bones in the middle ear and explain their function.

Practical activity 11.7
To investigate the ear and the binaural effect

1 Examine a model of the ear.
2 Close your eyes while somebody makes a noise (e.g. clapping hands) in the room.
3 Point to the source of the noise and then open your eyes to see how accurate you were in detecting the source.
4 Repeat the experiment with one ear blocked.

Questions

1 Name the parts on the model and alongside list their function.
2 Note your accuracy in detecting the location of the sound source.
3 Explain what happens with one ear blocked and hence how the two ears work together.

Detection of gravity and balance

semicircular canals ▶

The other part of the inner ear consists of the semicircular canals above the cochlea Each semicircular canal is at right angles to the other two, so that whichever way the head is moved, at least one canal moves.

Movement of the head will cause the fluid to stimulate sensitive hairs in swellings at the end of each canal. Nerves leading from these send impulses to the brain. These impulses coordinate the correct muscles for balance (see figure 11.13).

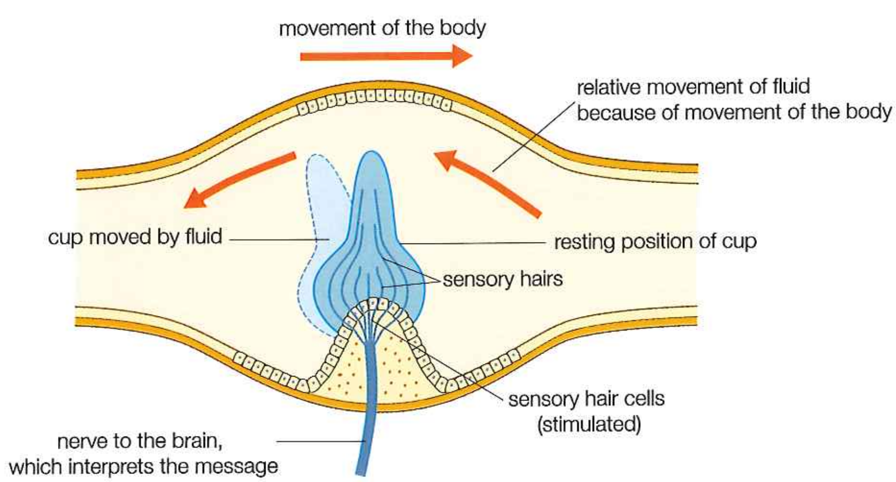


Figure 11.13 How head movements move hairs to make nerve impulses in the base of the semicircular canals to control balance.

ITQ12

Explain the mechanisms in the ear causing staggered walking after a fairground ride spinning round.

Dizziness after rapid spinning round of the body is caused by the fluid oscillating back and forth in the semicircular canals. This sends false information to the brain. Hence muscles wrongly move and the body becomes unbalanced.

Practical activity 11.8
To investigate balance

1. A person is blindfolded and spun round while sitting on a rotating stool or swivel chair. He is told to point in the direction of his motion.
2. After a few trials and a rapid turn in one direction, if the chair is stopped and rocked, the person points to indicate he is turning in the other direction.

Questions

1. The fluid of the semicircular canal has flowed back to stimulate the hairs in the ampulla at the other end. The person gets the sensation of movement. Using this information, explain this result with reference to figure 11.13.
2. Why after spinning round in this experiment with no vision do you sometimes become dizzy?

gravity ▶

- What part of the ear detects movement, gravity and balance?

The importance of seeing things is shown by the loss of balance if you spin your body around with your eyes closed. Information about the position of the head in relation to the pull of gravity is provided by the inner ear between the semicircular canals and the cochlea. These contain granules of chalk held above sensitive hairs. Gravity pulling on the particles will stimulate the hairs (see figure 11.14). Tilting

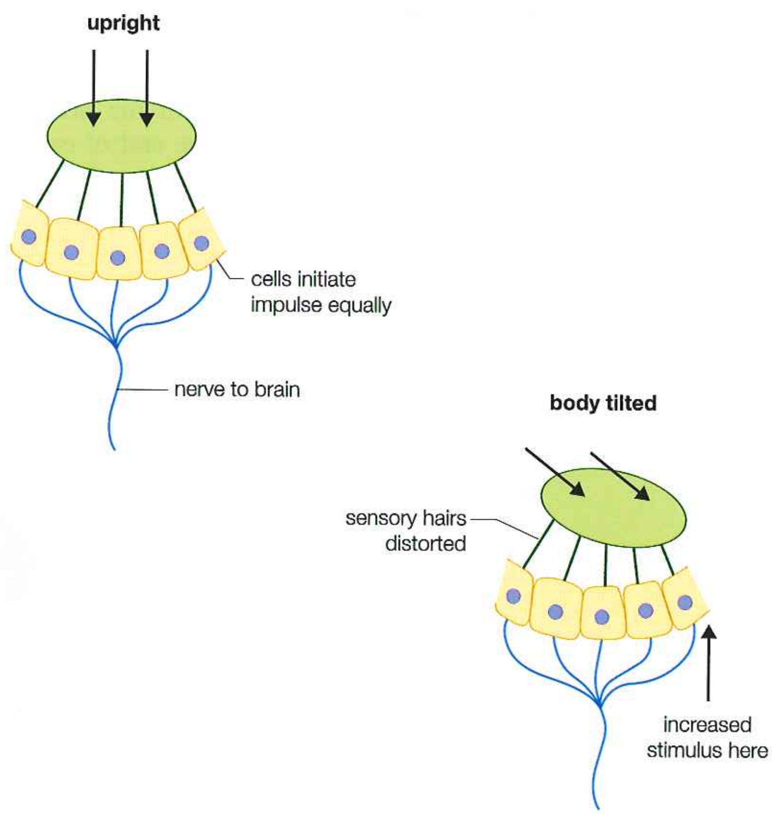


Figure 11.14 How gravity is detected in the utriculus.

the head will stimulate them more on one side than the other. This information is passed to the brain and reflex actions occur so that the muscles return the body to its normal posture.

proprioceptors ▶

- What in muscles detects changes in their tension and informs of their position?

Within the muscles there are receptors called proprioceptors that detect changes in the tension of the muscles. Impulses from the proprioceptors as well as the eyes continually activate 'righting' responses by the muscles. Pressure receptors in the skin, particularly in areas such as the feet, are also important to provide stimuli for balance. Hence control of balance requires stimuli from the semicircular canals, utriculus and sacculus, the proprioceptors and the eyes.

Practical activity 11.9
To investigate control by proprioreceptors

1 Stand about 10 cm from a wall. With the body held firmly upright and without bending the arm, push out hard on to the back of your hand on the wall for one minute.
2 Stand well away from everything and let your arm completely relax by your side (see figure 11.15).

Questions

1 What happens to your arm?
2 Some proprioceptors in the muscles of the arm become fatigued by the continual pressure. How can this explain what happens?

Figure 11.15 Proprioceptors, tired by pushing, cause these Caribbean schoolgirls' arms to rise on their own.

The skin

Since the skin first comes into contact with the surroundings, sense receptors within it are well suited to provide information.

Practical activity 11.10
To investigate skin sensitivity

A Touch and pressure

1 An experimenter should touch the back of the hand of the subject with either one bristle, or two bristles held together about 0.5 cm apart. Random trials should be devised.

2 The subject, without looking, records whether they can feel this and, if so, whether they can detect one or two bristles.

3 The experimenter can try a variety of spots.

4 Now repeat this experiment on various parts of the body to find the difference in sensitivity.

Questions

1 Explain your design of the trials in step 1 above.

2 Construct tables and a map of the regions of the body with sensitivity to touch.

3 What conclusions can you draw from this activity?

B Temperature difference

1 We can of course detect hot and cold water with our fingers. Place one finger in hot water and one finger in cold.

2 Remove after a minute and place them in tepid water. One finger detects this water as being cold and the other as hot. This shows that what is detected is *changes* in temperature.

3 Warm the tip of a fine glass rod in water and apply it to various regions of the skin.

4 Repeat with a cold glass rod.

Questions

1 What does step 2 above show?

2 Record the differences noted on different regions of the body to the hot and cold rods in steps 3 and 4 above. What conclusions can you draw?

pressure and touch ▶
cold and warmth ▶
pain ▶

Receptors in the skin detect pressure and touch (see figure 11.16). Others detect cold and warmth. All these sense receptors, as well as other nerve endings, detect pain. Some regions have more of certain receptors than others, as you may

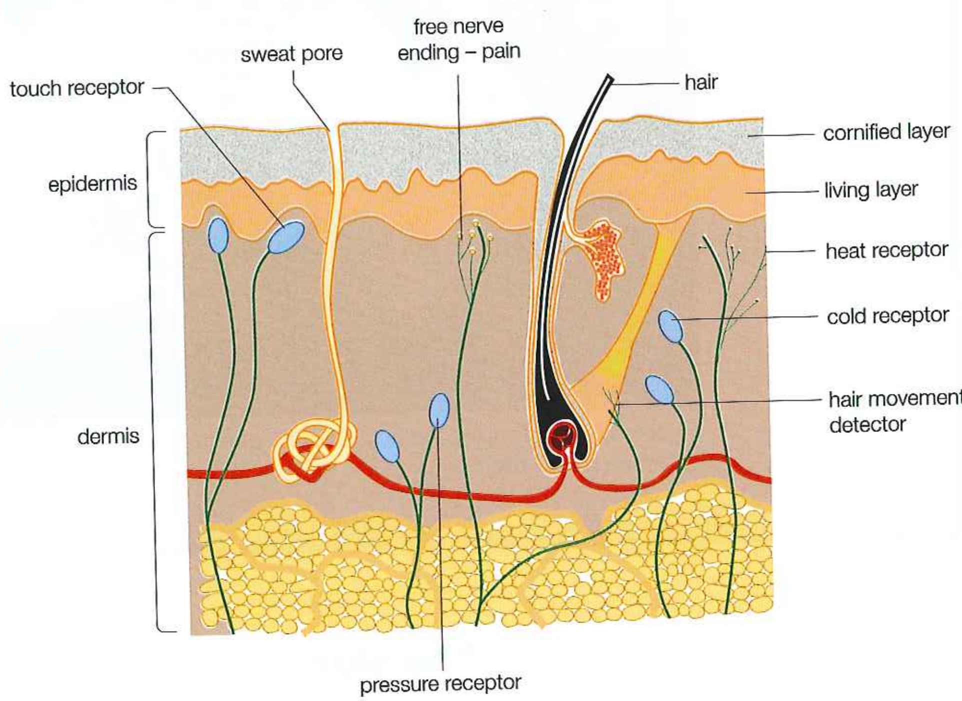


Figure 11.16 Receptors in the human skin detecting temperature difference, pain, pressure and touch.

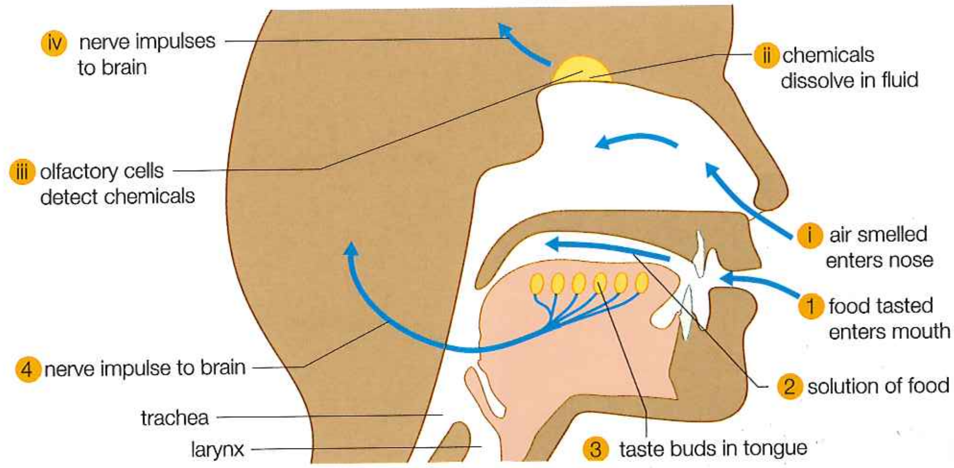


Figure 11.17 Taste (1 to 4) and smell (i to iv) detection.

have found in the above practical activities. For instance, the finger tips have more touch receptors and the elbow more temperature receptors.

Taste and smell

taste ▶ **taste buds ▶** **chemoreceptors ▶**

Taste is detected by delicate taste buds in the mouth, particularly on the tongue (figs 11.17–11.19). Taste buds contain sensory epithelial cells, called chemoreceptors. Each cell detects one taste: salt, sweet, bitter or sour. A fifth taste detects glutamic

Practical activity 11.11
To investigate the sensitivity of the tongue to different tastes

Safety precautions: eating and drinking is not allowed in laboratories. This experiment should be performed in a dining area. Use one drinking straw for each pupil for each solution.

1 Prepare the following solutions: sugar solution (sweet), lemon juice (sour), common salt solution (salty), 'angostura bitter' (bitter) and soy sauce or Marmite (savoury).

2 Working in pairs, one student with their eyes closed receives at random one drop, from one of the solutions. This is put on the tongue from a drinking straw by the other student. The first student records the taste detected.

3 Repeat with the other four solutions. Rinse your mouth with distilled water each time you have finished with one solution.

4 Repeat one trial with each solution while the student pinches their nose to avoid smelling the solution. How accurately did you detect each of the tastes and what was the effect of pinching the nose?

Question

1 Were areas of the tongue particularly sensitive to each taste?

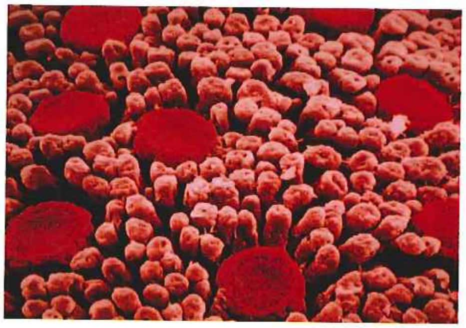


Figure 11.18 Taste buds on the human tongue.

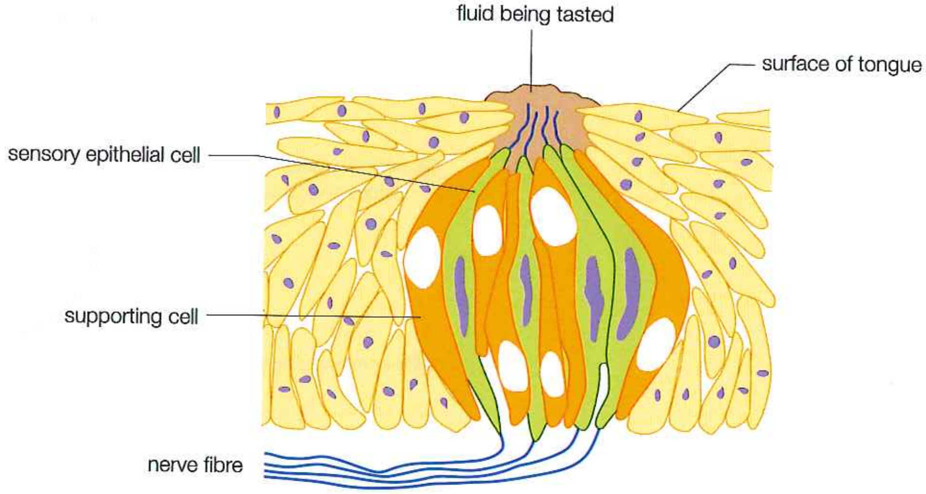


Figure 11.19 Section of a taste bud in the tongue.

acid, described as amami or 'savoury'. Research also now shows that the tongue does not have particular regions sensitive to one type of flavour. All taste buds contain each type of sensory cell.

smell ▶

From the experiment you will have found that the tongue is sensitive to sweet, sour, salt, bitter and savoury. Pinching the nose will have shown you that smell receptors are much more sensitive than taste receptors.

Taste enables us to tell whether a food is suitable to eat. Smell (figure 11.20) serves a similar purpose, although this is more important in animals, which use it for hunting, or detecting a mate. Smell is similar to taste in that the nasal passages contain mucus, which dissolves the chemicals causing the odour.

These then stimulate sensory neurone endings similar to taste buds. Hence the truth of the statement that some odours are so strong they can be tasted.

Food flavour then is detected by both taste and smell. Note that with heavy catarrh, or by blocking the nose, tastes as well as smells are not so strong. With your

ITQ13

Explain why it is said that unpleasant smells can be tasted.

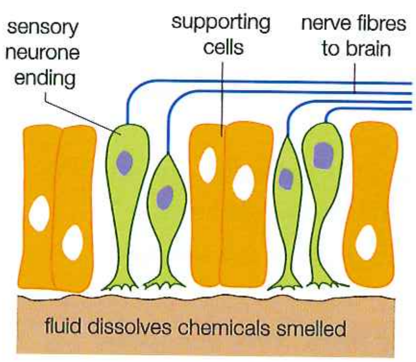


Figure 11.20 Olfactory cells detect smells in nasal passages.

Part	Sensory function
eye	The parts of the eye focus light rays onto the retina to produce a clear, inverted image. The light initiates nervous impulses in the retina, which travel to the brain via the optic nerve and which the brain interprets as colour, shape, form and distance.
ear	Receptor detects sound (and vibrations) passed to the cochlea that generates nerve impulses that the brain interprets. Semicircular canals detect head movements, body movements and control balance. Utriculus detects gravity, body position and controls body posture.
skin	Detects touch, pressure, pain and temperature differences.
mouth and nose	Chemoreceptors (sensory epithelial cells) detect tastes – salt, sweet, bitter, sour; sensory nerve endings detect smells.

Table 11.2 The functions of sense organs.

eyes closed, try to name the smells of substances placed near to your nose by your partner. From what distance can you detect the smells of various substances?

Summary

- Sense organs (the eye, ear, skin, nose and mouth) contain receptors to detect stimuli.
- The eye detects light intensity and colour by cells in the retina.
- Cones detect colour at high light intensity; rods detect black and white at low intensity.
- Accommodation is the focusing of light on the retina by changing the shape of the lens.
- Parallel light from distant objects is focused, as the lens is thin, the suspensory ligaments tight and the ciliary muscles relax.
- Diverging light from near objects is focused, as the lens is thick, the suspensory ligaments loose and the ciliary muscles contract.
- Long sight needs spectacles with convex (converging) lenses to correct the diverging light from blurred near objects.
- Short sight needs spectacles with concave (diverging) lenses to correct the converging light from blurred distant objects.
- The ear detects sound, pitch and intensity, as it is passed from eardrum by ear ossicles to the receptors in the cochlea.
- The inner ear detects movement, by fluid in the semicircular canals stimulating the receptors in the ampullae. Gravity is detected by receptors in the utriculus of the inner ear.
- The skin has receptors to detect temperature difference, pain, pressure and touch.
- Chemicals are tasted by receptors in the mouth as taste and in the nose as smells.

Answers to ITQs

ITQ1

Sense organ	*All stimuli detected*
eye	light: intensity and colour
ears	sound: loudness and pitch
	gravity: for balance and movement
skin	pressure/touch, pain, temperature difference
nose	smell: chemicals – numerous
mouth	taste: chemicals – sweet, sour, salty, bitter

ITQ2 The orbit of the skull protects the eye from a punch. The conjunctiva prevents windblown dust from getting behind the eyeball. Closing the eyelids and eyelashes help prevent entry.

ITQ3 Because the optic nerve passes laterally (sideways) to the brain. A vertical section (from top to bottom) would not pass through the optic nerve as shown in the diagram.

ITQ4 Light from what you are directly looking at falls on the fovea (yellow spot), which only detects colour. Hence you may not see a black cat in a dark room when looking directly at it. The rest of the retina additionally contains rods, which detect low-level light intensity, so that the cat may be seen.

ITQ5 Several rods supplying one neurone will increase the stimuli to it, making them more sensitive in dim light. One cone supplying one neurone will be less sensitive, but allows detection of just one of the primary colours making up white light.

ITQ6 The trees in dim light at dusk are not bright enough to stimulate the cones so their colour is not seen. They only stimulate the rods that provide black and white only. The brighter red sunset does stimulate the cones so colour is seen.

ITQ7 In the dim light of the cinema the eye quickly adapts when the pupil enlarges as the radial muscles contract. Hence more light enters. Later a friend is seen, because the retina becomes accustomed to very dim light. The pigment rhodopsin in the rods of the retina has regenerated, it becomes more sensitive, and so it is stimulated to allow seeing in very dim light.

ITQ8 The lens is thinner, as the ciliary muscles relax, to increase the tension on the suspensory ligaments, to view parallel light rays from the distant ball in the bowler's hand.

As the ball reaches the bat, the ciliary muscles contract, the suspensory ligament becomes loose, making the lens fat, to converge the light rays from the nearer ball.

ITQ9 A person with one eye lacks stereoscopic vision. They cannot subtend an angle between two eyes, so distance is difficult to judge. They rely on previous knowledge of perspective relating size to distance away.

ITQ10 With an elongated eyeball light rays will be focused in front of the retina. A concave lens will diverge the rays to correct it.

ITQ11 (a) Digging a pencil into the ear to remove wax may perforate the eardrum and cause permanent deafness. It is very dangerous.

(b) Swallowing removes deafness caused by lower pressure at altitude. This allows air passage through the mouth and eustachian tube, to equalise the air pressure either side of the eardrum in the middle ear, to that outside.

ITQ12 Spinning round causes fluid movement in the semicircular canals to stimulate receptors to send false information to the brain, causing muscle response that causes the dizziness. The gravity receptors will also send false information to cause the staggered walking.

ITQ13 Smell is detected by the molecules in the air dissolving in fluid, which stimulates receptors, in a similar way to taste receptors detecting solutions of food.

Examination-style questions

Multiple choice questions

(Write down the number of the question followed by the letter of the correct answer. You can check your answers on page 417.)

1 In which part of the eye is the yellow spot (fovea) found?

A choroid
B lens
C retina
D sclera

2 In passing through the eye where is most light refracted?

A aqueous humour
B cornea
C lens
D vitreous humour

3 A boy looks up from a book at a distant aeroplane. What happens to the ciliary muscles and the lenses in his eyes?

	Ciliary muscles	*Lens*
A	contract	becomes more convex (fatter)
B	contract	becomes less convex (thinner)
C	relax	becomes more convex
D	relax	becomes less convex

4 Which occurs to the muscles in the iris and the pupil size when a person moves from a dark room to bright sunlight?

	Muscles in the iris	*Pupil size*
A	radial muscles relax	gets larger
B	circular muscles relax	gets smaller
C	circular muscles contract	gets smaller
D	radial muscles contract	gets smaller

5 Which is most likely damaged in a colour-blind person?
A blind spot
B medulla of the brain
C cones of the retina
D rods of the retina

6 Which parts of the ear both contain air?
A cochlea and the sacculus
B sacculus and the middle ear
C middle ear and the eustachian tube
D eustachian tube and the semicircular canals

7 Why is it advisable to swallow when the surrounding air pressure decreases, as sometimes occurs in an aircraft taking off?
A to remove fluid from the eustachian tube
B to remove any contents in the oesophagus
C to allow air to enter the middle ear
D to allow air to leave the middle ear

8 After spinning around several times a person feels dizzy because nerve impulses are made first in the:
A cochlea
B ear ossicles
C semicircular canals
D oval window

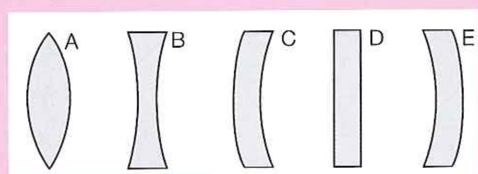


Figure 11.21

9 Which of the lenses A, B, C, D or E in figure 11.21 would be used to correct short sight?

10 Which of the lenses A, B, C, D or E in figure 11.21 would be used in the sunglasses of a person with normal vision?

Short answer and essay type questions

11 Name as accurately as you can the exact part of the body which detects the following environmental stimuli: coloured light, gravity, head movements, heat, smell, low intensity light, sound, taste, touch.

12 Copy the diagram of the eye from figure 11.2. Draw an arrow pointing upwards in front of your drawing. Draw on lines to show the path of the rays of light to the retina and the image of the arrow on the retina.

13 On the diagram drawn for question 12, mark with: X a position where tough tissue helps keep the shape of the eye spherical; Y a position with numerous blood capillaries; Z the position where most cones are found.

14 With front view diagrams of the pupil and iris explain how the eye adapts to view in both bright and dim light.

15 In an experiment to show the blind spot, a dot and a cross are viewed with one eye. Why does this experiment not work if both eyes are open?

16 What are the causes of (a) long sight (b) astigmatism?

17 Explain the condition of the ciliary muscle, suspensory ligament and lens shape when viewing a near object.

18 How is sound passed from the tympanic membrane (eardrum) to the oval window?

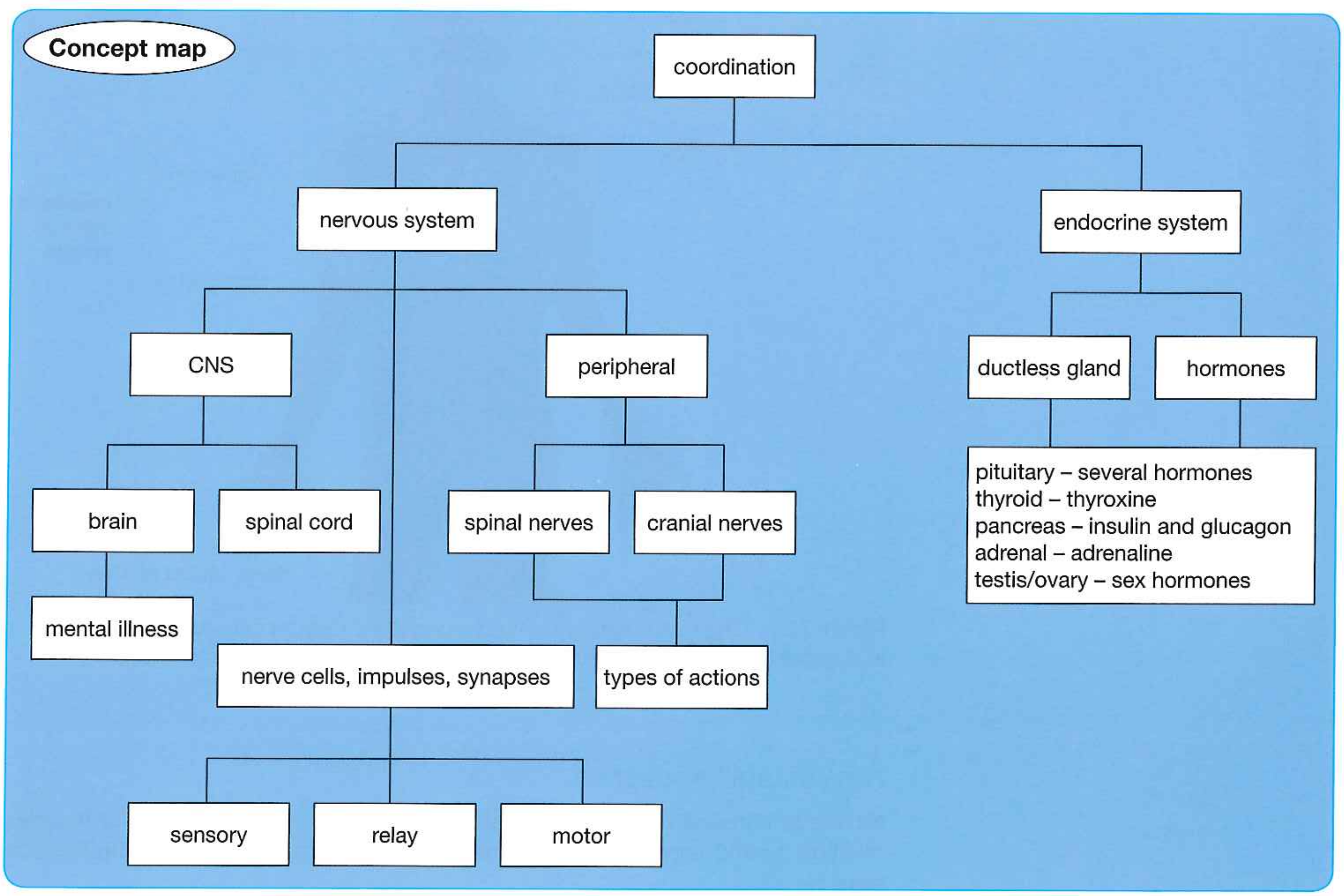
19 Explain how balance is maintained while walking.

20 Describe experiments to show the various senses detected by the skin.

12 Coordination and control

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

- ☑ state the main divisions of the nervous system;
- ☑ know that the peripheral nervous system has spinal and cranial nerves;
- ☑ know that the central nervous system is the brain and spinal cord;
- ☑ distinguish between a neurone and a nerve and their properties;
- ☑ describe the functions and types of nerves: motor, sensory, relay;
- ☑ understand the nature of the nerve impulse;
- ☑ describe the action at a synapse and chemical neurotransmitters;
- ☑ describe the regions of the brain and their function;
- ☑ draw and describe the structure of the spinal cord;
- ☑ define a reflex action and explain the mechanism;
- ☑ explain the spinal reflex action of the knee-jerk reflex;
- ☑ describe the response to painful stimuli and understand reaction times;
- ☑ understand the types of reactions, voluntary, involuntary, reflex, conditioned reflexes and how they occur;
- ☑ distinguish and describe hormonal and nervous coordination of the body;
- ☑ define hormones, the endocrine and exocrine glands in the body;
- ☑ know the location of endocrine glands and the function of their hormones;
- ☑ define mental illness.



The nervous system

We have seen how the sense organs provide us with information about our surroundings. As a result we are able to perform many varied activities in our everyday life. All these activities must be controlled and coordinated, so that our muscles work together to do them. The control and coordination is carried out by the nervous system.

nervous system ▶

Responses to stimuli may be made by muscles, or by groups of secretory cells called glands. These are together known as effectors. The nervous system coordinates these effectors and receptors, by impulses rapidly conducted around the body by nerves.

glands ▶ **effectors ▶**

Chemical messengers called hormones carried in the blood also coordinate the activities of animals.

hormones ▶

All these parts of the nervous system (brain, nerves, sense organs and hormones) work together to coordinate all the activities of the body in an extremely efficient way.

ITQ1
What are effectors?

Main parts of the nervous system

The nervous system consists of the central nervous system with the brain and spinal cord and the peripheral nervous system with the paired cranial and spinal nerves (figure 12.1). These paired nerves connect the central nervous system with the sense and effector organs.

central nervous system ▶ **peripheral nervous system ▶**

- Name the two parts of the nervous system and the main parts they contain.

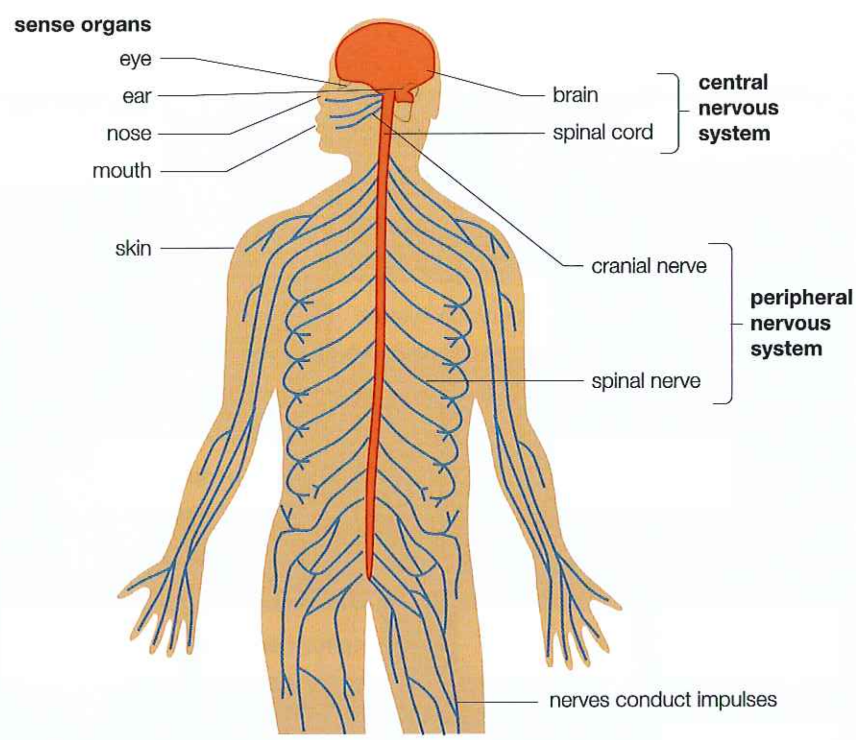


Figure 12.1 The main parts of the nervous system. Central nervous system – brain and spinal cord. Peripheral nervous system – paired spinal and cranial nerves.

Nerves and neurones

Nerves in a dissection appear as white threads. These threads consist of bundles of fibres bound together in one sheath (figure 12.2). A sheath also binds each separate fibre.

neurone ▶
dendron ▶
axon ▶

- How does an axon differ from a dendron?

myelin sheath ▶

nodes ▶

Inside the fibres are the long processes from the cell bodies of nerve cells. A whole nerve cell is called a neurone. The long process that conducts impulses towards a cell body is called a dendron. An axon conducts impulses away from the cell body. The longest cells known are the nerve cells in the neck of the giraffe, since the axons pass right up the neck and back down again!

Axons and dendrons are surrounded by a myelin sheath. This fatty sheath has an insulating effect on the electrical activity inside the neurone. It also causes impulses to pass rapidly by jumping from node to node along its length. The nodes are small gaps in the myelin that increase the rate of conduction of impulses.

ITQ2
What part does the myelin sheath play during a nerve impulse?

The difference between a nerve and a neurone is that nerves are made up of bundles of neurones and appear as white threads. A neurone is a single cell, microscopic, but many are very long because of their axons (see figures 12.2 and 12.3). A stimulated nerve carries the impulse along many axons.

effector neurone ▶

An effector (motor) neurone conducts an impulse outwards from the central nervous system to the effector organ (figure 12.3). The axon has the cell body at one end and a nerve ending at the other end in the muscle, or a gland.

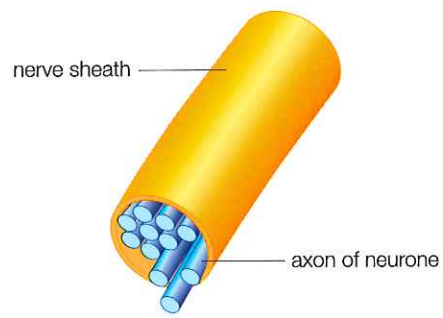


Figure 12.2 A nerve.

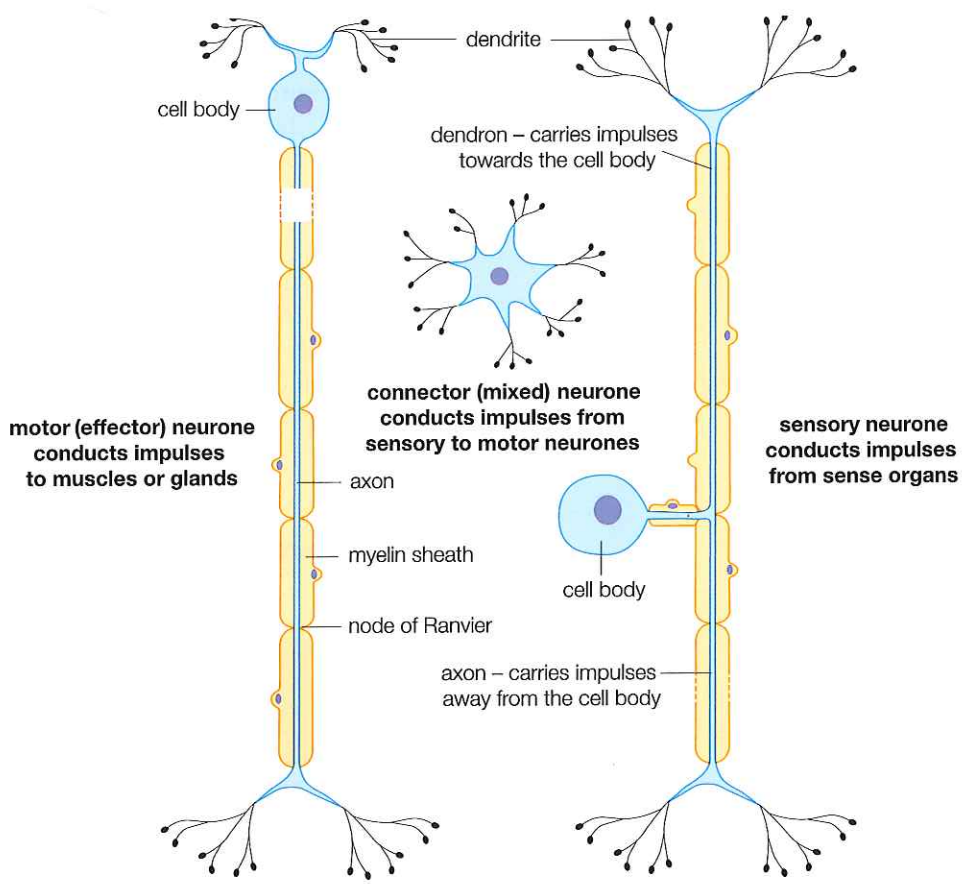


Figure 12.3 A motor, relay and sensory neurone.

ITQ3
What is the difference between motor, relay and sensory neurones?

sensory neurone ▶

• Which way does an impulse pass in a sensory neurone?

ganglia ▶
dendrite ▶
mixed neurone ▶

Sensory neurones conduct incoming impulses from the sense organs to the central nervous system. Sensory neurones differ from motor neurones in that the cell body is not at the end part of the neurone, but in some position along the axon, as shown in figure 12.3. These cell bodies, all together, make swellings called ganglia. Motor neurones have projections from the cell body called dendrites.

A third type of neurone called a mixed neurone (or connector neurone) is found in the central nervous system. These smaller cells connect sensory to motor neurones.

The nature of the nerve impulse

A nerve acts in a similar way to a telephone cable. A message is passed along a fibre from one place to another. When the message arrives the body part responds accordingly.

The nerve impulse is not like an electric current, although such a current applied to a nerve cell will cause an impulse to be passed.

The nerve impulse depends on the membrane of the axon becoming permeable to certain ions. On conduction of an impulse sodium ions pass through the membrane.

The axon of a neurone in the resting condition has a difference in electrical charge between the inside and outside. The outside is positive and the inside negative. An impulse causes the membrane to become permeable to the high concentration of positive sodium ions on the outside. These sodium ions flow in, making the inside positive and the outside negative. These ions affect those next to them along the neurone so that a small local circuit is formed, which causes the impulse to travel.

• What passes through the neurone membrane to create a nerve impulse?

nerve impulses ▶

'all or nothing' ▶

ITQ4
Define a nerve impulse.

Sodium ions are pumped out for the neurone to recover. The charge difference is restored. Hence, nerve impulses are waves of electrochemical changes that travel in one direction along a neurone (figure 12.4).

In *one* neurone the 'all or nothing' principle applies. Once the stimulus is strong enough, an impulse fires and this is not increased however strong the stimulus to the one neurone. However a nerve contains many neurones, so the greater the stimulus, the more neurones are fired. Hence a strong stimulus fires more neurones, creating a stronger response.

Synapses

synapse ▶

• What is found at the junction of two dendrites?

Many of the end or terminal parts of neurones and the dendrites connect with each other in the brain or spinal cord. In fact, there is a tiny gap so they do not quite join. This gap is called a synapse. The impulse crosses this gap from one dendrite to the other as a chemical. The synapses act like junctions and switches, so that messages can be passed to where they are needed. Synapses will be found

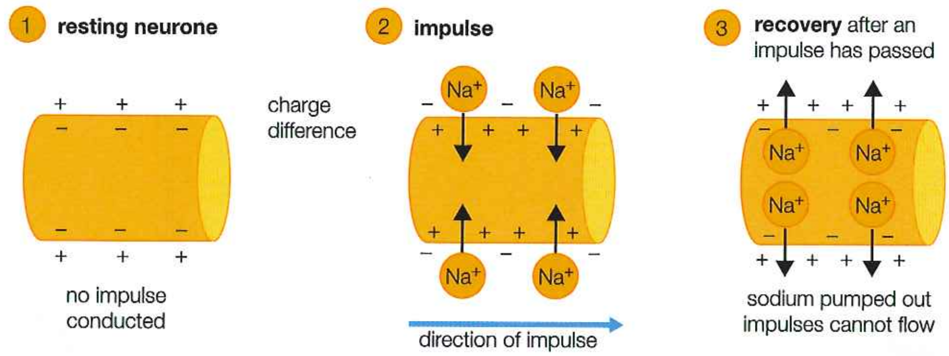


Figure 12.4 Movement of ions making a charge difference across the membrane during the conduction of an impulse.

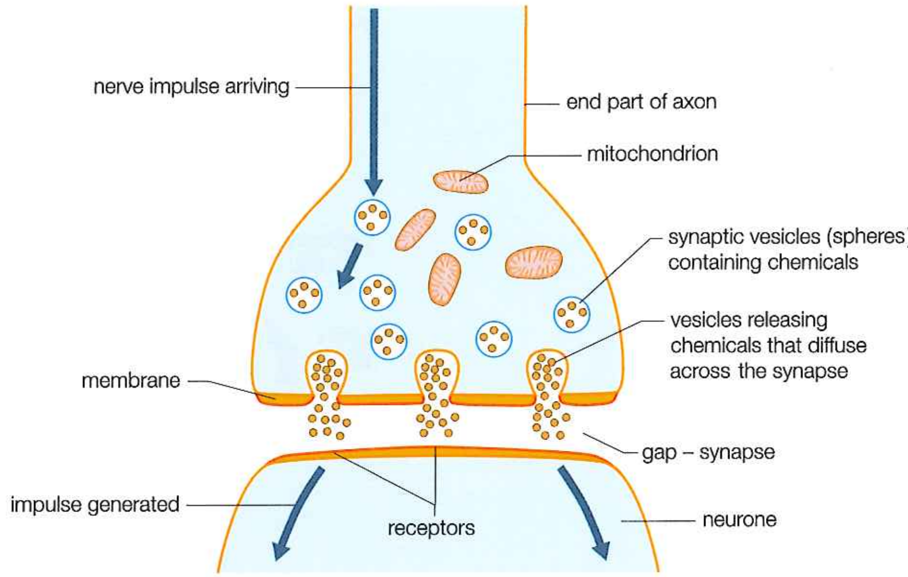


Figure 12.5 The passage of a chemical neurotransmitter at a synapse.

between dendrites of two neurones, or between dendrites and cell bodies to which they are applied.

Transmission across a synapse

neurotransmitter ▶

When the nerve impulse arrives at the synapse it causes the release of chemicals from vesicles. These chemicals are called neurotransmitter substances. One common substance is acetylcholine. This chemical passes across the gap of the synapse. When they arrive at the membrane on the other side, they attach to receptors, which make an impulse flow in the other neurone (figure 12.5).

- In what form does an impulse jump across a synapse?

ITQ5

Some drugs (a) speed up (b) slow down action at a synapse. What effect will this have on behaviour?

You will see in chapter 18 how the neurotransmitter substances and the synapse membranes are the parts affected by drugs. The brain contains countless numbers of synapses so that drugs considerably alter behaviour.

The brain and spinal cord

The brain

The brain acts as a central exchange for information, passed to it from all the sensory receptors in the body. It acts on this information to send motor impulses

Practical activity 12.1
To investigate the preserved brain of an animal

1 A section cut through the whole head of a pig can be examined.
2 Specimens of brains from dissected animals may be available for examination.
3 Examine a model of the brain.

Questions

1 Make drawings and identify the parts mentioned below.
2 What parts on the brains examined are enlarged and how does this reflect the lifestyle of the animal?

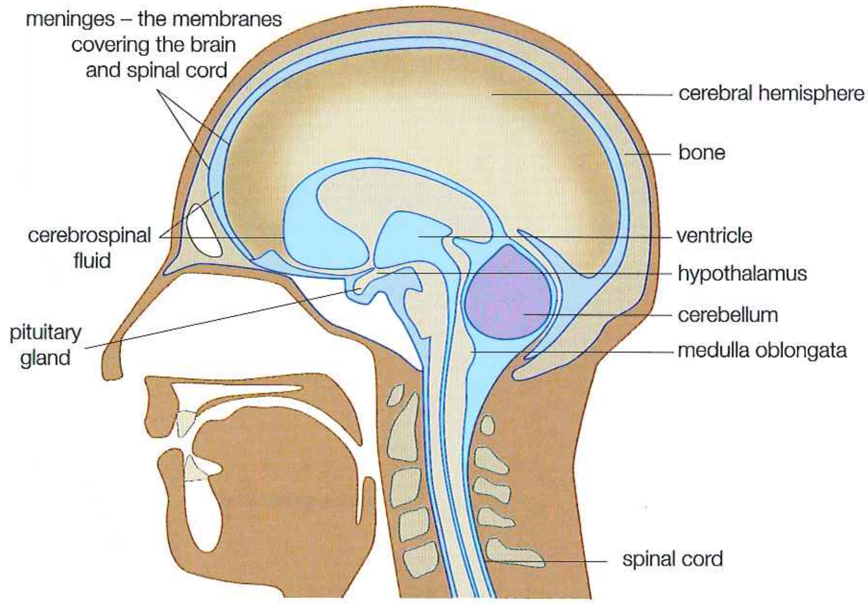


Figure 12.6 A side view of a head and brain showing the main regions.

to control the actions of the effector organs such as muscles and glands. Hence the various actions of the body are coordinated in this way by the brain.

The brain also stores information so that humans have a most remarkable memory. Intelligence in the human brain is in the cerebral hemispheres, which are enormously enlarged compared with those of other mammals.

ventricles ▶

The brain is within the cranium of the skull, which has an opening through which passes the spinal cord (figure 12.6). The brain has four interconnecting chambers called ventricles. These contain cerebrospinal fluid and lead to the central canal of the spinal cord.

medulla oblongata ▶

- What fluid is found in the ventricles of the brain and the central canal of the spinal cord?

The posterior region of the brain is called the medulla oblongata. This contains regions that control involuntary actions such as breathing movements and heartbeat.

Hindbrain

cerebellum ▶ **balance ▶** **posture ▶**

The cerebellum lies behind and above the medulla oblongata. It receives information on the balance of the body from the ear and the muscles and constantly sends out impulses to the muscles to maintain correct posture.

Midbrain

The midbrain is a small region containing nerve fibres, which connect the parts of the hindbrain with the forebrain.

Forebrain

cerebral cortex ▶

The forebrain consists mainly of the cerebrum, made up of the two enormous cerebral hemispheres. The surfaces of these have folds or convolutions called the cerebral cortex. This increases the surface area to contain the enormous number of neurones present. Something like 10 000 million neurones in this region are interconnected by even more synapses, so that the whole structure is very complicated. Impulses passing through these in some way provide us with memory, consciousness and the ability to perform intelligent actions.

memory ▶

- Name the three main divisions of the brain.

intelligence ▶

Intelligence obviously depends on the enormous number of neurones each of which has numerous synapses to connect with other neurones. Unlike connections in a computer, impulses create wave actions between neurones that

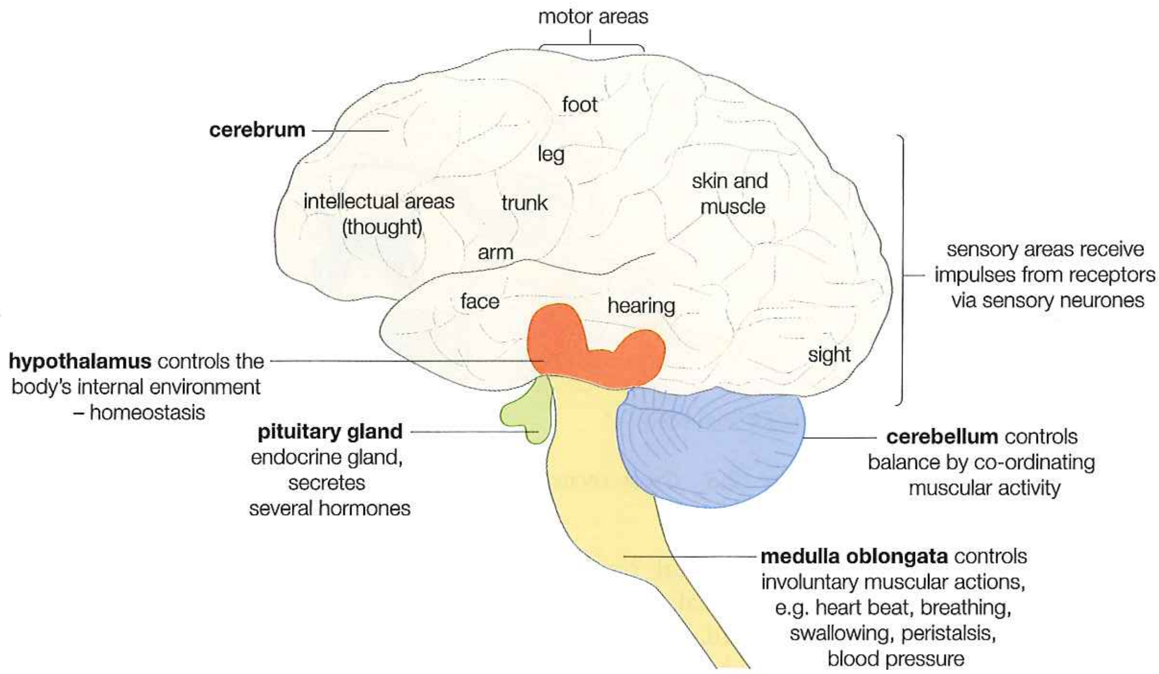


Figure 12.7 Functions controlled by various parts of the brain.

EEG ▶ interfere with each other. This produces waves that can be detected on an EEG (electroencephalograph). These brain wave patterns when abnormal can be used to detect some forms of mental illness.

The actual mechanism for these processes is unknown.

- Which part of the brain controls (a) conscious thought (b) breathing (c) balance?

Certain regions of the cerebral hemispheres are concerned with particular activities, for example, regions are concerned with vision, or hearing, or moving certain muscles (figure 12.7). These regions have been found by examining patients with injury to specific parts of the brain.

hypothalamus ▶ The hypothalamus forms the floor and sides of part of the brain just behind the cerebral hemispheres. Blood pressure, heart rate, peristaltic gut movements and other body functions are coordinated here through the sympathetic nervous system (see below). **pituitary gland ▶** With the pituitary gland situated below the hypothalamus, body temperature and water content are controlled.

osmoregulators ▶ Osmoregulators in the hypothalamus detect changes in blood concentration, releasing more or less antidiuretic hormone (ADH), which causes the kidney to reabsorb more or less water (see page 179).

temperature receptors ▶ Temperature receptors in the hypothalamus send impulses to initiate vasodilation when the blood temperature is high, and vasoconstriction when it is low (see page 176).

The spinal cord

ITQ6
Why is a slipped disc (intervertebral cartilage displaced) painful?

The spinal cord passes from the base of the brain down the vertebral column. The spinal cord acts as a relay system for impulses as well as a centre for coordinating actions.

grey matter ▶ **white matter ▶** Figure 12.8 shows that the spinal cord gives off paired nerves that come from both dorsal (top) and ventral (underneath) roots. The grey matter appears darker because cell bodies of motor and relay neurones are here. The neurones in the white matter run lengthways along the spinal cord. They are wrapped in a white fatty substance and so appear white. The white matter conducts impulses from the brain to the spinal nerves and vice versa.

ITQ7
Which part of the spinal cord passes impulses (a) up and down the body (b) across the body side to side?

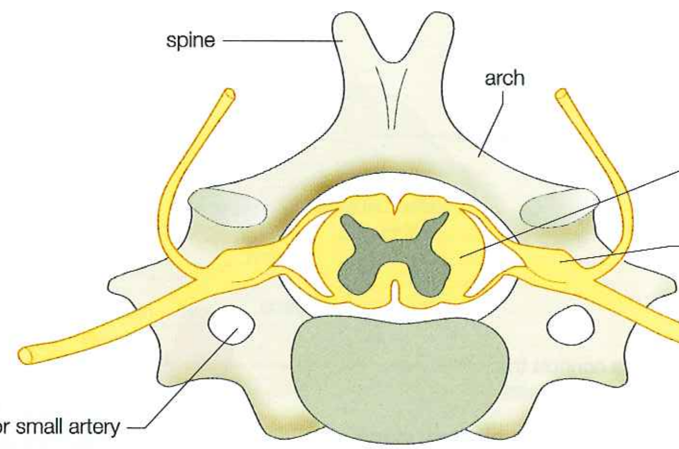


Figure 12.8 Cross-section of the spinal cord within a vertebra.

cerebrospinal fluid ▶

The central canal is continuous with cavities in the brain and contains cerebrospinal fluid. This acts as a transporting system. In the brain, unlike the spinal cord, white matter is found in the centre of the cerebrum and grey matter is around the outside. White matter is mainly the nerve fibres of neurones seen in transverse section, while grey matter contains the cell bodies.

Reflex actions

reflex action ▶

- What is the name given to a quick automatic response to an external stimulus that does not involve the brain?

When we have a sudden sharp pain, such as a prick with a pin, then we very quickly remove our body from that source of pain. This action is called a reflex action. The reflex action is very fast and its purpose is to avoid the body getting damaged. The impulses from the receptor follow a special pathway through nerves, which do not pass to the brain. Hence a reflex action is a quick automatic response to a stimulus, not involving the brain.

While we learn and make conscious decisions to avoid danger, reflex actions are very important to protect the body quickly from danger. Think of the number of occasions reflex actions have saved you from damaging your body.

Spinal reflex action

spinal reflex action ▶

A spinal reflex action (see figure 12.9) gives us a quick response because impulses pass from sense organs in the skin, to the spinal cord and straight back to the effector muscles. This quickly moves the body parts away. This quick response serves to protect the part of the body near the dangerous external stimulus.

When the hand touches a hot plate, temperature and pain receptors in the skin will stimulate sensory neurones to conduct an impulse along the arm, to the spinal cord. Such sensory neurones enter the dorsal (upper) root of the spinal cord. The dorsal root ganglion is a swelling formed from all the cell bodies together.

The neurones enter the spinal cord in the dorsal part of the grey matter. Here the cell bodies form a synapse with the cell bodies of relay neurones. The impulse carried across this synapse passes across the spinal cord in the relay neurone to the ventral (under) part of the grey matter. Here it jumps another synapse to the dendrites on the cell body of the motor neurones.

The motor neurones leave the spinal cord by the ventral root and have nerve endings in muscles of the arm. These are stimulated to contract and remove the hand from the hot plate.

- Name the three types of neurones involved in a spinal reflex.

In its simplest form, such a reflex arc involves three neurones: the sensory, the relay (connector) and the motor neurone. The response is quick, since the information does not have to be passed to the brain. Some impulses do pass from the relay neurone into the white matter and then to the brain. Hence we are quickly aware that the reflex action has taken place.

The first response is not dependent on the brain. A freshly killed frog whose

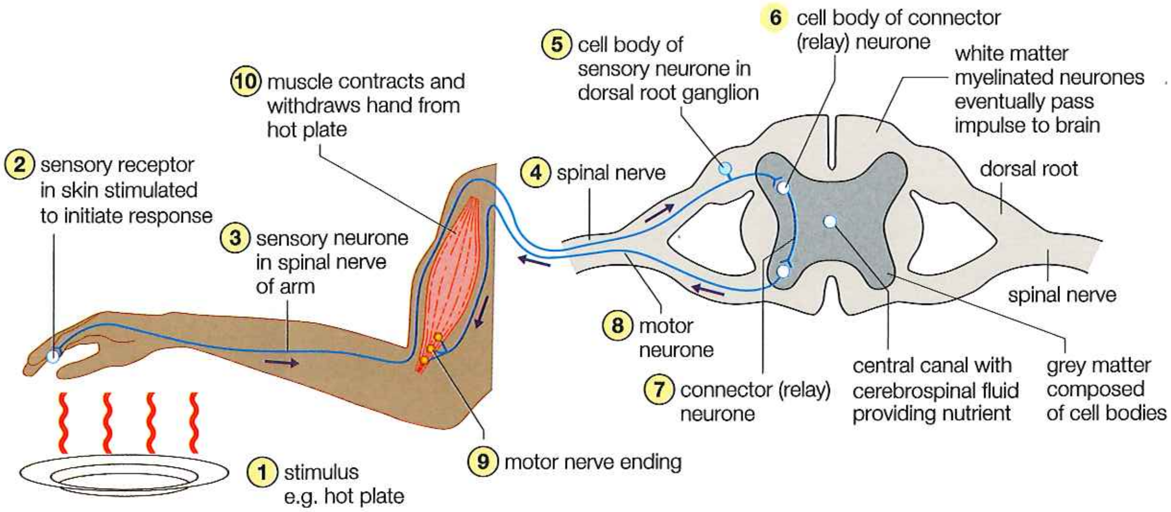


Figure 12.9 A spinal reflex. Steps 1 to 10 show the sequence of actions in withdrawing the hand from a painful stimulus.

ITQ8
List the parts of the nervous system in the order they act, when you withdraw your hand from a sharp pinprick.

brain has been destroyed can withdraw its foot from a pinprick because the body cells are still alive.

knee-jerk reflex ▶ The knee-jerk reflex is convenient for studying a spinal reflex. It differs from that described above because there is no relay (connector) neurone. The stimulus passes directly from sensory to motor neurone. A doctor may perform this to check that your nervous system actions are working properly (figure 12.10).

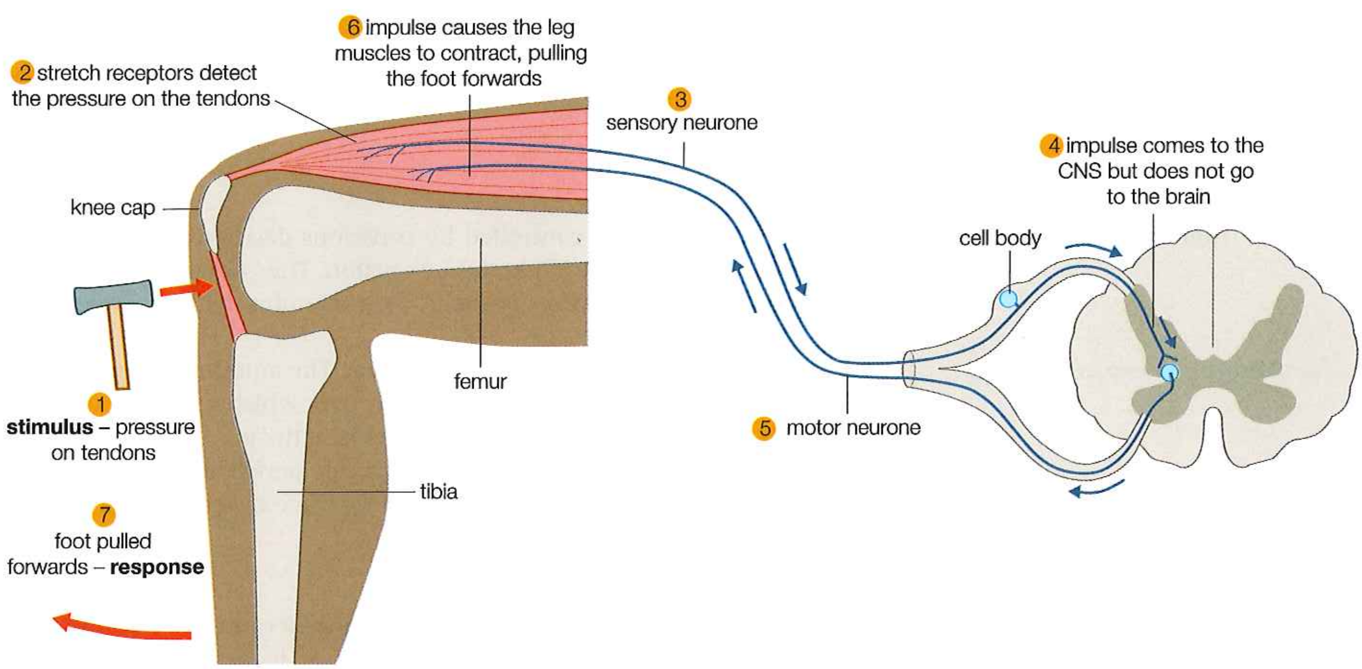


Figure 12.10 The knee-jerk spinal reflex.

Practical activity 12.2
To investigate the knee-jerk spinal reflex

1. Cross one leg over the other in a sitting position so that the top leg hangs freely.
2. A second person gives the free knee a sharp tap with the edge of their hand just below the kneecap.
3. The muscle in the thigh immediately contracts, making the lower leg kick upwards.

Questions

1. List the parts of the nervous system involved from stimulus to response.
2. Design a test to see if this reaction is completely automatic and cannot be stopped.
3. In performing this reaction what exactly is a doctor checking?

Types of action

Voluntary actions

voluntary actions ▶

Voluntary actions are actions such as movements, which you *decide to do*.

For a voluntary action to occur, a nerve impulse has to be started in the brain. You may initiate the action by your own thoughts, as for example if you decide to go for a walk.

Alternatively, you may receive a stimulus, as when somebody calls out your name and you decide to reply. In this case the ear as the receptor passes the information to the brain, which makes the decision to reply or not. It is a voluntary decision because you have a choice.

You may get the stimulus of being hungry, but your decision to eat is voluntary. You may see food you want to eat so this provides a stimulus, but again the decision to eat is made by your brain. (Interestingly, it is unlikely that this is a voluntary action in many animals. Read to the end of this section and see what you think.)

In humans in all these cases, the brain decides whether to respond. If so, the impulse will pass down the white matter of the spinal cord. It will leave the spinal cord along a motor neurone near to the effector muscle that will act to bring about your desired (voluntary) action.

Involuntary actions

involuntary actions ▶

Involuntary actions are not controlled by conscious decisions. Reflex actions as described above are examples of involuntary action. They are not under conscious control of the brain. A reaction is made to a stimulus without involving the brain.

autonomic nervous system ▶

The brain controls some involuntary reactions. The autonomic nervous system controls all the internal mechanisms in the body over which we have no conscious control. We have seen how peristaltic movements of the gut, heartbeat, breathing and the homeostatic mechanisms are unconsciously performed all the time. They are all involuntary actions controlled by the autonomic system and the brain.

Conditioned reflex

Some reactions have to be learned first, but then they can be performed without conscious thought. The child learning to walk, or learning to ride a bicycle, must at first concentrate on voluntary movements. Later these movements can

conditioned reflex ▶

- What type of reaction is used when riding a bicycle?

ITQ9

Name as far as you can the types of action controlling the following events. (a) Moving the hand quickly after a wasp sting. (b) Seeing a wasp and killing it. (c) Walking. (d) Heartbeat at rest. (e) Heartbeat after a fright.

ITQ10

How can a chicken continue to run for a short time after its head has been cut off?

be performed without conscious thought. They are called conditioned reflexes because they have to be acquired through learning. Once learned, conditioned reflexes are controlled by a part of the brain which is not concerned with conscious thought. For example, you do not have to think about how to move your legs when you walk.

These conditioned and unconditioned reflexes are sometimes very difficult to distinguish. For example, when you walk to school, can you work out all your activities involved at the time? Which actions are voluntary and how are they initiated, which are involuntary, conditioned reflexes and which are unconditioned reflexes?

If you ring a bell before feeding a dog on several occasions, a ringing bell makes the dog produce saliva in the absence of food. A reaction has been conditioned.

Practical activity 12.3

A To investigate reaction times

1 The experimenter holds a ruler with the 0 cm between the thumb and finger of the subject resting their hand on a desk (figure 12.11).

2 At random periods of time the ruler is dropped and the subject *visually* watches to catch it as quickly as possible.

3 The distance travelled by the ruler is a measure of the reaction time. Design your experiment to provide a practice period and sufficient trials to give a valid mean (average) result.

4 Now repeat this experiment with the subject blindfolded and the ruler just touching the forefinger. Hence the initial stimulus is now *touch* and a different nerve pathway is involved.

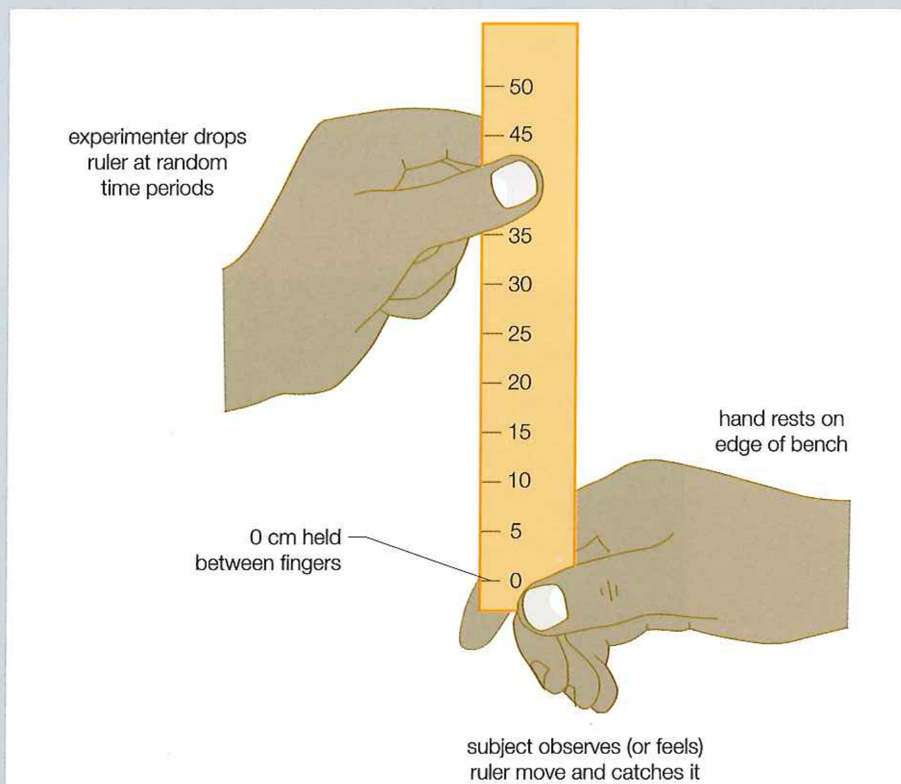


Figure 12.11 To calculate reaction time.

Questions

1 Explain how you designed the trials and recorded the results.

2 Why was a practice period needed and how did you determine the time needed?

3 Compare the response time with the visual stimulus and the touch stimulus.

4 List all the parts of the nervous system through which impulses will pass in this practical activity (both with sight and touch as the stimulus).

5 Compare the reaction times of various members of the class. Is there any correlation with sporting ability (record membership of teams, or ability to perform physical tests), height (measure limbs etc. for distance travelled by impulses), sex, etc?

B Group reaction time estimation

1 A group of about 10 students hold hands in a ring.

2 The experimenter with a stopwatch squeezes the right hand of one subject, who immediately squeezes their left hand. The next subject receive the stimulus to their right hand and squeezes their left hand and so on around the ring until the original experimenter calls out that their right hand has been squeezed.

3 Record the time taken for the stimulus to pass around the ring and divide by the number of subjects to get the mean reaction time. (Again, design some trial experiments.)

Questions

1 Record each part of the nervous system involved in this activity.

2 The total distance moved by the impulse can be measured from person to person, hence calculate the total speed of conduction through the nervous systems of the group.

3 Calculate the average speed through each person as a measure of reaction time.

4 Why can you not calculate the speed of conduction in a neurone from this experiment?

5 List all the variables not controlled, if this experiment is to find the reaction times of individuals.

Reflex actions	Voluntary actions
1 Quick and simple	More complex and variable actions
2 Automatic and involuntary	Not automatic
3 Not under conscious control	Under conscious control
4 Cerebrum (brain) not involved	Cerebrum (brain) starts the action
5 Involves 3 types of neurones: sensory, relay and motor	Involves neurones in the brain, white matter of the spinal cord and motor neurones
6 At one level in the spinal cord	Many levels of spinal cord involved
A **reflex action** is a quick automatic response to a stimulus not involving the brain. A sensory, relay (connector) and motor neurone control it.	
A **voluntary action** is controlled by conscious thought from the brain.	

Table 12.1 Comparison of reflex actions with voluntary actions.

Psychologists, who study human behaviour, have great difficulty in deciding the actual method by which many of the various human reactions are controlled.

The effects of alcohol on the nervous system and on reaction times is described on pages 353–5.

Damage to the nervous system

Damage to the nervous system may be caused by injury (e.g. a car crash), harmful drugs (e.g. heroin), by infection (e.g. infantile paralysis) or degeneration as with age (memory loss). High blood pressure may cause a haemorrhage. Here blood vessels rupture releasing blood into the brain cavities, damaging the neurones.

With such an important system, damage often has permanent tragic effects. Nerves, unlike other cells, do not always regenerate, hence the damage lasts for life. If the particular areas of the brain such as shown in figure 12.7 are damaged, then the part controlled fails.

Hence paralysis may result from a loss of muscle control. Speech, hearing and sight may suffer if the area of the brain controlling them is damaged. Interestingly, experiments on animals show that one incision into the cerebral cortex does not destroy a specific memory. What does destroy memory is the 'amount' of the cortex damaged.

Mental illness

mental illness ▶

Mental illness is when the brain does not work properly so that it seriously affects normal thinking. It may involve a disorder of mood, a loss of memory, delusions, hallucinations and a failure to communicate with other people. The illness is often temporary but may be permanent. Although heredity plays a part, mental illness is frequently associated with drug taking, alcohol and the other diseases induced by human social behaviour. These diseases will be considered in chapter 18.

Figure 12.12 Playing sport regularly helps to reduce stress.

Mental illness often occurs when problems in life seem too difficult to solve. There are many examples of this and getting into debt is one example.

A common social problem in the Caribbean occurs when child maintenance is levied by employers on men who have fathered several children. Such men may 'drop out' from society, become vagrants or tramps and suffer from severe mental illness. Had such men behaved responsibly in the first place, such a social problem would not occur. In all cases the solution is to try to live a life so that stress is avoided. Without stress mental illness is much less common (figure 12.12).

Other forms of mental illness may occur. For example, breathing in lead from petrol fumes damages neurones, causing memory loss. Apart from direct damage to the neurones by injury and disease, factors that affect the neurotransmitter substances and synapse membranes are thought to be a cause of mental illness.

Alzheimer's disease ▶

ITQ11
Define mental illness.

Old age may be responsible for mental illness such as Alzheimer's disease. Neurotransmitter substances in the brain such as acetylcholine and cholinesterase may be altered in different ways. The irreversible brain disorder causes, among other symptoms, memory loss, personality changes, sleeplessness and early death.

neurosis ▶
anxiety disorder ▶

A neurosis is a common form of mental illness caused by anxiety. Anxiety disorders may take the form of phobias such as fear of spiders (arachnophobia), confined spaces (claustrophobia) and so on. These may be minor phobias, in most cases, but in others they can severely affect the quality of life.

depression ▶
suicide ▶
eating disorder ▶

Some people suffer from severe depression. This can be associated with 'mood swings' often due to drug taking. Cases of suicide are also increasing with depression. We have already met the eating disorder anorexia, where individuals starve themselves sometimes to death.

post-traumatic stress ▶

Post-traumatic stress may occur after an emotional experience such as witnessing a violent death, or being raped. This is understandable in such individuals who often relive the experience, becoming both anxious and depressed.

ITQ12
What physiological changes could cause mental illness?

We could describe more, for there are other forms of mental illness, too many to mention here. The physiological response to mental illness, being associated with neurones and synapses, is biological. However, the causes move into the realm of social biology and the psychologist. Human behaviour and mental illness are closely linked. We shall see below that hormones also have a large influence on human behaviour.

Coordination by hormones

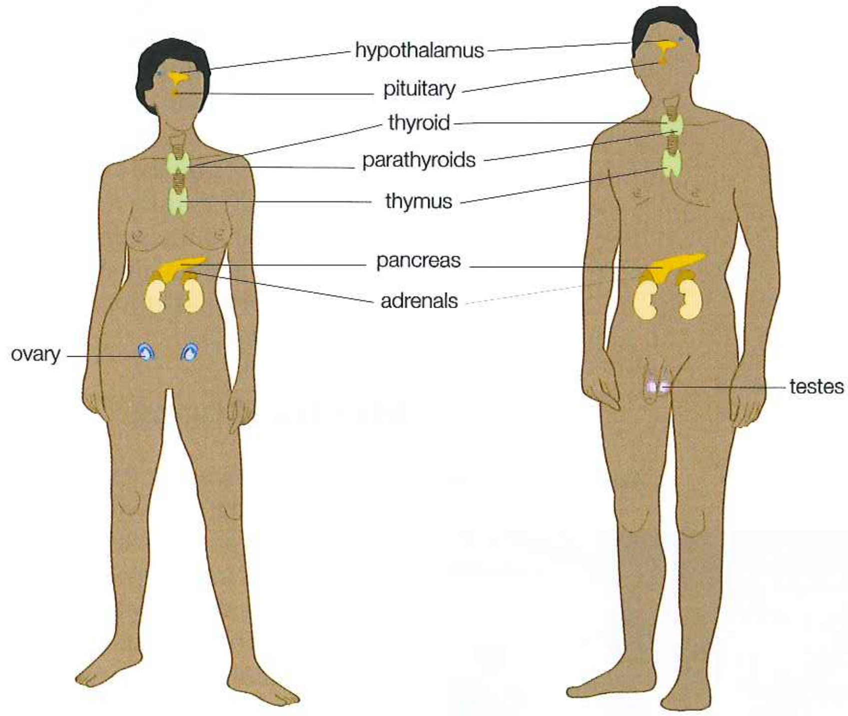


Figure 12.13 The position of the endocrine glands in a man and a woman.

endocrine glands ▶

Hormones are chemical substances, which are secreted from endocrine glands into the blood. These are also called ductless glands because the secretions from these glands pass directly from the cells of the gland into the blood.

The blood transports the hormones to the organs they affect. Hormones are responsible for regulating body processes (figure 12.13). Once used, hormones are changed in the liver to inactive compounds. The kidneys then excrete these.

- What are secreted by ductless glands?

exocrine glands ▶

- What type of gland is a salivary gland and how does it differ from the adrenal gland type?

Exocrine glands differ from endocrine glands because they have ducts along which their secretions pass (figure 12.14). Thus the salivary glands are exocrine glands because ducts carry saliva from them to the mouth. The pancreas is an

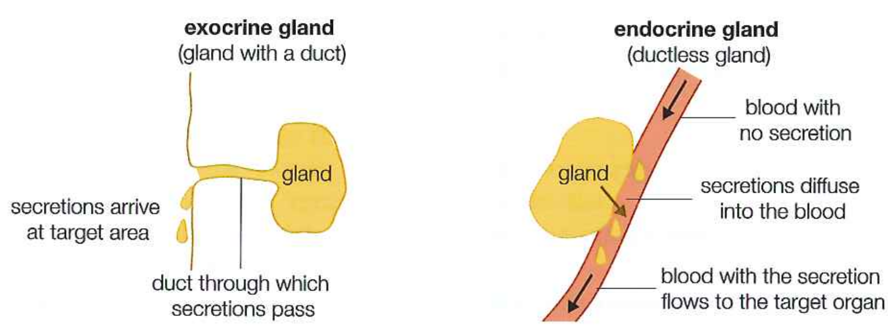


Figure 12.14 The difference between exocrine and endocrine glands.

exocrine gland because it secretes pancreatic juice along a duct into the duodenum. The pancreas is also an endocrine gland, because it secretes insulin and glucagon directly into the blood capillaries.

Adrenaline

adrenaline ▶

- What hormone is released into the blood after a sudden fright?

Some hormones, such as adrenaline, cause quick responses, but most cause slow growth responses. We saw how adrenaline converts glycogen to glucose and affects the rate of heartbeat (figure 12.15). Nicotine from cigarette smoke causes the release of adrenaline. However, it is best described as the 'fright or flight hormone' because it is released in these situations. You will have experienced its effect in your body after a sudden fright. No doubt it will be released before a bungee jump (figure 12.16) and before going in front of an audience to act.

Insulin and glucagon

insulin ▶
glucagon ▶

Insulin from the pancreas controls the blood sugar level, as we saw (page 180). Insulin converts excess glucose to glycogen. Glucagon converts glycogen to glucose. This is quicker acting than the slower growth hormones, but not as quick as adrenaline.

Pituitary gland

pituitary gland ▶

The pituitary gland is found at the base of the brain. It is very important because many of the hormones it secretes, stimulate, or inhibit the other endocrine glands. The hormones it secretes have a large influence on many metabolic activities, including growth. Overactivity leads to gigantism, due to the formation of large bones. Underactivity results in dwarfism.

ITQ13
How could a lack of iodine in the diet make a person lazy and lack energy?

Thyroid gland

thyroid gland ▶
thyroxine ▶

- What hormone is lacking in a cretin?

The thyroid gland lies in front of the trachea at the base of the larynx. The hormone thyroxine is secreted, which affects metabolism, such as the rate of tissue respiration and growth. Lack of thyroxine in a child results in reduced mental and physical growth (figure 12.17). The child is described as a cretin. Thyroxine extracts from animals can cure this condition.

In adults secretion of thyroxine plays an important part in the development of the personality. An overactive gland makes the person overactive and often obsessively hard-working. Underactivity may make a person unusually placid and

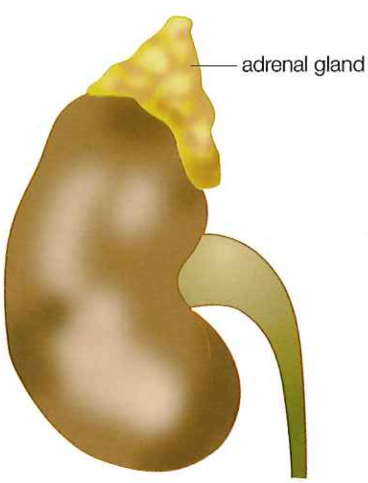


Figure 12.15 The adrenal gland in relation to the kidney.

Figure 12.16 Bungee jumping will cause an adrenaline release from fright and need for quick coordination.

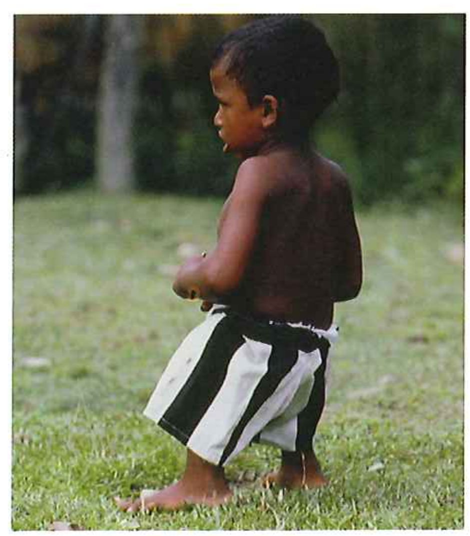


Figure 12.17 Child with stunted growth caused by thyroxine deficiency.

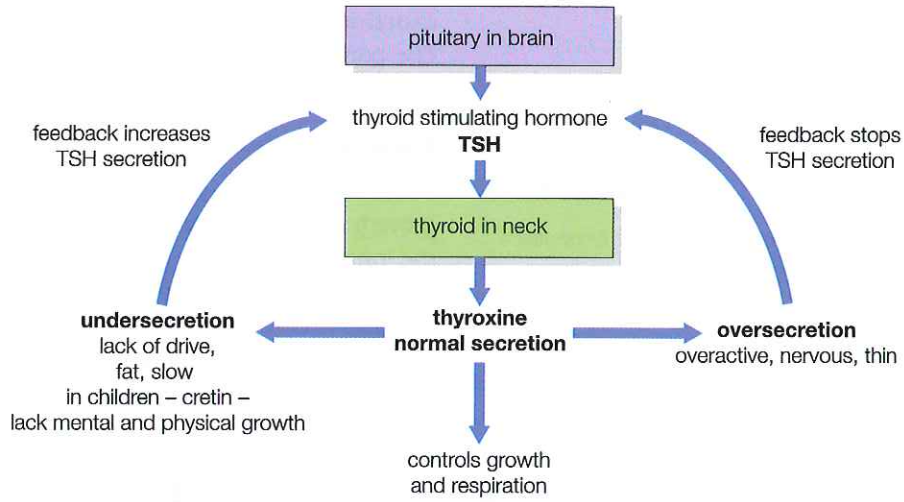


Figure 12.18 Summary of thyroid gland action and control by pituitary gland.

without real energy or drive. The former person is usually taller and thinner than the latter smaller and overweight individual. These are all effects of the influence of thyroxine on the metabolic rate. Thyroxine production is stimulated by thyroid stimulating hormone (TSH) from the pituitary. Thyroxine in turn inhibits the release of TSH so acting as a feedback mechanism (figure 12.18).

- What disease is caused by a lack of iodine in the diet?

We have already noted on page 62 that a deficiency of iodine in the diet results in a swelling in the neck called goitre. Iodine forms a part of thyroxine. A lack of iodine causes the gland to swell in an attempt to make up for the reduced output of thyroxine.

- Name one quick-acting and one slow-acting hormone and explain how they act.

The hormonal and nervous systems work closely together to control the various activities of the body. It has been said that 'we are what our hormones make us'. This is because the activity of hormones has such an influence on our behaviour, as we saw with thyroxine above.

The sex hormones, including oxytocin, oestrogen, progesterone and pituitary secreted hormones, are studied in chapter 13 (see table 13.4, page 241).

Gland	Position in body	Hormone secreted	Response of body to hormone	Abnormal functions
Hypothalamus	brain	several	control homeostasis	mechanisms fail
Pituitary	brain below pituitary	several e.g. TSH	metabolism and growth	growth defects as below
Thyroid	neck	thyroxine	controls growth rate	deficiency causes dwarfism and mental retardation in childhood; in adult, overproduction causes increased metabolism
Pancreas	loop of duodenum	insulin glucagon	sugar to glycogen glycogen to sugar	diabetes
Adrenal	above kidney	adrenaline	glycogen to sugar when high activity	slow responses
Sex hormone	see table 13.4			

Table 12.2 Functions of some hormones.

ITQ14

What similarities are there between hormonal and nervous coordination?

Hormonal coordination	**Nervous coordination**
Message: complex organic chemical	Impulse: charge difference produced by ions
Transport: in blood	membrane of neurone
Speed: slow (except adrenaline)	fast
Effect: long-lasting, may affect growth and many body parts (widespread)	immediate control directed to one part (localised)
Production: stimuli from sense organs affect ductless glands	stimuli from sense organs affect neurone membrane
Main coordination: by pituitary gland	by brain
Disease: metabolic, e.g. growth dwarfism	paralysis or mental illness when damaged
Similarities: Chemicals released at synapses are similar to hormones. Brain and ductless glands control each other. Both coordinate body activity.	

Table 12.3 Comparison of hormonal and nervous methods of coordination.

Summary

- Control and coordination are carried out by the nervous system and by hormones.
- The central nervous system is the brain and spinal cord and the peripheral nervous system is the paired cranial and spinal nerves.
- The white thread-like nerve is composed of many neurones.
- A sensory neurone conducts impulses from the sense organs to the central nervous system; a mixed neurone connects sensory to motor neurones; and a motor neurone conducts impulses from the central nervous system to the effector organ.
- A nerve impulse passes when the neurone membrane becomes permeable to sodium ions, which set up an electrochemical charge difference that passes along the membrane.
- A synapse is a small gap between two dendrites across which neurotransmitter chemicals pass to send on the impulse.
- The hindbrain with the cerebellum coordinates muscles for balance and movement.
- The midbrain connects the parts of the hindbrain with the forebrain.
- The forebrain consists mainly of the cerebrum made up of the two cerebral hemispheres concerned with memory and intelligence.
- A reflex action is a quick automatic response to a stimulus not involving the brain. A sensory, relay (connector) and motor neurone controls it.
- A voluntary action is controlled by conscious thought from the brain.
- Mental illness is the abnormal and often dangerous behaviour caused by damage to the nervous system of the brain.
- A hormone is a chemical secreted by a ductless gland into the blood that carries it to the effector organ.
- Thyroxine from the thyroid glands in the neck controls metabolism and growth.
- Adrenaline from the adrenal glands above the kidneys speeds up heartbeat and breathing.
- Glucagon and insulin from the pancreas control the blood sugar concentration.

Answers to ITQs

ITQ1 Effectors respond to stimuli they receive. They are muscles or glands.

ITQ2 The myelin sheath insulates the electrical activity inside the neurone and allows rapid transmission of impulses as they jump from node to node.

ITQ3 A motor neurone conducts impulses from the CNS to a muscle and has the cell body between a dendron and an axon. A sensory neurone conducts impulses from a sensory receptor to the CNS and has a cell body at the end in the CNS. A relay (connector) neurone connects motor to sensory neurones and is a much more compact cell.

ITQ4 A nerve impulse travels along neurones. They are caused by the neurone membrane becoming permeable to sodium ions, which set up an electrochemical charge difference, which passes along the membrane.

ITQ5 (a) A drug speeding up action at a synapse will create high activity and excitability in an individual. Those that slow down action will cause the person to become lethargic and possibly depressed.

ITQ6 At a slipped disc, the cartilage rubs on the spinal cord causing much pain.

ITQ7 Impulses pass up and down the spinal cord in the white matter. They pass from side to side in the grey matter.

ITQ8 Order of events in the pinprick reflex are: pin stimulates receptor, sensory neurone, relay neurone, motor neurone, nerve ending in muscle, which contracts.

ITQ9 (a) Moving the hand quickly after a wasp sting is an involuntary reflex action involving one level of the spinal cord. (b) Seeing a wasp and killing it is a voluntary action initiated in the brain. (c) Walking is an involuntary action, conditioned reflex, controlled by cerebellum. (d) Heartbeat at rest is an involuntary action controlled by the hypothalamus of the brain. (e) Heartbeat after fright is an involuntary action as above speeded up by the hormone adrenaline.

ITQ10 The brain of the bird is not needed to control the reflex action of walking, controlled at one level in the spinal cord. Receptors in the legs send impulses from the ground by sensory neurones to the spinal cord, which sends back impulses in the motor neurones to move the muscles for the bird to walk. Hence the head and brain are not involved.

ITQ11 Mental illness is the abnormal and often dangerous behaviour caused by damage to the nervous system, generally the brain.

ITQ12 Physiological changes causing mental illness include damage to the neurones, synapses or the neurotransmitter substances in the brain.

ITQ13 Lack of iodine will stop the formation of thyroxine (may cause goitre) that slows down metabolism, making a person lethargic.

ITQ14 Both the hormone and nervous system coordinate parts of the body by carrying messages. They also work in conjunction with each other. Hormones are chemical messengers and chemicals at synapses pass nerve impulses.

Examination-style questions

Multiple choice questions

(Write down the number of the question followed by the letter of the correct answer. You can check your answers on page 417.)

1 The central nervous system consists of the:
A brain and spinal nerves
B spinal nerves and cranial nerves
C cranial nerves and spinal cord
D spinal cord and brain

2 Which part of the brain coordinates muscle responses for balance and posture?
A cerebellum
B cerebrum
C medulla oblongata
D hypothalamus

3 Which part of the brain stores memories of past happenings?
A cerebellum
B cerebrum
C medulla oblongata
D hypothalamus

4 Which statement concerning nerves and neurones is wrong?
A nerves are made up of neurones
B neurones are single cells
C nerves and neurones are surrounded by membranes
D a nerve and a neurone both make greater responses to a stronger stimulus

5 Which of the following hormones acts very quickly?
A adrenaline
B glucagon
C insulin
D oestrogen

6 What occurs during the transmission of an impulse in a neurone?
A an electric current passes along the axon
B the axon becomes less permeable to sodium ions
C sodium ions enter the axon
D the outside of the axon becomes positively charged

7 What passes across the gap of a synapse at the junction between a muscle and a spinal nerve?
A ions
B vesicles
C complex organic chemicals
D an electric current

8 Which of the following is *not* a feature of hormones?
A secreted by ductless glands
B transported by blood
C increase rate of impulse conduction in neurones
D broken down in the liver for excretion by the kidneys

9 What is partly controlled by thyroxine?
A blood sugar concentration
B metabolic rate
C phagocytosis
D lactation

10 What is the most important function of reflex actions?
A to coordinate different parts of the body
B to link the brain with muscle action
C to protect body parts from damage
D to improve learned reactions

Short answer and essay type questions

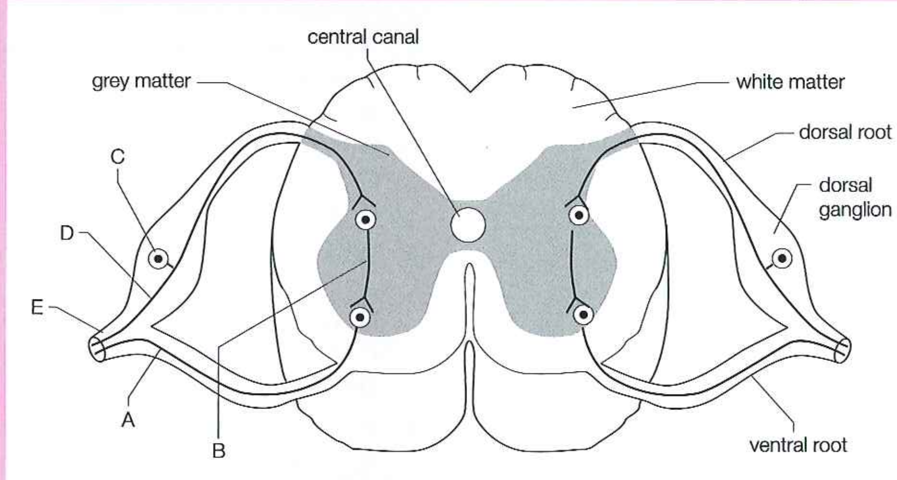


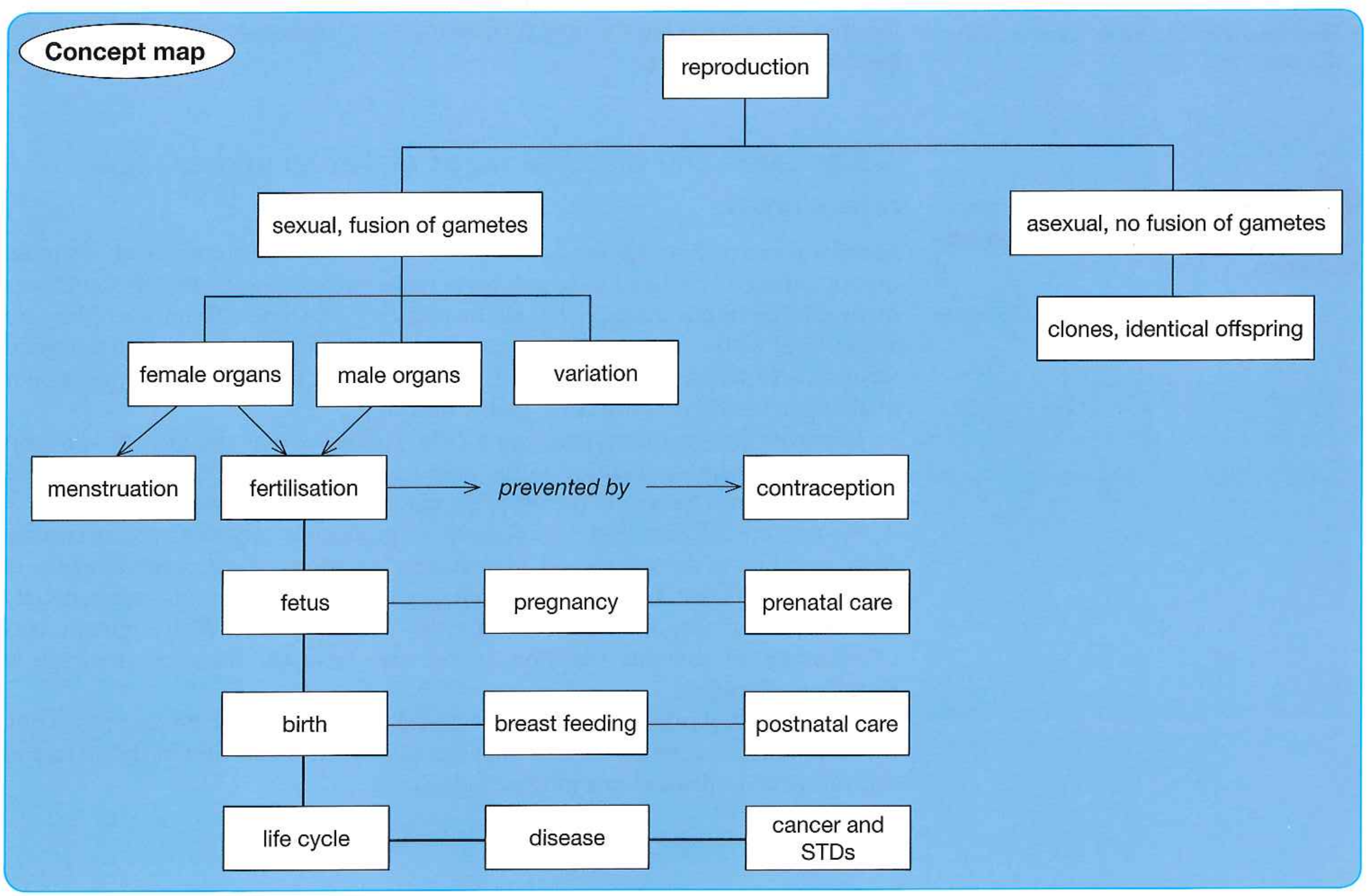
Figure 12.19 Transverse section of spinal cord and nerves.

11 Copy figure 12.19 into your book and show by means of arrows the path taken by an impulse during a reflex action.
12 Name the parts labelled A to E on the diagram.
13 Write down the letters from this diagram in the correct order in which an impulse would pass during a reflex action.
14 Also label on this diagram (a) a synapse (b) the position of cerebrospinal fluid (c) the part conducting impulses to the brain.
15 How does the position of the grey and white matter differ on figure 12.19 from that found in the brain?
16 What is the difference between an exocrine and an endocrine gland?
17 Briefly explain three differences between nervous and hormonal coordination.
18 Describe the sequence of events that take place in the nervous system when the hand is withdrawn from a sharp prick.
19 Briefly describe how the parts of the nervous system are concerned with learning to ride a bicycle.
20 Describe an experiment to measure the reaction time of a person. Explain the sources of error that need to be considered in your experiment.

13 Reproduction

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

- ☑ distinguish between sexual and asexual reproduction;
- ☑ describe the structure and function of the male and female systems;
- ☑ explain fertilisation, implantation, pregnancy and embryo development;
- ☑ describe the birth process;
- ☑ understand the importance of antenatal and postnatal care including the importance of breast feeding;
- ☑ describe the menstrual cycle and sex hormones including the functions of oestrogen and progesterone and the effects of pregnancy;
- ☑ know the stages of human growth and development;
- ☑ explain the importance of family planning;
- ☑ describe the advantages and disadvantages of the birth control methods, natural, barrier, hormonal, surgical;
- ☑ appreciate the reasons for abortion, its advantages and disadvantages;
- ☑ know how breast, cervical, ovarian and prostate cancer are detected and treated.



Sexual and asexual reproduction

reproduction ▶

Babies must be produced for the human species to survive. Reproduction is the process that ensures new individuals of the same species are produced. Humans reproduce sexually while some other organisms produce asexually.

asexual reproduction ▶
sex cells ▶

ITQ1
How does a cell in an organism produced sexually differ from a cell in one produced asexually?

Asexual reproduction does *not* involve the fusion of sex cells called gametes. Parts of the parents form the offspring. These may be structures such as bulbs in plants, or spores in fungi, or buds from the parent, or simple division such as when a fungal yeast cell divides into two (see figure 13.1). Some organisms, such as flowering plants, produce seeds sexually and other parts such as bulbs asexually.

Figure 13.1 Asexual reproduction in yeast – the cell simply divides into two identical cells.

sexual reproduction ▶
gametes ▶
sperm ▶
ovum ▶
fertilisation ▶
zygote ▶
embryo ▶

Sexual reproduction requires a male and female pair to produce different types of gametes (sex cells). The male gamete is called a sperm (plural spermatozoa) and the female gamete is called the ovum (plural ova). These two gametes fuse (join) during fertilisation. Fusion of the gametes forms a single cell, the zygote. The zygote then divides into many cells forming the embryo. The embryo develops into the fetus and baby.

placenta ▶

- Name the process involving the fusion of gametes and what is produced?

In humans, the young develop inside the body of the mother, where they are of course better protected. A special organ called the penis in the male assists internal fertilisation. This introduces the sperms into the female. The embryo obtains nutrients from the mother through a structure called the placenta. After birth, the mother provides food in the milk suckled from her mammary glands. This ensures good care of the young.

Advantages and disadvantages of sexual and asexual reproduction

ITQ2
List the advantages and disadvantages of asexual reproduction.

clones ▶

Asexual reproduction has the *advantage* of producing large numbers of offspring, quickly. There is no need to search for a mate with all the courtship sometimes involved. The disadvantage is that all the offspring are clones. That means they are all identical with each other. This is an advantage if the parent had desirable good features because all the offspring will be the same. A disadvantage is that a poor quality parent will produce poor quality offspring.

However, the major *disadvantage* for the species is that the lack of variation produces all offspring identical to the parents. This means if the environment or other conditions change, all the offspring may suffer, or be destroyed.

Sexual reproduction has the *advantage* of producing variation, which ensures some members of the species will adapt to new situations. The genetic variability of the species increases. This means that although poor quality parents may generally produce poor quality offspring, some may be of better quality. With large numbers of offspring, all showing variation, a few may have the features to survive if conditions change.

Human sexual reproduction has the added advantage of the mother protecting the fetus and it can be born much later on, fully developed. After birth the care of the young takes place over a long period of time.

ITQ3
List the advantages and disadvantages of sexual reproduction.

The *disadvantages* of sexual reproduction include the loss of energy and time in searching for a mate and courtship. Fewer offspring are produced and the development is slow. The variation, although advantageous to the species, means sometimes parents with good qualities may produce poor quality offspring.

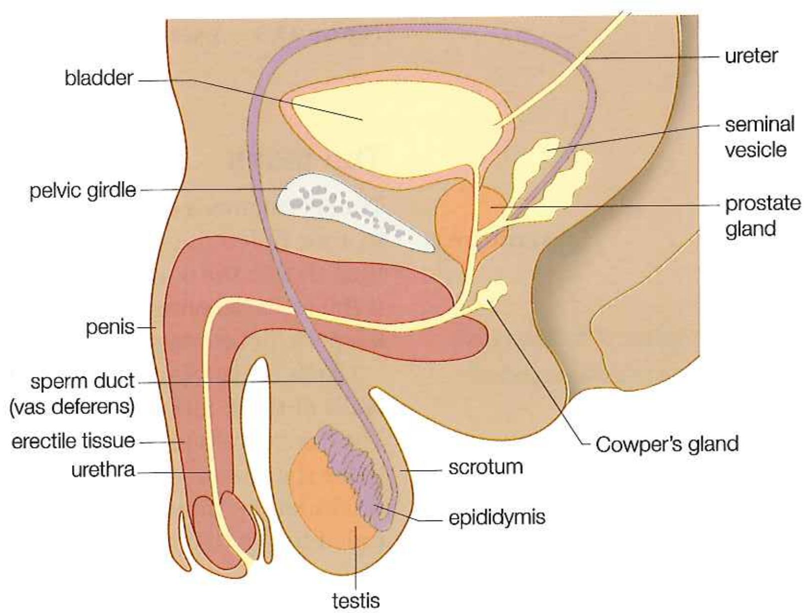
The gametes contain half the number of chromosomes found in all other body cells in their nuclei. Therefore, when fusion takes place, chromosomes from two individuals are combined in one cell. This restores the normal number of chromosomes with genes from both parents (see chapter 14).

The male reproductive system

The purpose of the male reproductive organs (figure 13.2) is to make spermatozoa and put them into the female system.

ITQ4
Which part shown on the diagram of the male reproductive system transports (a) urine only (b) sperm only (c) urine and sperm?

(a)



(b)

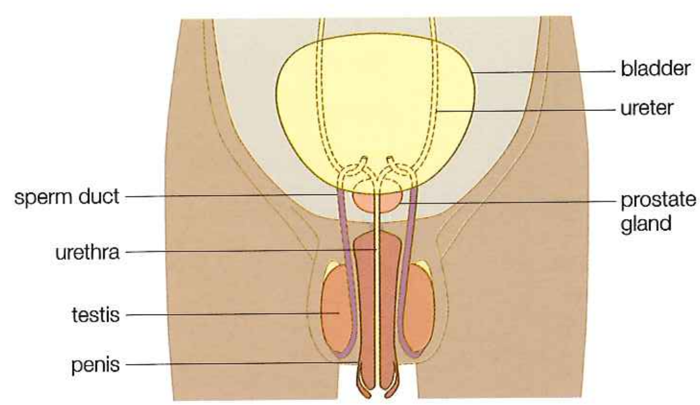


Figure 13.2 The human male reproductive system in sectional views: (a) side (b) front.

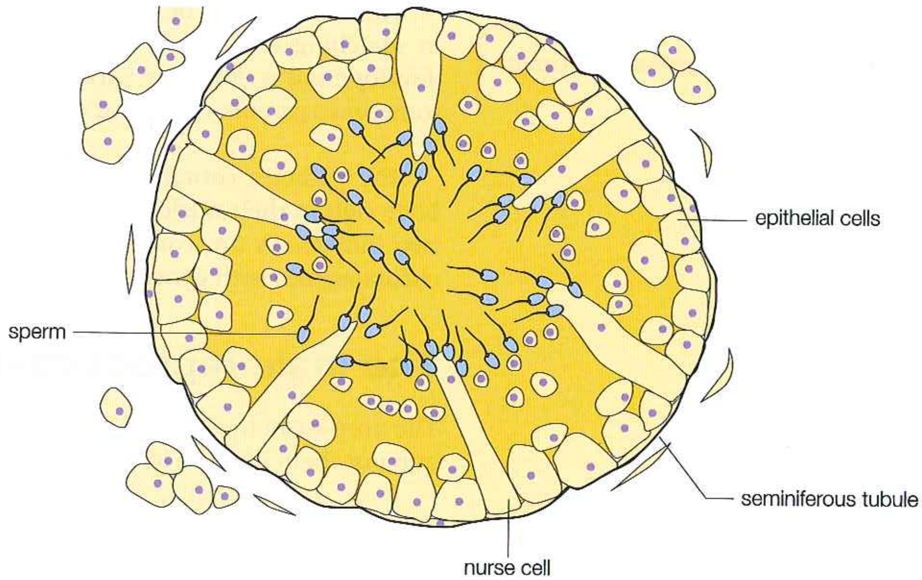


Figure 13.3 A section through one seminiferous tubule from the human testis.

The testis

scrotum ▶

- Why is the scrotum outside of the body cavity?
- What provides nutrient for developing sperm?

The spermatozoa are made in the two testes, which are held outside the body cavity in a sac called the scrotum. The temperature in the scrotum will be slightly lower than that in the body cavity and this is better for the development of spermatozoa. If the testis becomes cold, muscles in the scrotum pull them nearer to the body to keep the developing sperm warm.

Each testis (figure 13.3) consists of a mass of coiled seminiferous tubules. The walls of these tubules contain dividing cells, some of which grow into the sperm. The 'nurse' cells provide nutrient for the developing sperm. When fully developed, these spermatozoa are released into the centre of the tube and pass along it. The seminiferous tubules join to form a coiled tube at the outer edge of the testes, called the epididymis. Here the sperm mature and may be stored for a time.

epididymis ▶

- Where are sperm made and stored?

Structure	Function
testis	makes sperm
epididymis	stores sperm
scrotum	suspends testis outside body cavity at lower temperature
vas deferens/sperm duct	transports sperm to urethra
Cowper's gland prostate gland seminal vesicle	secrete seminal fluid containing nutrients and enzymes which activate sperm
urethra	transports sperm and urine
urethra muscle	contracts to ejaculate sperm
erectile tissue	makes penis stiff
penis	inserted into vagina during copulation

Table 13.1 Structure and function of the male reproductive system.

Passage of spermatozoa

vas deferens or sperm duct ▶

From the epididymis, the spermatozoa are moved along a muscular tube called the vas deferens or sperm duct. The vas deferens from each testis passes into the abdomen, loops over the ureter from the kidney and joins the urethra just below its connection to the bladder. Consequently, the urethra transports both spermatozoa and urine at different times. The urethra passes down the penis and opens at the end that is covered by the foreskin (prepuce). Some males have this removed by circumcision (see page 305).

foreskin ▶
circumcision ▶

seminal vesicles ▶
prostate gland ▶
Cowper's gland ▶

Just before the vas deferens joins the opposite one, they receive a duct from small glands called seminal vesicles. Just below this point, the urethra passes through the prostate gland and a little further down receives a duct from the Cowper's gland. The seminal vesicles, prostate gland and Cowper's gland secrete fluids, which together with the sperm make up the seminal fluid. These fluids contain nutrients and enzymes, which activate the spermatozoa, providing also a medium in which they can swim.

ITQ5
Name all the parts of semen saying where they are produced.

The female reproductive system

ovaries ▶
oviducts ▶
uterus ▶

The ova are produced in the ovaries that are found one at each side of the abdominal cavity (figure 13.4). They are small oval organs held by ligaments. The oviducts lead from the ovaries to the uterus. Near the ovary, the oviducts widen so that they

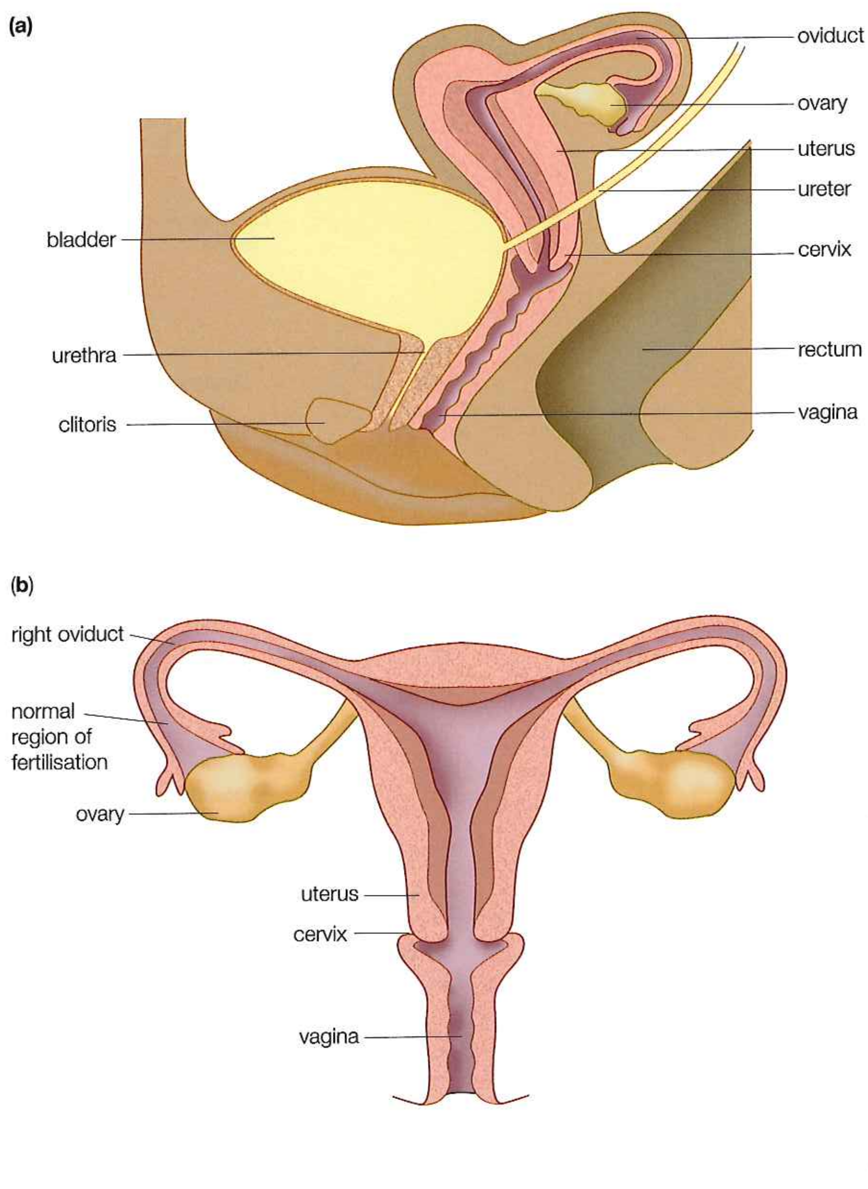


Figure 13.4 The human female reproductive system in sectional views (a) side (b) front.

• Where are ova produced?

form a kind of funnel almost touching the ovary. This funnel will collect the ova, which are shed from the ovary. Cilia within the oviduct beat to cause liquid to flow and so transport the ova along the tubes.

cervix ▶ The uterus is a pear-shaped structure. The oviducts enter on either side of this wide portion of the uterus. The lower end of the uterus, the cervix, consists of a ring of muscle closing the uterus where it leads to the vagina, which with the

vulva ▶ urethra opens to the outside at the vulva.

hymen ▶ A woman who has never had sexual intercourse (called a virgin) has an intact hymen. This is a thin membrane partly across the opening of the vagina. However, the hymen may also be broken by strenuous physical activity such as cycling. Thus some virgins lack an intact hymen.

The ovary

The epithelium of an ovary encloses a mass of connective tissue and ova in various stages of development. Tens of thousands of potential ova are already present at birth. Only about 400 of these will develop fully, at the rate of one a month during a woman's life between the ages of about 14 and 45. Ova develop inside follicles.

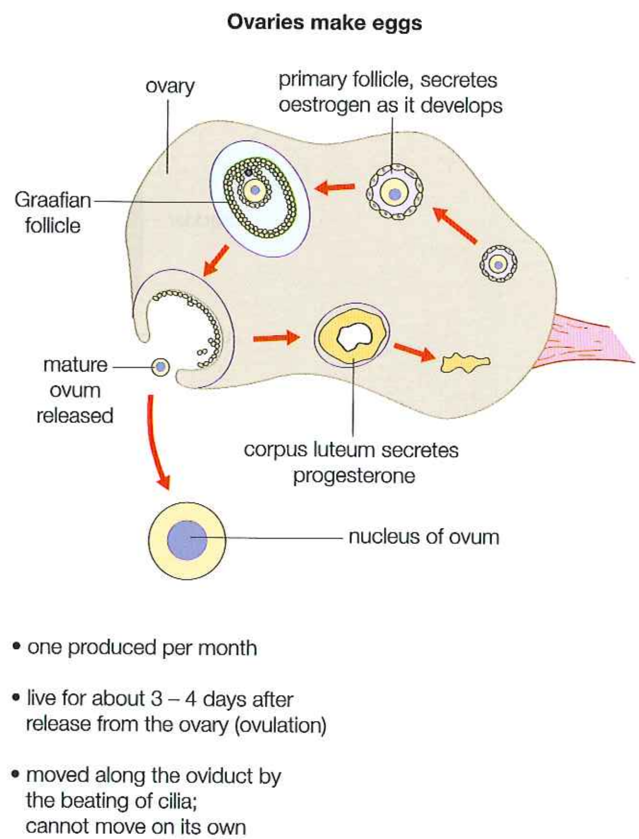


Figure 13.5 The ovary with ova in various stages of development and one released.

graafian follicle ▶

ovulation ▶
corpus luteum ▶

• What is formed when the ovum leaves the follicle?

oestrogen ▶

The more mature follicle is called a graafian follicle. When ripe it moves to the surface of the ovary where the follicle releases the ovum into the funnel of the oviduct (figure 13.5). The release of an ovum, called ovulation, is under hormonal control (see page 241). The follicle that has shed the ovum forms a corpus luteum. This breaks down unless pregnancy occurs.

During pregnancy the corpus luteum enlarges and secretes hormones. The follicles of the ovary secrete the hormone oestrogen, which controls the development of the female secondary sexual characteristics such as breasts and the distribution of fat. These characteristics are those that, apart from the sexual organs, distinguish male from female. Oestrogen also prepares the uterus wall and controls menstruation.

Structure	Function
ovary	produces ova (eggs)
oviduct funnel	collects ova released
oviduct	cilia/fluid move ova down; fertilisation occurs in upper part
uterus	where fertilised egg develops; fetus supplied with nutrients
vagina	receives penis at copulation; passage for baby at birth
vulva	surrounds opening

Table 13.2 Structure and function of the female reproductive system.

Fertilisation and implantation

Fertilisation

sexual intercourse ▶

ITQ6
Explain how the penis becomes erect for copulation.

The fusion of a sperm (figure 13.6) with an ovum occurs within the oviduct. This first requires the process of sexual intercourse. When a man becomes sexually excited, the penis becomes erect and stiff. This is due to an increase in blood pressure in the erectile tissue spaces surrounding the urethra. The pressure increases because arteries supplying the tissues dilate as the veins constrict.

The penis is inserted into the vagina of the woman and movement causes ejaculation of semen into the vagina. Ejaculation is brought about by contraction of the muscle surrounding the urethra. This expels semen through the urethra into the vagina.

ITQ7
Construct a table with headings *sperm* and *ovum* listing the similarities and differences.

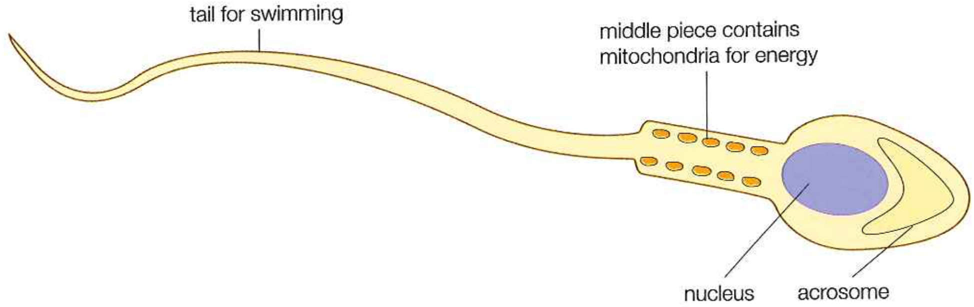


Figure 13.6 A human sperm.

Figure 13.7 Male spermatozoa are attracted to the female ovum before fertilisation.

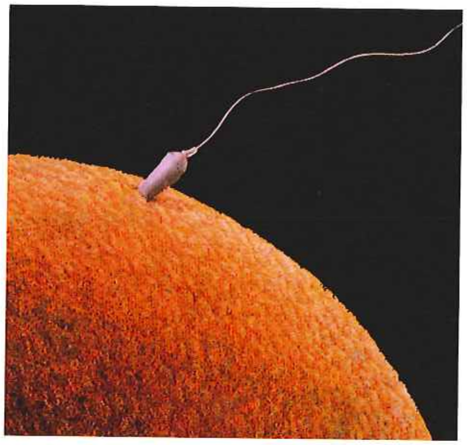


Figure 13.8 A sperm penetrating the ovum at fertilisation.

- Name the process when a sperm penetrates an ovum.

ITQ8
List the parts passed in the journey taken by a sperm from its point of production until it forms a zygote.

About 3 to 5 cm^3 of semen is expelled, containing between 180 and 500 million spermatozoa. The uterus of the woman also contracts and some of the semen is moved into the cavity of the uterus. The spermatozoa then swim up the oviduct. If an ovum is moving down the oviduct, one of the spermatozoa may enter head first, losing its tail as it does so (figure 13.7). The acrosome produces enzymes to help penetrate the ovum. Only one sperm is capable of entering into one ovum (figure 13.8), due to a chemical change at the membrane surface immediately after penetration. The resulting zygote has the contents of both male and female nuclei, which fuse. Each parent, therefore, contributes an equal part, in the form of one nucleus, towards the formation of the zygote.

Implantation

progesterone ▶

ITQ9
What does the hormone progesterone do?

implantation ▶

- Name the process when the fertilised egg passes into the wall of the uterus.

If fertilisation occurs, the corpus luteum continues to secrete the hormone progesterone, which prepares the wall of the uterus to receive the zygote. The uterus wall thickens. The blood supply to the wall increases. The zygote divides into a ball of cells on its way down the oviduct and sinks into the wall of the uterus. This process is called implantation (figure 13.9).

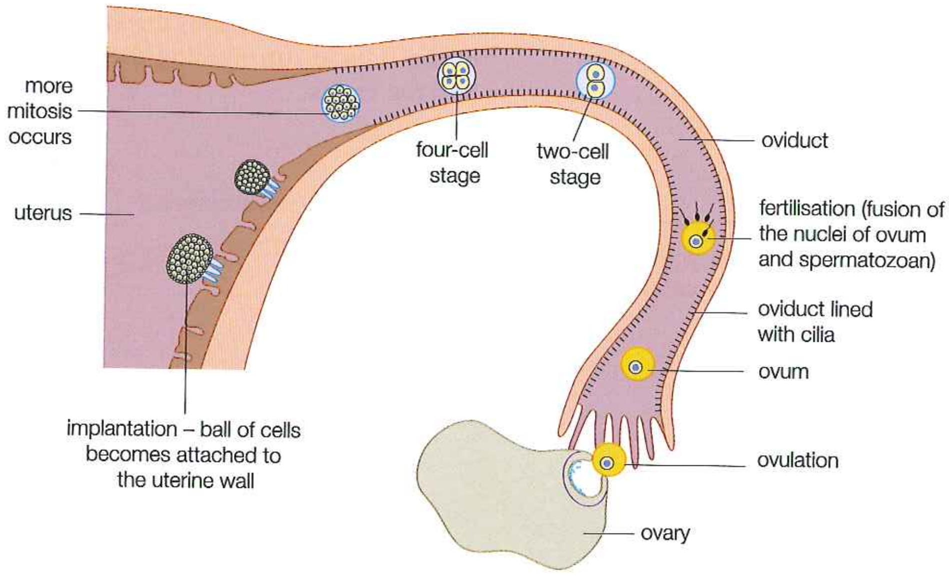


Figure 13.9 Human fertilisation and implantation (zygotes not to scale).

Practical activity 13.1
Examination of the gametes

1 Examine prepared slides of spermatozoa and ova under the microscope.

Questions

1 Make labelled diagrams of the sperm and ova.
2 Explain the function of the tail, mitochondria, acrosome and nucleus of the sperm.

Pregnancy, birth and the new baby

Pregnancy

The thickened wall of the uterus in which the fetus is embedded is called the placenta (figure 13.10). This region develops a rich supply of blood capillaries

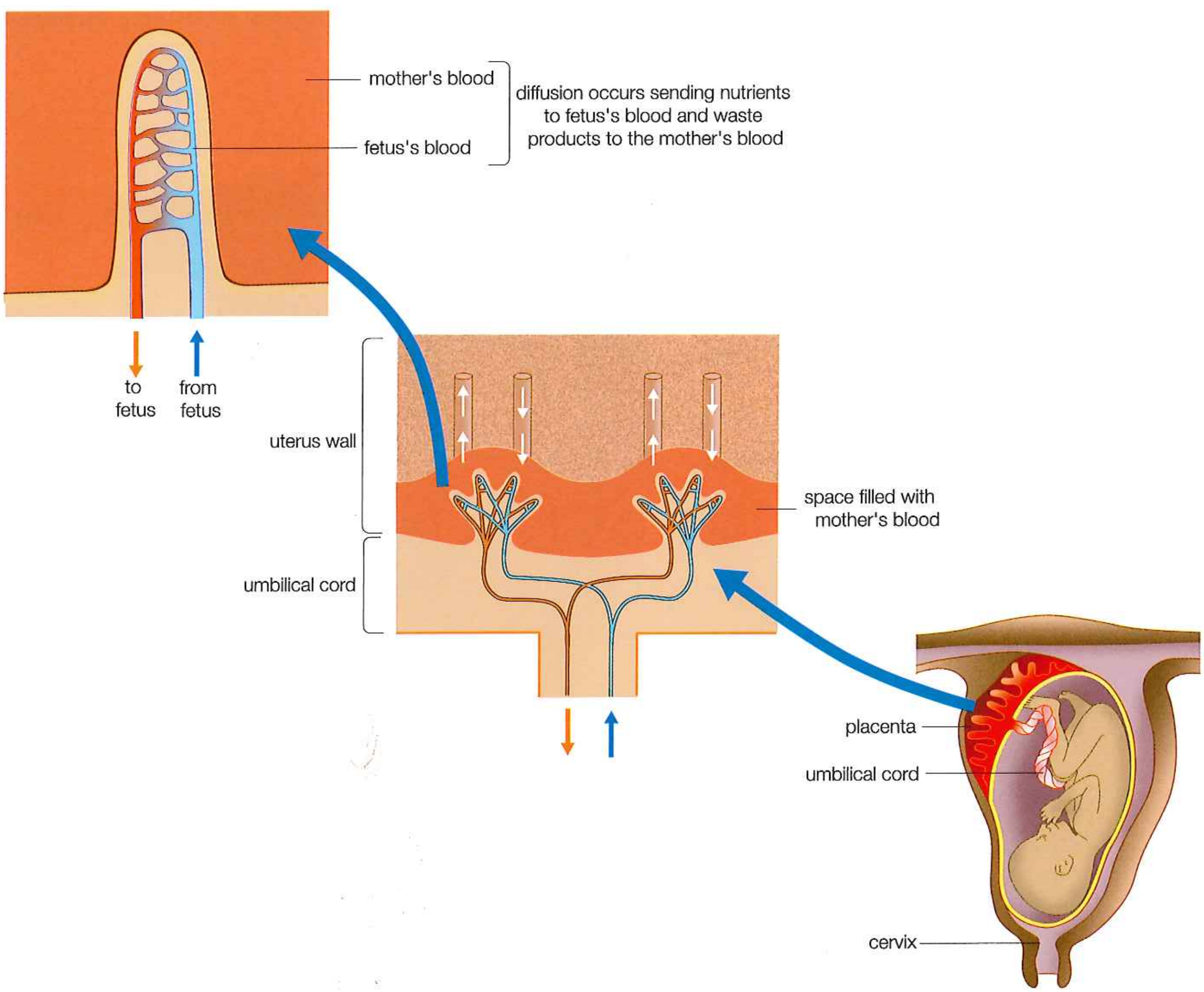


Figure 13.10 The human placenta and its role.

chorionic villi ▶

- What feature is shared by chorionic villi and the villi of the ileum?

- Name three dangerous substances that may cross the placenta.

ITQ10

In table form with headings *maternal artery* and *maternal vein*, list the substances passing in and out of the placenta to the fetus.

umbilical cord ▶

amnion ▶

- How does the amnion protect the fetus?

under the influence of two hormones, oestrogen and progesterone, from the ovary. Outgrowths from the embryo called chorionic villi pass into this region and become surrounded by maternal blood. Note the similarity in name and structure between the villi in the small intestine and the chorionic villi here. Both have folds increasing the surface area for absorption.

The complete placenta is formed mainly from the embryo and partly from the mother's tissue. There is no joining of the maternal and fetal blood capillaries. A thin layer of cells acts as a barrier, separating maternal and fetal red blood cells. Unfortunately nicotine, alcohol, some other drugs and some pathogens do pass across the placenta to cause harm (see below).

Food nutrients and oxygen diffuse from the maternal blood capillaries to those of the embryo, while carbon dioxide and other waste materials diffuse from the embryo to the mother.

Capillaries in the placenta are joined to an artery and vein, which pass through a structure called the umbilical cord. The cord runs from the embryo's abdomen to the placenta.

Protective membranes form around the embryo. The amnion makes a sac of water, which acts as an excellent shock absorber (figure 13.11). The water distributes pressure evenly around the fetus. This allows the young fetus to move its limbs from the age of about 16 weeks onwards.

In fact, after two months, the human form of the fetus is recognisable (figure 13.12) and at three months the sex can be seen. The remaining time is mainly for growth of the fetus (figure 13.13). Birth follows about nine months after fertilisation.

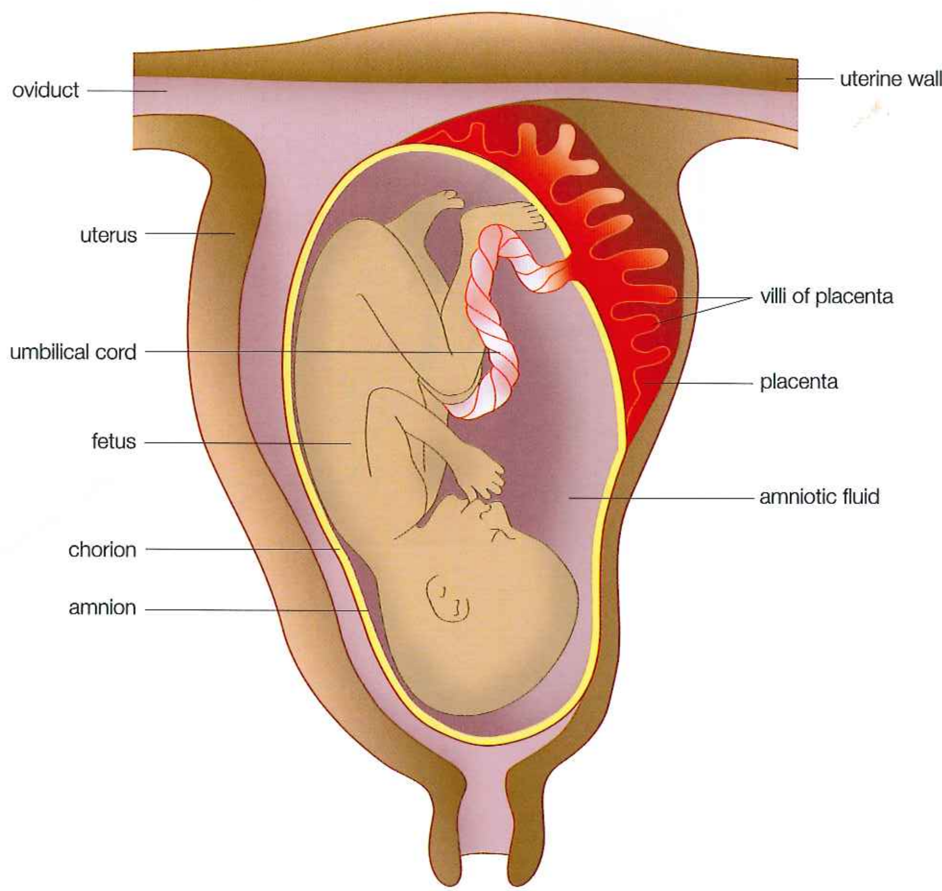


Figure 13.11 Fetus a few weeks before birth – note the placenta, umbilical cord and amnion.

Figure 13.12 An embryo at 4 to 5 weeks old.

Figure 13.13 Stages in the development of the embryo and fetus in the uterus.

Part	Function
uterus wall	muscular for contraction at birth, protects fetus
amnion	membrane enclosing fluid, protecting fetus from shock and allowing movement
umbilical cord	carries nutrients in vein and waste in artery
placenta	contains villi, formed from fetus and mother, acts as a barrier for blood, bacteria etc.
villi	large surface area for exchange of materials between blood of mother and fetus

Table 13.3 Functions of parts during pregnancy.

Birth

stage 1 ▶
oxytocin ▶

Contractions of the muscles of the uterus start stage 1 of the process of labour to push the baby out. The baby stimulates the maternal pituitary to make the hormone oxytocin, which starts this involuntary process. Rhythmic contractions of the uterus cause the amnion to break and the fluid within it passes out. These contractions cause further release of oxytocin as a positive feedback mechanism (see page 178).

stage 2 ▶

Stage 2 – increasing contractions of the uterine muscle push the baby through the cervix and then the vagina.

stage 3 ▶

- What happens in the three stages of birth?

Stage 3 – finally the baby is expelled head first (figures 13.14 and 13.15). The mother bending forward, holding her breath, aids this, to push the diaphragm on top of the uterus.

After birth, the umbilical cord is cut and tied so that the remains form the navel on the abdomen. The placenta and membranes are shed from the mother and are called the afterbirth.

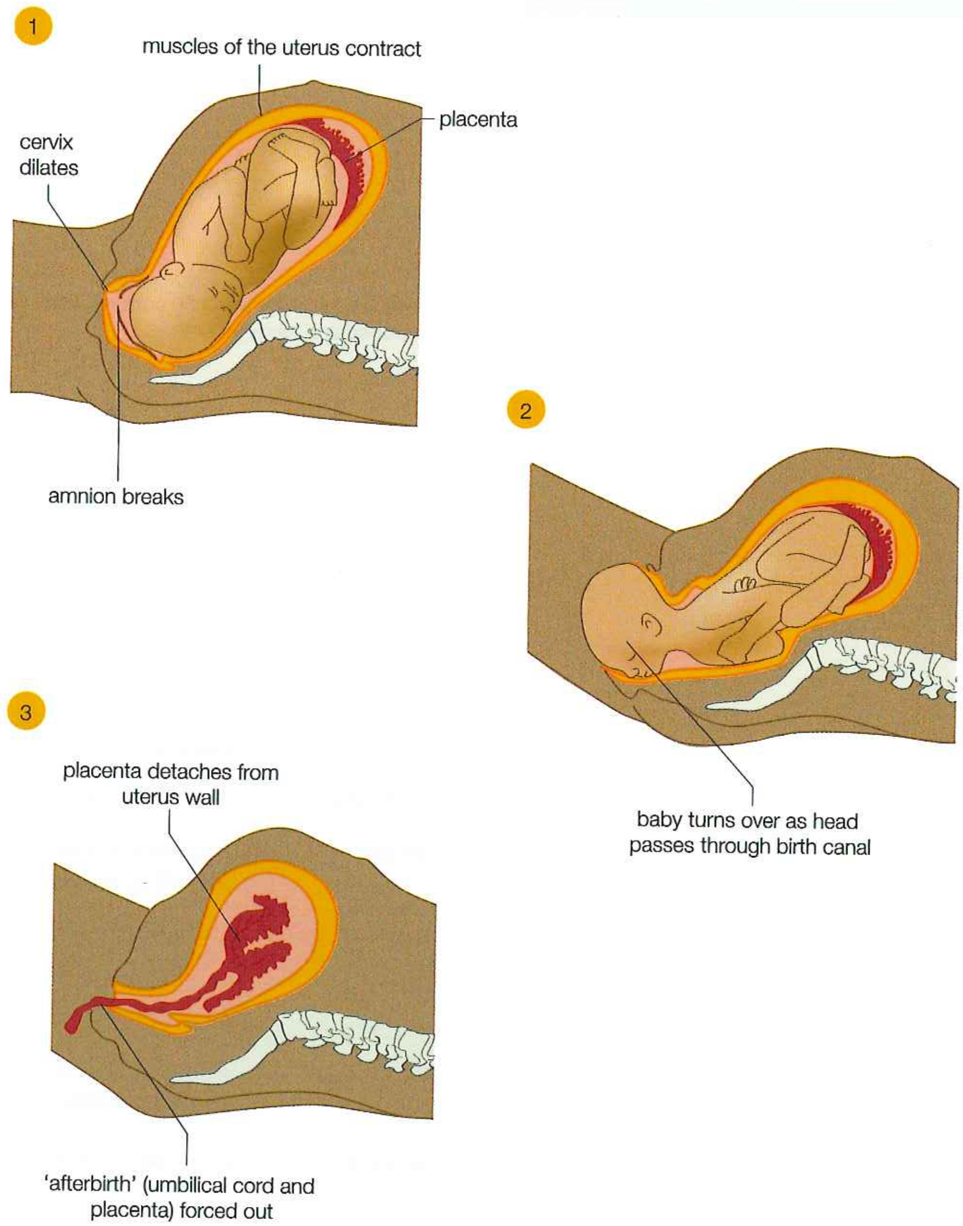


Figure 13.14 Three stages of birth.

Figure 13.15 A newborn baby.

Breast feeding

During pregnancy the mammary glands enlarge and become prepared to secrete milk. Shortly after birth, the baby will suck at the nipples, which stimulates the mother to release milk. The production of milk is called lactation and is induced by the hormones (e.g. prolactin) from the pituitary. Such breast feeding continues until the baby can take in solid food.

lactation ▶

weaning ▶

Weaning the child involves gradually changing the diet from mother's milk to other foods. Breast feeding ensures maternal care from birth. The milk also contains antibodies from the mother, giving passive immunity. It also contains all the essential nutrients except iron (see pages 71 and 315). The first breast milk produced is called the colostrum. This is particularly rich in antibodies to protect the baby from infections and in nutrients for growth.

colostrum ▶

- What does breast milk contain from the mother to provide immunity?

Antenatal and postnatal care

antenatal care ▶

Antenatal or prenatal care is the care and advice needed during pregnancy for the mother along with checks on the fetal growth.

The mother is given advice on a healthy diet (see page 67), exercise to stay fit and health precautions such as avoiding infections, tobacco, alcohol and other drugs. Nicotine from cigarette smoke damages the fetus (page 360). Alcohol also causes fetal growth damage (page 356).

German measles ▶

Viruses such as rubella causing German measles can cross the placenta and produce serious fetal damage such as deafness, blindness and 'hole in the heart'. Pregnant women should take precautions to avoid all infections.

- Why is it so dangerous to the fetus for a pregnant mother to become infected with the human immunodeficiency virus (HIV)?

Sexually transmitted diseases are particularly dangerous because the pathogens cross the placenta causing serious deformities to the baby. The HIV virus easily crosses the placenta and also blood leakage at birth may infect the newborn baby.

Regular checks by a doctor or at a clinic will provide blood tests, blood pressure measurement, urine analysis, weight gain and size of the uterus.

blood tests ▶

Blood tests will detect any harmful pathogens, although treatment given may prove difficult. A blood test will also show if the mother is anaemic. A lack of food rich in iron may reduce the haemoglobin in the blood, so that her oxygen supply and that to the fetus is reduced. The resulting lack of energy will severely affect fetal growth.

rhesus factor ▶ A blood test will detect the presence or absence of the rhesus factor. This is a protein on red blood cells that will induce the immune system to make antibodies to it (see page 313). If the mother is rhesus-negative she will lack these rhesus antibodies. The problem arises if her fetus is rhesus-positive (inherited from the father). At childbirth the rupture of capillaries causes the blood of the fetus and mother to mix. The mother now *makes* rhesus-positive antibodies. Should she have a second pregnancy with a rhesus-positive fetus, these antibodies will destroy the red cells of the fetus. This causes haemolytic disease, where the red blood cells have been destroyed, making the baby jaundiced and anaemic. Unless medical attention is given the baby will die.

haemolytic disease ▶

weight checks ▶ Regular weight checks ensure growth of mother and fetus is normal. Any increase in weight may detect water retention, or perhaps overeating of the wrong types of food. Blood pressure checks will identify hypertension, which may lead to kidney damage. Urine tests will establish the absence of sugar, which if present would show the onset of diabetes.

blood pressure ▶

urine tests ▶

A cervical smear may be taken to check for cervical cancer (page 250). An examination of the cervix and vagina will be made to ensure there are no infections such as the fungal infections, *Chlamydia* and thrush.

ultrasound scan ▶ Later, an ultrasound scan (figures 13.16 and 13.17) is given to produce a visual image of the fetus, to check it is properly formed and growing in the right position. Although the sex can generally be seen at this age, many parents prefer to find this out at birth.

The size and shape of the pelvis and uterus are measured giving an indication of the time of birth and whether a caesarean operation will be needed. Here the baby is removed through the abdomen during an operation, rather than naturally by passage through the birth canal.

caesarean operation ▶

postnatal care ▶ Postnatal care provides advice to the mother on her diet, behaviour (no smoking or alcohol) and how to care for the baby, with checks on its growth and development. Initially the mother has checks to ensure there is no bleeding from the uterus and that there are no infections, or damage to the cervix and vagina.

The mother needs to know the value of breast milk. Later she needs to learn how to wean the baby on to semi-solid and solid foods. Her own diet must supplement for the milk she produces, with plenty of protein, vitamins, calcium and other minerals.

Figure 13.16 An ultrasound scan to check the fetus.

Figure 13.17 The ultrasound picture scan showing the fetus.

The mother will take advice on sleep patterns for the baby, how to make it comfortable and watch for signs of normal development.

vaccination programme ▶

The baby will be given a vaccination programme to help build up their own immunity. Immunisation against diphtheria, whooping cough, tetanus, meningitis, hepatitis B, measles, mumps, rubella, pneumonia, tuberculosis and chicken pox may be given as a series of injections (see page 315).

The menstrual cycle

oestrogen ▶
menstruation ▶

Each month the hormone oestrogen from the ovary prepares the wall of the uterus for implantation, whether fertilisation occurs or not. This process ensures that there is a freshly formed lining to the uterus, should a zygote become implanted. If fertilisation has not taken place, the lining is then discharged with blood and mucus through the vagina. This is called menstruation, or the monthly period (figure 13.18). It occurs 12 to 14 days after release of the ovum. Menstruation stops if pregnancy occurs. This is often the first sign that a woman is pregnant.

follicle stimulating hormone ▶
luteinising hormone ▶
luteotropic hormone ▶

If fertilisation occurs, the corpus luteum, having shed the ovum, secretes progesterone as well as oestrogen so that implantation can occur. Changes in the ovary are under the control of three hormones secreted by the pituitary gland (figure 13.19). These are follicle stimulating hormone (FSH) that controls the growth of the follicles and their production of oestrogen, luteinising hormone (LH) that controls the release of developed ova, and luteotropic hormone (LTH) that stimulates the corpus luteum to secrete progesterone (figure 13.20). LTH stops the further production of other pituitary hormones. This action is known as a feedback mechanism (see page 178).

In the male, FSH controls the production of spermatozoa and LTH controls the production of testosterone, a male hormone.

Figure 13.18 Sanitary towels and tampons are used to absorb the discharged blood at menstruation.

Name of hormone	Secreted by	Effect
Follicle stimulating hormone (FSH)	pituitary	growth of follicles and production of oestrogen in the ovary
Luteinising hormone (LH)	pituitary	controls ovulation and forms the corpus luteum
Luteotropic hormone (LTH)	pituitary	stimulates corpus luteum to secrete progesterone, inhibits pituitary hormones, production of testosterone in the male
Oestrogen	ovary follicles	secondary sexual characteristics, prepares uterus wall, controls menstruation
Progesterone	corpus luteum	prepares uterus wall for zygote, stimulates milk secretion, stops ovulation
Testosterone	testes	secondary sexual characteristics
Oxytocin	pituitary	uterus contractions for childbirth
Prolactin	pituitary	breast milk secretion

Table 13.4 The function of the sex hormones.

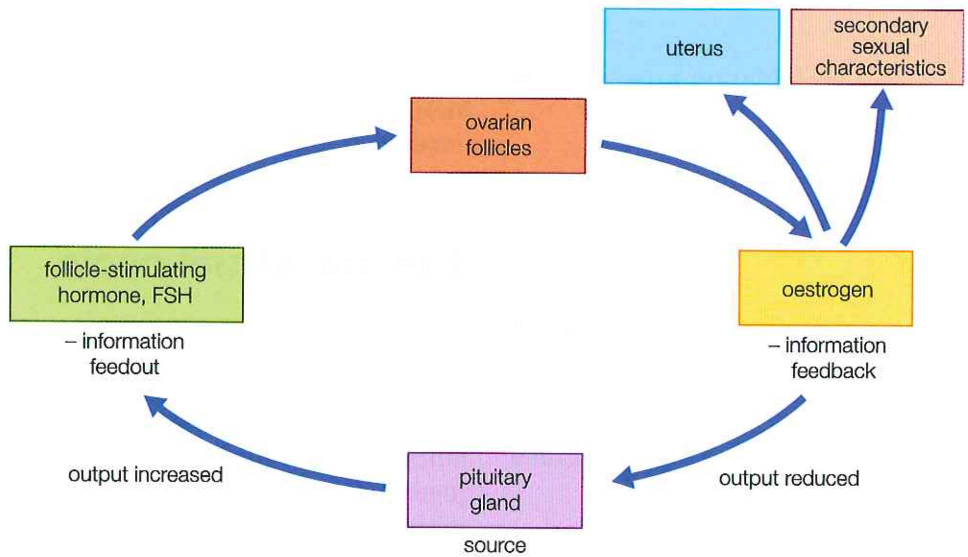


Figure 13.19 The pituitary feedback mechanism.

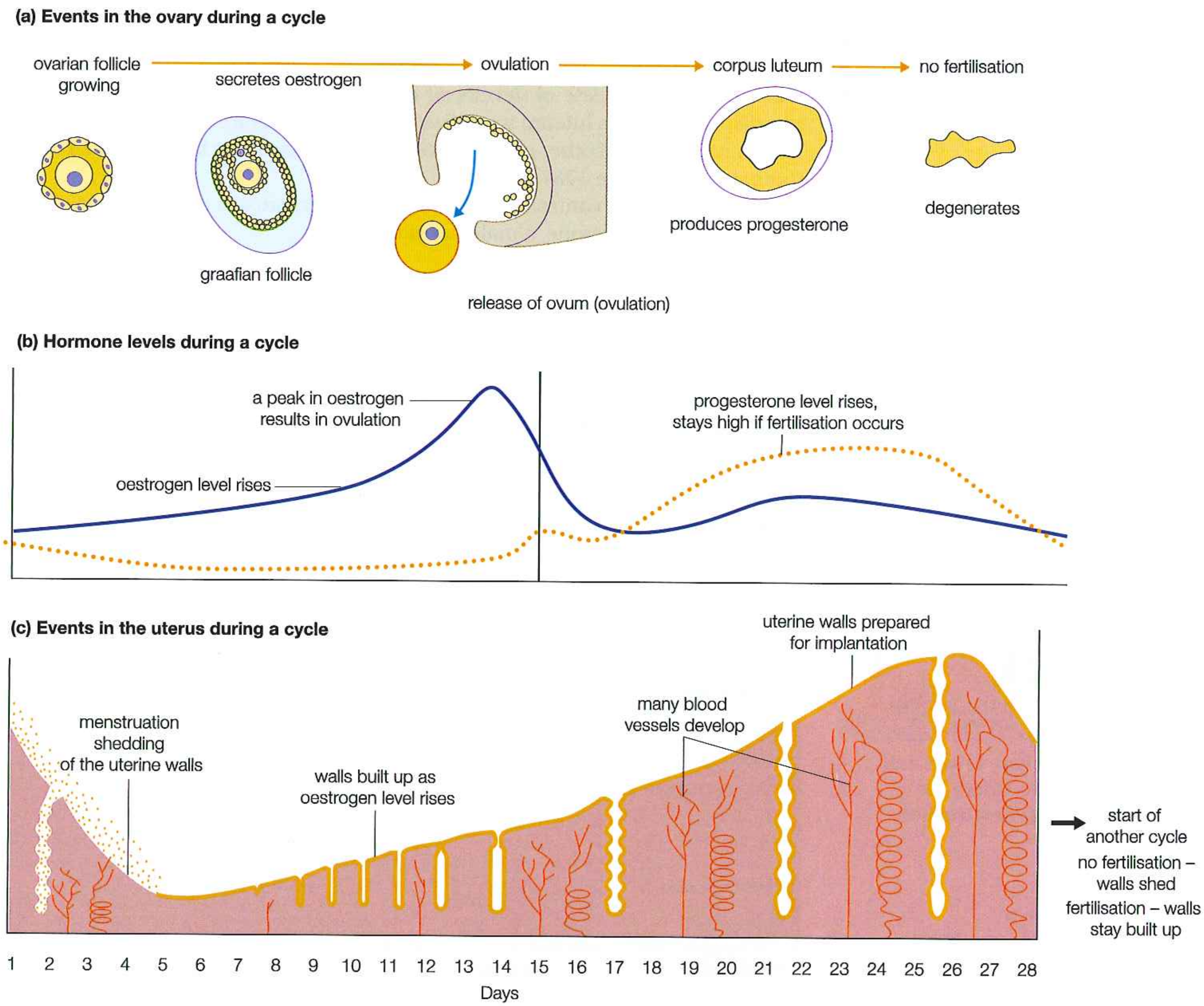


Figure 13.20 The menstrual cycle showing changes in the ovary, uterus and in hormone concentrations.

- Name the stages in the human life cycle.

Growth and development

The human life cycle is the time from conception to death and can be split up into a number of stages.

prenatal growth ▶ **postnatal ▶** **infancy ▶** **childhood ▶** **adolescence ▶** **adulthood ▶**

There is a stage of prenatal growth of the fetus during pregnancy. Following birth is the postnatal stage (0–1 year) and infancy (1–4 years). This is followed by childhood (about 4–12 years), adolescence (13–18 years), adulthood (18+ years) and old age.

The average rate of growth in height in boys and girls is shown in figure 2.4 (page 12). Figure 13.21 shows how the rate of growth varies by taking the weight

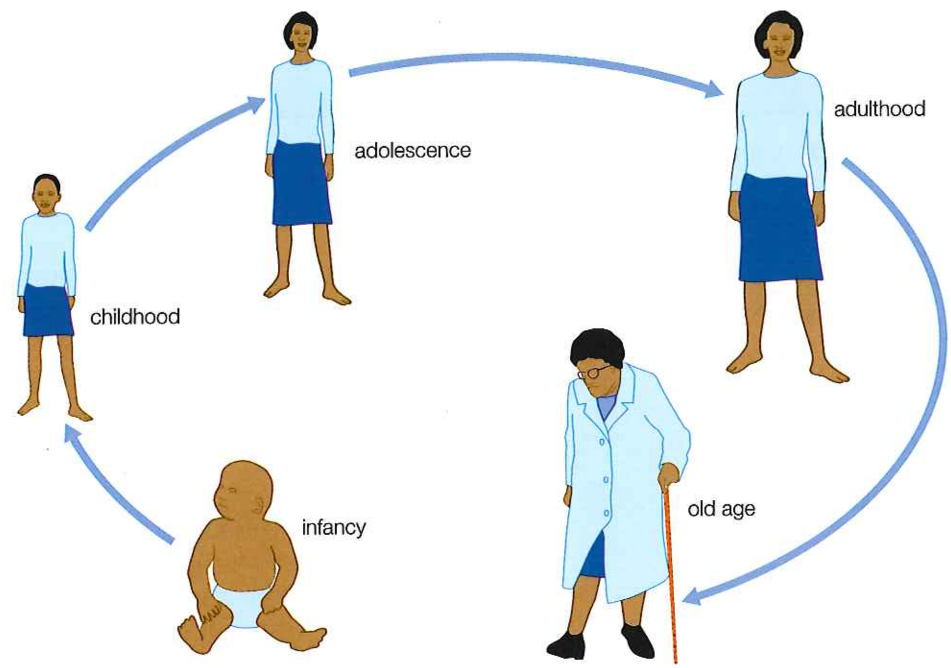


Figure 13.21 Growth and development stages in the life cycle.

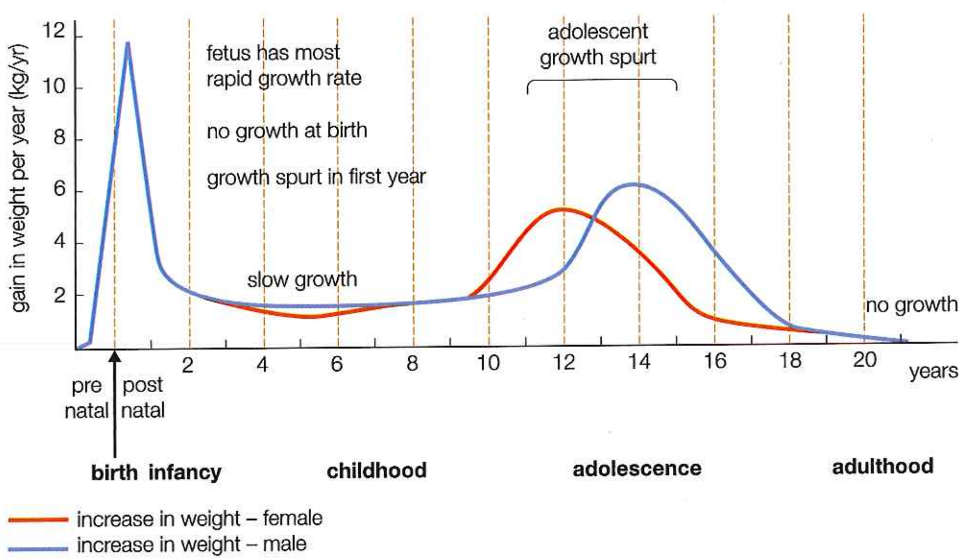


Figure 13.22 Stages in the human life cycle showing rates of growth.

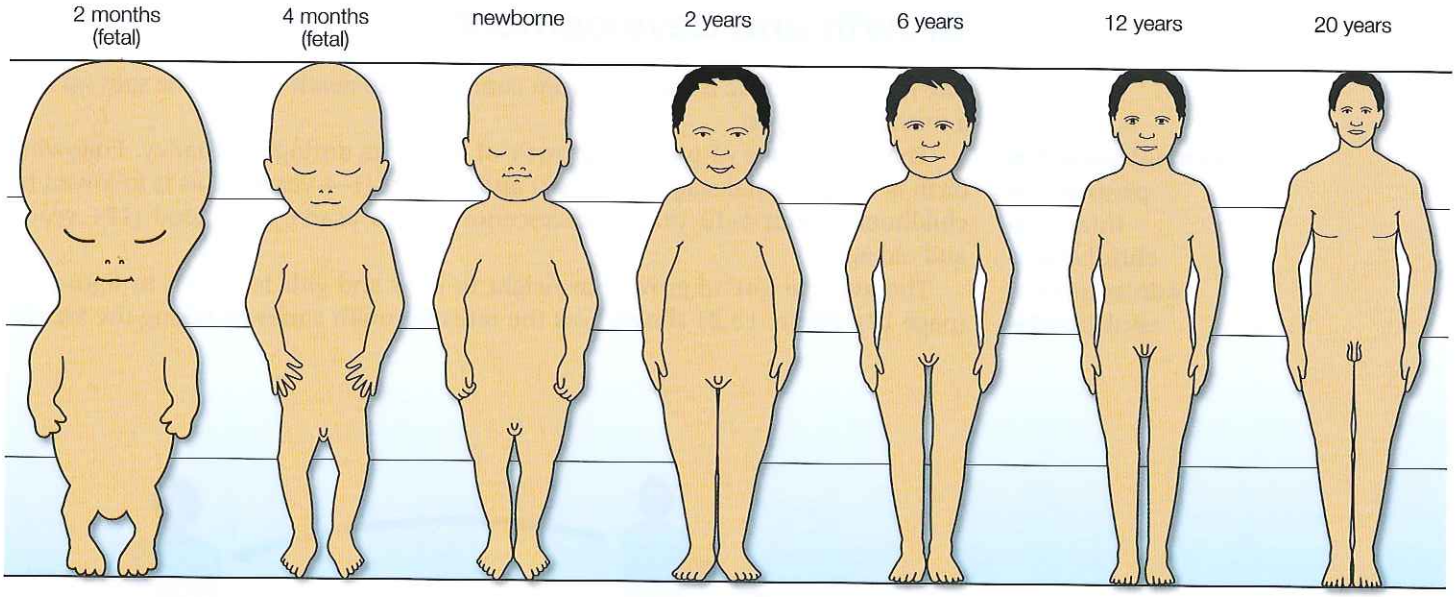


Figure 13.23 Growth of parts of the body during the human life cycle.

growth in each year. This shows how the maximum rate of growth occurs in the fetus, followed next by the first year of life and finally the growth spurt during adolescence. Certain body parts grow more quickly at certain stages. For example, the head grows faster in the fetus (figure 13.22) and the sexual organs grow faster at adolescence (see figure 13.23).

Childhood

Childhood is a period of fairly steady growth and a time when the child learns much through play (figure 13.24). The long period of childhood is necessary to learn all that is necessary. Children benefit enormously from growing up in a stable family, with mother, father and other children. Divorce and separation have a bad effect on young developing children and is a serious reason for stress for the whole family.

Figure 13.24 Children learn much through playing with each other.

Figure 13.25 Parental care is important for physical and social development.

Adolescence

Adolescence is when a sudden increase in both growth and maturity occurs. It is the stage when the child changes to an adult and gains sexual maturity. Adolescence starts at about the age of 12 in girls and 14 in boys, but this age varies in individuals. It starts with puberty, which is the period when the secondary sexual characteristics start to develop (figure 13.26). Hormones released into the bloodstream cause structural and mental changes.

puberty ▶
secondary sexual characteristics ▶

At puberty in the girl, mammary glands develop, the hips widen and hair grows around the external sex organs and under the armpits. At puberty in the boy, hair grows on the face, armpits and around the sex organs. The penis and testis enlarge and the voice breaks.

The lengthening of the long bones in the arms and legs may at first make some awkward in their movement. It is during this period that the gametes start to mature. Males produce spermatozoa and can ejaculate.

menopause ▶

In females the menstrual cycle starts and continues until an age of usually between 45 and 55 years. Then menopause occurs. This means hormone secretions reduce and the woman can no longer reproduce.

The change between childhood and adulthood involves new attitudes between the sexes and other adults and this requires social adjustment. Physical

ITQ11
List the secondary sexual characters that develop at adolescence in (a) boys (b) girls.

Girls only	Boys only	Both sexes
breasts enlarge	larynx enlarges, so voice breaks	sex hormones secreted
pelvic girdle widens	beard grows	hair grows in pubic regions and armpits
uterus and vulva enlarge	penis and scrotum enlarge	increase in growth rate
menstruation starts	prostate enlarges	sexual desire
ovulation starts	spermatozoa are made	attraction to opposite sex
		sexual maturity causes psychological changes

Table 13.5 Changes during adolescence and secondary sexual changes.

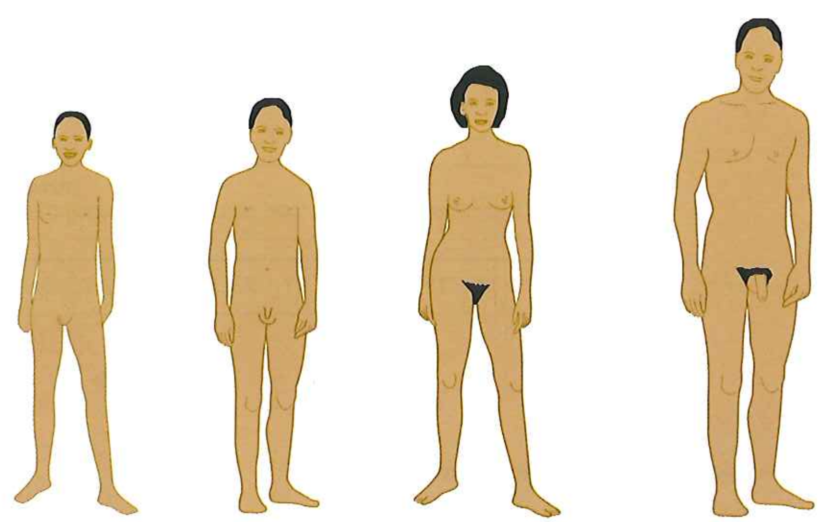


Figure 13.26 Changes in body form at puberty.

developments increase sexual desire and psychological changes may occur. In part, these changes may be due to frustration in societies where marriage has to be delayed. Different attitudes to love, play, exploration and human contact develop at adolescence.

By the time the adolescent reaches adulthood, the peak of physical and mental abilities has been reached.

Family planning

Reasons for family planning

birth control ▶ Family planning means controlling the number and timing of the births in the family. This is done by various methods of birth control.

There are many reasons why parents decide to space and control the number of births. More time for care and education can be given to each child in the small family. It is less expensive to have a small family so that both parents and children can benefit from the extra money available. Parents may decide they wish to have a career before starting a family. Or they may not want children in the later years of life when the age difference between parent and child is much greater. Older mothers have a greater risk of having babies with birth defects such as Down's syndrome (physical abnormalities and learning difficulties). No doubt you may think of other reasons.

Perhaps a major reason for family planning is to reduce the number of births because of the rapidly expanding population. Hence many countries have programmes to help educate people for family planning.

Methods of birth control

Natural methods

Not having intercourse is one certain method. Marriage later on in life naturally reduces the family size.

rhythm method ▶ Intercourse during the so-called 'safe period' is another method. This rhythm method requires couples not to have intercourse between the 11th and 17th day after the start of menstruation. At this time, the ovum is ready for fertilisation. This

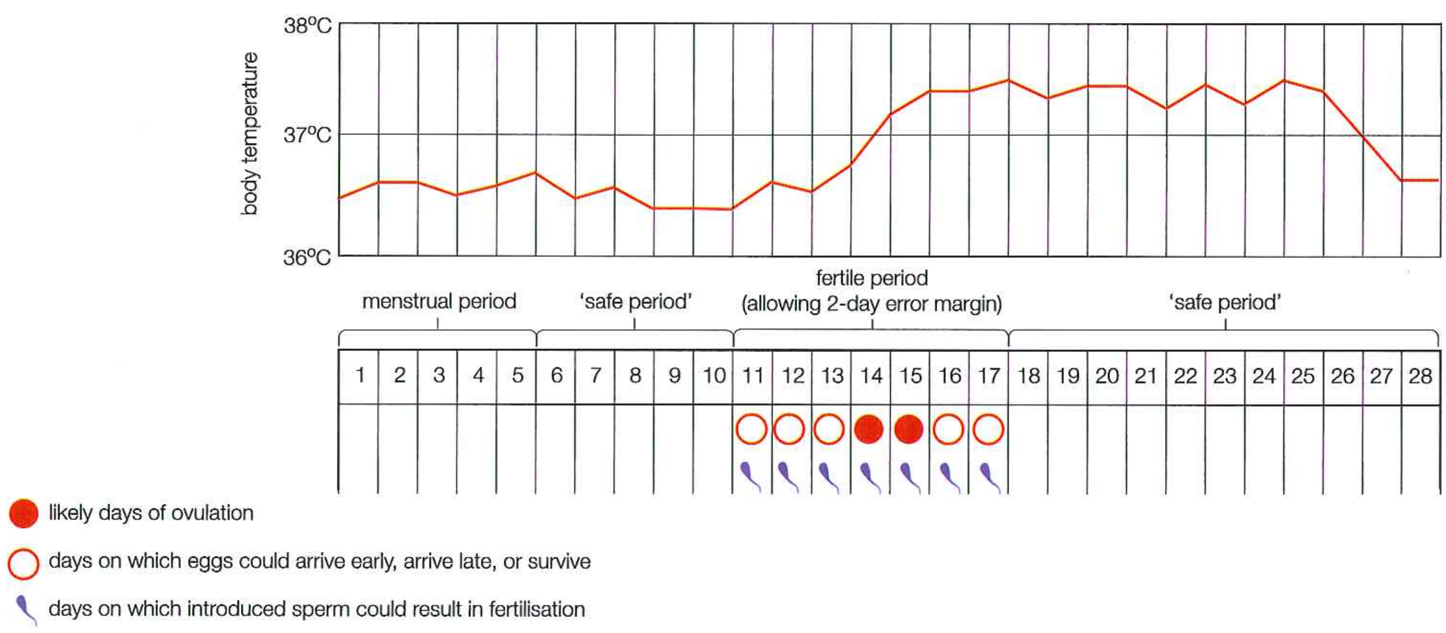


Figure 13.27 The rhythm method of family planning.

ITQ12
When is fertilisation most likely and what can a couple do to find the best time for conception?

- Why is the rhythm (safe period) of contraception unreliable?

takes into account the time the ovum takes in passing down the oviduct, as well as the length of the life of the spermatozoa in these tubes. This method of birth control requires keeping a calendar of the menstrual cycle. The body temperature rises slightly at ovulation and there is an increase in mucus secretion from the cervix. Women may observe these two features to calculate their period of ovulation (see figure 13.27). However, it is an unreliable method, as the menstrual cycle is not always regular.

Artificial methods

Other methods involve the use of a barrier to prevent the gametes meeting in the oviduct.

condom ▶

- Why is the condom better than the contraceptive pill to prevent infection?

The condom (figure 13.28) is a thin latex rubber sheath, which is unrolled to cover the erect penis. The sperms are retained in a teat at the end of the condom, which is removed after intercourse. Condoms are widely used and many people find them both convenient and effective. A particular advantage is that they act as a barrier to microorganisms. This helps prevent the spread of sexually transmitted diseases. With the spread of AIDS the condom is particularly recommended (see page 363). All the other forms of contraception described do not prevent the spread of infection from sexually transmitted disease.

diaphragm ▶

The diaphragm (or cap) (figure 13.29) is put into the vagina by the woman at least one hour before intercourse. The cap has a spring around its edge, which holds it tightly against the vagina. It covers the cervix, preventing the passage of spermatozoa. Medical advice is needed for the first fitting of the cap. Semen is prevented from entering the uterus.

spermicidal foam ▶

Spermicidal foams, cream or jellies are often used with other methods of birth control such as the diaphragm. They are put into the vagina (figure 13.30) before intercourse. They contain a chemical which destroys the spermatozoa in the female tract. They may slow down sperm movement. On their own they are not as reliable as many other methods.

intrauterine device ▶

The intrauterine device (IUD) (figure 13.31) is a loop, or coil, of steel, copper or plastic. It is put through the cervix into the uterus and remains there. Again, medical advice is needed. In some way it stops implantation of the embryo. IUDs are effective, although a certain number of women cannot use them because they cause discomfort.

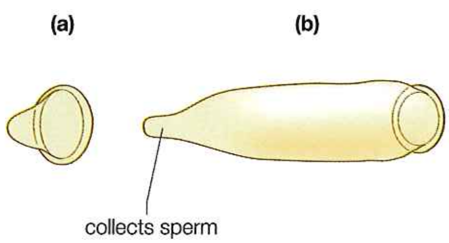


Figure 13.28 A condom (a) as supplied (b) unrolled.

Figure 13.29 A diaphragm is fitted over the neck of the cervix.

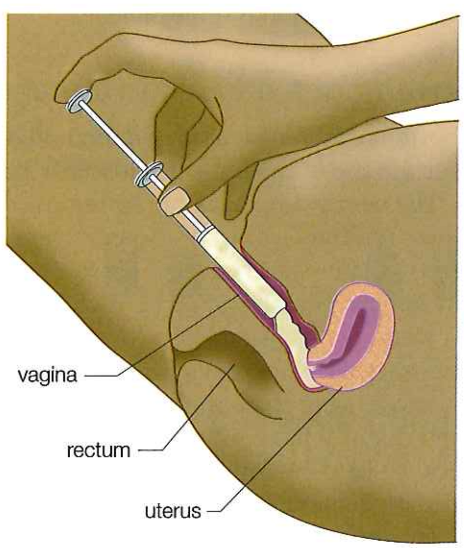


Figure 13.30 Spermicidal foam inserted into the vagina with the aid of an applicator.

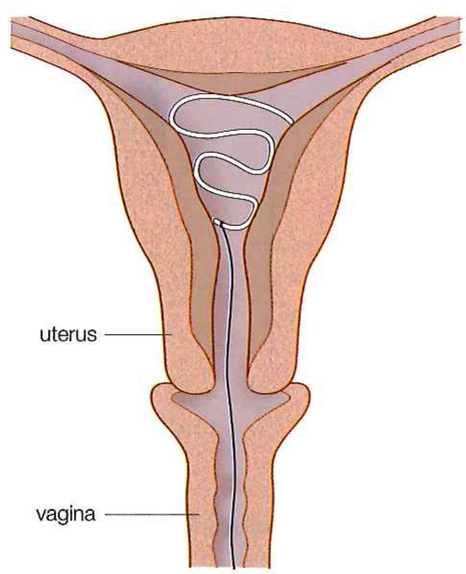


Figure 13.31 Intrauterine device (IUD) in position.

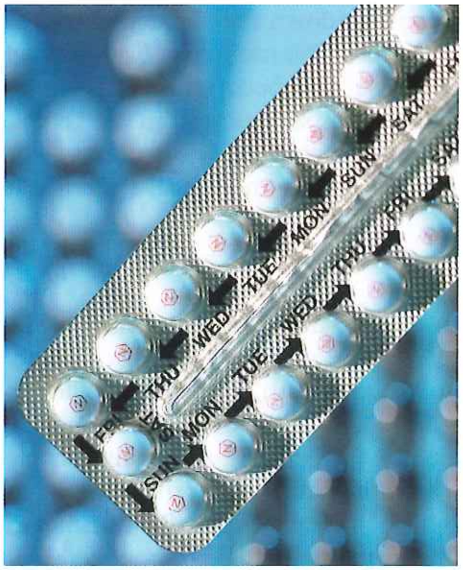


Figure 13.32 The contraceptive pill. The packaging design ensures one pill is taken daily.

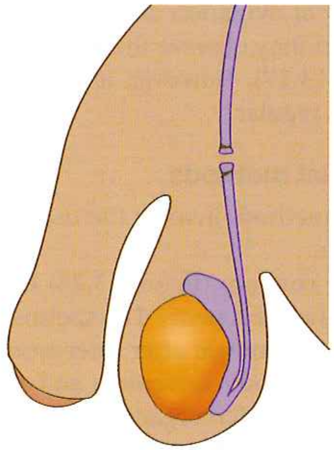


Figure 13.33 Vasectomy.

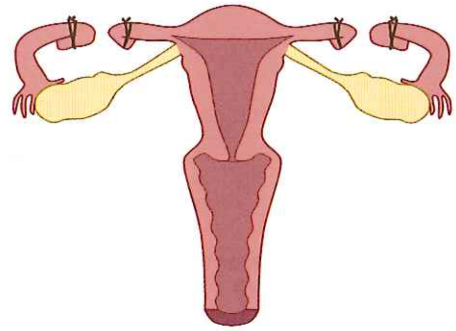


Figure 13.34 Tubal ligation.

contraceptive pill ▶

ITQ13
How does the contraceptive pill work?

Contraceptive pills (oral contraceptives) (figure 13.32) contain substitute hormones related to oestrogen and to progesterone. These two hormones stop the release of FSH (follicle stimulating hormone) from the pituitary so that ovulation does not occur. If eggs are not released, fertilisation is of course impossible. As an alternative, implants of slow-release hormones that stop ovulation can be medically inserted periodically. The so-called 'morning after' pill contains hormones that prevent implantation. This is taken after sexual intercourse.

sterilisation ▶
vasectomy ▶

Sterilisation involves a minor operation in either sex to block tubes, which normally carry the gametes. Vasectomy is a quick relatively easy way of sterilising the male (figure 13.33). About 2 cm is removed from each vas deferens (sperm tube) and the ends of the tubes are sealed. Thus spermatozoa cannot pass from the testis to the rest of the semen. A recently developed method blocks the tubes with a plug of latex. The advantage of this method is that sterilisation is not permanent.

tubal ligation ▶

Oviduct sealing or tubal ligation in women (figure 13.34) requires the oviducts to be cut and the ends sealed. This prevents the eggs passing down from the ovaries and so fertilisation is impossible.

ITQ14
In what ways is the condom a better form of contraception than a tubal ligation?

Advantages and disadvantages of medical abortion

abortion ▶

Abortion can also be used as a method of birth control. There is much controversy over the use of medical abortion in which the life of the fetus is destroyed.

The very young fetus can be removed by suction. Alternatively the lining of the uterus (endometrium) is scraped. Drugs acting in a similar way to oxytocin may be used. At later stages surgery is required. All these are forms of contraception, but few people think it should be used for these purposes.

Some use abortion for economic and social reasons. Some consider abortion necessary if the mother's health is at risk, or the fetus is deformed.

Those against abortion consider it is murder of the fetus. Many mothers subsequently have psychological problems and the operation is not without risk because later infertility can occur. So-called 'back street' abortion, performed by untrained operators, is highly dangerous.

spontaneous abortion ▶

On the other hand, spontaneous abortion frequently occurs and is a natural way of preventing the birth of some abnormal babies.

Legislation on abortion varies widely between Caribbean countries and may depend on preservation of life of the mother, rape or incest, fetal abnormality and sometimes the mental or physical health of the woman. When do you think abortion is justified? This makes a good topic for you to debate.

Birth control is a matter on which married couples should seek the advice of a doctor or other qualified person. Nearly all methods of birth control have some difficulties.

In the female		In the male
acting on the ovary:	oral contraceptive pill contraceptive injection/implant	barrier technique: condom
acting in the uterus:	intrauterine device (IUD)	
sterilisation:	tubal ligation	sterilisation: vasectomy
barrier techniques:	diaphragm (cap) spermicides	

Table 13.6 Methods of birth control.

fertility ▶ Fertility is the ability to produce offspring. Infertile men and women are unable to produce babies. If a woman is fertile from age 15 to 50 years, she is 35 years fertile. Theoretically she could have 14 children, one child approximately every 2.5 years. In a religious sect that encouraged large families, fertile women had between 10 and 12 babies. The various forms of contraception used reduce this number of pregnancies. How effective they are depends on how well the instructions are followed. If used properly the rhythm method can be fairly effective. In practice the instructions are not always followed properly and the changing cycle of periods makes it unreliable.

Table 13.7 shows in order, from least to most, the reliability of the methods of birth control.

Method of birth control	Reliability	
No contraception practices	80–90% of fertile women per year become pregnant	**LEAST**
Withdrawal of penis before ejaculation	very unreliable because early sperm leakage occurs	
Rhythm (safe period)	unreliable because of cycle variations	
Spermicidal cream only	unreliable, best used with other methods	
Condom	very reliable and reduces infections	
Diaphragm with spermicide	very reliable	
IUD	very reliable	
Contraceptive pill	very reliable	
Sterilisation (vasectomy and tubal ligation)	completely reliable if the operation was successful	
Abstain from sex	completely reliable	**MOST**

Table 13.7 Estimated effectiveness of contraceptive methods.

Cancer of the reproductive organs

metastasis ▶

Cancer is the abnormal uncontrolled division of cells. Such cells form a lump (tumour) and early discovery means the lump can be removed by surgery, or radiotherapy. A later stage in cancer, metastasis, involves the migration of these cells to infect other organs of the body. After metastasis, the disease is rarely cured. The migrating cells infect vital organs and death results. Hence the importance of early detection of cancer before metastasis occurs. Obviously abnormal rates of mitosis occur, so that drugs have been developed to arrest such cell division. The increased cell activity makes cancer patients tired and weak.

Cancer appears to be more common in advanced industrial countries. Cancers of the prostate, cervix and breasts are common. For other common forms such as lung cancer see page 358.

surgical removal ▶
radiation therapy ▶
chemotherapy ▶

Treatment given includes surgical removal of the tumour, radiation therapy to destroy the tumour and chemotherapy such as with drugs to reduce cell division.

Breast cancer

breast cancer ▶

• How is breast cancer detected?

Breast cancer can be detected early by hand pressure to detect the tumour lumps in the breasts. Mammograms, where X-rays are taken of the breasts, are given to those at risk. The risks include exposure to radiation, smoking and heredity (inherited from parents). The use of oral oestrogen and contraceptive pills for long periods and being more elderly increases the danger. Surgical removal of the tumour or the whole breast may be undertaken. Radiation therapy to destroy the tumour and drugs to control mitosis may be required.

Cervical cancer

cervical cancer ▶

Cervical cancer can be detected at an early stage by cervical smears taken for examination of the cells they contain. These tests should be taken by those most at risk. This includes women who have frequent sex with many partners, start sex at an early age, or have been infected with sexually transmitted disease. After breast cancer, cervical cancer is the most frequent cause of death from cancer in women.

This cancer is caused by a virus (human papilloma virus, HPV) that is sexually transmitted (page 361). Very recently a vaccine (Gardasil) has been developed that has to be given in three doses over 6 months. Whether this vaccine should be given to children generally is under consideration.

Ovarian cancer

ovarian cancer ▶

The problem with ovarian cancer is that the symptoms such as pain in the abdomen and lower back may be thought due to other causes. Consequently it is often not diagnosed until after metastasis when it is too late. It is more common in women over 55 and those with parents and close relatives who suffered. Activities that reduce ovulation such as numerous childbirths, the contraceptive pill and breast feeding make the disease less likely to occur. Treatment as described generally above is usually provided too late and is rarely successful.

Prostate cancer

prostate cancer ▶

The enlarged tumour causing prostate cancer blocks the urethra, causing frequent but slow urination with a weak flow. With such symptoms men should have the PSA (prostate specific antigen) blood test. This would detect a high level of antibodies to the tumour. Unfortunately, the test is not a completely reliable indicator of the disease. Removal of the prostate may cause sexual problems and

ITQ15
What is cancer of the prostate?

other methods of treatment may not be successful. This disease is now second to lung cancer (see page 358) as the main cause of death from cancer in men.

Sexually transmitted diseases and other diseases associated with the reproductive system will be considered in chapter 18 because they are diseases caused by human behaviour.

Summary

- Sexual reproduction involves the fusion of a male gamete (sex cell) with a female gamete to form the fertilised egg (zygote). This process of fusion is fertilisation. The offspring receive chromosomes from both parents, causing variation.
- Asexual reproduction does not involve fusion of gametes, but a part from the parent forms the offspring, such as buds, spores, and so on. There is no variation between offspring and parent.
- The male reproductive organs make spermatozoa and the penis puts them into the female system for fertilisation.
- The female reproductive system produces ova from the ovaries, receives the sperm for fertilisation, and allows the fertilised egg to implant in the wall of the uterus, where the fetus develops during pregnancy.
- At birth contractions of the uterine muscles push the baby out through the cervix.
- Antenatal care provides advice during pregnancy with checks on the fetal growth.
- Postnatal care provides advice to the mother on breast feeding, her diet, behaviour (no smoking or alcohol), and how to care for the baby, with checks on its growth and development.
- The menstrual cycle involves the monthly replacement of the wall of the uterus for implantation.
- Oestrogen from the ovary controls menstruation and secondary sexual characteristics.
- Progesterone prepares the uterus wall for pregnancy and breast milk secretion.
- The stages of human growth and development are prenatal, postnatal, infancy, childhood, adolescence, adulthood and old age.
- Family planning ensures spacing of children for convenience and economic reasons.
- Birth control methods are natural, barrier, hormonal and surgical. Condoms reduce infection.
- Abortion prevents unwanted pregnancies such as deformities, but involves fetus destruction.
- Cancer of the breast, cervix, ovary and prostate need early treatment before metastasis.

Answers to ITQs

ITQ1 The sexually produced cell will contain half its chromosomes from one parent and half from another and hence show variation. The asexually produced cell is a clone, containing cells from, and identical to, its one parent.

ITQ2 Asexual reproduction

Advantages	*Disadvantages*
Large numbers of offspring	No variation
Quickly made offspring	Cannot survive environmental changes
Good quality parent, good quality offspring	Poor quality parents, poor quality offspring
All the offspring are clones	
No need to search for a mate, no courtship	

ITQ3 Sexual reproduction

Advantages	*Disadvantages*
Produce variation Some of the species will adapt to new situations	Fewer offspring Some poorer quality offspring

ITQ4 (a) Urine only is transported in the ureter, (b) sperm only in the vas deferens (sperm duct) and (c) sperm and urine in the urethra.

ITQ5 Semen contains sperm made in the testis and fluid made in the testis, seminal vesicle, Cowper's and prostate glands.

ITQ6 The penis becomes erect when sexually excited, the arteries supplying the erectile tissue enlarge as the veins removing blood constrict. This increases the pressure in the erectile tissue, increasing the turgor, making the penis stiff.

ITQ7

Sperm	*Ovum*
smaller	larger, more cytoplasm
acrosome for penetration	
head, neck and tail	
motile	moved by fluid
They both have nuclei with the haploid number of chromosomes	

ITQ8 Sperm made in the testis, pass to the epididymis for storage, then the vas deferens (sperm duct), urethra through the penis into the female vagina, uterus, oviduct (fallopian tube) where it fertilises the ovum, forming the zygote.

ITQ9 Progesterone prepares the uterus wall for implantation of the zygote and stops ovulation. Later it stimulates milk production (lactation).

ITQ10

Maternal artery	*Maternal vein*
more oxygen	more carbon dioxide
more food nutrients	more waste, e.g. urea

ITQ11 The secondary sexual characters are:

(a) *Boys*	(b) *Girls*	*Both sexes*
Larynx enlarges, so voice breaks Beard grows Penis and scrotum enlarge Prostate enlarges Spermatozoa are made	Breasts enlarge Pelvic girdle widens Uterus and vulva enlarge Menstruation starts Ovulation starts	Sex hormones secreted Hair grows in pubic regions and armpits Increase in growth rate Sexual desire Attraction to opposite sex Sexual maturity causes psychological changes

ITQ12 Fertilisation is most likely during ovulation between the 11th and 16th days of the menstrual cycle, when the couple should have intercourse. The woman can detect a slight rise in body temperature and increased mucus secretion from the cervix as signs of ovulation.

ITQ13 The contraceptive pill has hormone substitutes similar to oestrogen and progesterone which stop the release of FSH (follicle stimulating hormone) from the pituitary. This stops ovulation.

ITQ14 The condom has the advantage of also preventing infection by acting as a barrier to pathogens. Tubal ligation is generally permanent and cannot be reversed if the woman later wants children.

ITQ15 Cancer of the prostate is the abnormal rapid division of cells in the prostate, which form a tumour. Metastasis of this infects other organs.

Examination-style questions

Multiple choice questions

(Write down the number of the question followed by the letter of the correct answer. You can check your answers on page 417.)

1 Which one of the following parts of the male reproduction system do *not* make parts found in the semen (seminal fluid)?
- **A** Cowper's gland
- **B** prostate gland
- **C** seminal vesicles
- **D** vas deferens

2 Where are spermatozoa stored?
- **A** Cowper's gland
- **B** epididymis
- **C** seminiferous tubules
- **D** seminal vesicles

3 Which is the path taken by a sperm from where it is produced to where it first enters the female during sexual intercourse?
- **A** epididymis → seminiferous tubule → vas deferens → urethra → vagina
- **B** seminiferous tubule → epididymis → vas deferens → urethra → vagina
- **C** seminiferous tubule → epididymis → vas deferens → urethra → uterus
- **D** seminiferous tubule → epididymis → urethra → uterus → vagina

4 Which of the following does *not* occur at fertilisation?
- **A** The tail falls off the sperm which enters the egg.
- **B** Chromosomes divide as the sperm enters the egg.

C The outer membrane of the egg will not allow a second sperm to enter.
D Head of sperm enters the egg.

5 Approximately how many ova will be released from a female's ovaries during her lifetime, assuming she does not have babies?
A 50–100
B 150–250
C 400–500
D 650–750

6 Which hormone controls the manufacture of sperms in the male and the growth of follicles in the female?
A LH
B FSH
C oestrogen
D oxytocin

7 Which hormone first stimulates the release of developed ova?
A LH
B FSH
C oestrogen
D oxytocin

8 Which hormone prepares the wall of the uterus for implantation?
A LH
B FSH
C oestrogen
D oxytocin

9 Which is the greatest growth rate during human development after birth?
A postnatal (0–1 years)
B infancy (1–5 years)
C childhood (5–12 years)
D adolescence (12–18 years)

10 At which age are most females likely to be taller and heavier than males?
A 0 to 1 year old
B 5 to 8 years old
C 10 to 12 years old
D 14 to 18 years old

Short answer and essay type questions

Question 11 refers to the graph in figure 13.35 showing the levels of the hormones progesterone and oestrogen present in a woman during part of October and November.

11 Give approximate dates when:
(a) menstruation would occur
(b) ovulation would occur
(c) sexual intercourse could produce fertilisation
(d) implantation could occur following fertilisation

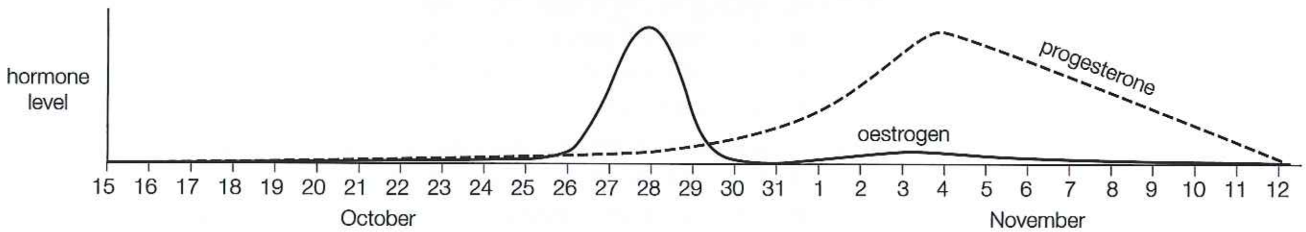


Figure 13.35 Progesterone and oestrogen levels over a 29-day period.

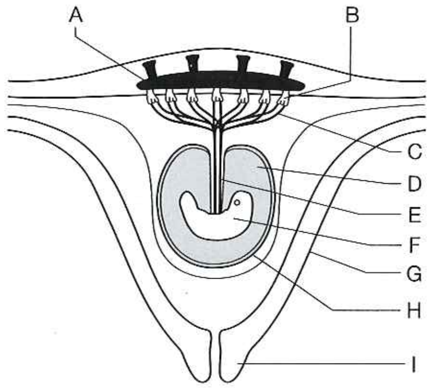


Figure 13.36 A developing human embryo.

Use figure 13.36 for questions 12 to 15.

12 Name the parts A to I on figure 13.36 of the developing human embryo.

13 What structures are found in part E?

14 (a) Name two substances passing from (i) the mother to the fetus (ii) the fetus to the mother.
(b) By what physical process do these substances pass across the placenta?

15 What is the function of part D?

16 (a) What two signs indicate that childbirth will shortly occur?
(b) What process expels the baby at birth?

17 State four main physical changes which occur at (a) adolescence (b) old age.

18 List the methods of birth control from the most effective to prevent pregnancy to the least effective.

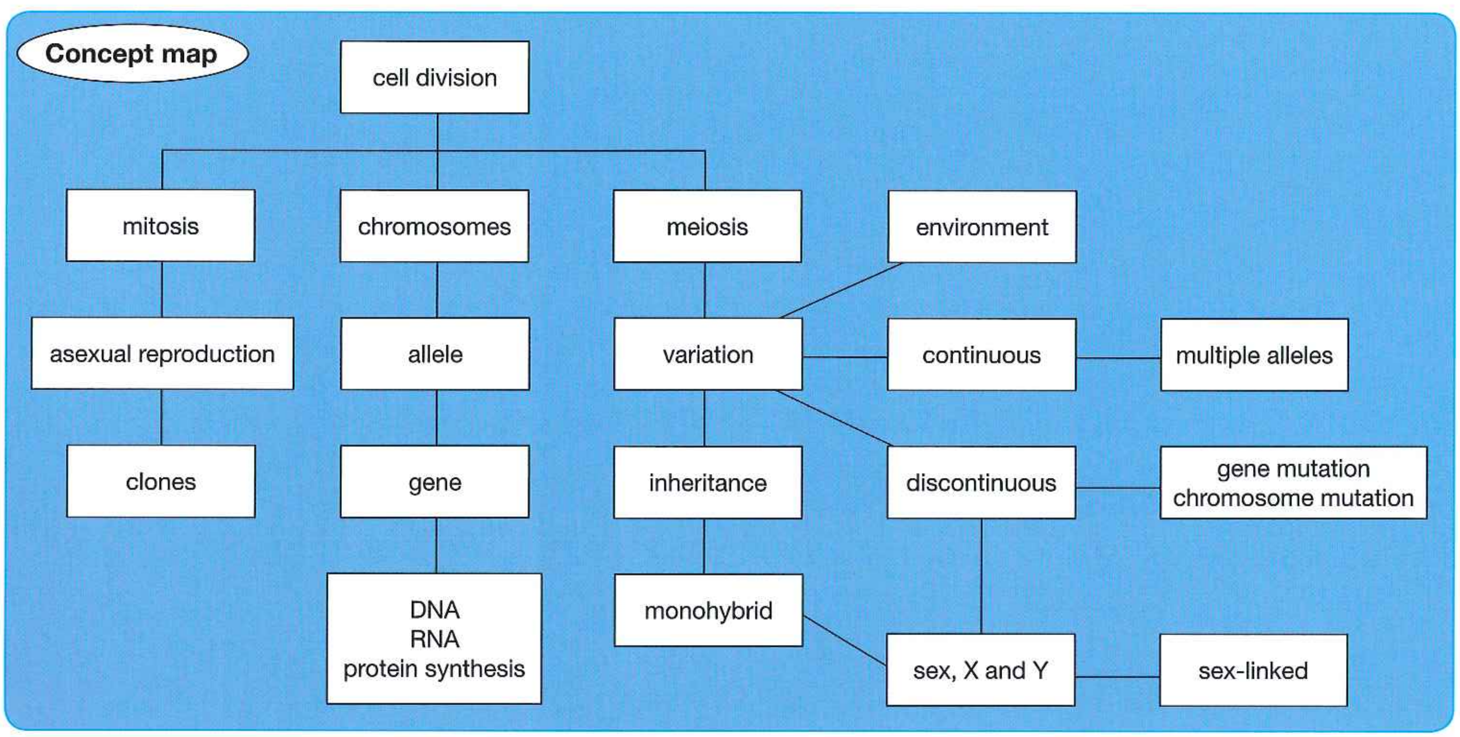
19 Write an account of abortion, explaining the advantages and disadvantages.

20 Explain why the rhythm (safe period) is not an effective method of birth control.

14 Inheritance and genes at work

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

- ☑ define mitosis and describe the movement of the chromosomes;
- ☑ explain how mitosis produces identical cells (clones) having the same chromosomes as the parent cell;
- ☑ appreciate that asexual reproduction involves mitosis only;
- ☑ explain the process of meiosis;
- ☑ realise the importance of meiosis in halving the chromosome number and introducing variation into the gametes;
- ☑ describe the inheritance of sex;
- ☑ define and explain the terms DNA, RNA, chromosomes, allele, dominant, recessive, homozygous, heterozygous, gene;
- ☑ explain monohybrid inheritance of a single pair of characteristics to include tasting PTC, albinism, and make reference to tongue rolling;
- ☑ show how incomplete dominance controls blood group inheritance;
- ☑ illustrate sex-linked inheritance in respect of haemophilia and red/green colour blindness;
- ☑ understand genetic counselling for recessive diseases and the gene pool;
- ☑ know the difference between continuous and discontinuous variation, caused by genetic and environmental variation;
- ☑ describe the types of variation to include height, weight, sex, blood type;
- ☑ describe the function of nucleic acids in protein synthesis;
- ☑ show how gene mutation causes sickle cell anaemia and chromosomal mutation causes Down's syndrome.



Gametes, genes and chromosomes

chromosomes ▶

Genes are found along the threadlike structures called chromosomes in the nuclei (figure 14.1). Each species always has the same number of chromosomes in the nuclei. All humans have 46 chromosomes in the body cells, which is the diploid number. Half this number of chromosomes is found in the gametes and is called the haploid number.

- Which cells contain the haploid number of chromosomes?

diploid ▶

haploid ▶

So each human gamete contains 23 chromosomes. Thus, when the gametes fuse during fertilisation, each nucleus contributes 23 chromosomes to restore the 46 chromosomes in the zygote (figure 14.2). The similar chromosomes are said to be homologous.

- What is the name of the threadlike structures with genes along their length?

homologous ▶

ITQ1

In humans how many chromosomes are present in (a) a gamete (b) a liver cell?

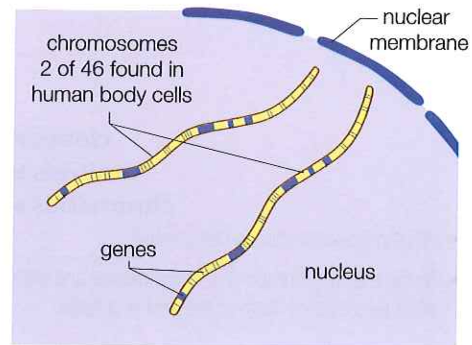


Figure 14.1 Chromosomes are threadlike structures with genes arranged in order along their length (only two of the 46 homologous chromosomes are shown).

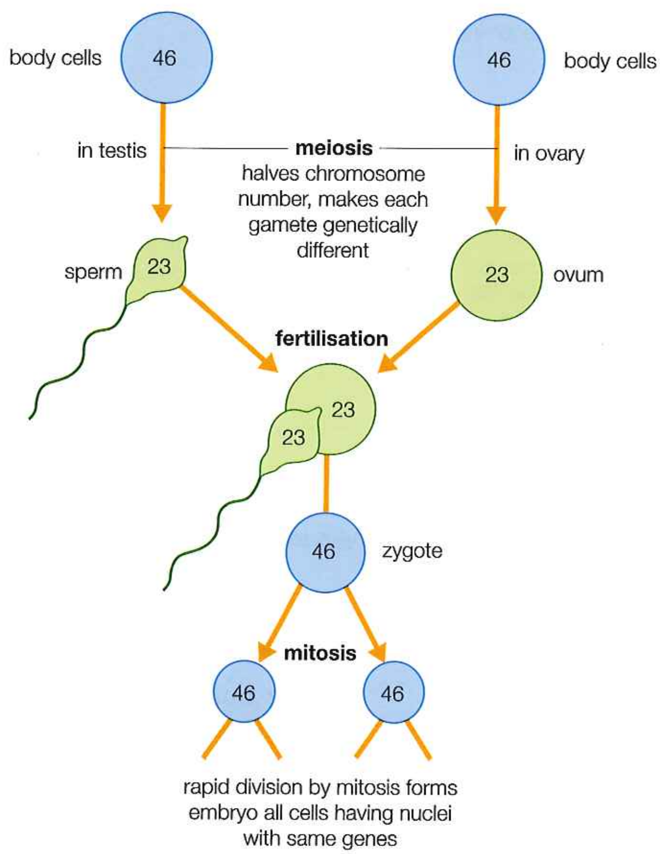


Figure 14.2 Meiosis halves the chromosome number and produces variation, while mitosis keeps the number constant with a similar genotype.

Mitosis and meiosis

Mitosis

clones ▶
mitosis ▶
chromatids ▶

- What process produces cell clones?
- Name the two threads of a chromosome and state what becomes of them at the end of mitosis.

First examine figure 14.3, which shows how a dividing cell passes on exactly the same chromosomes. They are passed on equally, without changing in structure, to the two new cells formed. Because these cells are identical they are called clones. This process is called mitosis.

Each chromosome consists of two chromatids. These chromatids separate, one passing to each cell to form the new chromosomes. This will ensure that each body cell will have received 46 chromosomes, 23 which originally came from the father and 23 from the mother.

The diagrams show the stages in mitosis and how chromosomes appear, split into two and separate to form two identical cells.

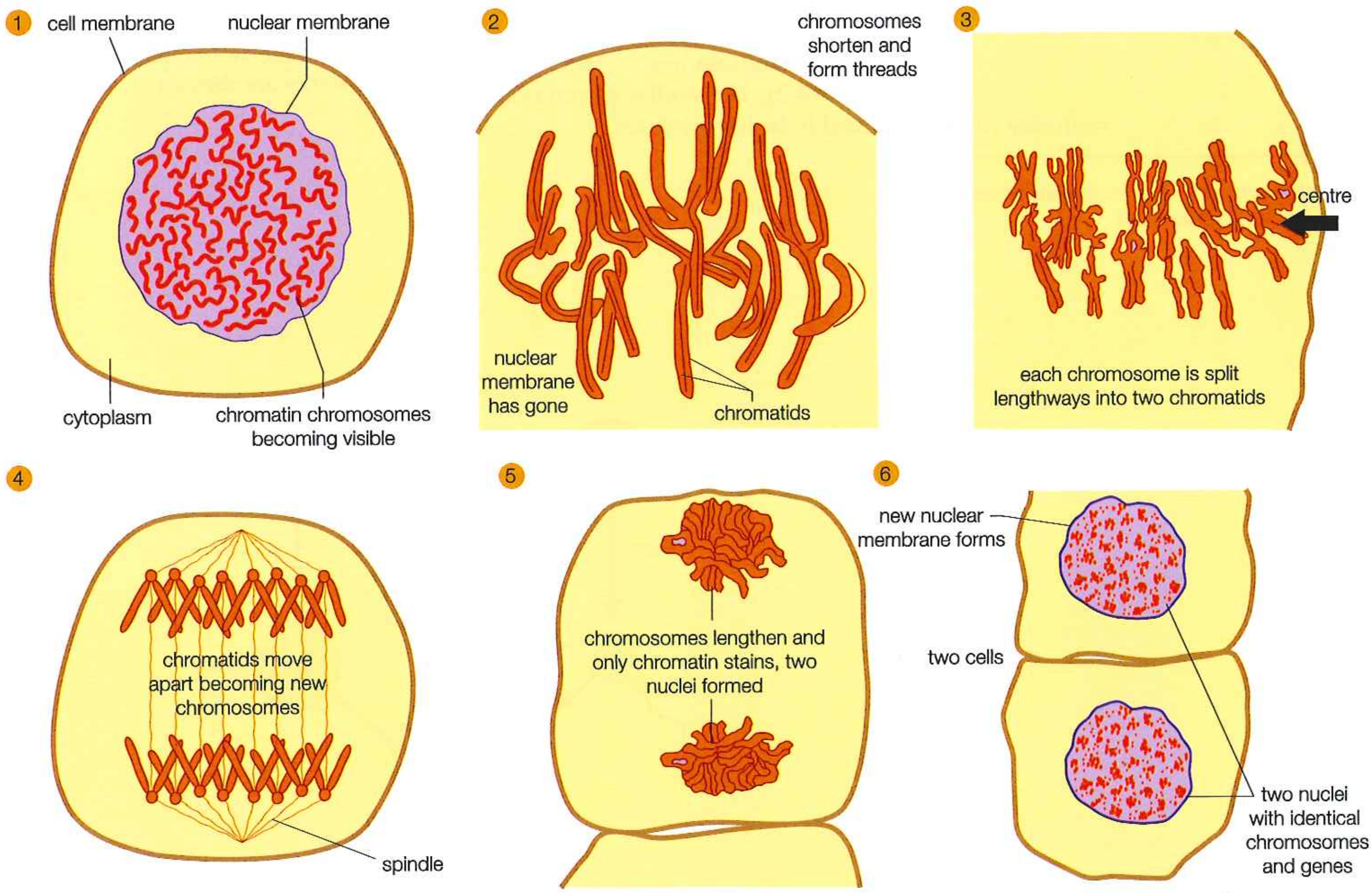


Figure 14.3 The diagrams show the stages in mitosis and how chromosomes appear, split into two and separate to form two identical cells.

Meiosis

meiosis ▶
crossing over ▶

ITQ2
In what two ways does meiosis ensure that gametes differ?

The number of chromosomes must be halved when the gametes are formed. Otherwise there would be double the number of chromosomes after they join at fertilisation in the zygote. This halving occurs at meiosis.

Also at meiosis similar chromosomes pair and exchange genes. This is called crossing over.

One chromosome in each pair has come from the father and one from the mother. Hence the genes from each chromosome are mixed up at crossing over, causing further variation.

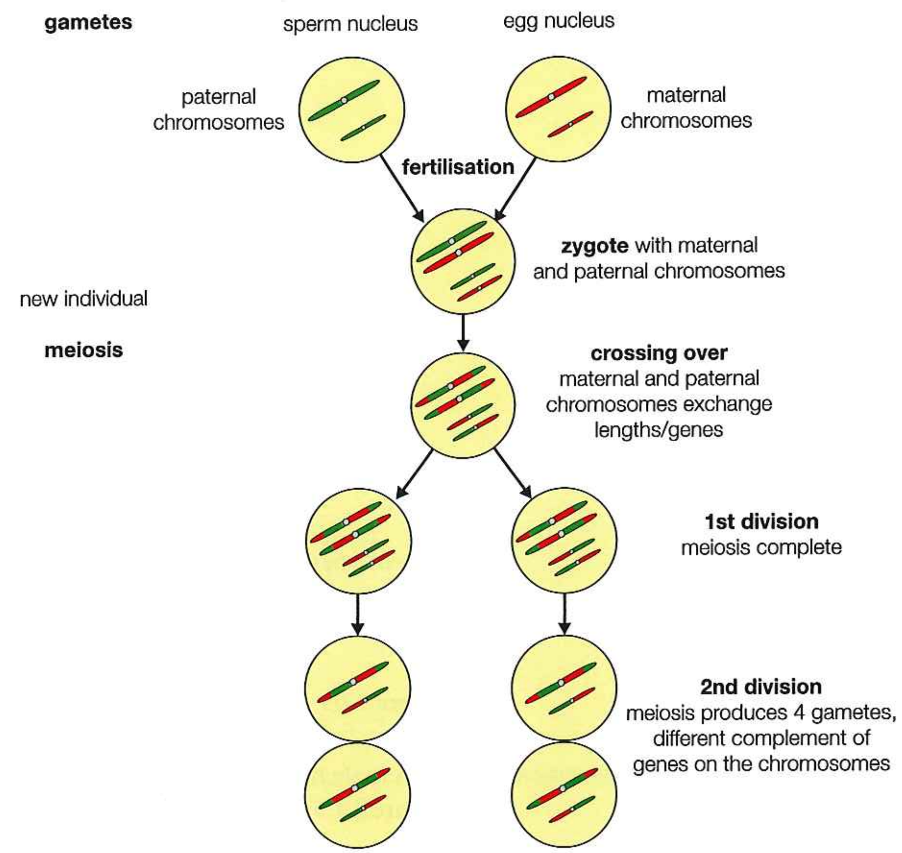


Figure 14.4 Summary of meiosis. Note variation by crossing over and the way the chromosomes may pass into different gametes at the second division.

This ensures that each gamete made is different, containing different genes. Then the cells divide twice so that only half the normal number (haploid number) of chromosomes passes to the gametes (figure 14.4).

	Mitosis	Meiosis
1	Occurs in normal body cells	Occurs in the formation of gametes
2	Passes on the normal diploid number of chromosomes – exact duplication	Halves the chromosome number to the haploid number
3	Nuclei have identical genes	Nuclei have genes mixed by crossing over
4	Produces identical cells (clones)	Provides variation – new genotype
5	For body growth and development	For fertilisation to restore diploid number
6	Ensures genetic continuity	Ensures variation

Table 14.1 The differences between mitosis and meiosis.

Types of inheritance

Inheritance of sex

The inheritance of sex difference is due to different chromosomes in the male and the female.

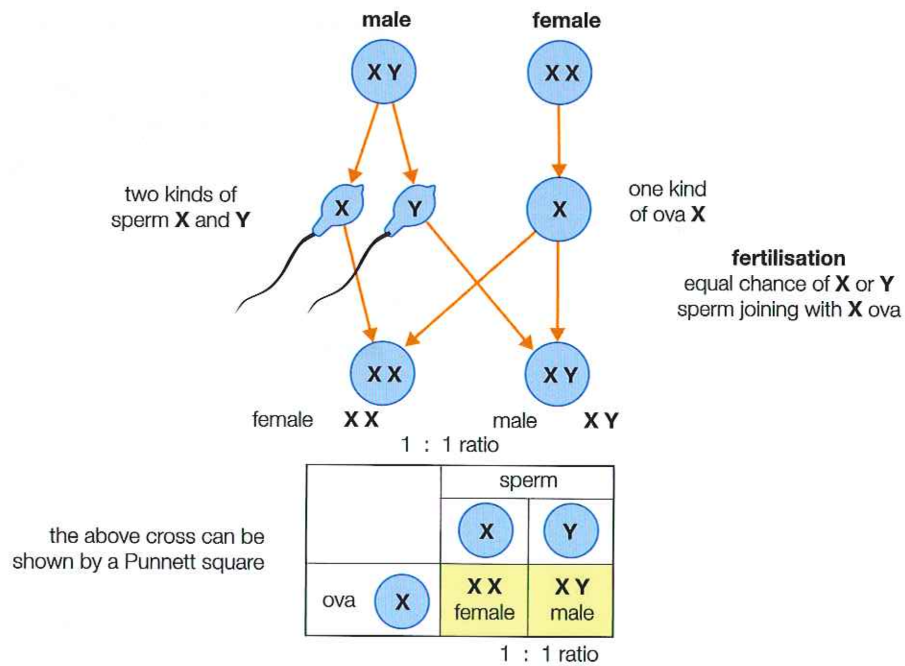


Figure 14.5 Inheritance of sex.

• What are the sex chromosomes in (a) a male (b) a female?

A male has an X and a Y chromosome, while the female has two X chromosomes (figure 14.5). These are in addition to the other 22 pairs of chromosomes.

Practical activity 14.1

To investigate the behaviour of chromosomes using coloured wire models

1 Cut blue wire into a number of lengths so that there are 4 pairs to represent the male chromosomes. Each member of a pair is the same size, except the 4th pair that has one long and one short piece of wire.

2 Make models to show how these chromosomes behave at mitosis (see figure 14.3).

3 Now cut an equal number and size of red wire lengths to those you have in blue.

4 With blue as the paternal chromosomes and red as the maternal chromosomes, make models to show how sex is inherited (see figure 14.5).

5 Use the model formed in step 4 to make further models showing how the chromosomes behave at meiosis (see figure 14.4).

(If you wish to keep models of each stage, you will have to cut fresh lengths of wire for each stage.)

Questions

1 What do the pair of unequal length wires represent?

2 Why are all the colours the same after mitosis?

3 What process is represented in step 4? What are the two colours of wire representing chromosomes called?

4 Why do you need to cut the chromosomes to show step 5? What is happening at the cut and why is it important? (Twist the ends to rejoin.)

5 How many chromosomes have you at the end of step 5?

ITQ3
In some rare cases individuals lack a Y chromosome and have only one X chromosome. What sex will they be?

The male has X and Y chromosomes and 44 other chromosomes (23 pairs). The female has two X chromosomes and 44 other chromosomes. Only one sex chromosome passes to each gamete. You can see how with each baby conceived there is an equal chance of producing a boy or a girl.

In fact, statistics show that for every 100 girls born, there are 105 boys. The reason for this seems to be that the spermatozoa carrying the Y chromosome move faster than those carrying the X chromosome. Hence they are slightly more likely to fertilise the ovum. Recent technology allows parents to choose the sex of their babies, which may present many social biology problems.

The Y chromosome has a gene, which causes the testis to develop and which produces male hormones. Absence of the Y chromosome causes ovaries to develop and female hormones.

Inheritance with dominance

inheritance ▶ **characters ▶** **phenotype ▶**

Inheritance is the passing on of genetic information from one generation to the next. Body structures are called characters. The characters which can be seen or found make the phenotype. Your height, hair colour, blood group, and so on are all phenotypes.

genotype ▶

- Define (a) genotype and (b) phenotype.

The genes contained in an organism make the genotype. A gene is the part of a DNA molecule (deoxyribonucleic acid) on a chromosome that determines one character (figure 14.6).

How are the characters we show inherited from our parents? For most characters this question cannot be answered. We know that the only parts passed from parent to offspring are the gametes. But because there are so many genes controlling characters to be passed on, their action is difficult to predict.

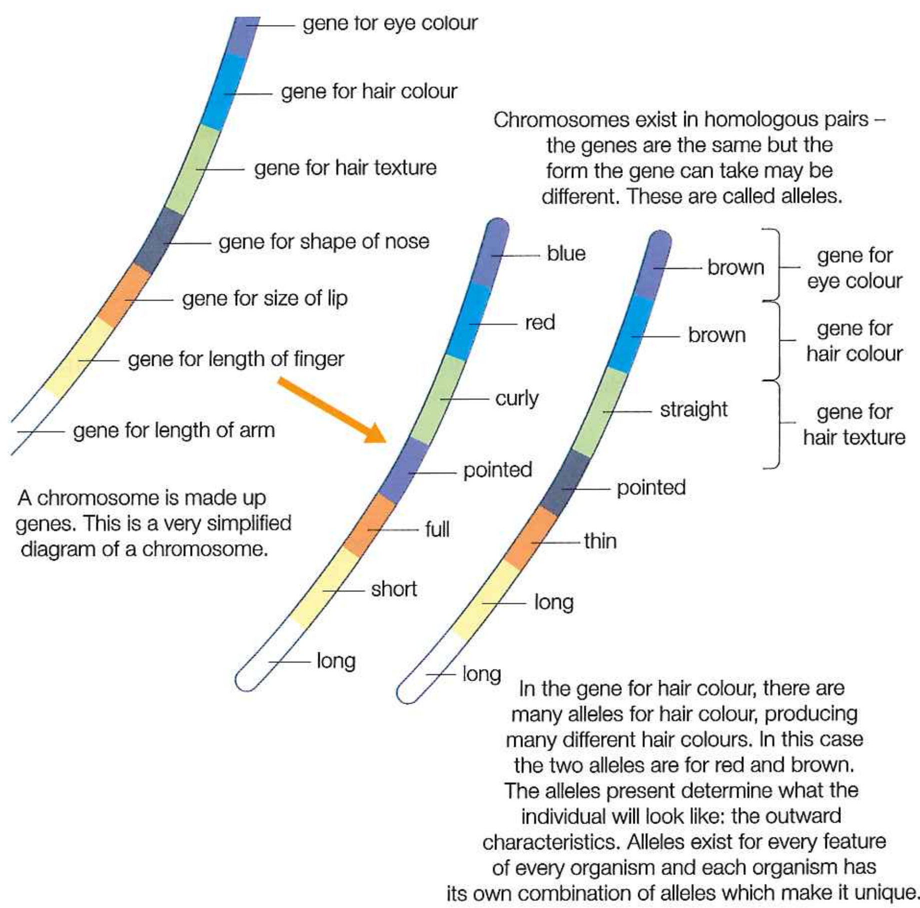


Figure 14.6 Homologous chromosomes showing genes as lengths of DNA.

Most characters, such as height, are controlled by many genes. However, there are some characters which are controlled by fewer genes and are inherited in a simple way. This is called mendelian inheritance, after the monk Gregor Mendel who made the first discoveries. Mendel used plants for his studies, but we can follow similar examples in humans.

mendelian inheritance ▶

Monohybrid inheritance, example: ability to taste PTC

The ability to taste the chemical PTC (phenylthiocarbamide) is controlled by a single pair of genes. The chemical has a bitter taste. This is an example of monohybrid inheritance because just one gene is involved. The gene has two alternative forms called alleles, that can control this one characteristic (see figure 14.6).

monohybrid inheritance ▶

allele ▶

There are more people who can taste this chemical than those who cannot taste it. This seems to suggest that the allele controlling the ability to taste is stronger than the one stopping the ability to taste. By tracing who can, or who cannot taste in families, it has been shown to work as follows.

The allele for tasting is dominant. The allele for non-tasting is recessive.

At meiosis, we have seen how only one chromosome of a pair passes to each gamete. Hence only one allele from each pair passes into the gamete. The chromosomes pair again at fertilisation and so the alleles pair. If a dominant allele is inherited *with* the recessive allele, then the character controlled by the dominant allele is the one that shows. The recessive allele does not show its character if inherited with the dominant allele.

dominant ▶

recessive ▶

All this is much easier to understand if a genetic cross is drawn as follows. (Whenever doing genetic crosses, set them out in this way.)

Let the dominant allele for tasting = **T**

Let the recessive allele for non-tasting = **t**

If a father can taste, then his alleles (genotype) will be **TT** (figure 14.7a) or **Tt** (figure 14.7b). (In either case having the **T** will make him a taster.)

TT means similar alleles of a pair and is called homozygous. **Tt** means dissimilar alleles of a pair and is called heterozygous.

homozygous ▶

heterozygous ▶

If the mother cannot taste the chemical she must be **tt**. She is homozygous. (If she had the **T** she would be a taster.)

Figure 14.7(c) shows what would happen if both parents were heterozygous. Thus a ratio of three tasters to one non-taster is shown. It is important to realise that these are not actual children produced by one family. This cross merely shows the *proportion* of offspring that could be produced. It is all down to chance which gamete fuses with another. Only if a number of families were studied, with many children, would the three to one ratio be seen. A Punnett square is another way of showing this result (figure 14.7d).

ITQ4

A mother who cannot taste phenylthiocarbamide (PTC) has a child whose father is heterozygous for the taste gene. What is the chance the child can taste PTC?

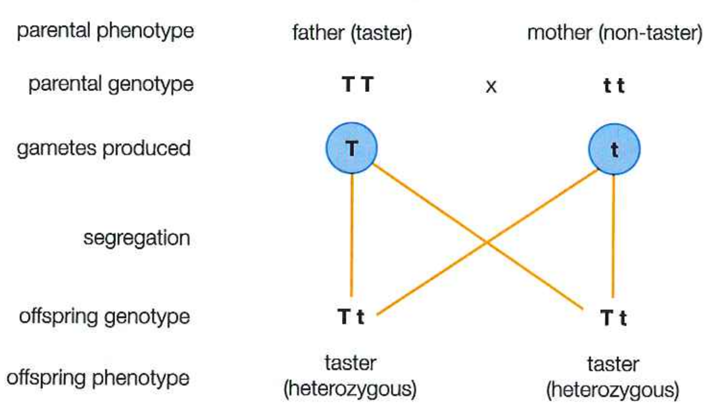


Figure 14.7(a) One possibility if the father is homozygous (TT) – all offspring are tasters.

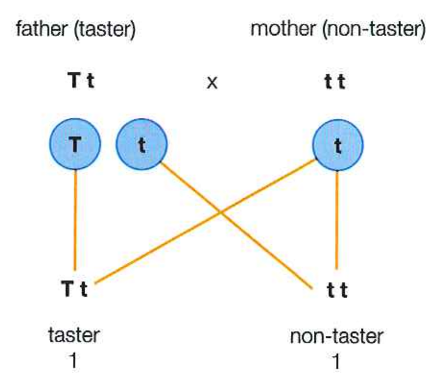


Figure 14.7(b) The other possibility if the father is heterozygous (Tt) – equal chance of taster or non-taster offspring.

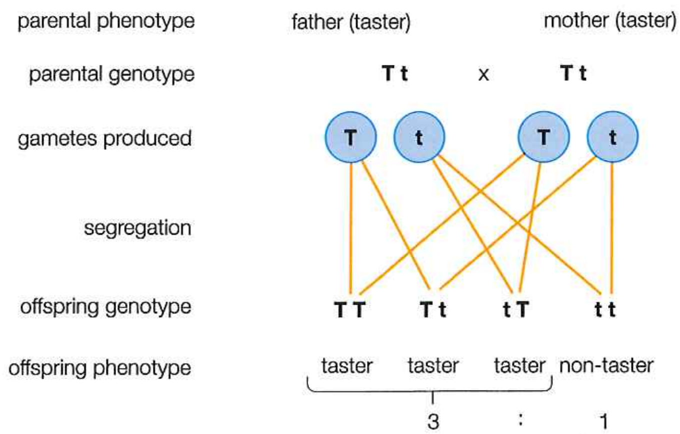


Figure 14.7(c) The cross if both parents are heterozygous (Tt) – 3:1 chances of a taster to a non-taster offspring.

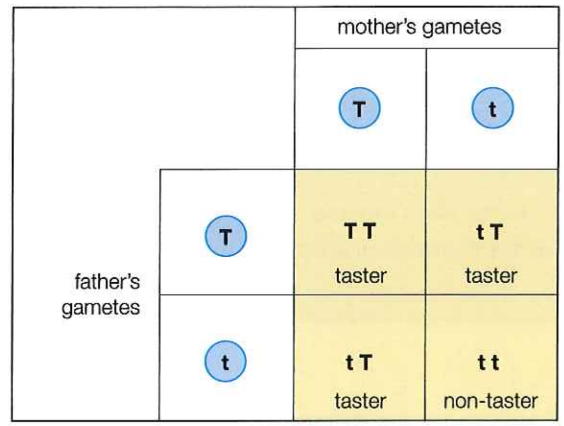


Figure 14.7(d) A Punnett square is another way of showing this result.

You must *not* taste PTC because this chemical may be carcinogenic, meaning it is cancer forming. Practical activity 14.3 suggested on page 264 may not be an inherited ability, but it serves to illustrate the PTC effect.

Practical activity 14.2
To illustrate how gametes segregate and combine at random

1 In two bags place equal numbers of coloured marbles, say red and blue (figure 14.8). Consider red marbles to be gametes with the dominant allele for tasting and the blue marbles the gametes with the recessive allele for not tasting.

2 The two bags represent the gametes available from the two heterozygous parents.

3 At random, take without looking a marble from each bag, putting the pairs of the same colour mix together.

This is the equivalent of the way the alleles from two heterozygous parents would go into gametes and combine to form offspring.

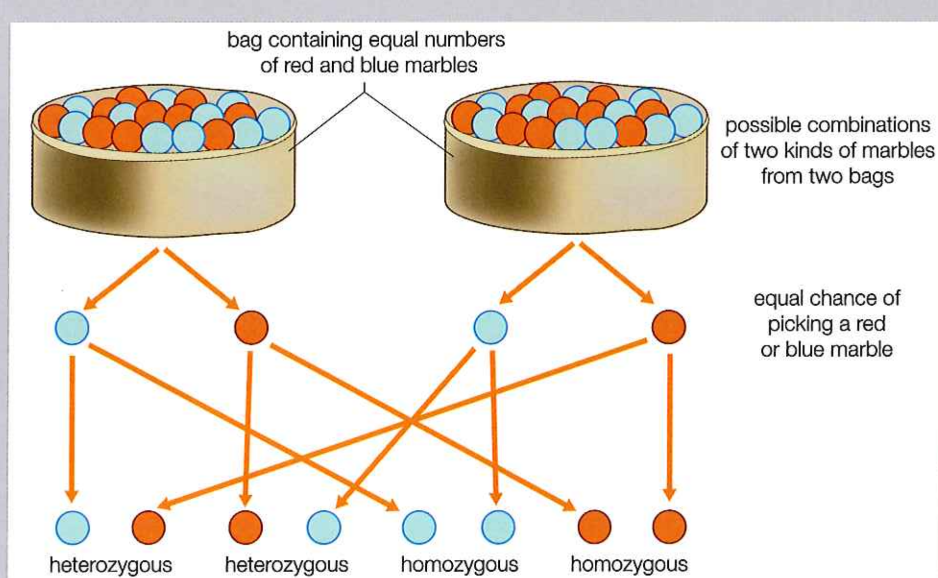


Figure 14.8 To show how random pairs selected can combine.

Questions

1 What are the chances of selecting a red or a blue marble from the bag?

2 Count the numbers of the same colour mix you obtain and work out the ratios to each other.

3 What would this ratio represent in numbers of tasters and non-tasters?

4 What is the ratio of carriers?

Practical activity 14.3
To illustrate monohybrid inheritance of two human characters

A To investigate tasting

1 Solutions of sugar and saccharine are labelled 1 and 2.

2 Each pupil uses a different drinking straw (for hygienic reasons) to place one drop of each solution on the tongue.

3 Pupils record whether they can taste the same or different solutions.

Questions

1 Explain exactly how you organised this experiment to obtain the results without guessing.

2 What is the proportion of tasters to non-tasters for each solution?

3 What are the dominant and recessive characters?

You may notice that, while most pupils can distinguish between these two chemical tastes, a proportion cannot tell the difference.

B To investigate tongue rolling

1 Push out your tongue and try to curl up the sides (figure 14.9).

Questions

1 Record the numbers of pupils who can, or cannot, curl their tongue.

2 What may be the dominant and recessive characters?

3 Construct a genetic cross for the possible offspring from two parents who *can* curl their tongues.

Figure 14.9 The Caribbean girl on the left can curl her tongue (homozygous dominant, or heterozygous). The girl on the right cannot curl her tongue (homozygous recessive) – but see text.

Again you will notice that, while most pupils can curl their tongues, there are a number who cannot. Ratios obtained suggest that this is also an example of monohybrid inheritance. (In fact many textbooks wrongly choose this as an example.) Recent research suggests that possibly *if* a gene exists, it simply gives the ability to *learn the skill* of tongue rolling. Some of this research is based on observations of many identical twins (who must have the same genes) not both being able to curl their tongues. Actors often learn to curl their tongues to improve their diction. This serves as an example of how carefully scientists must test the hypothesis made, before coming to a firm conclusion.

ITQ5
A boy who can roll his tongue discovers neither of his parents can do it. What is the significance of this?

Monohybrid recessive inheritance, example: albinism

albinism ▶

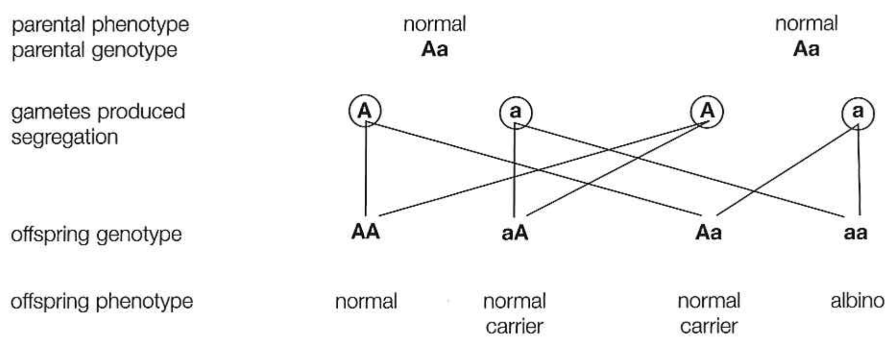
An albino lacks the skin pigment melanin and has white skin and hair. This means they lack screening from the dangers of ultraviolet light. They also lack pigment in the iris, causing vision difficulties in bright light. Hence an albino has to take precautions to avoid bright light.

The albino condition arises from the inheritance of two recessive alleles. A dominant allele controls the normal condition. Hence the incidence of this disease depends on the number of people in the population carrying the recessive allele.

carrier ▶

Let the dominant allele for normal skin pigment = **A** and the recessive allele for the albino condition = **a**. A carrier appears normal but has the recessive allele having the genotype **Aa**.

Let us suppose that two parents learn they are carriers for albinism. What are their chances of having an affected child?



ITQ6
If an albino person has a child with (a) a normal homozygous person (b) a carrier, show by genetic crosses the chances of their children being albino.

Hence the parents have a one in four chance of having an albino child and half their children will be carriers like themselves. One in four will be completely normal.

Their albino child grows up and wants to start a family. What will be the effect on his or her children?

If they have children with a normal person, all their children will be normal but carry the recessive allele for the disease. Should they have children with a carrier, half will be albinos and half normal.

cystic fibrosis ▶

Cystic fibrosis is another example of an inherited disease caused by recessive alleles. Here the lungs are affected by mucus and most affected individuals do not survive beyond the age of 30. In the next section we shall see that red/green colour blindness and haemophilia are also caused by single-allele recessive inheritance.

There are a number of harmful recessive alleles in populations. In European populations, there are 2% carriers for albinism and 3.5% carriers for cystic fibrosis. (It has been estimated that everybody is likely to carry a few harmful recessive alleles.)

genetic counselling ▶

It is possible by genetic counselling to have tests to identify carriers for some of these diseases. This presents a very interesting social biology problem, illustrated by the following questions on which you may have an opinion and try to answer.

1 Would you have a test to see if you and your partner, before or after marriage, have the same harmful recessive alleles? What would you do if you have?
2 If a couple have a child with a recessive disease, do they have further children? What are their chances of having another affected child?
3 Should governments legislate for genetic counselling for all? What effect would this have on the gene pool? (The gene pool is the genes present in the whole of a population.)
4 Should everybody be tested at birth and given their list of harmful recessive alleles, which they present to each other before marriage or courting?

gene pool ▶

Inheritance with codominance

ABO ▶

codominance ▶

The inheritance of the ABO blood groups is determined by a single gene. There are three alleles of this gene: $\mathbf{I^A}$, $\mathbf{I^B}$ or $\mathbf{I^o}$. (**I** represents the actual locus: position.) If alleles controlling group A and B are inherited together, then there is codominance, and group AB results. This is sometimes called incomplete dominance because both $\mathbf{I^A}$ and $\mathbf{I^B}$ alleles are expressed. Neither $\mathbf{I^A}$ nor $\mathbf{I^B}$ is dominant to each other. However, both $\mathbf{I^A}$ and $\mathbf{I^B}$ are dominant to $\mathbf{I^o}$.

Table 14.2 and figure 14.10 show how the ABO blood groups are controlled by different alleles (genotypes).

Blood group	Possible genotype
A	$I^A I^A$ or $I^A I^o$
B	$I^B I^B$ or $I^B I^o$
AB	$I^A I^B$
O	$I^o I^o$

Table 14.2 Control of ABO blood groups.

the allele for antigen A = $\mathbf{I^A}$

the allele for antigen B = $\mathbf{I^B}$

$\mathbf{I^o}$ = recessive gene producing no antigens

$\mathbf{I^A}$ and $\mathbf{I^B}$ are dominant to $\mathbf{I^o}$ $\mathbf{I^A}$ and $\mathbf{I^B}$ are codominant

ITQ7
Use genetic crosses to show the inheritance of blood groups to (a) parents who are group O and group AB (b) parents of group A and group AB.

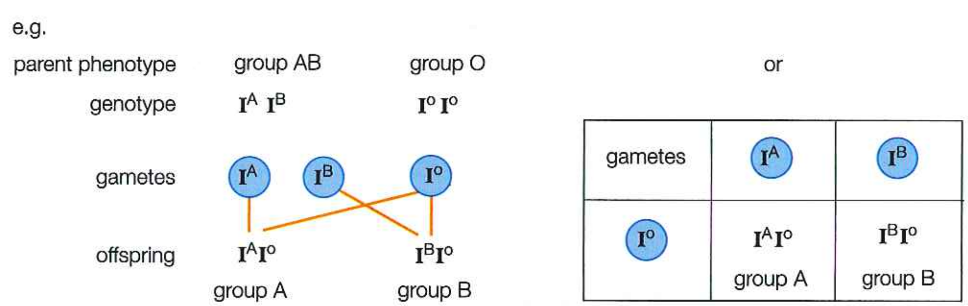


Figure 14.10 How blood groups are inherited.

Sex-linked inheritance

sex-linked ▶

Sex-linked inheritance occurs when the alleles are on the sex chromosomes. In all common cases the alleles are on the X chromosome. The Y chromosome lacks alleles that can be easily identified.

- Name one example of a sex-linked recessive condition.

Because males only have one X chromosome, they are much more likely to show sex-linked recessive conditions. Females having two X chromosomes are likely to inherit one dominant allele, masking the effect of the recessive allele. A female with one recessive allele masked in this way is called a carrier, as described above.

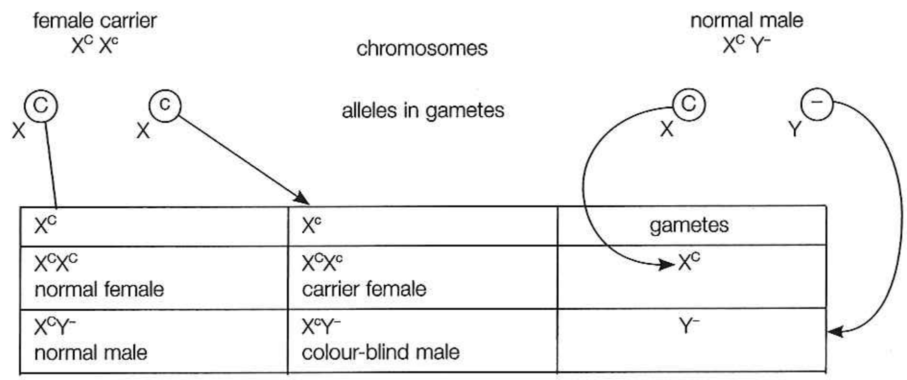
Red/green colour blindness

ITQ8
If a red/green colour-blind male had children with a normal female, what proportion would be colour blind?

When we studied the eye we looked at red/green colour blindness. This is a sex-linked recessive condition (figure 14.11).

The allele for red/green colour blindness is on the X sex chromosome. It is a recessive allele. Where there are two alleles, as in a female with two X chromosomes, one allele of a pair is almost always the dominant non-colour-blind allele. The recessive allele has no chance to show its effects, although it can be passed on to her children.

In males, with only one X chromosome, the colour-blindness allele, if it should occur, will make its effect felt. The male will be red/green colour blind.



C = dominant normal allele
c = recessive allele for red/green colour blindness

Figure 14.11 Inheritance of red/green colour blindness.

Haemophilia

- Name the disease where blood fails to clot at a wound.

Haemophilia, a disease in which the blood fails to clot at a wound, is also inherited in a sex-linked way.

If H = the allele for normal blood and
h = the allele for haemophilia
$X^H X^H$ = normal female
$X^H Y$ = normal male
$X^H X^h$ = carrier female
$X^h Y$ = haemophiliac male

ITQ9
Show by genetic crosses three types of parents who could produce haemophiliac children. Use the symbols in the text alongside.

The problem with haemophiliacs is that even a small cut will not heal and the loss of blood can be serious. Medication containing clotting agents is needed. Consider all the problems involved such as accidental cuts, having a tooth out, or needing an operation.

Monohybrid inheritance: worked example

Question

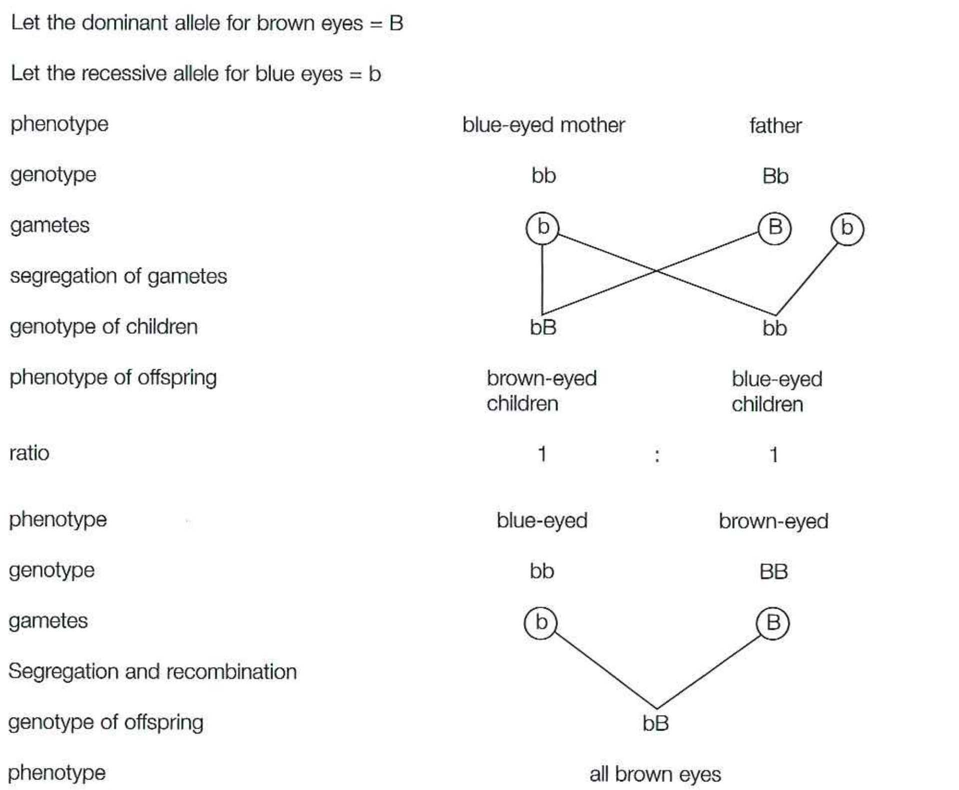
A certain type of blue eye colour is recessive to brown colour. A blue-eyed mother has several children; half are blue-eyed and half have brown eyes. What is the genotype of the father? One of the blue-eyed daughters grew up and married and had several children all with brown eyes. Explain these results.

Notes on answering

Always define any symbols you use and distinguish the characters observed from the alleles. Ring gametes and explain as follows.

The father must be a carrier with the genotype **Bb** to produce half blue-eyed and half brown-eyed offspring (see figure 14.12).

You should know this result, but if you do not, you can check various crosses in rough to find this is the only one that will work. For one of the blue-eyed offspring to produce all brown eyes, her husband must have had both alleles for brown eyes.



Note: only *some* brown and blue eye colours are inherited in this simple way. Punnett squares could be used as an alternative.

Figure 14.12 Inheritance of blue and brown eyes.

Multiple allelism

multiple allelism ▶

One pair of alleles controls characters such as tasting PTC, albinism, haemophilia, certain eye colour, and others. More often than not, many alleles work together to control the character. This is called multiple allelism. Instead of one allele, many alleles control the character. Height is one example. Tall parents generally have tall children, because they pass on a number of alleles for this character. But because of the mix of alleles passed on, some children may be small. Most human characteristics are controlled by multiple alleles. This is why human inheritance is so difficult to predict.

Variation

Variation is of two main kinds.

continuous variation ▶

Continuous variation is when there are very small differences between individuals arranged in order. For example, we could arrange people in order of height. Discontinuous variation occurs when there are distinct differences. For

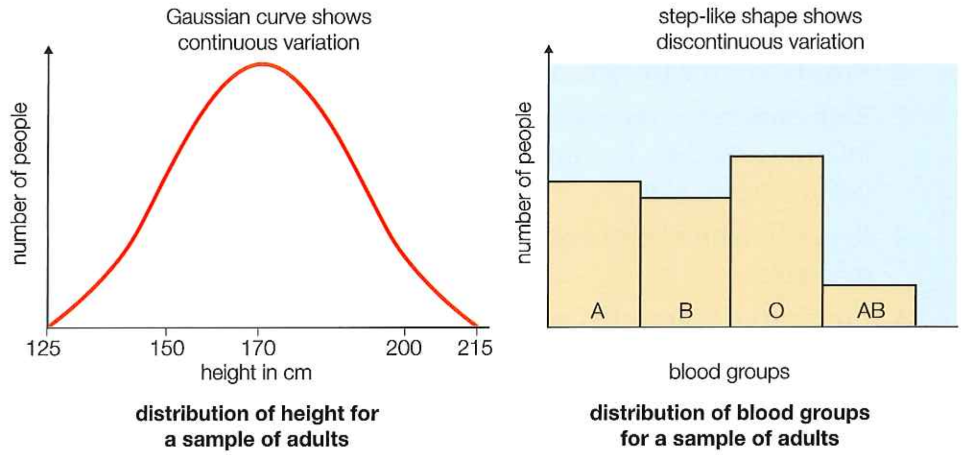


Figure 14.13 Continuous variation in height and discontinuous variation of the blood groups.

example people have either blood group A, B, AB or O with no 'in between' groups. Arranged as a graph, continuous variation produces a smooth Gaussian curve. Discontinuous variation produces a step-like graph (figure 14.13).

discontinuous variation ▶

Crossing over at meiosis mixes maternal and paternal genes
Division at meiosis also ensures that every gamete is different
Random fusion of an ovum with a sperm is by chance
Characters are inherited from two parents
Environmental influences, e.g. food, education, health, etc., make changes to a person
Penetrance: certain genes may be expressed more strongly in certain environmental conditions, e.g. genes for recovery of immunity during an infection work better when resting

Table 14.3 Sources of variation.

Practical activity 14.4
To investigate variation

A Finger length

1 Each member of the class measures the length of their forefinger from tip to knuckle.
2 Construct a table writing down the number in the class having the same length finger in groups of 5 mm difference (i.e. 80 mm, 85 mm, 90 mm and so on).
3 Plot a histogram from this table of results with length on the horizontal axis and number of individuals on the vertical axis.
4 Connect the histogram tops by line to form a curve.

Questions

1 What is the shape of your curve called and what type of variation does it show?
2 Record the shortest and longest finger lengths.
3 From the peak, what is the mean (mode) finger length?

B Pupils' colour preference

1. Each member of the class chooses from the following list their favourite colour: red, orange, yellow, green, blue.
2. Record the numbers of pupils liking each colour in a table.
3. Construct a histogram from the table.

Questions

1. How would you describe your histogram and what type of variation does it show?
2. List the frequency of each type of colour chosen from most to least common.

There were no distinct gaps in the sizes of fingers measured so the graph constructed was smooth. This shows continuous variation.

Because the colours were distinct, choices appeared as steps on the graph. This shows discontinuous variation.

Genetic and environmental effects

identical twins ▶

We have seen that because different gametes fuse, all the offspring show variation. The only exception to this is when identical twins (figure 14.14) are produced. In this case, after fusion of the sperm and egg, the resulting zygote divides into two cells, which separate. Each cell forms a new individual, but each cell was formed from the same sperm and egg and so will contain exactly the same genes.

ITQ10
One identical twin can ride a bicycle and the other cannot. How far is the genotype responsible for this difference?

Figure 14.14 Identical twins develop from the same zygote so have the same genes. Any differences between them will be due to the environment.

Identical twins are widely used to compare the effect of the environment on development. Any differences measured between the twins must be due to environmental effects. The problem arises in measuring the environmental effects scientifically.

For example, if two identical twins were separated at birth and one had the best education possible and the other had the least education, then the effects of education could be estimated.

Measuring the differences in intelligence between each twin should show what part the education contributed and what part the genotype contributed. The importance of heredity for inheriting intelligence could be estimated. Intelligence can be measured by scores from intelligence tests. The inaccuracies in measurements and factors not controlled make such experimental studies highly controversial. See if you can make a list of all the problems and variables not controlled in this investigation.

A little more is known about the following examples.

Characters entirely inherited

Your blood group is entirely inherited and controlled by your genes. This means it is entirely controlled by the genotype and cannot be changed. Your blood group will depend only on the genes you inherited from your parents. In a similar way many other characters are completely controlled by the genes, such as eye colour, natural hair colour, etc. Your sex is entirely inherited and depends on whether you receive a Y chromosome or not. Hence sex shows discontinuous variation with only two groups.

Characters mainly inherited

Genes also mainly control height, although with certain exercises and a good diet through childhood and adolescence a slight increase in height can be gained. Here the environment has a very small effect on height. Successive generations have been increasing in height over recent years, thought to be due to environmental influence of better food, exercise and living conditions.

Inherited characters, but also strongly affected by the environment

• Why is weight partly under environmental control?

Weight on the other hand is much more strongly influenced by the environment, although it is still partly genetically controlled. If you eat a lot you will become fat. If you genetically inherit a large skeleton you are likely to weigh more. Hence the phenotype (weight) is influenced by the genotype (genes) and the environment (eating habits).

Characters entirely environmentally induced

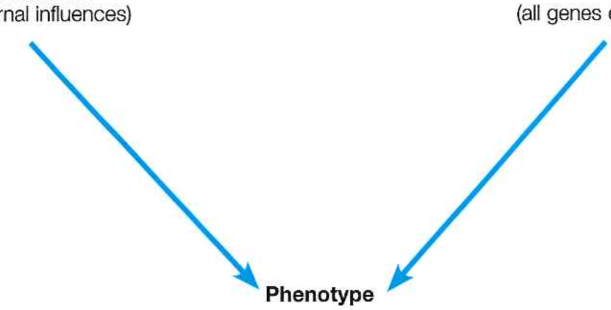
Death through a car accident is completely controlled by the environment. Similarly so is death by famine and starvation. The environment (an accident) is entirely the reason for the result (death).

The nature–nurture problem

We have seen that the environment has varying effect on many characters. If you do a lot of exercise, or manual work, you will develop larger muscles. If you smoke cigarettes you will damage your lungs, reduce your vital capacity and affect your breathing.

The problem arises in deciding how much a character is controlled by the genotype and how much by the environment. Sometimes known as the nature–nurture issue, it is summarised here.

nature–nurture ▶



There is much controversy among scientists over the importance of each of these controlling influences. How much of your personality is due to the genes you have inherited and how much is due to your way of life? This includes your life at home and play as well as at school. You will realise how difficult it is to answer this question and why scientists, particularly psychologists, cannot agree on this point.

Some adults believe that if they had received a better education they would be professors making outstanding contributions to research. Others think that the genes they have set the limits to their achievements. Education will only allow them to achieve the best these genes can express.

ITQ11
What controls your (a) eye colour (b) ability at sport?

The only point of agreement is that characters developed by environmental influences are not inherited. You cannot inherit a broken arm, for example.

Because the only parts passed from one generation to the other are the nuclei of the gametes, only changes in these can affect the offspring. Gametes are not affected by environmental differences. This means that however hard you work in your lifetime, these features cannot be passed on genetically to your offspring. In an experiment the tails were cut off mice for many successive generations. This had no effect on tail size of mice born later.

ITQ12
A father involved in heavy manual work is pleased to think his son will inherit his muscular physique. How far is he right?

Practical activity 14.5
Debate on the nature–nurture issue

1 Social biology has many controversial issues open to debate. The formal proposal is 'The intelligence of the pupils in this class depends on the genes they have inherited from their parents'.

2 Spend some time considering this issue in the light of what you have learned in this chapter and your own experience in life.

3 Decide whether you are for or against the motion and jot down some notes on what you would like to say.

4 Elect by ballot a speaker and seconder both for and against the motion.

5 The four elected speakers have their say, followed by individuals from the class.

6 Finally the proposers in each case sum up and everybody in the class votes for, or against, or abstains from, the motion.

Questions

1 Write up an account of the debate giving your own conclusion. Try to separate scientific fact from opinion.

DNA, RNA and protein synthesis

The nature of the genetic substance

gene ▶

• What is the name given to a short length of DNA on a chromosome that controls a character?

What is a gene? We know genes are arranged in order along the chromosome (figure 14.1). We also know that they are the units of genetic substance. That means genes control the making of proteins in the cell. These proteins serve as building blocks to make the characters seen. Such characters are all the structures of the body including enzymes. Observable characters have genes controlling them.

The actual chemical which forms the genes is called DNA (short for deoxyribonucleic acid) (figure 14.15). DNA is the genetic substance. It is capable of exact replication (splitting into two identical copies).

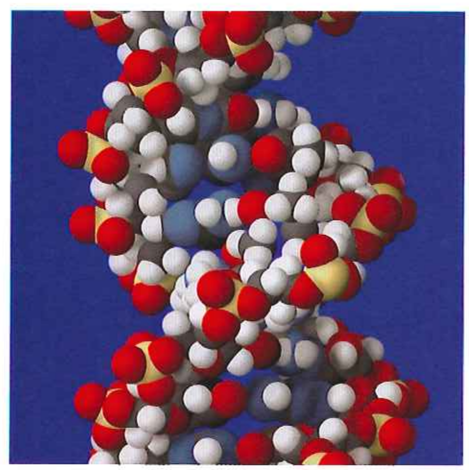


Figure 14.15 A model of DNA – the genetic substance.

plan ▶

DNA in the nucleus carries the plan for all proteins made in the body. The structure of the DNA molecule was worked out by the scientists Watson and Crick in 1952. As a result we now know how genes work.

Protein manufacture in the cell

Man is made up of a very large variety of proteins. But all proteins are made up of only 20 different types of amino acids. The DNA acts as a code (plan) to place each amino acid in the correct position to make the protein.

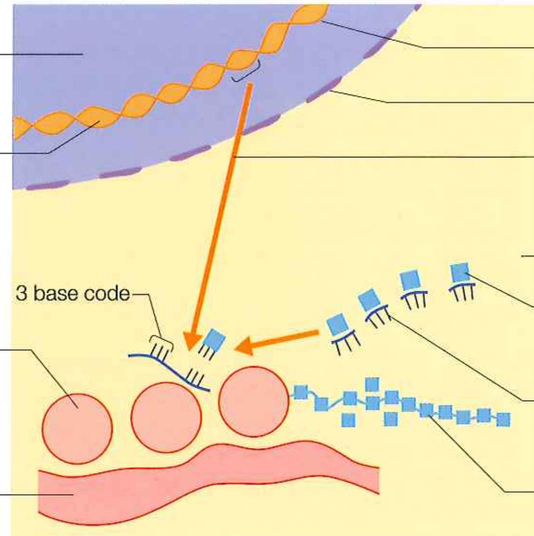


Figure 14.16 How DNA determines protein synthesis.

The actual protein is made on the ribosomes in the cytoplasm of the cell. Because the DNA is in the nucleus, the plan has to be carried to the ribosomes. Another nucleic acid called messenger RNA (mRNA) carries the code to the ribosomes. Study figure 14.16 as you read this account.

messenger RNA ▶

The process starts when the DNA in the nucleus unwinds, as it does during division. This time, however, a molecule of messenger RNA is produced, which passes out of the nucleus.

On reaching the ribosomes, the messenger RNA determines the order of the amino acids making the protein chain. These amino acids have come into the cell from protein foods broken down during digestion.

Each amino acid is picked up by yet another type of nucleic acid called transfer RNA (tRNA). Transfer RNA carries the amino acid from the cytoplasm to the ribosome, where the messenger RNA receives it. Hence amino acids are linked up in the ribosomes and the protein chains are made.

transfer RNA ▶

Genetic engineering explaining recombinant DNA technology for insulin production is described on pages 407–8.

- In the making of a protein (a) where is the plan found (b) where is it made (c) how is the information passed from one to the other?

Mutation

Gene mutation

gene mutation ▶

A gene mutation is a spontaneous change in a part of the DNA, which may alter the characteristic it controls.

Sickle cell anaemia

sickle cell anaemia ▶

base ▶

An alteration of the DNA coding for haemoglobin produces sickle cell anaemia (figure 14.17). One part of the DNA called a base is changed, so that the wrong amino acid is inserted into the haemoglobin molecule. The amino acid glutamic acid is replaced by valine. The effect of this is to make the red blood cells appear sickle-shaped and

Figure 14.17 Normal and sickled red blood cells – note the sickle shape.

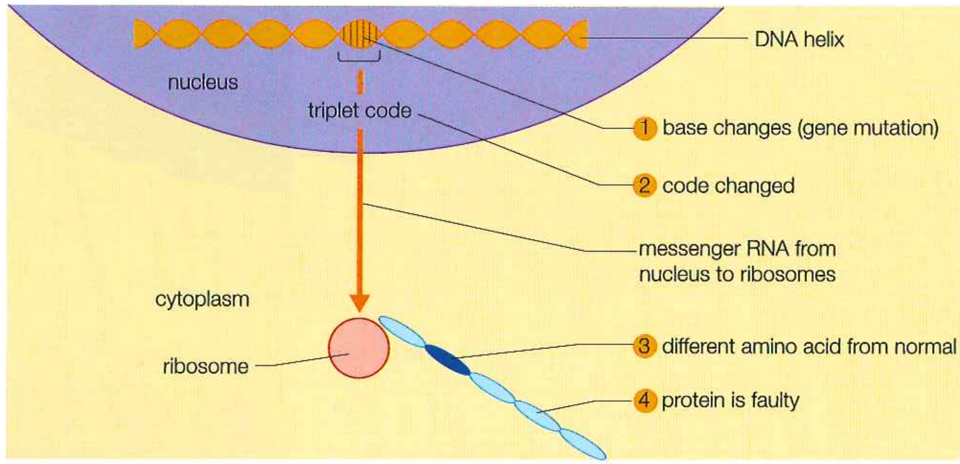


Figure 14.18 How a gene mutation produces faulty protein.

reduce their oxygen-carrying capacity. This causes anaemia. Death occurs in the homozygous recessive condition.

In the heterozygous condition only mild anaemia is experienced. The *Plasmodium* parasite causing malaria cannot live in these heterozygous people. Consequently such people survive malaria. Selection of the recessive allele is favoured in the heterozygous condition. Hence sickle cell carriers are more common in areas where malaria is common.

ITQ13
Why is sickle cell anaemia more common in certain parts of Africa?

The faulty allele arising by mutation (figure 14.18) can be passed on to offspring. Mutations may occur in pathogens such as viruses and bacteria, making new strains more virulent and not responsive to current vaccines (see page 309). For example if the influenza viruses causing bird or swine flu mutate, then pandemics occur.

Chromosomal mutation

ITQ14
What happens to cause (a) sickle cell anaemia (b) Down's syndrome?

Down's syndrome

Down's syndrome is also an example of an inherited disease. This time, instead of just one or a few genes being affected, a whole chromosome is affected. In Down's

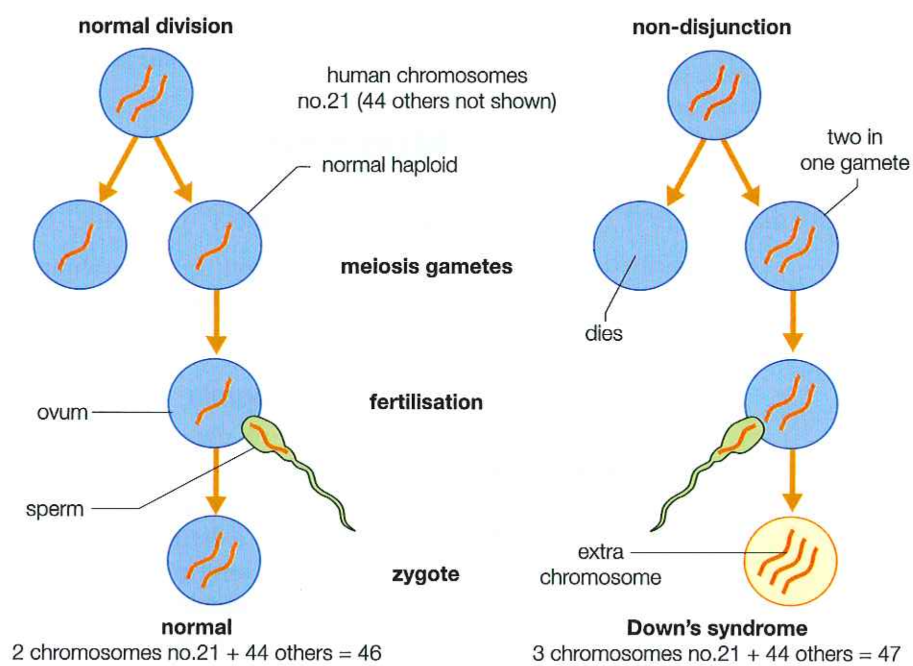


Figure 14.19 An extra chromosome passed on in ova causes Down's syndrome.

syndrome, the zygote receives an extra chromosome due to unequal division of the chromosomes when the ova are formed. Two chromosomes (number 21) pass into one ovum. The sperm provides one, so the zygote receives three (figure 14.19). This extra chromosome causes Down's syndrome.

Down's syndrome children have learning difficulties. They have short arms and legs and sometimes internal defects. However, Down's syndrome children are generally very friendly and often cheerful.

The extra chromosome they inherit that causes these features comes from their mother. Mothers over the age of 40 are much more likely to have a child with Down's syndrome than are younger mothers.

Mutation and evolution

evolution ▶

- What is the name given to the changes believed to have occurred to form the complex organisms of today from simpler forms in the past?

selection ▶

Evolution describes the very slow development of generally more complicated animals and plants from their simpler ancestors. In the hundreds of million years of evolutionary time, mutations are believed to be responsible for the changes in species. While most mutations are harmful, as described for diseases, above, when they are responsible for variations (differences between individuals) they can be useful. Those organisms with useful differences are more likely to survive and reproduce. They are said to be selected by the environment. If the differences are large enough a new species is formed.

Importance of mutations

ITQ15
Why is variation so important in evolution?

Changes produced by mutations have had a profound influence on our lives. For good: in the evolution of all organisms, including the features so successful for our survival. For bad, apart from causing human defects, they make some pathogens more virulent, and give them the ability to survive vaccinations.

Term	Definition
Inheritance	Transmission of genetic information from one generation to the next
Gene	A part of the DNA on a chromosome that sends instructions by RNA to the ribosome which makes a polypeptide chain. These form cell structures or enzymes controlling characteristics
Phenotype	The observable characteristics of an organism, e.g. tall, blue eyes, and so on
Genotype	The actual genes present in an organism (many are not expressed in the phenotype)
Homologous	A pair of matching chromosomes (of maternal and paternal origin)
Allelic pair (alleles)	A pair of genes controlling alternative characteristics, e.g. tall and short, which occur at the same place (locus) on homologous chromosomes
Heterozygous	Both alleles are present at a locus (i.e. one on each of the homologous chromosomes)
Homozygous	The locus has the same allele on each of the homologous chromosomes
Dominant	In the heterozygous condition the dominant allele controls the characteristic shown in the phenotype, e.g. **Tt** is tall, as the allele **T** (for tallness) is dominant
Recessive	The allele which is not expressed (shown) when inherited in the heterozygous condition
Mutation	Occurs when the DNA is in some way altered so that the characteristic produced is changed
Gene mutations	May affect only a very small part of the chromosome, e.g. sickle cell anaemia, haemophilia
Chromosomal mutations	Occur when the chromosome breaks or duplicates, producing major changes which are harmful, e.g. Down's syndrome

Table 14.4 Genetic terms.

Summary

- Chromosomes are threadlike structures with genes as DNA along their length.
- Mitosis produces two identical cells (clones) with the diploid number of chromosomes.
- Meiosis provides variation at crossing over and halves the chromosome number (haploid).
- Continuous variation is when there are very small differences between characters arranged in order, e.g. height. Discontinuous variation occurs when there are distinct differences, e.g. blood groups.
- A male inherits an X and a Y chromosome; a female has X and X chromosomes.
- Monohybrid inheritance is when a character such as albinism is controlled at one allele.
- A carrier has a recessive allele that in the homozygous condition causes diseases such as albinism and cystic fibrosis.
- Sex-linked inheritance occurs when the gene is on the X chromosome as for red/green colour blindness and haemophilia.
- Inheritance of blood groups shows codominance where alleles I^A and I^B together produce I^AI^B. Both I^A and I^B are dominant to I^0.
- Most human characters are controlled by many alleles – multiple allelism.
- Both the genotype and the environment control most characters such as weight. It is usually difficult to evaluate the influence of each.
- Some characters such as eye colour are entirely controlled by the genotype.
- Mutations are changes to the DNA. One gene change causes sickle cell anaemia.
- A whole chromosome mutation causes Down's syndrome.
- Mutation provides the character differences selected by the environment for evolution.
- The plan in the nucleus to make protein is stored in DNA. The mRNA carries this plan to the ribosomes. The tRNA brings the amino acids to the ribosomes, where they are linked together according to the mRNA plan, to form protein.

Answers to ITQs

ITQ1 (a) A man's gametes contain 23 chromosomes; (b) his liver cells contain 46 chromosomes.

ITQ2 Meiosis produces variation at crossing over when maternal and paternal chromosomes mix DNA lengths. At the second division chromosomes enter different gametes.

ITQ3 If a Y chromosome is absent a female is produced.

ITQ4 A mother who cannot taste PTC must be homozygous recessive, i.e. tt.

A father who is heterozygous has both alleles, Tt.

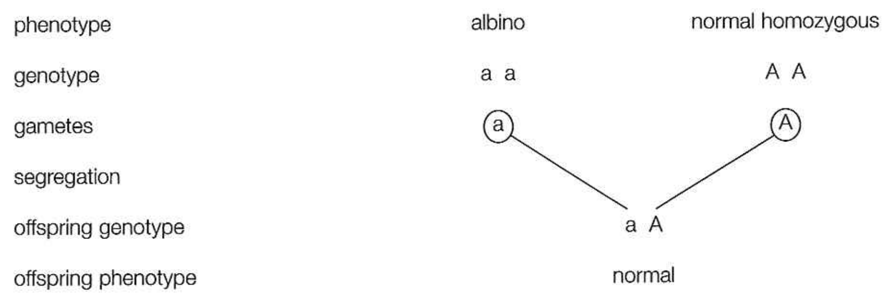
parental phenotype	father taster		mother non-taster
parental genotype	Tt		tt
gametes	(T)	(t)	(t)
segregation			
offspring genotype	Tt		tt
offspring phenotype	taster		non-taster

i.e. half the children will be able to taste and half will not.

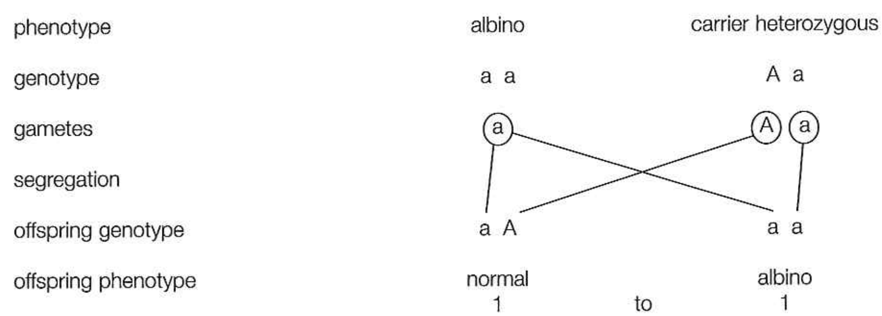
ITQ5 There is no significance because tongue rolling can be learned. At one time it was thought to be an example of monohybrid inheritance, in which case one of the parents would not have been his true parent.

ITQ6 An albino must have both recessive alleles with the genotype aa.

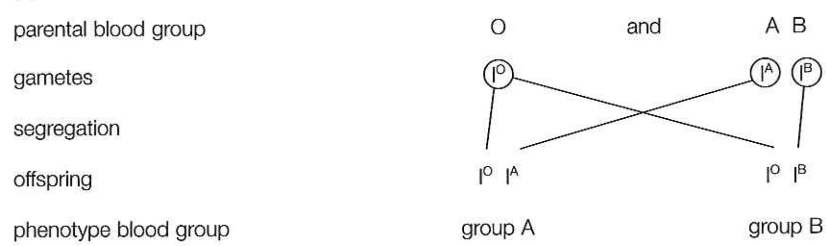
(a) With a normal homozygous person AA all the offspring would be normal but carriers.



(b) With a carrier half the children would be albino and half would be normal carriers.

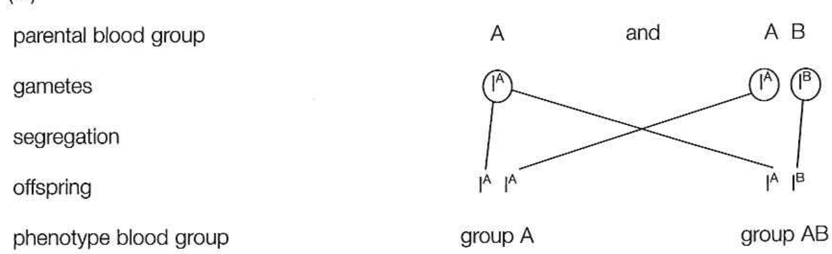


ITQ7 (a)



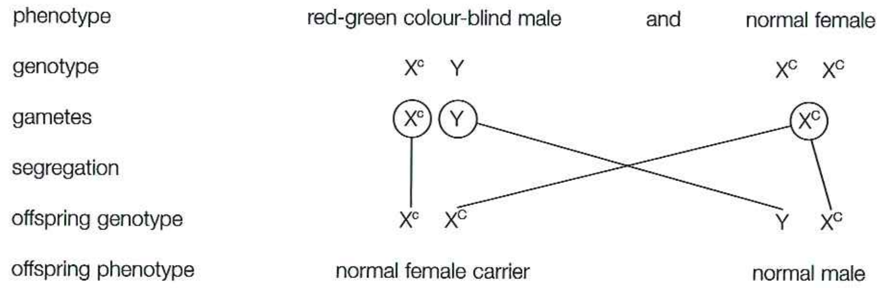
Half children will be blood group A and half B.

(b)



Half children will be blood group A and half AB.

ITQ8 Let ^{c} represent the recessive colour-blind allele and ^{C} the dominant normal allele.

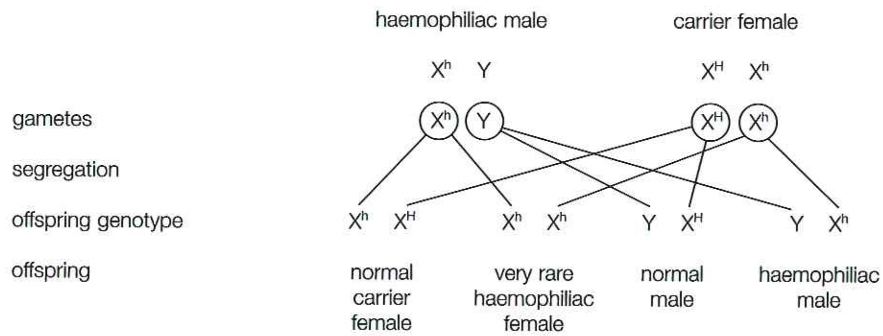


All the offspring will be normal, but the females will be carriers.
Hence no offspring would be colour-blind.

ITQ9 Let the recessive allele for haemophilia = ^{h} and the dominant allele = ^{H}

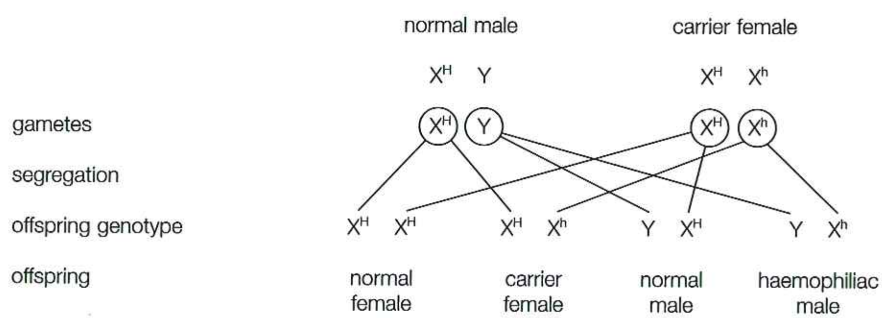
The following parents could produce haemophiliac offspring.

(1) A carrier female $X^H X^h$ with a male with haemophilia X^h Y



1 normal (carrier) female : 1 haemophiliac female : 1 normal male : 1 haemophiliac male

(2) A carrier female $X^H X^h$ with a normal male X^H Y



i.e. half normal males, half with haemophilia. All females normal, half carriers.

(3) The rare haemophiliac female $X^h X^h$ would pass on both of her affected X chromosomes so that all her male offspring would be haemophiliacs and half her female offspring would be haemophiliacs. (Half would obtain a normal X from the male.)

(4) In the very unlikely event of a female haemophiliac and a male haemophiliac having offspring they would all be haemophiliacs. All possible X chromosomes have the recessive alleles.

ITQ10 The genotype cannot be responsible for the difference since it is the same in each twin. Thus one twin needs the environmental influence of learning to ride the bicycle.

ITQ11 (a) Eye colour is entirely controlled by the genotype. (b) Ability at sport will depend on both the genotype for the basic body physique and the environment for training and fitness.

ITQ12 The father is wrong because his son cannot inherit characters he has acquired. The son only receives his father's gametes that are not influenced by his lifestyle.

ITQ13 The *Plasmodium* parasite causing malaria cannot survive in the blood of individuals heterozygous for sickle cell anaemia. Such individuals only suffer mild anaemia, but they survive malaria. Hence the gene for sickle cell anaemia survives in Africa and is passed on by these heterozygous individuals.

ITQ14 (a) Sickle cell anaemia is caused by a gene mutation, which changes part of the DNA making the amino acid glutamic acid. This is changed to valine, which causes the sickle shape of the red blood cells, reducing their oxygen-carrying capacity.

(b) Down's syndrome is caused by an additional chromosome present, due to unequal division when the ova were formed. The extra chromosome causes the learning difficulties and changes in features.

ITQ15 Variation provides the changes in individuals, which have been selected by the environment for survival through evolution.

Examination-style questions

Multiple choice questions

(Write down the number of the question followed by the letter of the correct answer. You can check your answers on page 417.)

1 What is the number of chromosomes found in human body cells and gametes?

	Body cells	*Gametes*
A	23	23
B	23	46
C	46	23
D	46	46

2 Which does *not* help to produce variation in offspring?

A sexual reproduction
B meiosis
C mitosis
D environmental factors

3 Which character is likely to be most affected (changed) by environmental conditions?

A ABO blood groups
B haemophilia
C height
D weight

4 Where are most proteins made?

A in the DNA
B in mitochondria
C in the nucleus
D in ribosomes

5 Which shows the sex chromosomes present in a sperm and ovum?

	Sperm	*Ovum*
A	X only	Y only
B	Y only	X or Y
C	X only	X or Y
D	X or Y	X only

6 Blue or brown eye colour is an example of monohybrid inheritance with the brown allele **B** dominant to the blue allele **b**. Which of the following genotypes would produce a ratio of half blue-eyed and half brown-eyed offspring?

A Bb × Bb
B BB × bb
C bb × Bb
D BB × Bb

7 Which best indicates the sequence of events in protein synthesis?

A mRNA → DNA → ribosomes → polypeptide → protein
B DNA → mRNA → ribosomes → polypeptide → protein
C DNA → ribosomes → mRNA → polypeptide → protein
D mRNA → ribosomes → DNA → polypeptide → protein

8 What proportion of the sons and daughters from a normal man and a woman carrying the recessive red/green colour-blind allele will suffer from colour blindness?

	Sons	*Daughters*
A	all	half
B	half	none
C	half	half
D	all	none

9 Mitosis differs from meiosis because in mitosis:

A identical cells are produced
B similar chromosomes pair
C variation is produced
D half the chromosome number is produced

10 What is *not* made by ribosomes?

A amylase
B fibrinogen
C glycerol
D haemoglobin

Short answer and essay type questions

11 Explain why, apart from identical twins, no two people look alike.

12 Show by means of a sketch why approximately equal numbers of males and females are born in a population.

13 Why are men more frequently red/green colour-blind than women?

14 The inheritance of the blood groups A, B, AB and O is controlled by single alleles which form the antigens on the red cells. The alleles for A and B are dominant to O, while A and B together show no dominance. Complete the following table.

Parents' genotype	*Possible genotypes of the offspring*	*Possible blood groups (phenotypes) of the offspring*
AA × AO		
BO × BO		
AB × AO		
AO × BO		

15 Explain two important properties of DNA which allow it to function as the genetic substance.

16 What is an allele? How does it differ from a gene?

17 Briefly explain the function of (a) DNA (b) mRNA (c) tRNA.

18 If the ability to curl up the two sides of the tongue is controlled by a single pair of alleles with curling dominant to non-curling, work out the possible genotypes (genetic constitutions) of parents who can have children of both curling and non-curling types. Complete the following table.

Let the allele for curling = **C** and the allele for non-curling = **c**.

	Cross 1	*Cross 2*
Types of parents i.e. curling or non-curling (phenotype)		
Alleles possessed by parents (genotype) i.e. **CC**, **Cc** or **cc**		
Allele in the gametes, i.e. **C** or **c**		
Offspring's alleles (genotype)		
Type of offspring (phenotype) i.e. curling or non-curling		

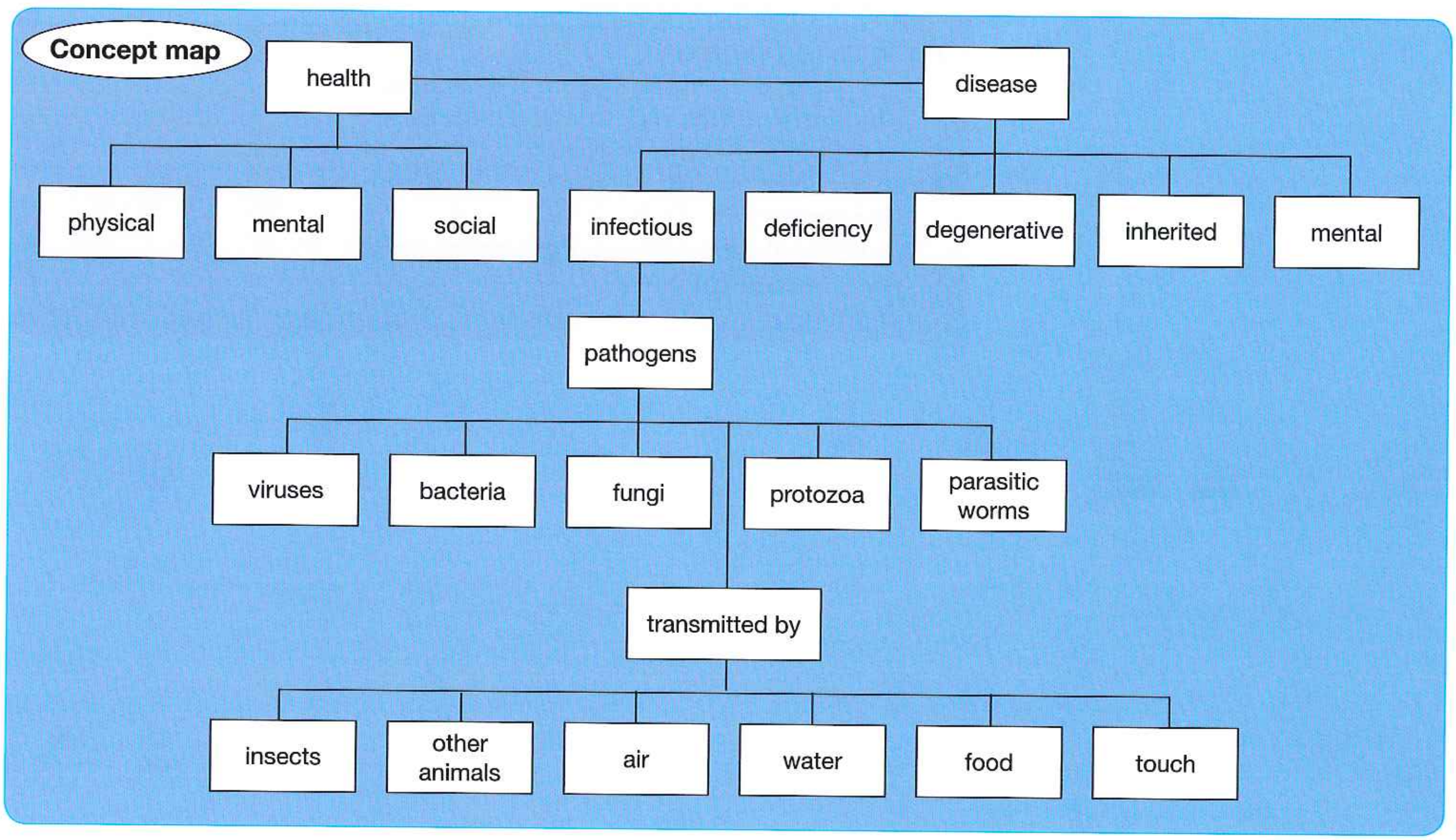
19 What part of the cell:
(a) stores the code for making new protein?
(b) transports the code from the nucleus?
(c) assembles the amino acids?

20 What advice would you give to a person with sickle cell anaemia concerning:
(a) how their children may inherit the defect?
(b) contracting malaria?

15 Health and disease organisms

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

- ☑ define good health as it relates to physical, mental and social wellbeing;
- ☑ outline the ways to maintain good health;
- ☑ define disease, explaining infectious, nutritional deficiency diseases, degenerative, mental and inherited disorders;
- ☑ explain the difference between signs and symptoms of a disease;
- ☑ outline the nature of the major diseases in developed and developing countries;
- ☑ appreciate the variety of pathogens, organisms affecting human health;
- ☑ describe the features, mode of life and name diseases caused by viruses, bacteria, fungi, protozoa and parasitic worms;
- ☑ explain how vectors carry pathogens and how they enter the body.



Definitions of health and disease

healthy ▶

• What three features are needed for a person to be healthy?

physical signs ▶

Health is defined by the World Health Organization (WHO) as a state of complete physical, mental and social wellbeing. A healthy person must be normal for all three of these aspects of health.

Free from physical signs of disease and injury means not having, say, spots on the skin, or a broken bone. A balanced diet, exercise and methods of control to avoid contracting disease ensures physical fitness.

mental health ▶ Mental health means having a healthy mind free from depression and worry. People who worry a lot are not healthy. Hence avoid worry and adopt a positive attitude to life to maintain good mental health.

social wellbeing ▶ Lastly, social wellbeing means having a satisfactory relationship with other people and a good attitude to life in general. Show altruism, which means showing interest and concern for other people. With a friendly optimistic outlook you will obtain social wellbeing, which you will find improves your own way of life.

ITQ1
Define (a) health (b) disease.

So to be healthy you need a balanced diet, plenty of exercise, taking action so you avoid infections, a healthy mind and a good social attitude.

disease ▶ Disease is the loss of health brought about by an association between the person (host) and a disease agent (cause).

infectious disease ▶
pathogen ▶

- What causes all infectious diseases?

In this chapter we are mainly concerned with infectious or communicable diseases. Infectious diseases are all caused by pathogens. A pathogen is any organism that causes disease. The main pathogens are microorganisms (viruses, bacteria, protozoa) and worms. In this chapter we will study these pathogens. Disease occurs when the pathogens live with humans in such a way that they affect our health for the worse.

vectors ▶

- What name is given to any organism (a) causing a disease (b) carrying disease organisms?

Pathogens are transmitted to humans by vectors. Vectors are insects and some other animals that carry pathogens to the body. Air, water, food and direct contact also carry pathogens to the body.

non-transmissible disease ▶ Non-transmissible or non-communicable diseases are not caused by pathogens and cannot be passed from one person to another, or acquired from a disease vector.

degenerative disease ▶
chronic disease ▶

- What type of disease is atherosclerosis?

A degenerative disease is caused by a breakdown of body tissues preventing them from working normally. Most are also chronic diseases, that is they are long lasting and usually non-communicable, leaving the patient disabled and without a complete cure. See page 357 for chronic bronchitis and emphysema as examples. Many chronic and degenerative diseases are associated with ageing. For example, damage to the insulin secreting cells causes the degenerative disease of diabetes. The degenerative disease atherosclerosis is caused by a blockage of the arteries by lipid substances. We saw on page 72 how a lack of exercise and a diet of animal fats speed up this process and causes obesity. The abnormal division of cells causing cancers (see page 250) is in some cases a degenerative disease.

Many diseases are caused by self-infliction by smoking, drug taking including alcohol, and pollution. These are all non-transmissible diseases.

Types of disease	Agents responsible for disease
Infectious	pathogens, e.g. viruses, bacteria, fungi, protozoa, worms
Deficiency	malnutrition, lack of nutrients, e.g. vitamins, mineral salts (lack of vitamin D and calcium causes rickets)
Mental	anxiety, stress and depression
Degenerative	physiological defect, e.g. too little hormone secretion as in diabetes; coronary heart disease, cancer, ageing
Inherited/genetic	inheritance of harmful genes, e.g. albinism, sickle cell anaemia, Down's syndrome
Physical injury	accidents, e.g. limb damage in car crash
Poisoning	ingestion of poisons, e.g. toxins from 'bad' meat
Self-inflicted	by smoking, drug taking, pollution and so on

Table 15.1 Types and causes of disease (disease agents).

Detection of diseases

symptoms ▶
signs ▶

Diseases are detected by symptoms and signs (figure 15.1). Symptoms are *felt* by the patient. An observer cannot always see symptoms, e.g. pain, a headache, feeling dizzy. Signs also indicate disease and can be *seen* by an observer, e.g. spots (rash), rise in body temperature.

ITQ2

A profusely sweating person has a high temperature, sore throat and headache. Which of these are signs and which are the symptoms?

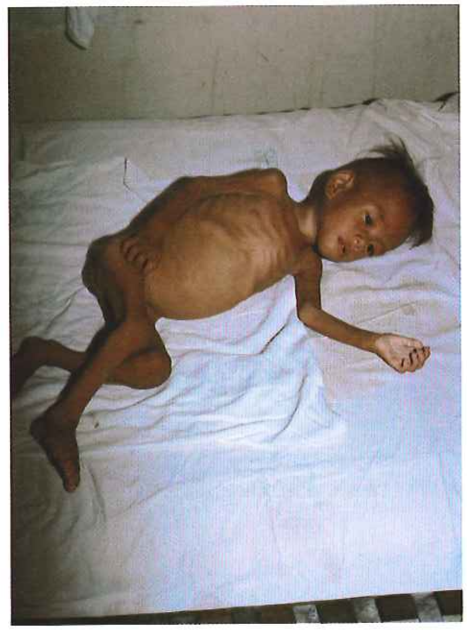


Figure 15.1 This child is suffering from protein deficiency: kwashiorkor. *Signs* (we can see): thin limbs, swollen abdomen, sparse hair, underweight. *Symptoms* (felt by the child): hunger, tiredness, sleepy, no interest.

Patterns of disease

Endemic and epidemic diseases

endemic ▶

- Malaria is always present in Africa. What is such a disease called?

An endemic disease is one that is always present in an area. There are many areas of the world where malaria is endemic. In spite of all the methods for the control of malaria, people are still infected and suffer from the disease. Malaria has been eradicated from the Caribbean with the exception of Haiti and the Dominican Republic. AIDS has become endemic in the Caribbean and many parts of the world (figure 15.2).

epidemic ▶

notifiable disease ▶

Epidemic diseases occur in outbreaks when a number of people are affected, but later the disease is brought under control. For example, minor epidemics of cholera often occur in crowded refugee camps. Cholera is a notifiable disease, meaning that cases have to be reported to the World Health Organization.

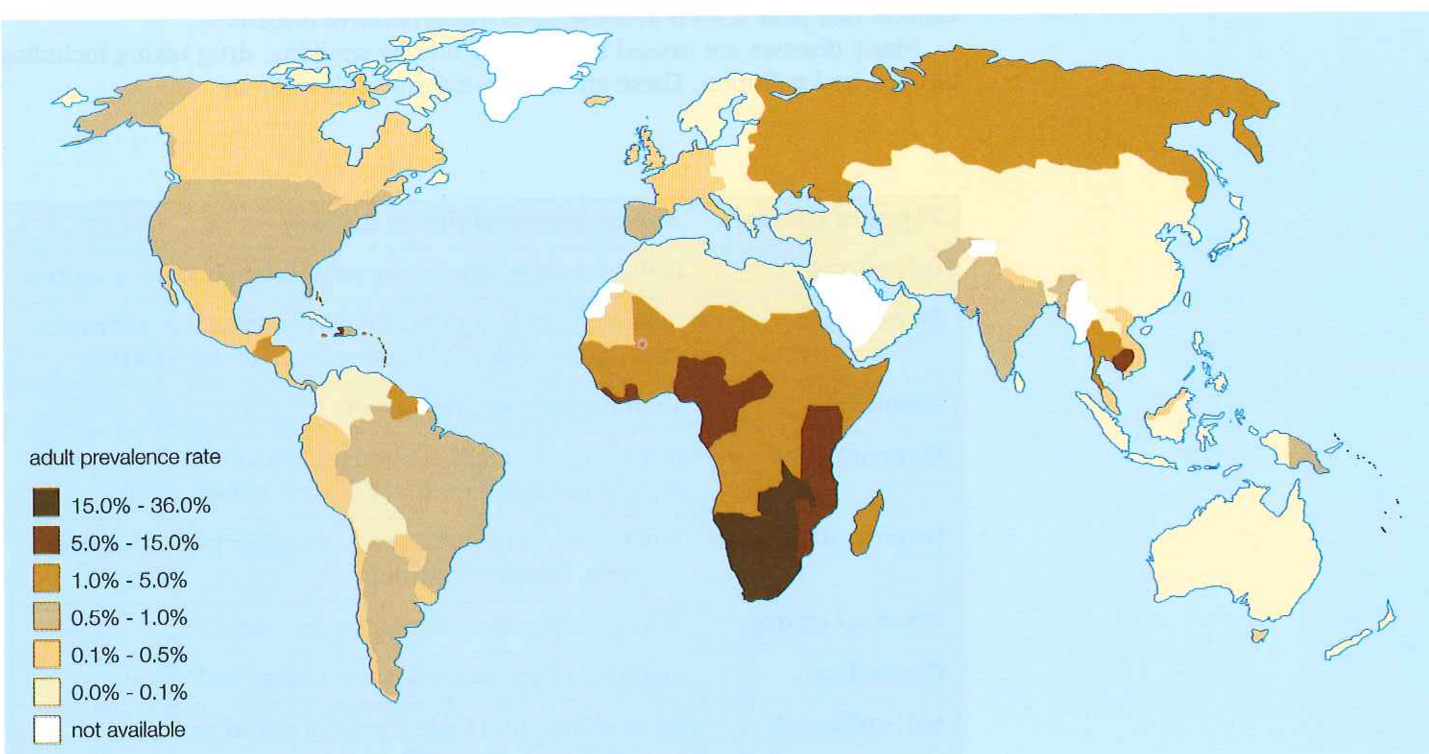


Figure 15.2 Global distribution of HIV/AIDS (data from UNAIDS/WHO, 2003).

sporadic ▶

Epidemics of dengue and influenza occur in the Caribbean along with sporadic outbreaks of several other diseases. Sporadic means isolated outbreaks of disease in various places.

Impact of diseases on populations

smallpox ▶

- What is the main way WHO eliminated smallpox from the world?

The pattern of disease in modern society is changing. In the past the most common causes of deaths were from infectious diseases in all regions of the world. Diseases such as smallpox were responsible for a very large number of deaths, which helped control the population explosion (figure 15.3). Smallpox was a very contagious virus disease spread by direct contact, or indirectly from the scabs on an infected person. Nowadays nobody suffers from smallpox, because the viral pathogen has been completely destroyed in the whole world population. The WHO organised large vaccination programmes to provide immunity to those at risk, and isolated infectious people.

developed countries ▶

In the developed countries many other infectious diseases are no longer so dangerous because of all the medical methods of prevention. Infectious diseases have been replaced by an increase in the diseases of affluence. These include diseases of the circulatory system associated with obesity caused by the wrong diet and a lack of exercise. This may cause coronary thrombosis (heart attack) and cerebral thrombosis (brain stroke). Cancer is another major cause of death in the more affluent societies. Diseases associated with affluence are increasing in the Caribbean.

developing countries ▶

In the developing countries the infectious diseases such as malaria and tuberculosis are still the major cause of death. AIDS is the most rapidly *increasing* disease leading to death.

Tuberculosis is endemic both in cattle and people in many of the developing regions of the world. Control measures adopted by the WHO reduced the incidence of this disease between 1950 and 1988 in the developed world. Unfortunately, it is again on the increase (figure 15.4) partly because AIDS patients so frequently suffer and partly because drug-resistant pathogens have evolved. WHO estimates over 8 million people suffer from tuberculosis with 3.5 million deaths annually. The increases in the developed nations are also due to travellers from endemic areas.

ITQ3

Why is tuberculosis on the increase in certain developed countries?

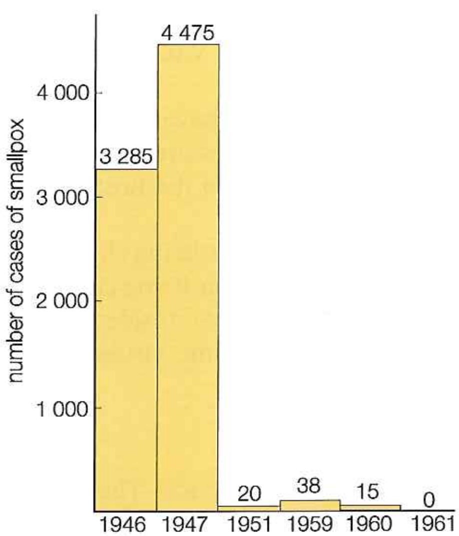


Figure 15.3 Medical statistics for the incidence of smallpox until its final elimination.

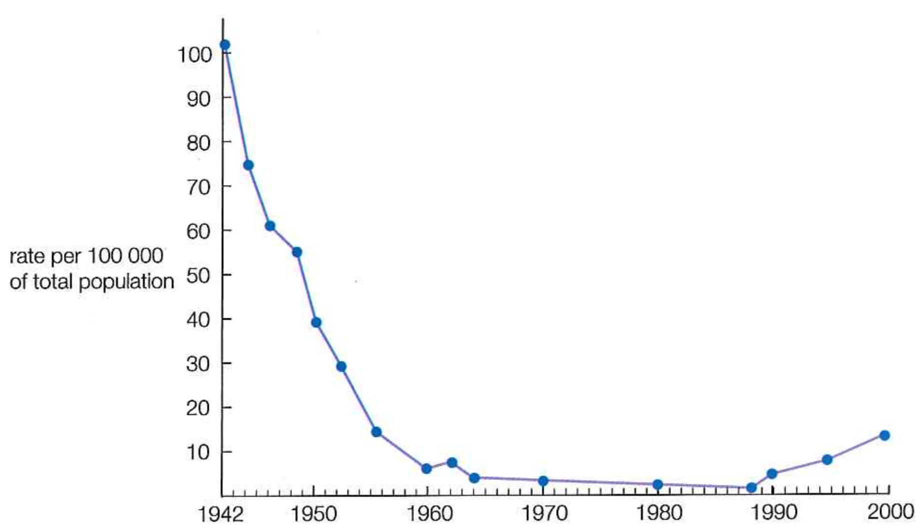


Figure 15.4 Medical statistics for death from pulmonary tuberculosis in London, up to the year 2000. The lowest incidence occurred in 1988 and there has been a 25% increase since 1990.

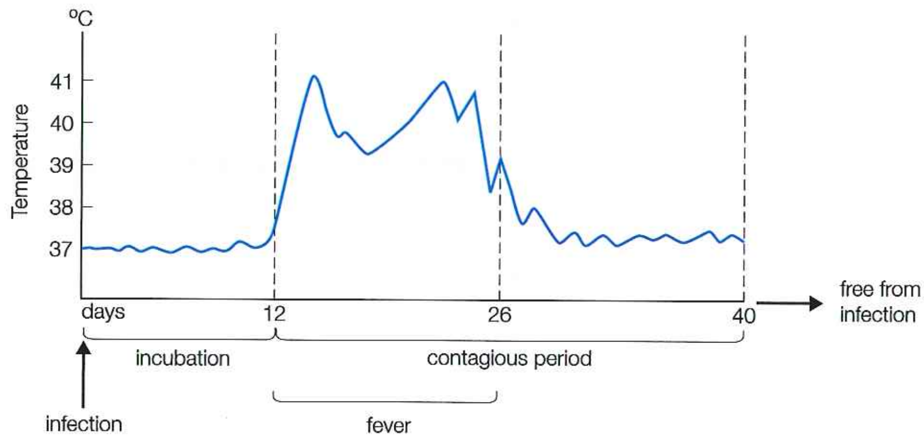


Figure 15.5 Stages in a typical infectious disease.

Course of disease

infection ▶ incubation ▶ contagious ▶ recovery ▶

• What does contagious mean?

Most infectious diseases follow a particular pattern. Following infection by the pathogen there is a period of incubation. The parasite is multiplying and adapting to its human host. This is often followed by a fever and a contagious period, when the pathogen may be spread to others. Finally, if treatment or the body's immune system destroys the pathogen, recovery follows and the person becomes free from infection. This general pattern is shown by changes in body temperature (see figure 15.5), which is of course variable depending on the particular disease.

Now let us study the pathogens (causative disease organisms) causing diseases.

Viruses and bacteria

Viruses

Many diseases are caused by viruses. These include human immunodeficiency (HIV), dengue, rabies, common cold, influenza, measles, herpes and poliomyelitis, to mention but a few.

Structure and classification

Viruses are extremely small. They vary between 0.01 and 0.025 micrometres in diameter. They can only be seen using electron microscopes. Viruses are non-cellular (i.e. not cells).

• Where do viruses reproduce?

parasite ▶ host ▶

Viruses can only reproduce in living cells. The virus only behaves like a living organism when it is inside another organism. Hence all viruses are parasites. A parasite is an organism living in, or on, another organism called the host, which suffers a loss of nutrient as a result.

ITQ4
Why must all viruses be parasites?

bacteriophage ▶

Outside of cells viruses can exist for years as complicated non-living chemicals. Hence the virus can behave both like a living organism and a non-living chemical. The virus has an outer protein coat of various shapes (figure 15.6). Inside the coat is the genetic material, nucleic acid (either DNA or RNA). Some viruses called bacteriophages infect and then live in bacterial cells.

Life cycle

ITQ5
Define a parasite.

The virus attaches itself to the human cell and injects the nucleic acid. The protein coat remains outside. Inside the cell, the viral nucleic acid takes over from the cell's DNA. This causes the cell to make new viruses in its cytoplasm instead of the normal materials. The new viruses are released to infect other cells in the same human, or spread to another person (see figure 15.7).

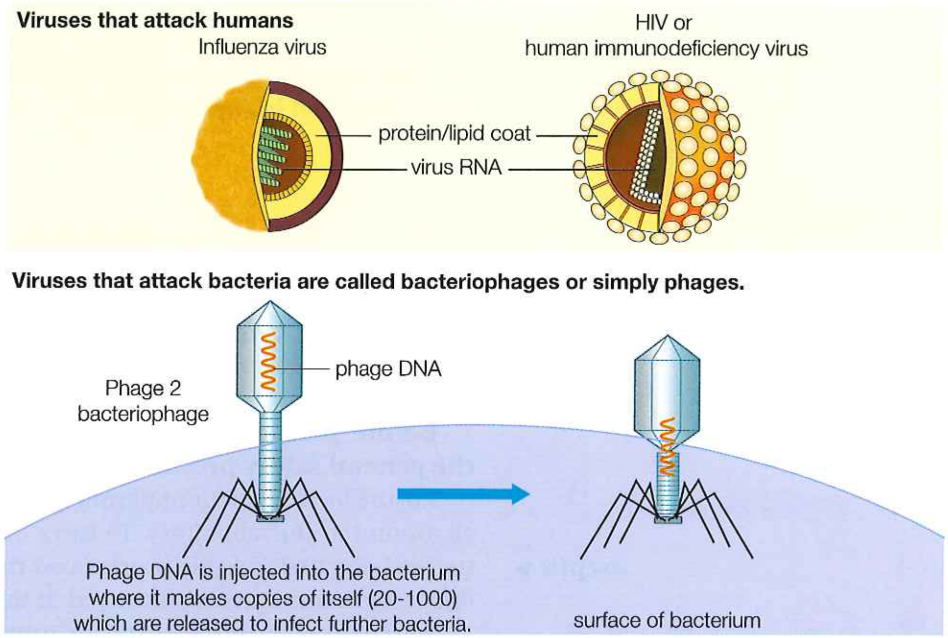


Figure 15.6 Some examples of viruses, very highly magnified.

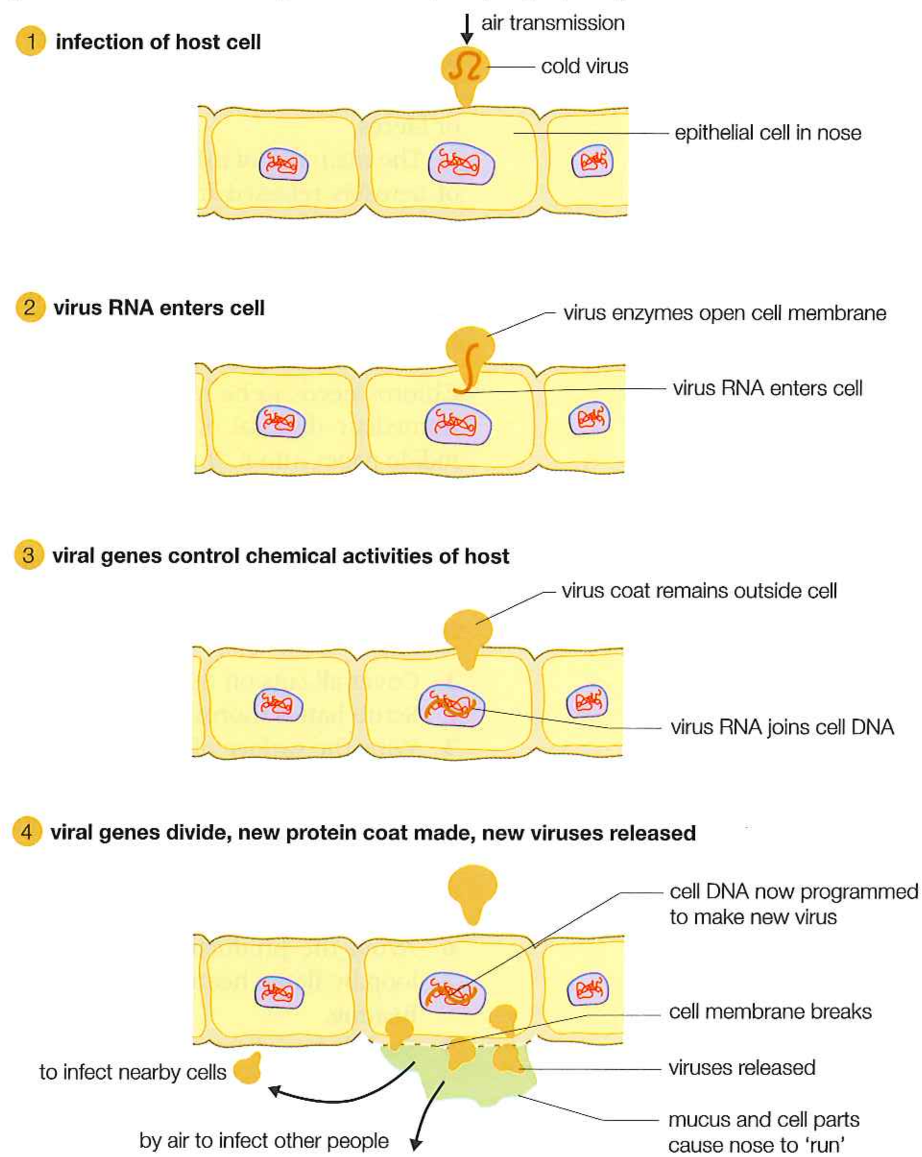


Figure 15.7 How the virus affects the nose epithelial cell to cause the common cold.

Viruses multiply very quickly and are easily carried through the air or by contact.

interferon ▶ Healthy cells produce interferon, a substance that destroys viruses. Interferon can be made artificially, but attempts to produce an 'all-purpose' drug to destroy viruses with it have not been successful.

Bacteria

Sizes

A large cell is about 0.1 mm in diameter, the bacterium 0.001 mm (1 µm) and a virus 0.000001 mm (0.01 µm). Hence while a bacterium is a hundred times smaller than a cell, the virus is ten thousand times smaller than a cell. *Note*: 1 µm = 1 micrometre = 10^{-6} metre.

Before performing the following experiments read and then follow the general safety precautions.

Ensure local regulations permit the following experiments. Microorganisms are all around in the laboratory. To carry out microbiological experiments safely and successfully, basic aseptic precautions must be taken at all times. That means all microorganisms must be destroyed in the apparatus and surroundings.

aseptic ▶

All cultures of microorganisms must be treated as potentially dangerous, as there is always a chance that they may be contaminated with pathogens, or that pathogenic strains may have developed. Do not incubate the cultures at 37°C as this tends to select human pathogens. In no circumstances should cultures be obtained from potentially dangerous sources such as sewage-polluted water, sputum, pus or faeces.

• What is asepsis?

The main risk of infection with microorganisms in a laboratory is the inhalation of aerosols released from cultures of microorganisms into the air as a result of careless handling. Contact with the cultures, or their spillage in accidents, may result in skin or eye infections. Ingestion of microorganisms is likely to occur in pipetting by mouth, licking of the labels, or eating in the laboratory. Always use pipette fillers.

A disinfectant solution such as sodium hypochlorite or a 10% solution of Chloros needs to be readily available on the bench to cover spillage and for the immediate disposal of used cultures. Check your disinfectant by dipping starch iodide paper into it. If the disinfectant is still active, the paper will go black.

Safety precautions for pupils

Pupils should be thoroughly instructed on the safety precautions before allowing them to carry out microbiological experiments. All pupils must observe the following:

1 Cover all cuts on the body surface with a waterproof dressing.
2 Scrub hands thoroughly with soap and water before and after the experiment.
3 Wipe the surface of the bench with a disinfectant solution before and after the experiment.
4 Keep the bench clear and equipment neatly laid out to reduce the risk of accidents.
5 All hand-to-mouth operations are strictly forbidden. Use pipettes with fillers to transfer liquid cultures. Never suck up liquids using a pipette.
6 Avoid the production of aerosols during the sterilisation of the inoculating loop by flame heating. Always immerse the loop in 70% alcohol before flame heating.
7 Seal all petri dishes containing microorganisms with self-adhesive tapes. Do not open any container holding a culture unless told to do so. Avoid breathing over the cultures.
8 If a culture is accidentally spilled, flood the area with a disinfectant solution. Report the accident to the teacher.

Any culture must be destroyed either by autoclaving or immersing in a disinfectant solution for several hours before disposal. Likewise, all apparatus contaminated with microorganisms should be sterilised by autoclaving, or immersing in a disinfectant solution for a number of hours before cleaning or disposal.

Practical activity 15.1
To investigate the structure of bacteria

1 Examine some bacteria under the high power of a microscope. Use some colonies of bacteria provided by your teacher, which are known to be safe and non-pathogenic.

2 Take a very small portion of the colony on to a sterile wire loop. Mix this material with a few drops of distilled water on a microscope slide.

3 Examine this film of bacteria under the microscope. You will see more if you add a little dye to the film. A good stain is crystal violet.

Questions

1 Examine figure 15.8 and classify the bacteria seen on your slides according to their shape.

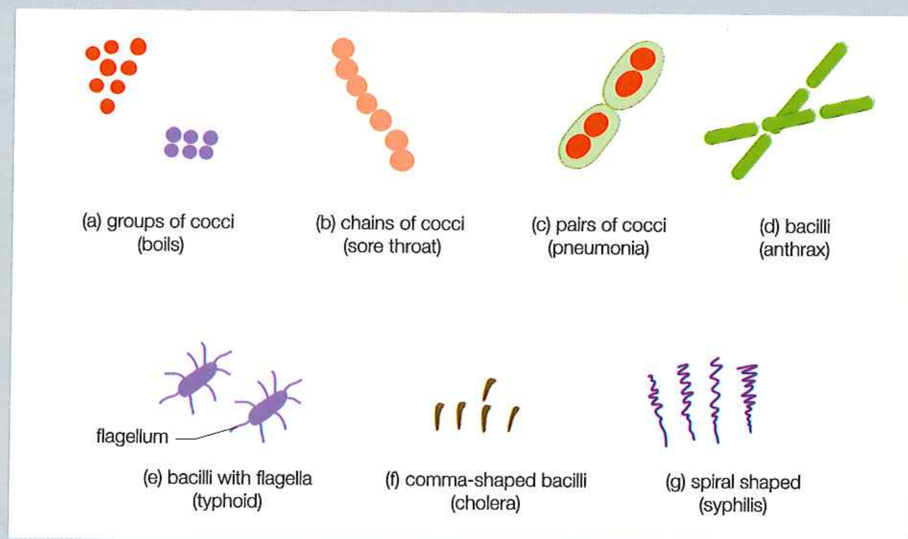


Figure 15.8 Bacteria (three basic shapes – cocci, bacilli and spirilla) and the diseases they cause.

Practical activity 15.2
To demonstrate the presence of bacteria on the teeth

1 Prepare a sterile nutrient agar plate as shown in figure 15.9.

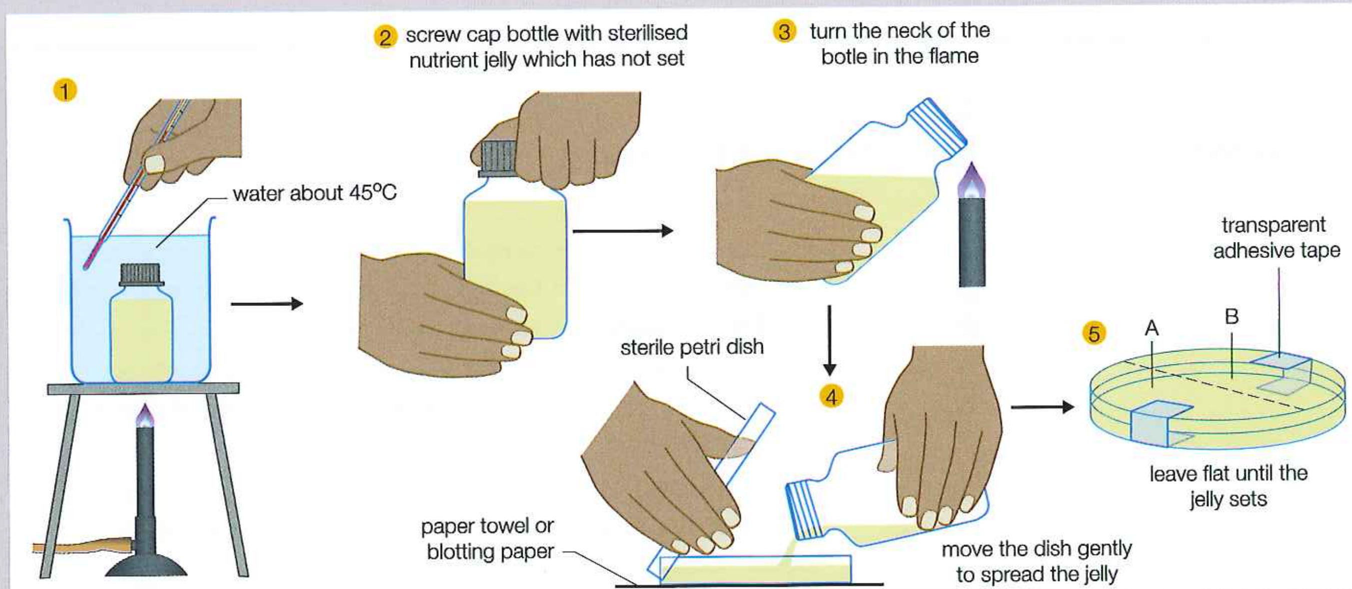


Figure 15.9 Flow diagrams showing how to make agar plates – the preparation of culture plates.

2 Rub a sterile cotton swab on the teeth.

3 Rub the cotton swab across the surface of the nutrient agar plate.

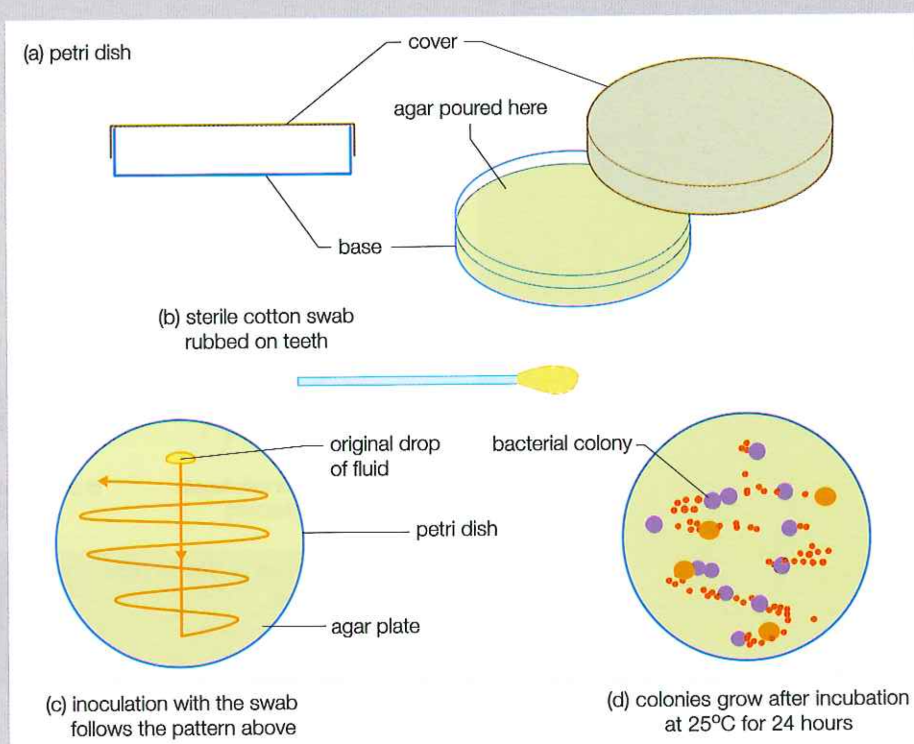


Figure 15.10 An experiment to show the presence of microorganisms on teeth.

Figure 15.11 Colonies of bacteria growing on an agar plate.

4 Set up a control plate by dipping a sterile cotton swab in sterile distilled water and rubbing it across a sterile nutrient agar plate.
5 Incubate the two agar plates at 25°C for at least 48 hours.
6 Observe the plates for bacterial colonies (see figure 15.11).

Other useful experiments can be found on page 310 (activtity 16.3) and page 384 (activity 19.4)

ITQ6

What control is always necessary in all microbiological plate experiments?

Practical activity 15.3
To demonstrate the presence of microorganisms in air, water and food

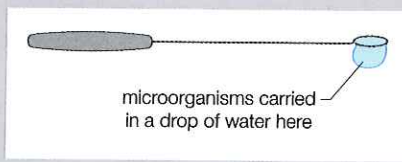


Figure 15.12 A nichrome wire loop used for inoculation.

1 Expose to the air sterile nutrient agar plates at various sites in the laboratory for 30 minutes. Replace the lids.
2 Add a few drops of water onto the agar surface of a sterile nutrient agar plate. Use a nichrome wire loop (figure 15.12) to inoculate, by making a thin film of water on the surface of the nutrient agar.
3 Spread a small slice of food on the agar surface of a nutrient agar plate. (A number of foods such as meat, bread and fruit can be tested.)
4 Seal off the petri dishes with adhesive tapes.
5 Incubate at 25°C for at least 48 hours.
6 Observe the plates for bacterial colonies. Each colony is likely to develop from one spore.

Questions

1 What plate is missing from this experiment and should be added?
2 Why is each colony likely to develop from one spore?
3 Explain the likely reasons for the differences in each plate observed.
4 Why was incubation not made at 37°C?

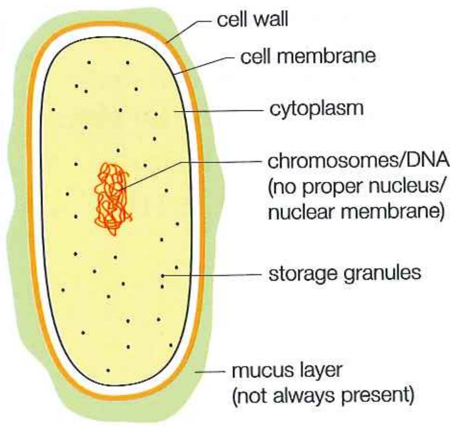


Figure 15.13 Structure of a bacterium.

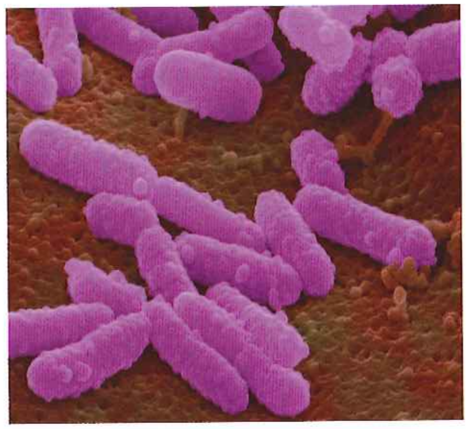


Figure 15.14 *Escherichia coli*, a rod-shaped bacterium found in the gut.

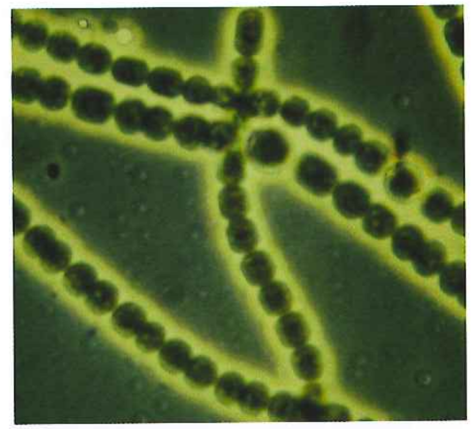


Figure 15.15 Chains of cocci in pus in a boil.

Structure

Each bacterium consists of a single cell, but no separate nucleus can be seen (figure 15.13). Instead the nuclear material is spread throughout the cell and is not confined to one region as in other cells. A cell membrane around the outside is covered by a cell wall, which often secretes sticky mucus. This may fuse many bacteria together into chains. The mucus also helps protect the bacterium from the body's defence mechanisms (e.g. hydrochloric acid in the gut, phagocytes and antibodies in blood).

Types

bacillus ▶ **coccus ▶** **spirillum ▶**

There are a very wide variety of types of bacteria that can be placed into smaller groups depending on their shape. The bacillus is rod-shaped (figure 15.14), with round or square ends. The coccus is spherical, and may be grouped together in pairs, chains (figure 15.15) or irregular groups. The spirillum is a rod, which is curved or twisted into a spiral.

- What is a rod-shaped bacterium called?

aerobic ▶ **anaerobic ▶**

Some bacteria use oxygen for respiration; these are called aerobic bacteria. Others are anaerobic and produce their energy by a chemical breakdown without oxygen. We have already seen (page 50) how denitrifying bacteria are anaerobic and grow in badly aerated soils.

Life cycle

binary fission ▶

Bacteria reproduce by asexual means. They simply divide into two in a process called binary fission (figure 15.16). The rate of division can be very rapid – about once every 20 minutes. At a geometric rate of increase, the vast numbers produced

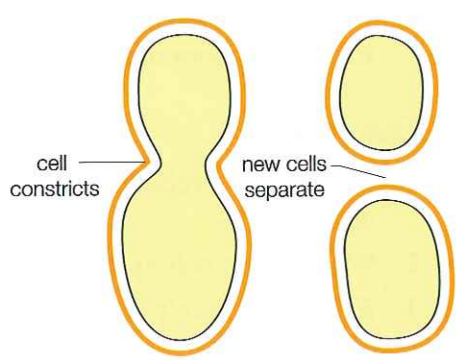


Figure 15.16 Binary fission – rapid division produces many bacteria quickly.

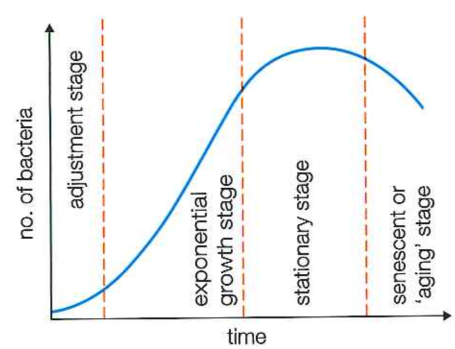


Figure 15.17 Growth of a colony of bacteria on a food supply, which gets used up.

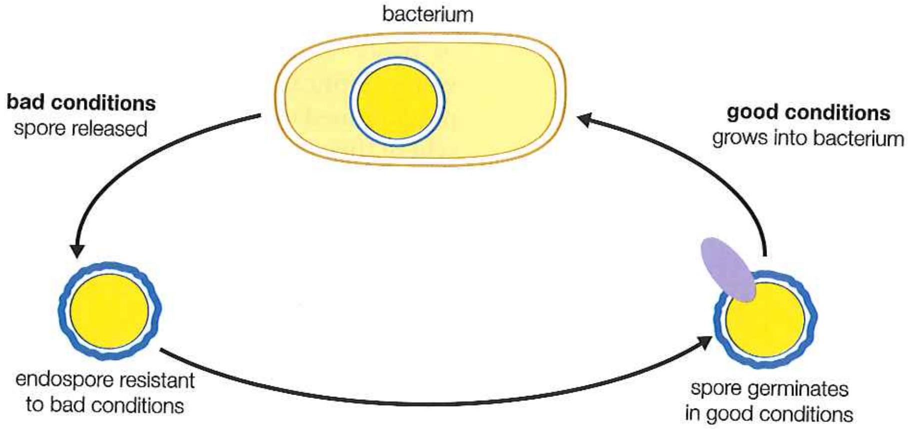


Figure 15.18 Endospore formation.

are held in check after a while by limited food supply as the food gets used up by the bacteria (figure 15.17).

endospore formation ▶

In bad conditions bacteria reproduce by endospore formation (figure 15.18). At first the cytoplasm rounds off to form a spore inside the cell. A thick coat surrounds the spore. This makes it resistant to drying up and hot and cold conditions. They remain dormant (no activity) for a long time. These spores may be spread by a variety of means; when they find good conditions they germinate and grow.

ITQ7
In which two ways do bacteria reproduce?

- What is an endospore?

Bacteria obtain their food by absorption from their surroundings, and hence require moisture. Many secrete enzymes, which first digest the food outside the bacteria. These are called saprophytes.

Bacteria and disease

toxins ▶

The harmful effects of disease-producing bacteria are often due to the toxins they secrete. Toxins are poisons. Apart from direct damage to the cells by these toxins, the bacteria also damage the cells by their activities (figure 15.19). Toxins may be produced outside the human body and still cause disease. Hence bad meat causes food poisoning.

ITQ8
Why does even really well-cooked meat sometimes cause food poisoning?

faulty cans ▶
botulism ▶

Bacteria decomposing food may cause food poisoning. Cases of food poisoning are very common in the Caribbean, particularly among visitors who suffer from travellers' diarrhoea. Faulty cans allowing air to enter become contaminated with bacteria and appear 'blown'. If eaten, the food may cause botulism where the blood is poisoned. This may cause death. Other diseases caused by bacteria include tuberculosis, typhoid, cholera, diphtheria, leptospirosis and pneumonia that will be studied in the following chapters.

- What is a poisonous substance secreted by bacteria called?

Useful bacteria

We have already noted how bacteria are so useful in decomposing waste, when we described the carbon and nitrogen cycles. This means that while many bacteria

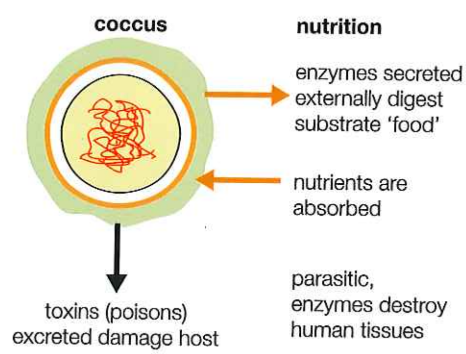


Figure 15.19 Damage caused by bacteria.

are harmful, without them life would be impossible, because of the accumulation of waste. Later we shall see how important they are in sewage disposal and water purification. Bacteria are very important in biotechnology where they are programmed to make substances such as drugs. Bacteria are important in the colon where they digest part of the fibre and some synthesise vitamin K.

Fungi, protozoa and parasitic worms

Fungi

saprophyte ▶ Fungi, like bacteria, are either saprophytes or parasites. Saprophytes secrete enzymes, which digest organic matter externally and then absorb the products.

Practical activity 15.4
To investigate the structure of fungi

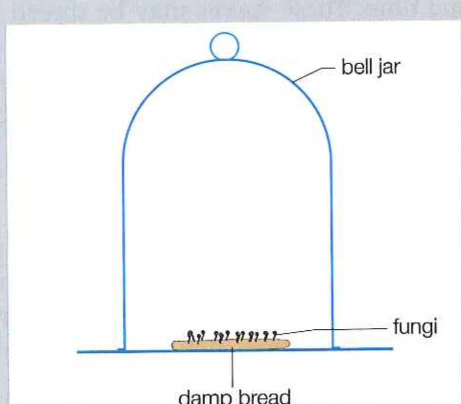


Figure 15.20 Growth of fungi in moist air.

1. Leave a piece of damp bread under a bell jar for a few days (figure 15.20).
2. Examine the fungi with both a hand lens and on a microscope slide. Fungi such as *Mucor* (figure 15.21) or *Rhizopus*, which have fine white threads called hyphae, are likely to be seen. The black heads of those parts carrying spores should appear. *Penicillium* (figure 16.6, page 309), a green mould, may also appear.

Questions

1. How do these fungi feed on the bread?
2. What happens to the spores?

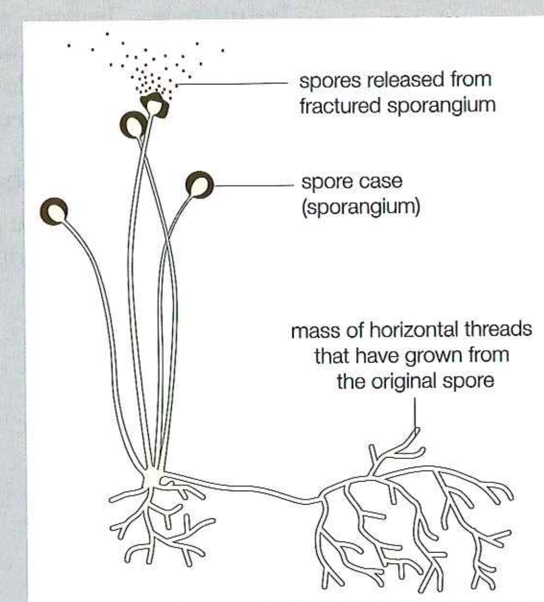


Figure 15.21 *Mucor* growing on bread.

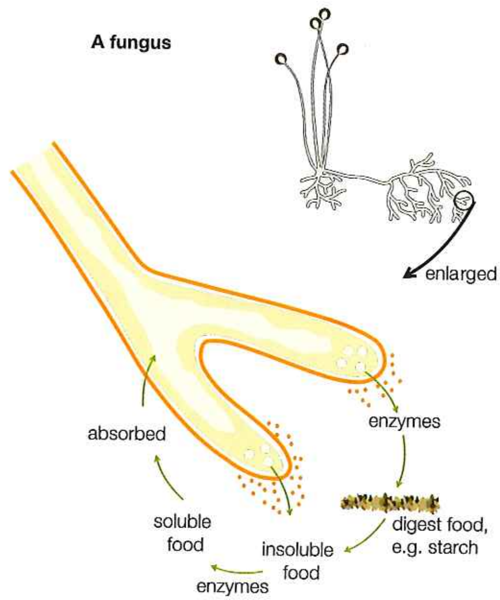


Figure 15.22 Fungal hyphae and sporangia of *Mucor.*

Structure and life cycle

hyphae ▶
mycelium ▶
• What does a mass of hyphae form?
saprophytic ▶
sporangia ▶

The white threads of hyphae of fungi have cellulose walls, a thin layer of cytoplasm and large vacuoles. Together hyphae form a mass called a mycelium. The tips of these hyphae secrete the enzymes, which digest nutrients externally. The nutrients in solution are then absorbed through the cell wall. This is saprophytic nutrition. Erect hyphae have black swellings called the sporangia on their tips that release numerous spores. These grow into new hyphae when they settle in suitable conditions. Saprophytes absorb nutrients through their hyphae (figure 15.22).

ITQ9
Define a saprophyte.

Fungal disease

ringworm ▶
• What organism causes ringworm?

A parasitic fungus (*Tinea corporis*) growing on skin causes ringworm in humans. The hyphae cause red patches on the skin. A different species of *Tinea* that grows between the toes causes athlete's foot. Fungi require moist conditions for their growth and so commonly appear in the humid conditions found in the Caribbean. Their spores, easily spread by air currents, soon cause infection. Fortunately, our bodies are well adapted to resist infection by most fungi. However, hygienic washing of clothes and utensils, especially those of young children, is very necessary. Fungi may also affect shoes and clothes if they are stored in damp surroundings in the tropics. Airing and drying in sunshine prevents fungal growth.

Useful fungi

Yeasts are also fungi, although hyphae are not present. They are important in the many fermentation processes to produce wines, beers, spirit and bread. Fungi are important for the part they play in decomposing dead organisms, as we noted when the carbon cycle was considered. Fungi such as mushrooms are a source of food and biotechnology (see chapter 20) is producing new fungal foods. They are also used to flavour cheese and produce other foods. We shall see how *Penicillium* and a whole range of fungi have proved so important as antibiotics that destroy pathogens.

ITQ10
Explain three ways fungi may be useful to humans.

Protozoa

unicellular ▶

The protozoa take in organic food, which they digest within their body. The body is made up from one cell, that is, protozoa are unicellular. A living membrane surrounds the cytoplasm, which contains a distinct nucleus. *Amoeba* is a protozoan

Practical activity 15.5
To investigate the structure of a protozoan

1 Examine a prepared slide of an *Amoeba* under a microscope.
2 If possible examine a culture of living protozoa.

Questions

1 Place labels on the diagrams made from the specimens observed.
2 What feature is common to all the specimens observed to classify them as protozoa?
3 Describe the method of locomotion common to the phagocyte and *Amoeba*.

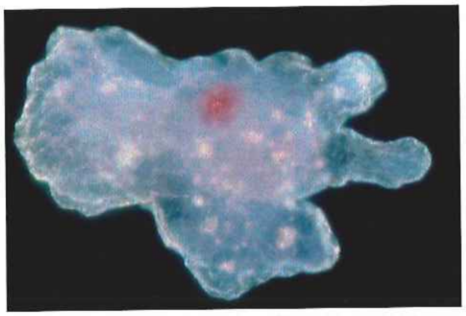


Figure 15.23(a) *Amoeba proteus* × 200.

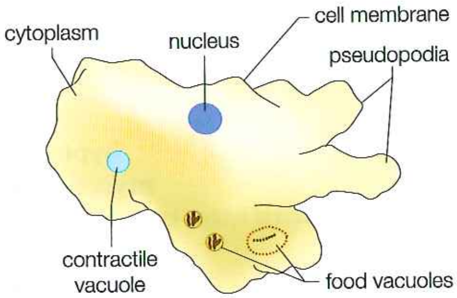


Figure 15.23(b) Diagram of *Amoeba*.

found in fresh water (figure 15.23). *Amoeba* moves by pushing out false feet as the cell changes shape. Food is taken in and digested in food vacuoles.

- Name the process by which organisms divide into two identical ones.

Many protozoa reproduce by binary fission (see figure 15.24). The nucleus splits into two, followed by the cytoplasm. Spores are frequently produced for dispersal. These are resistant to bad conditions. In good conditions they germinate and young *Amoeba* flow out.

Diseases caused by protozoa

- What disease is caused by *Entamoeba histolytica*?

A one-celled animal called *Entamoeba histolytica* found in the large intestine of humans causes amoebic dysentery. Here it may cause inflammation and damage, shown by blood in the faeces and severe diarrhoea.

The malarial parasite *Plasmodium* is another protozoan. This has a complicated life cycle involving the mosquito and humans and resulting in the production of spores. These two parasites are an excellent example of the interaction of humans and other

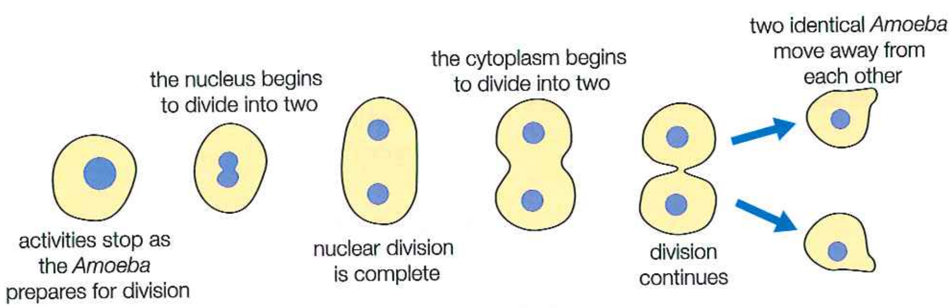


Figure 15.24 *Amoeba* reproducing by cell division.

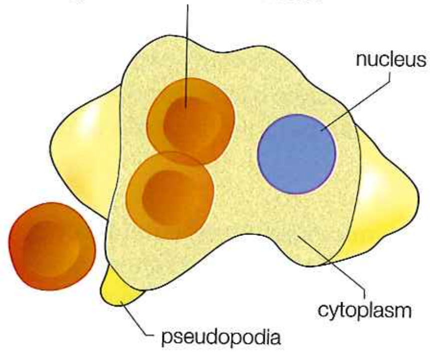


Figure 15.25 *Entamoeba histolytica* feeding on red blood cells – causes dysentery.

Figure 15.26 Two tapeworms (*Taenia*).

organisms. Although several protozoa are responsible for diseases, many of them are not harmful. For example, one millilitre of soil may contain as many as 10 000 protozoa. They are widely distributed in nature, causing no ill effects to man.

Parasitic worms

- How do tapeworms enter the body?

Worms are larger animals than protozoa and include the flatworms or flukes, tapeworms (figure 15.26) and many kinds of roundworm. They often have complicated life cycles. The flukes require other organisms known as secondary hosts in which they live to complete their life cycle. See page 332 for tapeworm infection from undercooked meat and fish. Hookworms and schistosome worms are caught by bathing in infected water. The larvae bore through the skin. They cause anaemia and general weakness. Many roundworms are also found in the intestines.

Entry of disease organisms

Pathogens

Viruses, bacteria, fungi, protozoa and certain worms are the main organisms causing diseases. To cause disease, they must first gain entry into the body (figure 15.27). Such entry must either be through the skin, or through the nose into the respiratory system, or through the mouth to the alimentary canal.

Vectors

vectors ▶

The method of carrying these pathogens to the body is varied. The animal (mainly insect) carriers of disease organisms are called vectors. They transmit diseases. Other means of disease transmission are by air, water, food and direct contact. Although these methods of transmission are placed under headings, you will note that there are sometimes two methods involved. Our first example illustrates this.

Insect vectors

Insects such as houseflies settling on food are particularly dangerous. You will see on page 330 how the housefly picks up microorganisms in, for example, one meal on dung, and then drops it on its next meal on human food. Food here is also the vector.

- What is the pathogen and what is the vector for dengue?

Many other pathogens enter through the skin in saliva when it is pierced by the mouthparts of insects concerned with sucking blood for food. In this way, mosquitoes spread malaria. The mosquito *Aedes* transmits dengue in this way.

- What is the pathogen and what is the vector for rabies?

Other animal vectors

A dog bite will transmit rabies directly if it is infected. Rats harbouring the rat flea that bites humans can infect them with the plague. Rat urine may contain the spirochaete bacterium that causes leptospirosis (Weil's disease). Animals in the home may harbour lice, ticks and microorganisms, which they pass to humans.

Air

droplets ▶

- What is droplet infection?

Many microorganisms enter through the nose or mouth and penetrate the delicate membranes of the respiratory system. Viruses causing colds and influenza enter in this way. Most microorganisms entering in this way are transmitted on tiny droplets of water, or tiny dust particles. Such droplets are extremely numerous as in a sneeze. But even normal breathing will fill the air with such droplets, which are not visible and are easily breathed in by others. Spitting is particularly dangerous because, as it dries up, spores and viruses are released into the air. Good ventilation and avoiding crowds reduce the likelihood of infection by droplets. Tuberculosis, readily spread by droplet infection, is reduced by these measures.

means of infection	pathogen	disease	natural opening
air droplet infection	virus	colds	nose
	virus (rubella)	German measles	
	bacterium	TB	
	bacterium	diphtheria	
food and water	bacterium	food poisoning	mouth
	bacterium	typhoid cholera	
	protozoan	amoebic dysentery	
	worm	tapeworm	
sexual intercourse	bacterium	syphilis	reproductive and anal passages
	bacterium	gonorrhoea	
	virus	AIDS	
insect	virus	dengue	insect bites
skin contact	bacterium	tetanus	cuts and skin surface
	fungus	ringworm	
	mite	scabies	
	worm	hookworm	
animal bites	virus	rabies	skin puncture

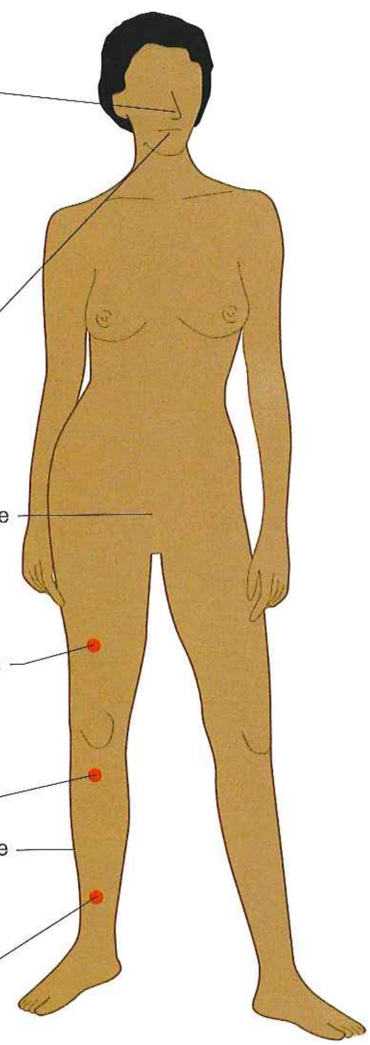


Figure 15.27 The main means of entry of disease organisms.

Food

Harmful microorganisms in food and drink can easily be taken in through the alimentary canal unless high standards of hygiene are followed. We have seen how easily gastroenteritis is caused. Typhoid, cholera, amoebic dysentery and food poisoning are all caught this way.

The food may become contaminated in a variety of ways. Bacteria may enter the food causing it to go bad, if food is not properly stored. Not all toxins (poisonous chemicals) made by the bacteria are destroyed by heat. The food may contain cysts or spores, which develop on entry into the body. Hence hygiene in the kitchen (see page 305) is very important.

Water

Drinking infected water easily picks up the bacteria causing cholera and typhoid and the protozoan causing amoebic dysentery.

Hookworms and schistosome worms both have larval (young) stages, which can directly penetrate the skin. These larval stages are found in water that transmits them to the skin.

Touch

contagious disease ▶

A contagious disease means it is spread by direct contact. Some organisms pass directly through the surface of the skin. Such is the case with the spores of the fungus which causes ringworm. The transmission is by direct contact, or contact with infected clothing.

Other pathogens enter when the skin surface becomes damaged. Bacteria frequently enter the skin through a wound, causing inflammation to the wound. Contact with soil may allow entry of the bacteria which cause tetanus.

- Give one example of a contagious disease.

AIDS, syphilis and gonorrhoea are all contact diseases spread by sexual intercourse.

All of the vectors above are causes of concern in the Caribbean. The control of mosquitoes, particularly *Aedes* responsible for outbreaks of dengue, and the vectors for all the infectious diseases are important. The socially significant diseases to be dealt with in chapter 18 are also of particular concern.

Summary

- Health is a state of complete physical, mental and social wellbeing.
- A disease is the loss of health brought about by an association between the person (host) and a disease agent (cause).
- A pathogen is an organism that causes disease. Vectors carry pathogens to the body.
- Symptoms are *felt*, e.g. pain; signs can *be seen*, e.g. spots.
- An endemic disease is one that is always present in an area; an epidemic disease occurs in outbreaks that are controlled later.
- Viruses can only reproduce in living cells and exist in a non-living chemical state outside.
- A parasite lives in, or on, another organism, which suffers a loss of nutrient as a result.
- A bacterium consists of a single cell, with no separate nucleus.
- Fungi secrete enzymes, which digest organic matter externally, and then absorb the products. That is, they are saprophytes.
- Protozoa are unicellular and take in organic food, which they digest within their body. Worms are animals including flatworms or flukes, tapeworms and roundworms.
- The main vectors are insects and some other animals. Pathogens can also be carried by air, water, food and direct contact.

Answers to ITQs

ITQ1 (a) Health is a state of complete physical, mental and social wellbeing.

(b) Disease is the loss of health brought about by an association between the person (host) and a disease agent.

ITQ2 The signs are sweating and a high temperature, the symptoms are the sore throat and headache.

ITQ3 Tuberculosis is on the increase in certain developed countries because of travellers from infected regions and because the more AIDS patients are prone to the disease. Some forms of the bacterium are becoming drug resistant.

ITQ4 All viruses can only live in a host living cell, so they must be parasites.

ITQ5 A parasite is an organism living in, or on, another organism called the host, which suffers a loss of nutrient as a result.

ITQ6 A control plate lacking inoculation is always needed to check the medium is sterile.

ITQ7 Bacteria reproduce by binary fission (splitting into two) or by spores.

ITQ8 Really well-cooked meat may contain toxins, causing food poisoning, if previously infected with bacteria.

ITQ9 A saprophyte secretes enzymes that digest organic matter externally and then absorb the products.

ITQ10 Fungi such as yeast are used to make alcoholic drinks and bread. Penicillin and other fungi make antibiotics. They are important for decomposition (waste disposal) and as a food source (mushrooms, etc).

Examination-style questions

Because there is considerable overlap between the questions in chapters 15 (disease organisms) and 17 (disease transmission), you may prefer to answer all these questions after completing chapter 17. However all the answers to the questions below can be found out from this chapter or previous chapters.

Multiple choice questions

(Write down the number of the question followed by the letter of the correct answer. You can check your answers on page 417.)

1 To satisfy the WHO definition of health, people must be free from:

A infections
B infections and injury
C infections, injury and social deprivation
D infections, injury, mental illness and social deprivation

2 Which may cause an infectious disease?

A poison
B protozoa
C genetic defect
D overeating

3 Which is a degenerative disease?

A atherosclerosis
B malaria

C rickets
D sickle cell anaemia

4 Which type of disease is coronary thrombosis (heart disease)?
A deficiency (diet)
B degenerative (breakdown)
C genetic (inherited)
D infectious (transmissible)

5 Which is always caused by a pathogen?
A anaemia
B cancer
C dengue
D haemophilia

6 Which is a feature of all viruses but not all bacteria?
A contain RNA or DNA
B contain enzymes
C contain protein
D are parasites

7 What is the common vector for bacterial dysentery?
A contaminated towels
B contaminated air
C houseflies
D mosquitoes

8 Which is *not* a common disease vector?
A flies
B rats and mice
C mosquitoes
D protozoa

9 How does the pathogen causing dengue enter the body?
A by insect bite through the skin
B by direct skin penetration
C into the alimentary canal during feeding
D into the respiratory system during breathing

10 Broth inoculated with bacteria is placed in four tubes, boiled and treated as follows. In which tube will the broth first go bad?
A sealed from air
B frozen
C water added
D salt added

Short answer and essay type questions

11 Minced meat, which was kept for five days, was thoroughly boiled. However, people eating this meat suffered from food poisoning. The health inspector testing the food found it free from microorganisms. How do you explain this illness?

Examine the following data and answer questions 12 to 16. From the following figures plot the graph showing the number of divisions per hour by bacteria maintained at different temperatures. (Graph paper is needed.)

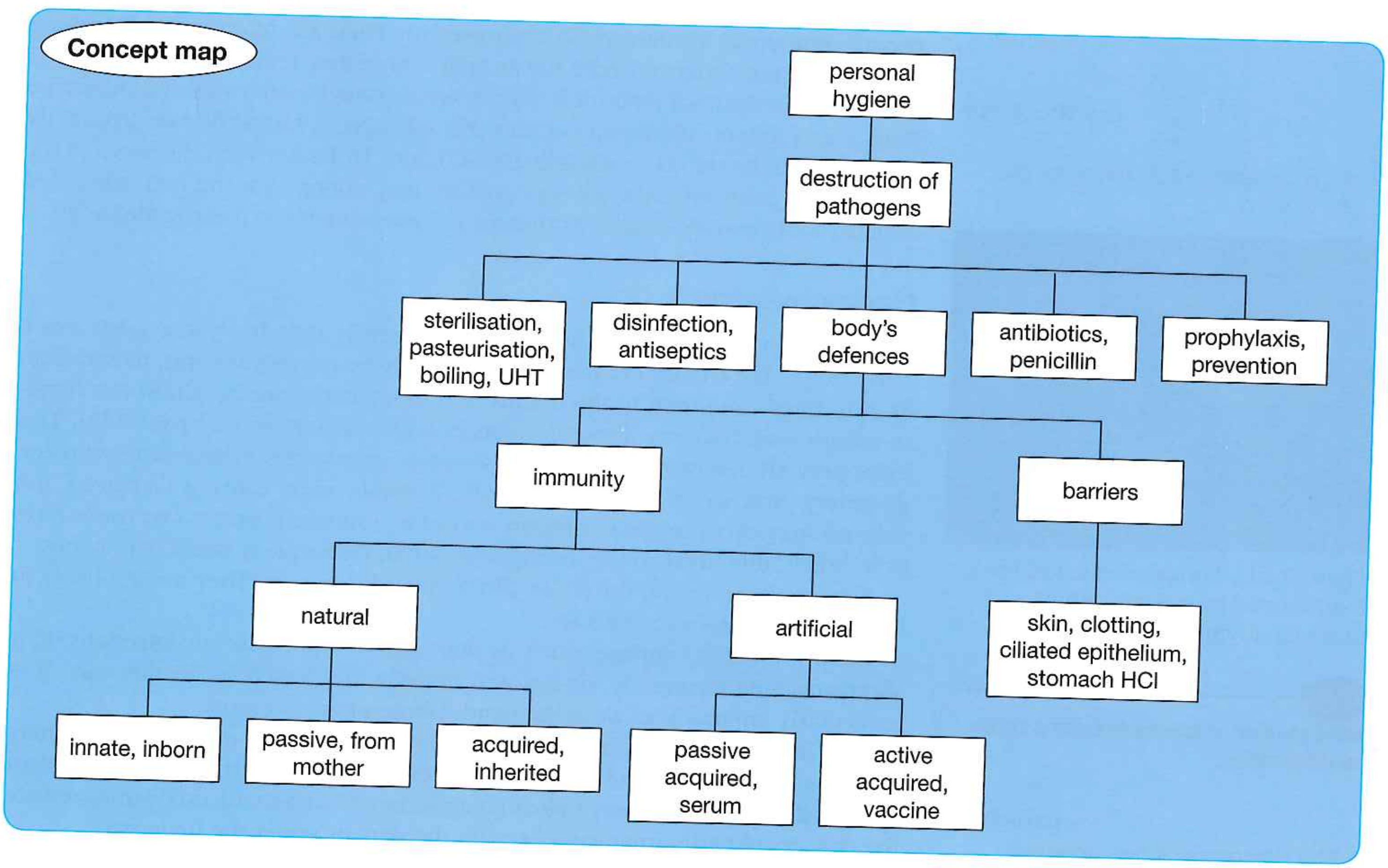
Temperature/°C	0	10	15	20	25	30	35	40	45	50
No of divisions/hour	0	0	0.5	1.0	1.5	2.0	2.5	3.0	3.0	0

12 How do you account for the lack of division below 10°C?
13 Between what temperatures is growth at a maximum?
14 Why are there no divisions at 50°C?
15 Why do the number of divisions of the bacteria give a measure of their growth?
16 Suggest one reason why the bacteria used in this experiment could be parasitic in humans.
17 With the aid of diagrams describe the life cycle of a virus.
18 Name one disease caused by (i) a virus (ii) a bacterium (iii) a protozoan (iv) a fungus (v) a worm. For each disease name the vector concerned.
19 Describe with full safety precautions how you would perform an experiment to show the presence of microorganisms on your fingers.
20 Explain three causes of gastroenteritis and give reasons why it is dangerous.

16 Hygiene and defences against disease

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

- ☑ explain how personal hygiene is maintained by regular shampooing of hair, regular baths or showers, care of nails, use of deodorants, hygiene of genital areas and the importance of clean clothing;
- ☑ understand how social acceptance and prevention of infections depend on good personal hygiene;
- ☑ appreciate the hygiene concerned with handling and preparation of food;
- ☑ define the term sterilisation;
- ☑ explain the effects of UHT, pasteurisation, autoclaving and boiling;
- ☑ use disinfectants and antiseptics in the control of microorganisms;
- ☑ define antibiotics and explain their use and antifungal agents;
- ☑ describe skin protection, phagocytosis, inflammation, liver detoxification;
- ☑ define the terms immunity, immunisation, vaccine and vaccination;
- ☑ explain various ways immunity is obtained;
- ☑ describe the causes, symptoms and treatment of asthma;
- ☑ realise the importance of prophylaxis.



Personal hygiene

We have seen that microorganisms surround our bodies all the time. Yet, with the exception of the alimentary canal and the skin, our bodies are free from these organisms, except when we suffer from disease.

hygiene ▶

The likelihood of microorganisms infecting our bodies can be reduced by good personal hygiene. Hygiene is the various measures a person takes to avoid infection, maintain cleanliness and ensure good health.

Skin hygiene

The skin has a very large surface area and all this area is at some time exposed to dirt, pollution and disease organisms. Unwashed skin will have a layer of dried sebum over it. This contains the solids from evaporated sweat, including salts, urea and the loose dead cells from the cornified layer. All of this makes a good breeding ground for microorganisms.

ITQ1
What is present in dried sebum on unwashed skin?

Apart from causing offensive body odours, these microorganisms cause skin infections, particularly if a small scratch breaks the skin. These bacteria can also enter the hair follicles, where they use the sebum as a food source.

shampoo ▶

- Why should the hair be washed regularly?

Regular washing of the hair with a good shampoo will remove dirt and unwanted sebum from the hair and hair follicles.

washing ▶

Washing is essential to remove this unpleasant, smelly, dirty film. Where considerable sweating occurs, with weather such as in the Caribbean, it is important to try to wash all over every day.

soap ▶

Soap speeds up removal of the dirt, because it emulsifies oils and so acts like a solvent for the oils in sebum. Soap and shampoo also lower the surface tension of water, so it more readily penetrates parts containing dirt. Warm water and hard rubbing while washing will stimulate the blood supply to the skin. This improved circulation ensures the skin tissues remain healthy.

ITQ2
How does soap clean the skin?

deodorants ▶

Deodorants may be applied to clean skin where they reduce sweating and contain antiseptics to destroy bacteria present. They are often scented and are applied to regions such as under the armpits where they reduce smells.

dry the skin ▶

- Why is it important to thoroughly dry the skin after washing?

In humid areas it is important to dry the skin thoroughly after washing, otherwise fungi may grow on the damp surfaces. For example, a fungal disease frequently occurs where the skin is continually moist (figure 16.1). Between the toes and the thighs are regions where these sore patches may appear. On the toes it is called athlete's foot. Specific ointments (fungicides) are available to destroy the fungi.

Figure 16.1 Fungal disease (athlete's foot), caused by lack of washing and thorough drying afterwards.

Hands hygiene

It is most important to wash the hands before meals and after going to the toilet. This reduces the chance of infection, particularly by microorganisms, passed from anus to hands and then to the mouth. Worm infections are caught in this hand-to-mouth way. Sanitary disposal of faeces is also important (see page 388). This helps prevent diseases such as schistosomiasis, tapeworms, hookworms, cholera, dysentery, and so on. Outbreaks of the Norwalk virus causing diarrhoea and sickness may occur in the Caribbean, spread by tourists. It occurs on cruise ships, or in hotels, due to crowding, eating together and infrequent washing of hands.

ITQ3
Name one hand-to-mouth infection and explain what this means.

The scabies mite also thrives on dirt and dead skin cells. They are less likely to live on clean skin (see page 339).

Simply touching surfaces such as door handles can pass on infections. It is surprising how frequently viruses and bacteria are passed on in this way. It is particularly important to wash the hands before preparing food.

manicure ▶

- What is the purpose of finger manicures?

Dirt from under the fingernails may get into food. The microorganisms may also be passed on by hand contact. For these reasons fingernails should be kept short and clean. Apart from a pleasing appearance, well-manicured hands reduce the chances of harbouring pathogens on the skin, or under the fingernails.