Heinemann

senior science 1

Preliminary

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Contents

Chapter 3

humans at work

Playing a sport and performing other physical activities require good coordination. There are complex interactions between sense organs, nerves, muscles and bones. The bones and muscles of the body support the soft tissues. They give the body shape and good posture as well as allowing movement.

The body is protected in many ways. Bones of the skull and the vertebral column protect the brain and spinal cord. Strong back and abdominal muscles also help support and protect the back. Bones at a joint end with a cushion of softer cartilage and are bathed in a fluid which helps them move smoothly.

Reflexes are another protective mechanism. You blink when a foreign object approaches your eye. Your hand moves away quickly if you touch a hot iron. These reflex responses are much faster than your usual responses. They reduce the risk of damage to the body.

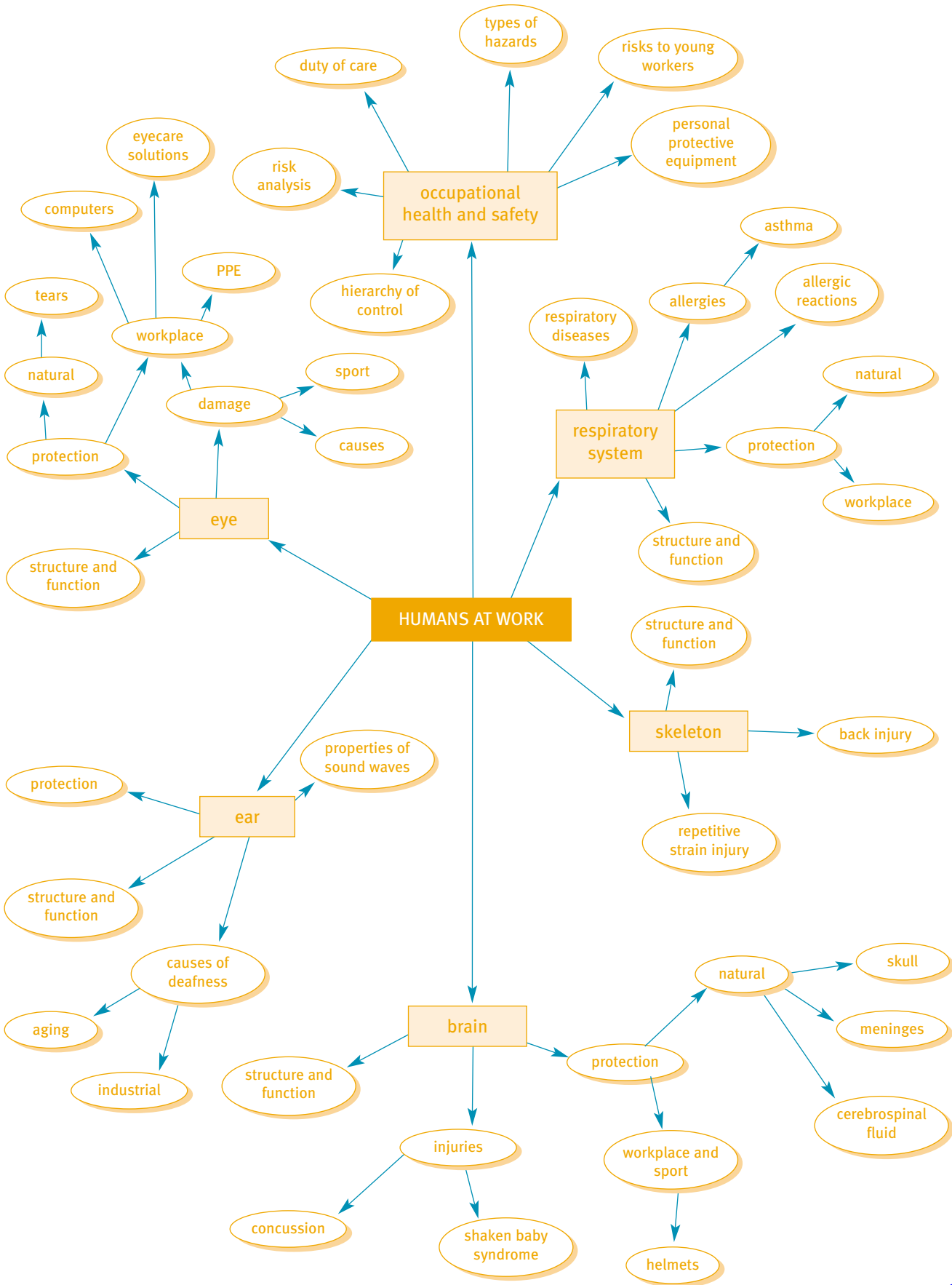
The immune system can also make a huge range of responses to defend the body against invading microorganisms.

In spite of all this natural protection, our modern way of life requires other ways to protect the human body. Different demands are placed on the body in the workplace and when playing sport. We should all be aware of safety risks because it is far easier to prevent damage to the human body than it is to repair it.

Outcomes

This chapter contributes to the following Preliminary Course outcomes:

- **P2** applies the processes that are used to test and validate models, theories and laws of science, with particular emphasis on first-hand investigations
- **P3** assesses the impact of particular technological advances on science
- **P4** identifies applications of science that affect society and the environment
- **P9** describes the structure of body organs and systems
- **P10** describes the effect of energy transfers and transformations
- **P11** identifies and implements improvements to investigate plans
- **P12** discusses the validity and reliability of data gathered from first-hand investigations and secondary sources
- **P13** identifies appropriate terminology and reporting styles to communicate information and understanding in science
- **P14** draws valid conclusions from gathered data and information
- **P15** implements strategies to work effectively as an individual or as a member of a team
- **P16** demonstrates positive values about and attitudes towards both the living and non-living components of the environment, ethical behaviour and a desire for a critical evaluation of the consequences of the applications of science.



3.2 Breathing clean air

FIGURE 3.9

SECTION OUTCOMES

When you have completed this section you should be able to:

- recall the role of the human respiratory system
- relate the moist lining of lungs to the need to dissolve oxygen so that it can then diffuse into the blood
- perform a first-hand investigation to observe diffusion
- outline how mucus, cilia and white blood cells protect the lungs
- describe how inflammation occurs and allergic responses which may result
- outline the effect on lung tissue of chronic exposure to inhaled solids
- identify safety procedures in the school and workplace to reduce inhalation of harmful substances.

The human respiratory system

The human respiratory system (breathing system) provides oxygen and excretes carbon dioxide. The oxygen is needed for cellular respiration.

Recall

Every living cell in the human body needs a supply of energy to perform its functions. This energy is provided by **cellular respiration**. The usual type of respiration is summarised by the following equation:

Glucose + oxygen → carbon dioxide + water + energy

Respiration uses the reaction between oxygen and food to slowly convert stored energy into forms that can be used by the cell for activities such as growth and repair.

The human **respiratory system** provides the body with a plentiful supply of oxygen this process and excretes the waste product carbon dioxide.

Gas exchange

Diffusion is the movement of particles from regions of high concentration to regions of lower concentration. The change in concentration from high to low is called a concentration gradient.

Any particles which move about are capable of diffusion. If perfume is spilt from a bottle, the fragrance can be detected very quickly around the room because of diffusion of the evaporated perfume molecules. Gases diffuse very quickly because the particles in a gas move very fast and there are only weak attractive forces between them to slow them down. However, before oxygen from the air can enter a living cell, it must be dissolved in water so that it can diffuse through the cell membrane. This also applies to carbon dioxide gas.

INVESTIGATION 3.1 Diffusion across a membrane

All living cells are surrounded by a cell membrane, through which some substances may diffuse. The membrane is described as semi-permeable ('half penetrable') because not all dissolved substances can pass through it.

Aim

To observe evidence of diffusion through a semi-permeable membrane.

Materials

- 3 × 250 mL beakers
- 3 × 20 cm lengths of dialysis tubing
- 2 dropping pipettes
- starch solution
- dilute iodine solution
- concentrated iodine solution
- safety glasses

Warning: Iodine stains skin and clothing. Take care not to spill it. Wipe up any spills immediately. Wear safety glasses.

Method

1. Moisten one end of each dialysis tubing under a tap to help you separate the sides and form the flat tubing into a cylinder.
2. Tie a firm knot at one end of each piece of tubing.
3. Use a dropping pipette to partly fill one of the tubes with concentrated iodine solution. Tie the top of the tubing and rinse it with water to remove any traces of iodine solution from the outside.
4. Place this tubing in a beaker containing the dilute iodine solution as shown in Figure 3.12.
5. Rinse the dropping pipette and use it to add the dilute iodine solution to the second dialysis tubing. Tie the top of the tubing and rinse it with water to remove any traces of iodine from the outside.
6. Place this tubing in a beaker containing starch solution as shown in Figure 3.12.
7. Use the second dropping pipette to partly fill the third tubing with starch solution. Tie the top of the tubing and rinse it with water to remove any traces of starch solution from the outside.
8. Place this tubing in a beaker containing dilute iodine solution as shown in Figure 3.12.
9. Note any colour changes and any changes in water levels that occur in the next 20 minutes.

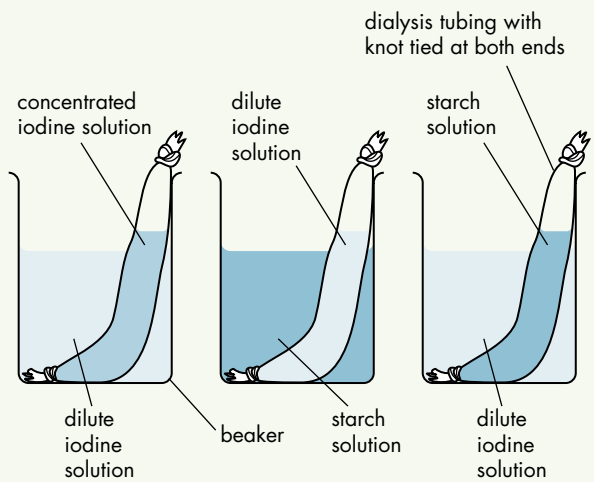


FIGURE 3.12
Experimental set-up.

Discussion

1 Draw a labelled diagram to summarise the results of the experiment.
2 Which substances were able to travel through the dialysis membrane? What evidence supports this?
3 Is this membrane semi-permeable (i.e. can some particles travel through it but not others)?
4 Suggest a property of the iodine and starch molecules which could account for any differences in particle movement in the experiment.

Extension

Use library references to find out about the structure of the cell membrane and how this relates to the type of substances which can travel through it.

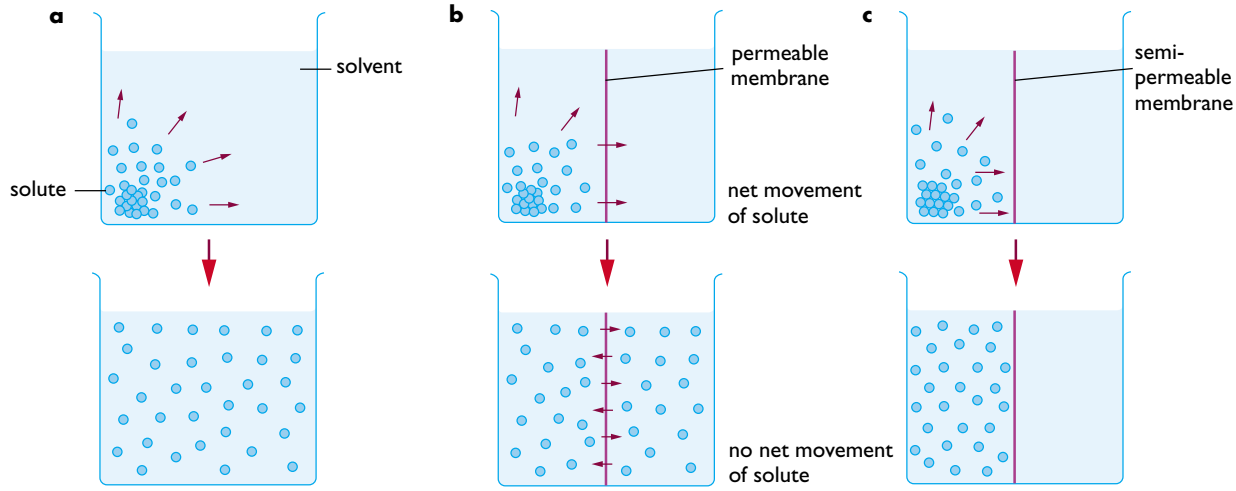


FIGURE 3.13
(a) Solute molecules diffuse through a solvent as they dissolve in it. (b) Solute molecules may diffuse through a permeable membrane until the concentration of solute on both sides of the membrane is the same. (c) A semi-permeable membrane may not allow some solute particles to diffuse through it.

Exchange of gases in the lungs

The internal lining of the human lungs provides a large moist surface area which allows exchange of the gases oxygen and carbon dioxide. About 1 cm^3 of human lung tissue has a surface area of 300 cm^2 for gas exchange.

This large surface area is provided by tiny air sacs called **alveoli**. Each alveolus is surrounded by tiny blood capillaries. Oxygen must diffuse through cells in the alveoli walls and the walls of the capillary blood vessel before it can come into contact with the blood. Dissolved in water, it can diffuse along a concentration gradient through spaces between the cell membrane molecules to reach the blood. Here, it combines with the red pigment **haemoglobin** in red blood cells to be transported around the body in the blood. As this oxygenated blood moves through capillaries in other body tissues, the concentration gradient is reversed. The oxygen is released from the haemoglobin and diffuses into surrounding cells which have a lower concentration of oxygen.

Oxygen must dissolve in water before it can diffuse into body cells.

Protecting the airways

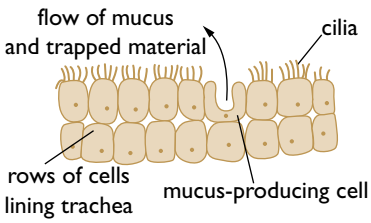


FIGURE 3.19
The epithelial (outer) layer of cells in the respiratory system contains some cells which produce mucus and other cells which have tiny hairs called cilia. The cilia beat back and forth to move the mucus to the back of the throat where it is swallowed or coughed, or to the pharynx where it can be swallowed. This removes dust and invading microorganisms.

First defences

Special mechanisms protect the warm moist surfaces in our airways from invasion by pathogens (microorganisms which cause disease).

- **Mucous membranes** line the nasal passages, trachea, bronchi and alveoli. The thick, sticky mucus that is secreted can trap dust and bacteria. It also contains **lysozyme**, an enzyme which is capable of destroying the cell walls of some bacteria. Another substance, an antibody called IgA, may also be present in mucus. This reacts with invading pathogens and destroys them.
- **Cilia** are tiny hairs that project from the cells lining the airways of the respiratory system. They sweep mucus along towards the openings of the nasal passage or the pharynx so that the dust and any bacteria it contains may be removed from the respiratory system by coughing, sneezing or swallowing.

Protection from foreign infiltration

If these first lines of defence are breached, and microorganisms enter the blood, the immune system is mobilised. The primary organs and tissues of the immune system are the **bone marrow** and **thymus gland**, which is found just underneath the breastbone. The secondary parts are the lymph nodes, spleen, tonsils, adenoids and appendix.

Mucus and tiny cilia provide the respiratory system with protection from invasion.

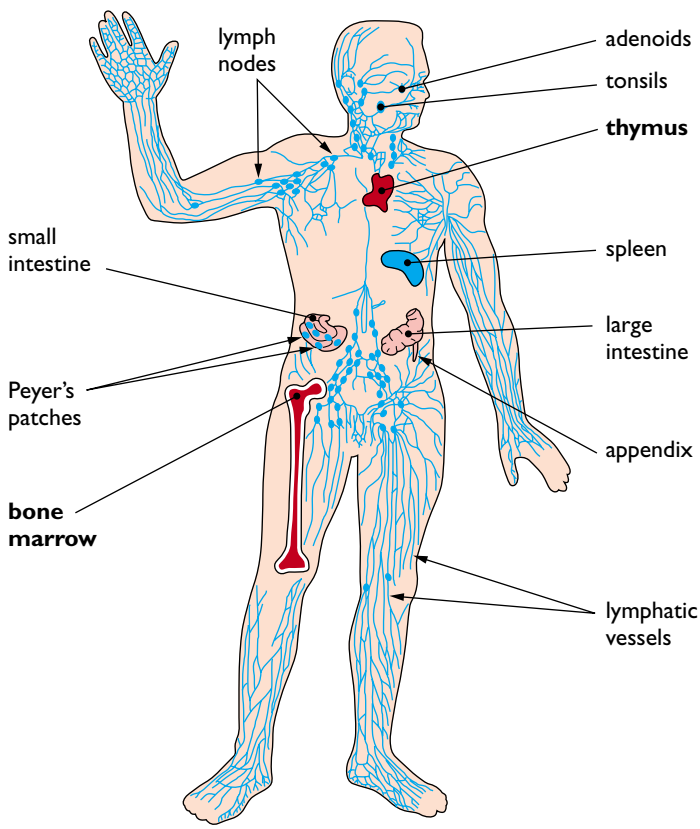


FIGURE 3.20
The primary and secondary organs of the immune system are linked by blood vessels and the lymphatic system.

To understand some of the complex steps in the body's response to invasion by foreign material and microorganisms, it is important to realise that there are a variety of different white blood cells that can be recruited. These cells are made in the bone marrow and some of them are modified in the thymus gland before being released into lymph fluid.

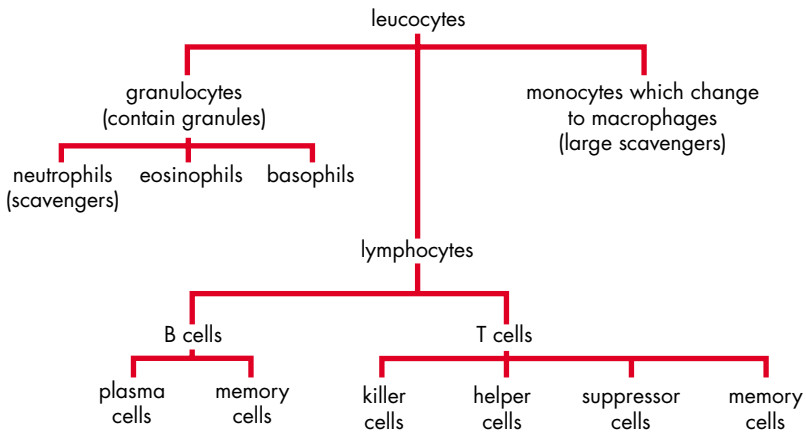


FIGURE 3.21
Types of white blood cells (leucocytes).

A variety of white blood cells (leucocytes) protect the respiratory system from infection.

Front line troops

Human body cells have proteins on their surface. These are called markers as they help our immune system recognise them as its own cells. The ability to recognise 'self' and 'non-self' cells prevents the immune system from attacking its own cells.

Foreign protein entering the body, such as on the surface of **pathogens** (microorganisms such as bacteria and viruses) or the toxins they produce, are called **antigens**. They stimulate the formation of **antibodies** by B cells. It is the presence of foreign antigens and the absence of 'self' markers that can stimulate a complex series of responses by the immune system.

Macrophages are scavenger cells found near any site in the body that might be a target for invasion by pathogens. For example, they are found in the airways, including the alveoli. They respond to the presence of foreign antigens by surrounding foreign cells with their cytoplasm and then producing chemicals to destroy them. This process is known as **phagocytosis**. They also release chemicals which attract the other type of scavenger, **neutrophils**, to the infection site. Neutrophils are the most abundant of all the white blood cells but they are also very short lived. They mobilise in large numbers from the bloodstream to engulf the invaders. As they die, they form pus at the infection site.

The two other types of granulocytes, eosinophils and basophils, release toxic chemicals from their granules to help destroy the invaders. Eosinophils produce chemicals which can destroy parasites in skin and lungs, but they are also involved in allergies. Basophils release histamines which help to bring about **inflammation** of the tissue being invaded.

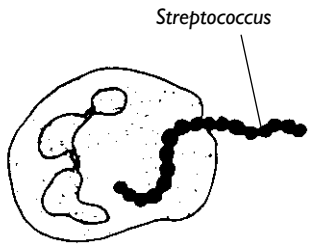


FIGURE 3.22
Macrophages are 'giant scavengers'. They are also called phagocytes. This diagram shows a phagocyte engulfing a *Streptococcus* bacterium. The cytoplasm of the phagocyte surrounds the bacterium and digests it. Neutrophils are the other type of phagocyte.

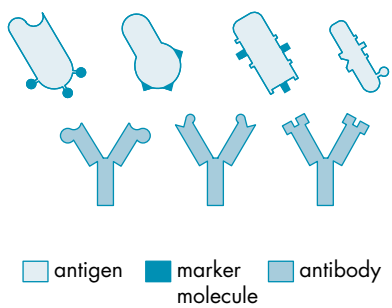


FIGURE 3.23
Antibodies are Y-shaped molecules produced by white blood cells called lymphocytes. Each antibody must be designed to fit the marker of a particular antigen as a lock and key fit together.

Did you know?

The complement system of proteins is responsible for the initial rejection of foreign organs in transplant operations. The complement proteins attack the outer proteins on the membrane of the foreign cell. Pig cells have been developed for use in human transplants by genetically modifying the outer cell membrane to produce the correct protective proteins that destroy complement.

Did you know?

Platelets are not classified as cells. They have no nucleus but they are surrounded by a membrane. They are made in bone marrow by breaking off from one type of large white blood cell called a megakaryocyte.

Antigens and antibodies combine in a lock and key arrangement.

Extra help for the immune system: complement proteins

A group of about 30 proteins, called **complement** proteins, is produced by the liver and is present in blood plasma. It has a number of different roles to play in stopping an invasion. Complement proteins include enzymes which may start to attack the outer proteins on the surface of invading pathogens. The protective protein found on all the body's own cells prevents a similar attack. Others complement proteins attach to the outer cell wall of pathogens to help phagocytes in the blood identify them as intruders.

Inflammation

Any damage to tissues will activate tiny fragments of white blood cells called **platelets**. Platelets have a role in blood clotting but they also release **histamines** which can begin the process of inflammation. Complement proteins are also involved in the inflammation process.

Inflammation can be identified by swelling and redness of the body's tissues There is increased blood flow to the damaged area, blood vessels dilate and their walls become more permeable. Blood plasma and lymph fluid leak into the inflamed area. The heat of inflammation results from the extra blood supply, and the pain is caused by the increased volume of fluids stretching the tissue. Phagocytes move from the blood into the damaged tissue to engulf invading pathogens. Complement proteins also join the attack. Damaged tissue, cell debris and any pathogens are washed away by the increased volume of fluid at the site of the inflammation. They enter the lymph system where another immune response may be triggered.

Rearguard attack

The presence of antigens on the surface of invading organisms or their toxins triggers B cells to begin dividing. Some form plasma cells which produce large numbers of antibodies against the foreign antigen, and others form memory cells. The plasma cells are assisted by another type of lymphocyte, helper T cells. The antibodies are proteins which lock on to the antigen in a lock and key arrangement.

How lymphocytes work

The two types of lymphocytes, B cells and T cells, can take part in a variety of responses to the presence of foreign antigens in the body, for example, a virus.

Some macrophages can absorb the foreign cell with its antigen marker, but then present a fragment of that antigen, held by one of its own marker proteins, on the outside. The macrophage then moves through the lymph system to lymph nodes. This is a signal for other cells to attack the antigen.

T cells are mobilised. One type of T cell, called a helper cell, can recognise an antigen if it is displayed by a macrophage. It forms an antibody-type structure on its surface and binds to the macrophage (see Figure 3.24). Both cells then produce a number of chemical messengers called lymphokines. These lymphokines have a variety of roles:

- stimulating the formation of more helper T cells and another type of T cell called a killer cell
- acting on one part of the brain, the hypothalamus, to induce a fever. This increases the rate of all chemical reactions in the body, including the rate at which the defence system can work
- triggering the formation of B cells, the other type of lymphocyte. The B cells release antibodies to attach to the virus antigen

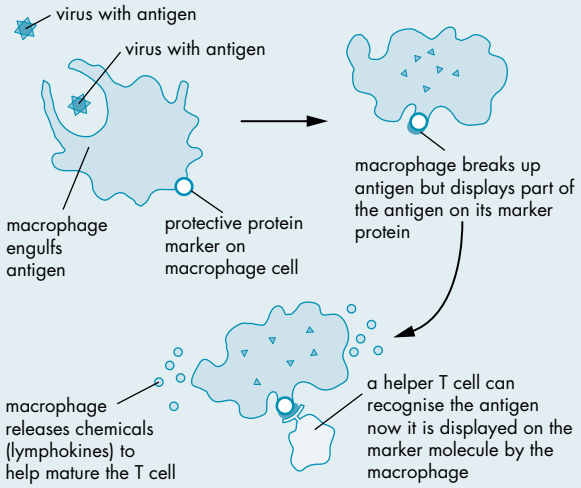


FIGURE 3.24
A T cell cannot recognise an antigen unless it has first been broken down and then displayed on a protein marker molecule by another white blood cell, for example, a macrophage.

- releasing a class of chemicals called interferons. These chemicals help healthy body cells resist attack by viruses.

Some of the invading virus particles may manage to penetrate the defence system, avoid further attack and then enter host body cells. Once inside the host cell, the antigen in the protein coating of the virus is broken down and can no longer trigger an antibody response.

The virus overrides the genetic material of the host cell and makes the host cell manufacture more virus particles. In the process, the virus usually causes some change to the outer cell membrane so that the normal protective MHC markers are altered. Killer T cells are capable of detecting this change on the outer surface of human body cells. They lock onto the infected cell and release chemicals which puncture the cell membrane and destroy it.

B cells also join the attack. They move to lymph nodes and divide to form plasma cells. Plasma cells produce antibodies in response to the presence of antigens. Each cell may produce antibodies directly when it encounters an antigen or it may process the antigen in a similar way to a macrophage to attract a helper T cell.

Once antibodies have attached to antigens, macrophages can engulf them or complement proteins can start to destroy them by attacking the cell membranes.

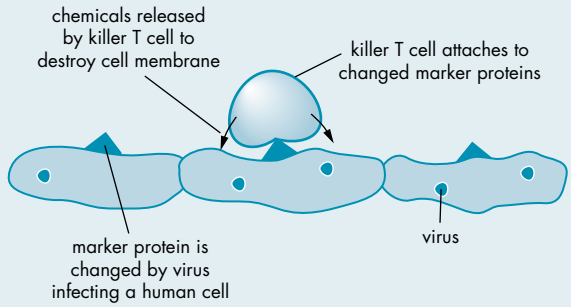


FIGURE 3.25
Killer T cells are stimulated into action by the chemicals (lymphokines) produced by helper T cells which have detected an antigen. They attack human body cells infected with virus particles. The killer cells have detected a change in the outer protein markers of the cell. They produce chemicals which attack the cell's outer membrane. Killer T cells also attack cancer cells, fungi and transplanted tissue.

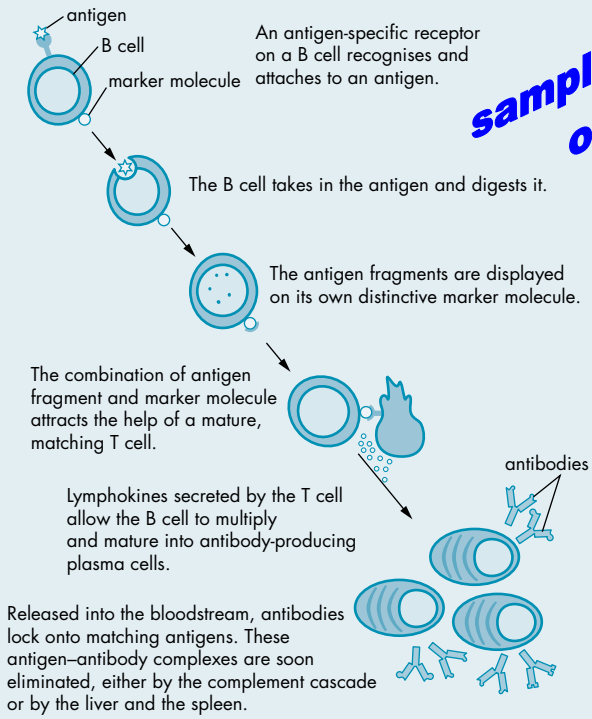


FIGURE 3.26
B plasma cell absorbs the foreign cell and displays part of the antigen fragment, attached to a marker molecule, on its surface. This combination then attracts a helper T cell which will start to produce lymphokines to stimulate the production of more B plasma cells and more antibodies.

1. What must happen to an antigen before a helper T cell will be able to recognise it as foreign?
2. Once a helper T cell has attached to an antigen fragment, it produces chemicals called lymphokines. What changes are caused by lymphokines?
3. Helper T cells and B plasma cells benefit from each other. Explain how.
4. What triggers a killer T cell to attack a body cell which contains viruses?
5. What role do the complement proteins play in working with B cells and helper T cells to fight an infection?

Did you know?

HIV (human immunodeficiency virus) invades T cells. Because the virus blocks the normal functioning of these cells in fighting infection, people suffering from HIV may develop a whole range of unusual infections which are associated with AIDS (acquired immune deficiency syndrome).

Did you know?

Some toxins can stimulate the formation of such a large number of T cells, that toxic shock syndrome can occur. The immune response is so massive, the chemicals produced can cause death.

Antibodies

There are five main groups of antibodies. They are all called **immunoglobulins** (symbol Ig).

- IgA concentrates in body secretions, for example, tears, saliva, respiratory system, intestine.
- IgD is found on the membranes of B cells. It helps in activating B cells.
- IgE is probably intended as a defence against parasites, but is the antibody responsible for the symptoms of allergies like hay fever.
- IgG is the major immunoglobulin. It works by making a coating around bacteria and viruses so that they may be taken up and destroyed by phagocytes.
- IgM is found in the bloodstream where it kills bacteria directly.

Antibodies work in different ways depending on the antigen. Some lock onto toxins and deactivate them. Others form an antigen–antibody pair which is destroyed by complement proteins. Some block viruses from entering cells. Some cover bacteria with a coating which attracts phagocytes. Some form a coating which attracts other white blood cells.

After the battle has been won, suppressor T cells stop the formation of more B plasma cells and helper T cells. Some of the B cells and T cells become memory cells, ready to respond quickly if there is a second attack by the same antigen.

FIGURE 3.27
Sir Frank Macfarlane Burnet (1899–1985) was an Australian scientist who, in 1960, was awarded the Nobel Prize for Medicine and Physiology with an English scientist, Peter Medawar, for his work in immunology. He studied how the immune system recognises the difference between its own cells and foreign cells ('self and non-self').

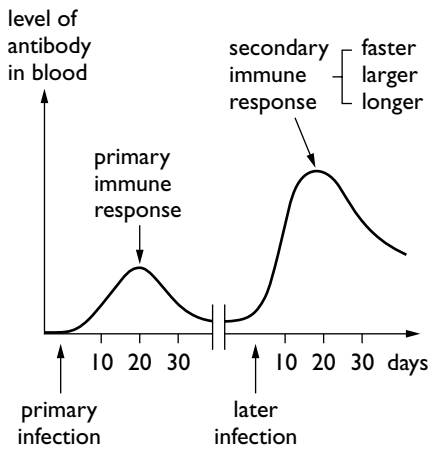


FIGURE 3.28
The second time an antigen enters the body, memory T cells and B cells have the antibody code ready. They divide quickly to mount a quicker response to the infection.

Where these battles happen

Inflammation occurs at the site of an invasion. Neutrophils converge on the site to engulf the invaders. As they die, they form pus. Macrophages also engulf the invaders and present the antigens on their surface to stimulate T cells and B cells into action. B cells are manufactured by bone marrow and mature quickly to form plasma cells in response to an infection. T cells are made in bone marrow but migrate to the thymus gland where they mature.

B cells and T cells move through the blood and lymph system but they are concentrated at lymph nodes, the spleen and the thymus gland. Macrophages move from the infection site to lymph nodes to get a quicker response.

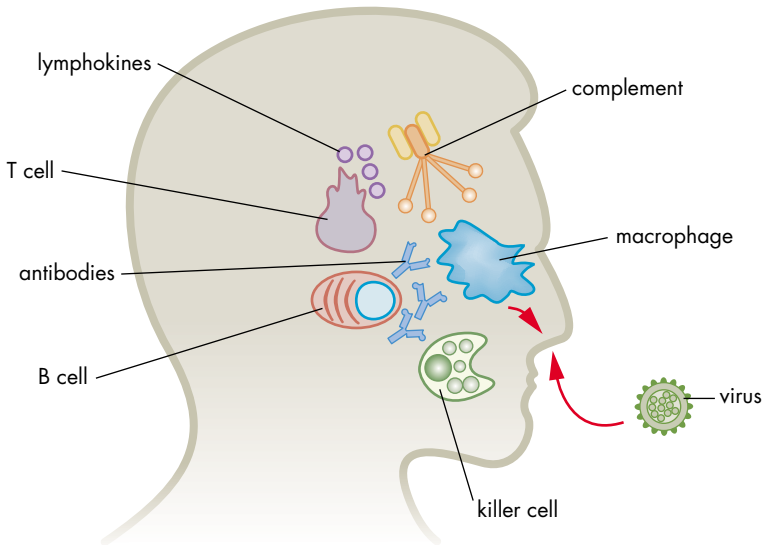


FIGURE 3.29
An arsenal of immune responses is awaiting a virus which enters the nasal passage to invade the respiratory system.

Allergies

In an allergy sufferer, substances that are normally harmless are identified as antigens (allergens) by the immune system.

The symptoms of **allergy** include wheezing, sneezing, runny nose, itching, nausea, vomiting and diarrhoea. These symptoms are triggered in sensitive individuals by materials such as pollen or house dust mite.

People who suffer from allergies have inherited the tendency. Their immune system identifies as an antigen a substance which is normally considered harmless. Such antigens are called **allergens**. B cells respond to the allergen by producing large quantities of IgE antibodies. These antibodies then attach themselves to one type of white blood cell, a **basophil**, and a related cell called a **mast cell**. Mast cells are present in the lining of the respiratory system and the digestive system. They are designed to be part of the immune response system. Once the IgE antibodies have attached to basophils and mast cells, they release large quantities of histamines the next time the antigen is encountered. Other chemicals are also released which attract other white blood cells, the eosinophils and neutrophils, and cause the symptoms of allergy. Blood vessels dilate, causing blood pressure to drop. The spaces between cells fill with fluid.

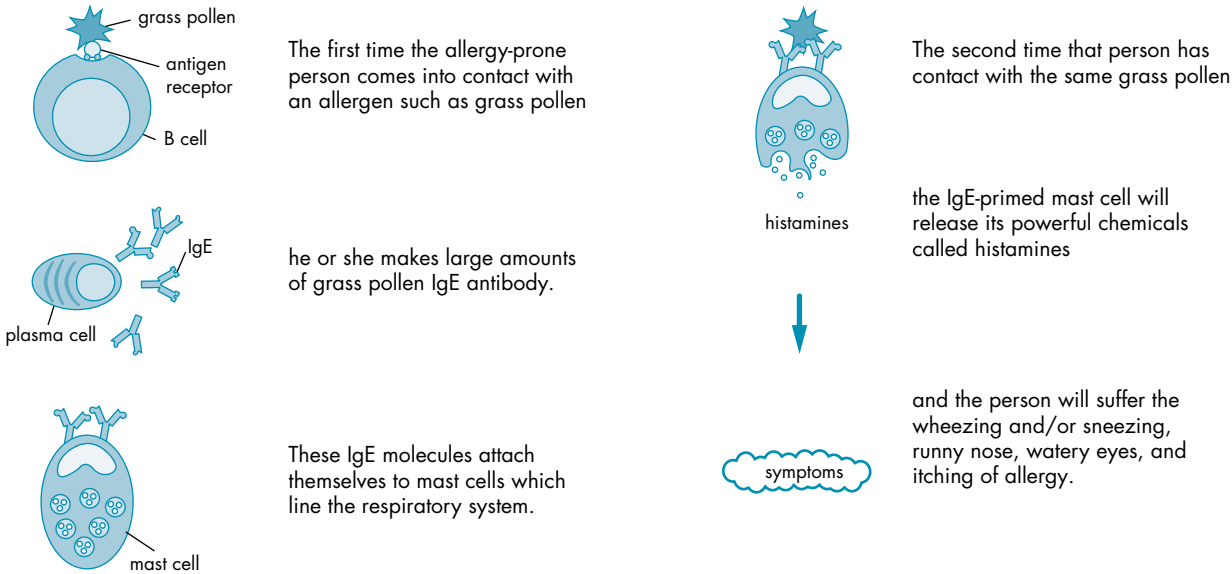


FIGURE 3.30
B plasma cells make antibodies in response to the presence of an allergen. These antibodies attach to mast cells in the respiratory tract. A second contact with the allergen causes the mast cells to release histamines.

If the response of the immune system is severe enough, the person may go into anaphylactic shock, a life-threatening reaction where the allergic response occurs throughout the body, causing a sudden large fall in blood pressure and swelling of body tissues. This swelling may be severe enough to block airways and cause death. The only effective treatment for anaphylaxis is the immediate injection of adrenaline (also called epinephrine). This hormone constricts blood vessels and opens airways.

Another role of complement

Complement proteins play a role in causing the symptoms of allergies such as asthma.

Complement takes part in the allergic response. Complement proteins begin binding to the allergen–antibody site of the basophil and mast cell. They set off a chain of reactions which results in protein channels being set up in the cell membranes. These channels allow the histamines to leak from the mast cells and basophils. These cells die. Protein fragments released by the complement also trigger the formation of other chemicals and stimulation of other white blood cells.

Asthma

Over 2 million Australians suffer from **asthma**. The incidence of asthma is growing in Australia, with one in four children, one in seven adolescents and one in ten adults suffering from it. Fortunately the death rate is decreasing, thanks to better diagnosis and treatment. A National Asthma campaign has estimated that asthma costs the Australian community up to $720 million each year. It also claims that asthma is the main cause of hospitalisation of children and the most common reason for school absenteeism.

Causes

Asthma can be caused by an allergic reaction. The main triggers for the allergy are dust mites, pollen, fur from household pets and moulds. Smoking or passive smoking (inhaling smoke from other people's cigarettes) may also trigger asthma or make a person more likely to suffer asthma if they are allergic to any of the triggers already mentioned. Asthma may also be triggered in susceptible people who are suffering from a respiratory tract infection such as a cold, bronchitis or influenza.

Effect on respiratory system

Asthma causes the muscles surrounding the air passages to contract and constrict the airway. At the same time, the mucous membranes lining the airway may swell and secrete more mucus.

Symptoms

Because the passage of air is restricted, people with asthma have difficulties breathing. It is harder to exhale than it is to inhale. There may be wheezing, coughing and shortness of breath. Oxygen supply to body cells is therefore restricted and the person suffering from asthma lacks energy. If untreated, a severe attack of asthma can result in death.

Prevention

Sometimes it is possible to restrict access to the materials that trigger an allergic reaction. For example, the dust mite is the major cause of asthma and other allergic reactions of the respiratory tract. It lives in beds and carpets. It eats discarded human skin cells and produces droppings which are responsible for the allergic response. Dust mites are harboured in thick woollen underlays, mattresses and doonas. They also live in carpet. Removing wall-to-wall carpets from a house and replacing them with polished floorboards or tiles is one solution. Covering pillows, mattresses and doonas with mite-proof covers and washing bed linen with very hot water to kill dust mites may also help.

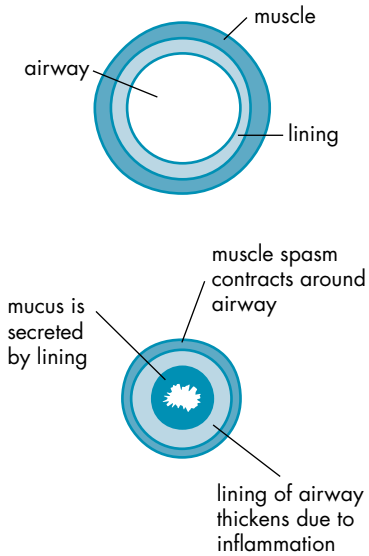


FIGURE 3.31
In asthma, a combination of muscle spasm, inflammation and mucus production narrows airways. It is harder to breathe out than in.

The incidence of asthma is increasing in Australia. Severe cases may result in death if not treated.

FIGURE 3.32
The human dust mite uses discarded human skin cells as food. Its droppings can cause allergies like asthma.

Avoiding cigarette smoke and having vaccinations against respiratory diseases such as influenza also help prevent this disease.

Chronic sufferers of asthma can also take special medications such as **corticosteroids** which suppress the immune system and stop an allergic response.

Treatment

Bronchodilators such as Ventolin cause the muscles surrounding the airways to relax and thus help airflow once an asthma attack has been triggered. Artificial ventilation may also be necessary for severe asthma attacks.

Current areas of research

The incidence of asthma is increasing worldwide. Current research aims to find out why this is happening as well as better means of treatment. Occupational asthma is one area that needs continuing study. There is a growing list of dusts, vapours and other chemicals which have been identified as triggering asthma in the workplace for some susceptible individuals.

Finding out more about respiratory diseases — ACTIVITY 3.4

1 Perform a survey at your school to estimate the prevalence of asthma among school children. Find out how your estimates compare with figures provided by the National Asthma Foundation. Is there any relationship between climate and the incidence of asthma?
2 Construct a mind map to summarise what you have learned about asthma.
3 Use the library, WorkCover pamphlets or Internet sites to gather, process and analyse information about one of the following respiratory diseases: silicosis, hypersensitivity pneumonitis, legionnaire's disease, black lung disease (coal workers' pneumoconiosis), brown lung disease (byssinosis). Present your findings as a descriptive report under the following headings: cause, effect on the respiratory system, symptoms, prevention, treatment, history and current research.

The workplace and respiratory disease

Lung disease is often very slow to develop and may be triggered by low concentrations of irritants over a long period of time in the workplace. Once it has developed, it is difficult to treat.

Large dust particles may be removed by cilia and mucus that line the respiratory tract but some very fine particles may move down and become lodged in the alveoli. The body's defence mechanisms will be activated and inflammation will occur. If these particles are too large to be

engulfed by phagocytes, they may be surrounded and isolated. Layers of macrophages and lymphocytes surround the foreign body. They in turn become surrounded by a protein called fibrin which forms a tough protective wall. The whole structure is called a granuloma. Some infections such as tuberculosis also cause the formation of granulomas in the lungs.

Exposure to asbestos is associated with a variety of very serious diseases.

FIGURE 3.33
In this chest X-ray, the dark areas represent granulomas caused by a tuberculosis infection. The tuberculosis bacteria are isolated by dead white blood cells and a wall of fibrin protein to make the granuloma.

Diseases related to asbestos

Asbestos is the general name given to a number of related minerals which have been used in the building industry. It was not until 1968 that it was identified as the cause of a number of potentially fatal lung diseases. There is usually a lapse of between 20 and 40 years from when asbestos dust is first inhaled to the time that the first symptoms of disease appear. WorkCover estimates that over 1000 workers have died in Australia since 1968 because of exposure to asbestos fibres.

Asbestos may cause any of the following diseases.

- *Asbestosis*—scarring of lung tissue. This reduces the elasticity of the lungs and lung volume. It is a progressive disease, so the supply of oxygen to body tissues is slowly reduced.
- *Pleural disease*—the pleura are membranes which surround the lungs and anchor them to the chest wall. If these membranes become inflamed, fluid may build up between the chest wall and the lungs. Sufferers are short of breath and experience pain on breathing. In severe cases, fluid build-up in the alveoli severely restricts the volume of oxygen available to the body.
- *Mesothelioma*—cancer of the outer lung lining (pleura) or the lining of the abdominal cavity (peritoneum). All identified cases of mesothelioma so far have been associated with exposure to airborne asbestos particles.
- *Carcinoma (cancer)*—starts as abnormal growth of cells in outer layers of the bronchi. The tumour invades surrounding tissue and blocks airways.

As the health risks of asbestos became apparent, its use in the building industry was reduced. Before 1976, white asbestos was sprayed on surfaces needing fire protection or insulation from heat or sound. It

Did you know?

The most common types of asbestos are white asbestos (chrysotile), blue asbestos (crocidolite) and brown asbestos (amosite). White asbestos was the type most often used in industry. It is less dangerous than the others.

was used in brake and clutch linings, in adhesives and cements, in fibro sheeting, asbestos cement pipes and in filter papers and gasket materials. It was also found in the insulating heat mats used to protect benches when using Bunsen burners in school science laboratories.

Today, new fibrous cement products no longer contain asbestos. Asbestos has been removed from a number of building sites, with the workers involved wearing special protective clothing and protective masks. However, old fibro sheeting containing asbestos is still in some buildings and old asbestos cement pipes are still used to carry water, for drainage and as flue pipes. WorkCover states that these materials are safe if they are maintained in good order. They are a risk to health only if they are disturbed in renovations or demolitions, with asbestos dust then being released.

CASE STUDY 3.1 Power stations in the Latrobe Valley

The Latrobe Valley is about 160 km east of Melbourne. From the 1920s, it was developed as a site for power stations, using coal from local open-cut mines. The State Electricity Commission of Victoria (SECV) built Yallourn A power station in 1924. This was the first in a complex of power stations (Yallourn A, B, C and D) which was a major supplier of electricity for the city of Melbourne for many decades. The town of Yallourn was later built especially to cater for the needs of thousands of electricity workers and their families. Asbestos materials were used extensively in all these power stations to insulate against the large amounts of heat generated. For example, it was used for lagging pipes and for walls, ceilings and roofs.

In February 2001, an ABC Four Corners program stated that some reports had been published in the 1930s suggesting that asbestos might cause disease. In 1944, a doctor working for the Victorian Health Department noted that asbestos formed a very harmful dust and suggested that the Yallourn electricity workers should be given health checks. The ABC program claimed that at that time the Electricity Commission stated that the need for medical checks was a private matter for each individual to decide. By the 1960s a number of workers were developing symptoms such as coughing and shortness of breath. At that time, the symptoms were not associated with any workplace hazards.

By the early 1970s, it was becoming apparent that asbestos dust might be a great health risk to the workers in the power stations, but the full effect of exposure to asbestos only became apparent decades later. Today, a large number of power station workers have been diagnosed with mesothelioma and the State Electricity Commission of Victoria has paid 'pain and suffering' workers compensation to thousands of ex-employees.

FIGURE 3.34
Cooling towers of the Loy Yang power station, Victoria's Latrobe Valley.

The town of Yallourn was disbanded by the 1980s so that the rich coal seam underneath it could be mined. The massive Yallourn power complex stopped operations in 1989. Asbestos inside these power stations was removed before they were demolished in 1998. Explosives were used to help demolish them. Huge clouds of dust were released into the atmosphere as the power stacks collapsed. Onlookers were hopeful that all the asbestos had been removed effectively before this demolition.

The SECV no longer exists because the power industry has been privatised. However, workers' compensation claims from Yallourn power workers are still continuing.

1 Why was the town of Yallourn built? Why was it later levelled?
2 Where was asbestos used in the Yallourn power station complexes? What was its function?
3 What were the first symptoms of respiratory disease reported by Yallourn electricity workers? Why do you think there were no grave concerns for the workers at that time?
4 If given the opportunity, would you have chosen to be an onlooker when the Yallourn power stations were demolished? Give a reason for your answer.
5 What disease has been identified in Yallourn electricity workers?
6 Use Internet sites or recent medical journals to research current treatments for this form of asbestos-related cancer.

Preventing lung disease

Lung disease is a common workplace problem. It is very difficult to treat successfully. A much better solution is to prevent the disease by controlling exposure to the irritants and triggers that cause it. According to occupational health and safety legislation, it is part of an employer's duty of care to protect workers from exposure to dust and chemicals which cause irritation and lung disease. This is particularly important in industries such as spray painting, carpentry, mining and sand blasting.

A number of different procedures can be followed.

- Any potential source of dust should be kept moist to reduce the chance of it becoming airborne.
- Dust extractors should be provided to extract gases and dust from the workplace area.
- Masks may also be provided. For very hazardous sites, these masks should include respirators to completely isolate the worker from the factory air.
- Protective clothing and boots must be worn and removed before leaving the worksite. In some very hazardous conditions, workers may need to shower at the worksite.
- The worksite should have adequate ventilation.

Did you know?

A group of Australian scientists announced early in 2001 that they had shown that malignant tumours are able to create lymph vessels. These lymph vessels feed into the body's lymph system and allow the cancer to spread (metastasis). The scientists identified a protein on the outside of the cancer cell that caused the vessels to form. It is called VEGF (vascular endothelial growth factor). They also showed that VEGF could be blocked by an antibody.

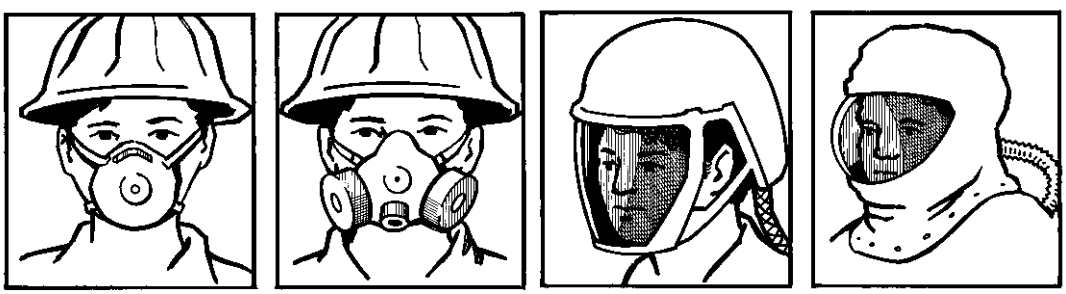


FIGURE 3.35
It is far easier to prevent lung disease than to cure it. Employers are required to provide protective face masks if there is any danger of exposure to dust or fumes in the workplace. (a) Disposable dust mask (for low to medium dust levels). (b) Cartridge respirator (for low to medium dust levels). (c) Battery-powered respirator, filters the air (for medium dust levels). (d) Air-line hood respirator, supplies clean air (for very high dust levels).

Investigating a worksite

ACTIVITY 3.5

1 Prepare a survey of your school to find out if there are any areas where harmful dusts and vapours may be inhaled. List the safety procedures and PPE which are supplied to reduce any risks that these substances may pose.
2 Research a particular worksite where dust or hazardous fumes pose a risk. Find out what PPE is used. As part of your research, you may be able to visit the worksite or interview someone who works there. Prepare a safety poster which could be displayed at the worksite, describing the types of hazards, the risks they pose and the precautions which must be taken to ensure the safety of everyone there.

Smoking

Cigarettes were first manufactured on a large scale towards the end of the 19th century. In World War 1, they were supplied to soldiers as part of their rations, and after that war, cigarette smoking became more popular. In the early 20th century, lung cancer was a rare disease, but by the 1930s, doctors were reporting an alarming number of lung cancers in their patients. By the 1970s, lung cancer was estimated to be the major cause of death by cancer in the western world.

The Cancer Council New South Wales supplies statistics on cancer-related deaths in Australia. In 1997, 22 per cent of all cancer deaths in males were due to lung cancer, the highest figures for any form of cancer. In the same year, more women died of breast cancer than lung cancer (18 per cent compared with 15 per cent) but the incidence of lung cancer in women has doubled over a 10-year period. Statisticians estimate that 90 per cent of all lung cancers are preventable and the way to prevent them is to avoid exposure to cigarette smoke.

Exposure to cigarette smoke increases the risk of developing lung cancer and other serious diseases.

Cigarette smoke

Cigarette smoke contains more than 3800 chemicals. These include:

- 30 identified poisons, including a range of benzene compounds
- 43 known carcinogens (chemicals which cause cancer). These include naphthylamine and nitrosamines which produce lung cancer. These compounds may also be absorbed through the lungs and cause cancer in the kidneys, bladder and pancreas
- chemicals which damage the cilia lining the respiratory system. These include hydrogen cyanide, ammonia, nitrogen dioxide and formaldehyde. The cilia become paralysed and cannot sweep mucus and the dust it contains out of the lungs
- carbon monoxide, which combines with haemoglobin in red blood cells, preventing the uptake of oxygen. Chronic smokers are not as fit as they should be because less oxygen is getting to their body tissues, including muscles
- tar, a mixture of gases which cools to form a sticky brown substance which can build up in the alveoli. This blocks oxygen uptake and triggers allergic responses like inflammation
- nicotine, which is addictive and poisonous in very high concentrations. It is used in some pesticides.

Passive smoking

People who are near smokers are exposed to the hazards of cigarette smoke. Sidestream smoke is the smoke emitted from the end of a lighted cigarette. It has been shown to contain greater concentrations of harmful substances than the mainstream smoke inhaled and then exhaled by the smoker. Sidestream smoke also contains smaller particles which can penetrate more deeply into lung tissue.

Passive smokers may therefore be more prone to respiratory diseases (asthma, bronchitis), heart problems and increased risk of lung cancer. The Occupational Health and Safety Act 1983 makes no direct mention of exposure to cigarette smoke in the workplace but employers have a duty of care to ensure the health and wellbeing of their employees.

Since the effects of passive smoking have been published by a wide range of scientific studies, employers risk fines and large workers compensation payouts if they do not ensure clean air in the workplace.

Did you know?

Smokers are 11 times more likely to suffer from lung cancer than non-smokers. If smokers are also exposed to asbestos dust, they are 92 times more likely to contract lung cancer. Cigarette smoking and passive smoking increase the risk of a wide range of cancers.

INVESTIGATION 3.2 Estimating tar content in a cigarette

Aim

To measure the tar content of different brands of cigarette.

Materials

- 2 different brands of cigarette
- plastic syringe
- filter paper
- extraction equipment (see Figure 3.36)

Method

Warning: This experiment should be done in a fume cupboard.

If you either have a cigarette tar extractor or can improvise equipment to make one (see Figure 3.36), perform an experiment to determine the tar content of two different brands of cigarette supplied by your teacher.

Discussion

What factors need to be controlled to make it a fair test? Write up your findings as an experimental report.

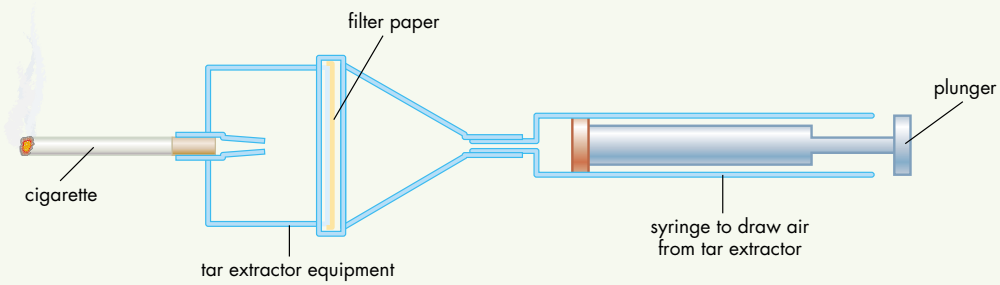


FIGURE 3.36
Equipment used to collect tar from a lighted cigarette.

An anti-smoking campaign ACTIVITY 3.6

Find out what types of information and help is available to help people stop smoking. Design your own pamphlet to be used as part of a QUIT campaign.

Questions

1 Describe the process by which oxygen in the alveoli of the lungs reaches haemoglobin in red blood cells.

2 Name three different types of white blood cells and describe their role in providing immunity.

3 Describe how inflammation of tissues occurs.

4 Describe the steps which trigger an allergic response.

5 Name four respiratory diseases which are caused by exposure to dust or harmful chemicals.

Further questions ▸

1 Choose a respiratory disease you have studied and write a descriptive report with the following paragraphs: symptoms, causes, prevention and treatment.

2 What type of allergens can trigger asthma? What steps can be taken in a home to minimise exposure to these allergens?

3 Explain why passive smoking may be more harmful than smoking cigarettes directly.

4 In Figure 3.37 which stages in the hierarchy of control do each of the diagrams address? Name two worksites where each of these practices would be used to ensure the safety of workers.

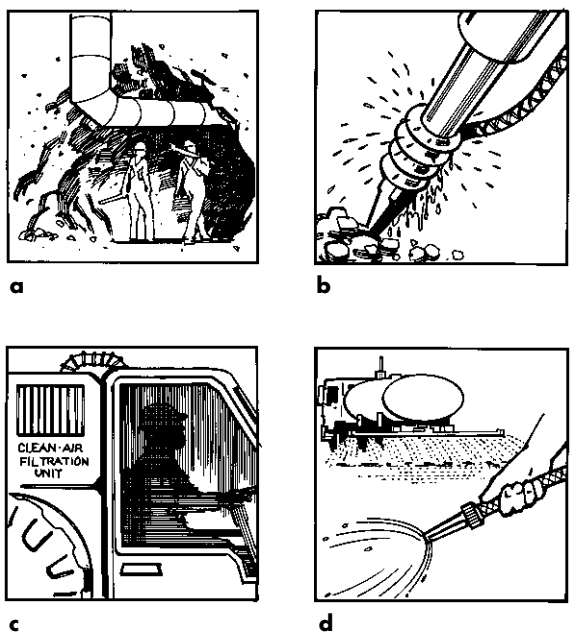


FIGURE 3.37
(a) Extraction ventilation in a mine; (b) water coil attachment fitted to a jackpick; (c) cab fitted with air filtration unit (not an ordinary air-conditioner which does not trap fine dust); (d) wetting down work areas.

chapter summary

- The Occupational Health and Safety Act 1983 states that employers have a 'Duty of Care' to ensure the health, safety and welfare of all their employees. Employees also have an obligation to follow all safety procedures and behave responsibly.
- Potential sources of risk should be assessed at a worksite. Once a risk assessment is done, a series of steps called the Hierarchy of Hazard Control should be followed to eliminate or minimise the identified risk.
- The human respiratory system provides a large surface area where dissolved oxygen diffuses from the lungs to bind with haemoglobin in red blood cells. From there it can diffuse through interstitial fluid into body cells to be used in cellular respiration.
- Mucus and fine cilia lining the respiratory tract help protect the respiratory system from dust and microorganisms. A variety of white blood cells can respond to the presence of microorganisms by destroying them and providing natural immunity.
- Exposure to fine dust at a worksite can increase the risk of respiratory diseases like lung cancers, asbestosis, silicosis, mesothelioma and pleural disease. Personal protective equipment like face masks and respirators can reduce the risk of these diseases.
- Good vision is very important. The retina in the human eye has receptors called rods to detect light and three types of cones to detect the three primary colours of light.
- The eye has natural protection. Although the bones of the skull, the eyelid and tears all provide some form of protection, the eye can be very easily damaged when playing sport or at some worksites. Most eye injuries can be prevented by wearing protective eyewear.
- The middle and inner parts of the ear are protected by the skull, but wave energy from loud noises can enter the auditory canal and cause hearing damage. Loud noises at worksites can be reduced by the use of ear plugs and ear muffs.
- The brain controls the coordination of the body. It regulates activities needed for survival such as heartbeat and breathing rate. It is the site of all our thinking, our memories and all our learning.
- Natural protection for the brain is the skull, the meninges and the cerebrospinal fluid but the workplace and sporting activities can pose hazards to the brain.
- Brain damage is most often associated with movement—either a person stopping suddenly or a moving object impacting on the brain. Protective headgear is designed to absorb the energy over a longer period of time and for a longer stopping distance if a person is stopping suddenly (e.g. bicycle helmets). For impact with a moving object, protective headgear is designed to deflect the energy of impact.
- The human skeleton protects and supports the body. It also allows movement.
- Back injury is a very common workplace injury which can be prevented or minimised if appropriate work practices are followed. Other workplace injuries include repetitive strain injuries. These injuries can also be minimised by workplace procedures.
- The majority of workplace injuries and sporting injuries can be prevented. Many workplace injuries cause permanent damage to the body. It is much easier to prevent an injury than to treat it.

Exam-style questions

1 The activity which could provide a biological source of risk at a worksite is
- **A** wearing a hard hat when working in a coal mine
- **B** wearing protective gloves all day at a worksite where food is prepared
- **C** working in a spray booth at a car manufacturing site
- **D** welding metal while wearing a safety helmet and face shield

2 The last step in the Hierarchy of Hazard Control is
- **A** eliminate the hazard
- **B** isolate the worker from the hazard
- **C** provide personal protective equipment
- **D** substitute a less hazardous substance

3 In New South Wales Workcover has identified the industry with the most workplace injuries as
- **A** construction
- **B** hospitality
- **C** transport
- **D** mining

4 Of the following statements the incorrect one is
- **A** lymph vessels contain valves which allow lymph to move in one direction only
- **B** the thymus gland is an important part of the lymphatic system
- **C** lymph nodes may swell at the time of an infection
- **D** the lymphatic system is a closed system of vessels

5 The white blood cell which acts as a scavenger to engulf invading microorganisms in very large numbers and which makes pus is the
- **A** neutrophil
- **B** macrophage
- **C** T helper cell
- **D** B plasma cell

6 The smoke from cigarettes
- **A** contains large amounts of carbon dioxide which blocks uptake of oxygen by haemoglobin
- **B** contains no identified carcinogens
- **C** is removed from the lungs by the cilia which line the respiratory tract
- **D** is more hazardous as sidestream smoke which is inhaled by passive smokers

7 In the human eye
- **A** the main structure for focusing light is the lens
- **B** cones are responsible for colour vision
- **C** rods are receptors found mostly in the fovea
- **D** the iris is responsible for accommodation

8 In the human ear
- **A** the semicircular canals detect different frequencies of sound
- **B** most noise damage is caused by loud sounds with a very low frequency
- **C** loud sounds increase the amplitude of vibrations of the eardrum
- **D** nerve messages are carried from the inner ear to the brain by the optic nerve

9 In the human brain
- **A** cerebrospinal fluid is part of the lymphatic system, helping the body fight infections in the brain
- **B** damage can occur by a blow to the head causing the brain to hit the skull
- **C** concussion occurs only if the patient has been unconscious for over five minutes
- **D** damage to the left hemisphere can be detected by dilation of the left pupil in the eye

10 In the human skeleton
- **A** all cartilage has formed bone by adulthood
- **B** ligaments apply forces to bones which allow joints to bend
- **C** the elbow and knee are examples of a hinge joint
- **D** there are no fixed joints

11 Emphysema is a respiratory disease that begins with narrowing of the bronchioles. Lung tissue also loses its elasticity.
- **a** Name two symptoms you would expect if a person were suffering from emphysema.
- **b** What effect would emphysema have on the heart?
- **c** Name another respiratory disease you have studied. What causes this disease? What are the symptoms?

12 Tears contain secretions from goblet cells, lachrymal glands and from Meibomian glands. Describe how each of these secretions contributes to the protective function of tears.

13
- **a** What natural protection does the eye have from UV light?
- **b** Give two examples of eye damage by UV light.
- **c** Explain why UV light from a laser causes more damage than UV light from the Sun.
- **d** What type of protective lens must be used to prevent damage from laser light?

14 Outline a first-hand investigation that you have performed to find the effect of loud noise on hearing and learning. Discuss your findings.

15
- **a** Describe how a baby's brain can be damaged by violent shaking.
- **b** Explain how a bicycle helmet is designed to reduce brain injury.
- **c** What are the limits to the effectiveness of a bicycle helmet?