Chapter 14
Protective systems

Unit
1A

Unit content

Cells, metabolism and regulation
Dysfunctions occur from the failure of protection from pathogens and foreign materials.

Pathogens and foreign materials:
- types of pathogens: bacteria, viruses, parasites, fungi
- example of disease caused by each type with emphasis on mode of transmission and entry into the body
- the body recognises and reacts to foreign materials.

Body systems
The body is organised from cells to tissues, organs and systems. The major body systems are the digestive, excretory, skeletal, muscular, respiratory, circulatory, nervous, endocrine, immune and reproductive systems and are related to life processes.

Organisation:
- hierarchy of organisation in the body
- location of organs associated with each body system in the body.

Functions:
- function of each organ system related to life processes.

Approaches to investigating and communicating human biology
- given a relevant contextual research question, use a prescribed format to plan and conduct a safe and ethical investigation
- use simple equipment to collect reliable data presented in simple tables and graphs
- make valid conclusions using appropriate terminology.

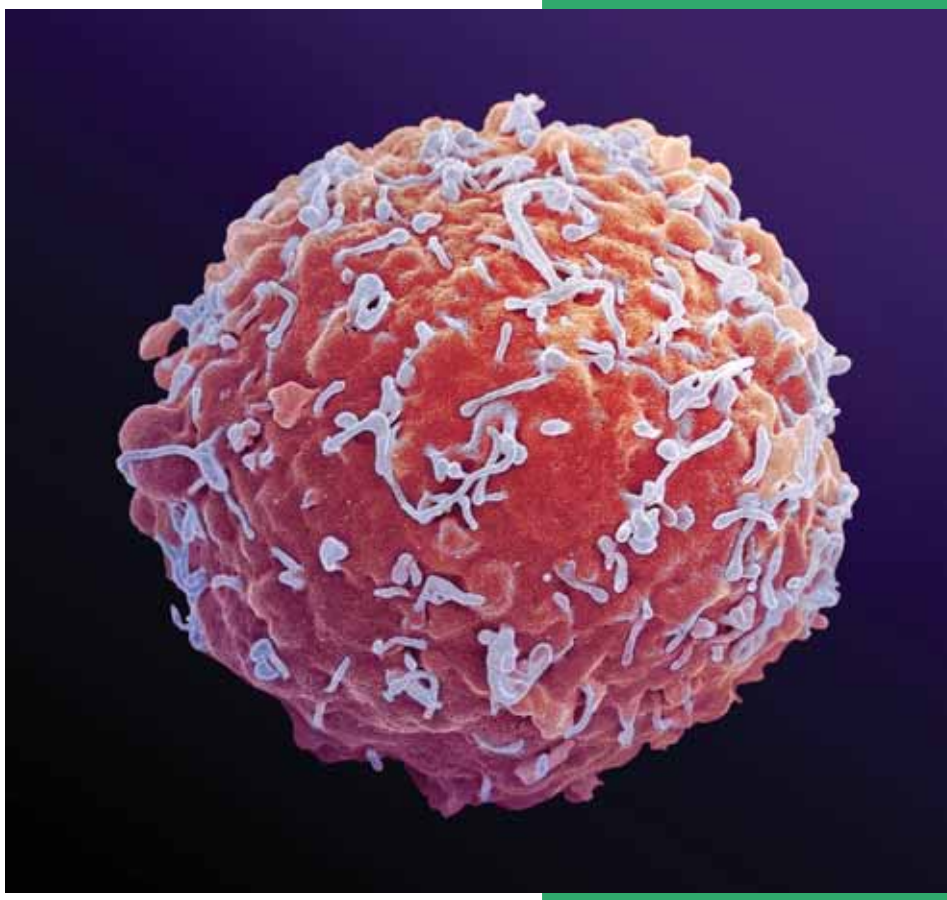


Figure 14.1 Coloured scanning electron micrograph of a lymphocyte, one of the types of cell involved in defence against disease

Every day we are exposed to disease-causing organisms. Fortunately the human body has a number of ways of protecting itself against invaders. However, if organisms do overcome the body's defences, then a disease may occur. Disease-causing organisms are called **pathogens**. A disease caused by a pathogen invading the body is called a **communicable** or **infectious disease** because the pathogen can be passed from one person to another. Some communicable diseases are said to be **contagious**. This means that they are passed on by physical contact with a person suffering from the disease, or by contact with something touched by the infected person.

Pathogens

Bacteria

Most bacteria are harmless to humans. Harmless bacteria are said to be non-pathogenic. Many bacteria are essential to life on earth. They have a role in the decomposition of organic material and the cycling of the elements. Some bacteria are used in processing food. For example, *Lactobacilli* are used to make yoghurt, and the flavour of cheeses depends on the type of bacteria used in their production.

Huge numbers of bacteria live on our skin, in our alimentary canals and in other parts of the body. For example, in the armpit of an adult male there are more than two million bacteria per square centimetre of skin surface. The intestine also has extremely large numbers of bacteria. These help break down our food. While these bacteria have no ill effect on our health, there are others that may cause illness or death when present in relatively small numbers.

Bacteria are so small that they can only be seen with a microscope. They all consist of a single cell (see Fig. 14.2) and the shape of their cells is about all that can be seen with a light microscope. Cell shape is used to classify bacteria (see Fig. 14.3).

Compared with the great numbers of different species of bacteria, relatively few cause disease in humans. Those that do cause disease do so in a number of ways. In many cases the disease is the result of **toxins**—substances produced by the bacteria. Tetanus, diphtheria and bubonic plague are the result of such toxins. Sometimes disease symptoms are an allergic response to the substances produced by bacteria. Most of the symptoms of tuberculosis and rheumatic fever result from such allergic reactions. Some of the better known diseases that are caused by bacteria are shown in Table 14.1.

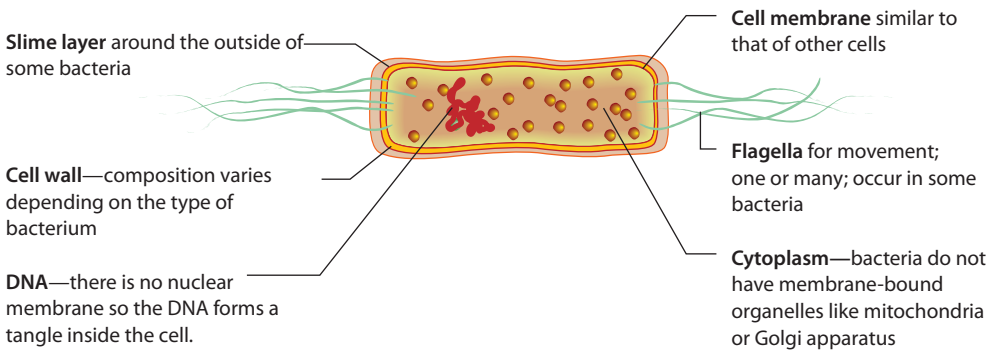
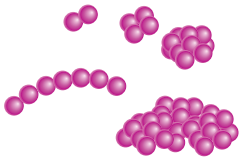
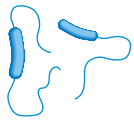


Figure 14.2 The structure of a bacterial cell



cocci (sing. coccus) are spherical cells that may occur singly, in pairs (diplococci), in clusters (staphylococci) or in chains (streptococci)



bacilli (sing. bacillus) have rod-shaped cells; many have flagella for movement

spirilla (sing. spirillum) have twisted cells

vibrio are like curved rods and are often shaped like a comma

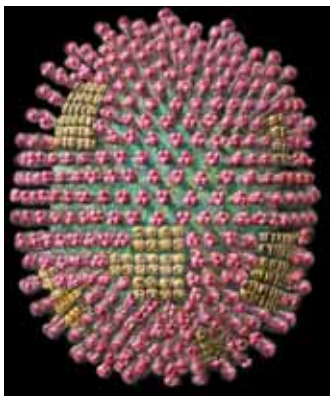
Figure 14.3 Types of bacteria

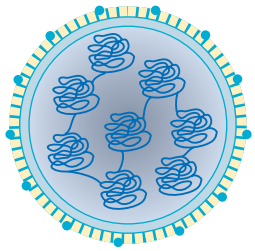
Viruses

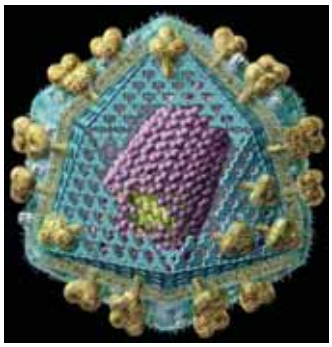
The discovery, by scientists such as Louis Pasteur, that some diseases are caused by bacteria was a great step forward for medical science. There were, however, certain diseases for which no bacterial cause could be found. Pasteur tried in vain to find a bacterium that caused the disease rabies. We now know that the causes of these diseases are **viruses**, structures too small to be seen with the ordinary light microscope.

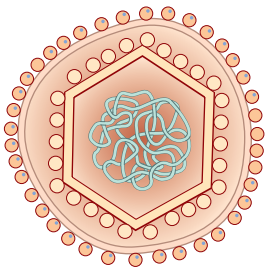
It was not until 1938, when electron microscopes came into use, that scientists were able to see viruses. Viruses have distinctive structures and differing sizes. All contain genetic material in the form of either DNA (see Chapter 17) or RNA, but they never contain both. The molecule containing the genetic material is surrounded by a coat of protein (see Fig. 14.4).

(a)



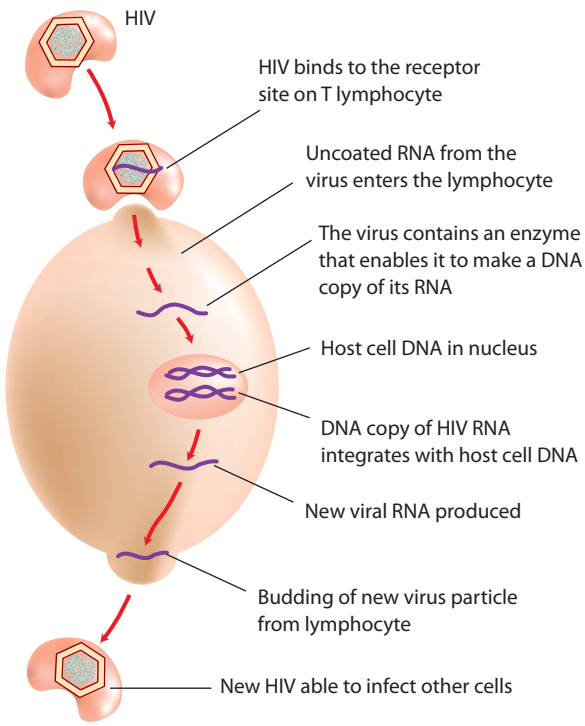






Viruses all contain either DNA or RNA but not both. Around the nucleic acid is a protein coat. Flu virus (top) has RNA divided into eight segments. **Human immunodeficiency virus** (HIV) (bottom) is also an RNA virus.

(b)



Viruses cannot reproduce themselves. They attach to the outside of a host cell and the nucleic acid enters the cell. New viral genes are produced by the host cell so that hundreds of new virus particles are formed.

Figure 14.4 **(a)** Viruses and **(b)** how they replicate

Table 14.1 Pathogenic organisms and some of the better-known diseases that they cause

Bacteria	Viruses	Fungi	Animal parasites
Anthrax	HIV/AIDS	Ringworm	*Protozoans (Single-celled animals)*
Botulism	Bird flu	Thrush	Amoebic dysentery
Chlamydia	Chickenpox	Tinea	Amoebic meningitis
Cholera	Cold sores (herpes)		Malaria
Dental caries (tooth decay)	Colds		Sleeping sickness
Diphtheria	Encephalitis (viral)		Toxoplasmosis
Gastroenteritis	Genital herpes		
Gonorrhoea	Glandular fever		*Platyhelminthes (flatworms)*
Impetigo (school sores)	Hepatitis A, B, C, D, E and G		Blood flukes
Legionnaires disease	Influenza		Hydatids
Leprosy	Measles		Liver flukes
Meningitis (bacterial)	Meningitis (viral)		Tapeworms
Peptic ulcers	Mumps		
Plague	Poliomyelitis		*Nematodes (round worms)*
Pneumonia	Rabies		Hookworms
Scarlet fever	Ross River virus		Roundworms
Syphilis	Rubella		Threadworms
Tetanus	SARS (severe acute respiratory syndrome)		
Trachoma	Shingles		*Arthropods (ectoparasites)*
Tuberculosis	Smallpox		Lice
Typhoid	Warts		Scabies (mites)
Whooping cough	Yellow fever		Ticks

Viruses do not carry out any of the processes described in Chapter 2 that are common to all living things. For example they do not feed, respire, respond or grow. When a virus infects a living cell its DNA or RNA induces the cell to manufacture more virus particles. The new virus particles are then able to leave the host cell and infect other cells (see Fig. 14.4b). Some diseases caused by viral infections are shown in Table 14.1.

Figure 14.5 Ticks are ectoparasites of humans and other mammals; the tick shown here has its head buried in human skin and it is feeding on the blood of the host

Animal parasites

Parasites are organisms that live on or in another living thing, called the **host**. It is from the host organism that parasites gain food and shelter. They may not cause the host much harm, or they may be fatal, depending on the nature of the relationship. Humans are potential hosts for many parasites. Some, such as fleas and lice, live on the surface of the body and are called **ectoparasites**. Others, such as worms or single-celled animals, live inside the body. Such parasites are **endoparasites**.

Fungi

Compared with bacteria and viruses, there are few fungi that are pathogenic to humans. Most of the pathogenic fungi cause diseases of the skin, some of which are mentioned in Table 14.1.

Figure 14.6 Tinea, sometimes called athlete's foot, is a skin disease caused by a fungus

Types of defence

The body's defences against invading micro-organisms can be described as either non-specific or specific.

- **Non-specific defences** work against all pathogens. For example, the skin protects us against entry of all types of bacteria, viruses and fungi. Some non-specific defences, like the skin, are external; others are internal.
- **Specific defences** work against one particular pathogen. For example if a 'flu virus gets past your non-specific defences your body will manufacture antibodies that will attack the virus particles. This will help you to recover from the 'flu but those antibodies will not protect you against any other viruses or bacteria.

In this chapter we are concerned mainly with non-specific defences.

External defences

The body has many external defences to try to stop pathogens from entering (see Fig. 14.7). All of them are non-specific. Some of the external defences that prevent pathogens from invading our tissues are:

- The **skin** is an effective barrier covering the outside of the body. It is very good at stopping the entry of micro-organisms provided it is not broken by cuts or abrasions. At openings in the skin, such as the mouth, eyes and anus, special protection is provided by other defences.

- Huge numbers of bacteria live on the skin all the time. These normal bacteria occupy the area so that potential pathogens find it difficult to become established. In addition, the skin has other protective mechanisms. An oily secretion called **sebum** is produced by oil glands in the skin. It contains substances that kill some pathogenic bacteria. **Sweat** secreted onto the skin contains salts and fatty acids that prevent the growth of many micro-organisms.

- **Mucous membranes** line body cavities that open to the outside of the body. They secrete mucus, which traps micro-organisms and prevents their entry to the cells. The whole of the respiratory, digestive, urinary and reproductive tracts are protected in this way.

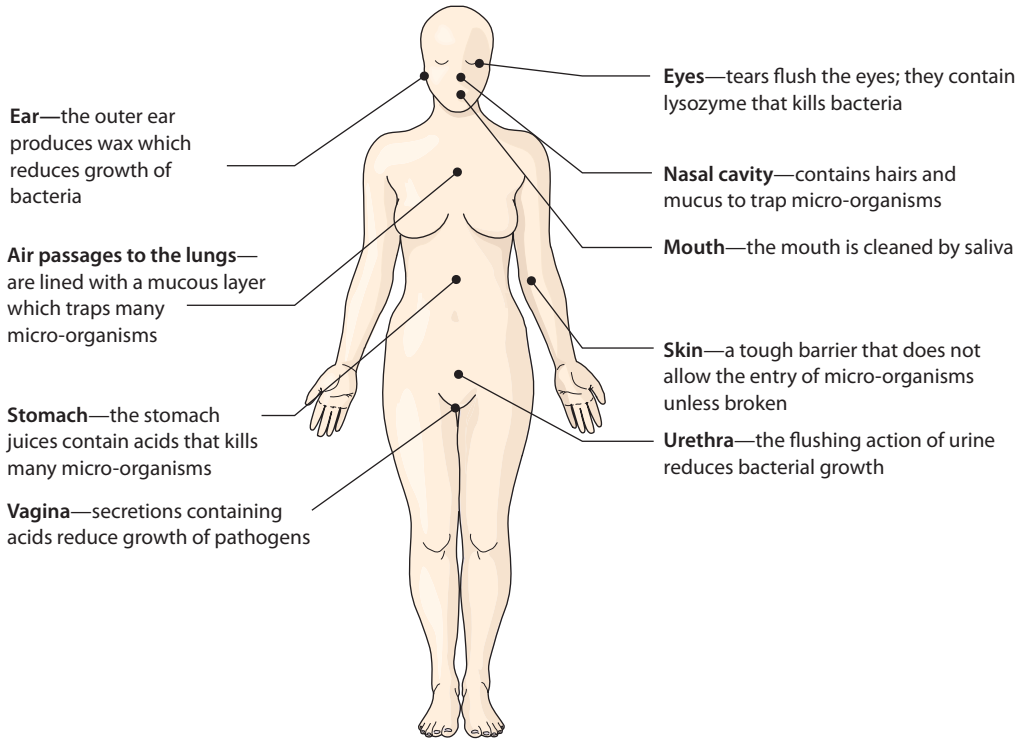


Figure 14.7 The body's external defences against the entry of disease-causing micro-organisms

Figure 14.8 Scanning electron micrograph showing the cilia of cells lining the respiratory system: the gaps between the cilia are mucus-secreting cells

- **Hairs** are found in the nose cavity and the ears. In the nose, the hairs and a layer of mucus enable the nose to trap up to 90% of the particles inhaled when breathing.

- **Cilia** are tiny hair-like projections from cells. They are capable of a beating motion. The mucous membranes lining the nose cavity, the windpipe and other air passages have cilia (see Fig. 14.8). The beating of the cilia moves mucus, containing trapped particles and micro-organisms, towards the throat, where it may be coughed up or swallowed.

- **Acids**. Stomach juices are strongly acidic. The acid kills many of the bacteria taken in with food or those contained in the mucus swallowed from the nose and windpipe. The vagina also has acid secretions that reduce the growth of micro-organisms. The sweat on the skin is slightly acidic.

- **Lysozyme** is an enzyme that kills bacteria. The eyes are protected by the flushing action of tears, which contain this enzyme. Lysozyme is also found in saliva, sweat, secretions of the nose and tissue fluid.
- **Ear wax** protects the outer ear against infection by some bacteria. It is slightly acidic and contains lysozyme.
- The **flushing action** of body fluids helps to keep some areas relatively free of pathogens. Urine flowing through the **urethra**, the tube that empties the bladder to the outside, has a cleansing action. This prevents bacterial growth and helps to stop bacteria reaching the bladder and kidneys. Women have a shorter urethra than men and so they tend to suffer more bladder infections. Tears, sweat and saliva are also involved in flushing and cleansing.

Internal defences: the immune system

If our external defences are penetrated by an organism there are internal defences that can provide protection. These internal defences make up what is called the **immune system**.

See animations of phagocytosis at these websites:

- http://academic.brooklyn.cuny.edu/biology/bio4fv/page/phago.htm
- http://www.sp.uconn.edu/~terry/Common/phago053.html
- http://student.ccbcmd.edu/~gkaiser/biotutorials/eustruct/phagocyt.html

Phagocytes

Phagocytes are cells that can engulf and digest micro-organisms and cell debris. The phagocyte extends projections of the cell around the pathogen or particle until it becomes included in the cytoplasm of the cell (see Fig. 14.9). The pathogen or particle is then broken down by enzymes. Phagocytes are very important in our defence against disease.

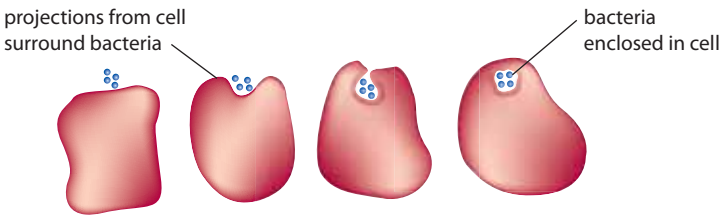


Figure 14.9 A phagocyte engulfing bacterial cells

White blood cells are a type of phagocyte. There are a number of different types but they are all important in defence against disease. White blood cells are able to leave the blood capillaries and move through the tissues to places where there are infecting micro-organisms or where there has been an injury. At the place of infection some secrete substances that destroy bacteria before they are engulfed, whereas others engulf live bacteria and digest them.

Macrophages are large phagocytes that develop from some white blood cells. Some are roving cells that move through the tissues looking for pathogens to destroy. Others are fixed in one place and only deal with the pathogens that come to them.

These processes eliminate many pathogens before an infection has a chance to take hold. Figure 14.9 shows macrophages attacking bacteria.

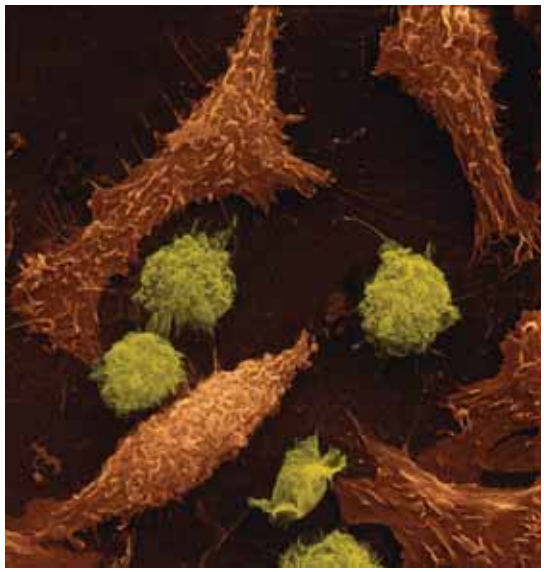


Figure 14.10 An electron micrograph that has been coloured to show macrophages (brown) and lymphocytes (green)

The inflammatory response

Sometimes organisms get past the external defences and enter the body. Cells of the immune system are spread throughout the body and when our external defences are broken an **inflammatory response** occurs. White blood cells release chemicals into the area where pathogens have entered. One of the effects of the chemicals is to make the nerve endings more sensitive. The area around the wound then becomes painful.

At the same time, the chemicals:

- attract more white blood cells to the area
- increase the flow of blood
- allow materials to pass through the capillary walls more easily.

For animations of the inflammatory response see:
- http://www.youtube.com/watch?v=CmbWE3jLUgM
- http://www.sumanasinc.com/webcontent/animations/content/inflammatory.html

The increase in the number of white blood cells allows phagocytosis to take place. Micro-organisms and cell debris are engulfed. The phagocytes, filled with bacteria, debris and dead cells, begin to die. The dead phagocytes and tissue fluid form a yellow liquid called **pus**. New cells are produced by mitosis and repair of the damaged tissue takes place (see Fig. 14.11).

The increase in blood flow results in the area of the wound becoming warm and red, while the increase in materials flowing through the capillaries results in swelling. Therefore the four signs of inflammation are redness, swelling, heat and pain.

A pimple is an excellent example of the inflammatory response. The pimple is painful, red and swollen and pus eventually develops at the site. Dysfunctions that involve inflammation have the ending *-itis*, for example tonsillitis, laryngitis, appendicitis and bronchitis.

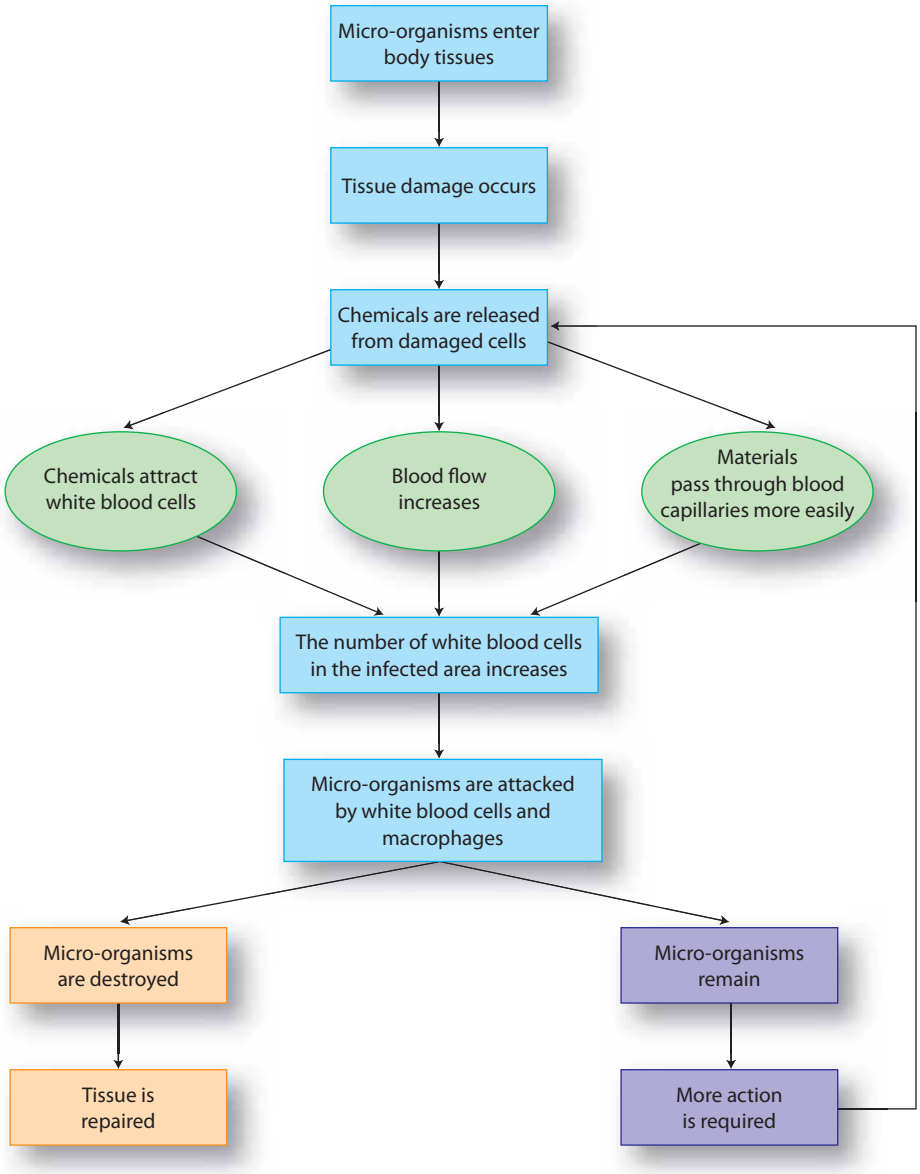


Figure 14.11 A summary of the inflammatory response

The lymph system

Lymph is the colourless fluid that has leaked out from the capillaries into the spaces between the cells. It has a similar composition to blood plasma (see Chapter 6), but with fewer proteins. It contains white blood cells that are important in fighting disease. Lymph returns to the circulatory system in lymph vessels. Lymph vessels begin as blind-ended tubes in the spaces between the cells of most tissues. These **lymph capillaries** are usually slightly larger than blood capillaries. They are also more permeable than most capillaries. Proteins, and any disease-causing organisms in the fluid between the cells, can easily pass through the walls of the lymph capillaries into the lymph.

Lymph nodes (also called **lymph glands**) occur at intervals along the lymph vessels. There are large numbers of them in the neck, armpits, groin and around the alimentary canal (see Fig. 14.12). These nodes contain white blood cells (see Fig. 14.1) and macrophages. Spaces between the cells are criss-crossed by a network of fibres.

For more information about the lymph system go to:

- http://www.betterhealth.vic.gov.au/bhcv2/bhcarticles.Nsf/pages/Lymphatic_system?OpenDocument

or

- http://www.cancerhelp.org.uk/help/default.asp?page=117

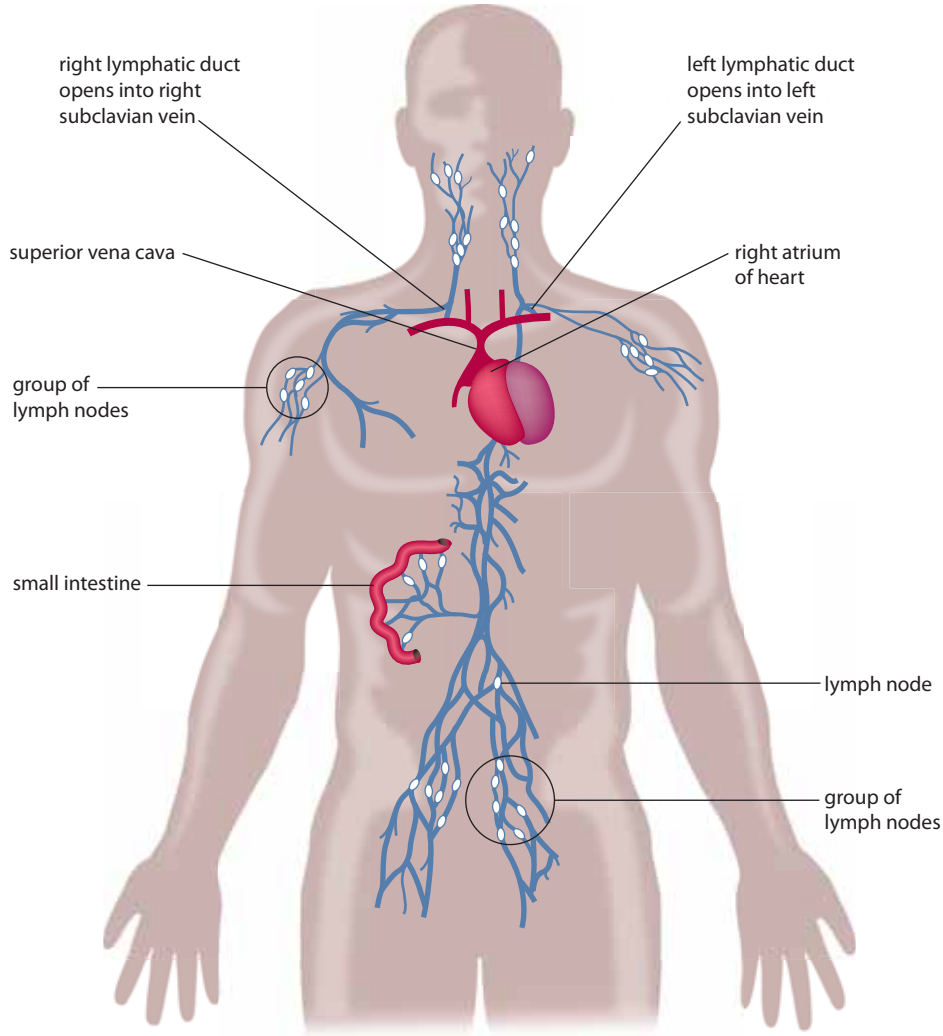


Figure 14.12 The main vessels of the lymph system

Lymph entering the lymph nodes contains particles from broken cells and any micro-organisms that have got through the body's external defences. Some of the micro-organisms may be pathogenic and, if not destroyed, could cause disease. Particles and micro-organisms such as bacteria are trapped in the network of fibres as the lymph flows through the spaces in the nodes. Macrophages engulf micro-organisms by phagocytosis and then destroy them.

When infections occur, the formation of white blood cells increases and the lymph nodes become swollen and sore. For example, an infected finger may result in swelling and tenderness in the armpit, where there are a large number of lymph nodes (see Fig. 14.12).

Specific internal defences

The internal defences we have just described are all non-specific. That is, they will work against any type of micro-organism or particle that is foreign to the body.

A specific defence is aimed at a particular pathogen. For example, if you get infected or vaccinated with the measles virus, your immune system will learn to make antibodies that will combat the virus. Those antibodies will only work against the measles virus; they will not work against any other virus or any other bacterium.

Working scientifically

Activity 14.1 Airborne bacteria

Although we cannot see them, bacteria are found almost anywhere. Any environment that can support life in any form has populations of bacteria.

The purpose of this activity is to check the bacterial content of the air in various places around your school. In doing so, the hypothesis 'That bacteria are in greater numbers where there is a lot of human activity' will be tested. (Chapter 1 explains the meaning of hypothesis.)

The presence of bacteria in the air can be shown by exposing the contents of a sterile culture plate for a fixed amount of time. A culture plate is a Petri dish with a thin layer of agar jelly in the bottom. It is sterile because it has been treated so that any micro-organisms inside will be killed. The agar contains nutrients for any micro-organisms that may grow on its surface (see Fig. 14.13). When the lid is lifted off and the agar exposed to the air, bacteria can enter and begin to reproduce. After exposure the plate is incubated (kept in a warm place) for several days. Bacteria that entered from the air will reproduce and form colonies that can be seen with the naked eye. The more colonies, the more bacteria there were in the air.

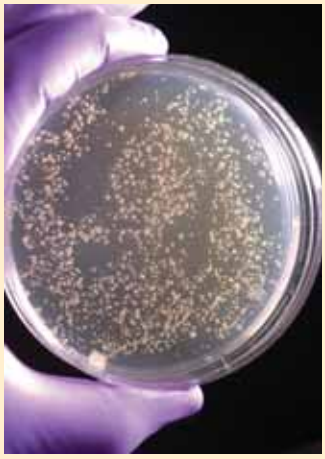


Figure 14.13 A culture plate with bacterial colonies growing on the surface of the agar

You will need

For each pair or group: two sterile nutrient agar plates; a timing device (you could use your watch); marking pen; adhesive tape; an incubator (if available)

Special instructions

When handling the culture plates you must take the following precautions.

- Do *not* open the lid of the sterile culture plate until you are ready to expose the agar. It is most important that exposure of the plates to the atmosphere be kept to the same time for all plates.
- Replace the lid on the culture plate as quickly as possible after the exposure period.
- Label the plate.
- Tape the lid onto the plate with two pieces of adhesive tape so that it cannot be accidentally removed.

- **Do not remove the lid after the plate has been exposed.** The plate should be destroyed with the lid still in place.
- Incubate the plates upside down so that any moisture condensing on the lid of the plate cannot drip onto the nutrient medium.

What to do

1. In your pairs or groups, and in consultation with the other groups in the class, decided on the location within the school where your group will expose your sterile agar plates. Locations that could be used are the classroom or laboratory, a crowded passageway, the school canteen, near the lockers at change of lessons, the gymnasium, the library and the school oval.
2. You will need to expose one plate when there is little human activity, and the other when there is a lot. Label the plates as either 'quiet' or 'busy', and ensure the exposure time is the same for both plates. A good exposure time to select would be three minutes.
3. Remember to tape the plates with adhesive tape once they have been exposed.
4. Incubate the plates for at least forty-eight hours. If you use an incubator, set the temperature between 35°C and 37°C. If you do not have an incubator, bacteria will still grow at room temperature, but their growth will be slower.
5. At the end of the incubation period you will see small colonies of bacteria growing on the surface of the agar in the plates. You may also see mould colonies. These are much larger and are furry in appearance. Count the number of bacterial colonies that have grown on the agar (ignore any mould colonies). If there are a large number you may have to estimate by counting just one-quarter or one-eighth of the plate. You could also count the number of different species of bacteria—the colonies will have a different colour or texture.
6. Draw up a suitable table in which to record your results (see Chapter 1, page 7 for the correct format for a results table). You should combine your results with those from other groups so that you have a larger sample of data.

Studying your results

Discuss the results of this activity. Your teacher may want to do this as a class exercise. Your discussion should include answers to the following questions:

1. Did your group results support or disprove the hypothesis 'That bacteria are in greater numbers where there is a lot of human activity'?
2. Did the class results support or disprove the hypothesis?
3. What are some of the sources of error in this activity?
4. What further investigations need to be made?
5. How could this investigation be improved if you were to do it again?

Activity 14.2 Keeping Australia free of communicable disease

Australia is an island continent and health authorities across the nation work hard to keep it free of communicable disease.

In this activity you will look at three areas in which health authorities work:

- immunisation programs
- quarantine
- notifiable diseases.

What to do

Using a range of different reference material including the Internet, answer the questions listed below.

1. The Australian Government Department of Health and Ageing encourages people to be vaccinated for a range of possible infections. If you (or your parents) had followed the recommended immunisation schedule, to what diseases would you now be immune?
2. People arriving in Australia from certain countries may have to show evidence of being vaccinated against yellow fever. Why do health authorities insist on vaccination against yellow fever and not diseases like diptheria and whooping cough?
3. Why are passengers arriving in Australia asked to state their intended place of residence?
4. **(a)** What is a notifiable disease?
   (b) Which diseases are notifiable in your State?
   (c) Why do you think health authorities want to know when these diseases occur?

Summary

Write a short paragraph outlining the importance of keeping Australia free of communicable disease. Explain how the general public can assist health authorities trying to prevent communicable disease in Australia.

REVIEW QUESTIONS

1. What is a communicable disease? Give five examples of such diseases.
2. What is a pathogen? Use examples in your answer.
3. **(a)** What is the basis for classification of bacteria?
   (b) Describe the main types of bacteria.
   (c) Draw a diagram to describe the structure of a bacterial cell.
4. What are toxins?
5. **(a)** Bacteria were first seen in 1683 but viruses were not seen until 1938. Why?
   (b) List four differences between bacteria and viruses.
6. Explain the difference between:
   (a) RNA viruses and DNA viruses
   (b) ectoparasites and endoparasites
7. Describe the external defences that help to prevent the entry of pathogenic organisms into the body.
8. **(a)** List the steps in the inflammatory response.
   (b) What are the four signs of inflammation?
9. List the differences between:
   (a) blood and lymph
   (b) blood capillaries and lymph capillaries
10. **(a)** What is a macrophage?
    (b) Describe the process of phagocytosis.
    (c) What is the importance of phagocytosis in the defence against disease?

APPLY YOUR KNOWLEDGE

1. What conditions inside our bodies make it ideal for the growth of micro-organisms?
2. Smoking leads to the paralysis of the cilia that line the respiratory system. Suggest why people who smoke are more likely to get lung infections than people who do not smoke.
3. An economist claimed that, economically, the virus causing the common cold was the most important of the viruses that cause disease in humans. What do you think would be the economic importance of the cold virus?
4. During the inflammatory response a chemical, histamine, allows materials to pass more easily through the blood capillaries. How would this assist phagocytosis?
5. Describe the events that would occur if a cut finger became infected.
6. It has been possible to keep Australia relatively free of diseases such as typhoid, cholera and yellow fever. Why do you think a disease like HIV/AIDS has been able to spread so rapidly throughout Australia?
7. Are viruses living things? Explain the reasons for your answer. (Whether you answer yes or no to this question is not important. It is the reasons you give for your answer that are of importance.)