



Overview  
(/study/ap/  
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cid-  
755105/o)

Teacher view



Table of  
contents



Notebook



Glossary



Reading  
assistance

C3. Interaction and interdependence: Organisms / C3.2 Defence against disease

## The big picture

### ? Guiding question(s)

- How do body systems recognise pathogens and fight infections?
- What factors influence the incidence of disease in populations

Keep the guiding questions in mind as you learn the science in this subtopic. You will be ready to answer them at the end of this subtopic. The guiding questions require you to pull together your knowledge and skills from different sections, to see the bigger picture and to build your conceptual understanding.

Pandemics are not new in the history of the Earth; the so-called Spanish flu killed an estimated 25 million people in 1918–1919. Yet the impact of the COVID-19 pandemic was devastating and unexpected, considering the advances in medicine over the last 100 years.

The first reports of a new virus came in December 2019; by 11 March 2020, the WHO declared COVID-19 a global pandemic. By the end of March, over 100 countries across the world had imposed full or partial lockdowns to prevent the spread of infection. Yet by May 2023, nearly 7 million people had died.

Where did the new virus come from? How did the virus that originated in one part of the world lead to a pandemic? What factors influenced the incidence of the disease? Why did the effects of the disease vary from one person to another? Why did measures like lockdowns, hand sanitising and mask wearing prevent the spread?

### Index

- The big picture
- Barriers to the entry of pathogens
- Innate and adaptive immune systems
- Adaptive immune responses
- Helper T-lymphocytes and activation of B-lymphocytes
- HIV and AIDS
- Antibiotics and antibiotic resistance
- Vaccinations and more
- Summary and key terms
- Checklist
- Investigation
- Reflection



Student  
view



**Figure 1.** COVID-19 pandemic headlines.

Credit: Adrian Hillman, Getty Images

More information for figure 1

The image is a collage of various newspaper headlines related to the COVID-19 pandemic. The headlines are arranged scatteredly on the image, creating a chaotic and crowded impression. Some of the headlines include phrases like "Coronavirus," "Panic buying," "VIRUS," "COVID-19 spreads through city," "Face mask shortage," "Travel restrictions," "Elderly most at risk," and "Economic impact," among others. The headlines vary in color, size, and font, mimicking the variety found in actual newspaper print. This collage captures the heightened media attention and public concern during the COVID-19 pandemic.

[Generated by AI]

As borders were being closed across the world, the reverse was happening in the fields of science and technology. The pandemic led to international collaboration, especially scientific collaboration, at unprecedented levels and new therapies and vaccines were made available at a rapid pace. Why was it important to roll out new vaccines? How did these help the body to fight the virus?

## Prior learning

Before you study this subtopic make sure that you understand the following:

- Why viruses are considered non-living (see [section A2.1.2–6](#) (/study/app/bio/sid-422-cid-755105/book/the-origins-of-cell-hl-id-43955/)).
- The role of nucleic acids (see [subtopic A1.2](#) (/study/app/bio/sid-422-cid-755105/book/the-big-picture-id-43236/)).
- The mechanism of endocytosis (see [section B2.1.11–13](#) (/study/app/bio/sid-422-cid-755105/book/membrane-fluidity-hl-id-44646/)).



## Learning outcomes

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

- Identify the categories of pathogens.
- Describe the role of the skin and mucous membranes in the primary defence of the body.
- Explain the process of clotting of blood.

An interesting yet similar pattern is seen in the spread of infectious diseases, whether it is an outbreak of cholera in a refugee camp or the spread of COVID-19. These diseases are contagious, spreading easily from one person to another. Often, a chain of infection is seen: when one member of a household tests positive for SARS-CoV-2, other members of the household are more likely to test positive, resulting in rolling infections lasting for several weeks.

How does the infection spread? Who or what was the index case or patient zero?

## Pathogens as the cause of infectious diseases

Pathogens, often referred to as infectious agents, are organisms that cause disease. They are the ‘starting points’ in the chain of infection. There are around 1400 species of pathogens known to cause infections in humans.

Pathogens act by invading the human body and living there parasitically, thereby causing diseases. Infectious or communicable diseases occur when the pathogens pass from the diseased person or host to a healthy person.

Pathogens include:

- Certain species of bacteria

Bacteria (see [section A2.2.4–6 \(/study/app/bio/sid-422-cid-755105/book/prokaryotic-and-eukaryotic-cells-id-43583/\)](#)) are unicellular, prokaryotic organisms that are found almost everywhere on Earth including the human body.

Though a vast majority of bacteria are beneficial, a small percentage are pathogenic, causing diseases like tuberculosis, plague, diphtheria and cholera.

- Certain species of fungi

Fungi (see [section A2.2.8–11 \(/study/app/bio/sid-422-cid-755105/book/animal-plant-and-fungal-cells-id-44719/\)](#)) are unicellular or multicellular eukaryotic organisms. Like bacteria, only a small percentage of fungi are pathogenic, however fungal pathogens are becoming not only more common but also increasingly resistant to treatment. Some common fungal diseases include ringworm, thrush and athlete’s foot.

- Certain species of protists

Protists (see [section B4.2.3–7 \(/study/app/bio/sid-422-cid-755105/book/types-of-nutrition-id-46625/\)](#)) are a diverse group of unicellular or multicellular eukaryotic organisms. The pathogenic protists are unicellular organisms and are responsible for a host of diseases including malaria, toxoplasmosis and sleeping sickness.

- Viruses (see [subtopic A2.3 \(/study/app/bio/sid-422-cid-755105/book/big-picture-hl-id-43527/\)](#))

Viruses differ from the other categories as they require a living cell for replication and hence are considered to be pathogenic. Viruses are responsible for a number of diseases including the common cold, influenza (‘flu’), measles, mumps and, of course, COVID-19.



- Prions

Prions are infectious proteinaceous substances that are responsible for diseases that cause degeneration of the nervous system in mammals. One example is bovine spongiform encephalopathy (BSE) or 'mad cow disease' that affects cattle.

Overview  
(/study/app/bio/sid-422-cid-755105/o)

Some of these pathogens are parasites, often obligate parasites (see [subtopic A2.3.5–6 \(/study/app/bio/sid-422-cid-755105/book/the-origins-and-evolution-of-viruses-hl-id-43926/\)](#)) and rely on their host for energy supply, nutrition, protein synthesis and other life functions.

To date, archaea are not known to cause any disease in humans. However, it is important to note that this is more due to existing limitations, as it is difficult to culture archaea in the laboratory. Scientists are currently investigating their potential involvement in human disease.

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**Section**

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Feedback



Print (/study/app/bio/sid-422-cid-755105/book/big-picture-id-43543/print/)

Assign



### Interactive 1. A Rogue's Gallery of Pathogens.

More information for interactive 1

This interactive consists of four slides, with each slide displaying a visual representation of different pathogens. At the bottom, a progress bar is visible, indicating the user's current slide (starting from 1 of 4), and it helps track the overall progression of the interactive. The progress bar also includes the option to view in full screen, which can be accessed via the button at the bottom right corner. The interactive allows users to move between slides using the arrow buttons on the left and right of the screen. The left arrow button will take the user to the previous slide, and the right arrow button moves to the next slide.

The first slide displays a highly magnified, coloured scanning electron micrograph of the bacterium *Vibrio cholerae*, which appears as curved, rod-shaped green cells densely packed together, with a scale bar indicating 1 µm. These cells show a smooth surface and some overlapping structures, highlighting their small size and abundant presence. The accompanying text reads, "The bacterium *Vibrio cholerae* causes cholera," reinforcing the identification of the microorganism and its link to disease. The progress bar at the bottom indicates the user is on slide 1 of 4.

The second slide presents a digitally rendered, colourful 3D illustration of the fungus *Trichophyton rubrum*, which causes athlete's foot. The image features long, branching hyphal structures with red spore-like elements embedded within translucent sacs, giving a vivid representation of fungal anatomy. The background is a soft-focus gradient of darker shades, which helps the fungal structures stand out clearly. The accompanying text states, "*Trichophyton rubrum*, a fungus, causes athlete's foot," and the progress bar shows 2 out of 4 slides completed.

The third slide shows a stained light micrograph of the protist *Trypanosoma brucei*, characterised by three purple-coloured, elongated and twisted forms with visible nuclei, swimming among circular red blood cells seen in the background. The visual gives a realistic view of this parasitic protist under a microscope, capturing its dynamic, wavy structure. The accompanying text reads, "Sleeping sickness is caused by a protist, *Trypanosoma brucei*," aligning the image with the biological agent and its associated disease. The progress bar advances to 3 out of 4.

The fourth and final slide depicts a 3D illustration of the SARS-CoV-2 virus. The image shows multiple spherical particles in light cyan with red core regions and prominent spike proteins protruding from the surface, set against a soft blue gradient background. The central virus particle is enlarged and detailed,

Student view

while others are blurred in the background to create depth. This artistic rendering visually represents the virus responsible for the COVID-19 pandemic.

The text below the image states, "The SARS-CoV-2 virus is responsible for outbreaks of COVID-19," and the progress bar reaches the final slide, showing 4 out of 4.

## Nature of Science

### Aspect: Observations

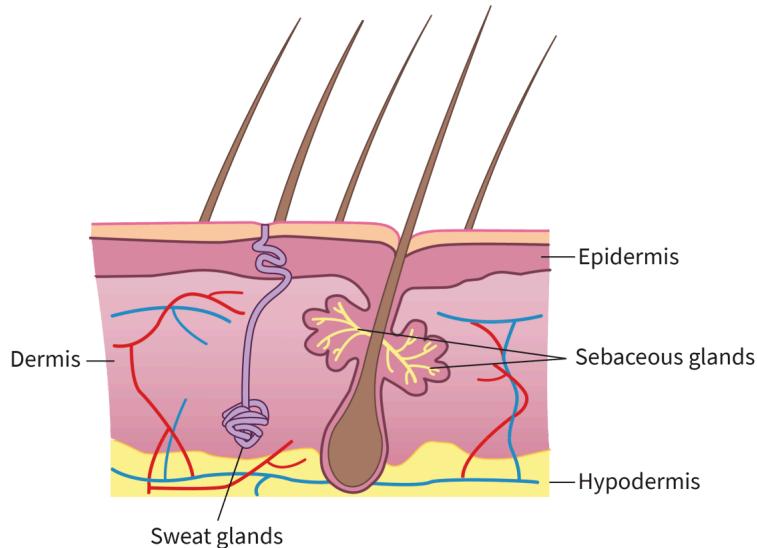
Several advances in the field of infection research came about due to careful observations of infected patients and their surrounding environment. For example, during the 1854 cholera outbreak in London, an English physician, Dr John Snow, showed that there was a link between contaminated water and the incidence of cholera. With the help of some local residents, John Snow meticulously mapped the cholera deaths and identified that most of them occurred around a pump in Broad Street. The water (contaminated with sewage) from the pump was the source of the cholera outbreak. The removal of the pump handle resulted in a decline in cholera cases. Snow had shown that cholera spread through contaminated water and was not due to bad air, as was previously believed.

In mid-nineteenth century Vienna, rates of maternal death from an infection called puerperal fever, or childbed fever, were high. A Hungarian doctor, Dr Ignaz Semmelweis, wanted to know why so many women were dying. In the hospital, he observed that maternal death rates were higher in the ward staffed by doctors and medical students than in the ward staffed by midwives. He realised that the doctors were not only examining women in labour but were also performing autopsies on women who had died of childbed fever, without washing or disinfecting their hands between procedures. His insistence that medical staff disinfect their hands using chlorinated lime solutions in between procedures, to kill the 'bits of corpses', resulted in a fall in cases of childbed fever. However, his observations were largely dismissed and most doctors refused to listen to him. Today it is widely acknowledged that good hand hygiene is one of the easiest ways to prevent the transmission of infections.

## Primary defence by the skin and mucous membranes

The skin and mucous membranes form physical and chemical barriers preventing the entry of pathogens to the body and, hence, are considered to be the primary defence. How do these barriers work?

The skin covers the entire body and seals the inside. Skin is composed of three layers: epidermis, dermis and hypodermis. The surface layers of the epidermis consist of dead cells with keratin deposits. These layers form a tough barrier that prevents the entry of microorganisms. The sebaceous glands on the skin produce oils that keep the skin at a slightly lower pH which prevents the growth of bacteria (a chemical barrier). You won't be required to label or draw a diagram of the skin, but **Figure 1** will help you visualise the structure.

**Figure 1. Layers of the skin.**

More information for figure 1

This diagram illustrates the structure of human skin, showing its various layers and components. At the top, there are hair shafts extending outwards. Beneath, the skin is divided into three main layers: the epidermis, dermis, and hypodermis. The outermost layer is the epidermis, followed by the dermis, which contains sweat glands, sebaceous glands, and blood vessels. The hypodermis, or subcutaneous tissue, lies beneath the dermis and is depicted with a lighter yellow area. The diagram is labeled to show sweat glands in the dermis and the locations of sebaceous glands, which are associated with hair follicles. Blood vessels are illustrated in red and blue, indicating supply within the dermis.

[Generated by AI]

Mucous membranes line the body cavities and the parts that open to the outside. These membranes line the digestive, urogenital and respiratory tracts as well as the salivary ducts, lacrimal ducts, mouth, nose and mammary glands. Such regions could be potential entry points for pathogens so the epithelial cells of the mucous membranes deal with this threat by producing mucus. The sticky mucus traps pathogens. It also contains an enzyme, lysozyme, that attacks bacterial cell walls and kills the bacteria. Lysozyme is also present in sweat, tears and saliva.

Mechanical actions help to flush away the mucus along with the trapped pathogens. The respiratory epithelium in most parts is ciliated, that is, it bears small, hair-like cilia. The cilia beat in a synchronised manner moving the microbes trapped in the mucus away from the lungs. The mucus is then expelled from the body by coughing or sneezing. Similarly, the flushing action of tears and urine prevents pathogens from establishing infections at these sites.

Pathogens could enter our body through the food we eat. The gastric secretion released by the lining of the stomach contains hydrochloric acid. Very few microbes can withstand the low pH of the gastric secretions, and pathogens that are ingested along with the food are killed.

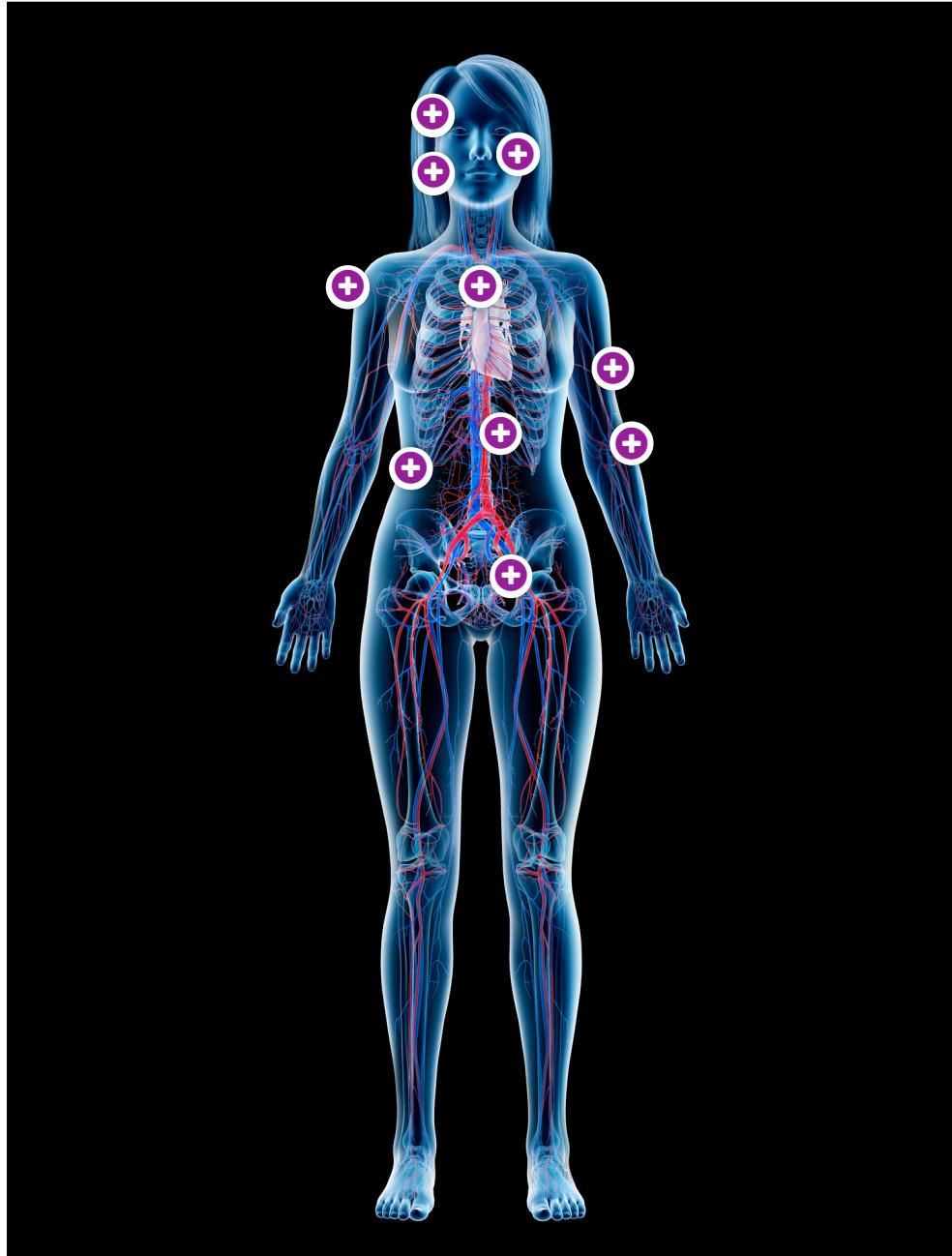
An interesting primary defence mechanism is the presence of commensal bacteria. These bacteria are naturally present in several regions of the body, including the skin, gut, mouth and nose, and can outcompete pathogens for nutrients and/or space.

Thus, from the above examples it is evident that the skin and mucous membranes act as physical and chemical barriers to protect us from a broad range of pathogens; in other words, they are non-specific. However, these barriers are not perfect, and pathogens may enter the body when the skin is broken due to a cut or burn. Situations like these necessitate the need for a second line of defence.



Use **Interactive 2** to explore the body's primary immune defence system.

Overview  
(/study/app/  
422-  
cid-  
755105/o)



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### Interactive 2. Primary Defense in Action.

More information for interactive 2

The interactive diagram can be used by students to understand the body's primary defence in action. The interactive shows a model image of the female human body. Internal organs such as ribcage, bones, spine, heart, lungs, blood vessels, and more are also visible in the image. The interactive consists of 10 hotspots located at different parts of the human body. The hotspots are represented by plus signs and are named as hotspot 1, hotspot 2, hotspot 3, hotspot 4, hotspot 5, hotspot 6, hotspot 7, hotspot 8, hotspot 9 and hotspot 10. Clicking on these hotspots reveals text about primary defence in that specific location of the human body.

Read below to learn about the location and text in each hotspot:

**Hotspot 1:** This hotspot is located near the eyes and clicking on it reveals the text "The flushing action of tears and the presence of lysozymes in them prevent the entry of bacteria."

**Hotspot 2:** This hotspot is located near the nose and clicking on it reveals the text "Mucous membranes secrete mucus that traps pathogens."

**Hotspot 3:** This hotspot is located near the mouth and clicking on it reveals the text "Lysozymes in saliva act as antibacterial enzymes."

**Hotspot 4:** This hotspot is located near the lungs and clicking on it reveals the text "Movement of cilia removes trapped particles."

**Hotspot 5:** This hotspot is located near the skin of right arm and clicking on it reveals the text "Intact skin seals the inside of the body."

Student view

Hotspot 6: This hotspot is located near the skin of left arm and clicking on it reveals the text "Oils produced by sebaceous glands lower the pH."

Hotspot 7: This hotspot is located near the stomach and clicking on it reveals the text "Hydrochloric acid present in gastric juice kills ingested pathogens."

Hotspot 8: This hotspot is located near the skin of the left-hand elbow and clicking on it reveals the text "Lysozymes in sweat act as antibacterial enzymes."

Hotspot 9: This hotspot is located near the intestine and clicking on the hotspot reveals the text "Commensal bacteria outcompete pathogens."

Hotspot 10: This hotspot is located near the urinary tract and clicking on the hotspot reveals the text "Flushing of the urinary tract by the flow of urine clears pathogens."

The interactive diagram helps viewers to learn about the primary defence mechanism of the immune system in different parts of the body. Through the interactive, the viewers learn the importance of skin and mucus as physical and chemical barriers and their different locations in the human body.

## Study skills

Did you notice that in this section 'mucus' seems to have two different spellings? This is not a typo: *mucus* is the slimy secretion that comes out of your nose when you have a cold, while the membranes that secrete mucus are the *mucous* membranes. In other words, *mucus* is a noun while *mucous* is an adjective as it describes the membrane.

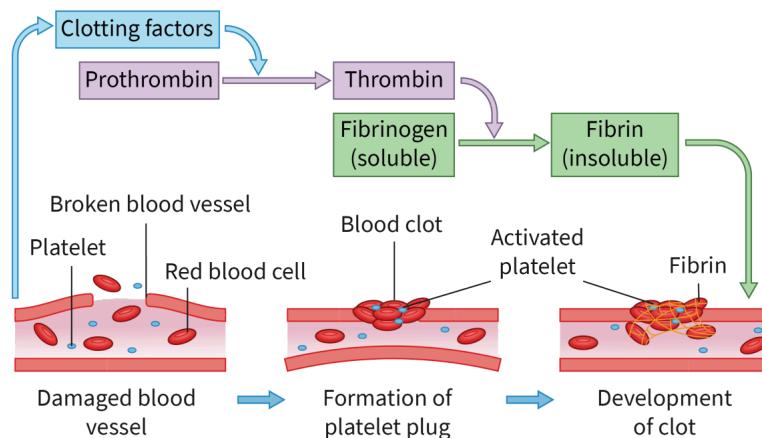
## Clotting of blood to seal cuts in the skin

It is evident that cuts in the skin would act as entry points for microorganisms. A cut or even a scrape is usually accompanied by bleeding. However, within seconds, blood clots seal the portal for entry for pathogens.

The clotting of blood involves a series of events.

- The process begins with the activation and accumulation of platelets (a type of blood cell) at the site of injury.
- The platelets form a plug sealing the injury.
- The platelets, along with the injured tissues, release several clotting factors including calcium ions. Most of these clotting factors are normally present in their inactive form. On activation, these factors interact in a cascade of chemical reactions. One of the clotting factors is thromboplastin, a plasma protein. Thromboplastin, along with calcium ions, converts prothrombin to its active state, thrombin. Thrombin in turn converts fibrinogen, a blood clotting factor which is normally dissolved in blood, to insoluble fibrin.
- Fibrin forms a mesh over the wound that entraps more platelets and red blood cells, resulting in a blood clot. Over a period of time, the clot dries and shrinks forming a scab.

Thus, the clotting of blood seals cuts in the skin, preventing undue loss of blood as well as the entry of pathogens. **Figure 2** and **Video 1** illustrate the process of clotting.





Overview

(/study/app

422-

cid-

755105/o

**Figure 2.** The sequence of stages involved in the clotting of blood.[More information for figure 2](#)

This diagram shows the stages of blood clotting, starting with a broken blood vessel. It begins with clotting factors leading to the conversion of prothrombin into thrombin. Next, thrombin converts fibrinogen into fibrin, which is insoluble. In the first section, labeled 'Damaged blood vessel,' a broken blood vessel with platelets and red blood cells is shown. The next stage is 'Formation of platelet plug,' where a blood clot forms as a temporary seal. Following this is 'Activated platelet,' showing the action of platelets initiating further clotting reactions. Finally, 'Development of clot' depicts the formation of a stable clot with fibrin threads that reinforce the blood clot, completing the coagulation process.

[Generated by AI]

**Platelets & Blood Clotting | Biology | FuseSchool****Video 1.** Clotting of blood.

Try the activity below to help with your understanding of the process of blood clotting.

**Activity**

- **IB learner profile attribute:** Knowledgeable
- **Approaches to learning:** Communication skills — Presenting data appropriately
- **Time required to complete activity:** 20 minutes
- **Activity type:** Pair activity

**Your task**

An infographic is a visual representation of data and typically includes a mix of images and text that makes it easy to remember the content.

Create an infographic to show the cascade of events that result in the clotting of blood.

Some sample infographics are given [here](#)

([https://cdn.agclassroom.org/media/uploads/LP791/How\\_do\\_germs\\_spread\\_.jpg](https://cdn.agclassroom.org/media/uploads/LP791/How_do_germs_spread_.jpg)) and [here](#)

(<https://media.istockphoto.com/vectors/blood-clotting-process-vector-id1129189618?k=20&m=1129189618&s=612x612&w=0&h=1UQ67TZ7sXiwo4I7sXQHDpbI08z79NS1oooajzwrG0w=>) for you to get

a better understanding.

**Instructions**



Before you begin this activity, read through the part of this section on clotting of blood.

Work in pairs. Plan by answering the following questions:

- What information or facts are essential and should be included?
- What colours or layout would be best for sharing the information?
- What should be the order or flow of information?

You can either use an online tool like [Canva](https://www.canva.com/create/infographics/) (https://www.canva.com/create/infographics/) or [Venngage](https://venngage.com/) (https://venngage.com/) or use pen and paper to create the infographic.

Display your infographic to the class on completion.

## 5 section questions ▾

C3. Interaction and interdependence: Organisms / C3.2 Defence against disease

# Innate and adaptive immune systems

C3.2.4: Innate immune system and adaptive immune system    C3.2.5: Infection control by phagocytes

### Learning outcomes

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

- Differentiate between the innate immune system and the adaptive immune system.
- State the role of phagocytes in controlling infection.

Medieval castles were built to prevent sieges. One of the notable features was the outer curtain wall, an enormous stone border that encircled the castle and was the main line of defence. In addition, high castle walls, a moat, towers with lookout points, heavy doors and strategically placed guards at entry points were other lines of defence. Yet, adversaries had to find just one way in to bring the castle to its knees and create havoc.

The skin and the mucous membranes are the ‘curtain walls’ of the human body. But what happens when the security is breached and the adversaries (pathogens) enter? How does the body prevent the pathogens from taking over and winning the war?

## Innate immune system vs adaptive immune system

Our immune system is designed to protect us from attacks from pathogens and other foreign substances. To do this, the immune system must have the ability to distinguish body cells (self) from foreign substances (non-self).

The immune system consists of the innate immune system and the adaptive immune system.

The innate immune system provides innate immunity; the immunity that is present from birth. It is responsible for rapid, non-specific defence responses against the pathogens we encounter in our daily lives. The innate immune system tries to prevent the entry of pathogens or, if they have already entered, limits their ability to spread. It does this using the

physical and chemical barriers provided by the skin and mucous membranes, as well as through generalised immune responses like phagocytosis.

Overview  
(/study/app/422-cid-755105/o)

It is important to note that the response of the innate immune system is not tailored to a specific pathogen. In other words, the immune response would be similar in the case of any potential pathogen, be it a bacterium, a fungus, a virus or any other foreign body.

The adaptive immune system comes into play when the innate immune system is unable to control the pathogens. While the innate immune response is primed and ready to respond to threats, the adaptive immune response is slower and is mediated by lymphocytes, a type of white blood cells.

The responses of the adaptive immune system are stronger and longer lasting due to the following features:

- Specificity

Unlike, innate immunity, the adaptive immune response is specific, directed towards a particular pathogen, making it more effective.

- Memory

The adaptive immune system has the ability to ‘remember’ the pathogens it encounters. This immunological memory ensures that a subsequent infection with the same pathogen results in a faster, enhanced immune response.

It is important to note that the innate and adaptive branches of the immune system do not work in isolation, and there is constant communication between the two branches to achieve an effective immune response.

## Phagocytes in controlling infection

When the skin and mucous membranes are breached and the pathogens enter the tissue spaces of the body, the next line of defence – phagocytosis (see [section B2.1.11–13 \(/study/app/bio/sid-422-cid-755105/book/membrane-fluidity-hl-id-44646/\)](#)) – comes into play. Phagocytosis is the process by which any foreign material, including pathogens, is ingested and digested, resulting in its elimination. Phagocytosis is mediated by specialised leukocytes (white blood cells): monocytes, neutrophils and macrophages. Collectively known as professional phagocytes, these cells are capable of amoeboid movement and can migrate from the blood to the site of the infection.

Phagocytosis consists of the following steps:

1. The first step in phagocytosis is the recognition of the pathogen by the phagocytes. The receptor molecules present on the plasma membrane of the phagocytes recognise and bind to the pathogen triggering a chain of reactions that lead to the formation of pseudopodia.
2. The pseudopodia encircle the target microorganism and then both the protrusions seal, resulting in the formation of a vesicle called the phagosome.
3. The phagosome undergoes numerous changes in a process known as phagosome maturation.
4. Next, the phagosome fuses with the lysosomes forming phagolysosomes. These newly formed structures contain digestive enzymes (that were originally present in the lysosome).
5. These enzymes digest the microbial components, which are then released from the cell.

Thus, phagocytosis is the non-specific secondary line of defence.

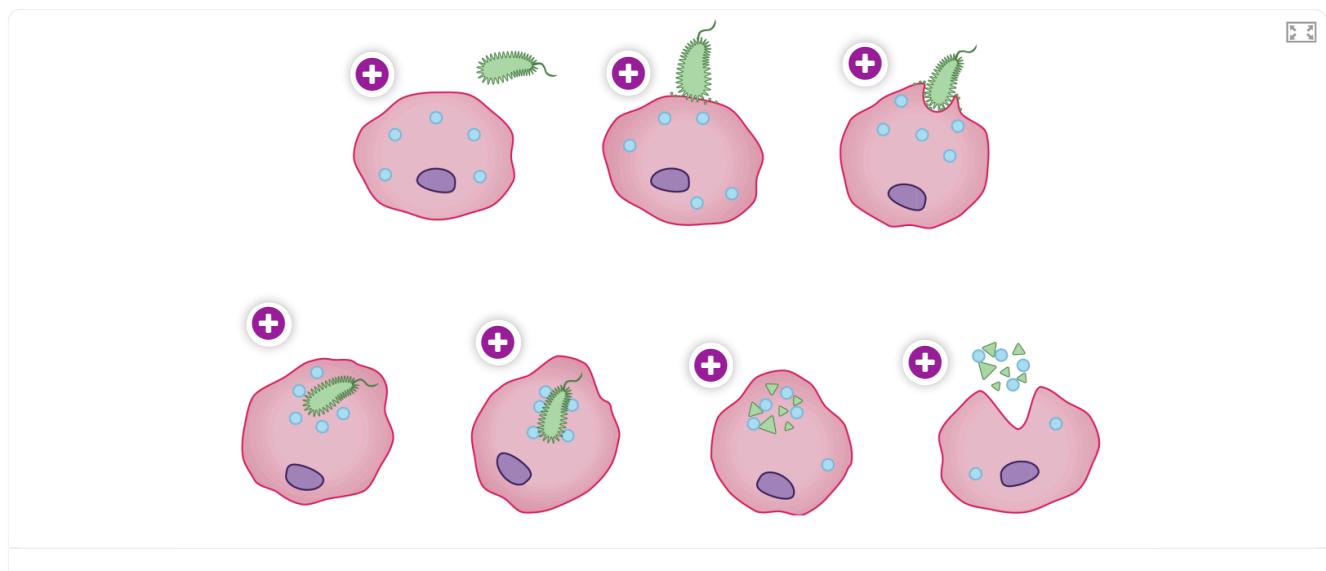
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Student view



## Making connections

Endocytosis (see [section B2.1.11-13 \(/study/app/bio/sid-422-cid-755105/book/membrane-fluidity-hl-id-44646/\)](#)) includes both phagocytosis (cellular eating) and pinocytosis (cellular drinking). In this section, the focus is on phagocytosis as a method of elimination of pathogens. However, phagocytosis has distinct roles in different types of cells. Some protists like Amoeba use phagocytosis to capture their food, while in our bodies, macrophages use phagocytosis to digest aged or dead cells.

Use **Interactive 1** to review the process of phagocytosis.



**Interactive 1.** Stages in the Process of Phagocytosis.

More information for interactive 1

The interactive resource illustrates the step-by-step process of phagocytosis, a critical immune response where specialized white blood cells (phagocytes) engulf and destroy pathogens. The visualization highlights the stages from pathogen recognition to digestion, emphasizing the role of phagocytes in innate immunity. The resource uses clickable hotspots that explain each stage.

The first stage is pathogen recognition. Neutrophils, monocytes, and macrophages detect pathogens (e.g. bacteria) via cell surface receptors. The hotspot reads "Recognition of the pathogen".

The second stage is binding. The receptors on the cell surface of the phagocytes bind with the pathogen. The binding induces the formation of pseudopodia through a series of reactions. The hotspot read "Binding of the pathogen to receptors."

The third stage is the engulfment. The pseudopodia extends arm-like projections to surround the pathogen on both sides. Both sides fuse, trapping the pathogen, and resulting in the formation of a vesicle called phagosome. The hotspot read "Formation of the phagosome."

The fourth stage is phagosome maturation. The phagosome undergoes structural changes, preparing to fuse with a lysosome. At this stage, the phagosome matures with an increase in the number of membrane-bound structures that are acidic. The hotspot reads "Maturation of the phagosome".

The fifth stage is the formation of phagolysosomes. The phagosome merges with lysosomes (enzyme-filled vesicles), forming a phagolysosome. The hotspot reads "Fusion with lysosomes to form phagolysosomes". Lysosomes, proteases, and reactive oxygen species break down the pathogen.

The sixth stage is digestion. The pathogen components are broken down into harmless fragments. The hotspot reads "Digestion of the microbial components."

The final stage is waste release. Debris is exocytosed from the cell. The hotspot reads "Release of the degraded material from the cell."

The interactive clarifies how phagocytes detect pathogens (via receptor-mediated recognition) and neutralize pathogens (through engulfment and enzymatic destruction).





Overview  
(/study/app/422-cid-755105/o)

Try the activity below to compare the adaptive and innate immune systems and annotate a diagram of phagocytosis.

## Activity

- **IB learner profile attribute:** Knowledgeable
- **Approaches to learning:** Thinking skills — Applying key ideas and facts in new contexts
- **Time required to complete activity:** 15 minutes
- **Activity type:** Individual activity

### Task

1. Download the worksheet.
2. Compare and contrast the innate immune system and the adaptive immune system using the Venn diagram supplied in the downloadable worksheet.
3. Annotate the diagram to explain the process of phagocytosis.

[Download worksheet](https://d3vrb2m3yrmfyi.cloudfront.net/media/edusys_2/content_uploads/Biology/C3.2.4-5%20ACTIVITY.51b675dcc2a133471986.pdf) (https://d3vrb2m3yrmfyi.cloudfront.net/media/edusys\_2/content\_uploads/Biology/C3.2.4-5 ACTIVITY.51b675dcc2a133471986.pdf)

## 5 section questions ▾

C3. Interaction and interdependence: Organisms / C3.2 Defence against disease

# Adaptive immune responses

C3.2.6: Lymphocytes    C3.2.7: Antigens

## Learning outcomes

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

- Explain the role of lymphocytes in adaptive immune responses.
- Recall that antigens trigger antibody production.

In nature, predators often adopt different tactics to capture their prey. For example, some may conceal themselves and ambush, while others may chase and hunt down their prey and others may immobilise their prey by injecting venom. In a similar way, different pathogens that invade the body attack in different ways. Pathogens could act by killing cells, producing toxins or disrupting the working of the cell machinery; alternatively, they could combine with peripheral proteins to disturb the cellular metabolism (see [subtopic A2.3 \(/study/app/bio/sid-422-cid-755105/book/big-picture-hl-id-43527/\)](#)). How does the immune system modify its response? How is the adaptive immune system able to mount pathogen-specific immune responses?



Student view



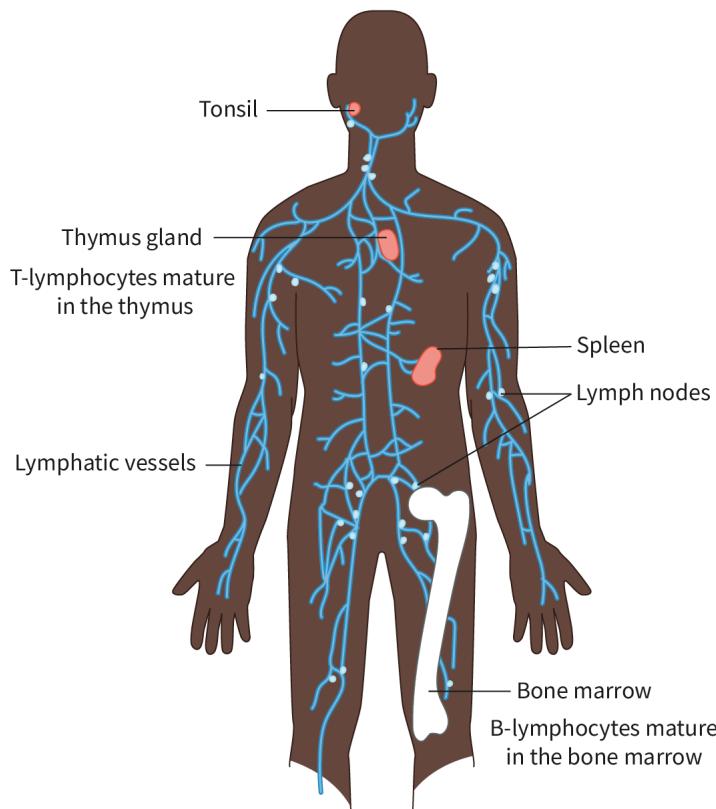
# Lymphocytes

Overview  
(/study/app/422-cid-755105/o)

Lymphocytes are a type of leukocyte (white blood cell) that play an important role in the adaptive immune responses of the body. Lymphocytes are produced in the bone marrow. Depending on where these cells mature, they can be divided into the T-lymphocytes (also called T-cells) that mature in the thymus, and the B-lymphocytes (also called B-cells) that mature in the bone marrow.

Before we continue, it is important to know a little bit more about the lymphatic system. The lymphatic system is composed of the lymph, lymphoid organs and tissues, and the lymphatic vessels. Lymph is a watery fluid derived from the blood (see section B3.2.11–13 (/study/app/bio/sid-422-cid-755105/book/transport-of-fluid-in-mammalian-id-44453/)) that moves through the lymphatic system. While a major function of the lymphatic system is to return the fluid back to the bloodstream, it also plays an important role in the immune response of the body. The bone marrow and thymus are regions where lymphocytes mature. Other lymphoid organs include the lymph nodes, spleen, tonsils and Peyer's patches. The lymphocytes travel through the lymph vessels and the lymph nodes, as well as through the blood vessels.

**Figure 1** illustrates the lymphatic system.



**Figure 1.** The lymphatic system.

More information for figure 1

The image is a diagram of the human lymphatic system shown on a silhouette of a human body. The main components are labeled as follows:

- **Tonsil:** Located in the head region.
- **Thymus gland:** Positioned in the upper chest area.
- **Lymphatic vessels:** Shown as blue lines branching throughout the body, representing the network of vessels.
- **Lymph nodes:** Illustrated as small nodes along the lymphatic vessels, with emphasis on their presence in the neck, armpits, and groin regions.
- **Spleen:** Found in the left side of the upper abdomen.
- **Bone marrow:** Indicated inside a cut view of the left femur to show its location in bones.

Student view

Home  
Overview  
(/study/app/  
422-  
cid-  
755105/o

Text on the diagram notes that T-lymphocytes mature in the thymus, while B-lymphocytes mature in the bone marrow. This diagram illustrates the structure and key components of the lymphatic system, including primary and secondary lymphoid organs.

[Generated by AI]

After reaching maturity, the B-lymphocytes and T-lymphocytes migrate. Some of them remain in circulation while others are concentrated in the secondary lymphoid organs (primarily the lymph nodes, spleen and tonsils) where they are more likely to encounter the antigens. In a way, lymphocytes 'patrol' the body moving between the lymph and blood to detect intruders.

## Antigens

An antigen is any substance that triggers the immune system, resulting in the production of antibodies against it. Most antigens are proteins (including glycoproteins and lipoproteins), however, they could also be polysaccharides, nucleic acids or lipids.

While the pathogen itself is the infectious agent, the antigen is the part of the pathogen that elicits the immune response. Antigens are usually found on the surface of a pathogen, such as on the cell wall of a bacterium or the coat of a virus.

Antigens need not always be parts of a pathogen. In some people, particular chemicals, pollen or certain types of food may trigger an abnormal immune response called an allergy; these substances are acting as antigens.

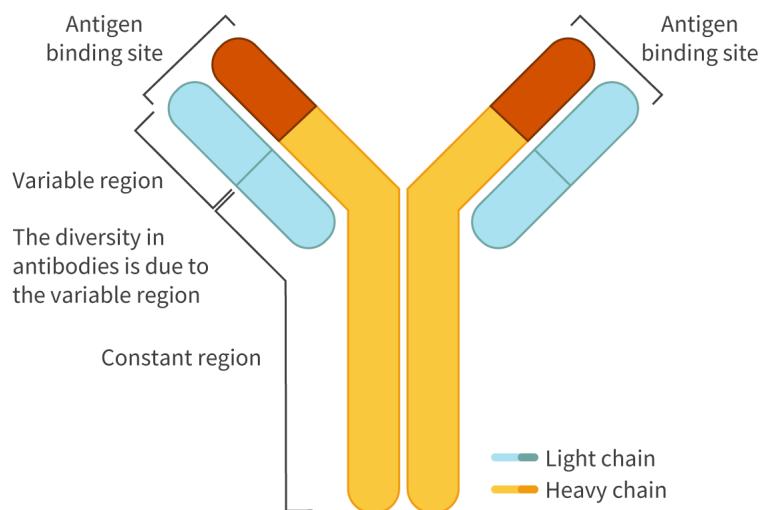
Antigens also exist on the cells of our own bodies, such as the surface of erythrocytes (red blood cells) or liver cells. These antigens are called self antigens; they help the immune system to identify and tolerate (read: not attack) these cells.

## Response by B-lymphocytes and T-lymphocytes

Though both B-lymphocytes and T-lymphocytes defend the body, their responses to antigens are very different.

### B-lymphocytes

B-lymphocytes produce antibodies leading to humoral immunity. Antibodies are essentially protein molecules that identify, bind to and neutralise the antigens that enter our body. The amazing diversity of B-lymphocytes ensures they can recognise millions of antigens and so produce highly specific antibodies. **Figure 2** shows a typical Y-shaped antibody molecule with two heavy and two light chains; the antigen binds to the variable regions of the antibody.



**Figure 2.** The typical Y-shaped structure of an antibody.

More information for figure 2

The image is a diagram illustrating the typical Y-shaped structure of an antibody molecule. It shows two arms branching out at the top, each with a segment labeled "Antigen binding site" at the ends. These sites are where antigens attach to the antibody. The arms consist of a light chain in blue and a heavy chain in yellow, with the variable region of both labeled. Text indicates that the diversity in antibodies stems from the variable region, which is responsible for antigen specificity. The bottom part of the diagram is labeled "Constant region," illustrating the part of the antibody molecule that remains unchanged across different antibodies. A legend in the diagram identifies the light chain as blue and the heavy chain as yellow.

[Generated by AI]

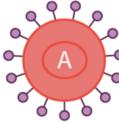
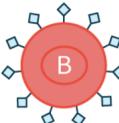
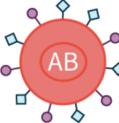
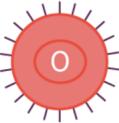
## T-lymphocytes

There are two types of lymphocytes: helper T-lymphocytes and cytotoxic T-lymphocytes. Helper T-lymphocytes, as the term implies, helps the immune system by activating several other components. Cytotoxic T-lymphocytes, on the other hand, kill the infected cells. The immune response mediated by the T-lymphocytes is called cell-mediated immunity.

## Red blood cells and blood groups

Humans have four main blood groups – A, B, AB and O – together known as the ABO system. The presence or absence of specific polysaccharide antigens on the surface of the erythrocytes (red blood cells or RBCs) determines the blood group as shown in **Table 1**.

**Table 1.** The ABO blood group system in humans.

Blood Group Characteristics	Blood Group A	Blood Group B	Blood Group AB	Blood Group O
<p>Section Student... (0/0)</p> <p>Print (/study/app/bio/sid-422-cid-755105/book/innate-and-adaptive-immune-systems-id-46470/review/)</p> <p>Assign</p>	 <p>More information...</p> <p>The image is an abstract diagram featuring a central red circle labeled 'A'. Surrounding the central circle are smaller circles connected by lines, forming a network-like pattern.</p> <p>[Generated by AI]</p>	 <p>More information...</p> <p>The diagram features a central red circle labeled with the letter 'B'. Around this central circle are several smaller blue diamond-shaped nodes connected by lines.</p> <p>[Generated by AI]</p>	 <p>More information...</p> <p>The image is a diagram showing a central red circular shape with the text 'AB' in the middle. This central circle is surrounded by smaller shapes connected by lines.</p> <p>[Generated by AI]</p>	
Antibodies in plasma	 <p>Anti-B</p>	 <p>Anti-A</p>	None	 <p>Anti-A and Anti-B</p>

Blood Group Characteristics	Blood Group A	Blood Group B	Blood Group AB	Blood Group O
Antigens on RBC	 A antigen	 B antigen	 A and B antigens	None

More inform...

The image shows a diagram representing a B antigen. The antigen is depicted as a geometric shape resembling a diamond, colored in light blue, positioned above the text 'B antigen'. A straight line extends downward from the bottom point of the diamond shape, symbolizing attachment or connection. The diagram visually represents the concept of a B antigen in a simplified, symbolic form.

[Generated by AI]

Our bodies produce antibodies against any antigen that is not present on our red blood cells. A person with blood group A has A antigens on the surface of their RBCs. Their immune system recognises the A antigen as 'self' and tolerates it, but will produce antibodies (anti-B) against B antigens.

This is extremely important during a blood transfusion when a patient receives blood from a donor. The blood groups of the donor and the recipient have to match, otherwise it triggers an often fatal immune response. For example, if a person with blood group B receives group A blood, the anti-A antibodies in the recipient's plasma are triggered. These attack the A antigen on the surface of the RBCs of the donated blood. This results in lysis of the donated RBCs, as shown in **Figure 3**, and may prove to be fatal.

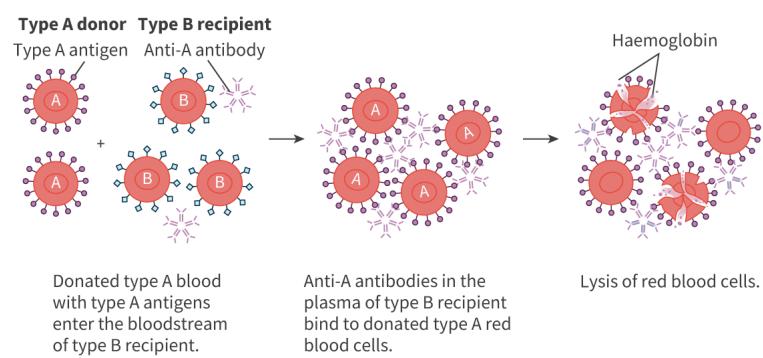


Figure 3. Transfusion reaction.

More information for figure 3

Overview  
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The image is a diagram illustrating a transfusion reaction involving a Type A blood donor and a Type B recipient. On the left, there are circular red cells labeled 'Type A antigen' with an 'A' in the center, surrounded by smaller irregular particles representing antigens. Adjacent to these are circular cells labeled 'Type B recipient' with a 'B' and smaller particles labeled as 'Anti-A antibody'. An arrow points from this setup to another grouping in the center where the Anti-A antibodies have surrounded the Type A antigens, indicating the binding process. Another arrow leads to the rightmost section displaying lysed red blood cells, showing pink inner contents labeled as 'Haemoglobin', indicating the destruction of cells in a transfusion reaction.

Text descriptions under each section state: - "Donated type A blood with type A antigens enter the bloodstream of type B recipient." - "Anti-A antibodies in the plasma of type B recipient bind to donated type A red blood cells." - "Lysis of red blood cells."

[Generated by AI]

It is interesting to note that people with AB blood group have both A and B antigens and hence are referred to as universal recipients (due to the absence of circulating antibodies in their plasma). People with O blood group have no antigens on the surface of the RBCs and are referred to as universal donors. Can you figure out the reason for this?

## Creativity, activity, service

**Strand:** Service

**Learning outcome:** Demonstrate how to initiate and plan a CAS experience

### Why is blood donation important?

As the World Health Organization (WHO) says, 'safe blood saves lives'. Blood can save the lives of millions of people, yet it is often in short supply. While there are strict guidelines (<https://www.who.int/campaigns/world-blood-donor-day/2018/who-can-give-blood>) for donating blood, one of them being age, you can help by:

- creating awareness around the importance of donating blood
- collaborating with local organisations, like the Rotary Club or the Red Cross, to organise a voluntary blood donation camp at your school.

## The Rhesus (Rh) system

You have learnt that there are four main blood groups. However, there is another antigen on the RBCs known as the Rhesus (RhD) factor. A person could be either RhD+ or RhD- based on the presence or absence of the RhD antigen. A person with blood group A is said to be A+ (A positive) if the RhD antigen is present or A- (A negative) if the RhD antigen is absent. This means that there are eight major blood groups: A+, A-, B+, B-, AB+, AB-, O+ and O-.

The activity below involves a game to help with your understanding of blood groups.

## Activity

- **IB learner profile attribute:** Thinker

Student view

- **Approaches to learning:** Communication skills — Applying interpretive techniques to different forms of media
- **Time required to complete activity:** 10–15 minutes
- **Activity type:** Individual activity

### Play a game!

Extend your learning about blood types (and the antigen—antibody reactions) by playing the blood typing game.

Watch the tutorials given [here](#) ↗

(<https://educationalgames.nobelprize.org/educational/medicine/bloodtypinggame/>) to review what you know, then [play the game](#) ↗

(<https://educationalgames.nobelprize.org/educational/medicine/bloodtypinggame/gamev3/index.html>) to check your understanding.

## 5 section questions ▾

C3. Interaction and interdependence: Organisms / C3.2 Defence against disease

# Helper T-lymphocytes and activation of B-lymphocytes

C3.2.8: Activation of B-lymphocytes    C3.2.9: Multiplication of activated B-lymphocytes    C3.2.10: Immunity as a consequence of retaining memory cells

### Learning outcomes

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

- Explain the activation of B-lymphocytes by helper T-cells.
- Outline the role of activated B-lymphocytes in production of sufficient quantities of antibodies.
- Describe the role of memory cells in immunity.

In 430 BCE, a plague devastated the city-state of Athens in ancient Greece. The plague killed between 75 000 and 100 000 people. The plague returned twice more. It was found that the citizens who had survived the previous attacks were not affected (at least not fatally) and could care for the newly stricken. Why were the people who survived the first attack of plague safer?

## Interaction between T-lymphocytes and B-lymphocytes

For every antigen in the world, there is a B-cell and a T-cell specific to it. Until the B-cells and T-cells present in the secondary lymphoid organs encounter their specific antigen, they are referred to as naive. Once they encounter the antigen, they are termed effector cells. The process of activation (conversion from the naive to the effector state) of both the cells is outlined below. (Note that this is a simplified version of the process.)

### Activation of helper T-cells

Phagocytes that digest a pathogen retain fragments of it. Antigen-presenting cells present the fragments to specific helper T-cells, thereby activating the latter. Once a helper T-cell is activated, it:

- results in an increase in the number of helper T-cells that recognise the same antigen
- activates the B-cells specific to the same antigen
- activates cytotoxic T-cells specific to the same antigen.

## Activation of B-cells

The activation of a B-cell depends on two integrated events. The first is when the receptor present on the surface of a B-cell recognises and binds to a specific antigen. The second is the stimulation by an activated helper T-cell that recognises the same antigen.

## Multiplication of B-lymphocytes

The activated B-cell undergoes repeated mitotic divisions to create many copies, or clones, of itself. This is explained by the clonal selection theory, that is, a pre-selected B-cell specific to the antigen divides to form clones, all of which recognise the same antigen.

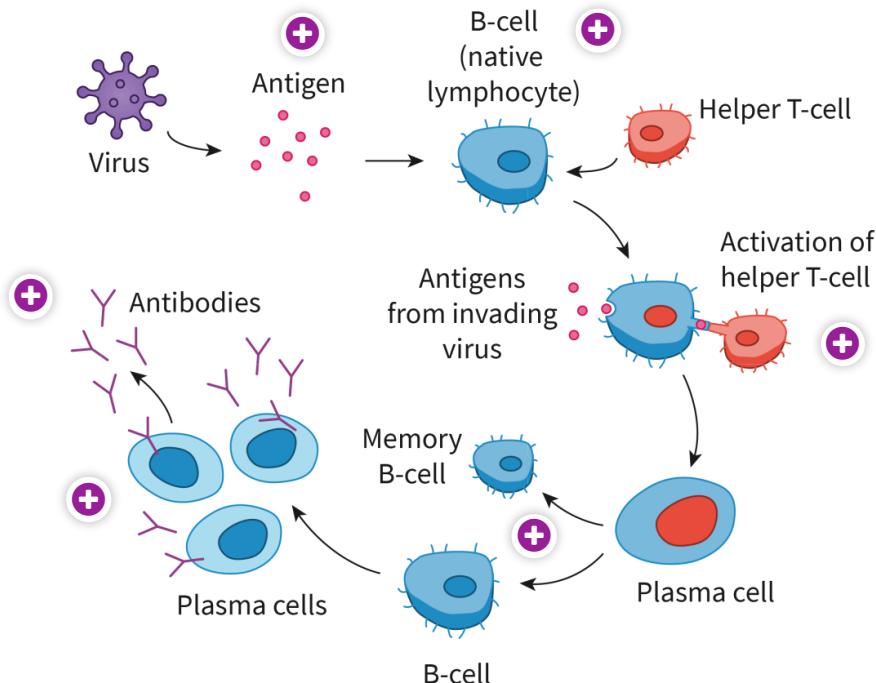
Once the B-cell is activated, it multiplies and differentiates to form plasma cells and memory cells. Each plasma cell produces and releases thousands of antibody molecules that are specific to the same antigen. These antibodies circulate in the blood and destroy the antigens.

The immune response triggered on the first exposure to the antigen is the primary immune response.

## Formation of the memory cells

A small percentage of the B-cells become memory cells. These cells are long-lived and persist in the bloodstream and lymph nodes. They retain a ‘memory’ of the antigen and so help your immune system to ‘remember’ the same antigen. The memory B-cells remain dormant until the body is reinfected with the same antigen, then they quickly differentiate to form plasma cells (that produce the antibodies). This leads to a faster and more effective response in the event of a future attack by the same antigen and is known as the secondary immune response. This long-lasting immunity to infection explains why the plague survivors of Athens were not attacked twice by the same disease!

View **Interactive 1** for a summary of how B-cells are activated.



### Interactive 1. Activation of B-cells.

More information for interactive 1

The interactive diagram illustrates the step-by-step process of activation of B-cells, a cornerstone of the adaptive immune system. The interactive highlights how B-cells respond to antigens, produce antibodies, and form immunological memory for long-term protection.

The diagram consists of six clickable hotspots represented by plus signs. Clicking on these hotspots reveals more information about the corresponding step of B-cell activation.

There is an image of a purple-coloured virus in the top left corner. The virus resembles a circle with several spikes, each ending in a circle. To the right side of the virus, there is an arrow mark, with its tip pointing towards the right. Beside this arrow mark, there are small pink circles that are labelled as "antigens", indicating that these are antigens produced by the virus. There is a hotspot above these antigens, clicking on which reveals the text "Antigen-presenting cell presents the antigen fragments to the helper T-cells".

There is an arrow mark to the right of these antigens, with its tip pointing toward the right. Beside this arrowmark, there is a blue-coloured cell with an uneven round shape and thread-like structures emerging from it. The cell also has a deep blue-colored oval shape inside representing a nucleus. It is labelled as "B-cell (native lymphocyte)". There is another cell towards the top right corner, beside this B-cell. It looks similar to the B-cell, but smaller in size and is red in colour. This cell is labelled as a "Helper T-cell". There is an arrow mark between these two cells, with the tip pointing towards the B-cell. There is a hotspot above this arrow mark, and clicking on it reveals the text "The B-cells are stimulated by the antigen".

There is another arrowmark below the B-cell, with its tip pointing downwards. Below this arrowmark, it is shown that the B-cell and the helper T-cell are joined by forming a tube-like structure in between. On the left side of the B-cell, the antigens represented as small pink circles are approaching the B-cell and get attached to them. There is a label to the left of antigens that states "Antigens from invading virus". There is also an antigen in the junction of these two cells. On the right-hand side of this image, there is a label that states "Activation of helper T-cell". Below this label, there is a hotspot, and clicking on it reveals the text "The helper T-cells activate the B-cell".

Below these cells, there is an arrow pointing downwards and below this, there is a cell labelled as "plasma cell". The cell looks similar to a B-cell, but it has a red-coloured nucleus inside. From this cell, two arrow marks emerge, each pointing towards a cell. One cell is labelled as "Memory B-cell" and the other cell is labelled as "B-cell". Both of them look similar to the B-cell in the first stage, but the memory B-cell is a bit smaller. There is a hotspot between these cells, and clicking on it reveals the text "The activated B-cells divide mitotically to produce memory B-cells and plasma cells".

To the left of the B-cell and the memory B-cell, there is another arrow mark, and then three cells labelled as "Plasma cells". These plasma cells are shown to produce Y-shaped structures called Antibodies. A hotspot in this step reveals the text "Plasma cells produce antibodies".

In the next step, it is shown that the plasma cells release antibodies. There is a hotspot in this step, and clicking on it reveals the text "Antibodies neutralise the antigens".

This interactive demonstrates how B-cells detect threats (via antigen-specific receptors), amplify response (through clonal expansion and antibody production), and ensure memory (via long-lived memory cells for future protection).



Overview

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422-

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Try the following activity, which involves creating a flow chart to summarise your understanding of the activation of B-cells and T-cells in the immune response.

## Activity

- **IB learner profile attribute:** Communicator
- **Approaches to learning:** Communication skills — Clearly communicating complex ideas in response to open-ended questions
- **Time required to complete activity:** 10–15 minutes
- **Activity type:** Individual activity

### Your task

Create a flowchart that shows the cascade of reactions on exposure to an antigen. Use both text and images in your flowchart.

Make sure that your chart includes the following key terms: B-cell, T-cell, helper T-cell, cytotoxic T-cell, plasma cell, memory cells, antibodies.

## 5 section questions ▾

C3. Interaction and interdependence: Organisms / C3.2 Defence against disease

# HIV and AIDS

C3.2.11: Transmission of HIV in body fluids    C3.2.12: AIDS and infection of lymphocytes by HIV

## Learning outcomes

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

- Describe the means of transmission of HIV.
- Study the effect of the virus on the functioning of the immune system (lymphocytes).

On 5 June 1981, the first official report of a new disease (later to be known as Acquired Immunodeficiency Syndrome or AIDS) was released in the US. Five young healthy men contracted a form of pneumonia that was normally seen only in immunocompromised individuals. Since then, the disease, characterised by a severely weakened immune system, has claimed millions of lives. What led to the weakening of the immune system? What were the consequences of this?

## Transmission of HIV

The causative agent of AIDS is now known to be HIV-1 or Human Immunodeficiency Virus. The virus (see [section A2.3.5–6](#) (/study/app/bio/sid-422-cid-755105/book/the-origins-and-evolution-of-viruses-hl-id-43926/)) is a retrovirus, which means that its genetic information is in the form of RNA. When the virus replicates in human cells, a viral enzyme called



reverse transcriptase is used to transcribe DNA from the RNA template.

Overview  
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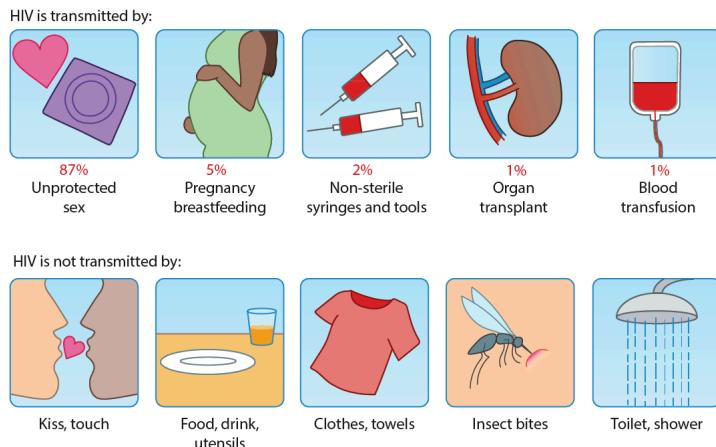
The virus weakens the immune system, reducing the ability of the person to fight everyday diseases. In severe cases, this can result in AIDS, a spectrum of conditions.

Initially it was thought that HIV was spread only through sexual contact. Later studies revealed that that the virus could be transmitted in the following ways:

- sexual intercourse with an infected person
- transfusion of infected blood
- sharing needles or syringes
- from mother to child during childbirth or breastfeeding.

It is evident that HIV is transmitted through infected vaginal fluids or semen, blood and breastmilk. In other words, if adequate care is taken, the transmission of HIV can be prevented. This could include steps like using condoms during sexual intercourse, not sharing needles and early anti-HIV treatment. The use of adequate protection by medical professionals when handling the body fluids of infected patients is important as the virus can be spread through the exposure of broken skin to infected blood.

**Figure 1** helps to outline the ways in which HIV can and cannot be spread. The final 4% is from sources that are unknown.



**Figure 1.** How HIV can be spread.

More information for figure 1

This diagram illustrates ways in which HIV can be transmitted and ways it cannot be transmitted. The top section is labeled "HIV is transmitted by:" and contains six icons with descriptions underneath each. These are: 87% unprotected sex, 5% pregnancy/breastfeeding, 2% non-sterile syringes and tools, 1% organ transplant, and 1% blood transfusion.

The bottom section is labeled "HIV is not transmitted by:" and contains six icons with descriptions underneath each. These are: Kiss, touch; Food, drink, utensils; Clothes, towels; Insect bites; and Toilet, shower.



## Theory of Knowledge

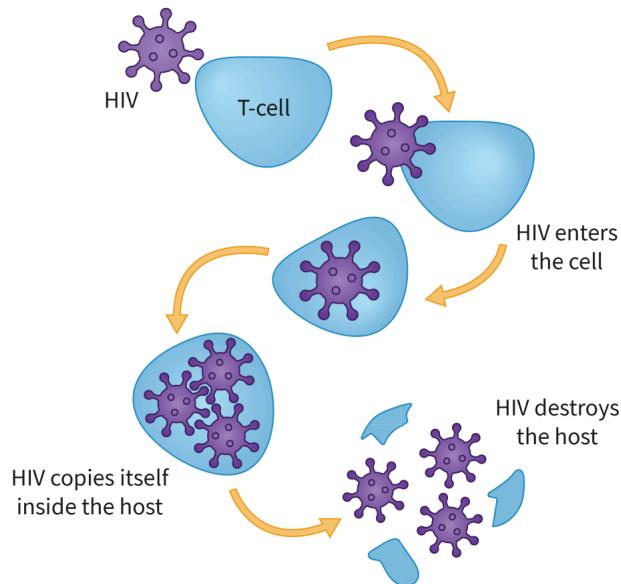
The HIV epidemic has been characterised by fear and social stigma. What could be the cause of HIV stigma? How does stigma affect mental health and become a barrier to testing and treatment?

It is important to remember that HIV cannot be spread:

- through insect bites
- by touching, hugging, shaking hands or sharing food with infected people
- through saliva, tears or sweat
- through air.

## The effect of HIV on the immune system

In the previous section, you learnt about helper T-cells (also called CD4<sup>+</sup> T-cells) and their role in activating both B-cells and cytotoxic T-cells. HIV works by attacking the helper T-cells (especially in the gut). In addition, the virus uses host cell machinery to replicate itself, leading to the lysis of the cell (**Figure 2**). The resulting depletion in the numbers of helper T-cells affects the activation of both the cytotoxic T-cells and the B-cells.



**Figure 2. Invasion of T-cells by HIV.**

More information for figure 2

The diagram illustrates the invasion of T-cells by HIV. It consists of four main stages arranged in a circular flow. Starting at the top, the HIV particle is shown approaching a T-cell. Arrows indicate the sequence of events.

1. HIV, represented as a purple structure, moves towards a blue T-cell.
2. The next stage depicts HIV entering the T-cell. An arrow points from the HIV to the T-cell with the label "HIV enters the cell."
3. In the third stage, several HIV structures are shown within the T-cell, with an accompanying label "HIV copies itself inside the host."
4. The final stage shows the T-cell bursting, releasing multiple HIV particles and fragments of the T-cell, labeled "HIV destroys the host."

The diagram visually represents the process of HIV infection, replication, and destruction of a host T-cell.

One way of determining the progression of HIV is to measure the helper T-cell count. In the absence of treatment, the cell count could fall so low that the immune system has trouble fighting infections. A weakened immune system makes the infected individual prone to opportunistic infections. Opportunistic infections are caused when pathogens that do not necessarily cause diseases in healthy individuals are able to establish themselves in HIV-infected individuals.

The three stages of HIV infection are outlined below.

[Section](#)[Student... \(0/0\)](#)[Print \(/study/app/bio/sid-422-cid-755105/book/helper-t-lymphocytes-and-activation-of-b-lymphocytes-id-46468/print/\)](#)[Assign](#)

## Stage 1

Acute HIV infection is the initial stage where the HIV multiplies and destroys the helper T-cells. During this period, the level of HIV in the blood is high, which increases the risk of transmission.

## Stage 2

Chronic HIV infection is the stage where the HIV multiplication drops to low levels. Individuals in this stage may not have obvious symptoms. This stage could last for several years.

## Stage 3

At the final stage, the body cannot fight opportunistic infections. The individuals suffer from a range of conditions affecting different organ systems due to the progressive weakening of the immune system, leading to the term, 'acquired immuno-deficiency syndrome' or AIDS.

It is important to note that with antiretroviral therapy (ART) the viral load can be reduced, thereby slowing down the progression of HIV infection and enabling individuals to lead longer and healthier lives.

What is Human Immunodeficiency Virus (HIV)?



### Video 1. HIV infection.

Try the activity below to discuss ways to improve behaviours and so reduce the stigma surrounding infection with HIV.

#### Activity

- **IB learner profile attribute:** Caring

- **Approaches to learning:** Communication skills — Clearly communicating complex ideas in response to open-ended questions
- **Time required to complete activity:** 20 minutes
- **Activity type:** Group activity

Many people suffering from HIV face stigma. This manifests as negative attitudes and behaviour towards them. You can take a stand by modelling positive behaviour and/or spreading awareness.

Form groups of four. Read the scenarios given below and discuss the ways you would address the same. Present your ideas in class.

1. A close friend reveals to you and a few others that she has tested positive for HIV. You notice that the first reaction of two friends was to take a few steps backward. How would you address the situation?
2. At work, a colleague shares that he is positive for HIV. The supervisor says that the organisation does not believe in discrimination. The next day, you notice that the colleague has been allotted a new workstation which is separate from the others. Later in the day, you see him having a solitary lunch. How would you help him?
3. There is a heated discussion on whether a teammate should be removed from the basketball team as she has tested as HIV positive. The reason cited was that she would infect others as she would be sharing the locker room. How would you address this?

## 5 section questions ▾

Section

Student... (0/0)

Feedback



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C3. Interaction and interdependence: Organisms / C3.2 Defence against infection/print/)

Assign ▾

# Antibiotics and antibiotic resistance

C3.2.13: Antibiotics C3.2.14: Evolution of resistance to antibiotics C3.2.15: Zoonoses

## Learning outcomes

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

- State the role of antibiotics in controlling bacterial infections.
- Infer the causes of bacterial resistance.
- Explain the transmission of zoonotic diseases.

In 1928, Alexander Fleming, a British scientist, returned from his two-week vacation to find that mould had grown on one of his plates containing a culture of *Staphylococcus aureus* (a bacterium that causes sore throat) culture. Much to his surprise, he noticed that while the plate was dotted with staphylococcal colonies, the area around the mould was clear of colonies. He went on to discover that the 'mould juice' could kill a wide range of bacteria. This was penicillin; the first antibiotic to be discovered. The advent of antibiotics heralded a new era in medicine but how did these newly discovered drugs work?



# Action of antibiotics

Overview  
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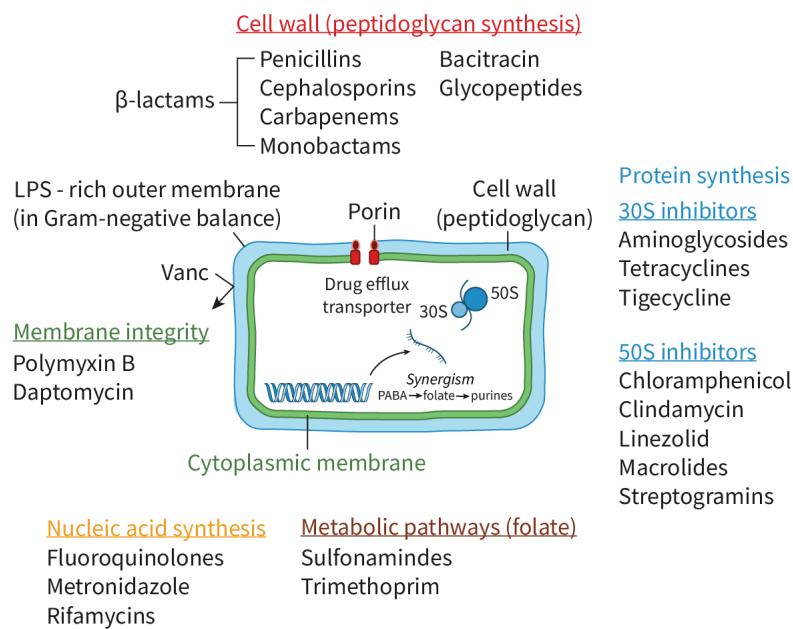
The literal meaning of the word antibiotic is ‘against life’. Antibiotics are produced naturally by several fungi and bacteria for their own survival to kill or inhibit other microbes that may be competing with them.

Antibiotics can be used to treat bacterial infections. Some antibiotics are bacteriostatic, that is they inhibit the growth or replication of bacteria, while others are bactericidal and kill the bacteria directly. The antibiotics prescribed by doctors can be broad-spectrum or narrow-spectrum. Broad-spectrum antibiotics tend to work against many different types of bacterial infection, while narrow-spectrum antibiotics only work against certain bacteria. Broad-spectrum antibiotics are often used when the exact bacterial species causing an infection cannot be diagnosed or is difficult to diagnose.

## 🔗 Concept

Antibiotics inhibit or kill bacteria. It is important to note that the term ‘antimicrobials’ can be used to refer to any substance that kills or inhibits the growth of a microorganism. This includes medicines used to treat fungal infections or viral infections as well as antiseptic liquids.

Antibiotics kill or inhibit bacteria using several mechanisms (**Figure 1**); they may interfere with the bacterium’s protein synthesis machinery, cell wall synthesis, DNA replication or metabolic pathways (see [section A2.2.4–6 \(/study/app/bio/sid-422-cid-755105/book/prokaryotic-and-eukaryotic-cells-id-43583/\)](#)).



**Figure 1.** Some common antibiotics and their effects.

🔗 More information for figure 1

The diagram illustrates the mechanisms of various antibiotics, divided into different categories based on their target and function.

**1. Cell Wall (peptidoglycan synthesis):** This area highlights antibiotics such as Penicillins, Cephalosporins, Carbapenems, Monobactams, Bacitracin, and Glycopeptides, which inhibit cell wall synthesis.

**2. Membrane Integrity:** Polymyxin B and Daptomycin are shown to affect this area, compromising membrane integrity.

**3. Nucleic Acid Synthesis:** Fluoroquinolones, Metronidazole, and Rifamycins are listed as inhibitors of nucleic acid synthesis.



4. **Metabolic Pathways (Folate):** This category includes Sulfonamides and Trimethoprim, which inhibit folate-related metabolic pathways.

5. **Protein Synthesis:** Here, 30S inhibitors like Aminoglycosides, Tetracyclines, and Tigecycline are listed along with 50S inhibitors such as Chloramphenicol, Clindamycin, Linezolid, Macrolides, and Streptogramins.

The diagram includes a graphical representation of a bacterial cell with components such as LPS outer membrane, Porin channels, Drug efflux transporter, 30S and 50S ribosomal units, and the concept of Synergism indicating interaction at the level of PABA, folate, and purines.

[Generated by AI]

While antibiotics are usually successful in killing or inhibiting bacteria, they do not block processes occurring in eukaryotic cells. This is because eukaryotic cells have different structures, mechanisms and metabolic pathways. Let's look at a couple of examples that illustrate this.

- Penicillin is used to treat several bacterial infections and kills bacteria by inhibiting the formation of peptidoglycan, an essential component of bacterial cell walls. Peptidoglycan confers the bacterial cell wall with strength and rigidity; in its absence, the bacterial cells become leaky and fragile. Since eukaryotic cells do not possess cell walls of peptidoglycan, the host is not harmed in the process.
- Tetracycline is a broad-spectrum antibiotic that inhibits the protein synthesis machinery of the bacterial cell, thereby hindering its growth and replication. In eukaryotic cells, tetracycline can weakly inhibit host protein synthesis, but its low concentration ensures that it does not have any significant impact.

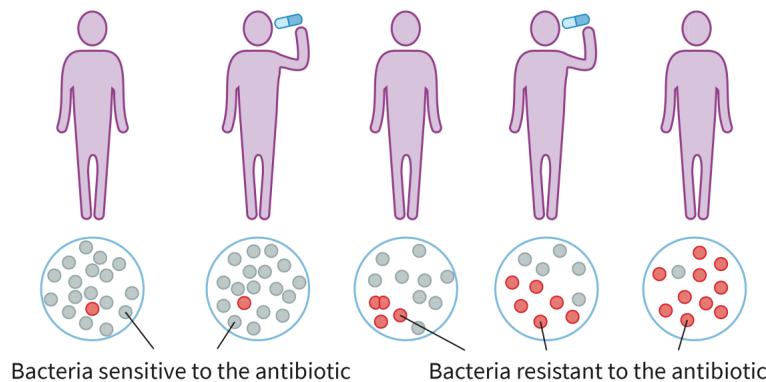
Antibiotics cannot be used to treat viral infections. Viruses (see [subtopic A2.3 \(/study/app/bio/sid-422-cid-755105/book/big-picture-hl-id-43527/\)](#)) are considered to be non-living. They do not have a cellular structure and they hijack the host cell's machinery to replicate themselves. It follows, therefore, that viruses do not have metabolic processes or structures that can be disrupted by antibiotics.

## Antibiotic resistance

More than 75 years ago, during his Nobel Prize speech, Fleming predicted that the careless use of antibiotics would make them less effective against bacteria over time. Today his prediction stands true as several strains of pathogenic bacteria have become resistant to antibiotics, a phenomenon known as antibiotic resistance.

Like other organisms, bacteria are constantly evolving to adapt to their environment. Evolutionary forces like mutation (see [subtopic D1.3 \(/study/app/bio/sid-422-cid-755105/book/the-big-picture-id-43250/\)](#)) and natural selection (see [subtopic D4.1 \(/study/app/bio/sid-422-cid-755105/book/the-big-picture-id-43238/\)](#)) act on the genetic diversity present in the bacterial population, resulting in antibiotic-resistant bacteria. In a population exposed to antibiotics, some bacteria may have favourable variations like protein pumps that remove the antibiotic from the cells, or enzymes that degrade the antibiotics. These bacteria survive and pass on the favourable traits to their offspring. Over the course of time, the population of antibiotic-resistant bacteria increases. **Figure 2** illustrates the process.





**Figure 2.** The evolution of antibiotic-resistant bacteria.

More information for figure 2

The image is a diagram illustrating the evolution of antibiotic-resistant bacteria. It depicts a sequence of five human figures, each paired with a magnified view of bacteria. The first human figure represents bacteria sensitive to antibiotics, with mostly gray bacteria and a few red ones in the circle. As the sequence progresses, the figures depict the human consuming an antibiotic. Over time, the composition of bacteria changes in subsequent circles. Red bacteria, representing antibiotic-resistant strains, increase in number. By the last figure, the circle shows only red bacteria, indicating a population resistant to the antibiotic. This progression visually explains the process of how bacteria become resistant due to antibiotic exposure.

[Generated by AI]

While this process is natural, the overuse and misuse of antibiotics has accelerated antibiotic resistance, making it a global health problem. A number of diseases like gonorrhoea, tuberculosis, pneumonia and some infections linked to routine surgeries are becoming harder to cure.

Moreover, many types of bacteria, including staphylococci and streptococci, are now resistant to multiple antibiotics, resulting in multidrug-resistant (MDR) bacteria. Treating infections caused by these MDR bacteria is an immense challenge resulting in longer hospital stays and increased mortalities. Thus, antibiotic resistance is often referred to as a 'silent pandemic' as it narrows the pool of antibiotics available to treat infections. We are losing decades of progress as we again become helpless in the face of infection.

## Nature of Science

### Aspect: Science as a shared endeavour

While the rapid spread of antibiotic resistance is worrying, ongoing research aims to develop new antibiotics or alternative therapies to treat bacterial infections. Chemical compound libraries refer to a collection of chemicals which can be utilised for drug discovery. This method can help screen several chemicals against specific bacteria to identify compounds with antibacterial properties. Another treatment option being researched as an alternative to using antibiotics is bacteriophage therapy. Bacteriophages are viruses that infect and kill bacteria. The ability of bacteriophages to kill bacteria is being harnessed to treat human bacterial infections and several of them are in the clinical trial stage.

It is clear that the more we use antibiotics, the more chance there is that resistant bacteria will emerge. The following measures can help prevent the spread of antibiotic resistance:

- Practise good hygiene to prevent bacterial infections from occurring.
- Take antibiotics only if they have been prescribed by a certified medical professional.
- Make sure to complete the full course of antibiotics. Do not stop midway and/or skip doses.

## Theory of Knowledge

Antibiotics are often given to livestock, not only to treat infection but also as a preventative measure. This has helped to lead to the evolution of antibiotic-resistant bacteria. These antibiotic-resistant bacteria spread easily, infecting other animals and even humans. Do scientists or the societies in which scientists operate exert a greater influence on what is ethically acceptable in this area of knowledge?

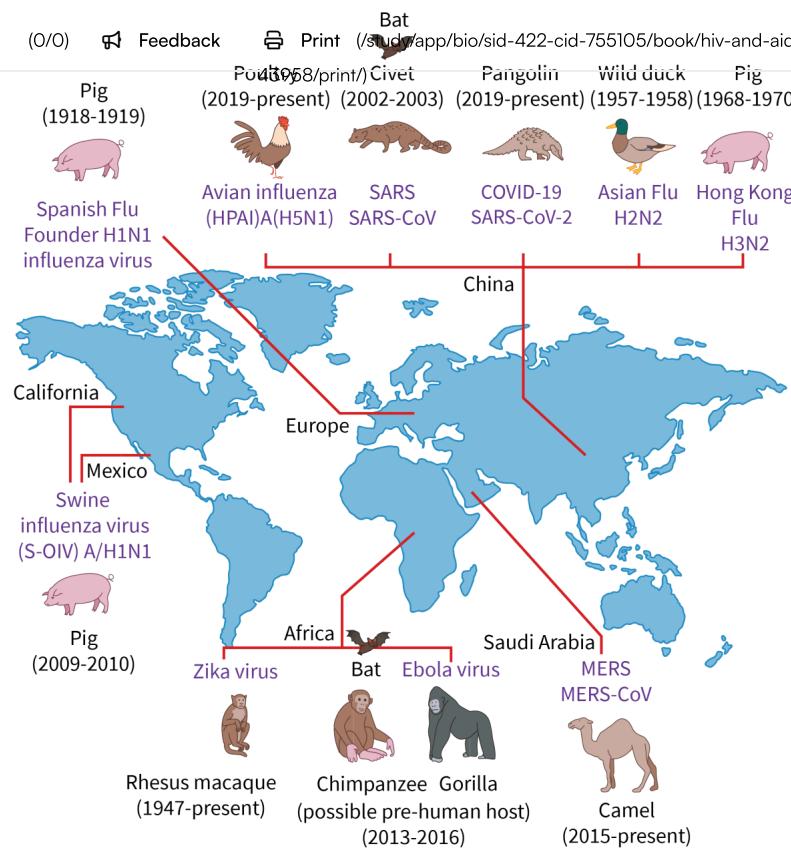
## Zoonotic diseases and their spread

In 1999, several slaughterhouse workers were admitted to hospital with fever and confusion followed by rapid neurological deterioration. This was the origin of the Nipah virus infection, characterised by fever, headache and drowsiness, progressing to coma and death. What caused this disease to emerge?

A zoonosis or zoonotic disease is an infectious disease that can spread from non-human vertebrate animals to humans. According to the WHO, there are over 200 types of zoonoses which cause millions of deaths annually. Zoonoses account for nearly 60% of emerging infectious diseases. Zoonotic diseases may be caused by viral, bacterial, fungal or protist pathogens and can be spread by either direct contact with the infected animal or by indirect contact (through food or water, for example). In the case of the Nipah virus, the natural reservoir was the fruit bat. From the fruit bats, the virus spread to pigs and from pigs to humans.

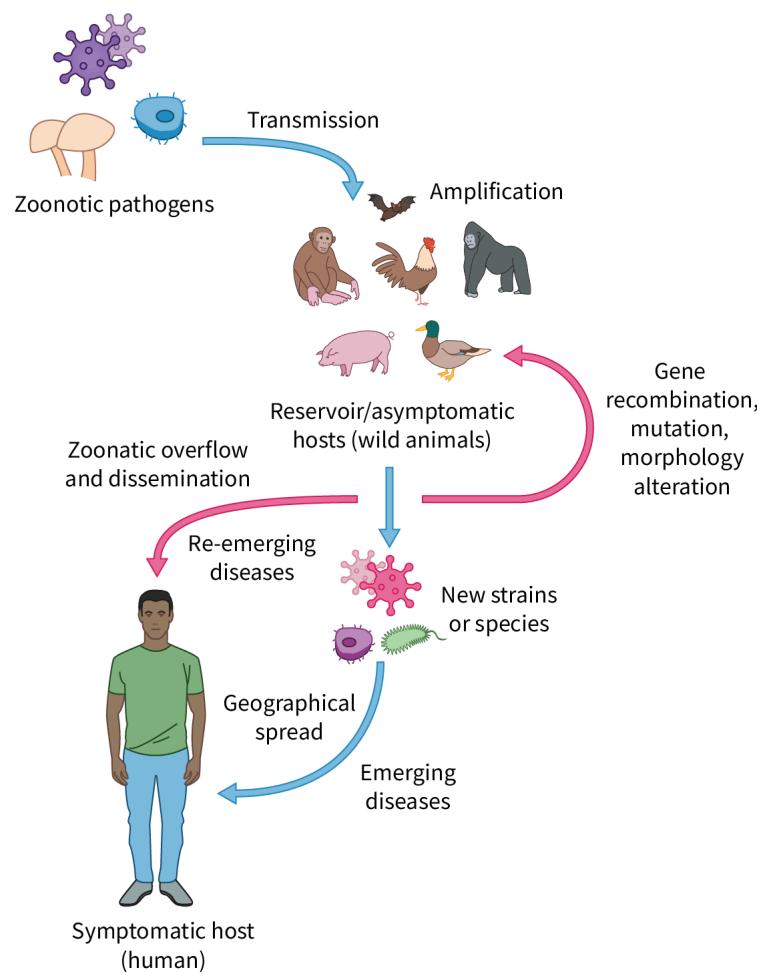
## From animal to human

Zoonotic diseases emerge when pathogens originally present in other animal species (reservoirs) cross the species barrier and enter humans, in a process often referred to as spillover (**Figure 3**). The chances of spillover events increase when the interaction of humans with different species of animals increases. Activities that act as spillover drivers include handling of wild animals, consumption of their meat, poaching, animal markets and even deforestation. Note regarding Spanish Flu: The origin of the Spanish Flu from 1918 is still uncertain, but it is believed to have originated in France, China, Britain, or the United States. The first known case was reported at Camp Funston in Fort Riley, Kansas, on March 11, 1918.


[More information](#)

This diagram displays a world map with red lines connecting various animals with locations and viruses. The animals shown include pigs, poultry, bats, civets, pangolins, wild ducks, rhesus macaques, chimpanzees, gorillas, and camels. Each animal is associated with specific viruses and time periods. For example, a pig from 1918-1919 is linked to the Spanish Flu H1N1 influenza virus with a line extending from the United States. Poultry from 2019-present is associated with Avian influenza (HPAI) A(H5N1) and is linked to China. Other connections include bats and Ebola virus in Africa (2013-2016) and camels linked to the MERS-CoV virus in Saudi Arabia (2015-present). The map highlights regions such as California, Mexico, Europe, China, Africa, and Saudi Arabia, illustrating the global origins and movements of these zoonotic diseases.

[Generated by AI]



**Figure 3.** (a) Major recorded outbreaks of zoonoses (prior to 2020). (b) The pathway of zoonotic diseases.

More information for figure 3

The diagram depicts the transmission pathway of zoonotic diseases. It starts with zoonotic pathogens, which are represented visually at the top. An arrow labeled 'Transmission' points to a collection of wild animals, including a bat, pig, chicken, monkey, and duck, indicating these animals as reservoir hosts or asymptomatic hosts. This section is labeled 'Amplification' and 'Reservoir/asymptomatic hosts (wild animals)'.

From here, the flow splits into two pathways. One arrow, labeled 'Zoonotic overflow and dissemination', leads to 'Re-emerging diseases', shown by re-emerging pathogens.

The other path, labeled 'Gene recombination, mutation, morphology alteration', indicates the development of 'New strains or species'.

These new strains are followed by 'Emerging diseases', and an arrow labeled 'Geographical spread' leads to a human figure labeled 'Symptomatic host (human)'.

[Generated by AI]

Several human infections are zoonotic in nature such as tuberculosis, rabies, Japanese encephalitis, COVID-19, brucellosis, anthrax, Ebola, avian flu and swine flu.

## Tuberculosis

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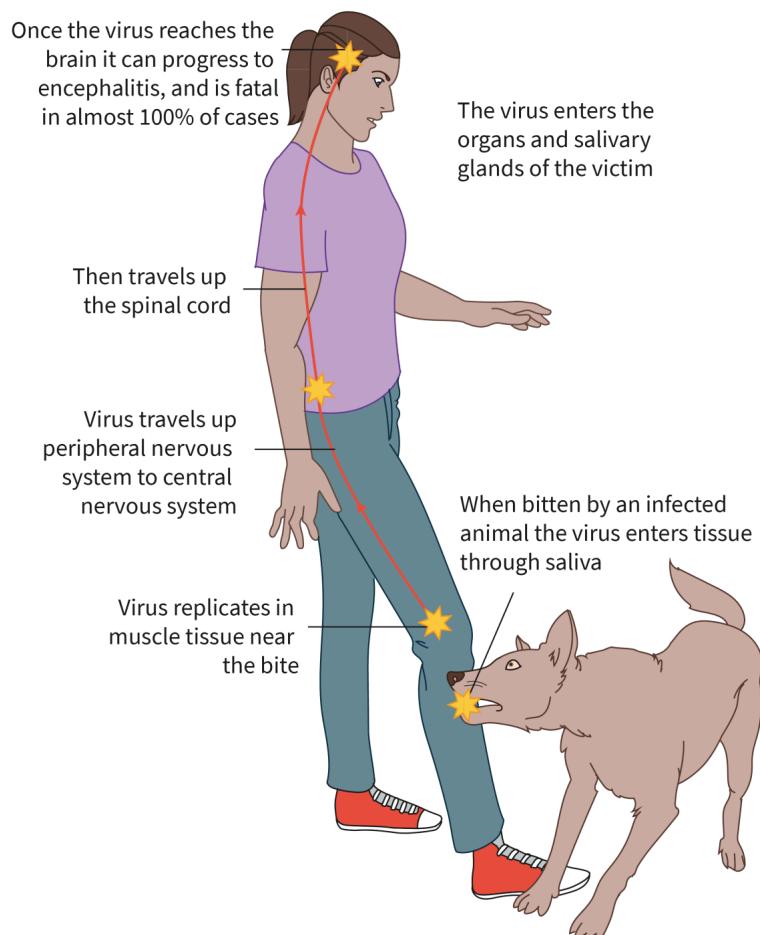
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Most cases of tuberculosis in humans are caused by *Mycobacterium tuberculosis*. Tuberculosis is also seen in cattle.

Known as bovine tuberculosis, the disease is caused by the bacterium *Mycobacterium bovis*. Zoonotic tuberculosis is a form of tuberculosis that spreads from cattle to humans through contaminated food like untreated dairy products. It is also an occupational risk for people in constant contact with infected animals like farmers and vets. Zoonotic tuberculosis is thought to cause a significant proportion of human tuberculosis cases, although the exact numbers are not known due to poor surveillance.

## Rabies

Rabies is a viral zoonotic disease caused by the rabies virus, RABV, that spreads from an infected (rabid) animal to humans through bites and scratches (**Figure 4**). The virus present in the saliva of the rabid animal enters the human body, affecting the central nervous system. Rabies can be transmitted by bats, raccoons, foxes and dogs. Though a fatal disease once the symptoms appear, vaccination helps to prevent the disease if taken immediately after an exposure.



**Figure 4.** The progression of rabies without a vaccine.

More information for figure 4

The diagram illustrates the progression of the rabies virus in a human. It shows the process starting with a bite from an infected animal, depicted as a dog, biting a person's leg.

Text near the bite states, "When bitten by an infected animal the virus enters tissue through saliva." Once the virus enters, it replicates in muscle tissue near the bite, indicated by a star on the leg and text "Virus replicates in muscle tissue near the bite."

The virus then travels up the peripheral nervous system to the central nervous system, shown by arrows moving upwards to the spine with the text, "Virus travels up peripheral nervous system to central nervous system. Then travels up the spinal cord."

Home  
Overview  
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Eventually, the virus reaches the brain, highlighted by a star on the head, where it can cause encephalitis, noted by text, "Once the virus reaches the brain it can progress to encephalitis, and is fatal in almost 100% of cases."

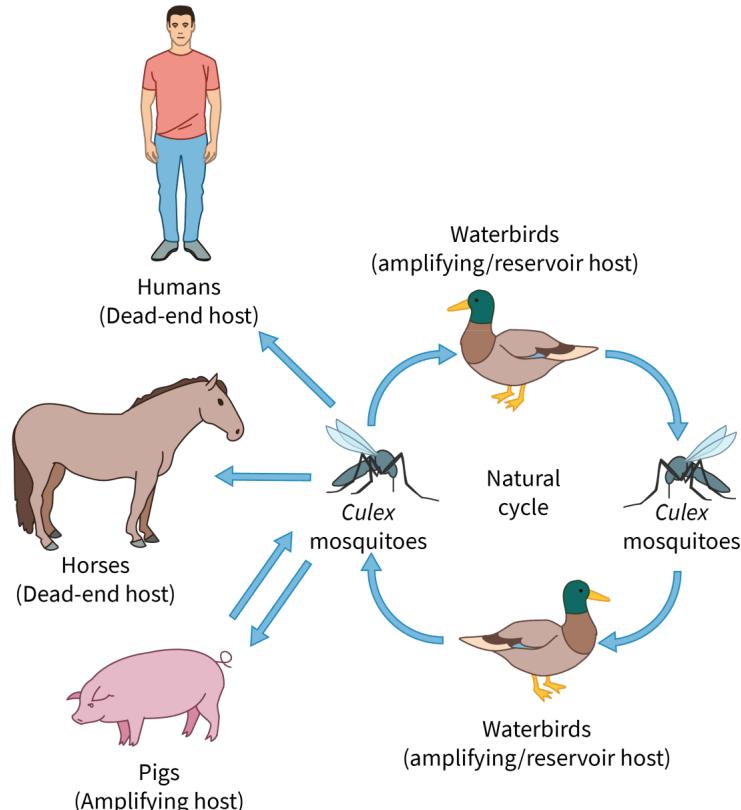
Additional text indicates, "The virus enters the organs and salivary glands of the victim."

[Generated by AI]

## Japanese encephalitis

Japanese encephalitis is a zoonotic disease caused by the Japanese encephalitis virus. The virus infects pigs and aquatic wading birds where it multiplies (**Figure 5**). The virus is passed from these animals to humans (as well as dogs, cattle, sheep and horses) by the bite of an infected mosquito. Japanese encephalitis is not passed from one person to another.

(Note: Japanese encephalitis is an emerging disease and these facts may change with new research.)



**Figure 5.** The pathway of Japanese encephalitis. Dead-end hosts like horses and humans do not transmit the virus.

More information for figure 5

The diagram illustrates the transmission pathway of Japanese encephalitis. It depicts a cycle involving Culex mosquitoes, waterbirds, pigs, horses, and humans. At the center, waterbirds are shown as amplifying/reservoir hosts in a natural cycle. Arrows indicate that Culex mosquitoes transmit the virus between waterbirds. There are additional arrows extending from the Culex mosquitoes towards pigs (identified as amplifying hosts) and further arrows from pigs to the Culex mosquitoes, forming a cyclical pattern. To the sides, humans and horses are labeled as dead-end hosts with arrows directed towards them, indicating they do not contribute to the virus transmission cycle.

[Generated by AI]

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## COVID-19

Coronaviruses are a family of viruses that cause respiratory diseases ranging from a common cold to severe diseases like the COVID-19 pandemic caused by the SARS-CoV-2 virus. These viruses are zoonotic and are transmitted from animals to humans. While this is subject to debate and ongoing research, it is thought that the reservoirs for SARS-CoV-2 are bats, and the intermediate hosts (the hosts which transfer the pathogen to the final host) are civets and pangolins, the latter two sold in exotic animal markets. From these animals, the disease spread to humans. Interestingly, from humans the disease has spread to a number of other animal species including cats, dogs as well as zoo animals like tigers and gorillas. This phenomenon is known as reverse zoonosis.

To prevent the emergence of zoonotic diseases, it is important that wildlife habitats remain undisturbed. This will in turn prevent the spread of infections such as COVID-19 which have pandemic potential.

### 🌐 International Mindedness

The [One Health approach](https://youtu.be/Ndfi9QbdXVY) (https://youtu.be/Ndfi9QbdXVY) is an initiative of the WHO that summarises a concept that is evident yet neglected: human health is inextricably linked to the health of plants, animals and the environment. The expansion of human populations into areas traditionally occupied by wild animals, as well as the destruction of habitats, has increased the chances of humans coming in contact with natural reservoirs. This, coupled with an increase in international trade in animals and animal products, has led to the emergence of new diseases. One Health is a holistic, unifying approach that recognises the interdependence of humans, animals and their environment.

What is One Health?



**Video 1.** The relationship between human health and the surrounding environment.

### ✍ Creativity, activity, service

**Strand:** Activity

**Learning outcome:** Demonstrate engagement with issues of global significance

Timpiyan Leseni is a survivor of zoonotic tuberculosis. She contracted tuberculosis from her staple diet consisting of unboiled milk and rare meat. Now she is an activist and works to educate her community on how to fight zoonotic tuberculosis . She talks about her journey in **Video 2**.

Student  
view

As human—animal interactions increase, the threat of emerging zoonotic diseases increases, however awareness can help to mitigate this threat. Plan an awareness campaign to educate your local community on zoonotic diseases.



**Video 2.** Educating the community about tuberculosis.

 More information for video 2

1  
00:00:00,367 --> 00:00:02,002  
[soft music plays]

2  
00:00:16,917 --> 00:00:18,652  
Timpian Leseni: The reason  
why I became a TB ambassador

3  
00:00:18,719 --> 00:00:21,855  
is because after I've been told that  
I got TB from our staple food

4  
00:00:21,922 --> 00:00:23,023  
as the Maasai community,

5  
00:00:23,423 --> 00:00:27,861  
I decided, man, my community need to know  
that tuberculosis is right here with us.

6  
00:00:28,095 --> 00:00:31,532  
We can get it from  
the, from our, our animals,

7  
00:00:31,598 --> 00:00:33,634  
the animals that are truly precious a lot,

8  
00:00:33,867 --> 00:00:35,736  
and it's something that is curable.

9  
00:00:36,036 --> 00:00:39,039  
So I decided I need  
to get out and talk about it.

10  
00:00:39,106 --> 00:00:41,441  
I started just by following up,

11  
00:00:41,508 --> 00:00:45,379  
looking for the fellows follow up,  
bringing them back to medication,



Overview  
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12  
00:00:45,445 --> 00:00:47,581  
telling them the importance of adherence,  
13  
00:00:47,648 --> 00:00:50,584  
educating the communities  
on the importance of  
14  
00:00:50,651 --> 00:00:53,253  
expanding their small holes  
in their Maasai Manyatta  
15  
00:00:53,320 --> 00:00:54,421  
to larger windows  
16  
00:00:54,488 --> 00:00:56,657  
because of their ventilation purposes.  
17  
00:00:56,723 --> 00:00:58,258  
Just because TB is airable.  
18  
00:00:58,425 --> 00:01:00,093  
So that's another way of preventing it.  
19  
00:01:00,394 --> 00:01:04,131  
And also by just really ensuring  
that whoever has started medication,  
20  
00:01:04,198 --> 00:01:06,600  
we get into their homes  
and we do contact tracing.  
21  
00:01:06,934 --> 00:01:11,338  
We, we also educate them  
on how to just prevent it,  
22  
00:01:11,405 --> 00:01:14,141  
and also letting them  
know that you don't get TB  
23  
00:01:14,208 --> 00:01:16,877  
by using the same spoon  
or using the same plate.  
24  
00:01:16,944 --> 00:01:18,011  
We get into the communities,  
25  
00:01:18,078 --> 00:01:21,215  
we educate them about the importance  
of adherence to TB medication  
26  
00:01:21,281 --> 00:01:23,317  
because all of us need  
to be resistance fighters.  
27  
00:01:24,184 --> 00:01:25,919  
[music swells]  
28  
00:01:30,858 --> 00:01:32,826  
[music fades out]



Student  
view



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Try the activity below and make a poster to highlight concerns about antibiotic resistance.

## Activity

- **IB learner profile attribute:** Caring
- **Approaches to learning:** Social skills — Actively seeking and considering the perspective of others
- **Time required to complete activity:** 30 minutes
- **Activity type:** Group activity

### Your task

Antibiotic (and antimicrobial) resistance is a major global concern and one of the leading reasons is the overuse of antibiotics. Create a poster to illustrate important information regarding antibiotic usage.

### Materials

Poster paper, sketch pens, crayons, pencils etc.

### Instructions

Work in groups of four.

Discuss and plan your poster, keeping in mind the following points:

- What is the purpose of the poster?
- What should the layout and format look like?
- What are the key ideas that you want to convey?
- How do you plan to convey these ideas?
- What sort of font would you use? What sort of images would you draw?

Make the poster.

Give a title to your poster and display it.

## 5 section questions ▾

C3. Interaction and interdependence: Organisms / C3.2 Defence against disease

# Vaccinations and more

C3.2.16: Vaccines and immunisation    C3.2.17: Herd immunity and the prevention of epidemics    C3.2.18: Evaluation COVID-19 pandemic data

## Learning outcomes

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

- Explain the role of vaccines in developing immunity.
- Describe the interdependence of a population in building herd immunity.



Overview

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- Evaluate data related to the COVID-19 pandemic.

A much dreaded disease, smallpox ravaged the world for centuries. Though it was known that the survivors of smallpox were resistant to the disease, there was no known cure. The first step towards eradication of the disease was the work done by Edward Jenner. Jenner, a British scientist, noticed that dairymaids who contracted cowpox did not get smallpox. He took the fluid from the cowpox lesions of a young dairymaid and inoculated an 8-year-old boy with it. Subsequent inoculation with matter from a smallpox lesion did not lead to the development of the disease. How did the resistance to the disease develop?

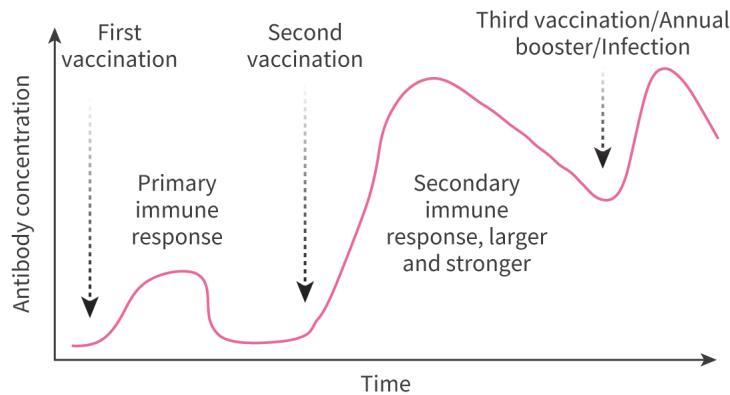
## Vaccines and immunisation

Vaccines are substances that produce immunity to a specific disease. In a previous section, you learnt that memory B-cells retain an ‘immunological’ memory of the pathogens that they encounter. Subsequent infections by the same pathogen result in a quick and efficient response.

Vaccines work in a similar way; they mimic the action of the antigen, creating memory B-cells specific to the antigen. Any subsequent encounter with the antigen triggers an immediate immune response by activating the memory B-cells. In other words, the vaccine prompts the immune system to respond the way it would on being exposed to the antigen for the first time.

Vaccines can be in the form of injections, oral drops or nasal sprays. Vaccination is the process of introducing a vaccine into our body. Immunisation, on the other hand, is the process by which our bodies develop immunity and become resistant to that disease.

Vaccines can be a single dose, however most vaccines require multiple doses spread over specified periods of time; the COVID-19 vaccine, for example, required two doses followed by a booster. Multiple doses keep the immune response ‘alive’ as this leads to the production of long-lived antibodies. **Figure 1** illustrates the importance of multiple doses of a vaccine.



**Figure 1.** The process of immunisation.

More information for figure 1

This graph illustrates the process of immunization by showing antibody concentration over time. The x-axis represents time, while the y-axis indicates antibody concentration without specific values. There are three labeled peaks on the graph: the first peak following "First vaccination" is labeled "Primary immune response," indicating a small increase in antibody concentration. The second peak, higher than the first, is associated with "Second vaccination"

and labeled "Secondary immune response, larger and stronger," suggesting a more significant antibody response. The third peak, the highest, follows "Third vaccination/Annual booster/Infection," showing a strong antibody response. The graph demonstrates the increasing antibody levels with successive vaccinations, emphasizing the importance of multiple doses in achieving a robust immune response.

[Generated by AI]

## Types of vaccines

Traditionally, vaccines contained weakened or inactive parts of the pathogen that triggered the immune response. Today there are different categories of vaccines.

- Live attenuated vaccines use a weakened form of the whole pathogen while inactivated vaccines use the inactivated form of the pathogen. This strategy ensures stimulation of the immune system without actually causing the infection. The oral polio vaccine is a live attenuated vaccine made using three strains of attenuated poliovirus, while the inactivated polio vaccine (IPV) is usually given as a shot on the arm or leg and consists of killed or inactivated polio strains.
- DNA vaccines make use of plasmids to introduce a gene encoding an antigen from a specific pathogen. Once injected, the DNA sequence is transcribed (see [section D1.2.1–3 \(/study/app/bio/sid-422-cid-755105/book/transcription-id-46485/\)](#)) and translated (see [section D1.2.4–6 \(/study/app/bio/sid-422-cid-755105/book/translation-id-46207/\)](#)). The resultant protein (antigen) then elicits an immune response. The world's first DNA vaccine approved for use was Zydus Lifesciences's vaccine against COVID-19.
- RNA vaccines work by introducing a strand of mRNA that codes for an antigen specific to the disease. The mRNA is translated and the resultant protein (antigen) triggers an immune response. Pfizer and Moderna's vaccines against COVID-19 were the first approved mRNA vaccines.

Both DNA and RNA vaccines are nucleic acid vaccines.

### Theory of Knowledge

Confirmation bias is the tendency for people to process information by giving greater value to evidence that supports their existing beliefs or values. In what way does confirmation bias affect thinking and decision making? How does confirmation bias affect vaccination rates?

## Herd immunity

A vaccination protects people from infectious diseases. However, there are people who have a weakened immune system and might not be able to get themselves vaccinated. This is where the power of the 'herd' or group comes in. If most of the people in a community are vaccinated, the transmission of the pathogen slows down as the majority are immune. This phenomenon is known as herd immunity. This simulation given [here](#) (https://www.youtube.com/watch?v=875wRCWwGVc) highlights the development of herd immunity.

Thus, herd immunity refers to the protection conferred against a specific infection when a significant proportion of the population develops immunity against the infection. This can be either by vaccination or by immunity from a prior infection. Herd immunity indirectly protects susceptible members of a population from an infection; this includes immunocompromised individuals: those who are unvaccinated due to medical reasons, babies and the elderly. It ensures that even if not all the members of a population are vaccinated against a pathogen or have previously been naturally infected, they are still protected and are at a relatively lower risk of being infected. **Video 1** illustrates this.

## What is herd immunity?



### Video 1. Herd immunity.

To achieve herd immunity, a minimum percentage of the population needs to be immune to a particular infection; this is the herd immunity threshold. According to the WHO, 95% of a population needs to be vaccinated against measles to achieve herd immunity. Similarly, 80% of the population needs to be vaccinated against polio to achieve herd immunity.



#### Aspect: Evidence

Scientists publish their findings for it to reach other experts in their field, policymakers and the wider public. Furthermore, when scientists send their manuscripts to reputed journals, the manuscript undergoes peer-review. Peer-review is a practice whereby scientific manuscripts are assessed by other experts in the field before publication to ensure the accuracy and validity of the findings.

The media acts as the intermediary between scientists and the public and communicates important advances in research to a lay audience in an easily digestible manner. However, it is important to remember that in some instances, the media might report research which has not been peer-reviewed or report findings where the research is still in the early stages. Furthermore, some media channels may exaggerate findings or present findings as a definitive answer or conclusion.

For example, when the vaccination drive against COVID-19 started, vaccine misinformation was rife, and stories about individuals experiencing adverse reactions to the vaccines were in the spotlight. However, it is important to understand that vaccines are administered to the public following rigorous testing and several rounds of clinical trials. Also, any given vaccine (and not just the COVID-19 vaccine) may cause individuals to experience side effects to varying degrees. Adverse reactions or side effects are monitored closely during clinical trials. Serious adverse events are reported and careful follow-up is carried out thereafter to minimise the risk of these to other individuals.

## Evaluation of data related to the COVID-19 pandemic

The COVID-19 pandemic was a rapidly evolving situation, one which was unexpected and brought with it unprecedented challenges. Information (on the number of cases, deaths, vaccinations, breakthrough infections, new strains) was being generated at a rapid speed and was being used to make decisions regarding social-distancing measures, lockdowns, testing and quarantine rules. It is important that information is presented in a clear and easily comprehensible manner for both policymakers and the public to understand. It was also necessary to analyse and evaluate the data that came in.



For evaluating data, some of the parameters that need to be kept in mind are:



- Data sources

The data can come from various sources like governments, research studies and the media and should be evaluated for both reliability and bias. For example, data from the WHO and Centers for Disease Control and Prevention (CDC) are more credible.

- Data types

The data types included a daily case count, positivity rate, mortality rate, testing rates, hospitalisation rates and number of individuals vaccinated.

- Data collection

The method of data collection is important. During the pandemic, for example, random sampling and rigorous testing procedures gave more accurate results.

- Data representation

Data can be presented in multiple ways and this in turn affects the ease with which they are read. For example, graphs or charts are easier to understand than raw data.

- Data limitations

It is important to understand that data collected could have limitations. For example, lower testing rates could lead to seemingly low case counts.

Try the activity below to evaluate the COVID-19 data presented in the form of graphs.

## Activity

- **IB learner profile attribute:** Inquirer
- **Approaches to learning:** Research skills — Using search engines and libraries effectively
- **Time required to complete activity:** 30 minutes
- **Activity type:** Group activity

### General instructions

- Form groups of four

### Part 1: Evaluating data

- This website <https://ourworldindata.org/coronavirus> contains a dataset on the COVID-19 pandemic which is updated daily. Here you can find information about cases, deaths, vaccinations and hospitalisations among other things.
- On this website, visit the 'Country Profiles' page. From the list, choose the United Kingdom. This will open a new webpage.
- Scroll down until you see the option to 'Select countries to show in all charts'. In addition to the United Kingdom, add Sweden, India and South Korea to visualise their COVID-19 data. (The countries have been selected to give you a range of data; you could select other countries.)
- Choose a specific time period between March 2020 and March 2021 and no more than 6 months long. Examine the graphs and answer the following question: which country had the highest and lowest number of cases in the specified time period?
- On some of the graphs, you would have seen two scale options: log and linear. The log (logarithmic) scale shows the percentage change between two values (for example, the growth rates in the number of cases). The linear scale shows the absolute values (for example, the daily increase in cases). On the graph showing



the ‘cumulative number of confirmed cases’, switch between the log and linear scales to visualise the differences.

- How do the graphs differ?
- Which of the graphs would seem more impactful to a layperson?
- Which would give authorities a better understanding of the health-care strategies to be adopted?
- The positivity rate refers to the total number of positive cases relative to the total number of tests performed. This is an important metric because some countries do not test as much as others and, therefore, will record a lower number of cases. Compare the graph showing the ‘daily confirmed cases’ with the graph showing the ‘positive rate’. (Ensure that both the graphs are on the ‘chart’ mode and choose the same time periods both.)
  - Is the country with the highest positivity rate the same as the country with the highest number of daily cases? Similarly, is the country with the lowest positivity rate the same as the country with the lowest number of daily cases?
  - Which of these two graphs do you think gives a more accurate picture about the COVID-19 situation in a country?

### Part 2: Standardising data — calculating percentage change and percentage difference

The percentage change is used to track changes in various parameters like the growth or decline in the number of cases, growth or decline of the vaccination rate etc.

#### Worked example

Calculate the percentage change in the number of new daily COVID-19 cases in South Korea from 17 August 2020 to 19 August 2020.

$$\text{Formula: percentage change} = \frac{(\text{new value} - \text{original value})}{\text{original value}} \times 100$$

Number of cases on 17 August 2020 (original value) = 127

Number of cases on 19 August 2020 (new value) = 192

$$\text{Percentage difference} = 192 - 127 / 127 \times 100 = 51.2\%$$

Use the ‘Daily confirmed COVID-19 cases’ graph and calculate the percentage change of COVID-19 cases. You could select any two consecutive days, for example percentage change of COVID-19 cases in the UK from 5 July 2020 to 6 July 2020.

The percentage difference is used when we want to compare two values that are on different scales. For example, if we need to compare the severity of the pandemic across different countries that have different populations.

#### Worked example

Calculate the percentage difference in the number of cases in the United Kingdom and Turkey on 23 November 2020.

$$\text{Formula: percentage difference} = \frac{(\text{value 1} - \text{value 2})}{\text{average of value 1 and value 2}} \times 100$$

Number of cases in the UK on 23 November 2020 = 19 346.29

Number of cases in Turkey on 23 November 2020 = 11 379.86

Average of the number of cases in the two countries on 23 November 2020 = 15 363.1

$$\begin{aligned} \text{Percentage difference} &= \frac{19\,346.29 - 11\,379.86}{15\,363.1} \times 100 \\ &= 51.85\% \end{aligned}$$

This means that the UK had 51.9% more cases than Turkey.

Use the ‘Daily confirmed COVID-19 cases’ graph to calculate the percentage difference in COVID-19 cases between Finland and Norway on 26 November 2020.

Together percentage change and percentage difference help to standardise data.



Overview  
(/study/app/  
422-  
cid-  
755105/o

## 5 section questions ▾

C3. Interaction and interdependence: Organisms / C3.2 Defence against disease

### Summary and key terms

- The skin and the mucous membranes are the first line of defence. They act as physical and chemical barriers to prevent the entry of pathogens.
- The clotting of blood seals cuts or wounds on the skin, preventing the entry of pathogens. The chain of reactions is caused by clotting factors released by the platelets and injured tissues, resulting in the formation of a clot.
- The immune system of the body consists of the innate immune system and the adaptive immune system. Innate immune responses are immediate and generalised while the adaptive immune responses are slower, but specific and long-lasting. Phagocytosis is a mechanism employed by the innate immune system to engulf and digest pathogens.
- Lymphocytes are responsible for the adaptive immune response of the body. There are two types of lymphocytes: B-cells and T-cells. Antibodies produced by B-cells neutralise antigens. T-cells are of two types: helper T-cells and cytotoxic T-cells.
- The ABO blood groups are determined by the antigens present on the surface of the red blood cells.
- When the T-cells and B-cells encounter an antigen specific to them they are activated. The activation of B-cells happens directly when they come in contact with both the antigen and the helper T-cell specific to the same antigen. The activated B-cells multiply to form plasma cells that produce antibodies while the memory cells 'remember' the antigen resulting in long-lasting immunity.
- HIV is a retrovirus that is spread through sexual contact, transfusion of contaminated blood, sharing needles and from mother to child during childbirth or breastfeeding. HIV attacks helper T-cells and causes the weakening of the immune system. HIV infection progresses to AIDS.
- Antibiotics block bacterial processes inhibiting their growth and/or killing them. Evolution of antibiotic-resistant bacteria is a global health threat.
- Diseases that transfer from animals to humans are known as zoonotic diseases or zoonoses. Transmission of diseases can be prevented by vaccination. Vaccines could be made of antigens, RNA or DNA. Vaccination leads to activation of the immune system or immunisation.
- Herd immunity occurs when the majority of a population are immune to a disease. This protects people who have underlying medical conditions and cannot vaccinate themselves.



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## ↓‡ Key terms

**Review these key terms. Do you know them all? Fill in as many gaps as you can using the terms in this list.**

1. Infectious diseases are spread through . Proteinaceous substances that act as infectious agents are known as
2. are proteins produced by the plasma cells while are substances that trigger the immune system. are substances that are prescribed by doctors to kill bacteria.
3. Unlike the immune response, the response of the immune system is characterised by specificity and
4. HIV targets , which play an important role in activating . They also help activate
5. B-cells divide mitotically to give rise to cells which produce antibodies and cells that retain a memory of the pathogen.
6. A global health concern is the misuse of antibiotics that leads to the development of resistant bacteria.
7. Rabies and Japanese encephalitis are examples of diseases. The pathogens that cause these diseases move out from their , cross the species barrier and enter humans.
8. Though often used interchangeably, is the process of introducing the antigen into the body while is the process by which the immunity of the body is built. Nucleic acid vaccines use either sequences like the Zydus vaccine or sequences like the Moderna vaccine that code for antigens.
9. The transmission of a pathogen through a population is greatly reduced when the population achieves

Check

### Interactive 1. Key Concepts in Immunity.



C3. Interaction and interdependence: Organisms / C3.2 Defence against disease

## Checklist

[Home](#)[Overview](#)[\(/study/app/bio/sid-422-cid-755105/o\)](#)**Section**

Student...

(0/0)

[Feedback](#)[Print \(/study/app/bio/sid-422-cid-755105/book/checklist-id-46470/print/\)](#)[Assign](#)[422-](#)[cid-](#)[755105/o](#)**What you should know**

After studying this subtopic you should be able to:

- Identify the categories of pathogens.
- Describe the role of the skin and mucous membranes in primary defence of the body.
- Explain the process of clotting of blood.
- Differentiate between innate immune system and adaptive immune system.
- State the role of phagocytes in controlling infection.
- Explain the role of lymphocytes in adaptive immune responses.
- Recall that antigens trigger antibody production.
- Explain the activation of B-lymphocytes by helper T-cells.
- Outline the role of activated B-lymphocytes in production of sufficient quantities of antibodies.
- Describe the role of memory cells in immunity.
- Describe the means of transmission of HIV.
- Study the effect of the virus on the functioning of the immune system (lymphocytes)
- State the role of antibiotics in controlling bacterial infections.
- Infer the causes of bacterial resistance.
- Explain the transmission of zoonotic diseases.
- Explain the role of vaccines in developing immunity.
- Describe the interdependence of a population in building herd immunity.
- Evaluate data related to COVID-19 pandemic.

C3. Interaction and interdependence: Organisms / C3.2 Defence against disease

**Investigation****Section**

Student...

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- **IB learner profile attribute:** Inquirer
- **Approaches to learning:** Research skills – Evaluating information sources for accuracy, bias, credibility and relevance
- **Tool 3:** Mathematics – Applying general mathematics:
  - Calculate rates of change from graphical or tabulated data
  - Calculate and interpret percentage change and percentage difference
- **Inquiry 2:** Collecting and processing data – Interpret diagrams, graphs and charts
- **Time required to complete activity:** 30 minutes
- **Activity type:** Individual activity

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## Your task

Overview  
 (/study/app/422-cid-755105/o)

Malaria is an infectious disease transmitted by the bite of a female *Anopheles* mosquito. There are different forms of malaria caused by protists like *Plasmodium vivax* and *Plasmodium falciparum*. The easiest way to control malaria is to prevent mosquito bites and to prevent mosquitoes from breeding.

The Malaria Atlas Project looked at the prevalence of malaria around the world in 2020. Study the map (<https://data.malariaatlas.org/trends?year=2020&metricGroup=Malaria&geographicLevel=admin0&metricSubcategory=Pv&metricType=count&metricName=incidence>) and discuss the following.

- Identify the regions of the world where malaria is prevalent.
- Is there a relationship between latitude and malaria outbreaks? Is there a relationship between longitude and malaria outbreaks?
- Do you think these regions would be risk areas for other mosquito-borne infections?
- Calculate the percentage change in the number of clinical cases (global) of *P. vivax* (*Pv*) from 2015 to 2020. What can you infer from this?
- Calculate the percentage change in the number of clinical cases and the number of deaths due to *P. falciparum* (*Pf*) from 2015 to 2020. What can you infer from this?
- Find out the number of clinical cases of *P. vivax* in Papua New Guinea and Ethiopia in 2020 from the graph.

Calculate the percentage difference and discuss what this means.

### Section

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C3. Interaction and interdependence: Organisms / C3.2 Defence against disease

## Reflection

### Section

Student... (0/0)

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### Teacher instructions

The goal of this section is to encourage students to reflect on their learning and conceptual understanding of the subject at the end of this subtopic. It asks them to go back to the guiding questions posed at the start of the subtopic and assess how confident they now are in answering them. What have they learned, and what outstanding questions do they have? Are they able to see the bigger picture and the connections between the different topics?

Students can submit their reflections to you by clicking on 'Submit'. You will then see their answers in the 'Insights' part of the Kognity platform.

### Reflection

Now that you've completed this subtopic, let's come back to the guiding question introduced in [The big picture](#) (/study/app/bio/sid-422-cid-755105/book/big\_picture\_id-43543/).

- How do body systems recognise pathogens and fight infections?
- What factors influence the incidence of disease in populations?

With these questions in mind, take a moment to reflect on your learning so far and type your reflections into the space provided.

You can use the following questions to guide you:



Overview  
(/study/app/  
422-  
cid-  
755105/o

- What main points have you learned from this subtopic?
- Is anything unclear? What questions do you still have?
- How confident do you feel in answering the guiding questions?
- What connections do you see between this subtopic and other parts of the course?

⚠ Once you submit your response, you won't be able to edit it.

0/2000

Submit

### Rate subtopic C3.2 Defence against disease

Help us improve the content and user experience.



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