6 Disease challenges and strategies

KEY KNOWLEDGE

In this topic, you will investigate:

Disease challenges and strategies
- the emergence of new pathogens and re-emergence of known pathogens in a globally connected world, including the impact of European arrival on Aboriginal and Torres Strait Islander peoples
- scientific and social strategies employed to identify and control the spread of pathogens, including identification of the pathogen and host, modes of transmission and measures to control transmission
- vaccination programs and their role in maintaining herd immunity for a specific disease in a human population
- the development of immunotherapy strategies, including the use of monoclonal antibodies for the treatment of autoimmune diseases and cancer.

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PRACTICAL WORK AND INVESTIGATIONS

Practical work is a central component of learning and assessment. Experiments and investigations, supported by a practical investigation eLogbook and teacher-led videos, are included in this topic to provide opportunities to undertake investigations and communicate findings.
6.1 Overview

Numerous videos and interactivities are available just where you need them, at the point of learning, in your digital formats, learnON and eBookPLUS and at www.jacplus.com.au.

6.1.1 Introduction

The world’s population is constantly increasing, with greater numbers of people moving greater distances. More interactions are happening between humans and pathogens, resulting in a continuous struggle between the two groups. Population movement is having an impact on both humans and our health systems globally. This can be seen in increases in outbreaks of diseases such as HIV/AIDS; the emergence of new diseases such as severe acute respiratory syndrome (SARS) and coronavirus disease (COVID-19); and the re-emergence of ancient diseases such as tuberculosis (TB).

Diseases have existed since before the first humans walked the Earth. However, it was not until the work of scientists, such as Robert Koch and Louis Pasteur, during the nineteenth century that there was greater understanding about disease transmission, impacts and control measures. In the twenty-first century, increased interaction between humans, and between humans and other animals and microorganisms, has meant greater risk of exposure to new pathogens and diseases. It has become a global challenge to control the spread of infectious diseases. However, new treatments are constantly being developed, from new antibiotics and antiviral drugs to immunotherapy strategies, such as the use of monoclonal antibodies like herceptin (which can be seen in the topic opener image).
6.2 The emergence and re-emergence of pathogens

**KEY KNOWLEDGE**

- The emergence of new pathogens and re-emergence of known pathogens in a globally connected world, including the impact of European arrival on Aboriginal and Torres Strait Islander peoples

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### 6.2.1 Different types of diseases

**Disease** is a condition in a living animal or plant body that impairs the normal functioning of an organ, part, structure or system. Broadly, we can split diseases into two main types: **non-infectious** and **infectious**.

**Non-infectious, or non-communicable, diseases cannot spread from affected people to healthy people via the environment. Examples include environmental, nutritional and inherited diseases.**

**Infectious or communicable diseases can be transmitted from one individual to another. These diseases are caused by pathogenic agents.**

#### Non-infectious diseases

Non-infectious diseases include:

- genetic diseases
- degenerative diseases
- nutritional diseases
- social diseases
- nutritional diseases
- cancers
- physiological malfunctions
- cardiovascular diseases.

#### Infectious diseases

In the early twentieth century, infectious diseases, such as pneumonia, cholera, diphtheria, tuberculosis (TB) and influenza, were some of the diseases that were determined to be the main causes of death in human beings.

However, by the end of the twentieth century, scientists had developed vaccines against some pathogens, which resulted in the near eradication of diseases such as mumps, measles, mumps, whooping cough, diphtheria and polio — at least in the developed world. Worldwide, only one disease affecting humans has been completely eradicated, which is smallpox. Therefore, many infectious diseases continue to be a threat to public health.

Every year, around five new diseases emerge in human beings due to factors such as environmental change, population growth and urbanisation.

**Emerging diseases** are defined as:

- a disease caused by a newly identified or previously unknown agent
- a disease that has existed in other species but whose incidence in humans has increased in the past two decades, either locally or internationally.

**A re-emerging disease** is a disease which reappears after a significant decline in its incidence. Re-emerging diseases were once controlled but have increased to a level that causes significant health issues.
TABLE 6.1 Examples of emerging and re-emerging diseases

<table>
<thead>
<tr>
<th>Category</th>
<th>Disease</th>
<th>Agent</th>
<th>Year identified</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Variant Creutzfeldt–Jakob disease (vCJD or mad cow)</td>
<td>Prion BSE</td>
<td>1996</td>
</tr>
<tr>
<td></td>
<td>Severe Acute Respiratory Syndrome (SARS)</td>
<td>SARS associated coronavirus</td>
<td>2003</td>
</tr>
<tr>
<td></td>
<td>Middle East Respiratory Syndrome</td>
<td>MERS coronavirus</td>
<td>2012</td>
</tr>
<tr>
<td></td>
<td>Zika</td>
<td>Zika virus</td>
<td>2007</td>
</tr>
<tr>
<td></td>
<td>COVID-19 (coronavirus)</td>
<td>SARS-CoV-2</td>
<td>2019</td>
</tr>
<tr>
<td>Re-emerging</td>
<td>Increase in incidence (re-emerging)</td>
<td>Ebola haemorrhagic fever</td>
<td>1976</td>
</tr>
<tr>
<td></td>
<td>Dengue</td>
<td>Dengue virus</td>
<td>1943</td>
</tr>
<tr>
<td></td>
<td>Cholera</td>
<td>Vibrio cholera</td>
<td>1854</td>
</tr>
</tbody>
</table>

FIGURE 6.2 A map showing global examples of emerging and re-emerging diseases as of 2020.

Some other examples of the emergence or re-emergence of disease include:
- unknown microbes or new strains or variants causing new diseases — for example, SARS and Zika virus
- known agents causing new diseases — for example, the Hanta virus in the United States in 1993 caused respiratory disease instead of kidney disease
- microbes of animal origin causing diseases in humans — for example, the influenza virus in pigs causing swine flu in humans.

In many cases, the disruption of ecosystems by humans and increased travel has increased our exposure to new or re-emerging disease-causing agents.
6.2.2 Pathogens, pandemics and epidemics

In 1918, the spread of the influenza virus (the ‘Spanish flu’) was facilitated by the deployment of large numbers of soldiers from different countries to the battlefields of Europe, from where it spread to Russia and even Greenland. In 1919, the spread of the virus was further facilitated by the demobilisation of soldiers returning to their home countries.

The world is more connected than ever before. The increased availability of air travel has allowed more individuals to move easily between countries. Technology and communication has improved so that people can connect across the world, which can be beneficial for providing health information and warnings, but it can also lead to miscommunication and the spread of incorrect information.

The greater mobility of people in the twenty-first century, particularly by air travel, has created the opportunity for pathogens to be exported from one country by infected passengers to another country in a day or less.

As the world is now so much more connected, pathogenic agents that in the past may have been isolated to only one region can more easily spread across multiple countries and regions. These can then develop into epidemics and/or pandemics. The terms pandemic and epidemic both relate to the uncontrolled spread of infectious diseases, but they differ in geographic spread. A pandemic affects a much larger geographical area compared with an epidemic. It affects multiple world regions (figure 6.3). In an interconnected world, an epidemic can develop into a pandemic (but not vice versa).

**FIGURE 6.3** The six different World Health Organization (WHO) regions and the location of the WHO offices in each region

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**pandemic** a situation when, over a relatively short time, many people worldwide contract a specific disease as it spreads from a region of origin

**epidemic** the widespread occurrence of an infectious disease in a community or in a restricted geographic area at a particular time
What is a pandemic?

A pandemic (from the Greek: pan all; demos people) refers to the global outbreak of a disease. Other definitions include:

- an outbreak of a disease that occurs over a wide geographic area and affects an exceptionally high proportion of the population (Merriam-Webster)
- the worldwide spread of a new disease (WHO).

For the WHO to declare an event as a pandemic, the infection must spread easily and sustainably among human populations in at least three countries in at least two different WHO regions.

Note that the term ‘pandemic’ refers to the spread of a disease, not to the severity of the disease — a pandemic could involve the global spread of a pathogen that causes a mild disease. However, the pandemics that attract greatest public interest and media coverage are those in which the disease involved is severe and has a high death rate.

**CASE STUDY: Examples of pandemics**

Examples of pandemics since the start of the twentieth century have included:

- **The influenza pandemics**: these include the 1918 (Spanish flu), 1957 (Asian flu), 1968 (Hong Kong flu) and the 2009 pandemics (11 June 2009–10 August 2010). Each of these pandemics resulted from a major change in the influenza A virus, known as a ‘shift’, that created a new or novel influenza A virus to which the population had no immunity.

**FIGURE 6.4** Death rates for five-year age groups for the 1919 influenza pandemic in New South Wales. Note that the second wave of the pandemic was more deadly than the first wave. (Reproduced by permission, NSW Ministry of Health, 2016 — Influenza Report 1920.)

- **The HIV/AIDS pandemic**: AIDS was recognised as a new disease in 1981. Its origin traces back to a cross-species transmission to humans of a virus (SIV) that naturally infects non-human African primates. Since the beginning of the pandemic, almost 71 million people have been infected with the HIV virus and about 34 million people have died from HIV.

- **Cholera**: Cholera has killed tens of millions of people throughout history. While pandemics of cholera are less common now, it still poses a severe threat in developing countries, with outbreaks occurring often. Over the past 200 years, there have been seven main cholera pandemics. The most recent pandemic occurred in the 1970s.

- **COVID-19 (SARS-CoV-2)**: On 11 March 2020, COVID-19 caused by the virus SARS-CoV-2 (often referred to as coronavirus) was declared a pandemic by the WHO.
CASE STUDY: COVID-19

In recent times, the biggest health pandemic seen was that of COVID-19 (coronavirus), a disease caused by the virus SARS-CoV-2. Differences between COVID-19, the common cold and influenza can be seen in Table 6.2. While the first infections were reported in 2019, the pandemic had its greatest impact in 2020. This affected the lives of individuals globally, not just through widespread infections and fatalities but on a vast economic scale. As a result of coronavirus, many countries locked down and implemented regulations around quarantine, the use of masks and social distancing. The spread of coronavirus worldwide reflected the hazards of a globally connected world.

Many documented cases exist of travellers who spent time in countries where COVID-19 was present and who inadvertently brought the virus back to their home countries. An outline of some of the key events in this pandemic are as follows:

- In December 2019, several individuals in the city of Wuhan, China, were reported to have unusual cases of pneumonia.
- In early January 2020, these unusual cases of pneumonia were determined to be caused by a novel coronavirus.
- On 9 January 2020, the first death in China from coronavirus was reported.
- By 13 January 2020, the first case of coronavirus was officially reported outside of China. A woman, who had travelled from Wuhan, was diagnosed in Thailand.
- By late January 2020, Wuhan was placed under quarantine.
- The first case of coronavirus was diagnosed in Australia on 25 January 2020.
- On 30 January 2020, the coronavirus was declared a global emergency by the WHO. On March 11, the WHO officially declared coronavirus a pandemic.
- At the start of March 2020, around 90,000 global cases of coronavirus had been reported. By the start of May, this had risen to over 4 million. In January 2021, almost a year after the first Australian case was documented, 100 million cases had been recorded globally, with over 2 million deaths.
- Almost a quarter of these cases were documented in the United States. Other countries that had high case numbers included India, Brazil, France, Russia, Spain and the United Kingdom.
- Australia, at the start of March 2020, had 30 diagnosed cases. By mid May, there were around 7000 diagnosed cases, with approximately 100 deaths. By late November, Australian cases had reached around 28,000 (with 900 deaths). However, the number of new cases in Australia had dramatically dropped, apart from some small outbreaks linked to hotel quarantine.
- As numbers continued to skyrocket globally, international travel was prevented and regulated. These regulations eventually reduced travel across state borders within Australia.
- People in Victoria faced some of the toughest restrictions in Australia, with individuals only permitted to leave their homes for exercise, medical services, purchasing essential goods and to attend work (if essential). Most schools adjusted to home learning in Victoria (and the rest of Australia) worked to get the virus under control.
- In late 2020, numerous vaccines (such as the Pfizer mRNA vaccine and Astrazeneca viral vector vaccine) were approved for use in Australia to combat the spread of COVID-19 and see the end of the pandemic.

| TABLE 6.2 Comparisons of Influenza, the common cold and COVID-19 |
|------------------------|-----------------|------------------|
| **Symptom**            | **Influenza**   | **Common cold**  | **COVID-19**    |
| Cough                  | Common          | Common           | Common          |
| Difficulty breathing   | N/A             | N/A              | Common          |
| Headache              | Common          | Common           | Occasional      |
| Runny nose            | Occasional      | Occasional       | Occasional      |
| Fatigue               | Common          | N/A              | Occasional      |
| Fever                  | Common          | Rare             | Common          |
| Aches and pains       | Common          | N/A              | Occasional      |
| Sneezing              | N/A             | Common           | N/A             |
FIGURE 6.5 Data showing total number of cases of COVID-19 between January and November 2020 (data taken at the end of each month) a. globally b. in Australia

Resources

Weblinks
- Timeline of COVID-19
- Data related to COVID-19

How do pandemics occur?

The conditions that favour the emergence of a disease and the start of a pandemic include the following:

1. A new pathogen or a novel strain of an existing pathogen suddenly appears in geographic areas where the human populations have not previously come into contact with the pathogen. The suddenness of appearance means that:
   - most people will have little or no immunity to the pathogen
   - a vaccine is unlikely to exist or is available only in limited amounts that are not sufficient to prevent the spread of the pathogen.

2. The pathogen is the cause of an illness, often serious, in people. In many cases, a disease that can develop into a pandemic is caused by a pathogen that infects not only people but also other hosts, such as birds, pigs, bats and monkeys. These various non-human hosts act as reservoirs of the pathogen, moving to human hosts via suitable vectors.

3. The pathogen can be transmitted easily from person to person. This spread may occur:
   - by airborne particles coughed or sneezed by an infected person (as in influenza virus)
   - by contact with blood or other body fluids of an infected person (as in AIDS and Ebola virus fever)
   - via vectors, such as mosquitoes (as in Zika virus) or fleas (as in the plague), that transmit the pathogen from an infected person to an uninfected person.

4. Uncontrolled spread of the pathogen occurs across a wide geographic area. This spread may be facilitated by the movement of infected individuals from their home range and/or by the migration of infected vectors that transmit the pathogen from infected to non-infected individuals.

What is an epidemic?

An epidemic (from the Greek: *epi* upon; *demos* people) refers to the widespread occurrence of an infectious disease in a community or in a restricted geographic area at a particular time. With any epidemic, a concern is that the disease may spread more widely and become a pandemic.
CASE STUDY: Examples of epidemics

- **Severe acute respiratory syndrome (SARS):** The SARS epidemic in China (2002–2003) was caused by a new coronavirus that jumped from another species to humans; transmission of SARS occurred by respiratory droplets from coughs or sneezes of infected individuals.

- **Cholera (Haiti 2010–present):** this epidemic was caused by the bacterial species *Vibrio cholera*, which is transmitted through faecal-contaminated water or food; these bacteria produce a toxin that binds to cells of the intestinal wall and interferes with the normal flow of water, sodium and chloride ions.

- **Ebola (West Africa 2013–2016):** the Ebola virus is transmitted by direct contact of broken skin or mucous membranes with blood or other body fluids. This epidemic led to around 10 000 deaths from 2013 to March 2016.

- **Yellow fever epidemics:** Yellow fever virus is an RNA virus that belongs to the genus *Flavivirus*, the same genus as the Zika virus. Yellow fever disease is transmitted by the bite of infected female mosquitoes that acquire the virus when they feed on infected people or infected monkeys. One yellow fever epidemic occurred in Angola in 2016. By October 2016 the number of suspected cases was 4347, including 884 confirmed cases with 377 deaths, throughout all provinces of the country. In December 2016, Angola declared the end of this outbreak. Another epidemic of yellow fever occurred in 2016–2017 in Brazil. Due to recurring epidemics of this disease in South America, vaccinations for yellow fever are often recommended. To access more information about the Ebola and yellow fever epidemics, please download the digital document.

**on Resources**

**Digital document** Case study: The Ebola, Zika and yellow fever epidemics (2016–17)

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**SAMPLE PROBLEM 1 Comparing pandemics and epidemics**

In 2009, there was an influenza pandemic that caused concern around the world as it was similar to Spanish flu virus of 1918. Each of these pandemics resulted from a major change in the influenza virus.

What is the difference between a pandemic and an epidemic? (2 marks)

**THINK**

The question is asking you to provide differences between an epidemic and a pandemic. Provide clear differences between the two, considering the main difference of geographical area.

**WRITE**

An epidemic is an outbreak of a disease in a localised area or population (1 mark). If an epidemic spreads widely, it can become pandemic. A pandemic is an outbreak of a disease that occurs over a wide geographic area, affecting at least three countries in two different regions (1 mark).

**on Resources**

**eWorkbook** Worksheet 6.1 Comparing epidemics and pandemics (ewbk-7849)

**Weblink** Managing epidemics — WHO
6.2.3 The impact of European arrival on Aboriginal and Torres Strait Islander peoples

In 1770, James Cook, during a Pacific voyage, proclaimed part of Australia’s eastern coast as Crown land for the British government. In 1788, the First Fleet arrived from Britain and invaded the land that was already owned by the pre-existing Aboriginal peoples. British colonisation in Australia led to the dramatic decline in populations of Australian Aboriginal peoples (as shown in figure 6.6). One of the main reasons for this significant decrease was the introduction of new diseases to these populations to which they had no prior exposure.

The Torres Strait Islander peoples traded with the Aboriginal peoples of Cape York and the peoples of Papua New Guinea before the Europeans arrived. The initial European contact with Torres Strait Islander peoples was made in 1606, when Luiz Vaez de Torres sailed through the Torres Strait. After 1770, many British ships used the Torres Strait as a passage.

Despite only a small number of individuals being in the First Fleet (around 1500 in total), they brought in various new diseases and pathogens. Prior to this invasion and the passage through the Torres Strait, there was no evidence of these diseases in Aboriginal and Torres Strait Islander populations.

The major epidemic diseases brought to Australia during the early contact stage were smallpox, chickenpox, syphilis, tuberculosis, influenza and measles. These diseases devastated Aboriginal and Torres Strait Islander peoples, who had no immunity against them. Because these peoples had never been exposed to most of the new infectious microbes, there were large numbers of susceptible individuals and low herd immunity, resulting in the spread of new infectious diseases and significant fatalities.

There are several factors that contributed to the devastating effects of introduced diseases on Aboriginal and Torres Strait Islander peoples:

- previous exposure to pathogens
- route of transmission of pathogens
• population density of populations
• health and nutritional status of Aboriginal and Torres Strait Islander peoples
• intergroup social relationships.

Table 6.3 shows a list of diseases that were found in Aboriginal and Torres Strait islander peoples before and after European colonisation. The effect of these diseases and pathogens caused irreversible damage to Aboriginal and Torres Strait Islander peoples.

<table>
<thead>
<tr>
<th>Before colonisation</th>
<th>After colonisation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Botulism</td>
<td>Chicken pox</td>
</tr>
<tr>
<td>Ross River Fever</td>
<td>Influenza</td>
</tr>
<tr>
<td>Query (Q fever)</td>
<td>Measles</td>
</tr>
<tr>
<td>Hepatitis B</td>
<td>Mumps</td>
</tr>
<tr>
<td>Mononucleosis</td>
<td>Rubella</td>
</tr>
<tr>
<td>Tetanus</td>
<td>Smallpox</td>
</tr>
<tr>
<td>Salmonellosis</td>
<td>Syphilis</td>
</tr>
<tr>
<td>Scabies</td>
<td>Malaria</td>
</tr>
<tr>
<td>Roundworm</td>
<td>Typhus</td>
</tr>
<tr>
<td>Streptococcal diseases</td>
<td>Salmonellosis</td>
</tr>
</tbody>
</table>

**CASE STUDY: The introduction of smallpox**

Smallpox was one of the most virulent and deadly diseases that infected and killed millions of people. In 1789, a major smallpox epidemic broke out in Australia. The outbreak of this disease did not affect the British colonists. However, the Aboriginal peoples had no previous exposure to the smallpox virus and therefore had no resistance to the disease. Since there was no immunological protection or herd immunity to the disease, the epidemic resulted in a significant number of deaths in Australian Aboriginal peoples (estimated as 70 per cent of the population in areas that were settled). Questions still remain about the nature of this exposure. Was it a deliberate action by colonists or the accidental spread of a devastating disease?

**Resources**

- Australian history of colonisation
- Smallpox epidemic

**Key Ideas**

- Human demographic changes, such as increasing population and urbanisation results in overcrowding, which speeds up the chances of spreading diseases.
- Increased international travel, especially without taking appropriate vaccines and other protective measures, leads to increased infection in travellers who then bring the infection home with them.
- Without proper control measures, disease outbreaks can develop into an epidemic (a large spread in a restricted geographical area). Further spreading to countries other regions may lead to a pandemic.
- The arrival of Europeans in Australia and the Torres Strait exposed the original inhabitants to many new diseases to which they had no resistance, leading to widespread fatalities.
6.2 Activities

To answer questions online and to receive immediate feedback and sample responses for every question, go to your learnON title at www.jacplus.com.au. A downloadable solutions file is also available in the resources tab.

6.2 Quick quiz

6.2 Exercise

1. **MC** A new disease spreads through the United States, China and Japan. This is known as

2. List two conditions that would be needed for a pandemic to develop.

3. Give three examples of emerging diseases.

4. Using an example, explain what is meant by a re-emerging disease.

5. Identify the following statements as true or false. Justify your response.
   a. People exposed to new or novel pathogens would be expected to have little or no immunity to those pathogens.
   b. Some pathogens have multiple hosts.
   c. A pandemic could develop into an epidemic.
   d. Deaths from the Spanish flu were higher in fit young adults than in older people.

6. Explain the impact of European arrival on the Aboriginal and Torres Strait Islander peoples.

7. While smallpox is now eradicated, the effect of novel and new diseases affects many individuals worldwide.
   a. Explain what would happen if Australians colonised an area that had previously been isolated from the rest of the world.
   b. What preventative measures could be taken to protect native inhabitants?

6.2 Exam questions

**Question 1 (1 mark)**

**MC** Pandemics are often caused by viruses. The reason that pandemics are often caused by viruses, rather than other pathogens, is that viruses
   A. are more infectious than other pathogens.
   B. are carried overseas by wind and ocean currents.
   C. often evolve to become resistant to drug treatments.
   D. mutate into new strains to which humans have no immunity.

**Question 2 (1 mark)**

**MC** Which of the following is not a condition which would favour the start of a pandemic?
   A. Exposed individuals have never come in contact with the pathogen previously
   B. The illness only is able to infect humans
   C. The pathogen can spread across a wide geographical range.
   D. The pathogen can be easily transmitted from person to person.

**Question 3 (2 marks)**

There are several recently emerged diseases that have threatened to become pandemics, such as SARS (severe acute respiratory syndrome), Avian flu and Zika virus.

Explain how a disease that starts in a small population, such as a family or a small village, can spread around the world within weeks or a few months.

**Question 4 (5 marks)**

In recent years, outbreaks of Ebola have occurred in Africa. Ebola is caused by the Ebola virus which leads to a haemorrhagic fever. The chance of dying after contracting Ebola is much higher compared to other diseases.

There have been many outbreaks of Ebola documented since it was first identified in 1976. Over the past ten years, there have been three separate outbreaks of Ebola, all in Africa:
   - Western Africa: primarily in Guinea, Liberia and Sierra Leone between 2013 and 2016, leading to over 10 000 deaths
Kivu: primarily in Democratic Republic of the Congo and Uganda between 2018 and 2020, leading to over 2000 deaths

Democratic Republic of Congo: smaller outbreak in the Democratic Republic of Congo (in a different province).

a. Ebola is classified as a re-emerging disease. Define the term re-emerging disease and highlight how this differs to an emerging disease. 2 marks

b. Would the Western African outbreak be classified as a pandemic or epidemic? Justify your response. 1 mark

c. Outline the evidence that suggests that Ebola is an infectious disease rather than a non-infectious disease. 2 marks

Question 5 (4 marks)

In 1788, the First Fleet invaded and colonised Australia, land that was already owned and inhabited by Aboriginal peoples. The arrival of Europeans in Australia led to the introduction of many pathogenic agents that were not found on Australia previously.

a. Diseases such as smallpox, syphilis, measles and tuberculosis devastated the Aboriginal peoples, leading to a dramatic drop in population. However, it did not significantly affect the European colonists. Explain these observations. 2 marks

b. The initial European contact with Torres Strait Islander peoples was made in 1606. Would the same observations about the effect of European diseases on Aboriginal peoples have been seen in Torres Strait Islander peoples? Explain your response. 2 marks

More exam questions are available in your learnON title.

6.3 Identifying and controlling the spread of pathogens

KEY KNOWLEDGE

- Scientific and social strategies employed to identify and control the spread of pathogens, including identification of the pathogen and host, modes of transmission and measures to control transmission

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6.3.1 Bringing outbreaks under control

The emergence of new diseases and the re-emergence of older diseases is a continual threat to public health. Outbreaks, epidemics and pandemics all have the potential to lead to a large loss of human life and long-term health consequences.

As well as this, epidemics and pandemics can have a massive effect on the economy, not just in the cost of preventing the spread of the disease, but because of the secondary consequences that quarantining individuals may have, such as the closure of businesses, growth in unemployment and decline in stockmarkets. Therefore, it is vital that pathogens be identified and controlled as quickly as possible, through both the rapid identification of the pathogen and host and a thorough understanding of the mode of pathogenic transmission.

When an outbreak of a serious disease occurs and begins to spread rapidly through person-to-person contact, there is a risk of an epidemic. An epidemic, if not brought under control, has the potential to develop into a pandemic. In this situation, the ‘boots-on-the-ground disease detectives’ of the Epidemic Intelligence Service (EIS) are quick to move into the affected region to work with local officials. The EIS is part of the US Centers for Disease Control and Prevention (CDC). Other groups, including the World Health Organization (WHO) also work to rapidly obtain answers and bring outbreaks under control. In Australia, the Australian Health Protection Principal Committee (AHPPC) coordinates the response to possible health crises.
Personnel such as those from the EIS, WHO and AHPPC seek rapid answers to key questions such as:

- What is the cause of the sickness?
- If a pathogen is identified as the cause, how can it be treated and how can the disease be prevented from spreading?
- What measures are needed to prevent another outbreak?

**FIGURE 6.7** Photograph taken in Liberia during the 2014 West African Ebola outbreak. A CDC staff member is being assisted by a Médecins Sans Frontières (MSF) staff member in an essential decontamination process before exiting an Ebola treatment unit. A hypochlorite spray is known to destroy Ebola virus.

*Source: Centers for Disease Control*

How do people get infected?

The epidemiological triad model (figure 6.8) is used to explain the three main components of disease causation. The model consists of:

- an agent or pathogen: the disease-causing organism
- a host: the target of a disease (e.g., an organism that carries and/or gets infected by a pathogen)
- the environment: conditions that allow the disease to be transmitted

**6.3.2 Identifying pathogens**

When an infectious disease breaks out, speedy identification of the causal pathogen is critical. Knowing the identity of the pathogen guides decisions about treatment of the disease and preventing it from spreading.

**Identifying viruses**

Viruses, as non-cellular pathogens, were previously introduced in section 5.2.4 in topic 5. Unlike most bacteria, viruses cannot be replicated in standard microbiological broths or on agar plates. Instead, because they are obligate intracellular parasites, viruses require living cells in order to replicate. Viruses must be cultured inside suitable host cells.
Finding a suitable host cell is often a difficult part of viral identification. The virus needs to be isolated from a patient sample. The sooner this can be done during a disease outbreak the better, as more time can be used to create vaccinations and treatments before the spread of the virus is out of control.

Once a host cell is found suitable, it is then grown and multiplied in the laboratory to produce a cell line. The cell line is then used to grow the virus. Usually, cell lines to grow the virus need to be able to easily replicate. Some cells lines that are used are kidney cells, fibroblasts from lungs, chicken eggs and carcinoma cells (such as the Hep G2 cell line).

Once a sample of the virus is available, identification can proceed.

A range of techniques can be used to identify viruses, and they include physical methods, immunological methods and molecular methods. Viruses must be grown in cell culture for these techniques to be used.

**Physical methods**

Physical methods can assist in identifying viruses based on size and shape.

These methods include:

- x-ray crystallography, which has determined the structure of many viruses
- electron microscopy, which has given us images that distinguish various kinds of virus. Figure 6.9 shows the contrasting shapes of Ebola virus and influenza. A virus as revealed by transmission electron microscopy.

**Immunological methods**

Immunological methods detect specific viral antigens or antibodies. One of the main techniques used is the enzyme-linked immunosorbent assay (ELISA) technique which allows for the diagnosis of diseases (including viral diseases).

There are many different types of ELISA technique. The main types, highlighted in figure 6.10 are:

- Direct ELISA
- Indirect ELISA
- Sandwich ELISA.
Direct ELISA
Direct ELISA is the simplest form of ELISA. In direct ELISA, a viral antigen is placed on a surface. Matching primary antibodies bind to this antigen. These primary antigens have an enzyme indicator directly attached to them (as shown in figure 6.10a). The steps of direct ELISA are as follows:

1. A plate (called microtiter plate) with wells is coated with an antigen (or toxins) specific to the disease being tested.
2. An antibody specific to a particular antigen is added to each well. This antibody also has an associated enzyme indicator.
3. During incubation, antibodies present in the sample bind to the antigen in the well.
4. The wells are then washed using a detergent solution to remove any unbound antibodies.
5. The substrate for the enzyme is added, leading to a colour change if an antigen–antibody complex is formed. This indicates a positive test.

Indirect ELISA
Indirect ELISA is similar to direct ELISA. However, the primary antibody does not have an enzyme indicator. Instead, the enzyme indicator is attached to a secondary antibody. This secondary antibody is attached to the enzyme indicator. This can help amplify the signal, as multiply secondary antibodies can be used (as shown in figure 6.10b).

Sandwich ELISA
Another type of ELISA, known as sandwich ELISA, involves antibodies bound to the surface (as shown in figure 6.10c). This differs to direct and indirect ELISA, which use bound antigens. The steps in this process are as follows:

1. A ‘capture’ antibody is used to identify the presence of a specific viral antigen through an antigen–antibody reaction.
2. All unbound material is washed away with a detergent solution.
3. A second antibody with an enzyme indicator is then added. This binds to the antigen. As such, the antigen is ‘sandwiched’ between two antibodies.
4. The substrate for the enzyme indicator is added. If colour appears, the specific viral antigen is present.

Often, rather than having the enzyme indicator on the antibody that binds to the antigen, an additional antibody is added with this indicator. This binds to the antibody in a similar way to indirect ELISA.

**FIGURE 6.10** The ELISA technique can be used to detect either viral antigens or antibodies for the virus. **a.** Direct ELISA uses an antigen captured on a support and only one antibody with an enzyme indicator. **b.** Indirect ELISA also uses an captured antigen, but involves a primary and secondary antibody. **c.** Sandwich ELISA involves an antibody captured on the surface to detect antigens.
CASE STUDY: Using ELISA to diagnose HIV

The ELISA test can detect the presence of antibodies to specific viral disease in cells or body fluids (see figure 6.11). This is exemplified in the screening test used to detect the presence of antibodies to human immunodeficiency virus (HIV) in a person’s serum.

In this ELISA screening test, a serum sample from the person to be tested is diluted 400-fold and applied to a plate on which HIV antigens are immobilised. If antibodies to HIV are present in the serum, they can bind to the HIV antigens. All unbound material is washed away. A second antibody linked to an enzyme is then added. Because of its high sensitivity and ease of application, ELISA is a powerful tool in the identification of viruses and is used routinely to test and diagnose many viral diseases, including HIV.

Molecular methods

Molecular techniques can be used to identify viruses.

Viruses are diverse. One way in which they are diverse is in their nucleic acids. Viruses can have either DNA or RNA, and this can be single-stranded or double-stranded (refer to table 5.5 in subtopic 5.2). The specific sequences of certain viruses are known and can be used to confirm their identities.

Molecular techniques include the use of in situ hybridisation with probes to detect and locate specific genetic sequences that are diagnostic of particular viruses. This involves using a short radioactively labelled strand of nucleic acid (a probe) to bind to a specific sequence in tissue (in situ) through complementary base pairing. If the specific sequence is present, this can be easily located through the radioactive label on the probe.

Reverse techniques can be used to identify RNA viruses. This allows for visualisation of the presence of different viruses as well as the type of viruses present.

DNA sequencing can also be used to assist in the identification of viruses and their different strains. DNA sequencing involves determining the sequence of DNA using a specialised machine (up to 400 to 600 million bases over 10 hours). This involves adding nucleotides with coloured dyes (a different dye for each nucleotide used). The machine is fed the DNA sequence. Computers can then analyse and construct the DNA sequence from this data, as shown in figure 6.13.
Identifying bacteria

Identification of bacterial species is important for several reasons, such as deciding on antibacterial therapy for patients or identifying the clinical significance of bacterial infections.

Various techniques can be used to identify bacteria and they fall into three categories: phenotypic, immunological and genotypic methods.

Phenotypic methods

Phenotypic methods use techniques that involve identifying particular traits or features in bacteria. They include:

- use of microscopy to differentiate bacteria on the basis of differences in cell shape, size and response to Gram stain, and physical features such as the presence or absence of a capsule. (Many of these differences were introduced in section 5.2.3 in topic 5. Refer to the upcoming case study to learn more about Gram staining).
- use of a range of biochemical tests eliciting different bacterial responses
- use of different media to differentiate bacteria on the basis of variation in growth patterns. This may be done by observing growth on non-selective, selective and differential media.
  - Non-selective media or agar can be used to detect and count the number of bacteria in the sample.
  - Selective media contain compounds such as antibiotics or growth nutrients, that selectively inhibit or enhance the growth of specific bacteria. For example, selective media can be used to distinguish aerobic bacteria from facultative anaerobes (which can survive with or without oxygen) and obligate anaerobes (which can only survive in anaerobic conditions).
  - Differential media contain a substrate that, under the action of an enzyme, produces a coloured or fluorescent product. This can identify bacteria according to various chemical reactions that are carried out during growth.

**FIGURE 6.14** Numerous biochemical tests being conducted at once to identify *Listeria monocytogenes*
An example of the process used to identify bacteria based on different properties is shown in figures 6.15 and 6.16.

**FIGURE 6.15** Diagram showing the identification of four species of Gram-negative bacteria based on their reactions to several biochemical tests

![Diagram](image)

**FIGURE 6.16** a. Positive indole test b. Methyl red test (red is positive) c. Citrate test (blue is positive)
CASE STUDY: What is Gram staining?

A special stain, known as Gram stain, is commonly used for the general identification of bacteria. This stain separates bacteria into two main groups, Gram-positive and Gram-negative, depending on the structure of their cell wall.

This staining technique involves the use of two dyes as outlined in figure 6.17. Some bacteria retain the first dye (crystal violet) and appear dark blue — these bacteria are said to be Gram-positive. In contrast, other bacteria do not retain the crystal violet dye and instead are stained by a second dye (safranin) so that they appear red or pink — these bacteria are said to be Gram-negative.

**FIGURE 6.17 Steps in the Gram staining technique**

1. Bacteria are stained with the dye crystal violet.
2. Iodine stabilizes the crystal violet.
3. Alcohol is used to extract the crystal violet from the Gram-negative cells.
4. Bacteria are stained with the dye safranin.

The contrasting responses of bacteria to Gram staining are due to differences in the structure of the external cell wall that lies outside the plasma membrane of bacterial cells. The cell wall of Gram-positive bacteria contains a thick layer of peptidoglycan (as shown in figure 6.18b), which retains the crystal violet dye used in the Gram staining technique.

Gram-negative bacteria have an outer membrane made of lipopolysaccharide (LPS) (see figure 6.18b). This LPS outer membrane enables these bacteria to expel or exclude certain drugs and antibiotics.

Due to the presence of this LPS outer membrane, Gram-negative bacteria are generally far more resistant to antibiotic treatment than are Gram-positive bacteria. Gram-positive bacteria are normally susceptible to antibiotics, such as penicillin and the sulfonamide drugs, but these antibiotics are not effective against Gram-negative bacteria. So, the result of Gram staining can give an indication of the type of antibiotic treatment that could usefully be given to a person with a bacterial disease.

**FIGURE 6.18.** a. Light microscope (LM) image showing the results of Gram staining of two kinds of bacteria. The majority of the bacteria are Gram-positive cocci stained purple, while the other bacteria are Gram-negative and are stained pink. b. Differences in Gram-positive and negative bacteria.

*peptidoglycan* a polymer consisting of sugars and amino acids that forms a major part of the cell wall of Gram-positive bacteria.
If a bacterial infection is suspected, Gram staining is carried out on either body fluids or cell samples. This procedure is a quicker method of identifying the presence of bacteria than that of culturing them (growing bacteria on a medium such as nutrient agar).

**TABLE 6.4** Examples of Gram-positive and Gram-negative bacteria

<table>
<thead>
<tr>
<th>Gram-positive bacteria</th>
<th>Gram-negative bacteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Streptococcus pyogenes</td>
<td><em>Escherichia coli</em></td>
</tr>
<tr>
<td>Staphylococcus pneumonia</td>
<td><em>Vibrio cholerae</em></td>
</tr>
<tr>
<td>Staphylococcus aureus</td>
<td><em>Yersinia pestis</em></td>
</tr>
<tr>
<td>Clostridium botulinum</td>
<td><em>Neisseria meningitidis</em></td>
</tr>
<tr>
<td>Clostridium tetani</td>
<td><em>Helicobacter pylori</em></td>
</tr>
<tr>
<td>Bacillus anthracis</td>
<td><em>Legionella pneumophila</em></td>
</tr>
<tr>
<td>Corynebacterium diphtheria</td>
<td><em>Treponema pallidum</em></td>
</tr>
</tbody>
</table>

**INVESTIGATION 6.1**

**Gram staining and biochemical testing**

**Aim**

To identify different types of bacteria using various phenotypic methods

**Genotypic and molecular methods**

**Genotypic and molecular methods** involve the examination of the genetic material of bacteria and use techniques such as gene probes, sequence analyses and plasmid fingerprinting to identify bacteria. Because of their speed and accuracy, genotypic techniques are increasingly important in the identification of bacteria and identification of the various **serotypes** of a single bacterial species. Figure 6.19 shows one example of a laboratory test to detect different serotypes. These serotypes of *Streptococcus* are tested on cards. Solutions containing antibodies that target specific parts of each serotype are added. If a sample is a certain serotype, a positive result is caused by the binding of the antibody with the specific antigen. The three main techniques used for serotyping are as follows:

- **Gene probes** are specifically designed, radioactively labelled sequences of nucleic acids that bind to specific genes. This may be a gene that is found in a certain type of bacterium or a specific serotype.
- **Sequence analyses** involve determining the order of sequences of the nucleotides in the bacterial DNA.
- **Plasmid fingerprinting** involves using DNA profiling techniques similar to those explored in topic 2) to identify the genetic profiles of specific plasmids and thus determine a bacterial species and strain. This can allow for the bacterial species and strain to be determined.

**genotypic and molecular methods** methods of identifying bacteria by examining its genetic material

**serotypes** variants within a species of bacterium or virus that are distinguished by their surface antigens.
Immunological methods

Immunological methods use techniques including monoclonal antibodies, ELISA and immunofluorescence to identify bacteria. These immunological methods are used in the following ways:

- Monoclonal antibodies are antibodies that are designed to have a specific antigen-binding site. These can be formed to target and bind to particular bacterial antigens. Monoclonal antibodies will be further explored in subtopic 6.5.

- ELISA was introduced in the subsection on identifying viruses, and works in a similar way for bacteria (refer back to figure 6.10). ELISA for bacteria can be used not only to detect antigens or antibodies, but also to detect toxins specific to a certain bacterium. Direct, indirect and sandwich ELISA may all be used for this. Another type of ELISA, known as reverse ELISA, may also be used to identify particular strains of bacteria. This technique does not use traditional wells, but leaves the antigens suspended in fluid.

- Immunofluorescence, in a similar way, uses an antibody with a fluorescent marker to bind to and detect specific antigens or antibodies in serum.

**SAMPLE PROBLEM 2 Using ELISA and immunological methods**

ELISA is a technique designed for detecting substances such as peptides, proteins, antibodies and hormones using antibodies and colour changes. ELISA is a common medical and research lab technique.

**a. Why is ELISA able to be used for both the detection of viruses and of bacteria?** (2 marks)

**b. Describe how ELISA can be used to detect substances.** (4 marks)

**c. Other than ELISA, phenotypic techniques can be used in the detection of bacteria. Provide two examples of phenotypic techniques.** (2 marks)

**THINK**

**a. 1.** Consider factors that both viruses and bacteria have in common that would be useful for ELISA. Outline the selected factor.

   2. Describe how this would be linked to ELISA.

**b. 1.** The question is asking you to describe and is worth four marks. Therefore, you need to consider your key factors on how ELISA is used. As this question does not mention direct, indirect or sandwich ELISA, you may select which you describe.

   2. Consider the factors involved in ELISA. You should ensure you mention both the antigens and antibodies, the antibody-antigen complex and the use of a substrate to signal a positive test. *Note*: While these have been shown in dot points for clarity, you may write a clear paragraph with four distinct points, with clear interlinking of ideas.

   **WRITE**

   Both viruses and bacteria have antigens that stimulate an immune response and the production of antibodies (1 mark).

   Therefore, ELISA works for both of these, as the specific antigens and antibodies can be used to allow a positive or negative result to be observed (1 mark).

   - A plate with wells is coated with an antigen (bacterial toxin) specific to the disease being tested (1 mark).
   - An antibody specific to a particular antigen is added to each well. During incubation, antibodies present in the sample bind to the antigen in the well (1 mark).
   - Next, enzyme-linked secondary antibodies are added to the well. If the antigen is present, the secondary antibodies bind to the antigen (1 mark).
   - A substrate is added which reacts with enzymes to produce a colour change, indicating a positive test (1 mark).
c. 1. This question asks only for examples and not an explanation. You should ensure you only follow the instructions of the question and do not provide extra information that may be incorrect.

2. Consider aspects of phenotypic testing: biochemical tests, Gram staining, growth in different media and microscopy.
   - Testing the growth of bacteria in different media
   - Biochemical tests (such as indole production)

Other pathogenic agents
While bacteria and viruses are some of the more common causes of diseases that are easily transmissible, they are not the only source of infections. In similar ways, other pathogens such as fungi, protozoa, prions and parasites need to be quickly identified to prevent the spread of disease. This can be done by identifying particular physical features, by genetic and molecular means or immunological techniques.

Resources

Resources

- Workbook Worksheet 6.2 Identifying pathogens (ewbk-7853)
- Weblink Identifying enteric pathogens

6.3.3 Identifying the host

Reservoirs and hosts
Transmission occurs when a pathogen-agent leaves its reservoir or host through a point of exit, is transmitted and enters through a point of entry to infect a susceptible host.

It is important to be able to identify both the reservoir and/or the host when exploring infectious diseases. This can assist with quarantine (isolating people who are infectious) or through other preventative measures (such as the use of insect repellent in areas where mosquito-borne infections are prevalent).

FIGURE 6.20 The chain of infection from reservoir to hosts

- Reservoir
- Agent
- Mode of transmission
- Susceptible host
- Portals of entry
- Vehicle
- Vehicle
- Airborne

transmission passing a pathogen on to another individual
reservoir the habitat in which a pathogen lives, grows and multiplies
quarantine the act of isolating infected individuals to prevent the spread of a disease
The reservoir of a pathogen is the habitat in which it lives, grows and multiplies. Reservoirs may or may not be the source from which the pathogen is transferred to its host. Reservoirs do not experience symptoms of the disease.

Reservoirs can include:

- humans
- animals: zoonotic diseases are infectious diseases that are transmitted from animals to humans. Some examples of zoonotic diseases include plague (rodents), anthrax (sheep) and rabies (dogs and other mammals).
- the environment: plants, soil and water are also reservoirs for some infectious agents.

A host refers to the organism who can get the disease (such as humans). Many infectious agents can infect more than one host (for example, swine flu was able to infect both humans and pigs).

Susceptibility of a host depends on many factors, including:

- genetic factors: an individual’s genetic condition affects their susceptibility to infection. For example, an individual suffering from sickle cell anaemia is less likely to get malaria.
- specific immunity: initial exposure to a pathogenic agent provides protection to the host in the form of specific antibodies. Such antibodies develop during secondary exposure to the pathogen and provide protection to the host.
- sex
- age
- nutrition.

Index cases

During an outbreak, epidemic or pandemic, it is vital to be able to determine the host and reservoir of a disease. Often, this involves finding ‘patient zero’. Patient zero or the index case, is the first individual to have a case of an infectious disease. This allows for not only the spread of an infectious disease to be better tracked, but also allows for the pathogenic agent (and other possible reservoirs) to be detected as early as possible.

It can be quite difficult to determine patient zero, particularly if a disease has a long incubation period. Often, many people are diagnosed around a similar time, such as in the case of COVID-19. In the case of Ebola, patient zero was more easily traced. It was also the case of an outbreak of typhoid fever, where patient zero was determined to be Mary Mallon (read about this in the case study box in 6.3.4).

While finding patient zero can help, it is more important to identify how a pathogen can be spread, and what organisms are able to spread an pathogenic agent, in order to improve preventative measures. This is often done through epidemiological studies.

6.3.4 Modes of pathogen transmission

If a pathogen can gain entry to the human body and reach the target cells, it may multiply rapidly and produce an infection. If the body’s immune system cannot overcome an infection, the infection will develop into a disease. So, an infection is not equivalent to a disease, but infection is a necessary pre-condition for an infectious disease.

Before an infection can develop into a disease, several events must occur. The pathogen, whether bacterial, fungal or viral must first:

- gain entry to the body and reach target site(s) in the body; typically, the portals of entry are the skin and the mucous membranes of the respiratory, uro-genital, and digestive systems of the body
- overcome the defence mechanisms of the body
• become established at one or more sites
• multiply rapidly, causing harm to the host and producing the symptoms of the disease.

**Modes of transmission**

Infectious diseases may spread from infected people to healthy people by various means:

- by direct transmission, such as by person-to-person contact, through kissing or sexual contact (e.g. chickenpox, chlamydia and conjunctivitis)
- by indirect transmission, such as:
  - by airborne droplets or particles, such as an uncovered sneeze or cough (e.g. influenza, hepatitis A and coronavirus)
  - by contact with contaminated objects, such as bedding, cups or medical instruments (e.g. glandular fever or tetanus)
  - by ingestion of contaminated food or water (e.g. salmonella, cholera and gastroenteritis)
  - by biological vehicles, such as contaminated blood, sputum, or faeces (e.g. HIV and hepatitis B and C)
  - by vectors that carry pathogenic agents and spread them to people through bites from infected ticks, mites, fleas or mosquitoes, or through contaminated particles that they leave on material, such as fly droppings on food. (e.g. bubonic plague, psittacosis, anthrax, West Nile virus disease and rabies). Many of these vectors transmit pathogens from their natural host (e.g. birds, bats or rodents) to people. These diseases are referred to as zoonotic diseases or zoonoses.

Many diseases have multiple forms of transmission. For example, glandular fever can be spread both through indirect means by being exposed to infected saliva (such as contaminated objects like drink bottles) or through direct contact such as kissing.

**FIGURE 6.21 Modes of transmission**

**When can pathogens be transmitted?**

Often, when individuals feel unwell, they are recommended to self-isolate to prevent the spread of pathogenic agents. This idea of self-isolation was a common occurrence during the COVID-19 pandemic, when unwell individuals were urged to get tested and stay home. However, the issue with the spread of diseases is that individuals can be infectious without showing symptoms.
Some pathogens can be transmitted from an infected person to a healthy person only after the infected person shows visible symptoms of the disease. These pathogens include those responsible for diseases such as Ebola virus disease, typhoid and pertussis. In contrast, other pathogens, including those causing diphtheria, rubella, influenza, measles and tuberculosis, can be transmitted, not only by people showing obvious disease symptoms, but also by infected people during the incubation period when they show no symptoms of the disease.

**Incubation period**

The period after infection and before the first symptoms of a disease appear is called the **incubation period**. An incubation period is the interval between a person’s exposure to a pathogen and the onset of disease symptoms in that person. During the incubation period, the disease-causing agent multiplies to concentrations that are sufficient to produce the symptoms of the disease.

<table>
<thead>
<tr>
<th>TABLE 6.5 Incubation periods for several diseases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disease</td>
</tr>
<tr>
<td>------------------</td>
</tr>
<tr>
<td>Salmonellosis</td>
</tr>
<tr>
<td>Influenza</td>
</tr>
<tr>
<td>Common cold</td>
</tr>
<tr>
<td>Coronavirus (COVID-19)</td>
</tr>
<tr>
<td>Typhoid</td>
</tr>
<tr>
<td>Measles</td>
</tr>
<tr>
<td>Tuberculosis</td>
</tr>
<tr>
<td>HIV</td>
</tr>
<tr>
<td>Kuru</td>
</tr>
</tbody>
</table>

**Asymptomatic carriers**

In addition, some people can be infected by a pathogen but be in good health and never show any signs or symptoms of the disease concerned. Such people are said to be **asymptomatic carriers** of the pathogen concerned and they can be a source of infection of people with whom they come in contact. Perhaps the most famous asymptomatic carrier of an infectious disease was Mary Mallon (1869–1938), who was infected with the *Salmonella typhi* bacteria, which cause typhoid fever.

**CASE STUDY: Typhoid Mary**

Mary Mallon (1869–1938) worked as a cook for several wealthy families in New York City in the early 1900s. In each household where she was employed, family members came down with typhoid fever. Health authorities recognised the connection between Mary and the outbreak of typhoid fever in the family members in that household. This was the first time that an asymptomatic carrier of a pathogen had been identified. Mary is estimated to have transmitted the bacteria to about forty-seven people, three of whom died from typhoid fever.

To learn more about Typhoid Mary, please download the digital document.
6.3.5 Measuring the spread of a pathogen

Monitoring the spread

Part of controlling the spread of disease is through careful surveillance to measure and determine the extent of the spread of a pathogen. As part of this, the WHO often categorises the disease into different alert phases. These phases allow for the appropriate social and scientific courses of action to be undertaken. The earlier the intervention is made, the quicker a disease can be identified and controlled, reducing the chance of a global pandemic. An example of these phases in influenza is shown in the case study box. The WHO (and other health organisations) aim to intervene as soon as possible to avoid pandemic alert periods and pandemic periods.

CASE STUDY: Influenza and pandemic alert phases

TABLE 6.6 The WHO pandemic alert phases for influenza

<table>
<thead>
<tr>
<th>WHO phases</th>
<th>INTER-PANDEMIC PERIOD</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No new influenza virus subtypes have been detected in humans. An influenza virus subtype that has caused human infection may be present in animals. If present in animals, the risk of human disease is considered to be low.</td>
</tr>
<tr>
<td></td>
<td>No new influenza virus subtypes have been detected in humans. However, a circulating animal influenza virus subtype poses a substantial risk of human disease.</td>
</tr>
<tr>
<td>PANDEMIC ALERT PERIOD</td>
<td>Human infection(s) detected with a new subtype, but no human-to-human spread, or at most rare instances of spread to a close contact.</td>
</tr>
<tr>
<td></td>
<td>Small cluster(s) detected with limited human-to-human transmission but the spread is highly localised.</td>
</tr>
<tr>
<td></td>
<td>Larger cluster(s), but human-to-human spread is still localised, suggesting that the virus is becoming increasingly better adapted to humans, but may not yet be fully transmissible (substantial pandemic risk).</td>
</tr>
<tr>
<td>PANDEMIC PERIOD</td>
<td>There is increased and sustained transmission in the general population.</td>
</tr>
</tbody>
</table>

Quantifying the spread using $R_0$ values

The spread of a pathogen is often quantified using the $R_0$ value (the basic reproduction number). This value shows the expected number of individuals that are infected by one individual.

TABLE 6.7 Example $R_0$ values of different pathogens

<table>
<thead>
<tr>
<th>Infectious disease</th>
<th>$R_0$</th>
</tr>
</thead>
<tbody>
<tr>
<td>COVID-19 (Coronavirus)</td>
<td>3.5</td>
</tr>
<tr>
<td>SARS</td>
<td>4</td>
</tr>
<tr>
<td>Measles</td>
<td>18</td>
</tr>
<tr>
<td>HIV</td>
<td>4</td>
</tr>
<tr>
<td>Ebola</td>
<td>2</td>
</tr>
</tbody>
</table>

$R_0$ value the basic reproduction number that identifies the expected number of individuals a person with a certain disease will infect.
FIGURE 6.22 Comparing the spread of diseases with different $R_0$ values

Ebola
$R_0 = 2$
Initial infected individual
Infects approximately two others
These two individuals each infect two others

SARS
$R_0 = 4$
Initial infected individual
Infects approximately four others
These four individuals each infect four others

6.3.6 Controlling the spread of pathogens

Controlling the spread of pathogens includes various measures that prevent and contain the spread of infectious disease.

There are many factors that contribute to the spread of disease, including the climate, diet and availability of medical aid. By implementing the change in behaviour and human intervention, the rate of disease transmission can be controlled or inhibited.

Methods of disease control

- **Prevention.** The transmission of disease can be prevented by changing behaviours. Examples include practising personal hygiene such as washing hands, using condoms to prevent the spread of sexually transmitted diseases and using insect repellent to prevent the spread of a particular disease by vectors. The access to improved sanitation and clean drinking water is also a vital measure to prevent against diarrhoeal and parasitic diseases, such as cholera.
- **Vaccination.** Vaccination is a way of providing long-term protection against infectious diseases. Vaccines help in preventing and, in some cases, eradicating diseases. For example, child immunisation schedules have resulted in the dramatic decline of diseases such as measles and polio.
- **Medication.** Antibiotics for bacterial infections are just one of many medications now used to manage infectious diseases. The global monitoring of disease outbreaks is another tool used to control the spread of several diseases.
- **Modification of the environment.** The environment can be made less suitable for the microbes to grow and be transmitted. Examples may include vector control like in case of malaria.
- **Infection control standards.** These help in preventing the spread of infectious diseases, and include sterilisation, isolation (quarantine) and proper hygiene.
FIGURE 6.23 Mechanisms of controlling the spread of disease

- Prevention
- Vaccination
- Surveillance
- Vector control
- Infection control standards

Hygiene
Long-term immunity
Antimicrobial drugs
Monitor disease outbreaks
Spray to eliminate the breeding of vectors
Sterilisation
Isolation
Monitor disease
Detect outbreaks
Insect repellent
Clean surfaces

FIGURE 6.24 Preventative measures such as mosquito nets and the use of quarantine can help prevent the spread of infection.

SAMPLE PROBLEM 3 Analysing methods to prevent the spread of disease

In recent times, COVID-19, a respiratory disease caused by a coronavirus (COVID-19) resulted in many countries, including China, Italy, the UK, Australia and Spain being placed into lockdown. Numerous workplaces and schools were closed and large events (including the Australian Grand Prix, AFL and NRL seasons, and theatre programs) were postponed or cancelled.

Outline why the lockdown of countries, including a ban on all travel and closing of major events and busy locations, would be used to help prevent the spread of disease. (2 marks)

THINK
1. Carefully examine the question. The first aspect you need to address is why travel bans would prevent disease spread. Ensure you specifically link your answer back to COVID-19.

Isolating individuals by banning travel reduces the chance that COVID-19 can spread to other individuals. Some people may leave a location, not knowing they are infected, and spread it globally. By stopping travel, the chance of coronavirus travelling further is reduced (1 mark).

The second aspect you need to address is why closing major events and locations would be helpful to control the disease. Again, ensure you specifically link your answer back to COVID-19.

WRITE
Isolating individuals by banning travel reduces the chance that COVID-19 can spread to other individuals. Some people may leave a location, not knowing they are infected, and spread it globally. By stopping travel, the chance of coronavirus travelling further is reduced (1 mark).

Closing major locations and events also reduces the chance that an infected individual will pass the coronavirus causing COVID-19 to other individuals, particularly in a location with a large number of people such as a sportsevent. Usually, an infected individual will spread COVID-19 to at least two other people. This number would be much higher if there were large numbers of individuals in close proximity (1 mark).
Defence against infection

While prevention is always the preferred method to combat the spread of infection, in many cases this is not always possible. It is vital to treat individuals who have contracted diseases to ensure that their health does not decline or mortality occurs.

When a novel or emerging disease is identified, it is often a race to not only find a vaccination, but also to find an effective treatment for it. Not every disease has a treatment. In some cases, the immune system resolves the infection on its own. In other cases, the pathogen can be dormant, hiding in cells and causing further disease at a later date (such as with HIV and herpes). Sometimes, the only option is to treat the symptoms rather than the disease, to ensure an individual is in the best health possible for their immune system to fight the infection.

Treatments for bacterial and viral infections are different: antibiotics are used to treat bacterial infections, and antiviral agents are used for viral infections.

Antibiotics

Antibiotics are a class of antimicrobial drug used in the treatment and prevention of bacterial infections. They act either by killing pathogenic bacteria or by inhibiting their growth.

Some antibiotics are narrow spectrum and act against a limited variety of microorganisms; others are broad spectrum and act against many different kinds of pathogens.

Antibiotics are substances that, in low concentrations, inhibit the growth of or kill microorganisms.

Antibiotics can be:
- naturally produced by other microorganisms (such as penicillin produced by Penicillium moulds)
- semi-synthetic and produced partially by chemical synthesis (such as ampicillin, which is derived from penicillin)
- synthetic and produced wholly by chemical synthesis (such as sulphonamides).

Actions of antibacterial drugs

The general action of an antibiotic is either by directly killing microorganisms (bactericidal) or by inhibiting their growth (bacteriostatic).

Different antibiotics act on different bacterial targets (refer to figure 6.25). For example:
- penicillin inhibits cell wall synthesis in bacteria and so targets actively reproducing bacteria. Since human cells do not have peptidoglycan cell walls, penicillin does not attack human cells and so has low toxicity.
- chloramphenicol, erythromycin, tetracyclines and streptomycin inhibit protein synthesis by acting on the ribosomes (70S) of prokaryotic cells.
- sulfanilamide acts as an antimetabolite by competitively inhibiting enzyme activity in bacteria.
- rifampin and minocycline inhibit nucleic acid synthesis.

Using sensitivity tests to determine the best antibiotic

One of the biggest crises we face is antibiotic resistance in many bacteria. Many strains are becoming resistant to certain antibiotics, which creates challenges for their treatment and management (this resistance will be further explored in subtopic 7.7). To control the spread of an infection, it is vital to use an antibiotic that will kill the particular bacterium.
**FIGURE 6.25** Various targets of different antibiotics on pathogenic bacteria

- **Inhibition of cell wall synthesis:** Penicillins, cephalosporins, bacitracin, vancomycin
- **Inhibition of protein synthesis:** Chloramphenicol, erythromycin, tetracyclines, streptomycin
- **Injury to plasma membrane:** Polymyxin B
- **Inhibition of nucleic acid replication and transcription:** Quinolones, rifampin
- **Enzymatic activity, synthesis of essential metabolites:** Sulfanilamide, trimethoprim

**TABLE 6.8** Different antibiotics and their modes of action

<table>
<thead>
<tr>
<th>Drug</th>
<th>Spectrum</th>
<th>Mode of action</th>
<th>Possible side effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Erythromycin</td>
<td>Narrow (Gram +)</td>
<td>Inhibits protein synthesis so bacteria are unable to make essential compounds</td>
<td>Gastrointestinal upset, Liver damage</td>
</tr>
<tr>
<td>Penicillin</td>
<td>Narrow (Gram +)</td>
<td>Inhibits cell wall synthesis so bacteria cannot reproduce</td>
<td>Allergic responses</td>
</tr>
<tr>
<td>Sulfonamides</td>
<td>Broad (Gram + and -)</td>
<td>Compete against and inhibit the bacteria</td>
<td>Allergic responses, Kidney and liver damage</td>
</tr>
<tr>
<td>Tetracyclines</td>
<td>Broad (Gram + and -)</td>
<td>Inhibit protein synthesis so bacteria are unable to make essential compounds</td>
<td>Gastrointestinal upset, Teeth discolouration, Sometimes kidney and liver damage</td>
</tr>
</tbody>
</table>

**Sensitivity tests** are carried out to determine the antibiotic that would be most effective to treat a bacterial infection. In one kind of sensitivity test, bacteria are spread across the surface of a solid nutrient plate and small discs with known concentrations of different antibiotics are put on the surface of the plate (see figure 6.26). If the bacteria are sensitive to a particular antibiotic, they will be killed by that antibiotic and so will not grow around the disc containing that drug. The lack of growth is shown by a clear zone around the disc of antibiotic. The larger the clear zone around a disc, the more effective the antibiotic in that disc.
Testing drug sensitivity of *Staphylococcus aureus*. From 12 o’clock, the drugs are fusidic acid (FD10), penicillin G (P10), ciprofloxacin (CIP5), rifampicin (RD5), gentamicin (CN10) and vancomycin (VA30). This bacterium is very sensitive to FD10, CIP5 and RD5. It is resistant to P10. (Image courtesy of Marjory Martin.)

**INVESTIGATION 6.2**

**Optimal antibiotic concentrations**

**Aim**

To determine optimal concentration of ampicillin to inhibit the growth of *E. coli*.

**Antiviral drugs**

Antiviral drugs are a type of medication that is used specifically for treating viral infections. Typically, these drugs are effective only when the viruses are located within cells and are undergoing replication. Antibiotics are ineffective against viral infections.

Most of the antiviral drugs presently available are designed to address the viruses that cause influenza A and B, hepatitis B and C (which can cause liver cancer), HIV (which causes AIDS), and various herpes viruses that cause many diseases ranging from cold sores to genital herpes infections. Advances in both our understanding of the details of the viral replication cycle in host cells and of the 3D structure of viral proteins has contributed to the development of many highly specific and effective antiviral drugs.

The possible modes of action of antiviral agents include:
- prevent viral attachment and/or entry
- prevent replication of the viral genome
- prevent synthesis of specific viral protein(s)
- prevent assembly or release of new infectious virions.
FIGURE 6.27 a. Diagram showing the replication cycle of HIV in human CD4 T-helper cells and antiviral targets, b. Antiviral targets across various viruses

TABLE 6.9 Mode of action of various antiviral drugs and the viruses they target

<table>
<thead>
<tr>
<th>Mode of action of antiviral drug</th>
<th>Example of drug</th>
<th>Target of drug</th>
</tr>
</thead>
<tbody>
<tr>
<td>Block entry of virus to host cell by binding to surface receptors on host cell</td>
<td>Maraviroc</td>
<td>HIV/AIDS</td>
</tr>
<tr>
<td>Block fusion of virus with host cell by binding to surface protein (gp41) on virus</td>
<td>Enfuvirtide</td>
<td>HIV/AIDS</td>
</tr>
<tr>
<td>Block uncoating of virus by inhibiting action of viral membrane protein M2</td>
<td>Amantadine rimantadine</td>
<td>Influenza A</td>
</tr>
<tr>
<td>Block DNA replication through use of nucleoside analogues</td>
<td>Lamivudine</td>
<td>HIV/AIDS</td>
</tr>
<tr>
<td>• interfering with reverse transcriptase</td>
<td>Acyclovir</td>
<td>Chronic hepatitis B</td>
</tr>
<tr>
<td>• interfering with viral DNA polymerase,</td>
<td>Acyclovir</td>
<td>Herpes simplex virus</td>
</tr>
<tr>
<td>Block integration of viral DNA into host genome through use of integrase inhibitors</td>
<td>Raltegravir</td>
<td>HIV/AIDS</td>
</tr>
<tr>
<td>Block viral protease polymers by use of protease inhibitors</td>
<td>Saquinavir</td>
<td>HIV/AIDS</td>
</tr>
<tr>
<td>Interfer with assembly of new infectious virions</td>
<td>Mitoxantrone</td>
<td>Vaccinia virus</td>
</tr>
<tr>
<td>Block release of new virions from host cells by inhibition of neuraminidase</td>
<td>46 seltamiv (Relenza)</td>
<td>Influenza A and B</td>
</tr>
<tr>
<td>Stimulate immune system</td>
<td>Interferon alpha</td>
<td>Multiple viral infections, including hepatitis B</td>
</tr>
</tbody>
</table>

TIP: While you don’t need to remember the names or actions of each antibiotic and antiviral drug, it is important to consider that they have different mechanisms of action. These actions differ greatly between antibiotics and antivirals and are often specific to certain pathogens or types of pathogens.
EXTENSION: Rational drug design

Many pathogens are constantly changing into new subtypes, making them harder and harder to treat. The ability of viruses and bacteria to do this will be further investigated in topic 7.

One concept that is useful in the treatment of changing pathogenic agents is rational drug design. The process involves finding a target enzyme on a pathogen that causes infection and designing a drug that blocks its active site.

To access more information about rational drug design and examples of different designer drugs, please download the digital document.

Other chemical agents to control pathogens

Other ways of controlling the spread of pathogens are:

- **Sterilisation.** This is the removal or killing of the microbes from surfaces. Sterilisation is done by heat through such methods as autoclaving. This is a very effective method and relies on pressurised steam at a high temperature.

- **Chemical agents.** Antiseptics and disinfectants are also used to control the spread of pathogens. The inhibition or killing of pathogenic organisms on non-living surfaces, such as taps and door handles, is termed disinfection. Antiseptics are used for inhibiting the growth of pathogens on living surfaces such as the skin.

**INVESTIGATION 6.3**

**Sensitivity testing using spices and different household disinfectants**

**Aim**

To explore the bacteriostatic and bactericidal actions of different household substances using sensitivity testing

**Resources**

- **eWorkbook Worksheet 6.3 Controlling the spread of pathogens (ewbk-7855)**

**KEY IDEAS**

- Identification of pathogens is important for both treatment and prevention.
- Methods to identify viruses include physical, immunological and molecular methods.
- Methods to identify bacteria include phenotypic, immunological and genotypic methods.
- It is also important to identify the host and/or the reservoir of a pathogenic agent to help prevent the spread of disease.
- The incubation period of a disease is the interval between a person’s exposure to a pathogen and the onset of disease symptoms in that person.
- Asymptomatic carriers of a disease show no symptoms of a disease but can spread it.
- Infectious diseases may be spread directly (by person-to-person contact) or they may be spread indirectly.
Methods to control the spread of disease includes prevention, vaccination, surveillance, modification of environment, infection control measures and medications.

- Antibiotics are agents that kill or inhibit bacteria using different bacterial targets.
- Antiviral drugs have been developed that target key viral enzymes involved in the viral replication cycle.

### 6.3 Activities

To answer questions online and to receive immediate feedback and sample responses for every question, go to your learnON title at [www.jacplus.com.au](http://www.jacplus.com.au). A downloadable solutions file is also available in the resources tab.

<table>
<thead>
<tr>
<th>6.3 Quick quiz</th>
<th>6.3 Exercise</th>
<th>6.3 Exam questions</th>
</tr>
</thead>
</table>

#### 6.3 Exercise

1. **MC** Commencing in 2018, an outbreak of Ebola occurred in the region of Kivu in Democratic Republic of the Congo.
   Which of the following would not be recommended to contain the outbreak?
   a. Quarantining infected individuals
   b. Testing individuals before they are permitted to travel out of the affected region
   c. Allowing families to partake in traditional funeral and burial methods of individuals who died from the disease
   d. Providing healthcare workers with personal protective equipment while treating affected individuals

2. Identify the following statements as true or false. Justify your responses.
   a. Viruses are not destroyed by antibiotics.
   b. The presence of a particular viral protein in a patient's serum could be identified using ELISA.
   c. Different viruses cannot be distinguished by the basis of their shape.
   d. Inhibiting the viral enzyme integrase is one strategy for controlling HIV.

3. Hand sanitisers are commonly used to kill 99.99 per cent of germs without water. These sanitisers act as antiseptics. What are antiseptics and how do they differ from antibiotics?

4. What is the term for mosquitoes transmitting a disease such as Zika virus?

5. Influenza, also known as the flu, is a highly contagious respiratory illness caused by influenza viruses.
   a. An individual has claimed that ‘preventing influenza through annual vaccinations is better than treating the disease using antivirals’. State whether this statement is true or false, and justify your response.
   b. How does flu get transmitted?

6. A certain bacteria underwent testing. It was found to be Gram-negative and tested positive for indole production and fermenting lactose, but was unable to use citrate as its sole carbon source.
   a. Using figure 6.15, identify the likely identity of this pathogen.
   b. Was this type of test phenotypic or genotypic? Justify your response.

7. a. A certain disease has a long incubation period. Describe the consequences this might have for the spread of the disease.
   b. The same disease has an $R_0$ value of 5.0. Outline what this represents and explain how it might affect the number of individuals infected.

8. Bacteria and viruses are both pathogens capable of causing diseases. However, there are many differences between the two.
   a. Explain why there are differences between techniques used to identify bacteria and techniques used to identify viruses.
   b. Describe the differences between antiviral drugs and antibiotics in both their use and mechanisms of action.
   c. Explain the difference between direct, indirect and sandwich ELISA. Use a diagram to support your response.

9. During the COVID-19 pandemic, two recommendations were washing hands with soap (or sanitiser) for at least 20 seconds and wearing face masks. Describe how each of these would be useful in preventing the spread of disease.
6.3 Exam questions

**Question 1 (1 mark)**

**Source:** VCAA 2020 Biology Section A, Q34

**MC** Bovine spongiform encephalopathy (BSE) is a prion disease of cattle. It is sometimes called mad cow disease. It is caused by feeding cattle food that contains prions from other infected animals. The time between infection and symptoms appearing can be up to five years. There are concerns that variant Creutzfeldt-Jakob disease (vCJD) in humans could be caused by eating infected cattle meat.

Yellow fever is a viral disease that affects humans. The yellow fever virus can cause symptoms three to six days after infection. The virus is carried by a mosquito vector.

Which combination of approaches would be most effective at controlling the risk of outbreaks of both vCJD and yellow fever?

<table>
<thead>
<tr>
<th>vCJD</th>
<th>Yellow fever</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Prevent all cattle that show symptoms of mad cow disease from reproducing.</td>
<td>Remove breeding grounds for mosquitoes.</td>
</tr>
<tr>
<td>B. Test all cattle for the presence of the prions.</td>
<td>Ensure that all healthcare professionals wear gloves when working with infected patients.</td>
</tr>
<tr>
<td>C. Destroy all cattle that have been fed infected food containing the prions.</td>
<td>Ensure that people take measures to reduce their chances of being bitten by mosquitoes.</td>
</tr>
<tr>
<td>D. Stop selling cattle meat.</td>
<td>Instead, people who are infected with yellow fever should wear masks in public places.</td>
</tr>
</tbody>
</table>

**Use the following information to answer Questions 2 and 3**

A diagnostic test for HIV infection includes the following steps.

1. **Step 1:** HIV antigen attached to inner surface of container.
2. **Step 2:** Patient blood serum added to container. Any HIV antibody in serum attaches to antigen.
3. **Step 3:** Man-made antibody with enzyme (E) attached added to container. Wash and add dye.
4. **Step 4:** Enzyme activates the dye which gives the measure of amount of antibody present.
Question 2 (1 mark)

**Source:** VCAA 2012 Biology Exam 1, Section A, Q24

**MC** This test for HIV is reliable because the
A. dye reacts with the patient’s blood serum.
B. enzyme has an active site for the HIV antigen.
C. man-made antibody has the same shape as the HIV antigen.
D. HIV antigen has a complementary shape specific to the HIV antibody.

Question 3 (1 mark)

**Source:** VCAA 2012 Biology Exam 1, Section A, Q25

**MC** A diagnostic test for HIV infection includes the following steps.

The results of the tests of three patients are given in the following table.

<table>
<thead>
<tr>
<th>Positive control</th>
<th>Negative control</th>
<th>Patient R</th>
<th>Patient S</th>
<th>Patient T</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.689</td>
<td>0.153</td>
<td>0.155</td>
<td>0.675</td>
<td>1.999</td>
</tr>
</tbody>
</table>

Numbers are expressed as optical density at 450 nm. The more intense the dye is, the higher the optical density.

The cut-off value indicating a positive result is 0.500. Values below 0.300 are considered to be negative.

The results of these tests suggest that
A. patient T has not been exposed to HIV.
B. patient R has been exposed to the HIV antigen.
C. patient S has responded to exposure to HIV by developing antibodies.
D. the positive control contained fewer HIV antibodies than the negative control.

Question 4 (1 mark)

**Source:** VCAA 2013 Biology Section A, Q17

**MC** Ross River fever is caused by a virus that lives in kangaroos and wallabies. When a female mosquito bites an infected animal, it picks up viral particles. When the mosquito bites a human, the virus enters the bloodstream. The virus then reproduces in blood cells, resulting in fever, rashes and joint pain.

The most effective way to reduce the incidence of Ross River fever in Australia would be to
A. prevent humans from living near the Ross River.
B. use an attenuated form of the virus to create a human vaccine.
C. increase spending on anti-inflammatory drugs to treat the symptoms.
D. isolate kangaroos and wallabies in nature reserves near the Ross River.

Question 5 (1 mark)

**Source:** VCAA 2012 Biology Exam 1, Section B, Q7c

As a requirement for re-entry, travellers returning to Australia from Africa and South America must have proof of vaccination against yellow fever.

Explain why this precaution is taken and what course of action Australian authorities may take for an unvaccinated person wanting to re-enter Australia.

More exam questions are available in your learnON title.
6.4 Vaccination programs and herd immunity

**KEY KNOWLEDGE**

- Vaccination programs and their role in maintaining herd immunity for a specific disease in a human population

*Source:* VCE Biology Study Design (2022–2026) extracts © VCAA; reproduced by permission.

### 6.4.1 Vaccination programs

The aim of vaccination programs is to reduce the impact of vaccine-preventable infectious diseases through achieving high rates of immunisation in the community. Vaccination programs are one of the best ways to protect the community against certain diseases.

When a large percentage of the population are immunised against some specific diseases, it becomes harder for those diseases to spread.

**BACKGROUND KNOWLEDGE: Reviewing how vaccinations lead to immunity**

Vaccines contain a pathogen in a weakened, live or killed state, or proteins or toxins from the organism to trigger the immune response. This is known as artificial adaptive immune response. This was first introduced in topic 5 as an example of artificial active immunity in section 5.12.2.

Various means are used to produce vaccines with no disease-causing capability. All these various types of vaccines are able to provoke the adaptive immune system to produce antibodies specific to the antigens of the pathogens or their toxins.

In a vaccination:
1. the vaccine (containing either live attenuated pathogens that cannot cause disease, inactivated or killed pathogens, inactivated toxins or subunits of pathogens) is injected into a person
2. the immune system produces antibodies and memory cells against the pathogen
3. additional injections lead to an amplified production of antibodies
4. the antibody is specific to the treated pathogen used in the vaccine so, if the person comes into contact with the live organisms at some future date, memory cells and antibodies will be ready to act and the person is immune to infection.

<table>
<thead>
<tr>
<th>Type of vaccine</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Live attenuated vaccines</td>
<td>Measles, mumps, rubella (MMR)</td>
</tr>
<tr>
<td></td>
<td>Yellow fever</td>
</tr>
<tr>
<td></td>
<td>Polio (Sabin vaccine)</td>
</tr>
<tr>
<td>Inactivated or killed vaccines</td>
<td>Polio (Salk vaccine) (IPV)</td>
</tr>
<tr>
<td></td>
<td>Rabies</td>
</tr>
<tr>
<td>Inactivated toxin of bacteria (called a toxoid)</td>
<td>Diphtheria, tetanus (part of DTPa vaccine)</td>
</tr>
<tr>
<td>Sub-units of bacteria or viruses</td>
<td>Hepatitis B (hepB)</td>
</tr>
<tr>
<td></td>
<td>Haemophilus influenza type b (Hib)</td>
</tr>
<tr>
<td></td>
<td>Human papillomavirus (Gardasil)</td>
</tr>
</tbody>
</table>
Why do we need boosters?

Vaccines are sometimes given as two (or three) injections at shorter intervals followed by a booster after a longer interval.

In general, killed or inactivated vaccines produce a weaker immune response compared to the response from using live attenuated vaccines, and the immunity lasts for a shorter period. As a result, killed or inactivated vaccines have to be administered more than once. This is vital in order to maintain immunity against a disease. This is shown in figure 6.28.

**FIGURE 6.28** Booster shots increase the immunity against a disease.

---

**on** Resources

- **Video eLesson** Memory cells and vaccination (eles-4366)

---

**Vaccination programs in Australia**

The National Immunisation Program Schedule in Australia, effective from 1 April 2019, shows the vaccinations required. Some minor variations exist between Australian states. The specific schedule in Victoria is shown in the provided weblink.

**TABLE 6.11** National Immunisation Program Schedule for babies, children and adolescents in Australia, effective from 1 April 2019. Those diseases in one dot point are administered as one single vaccine that is multivalent.

<table>
<thead>
<tr>
<th>Age</th>
<th>Diseases to be immunised against</th>
</tr>
</thead>
<tbody>
<tr>
<td>Birth</td>
<td>• Hepatitis B (preferably within 24 hours of birth)</td>
</tr>
<tr>
<td>2 months</td>
<td>• Diphtheria, tetanus, pertussis (whooping cough), hepatitis B, <em>Haemophilus influenzae</em> type b and polio</td>
</tr>
<tr>
<td></td>
<td>• Pneumococcal</td>
</tr>
<tr>
<td></td>
<td>• Rotavirus</td>
</tr>
<tr>
<td>4 months</td>
<td>• Diphtheria, tetanus, pertussis (whooping cough), hepatitis B, <em>Haemophilus influenzae</em> type b and polio</td>
</tr>
<tr>
<td></td>
<td>• Pneumococcal</td>
</tr>
<tr>
<td></td>
<td>• Rotavirus</td>
</tr>
<tr>
<td>6 months</td>
<td>• Diphtheria, tetanus, pertussis (whooping cough), hepatitis B, <em>Haemophilus influenzae</em> type b and polio</td>
</tr>
<tr>
<td></td>
<td>• Pneumococcal (for at-risk only)</td>
</tr>
</tbody>
</table>

(continued)
TABLE 6.11 National Immunisation Program Schedule for babies, children and adolescents in Australia, effective from 1 April 2019. Those diseases in one dot point are administered as one single vaccine that is multivalent.
(continued)

<table>
<thead>
<tr>
<th>Age</th>
<th>Diseases to be immunised against</th>
</tr>
</thead>
<tbody>
<tr>
<td>12 months</td>
<td>• Meningococcal ACWY</td>
</tr>
<tr>
<td></td>
<td>• Measles, mumps and rubella</td>
</tr>
<tr>
<td></td>
<td>• Pneumococcal</td>
</tr>
<tr>
<td></td>
<td>• Hepatitis A (for at-risk only)</td>
</tr>
<tr>
<td>18 months</td>
<td>• Haemophilus influenza type b</td>
</tr>
<tr>
<td></td>
<td>• Measles, mumps, rubella and varicella/chickenpox</td>
</tr>
<tr>
<td></td>
<td>• Diphtheria, tetanus, pertussis (whooping cough)</td>
</tr>
<tr>
<td></td>
<td>• Hepatitis A (for at-risk only)</td>
</tr>
<tr>
<td>4 years</td>
<td>• Diphtheria, tetanus, pertussis (whooping cough), polio</td>
</tr>
<tr>
<td></td>
<td>• Pneumococcal (for at-risk only, different vaccine to those used before 1 year old)</td>
</tr>
<tr>
<td>12–13 years</td>
<td>• Human papillomavirus (HPV)</td>
</tr>
<tr>
<td></td>
<td>• Diphtheria, tetanus, pertussis (whooping cough)</td>
</tr>
<tr>
<td>14–16 years</td>
<td>• Meningococcal ACWY</td>
</tr>
</tbody>
</table>

The most recent changes made in 2019 include the introduction of the meningococcal ACWY vaccine for 14- to 16-year-olds.

Many of these vaccinations are intramuscular (injected into the muscle). For younger babies, this is usually in the outer thigh. For individuals older than a year, this is more commonly in the upper arm (into the deltoid). The only orally taken vaccination is for rotovirus, which causes diarrhoeal disease in babies.

Several other programs are delivered as part of the National Immunisation Program.

Examples include:
• Influenza vaccinations for children between 6 months and 5 years, at-risk individuals, elderly and pregnant women
• Pertussis vaccination (whooping cough) in pregnant women
• Shingles in individuals aged between 70 and 79 years.

6.4.2 The importance of mass vaccination

Mass vaccinations have eliminated diseases

Presently, only two diseases have been eradicated worldwide: smallpox and rinderplast. Only one of these, smallpox, affects humans.
CASE STUDY: Eradication of smallpox

Smallpox is a devastating disease. Before the 1980s, smallpox, a disease caused by the variola virus, was widespread in many countries. Australians travelling overseas were required to carry a vaccination booklet (see figure 6.29 showing that they had been vaccinated against various diseases, including smallpox.

The vaccination for smallpox was discovered due to its similarity to a more minor pox disease known as cowpox. It had been found that milkmaids who had previously had cowpox were immune to smallpox. Edward Jenner used this idea to develop a vaccine against smallpox. This vaccine was refined over time.

The World Health Organization (WHO) began an extensive vaccination program against smallpox in 1959 and by December 1979, the WHO announced that the disease had been eradicated worldwide. Because of the widespread vaccination against smallpox, the infecting virus could no longer find appropriate hosts who were not immune. Since 1977, no naturally transmitted cases of smallpox have been recorded anywhere in the world.

FIGURE 6.29 a. Smallpox was a devastating disease that has been eradicated. b. Prior to the 1980s, Australians travelling abroad had to carry vaccination booklets to prove they had been immunised. (Image courtesy of Marjory Martin.)

Two laboratories in the world hold stocks of smallpox virus: the US Centers for Disease Control and Prevention (CDC) and the Russian State Research Center of Virology and Biotechnology (VECTOR); they are held in highly secure laboratories. All other samples of smallpox have been destroyed.

Some groups argue that these smallpox stocks should also be destroyed in order to prevent any possibility of their accidental release. Other groups argue that scientific opportunities will be lost if all smallpox stocks are destroyed and that they are needed for research into the development of antiviral drugs. As of 2020, the question remains whether they should be destroyed or not.
CASE STUDY: On the road to eradicate poliomyelitis

Poliomyelitis or polio is caused by the pathogen poliovirus. Poliovirus is spread by person-to-person contact through the exchange of nasal or oral secretions, or by contact with faecal-contaminated material.

The virus enters the mouth and replicates in the gut. In most cases, a polio infection results in a mild illness, but in a very small number of infected people the polio virus migrates from the gut, travels through the bloodstream and attacks nerve cells, resulting in paralysis.

Polio has been eradicated from Australia and almost all other countries through vaccination programs that have given people immunity to polio, with the result that the virus cannot find hosts for multiplication.

- The last case of locally transmitted poliovirus in Australia was that of a 22-year-old man in Victoria in 1986.
- The last confirmed case of polio in Australia was that of a 22-year-old student who returned from Pakistan in 2007 with the disease.

Pockets of polio infection remain in rural regions of Pakistan and Afghanistan. Global polio eradication initiatives are still making major efforts to officially eliminate polio.

The vaccination programs that are leading towards the worldwide elimination of polio are based on two different vaccines: the Salk vaccine and the Sabin vaccine (see table 6.12 below). In Australia, the oral Sabin vaccine was used from 1966 until it was replaced in November 2005 by the Salk vaccine.

| TABLE 6.12 Comparison of the Salk and Sabin vaccines against poliovirus |
|---------------------------------|-----------------|
| **Salk vaccine**                 | **Sabin vaccine** |
| Chemically inactivated virus developed by Jonas Salk                  | ‘Live’ attenuated virus developed by Albert Sabin |
| More expensive to produce        | Cheaper to produce |
| First used widely in 1955        | First available in 1962 |
| Administered by intra-muscular injection — requires trained staff and sterile equipment | Administered by mouth (orally) — very easy to deliver |
| Induces antibody production in blood but not in the gut mucosa; if virulent viruses are ingested later they can replicate in the gut and can be a source of infection for unvaccinated people. | Induces antibody production in both the gut mucosa and the blood; if virulent polioviruses are ingested later, they will be eliminated by the mucosal antibodies. |
| Cannot mutate to a virulent form | Can mutate and revert to a virulent form |

Reducing the incidence of other diseases

The incidence of a number of other diseases — the bacterial diseases diphtheria (caused by *Corynebacterium diphtheriae*), tetanus (*Clostridium tetani*) and pertussis (also known as whooping cough and caused by *Bordetella pertussis*), and the viral diseases measles, mumps and rubella (also called German measles) — has also been significantly decreased by the use of vaccines, in particular through the immunisation programs for babies and children and susceptible groups.

In Australia, contagious diseases have been contained and almost eliminated through mass vaccinations. Figure 6.31 shows the incidence of meningococcal disease in Australia in the period 1995 to 2019. Note the steady decline in the number of cases since the introduction of the pneumococcal vaccine in 2002. However, given the growth in international travel, the reintroduction of some diseases to Australia from offshore where these diseases are still endemic is always a possibility.
6.4.3 Herd immunity

As individuals, we can be protected against an infectious disease by being immunised against it — this is an example of direct protection, which we gain by developing antibodies against the disease in response to the injection of an antigen of the pathogen concerned.

In addition, indirect protection from infectious disease can exist, but only at the level of a population. This indirect protection is termed herd immunity, also known as community immunity.

Herd immunity is the indirect protection of populations from infection where that protection is created by the presence of immune individuals in the population and the protection is received by unvaccinated individuals.

The immune people in a population are those who acquired their immunity either artificially through vaccination or naturally by having recovered from the disease.

There are a number of factors that affect herd immunity:
1. Herd immunity operates only when a high proportion of the population has immunity to a particular disease.
2. Herd immunity applies only to those infectious diseases that are contagious — that is, diseases that are spread directly from person to person, such as influenza, measles, mumps, pertussis (whooping cough) and meningococcal disease.
Herd immunity is important for vulnerable members of a community who either cannot be vaccinated or for whom vaccination is ineffective. Such individuals include newborn babies, people whose immune systems are defective because of an inherited disorder (such as SCID) or an acquired condition (such as acquired immunodeficiency syndrome — AIDS), elderly people and people undergoing chemotherapy for cancer.

In a population, the higher the proportion of immune individuals to an infectious disease, the lower the chance that an unimmunised person will come into contact with an infectious individual. If enough people are immune, an infectious disease will not get the chance to become established and spread. If the pathogen cannot find a susceptible host, the infectious disease that it causes will, over time, gradually disappear from a population.

**FIGURE 6.32** Herd immunity protects those who are not immunised.

- **Not immunised, but still healthy**
- **Immunised, and healthy**
- **Not immunised, sick, and contagious**

No one is immunised.

Contagious disease spreads through the population.

Some of the population gets immunised.

Contagious disease spreads through some of the population.

Most of the population gets immunised.

Spread of contagious disease is contained.
High levels of immunised individuals in a population have been achieved through mass immunisation programs, such as through the National Immunisation Program (NIP), which was implemented in Australia in 1997 (see section 6.4.1). Mass vaccination programs have generated herd immunity and have successfully prevented the spread of infectious diseases. In several cases, mass vaccinations have led to the elimination of diseases, either worldwide or from a region, as for example, smallpox and polio. Recommendations for herd immunity to be effective is 95 per cent of individuals being vaccinated.

### INVESTIGATION 6.4

**Modelling herd immunity**

**Aim**
To model how herd immunity works and determine how the number of immunised individuals impacts its effectiveness

### Vaccination rates

While vaccination rates, particularly in children, have increased over the last 10 years, the 95 per cent aspirational target for vaccinations has not been reached in many populations, as seen in figure 6.33. Opposition to vaccination poses a challenge to herd immunity by allowing preventable diseases to persist in, or reappear in, communities because of a decline in vaccination rates.

### FIGURE 6.33

Immunisation coverage rates of all children in Australia and immunisation coverage rates of Aboriginal and Torres Strait Islander children.
SAMPLE PROBLEM 4 Understanding the immunisation schedule and herd immunity

Refer to table 6.11. 
The immunisation for diphtheria, tetanus, pertussis (whooping cough), hepatitis B, *Haemophilus influenzae* type b and polio (known as Infanrix hexa) is given at two months, four months and six months.

a. Given that a baby has been already immunised at two months with this vaccine, explain why booster shots are given. (2 marks)
b. Why is the polio vaccination given when there have been no cases in Australia for over 10 years? (1 mark)
c. Explain the benefit for giving six immunisations at once. How would this be associated with herd immunity? (2 marks)

THINK

a. The question is asking to give a reason for giving booster doses to babies. As it is worth 2 marks, you need to give two distinct points that clearly link back to Infanrix hexa. Consider the reasoning for boosters: producing an antibody response at a higher and faster rate.

b. Consider the key idea as to why we still vaccinate against polio. It is because it is not yet eradicated. Formulate your response using this as a basis.

c. Carefully read what the question is asking you to do. You are required to focus on two aspects: why six immunisations are given and the association with herd immunity.

WRITE

Killed or inactivated vaccines produce weaker responses and immunity lasts for a shorter period of time (1 mark).

By giving a booster shot of Infanrix hexa, the level of antibodies and memory cells is increased and the level remains high for a longer period (1 mark).

Polio is yet to be eradicated worldwide. Therefore, there is still a chance for it to come into Australia and become prevalent. By having babies immunised, it reduces the chance that it can become endemic in Australia (1 mark).

Giving six immunisations at once (in one injection) results in less harm to the baby, as they don’t need multiple injections and cases of inflammation occurring (1 mark).

It also means they are more easily covered against numerous diseases. This allows a greater chance of herd immunity to be reached for a greater number of diseases, providing a greater opportunity for 95 per cent of the population to be immune to six different diseases (1 mark).

Resources

- eWorkbook Worksheet 6.7 Herd immunity (ewbk-7865)
- Video eLesson Herd immunity (eles-4367)
KEY IDEAS

- Vaccination entails the exposure of a person to an attenuated, dead or inactivated pathogen that induces active antibody formation in the person receiving the vaccine.
- Herd immunity is an indirect form of protection against infectious contagious diseases that exists in populations containing a high proportion of immune people.
- The protection created by herd immunity applies to unimmunised members of the population.
- Some people within a population who depend on herd immunity are those who cannot be vaccinated because of age or those with malfunctioning immune systems and for whom vaccinations would be ineffective.
- Herd immunity is put at risk when immunisation rates fall because of opposition to vaccination.

6.4 Activities

To answer questions online and to receive immediate feedback and sample responses for every question, go to your learnON title at www.jacplus.com.au. A downloadable solutions file is also available in the resources tab.

6.4 Quick quiz

6.4 Exercise

1. Refer to the National Immunisation Schedule for babies, children and adolescents (table 6.11).
   a. What is the first vaccine given?
   b. What vaccine is administered at 18 months?
2. Does herd immunity exist in all populations? Explain.
3. Identify two ways in which a person can become immune to a disease.
4. Give an example of:
   a. a vulnerable member of the community who cannot benefit from immunisation
   b. a disease that has been eliminated worldwide by mass vaccination.
5. A person stated: ‘Meningococcal disease has almost been eliminated. There is no need to get vaccinated against this disease’. Is this a valid statement? Explain.

6.4 Exam questions

Question 1 (2 marks)
Source: VCAA 2018 Biology Exam, Section B, Q5b
Controlling the number of measles cases in a population relies on herd immunity.
What is herd immunity and how does it help control the number of cases of this disease?

Question 2 (6 marks)
Vaccination and herd immunity to a particular disease. Medical authorities in remote areas of developing countries can rarely ensure delivery of vaccination to all those at risk of a particular disease so alternative methods are being researched.

a. Identify two difficulties that prevent easy access to vaccination in remote areas.
   2 marks

b. One investigation on delivery of vaccination in remote areas of developing countries involves genetic material (DNA) and plant tissue. DNA from a pathogen is injected into embryonic plant DNA and the plant is allowed to develop and grow. The adult plants are dried and eaten by humans. Explain why such a strategy may be successful for the development of immunity.
   2 marks

c. When plants are used to produce proteins the same as those in particular pathogens, for use as a vaccine, certain precautions must be taken to ensure that the vaccine is effective. Explain two precautions.
   2 marks
Question 3 (1 mark)
MC Measles is a serious disease and the complications of measles can be fatal. Before funded vaccination programs against measles were introduced for Australian babies in 1970, serious measles epidemics happened every two to three years. By 1989, 85 per cent of babies had been immunised against measles. In 1993, a measles vaccination program was also introduced in schools for 10–14 year olds. The rate of measles dropped from 27 cases per 100 000 people in 1993 to just 7 cases per 100 000 in 1995. In 1998, primary schools introduced another additional measles vaccination program to 5 year olds. Ninety-four per cent of school children were immunised in that year. Only 2 cases of measles per 100 000 people were reported.

In February 2016, several cases of measles were reported in two inner-northern suburbs of Melbourne. This drew attention that in these suburbs, the proportion of fully-immunised children was only 83 per cent.

From this information it can be inferred that
A. vaccination is more effective for 5-year-olds than for babies 10- to 14-year-olds.
B. measles has become a less dangerous disease since vaccinations were introduced.
C. booster vaccination programs increase the chance of achieving herd immunity.
D. herd immunity for measles can be achieved successfully with an immunisation rate of 83 per cent.

Question 4 (1 mark)
MC Achieving herd immunity against a particular disease is an advantage because it
A. increases the chance of infection.
B. provides protection for individuals who are not immune.
C. allows more children to attend school and daycare centres.
D. reduces the cost of vaccination programs.

Question 5 (3 marks)
Source: VCAA 2016 Biology Exam, Section B, Q5a and b
Yellow fever is a potentially fatal, mosquito-borne, viral disease that occurs in many countries in Africa, the Caribbean, and Central and South America. An effective and safe vaccine has been available since 1938.

a. What is a vaccine? 1 mark

b. For the vaccine to be effective, it is recommended that travellers to these regions have the vaccination approximately two to four weeks before travelling. Why is this time frame recommended? 2 marks

More exam questions are available in your learnON title.

6.5 Development of immunotherapy strategies

KEY KNOWLEDGE
- The development of immunotherapy strategies, including the use of monoclonal antibodies for the treatment of autoimmune diseases and cancer

Source: VCE Biology Study Design (2022–2026) extracts © VCAA; reproduced by permission.

6.5.1 What is immunotherapy?

Immunotherapy strategies can be used to treat varying diseases. Immunotherapy involves altering the immune response to fight diseases such as cancer and autoimmune diseases.

This differs from treatments such as chemotherapy and radiotherapy, which both act to stop cells from growing (for example, chemotherapy, when used for cancer, destroys cells that can replicate quickly, which can also include body cells).
There are several types of strategies that we can consider to be immunotherapy, many of which can be used in cancer treatment and prevention:

- **Vaccination** — human papilloma virus (HPV) can cause many cancers, particularly cervical cancers in females. There is a vaccination against HPV which produces active immunity, stimulating the immune system to produce antibodies and memory cells against HPV.
- **CAR T Cell therapy** — Special T cells (chimeric antigen receptor T cells or CAR T cells) are extracted from a patient and reprogrammed to recognise cancer cells. These are then replaced into the patient’s blood so they can destroy cancer cells.
- **Monoclonal antibodies** — these are antibodies designed to target specific cells and cause an immune response.
- **Immune inhibitors** — these allow T cells to be more active and target immune cells by inhibiting the blocking of T cells that act to control the immune response.
- **Cytokine therapy** (with specific interferons and interleukins) — activates the immune system to better destroy cancer cells.

**FIGURE 6.34 a.** The process of CAR T cell therapy  
**b.** How this allows for recognition of cancer cells

Now many treatments, such as monoclonal antibodies, are being designed and tailored for specific individuals, as cancer and autoimmune diseases differ between individuals. Thus, immunotherapy is designed to target specific cells and allow the immune system to target the specific cells or components of the body that are causing disease.

### 6.5.2 What are monoclonal antibodies?

**Monoclonal antibodies (MAbs)** are a relatively new class of drug that can be used in the treatment of cancers.

MAbs are specially designed sets of antibodies, with every antibody in the set binding to the same antigen (protein marker).

Monoclonal antibodies (MAbs) are:

- artificially produced antibodies that bind to one specific type of antigen
- produced in the laboratory by stimulating the production of B lymphocytes in mice injected with a specific type of antigen.
Monoclonal antibodies are being used to treat some types of cancer and autoimmune diseases. They can be used alone or to carry drugs, toxins or radioactive substances directly to cells. Many monoclonal antibodies (such as rituximab) can be used to treat blood cancers (such as leukaemia and lymphoma) and autoimmune diseases (such as rheumatoid arthritis, systemic lupus erythematosus and multiple sclerosis).

Making monoclonal antibodies

The process to make monoclonal antibodies is summarised in figure 6.36. The steps to produce monoclonal antibodies are:

1. A mouse is injected with antigen X.
2. This activates the production of its B cells, which produce antibodies against antigen X.
3. To increase the concentration of these antibodies, repeat injections followed by a booster may be given.
4. The spleen of the mouse is removed, placed in culture medium and its cells are separated.
5. This produces a mixture of B cells, only some of which can form antibodies against antigen X.
6. Mouse tumour cells (myeloma cells) that can constantly divide are added to the separated B cells. Some B cells fuse with tumour cells to form new cells called hybridomas.
7. The unfused cells die, leaving only hybridoma cells.
8. Individual hybridoma cells are cultured in a new medium — one cell per well — and allowed to divide repeatedly. This is the cloning step during which multiple identical copies of each individual hybridoma cell are produced.
9. Each individual clone is screened for the presence of the required antibody so that clones of cells that produce antibodies against antigen X are identified.
10. The selected clones can be grown indefinitely in mass culture, and the required antibodies against antigen X can be harvested as required from the culture medium.

The amazing process uses immortal tumour cells to help create antibodies against other cancer cells. Usually, B cells cannot divide, but by fusing a B cell with a tumour cell that can divide indefinitely, a non-stop factory with an antibody production line is created. In 1984, Georges Kohler and César Milstein won a Nobel Prize for their work developing this technique.

The term monoclonal antibodies comes from their function, structure and source. They are ‘monoclonal’ because the antibodies come from clones of one parent cell and, importantly, they are antibodies specific for one known antigen.
6.5.3 Use of monoclonal antibodies to treat cancer

Researchers can design antibodies that target particular antigens on cancer cells, and they can make multiple copies of these antibodies in the laboratory. Table 6.13 shows some of the monoclonal antibodies that have been designed for use in the treatment of various cancers. Monoclonal antibodies are most commonly not used alone — they are used in combination with chemotherapy and/or radiotherapy. In some cases, the use of a particular MAb may be useful only for a particular subset of cancer patients, as, for example, the use of Herceptin for those breast cancer patients who are HER2-positive.

<table>
<thead>
<tr>
<th>Monoclonal antibody</th>
<th>Examples of type(s) of cancer treated with MAbs</th>
<th>Mode of action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bevacizumab (Avastin)</td>
<td>Various, including advanced colorectal cancers; lung, brain and breast cancers</td>
<td>Blocks growth of new blood vessels to cancer</td>
</tr>
<tr>
<td>Alemtuzumab (Campath)</td>
<td>Chronic lymphocytic leukaemia (CLL)</td>
<td>Attaches to a surface protein on cancer cells and signals immune cells to eliminate cancer cells</td>
</tr>
<tr>
<td>Trastuzumab (Herceptin)</td>
<td>Some breast and stomach cancers</td>
<td>Blocks signals for cancer cells to divide</td>
</tr>
<tr>
<td>Brentuximab (Adcetris)</td>
<td>Hodgkin lymphoma</td>
<td>Carries an attached chemotherapy drug to cancer</td>
</tr>
<tr>
<td>Ibritumomab (Zevalin)</td>
<td>Non-Hodgkin lymphoma</td>
<td>Carries an attached radioisotope (Y-90) to cancer</td>
</tr>
<tr>
<td>Rituximab (Rituxan®)</td>
<td>Non-Hodgkin lymphoma and chronic lymphocytic leukaemia (CLL)</td>
<td>Blocks growth signals of cancer cells</td>
</tr>
</tbody>
</table>
Modes of action of MAbs in cancer treatments

As highlighted in table 6.13, there are many different monoclonal antibodies that can be used in the treatment of cancer. These can act in different ways.

**Modes of action**
The four main modes of action of MAbs are to:
- stop the growth of new blood vessels
- signal immune cells to attack
- block growth factors
- deliver anticancer or radioisotopes to cancer cells.

Monoclonal antibodies used in cancer treatments can be divided into naked MAbs and conjugated MAbs. Naked MAbs do not have any other molecules joined to them, while conjugated MAbs have an additional group attached. Both types of MAbs are used in the treatment of cancers.

**Use of naked monoclonal antibodies in treating cancers**

1. **Stopping the growth of new blood vessels to cancers:** A solid cancer, such as a malignant tumour, cannot grow beyond a size of about two millimetres in diameter without being supplied with new blood vessels. These tumours release growth factors, such as VEGF (vascular endothelial growth factor), that diffuse to nearby blood vessels and signal them to sprout new blood vessels (see figure 6.37). These new blood vessels grow into the tumour, transporting oxygen and nutrients to the cancer cells, enabling further growth of the tumour.

   Monoclonal antibodies, such as bevacizumab (Avastin), block the growth of new blood vessels to malignant tumours. They do this by binding the growth factor (VEGF) released by cancer cells. This binding stops the communication between the tumour and nearby blood vessels. Because the blood vessels do not receive the signal, they do not sprout new vessels. Without an increased blood supply to provide oxygen and nutrients to its cells and remove wastes from its cells, a malignant tumour cannot continue growing.

2. **Signalling immune cells to attack cancers:** Some cancers are not very ‘visible’ to immune cells.

   Some MAbs bind to antigens on cancer cells (see figure 6.38) and act as markers that attract immune cells to attack the cancer cells.

   One monoclonal antibody used for this purpose is alemtuzumab (Campath). Campath may be used in the treatment of chronic leukaemia, a cancer of one class of white blood cells. Campath binds to the CD52 antigen on certain white blood cells. The attached antibody acts as a signal that attracts immune cells to the cancer, and the immune cells begin eliminating these white blood cells, including the leukaemic cells.
3. **Blocking signals for cell division:** When growth factors bind to receptors on cancer cells, this produces a signal for the cancer cells to divide. In healthy breast tissue, surface receptors receive signals from growth factors for normal cell replacement. These receptors are known as HER2 (human epidermal growth factor receptor 2). About 20 per cent of breast cancers are classified as HER2-positive breast cancers. In these cancer cells, the receptor is over-expressed, resulting in increased signalling that directs the cancer cells to divide uncontrollably. The monoclonal antibody trastuzumab (Herceptin) binds to these receptors, blocking them from receiving signals from growth factors (see figure 6.39). This slows or prevents the growth of the cancer. (A polarised light micrograph of Herceptin crystals was shown on the topic opener page.)

**Conjugated monoclonal antibodies**

Conjugated monoclonal antibodies are MAbs joined to a second molecule, such as a chemotherapy drug or a radioisotope particle.

1. **Delivering anticancer drugs to cancer cells:** Some monoclonal antibodies, such as brentuximab (Adcetris), can be joined to molecules of a chemotherapy drug and then deliver the cancer-killing drug directly to the target antigen on particular cancer cells. In the case of Adcetris, its target antigen is the CD30 protein on lymphoma cells, and it can be used to deliver a chemotherapy drug in some cases of Hodgkin lymphoma.

2. **Delivering radioisotopes to cancer cells:** Some monoclonal antibodies can be joined to a particle of a radioisotope and deliver it to a cancer cell. Once the antibody links to its target antigen on the cancer cell, the radioisotope emits radiation that can destroy the cancer cell. One such MAb is bromomomab (Zevalin), which has as its target antigen the CD20 protein on the surface of B lymphocytes. Zevalin can be used in the treatment of some types of non-Hodgkin lymphoma.

**Resources**

🔗 **Weblink** Lymphoma Australia — Monoclonal antibodies
6.5.4 Use of monoclonal antibodies to treat autoimmune diseases

A key feature of the immune system is its ability to distinguish between ‘self’ and ‘non-self’. Normally, a person’s immune system does not attack tissues whose cells carry that person’s own self HLA markers. Sometimes, however, this ‘self’ recognition fails, and a person’s immune system attacks and destroys their own body cells, tissues or organs, resulting in autoimmune diseases.

In autoimmune diseases, the body produces autoantibodies — that is, antibodies that attack the body’s own cells. Instead of defending the body against foreign pathogens, the immune system attacks the person’s own body cells. Autoimmunity occurs when T cells and/or B cells are inappropriately activated, resulting in autoimmune disease.

When the immune system produces autoantibodies, these antibodies can lock onto self-antigens on the person’s own body cells, resulting in an immune attack on those cells. What causes the body to mistakenly produce antibodies against its own cells is not known, but several factors, including viral infections, genetic factors, hormones and drugs, have been suggested as possible triggers for this malfunction.

In topic 5 (in subtopic 5.6), chronic inflammation was discussed. Many diseases that are linked to chronic inflammation are due to autoimmune diseases. Examples of these are shown in the following case study box.

CASE STUDY: Examples of autoimmune disease

More than 80 different autoimmune diseases have been identified. It is estimated that 1 in 20 people in Australia have an autoimmune disease. Some autoimmune diseases affect one type of cell or one organ of the body, while other autoimmune diseases affect several body systems.

Some examples of autoimmune diseases include:
- Multiple sclerosis (MS): Autoantibodies target myelin around nerve fibres. This results in numbness, slurred speech, fatigue and a lack of coordination.
- Type 1 diabetes: Autoantibodies target beta islet cells in the pancreas. This results in the inability to produce the hormone insulin, affecting the ability to regulate blood glucose.
- Systematic lupus erythematosus (SLE): Autoantibodies targets many tissues through the body (multisystem). This leads to symptoms such as light sensitivity, rashes, fever and fatigue.

To access more information about different autoimmune diseases, please download the digital document.

Resources

Digital document Case study: Examples of autoimmune diseases (doc-36103)
Strategies for treating autoimmune disease with monoclonal antibodies

While monoclonal antibodies used in cancer are often used to increase the immune response, they can also be used to decrease the immune response. As autoimmune disease is caused by the immune system attacking ‘self’ cells, monoclonal antibodies can be designed to act against specific cells of the immune system which cause autoimmune disease.

There are currently no reliable and safe strategies to cure autoimmune diseases such as systemic lupus or multiple sclerosis. Severe cases require cytotoxic drugs, which frequently cause serious side effects. The development of monoclonal antibodies has led to new therapeutic strategies through which the treatment can be focused more directly towards specific cells. Research into immunotherapy and the use of monoclonal antibodies for autoimmune disease continues. The success of this research could help millions of individuals with autoimmune diseases globally.

Certain antibodies are used as immunosuppressants and can thereby help in organ transplantation.

The most important advantage of monoclonal antibodies is the ability to produce pure antibody without a pure antigen. For example, a suspension of lymphocytes can produce monoclonal antibodies, each of which react with one specific antigen. This can be useful in treating different autoimmune diseases in individuals with unique self-antigens.

<table>
<thead>
<tr>
<th>TABLE 6.14 Different monoclonal antibodies used for treating autoimmune disease</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monoclonal antibody</td>
</tr>
<tr>
<td>---------------------</td>
</tr>
<tr>
<td>Infliximab (Inflecta®, Remicade)</td>
</tr>
<tr>
<td>Adalimumab (Humira®)</td>
</tr>
<tr>
<td>Basiliximab (Simulect®)</td>
</tr>
<tr>
<td>Natalizumab (Tysabri®)</td>
</tr>
<tr>
<td>Omalizumab (Xolair®)</td>
</tr>
<tr>
<td>Rituximab (Rituxan®)</td>
</tr>
</tbody>
</table>

Monoclonal antibodies can be used to alter the course of an autoimmune disease by directing the antibodies against major histocompatibility antigens to prevent them triggering an autoimmune response. The strategy was based on the fact that many autoimmune diseases are linked with HLA or MHC antigens. These antigens, also called MHC-II antigens, play important role in promoting the immune response.

Both humoral and cell-mediated immune responses are initiated when antigens are presented by dendritic cells (DCs) in association with MHC-II markers to help T cells. Because MHC-II are required to promote immune response and certain MHC-II are associated with autoimmunity, it might be possible to stop autoimmunity by using monoclonal antibodies to block certain MHC-II antigens. It is important that only specific markers are targeted to ensure that immunity against non-self material is still functional.
FIGURE 6.42 Blocking MHC-II markers can prevent autoimmunity.

Blocking MHC-II marker with MAb to stop autoimmunity and binding of helper T cell

SAMPLE PROBLEM 5 Comparing monoclonal antibodies

Monoclonal antibodies can be used in the treatment of both cancer and autoimmune diseases.

a. Compare and contrast the use of monoclonal antibodies in cancer and autoimmune diseases. (2 marks)

b. One target for monoclonal antibodies is the CD40 molecule, which is expressed on a range of tumour cells. Why might targeting CD40 with monoclonal antibodies conjugated with chemotherapy drugs be advantageous over using chemotherapy drugs alone? (2 marks)

THINK

a. This question is asking you to both compare and contrast. Therefore, you need to identify differences (contrast) and similarities (compare).

WRITE

Both cancer and autoimmune disease can be treated using monoclonal antibodies that are made to target a specific protein (or antigen) that causes disease (1 mark). However, in cancer treatment, monoclonal antibodies usually lead to the activation of the immune response (by making cancer cells more visible). In autoimmune diseases, monoclonal antibodies are used to suppress the immune response against self-cells (1 mark).
b. Consider the side effects of chemotherapy alone, and which of these side effects are less likely when monoclonal antibodies are used. This is a two-mark question, so you need to be able to include:
• how this occurs
• why it is advantageous.

Chemotherapy targets all fast-growing and replicating cells which, while including cancer cells, often include many other cell types in the body. By targeting only CD40, it is mostly only tumour cells being targeted (1 mark). Therefore, using monoclonal antibodies is advantageous as it will result in fewer of the side effects of chemotherapy, which usually target healthy cells (1 mark).

Resources

- eWorkbook Worksheet 6.8 Exploring monoclonal antibodies (ewbk-7867)
- Weblinks CAR T-cell therapy
  Rituximab in autoimmune disease

KEY IDEAS

- Monoclonal antibodies (MAbs) are produced by a single clone of a cell and consist of identical antibody molecules that bind to the same antigen.
- Monoclonal antibodies are being used in the treatment of various cancers.
- Various monoclonal antibodies block the division of cancer cells through different modes of action.
- Some monoclonal antibodies are attached to other chemotherapy drugs and radioisotopes which are also used for targeted delivery to cancer cells.
- Monoclonal antibodies may also be used in the treatment of autoimmune diseases and target immune cells to decrease the immune response against self cells.

6.5 Activities

To answer questions online and to receive immediate feedback and sample responses for every question, go to your learnON account at www.jacplus.com.au. A downloadable solutions file is also available in the resources tab.

6.5 Exercise

1. Give an example of a MAb that can block the growth of new blood vessels into a solid mass of cancer cells.
2. What is the expected outcome of preventing the growth of new blood vessels into a solid mass of cancer cells?
3. Why is it useful to combine monoclonal antibodies with chemotherapy drugs or radioisotopes?
   a. Briefly describe how Herceptin can slow or stop the growth of HER2-positive breast cancer cells.
   b. Could another MAb, such as Zevalin be used for the same purpose? Briefly explain.
4. a. How do autoimmune diseases occur?
   b. Why are monoclonal antibodies useful in the treatment of autoimmune diseases?
5. Summarise the steps used to produce monoclonal antibodies.
6.5 Exam questions

Question 1 (1 mark)
Source: VCAA 2020 Biology Exam, Section A, Q35

MC Monoclonal antibodies attaching to antigens on a cancer cell are shown in the diagram below.

Monoclonal antibodies
A. are used to suppress B cells acting on cancer cells.
B. make it easier for cells of the immune system to detect cancer cells.
C. can bind to dendritic cells to stimulate them to destroy cancer cells.
D. can attach to many structurally different proteins found on the surface of cancer cells.

Question 2 (1 mark)
Source: VCAA 2018 Biology Exam, Section A, Q24

MC Monoclonal antibodies can be produced and used to treat different types of cancer.

Which one of the following is a correct statement about monoclonal antibodies?
A. Monoclonal antibodies are carbohydrate molecules.
B. Monoclonal antibodies produced from the same clone of a cell are specific to the same antigen.
C. Monoclonal antibodies pass through the plasma membrane of a cancer cell and attach to an antigen within the cell.
D. Monoclonal antibodies produced to treat stomach cancer will be identical to monoclonal antibodies produced to treat breast cancer.

Question 3 (1 mark)
MC Monoclonal antibodies are cultured from a special ‘fused’ cell.

A specific, antibody-producing B-cell is obtained from a mouse that was previously treated with the desired antigen. The specific B-cell is fused with a hybridoma (cancer) cell. The resulting ‘fused’ cell divides indefinitely (like a cancer cell).

The main advantage of the ‘fused cell’ technique is that:
A. the antibody produced by the fused cells will target only hybridoma cells.
B. laboratory mice will not develop cancer through this procedure.
C. the fused cells provide a long-lasting supply of specific antibody for harvest in the laboratory.
D. the antigen confers life-long immunity in the mice for a range of human diseases.

Question 4 (1 mark)
Monoclonal antibodies can be made to differ in their structure according to their intended purpose.

Explain the structure of a type of monoclonal antibody designed to target specific cancer cells.

Question 5 (1 mark)
MC Monoclonal antibodies
A. occur naturally in mice.
B. occur naturally in humans.
C. are artificially produced in humans.
D. are artificially produced in a laboratory.

More exam questions are available in your learnON title.
6.6 Review

6.6.1 Topic summary

- Emergence of pathogens
  - Identify and control pathogens
  - Modes of transmission
    - Direct
    - Indirect
    - Quarantine
    - Vaccination programs
    - Treatments
    - Hygiene
    - Immunotherapy strategies
      - Monoclonal antibodies
        - Stop growth of new blood vessels
        - Deliver drugs
  - Measures to control transmission
  - Immunological
  - Phenotypic
  - Molecular
  - Genotypic and molecular
  - Vectors
  - Contamination
  - Aerosol/airborne
  - Herd immunity
  - Antivirals
  - Antibiotics
- Pandemic
- Larger geographical area
- Restricted geographical area
- Limited geographical area
- Immunological

Disease challenges and strategies
6.6 Exercises

To answer questions online and to receive immediate feedback and sample responses for every question, go to your learnON title at www.jacplus.com.au. A downloadable solutions file is also available in the resources tab.

6.6 Exercise 1: Review questions

1. In 2020, the Australian Department of Health advised people returning from China to remain isolated inside their homes for at least 14 days due to an outbreak of coronavirus. Explain the reasoning behind this process.

2. The following graph shows the death rates from influenza for males in various age groups in New South Wales during two influenza pandemics:

![Graph showing death rates from influenza for males in various age groups in New South Wales during two influenza pandemics.]

   Source: Reproduced by permission, NSW Ministry of Health, 2016.

   a. Explain why the 1891 and 1919 influenza outbreaks were classified as pandemics, rather than epidemics.
   b. What pattern in the death rates is apparent in the 1919 influenza pandemic?
   c. In 1919, compare the death rate for males in the 25 to 29 age group to males in the 65+ age group.
   d. What pattern in the death rates is apparent in the 1891 influenza pandemic?
   e. In 1891, compare the death rate for males in the 25 to 29 age group to males in the 65+ age group.
   f. Does this data indicate that the same strain of influenza was responsible for these two pandemics? Explain.
   g. Overall in Australia, the death rate from influenza in the 1919 pandemic was about three deaths per 1000 people. However, death rates differed in various countries. In the Pacific country of Western Samoa during the 1918–1919 pandemic, there were 8500 deaths in a total population of only 38 000, equating to approximately 224 deaths per 1000 people. Suggest two reasons these death rates differed.
3. Formulate a biologically valid explanation for each of the following observations:
   a. New influenza vaccines are typically developed on an annual basis.
   b. Epidemics tend to begin without warning.
   c. Antibiotics are not effective against virus infections.
   d. Monoclonal antibodies can reduce the side effects of chemotherapy and radiotherapy drugs in cancer treatment.

4. The following diagram shows the life cycle of *Plasmodium*, a malarial parasite, which involves two hosts:

   1. Mosquito transmits a motile sporozoite.
   2. A sporozoite travels through the blood vessels to liver cells.
   3. In the liver sporozoite reproduces asexually (schizogony), producing thousands of merozoites.
   4. The merozoites infect red blood cells, where they develop into ring forms, trophozoites and schizonts.
   5. Other merozoites develop into precursors of male and female gametes.
   6. When the mosquito bites an infected person, gametocytes are taken up and mature in the mosquito gut.
   7. The male and female gametocytes fuse and form an ookinete.
   8. Ookinetes develop into new sporozoites that migrate to the insect’s salivary glands.

   a. Define the role of mosquito in transmission of malaria.
   b. Suggest two measures to prevent the spread of malaria.
   c. An antigen known as apical membrane antigen 1 (AMA1) appears on the surface of the merozoite during the blood-stage of *Plasmodium* parasite and is a necessary component for the invasion of red blood cells.
   If a vaccine is created to protect the people from malaria, what information would be required?

5. Identify one key difference between the members of the following pairs:
   a. Infection and disease
   b. Gram-negative and Gram-positive bacteria.

6. Various kinds of bacteria can be grown in a special medium known as thioglycolate broth, which contains a chemical that absorbs oxygen. However, oxygen diffuses into the broth from the air so that the highest concentration of oxygen is present in the broth at the top of the tube but the concentration decreases with depth, with a zero concentration of oxygen at the bottom of the tube.
   This broth is used to identify different kinds of bacteria in terms of their oxygen requirements.
Consider the following kinds of bacteria in terms of their oxygen requirements:

i. obligate anaerobic bacteria
ii. obligate aerobic bacteria
iii. a mixture of obligate anaerobes and obligate aerobes
iv. facultative aerobic bacteria.

a. Match each group of bacteria (i to iii) to its predicted pattern of distribution in one of the tubes of thioglycolate broth (1 to 4) in the provided figure.

b. Other bacteria are termed aerotolerant; these bacteria do not require oxygen for their energy production, but they are not poisoned by oxygen as is the case for obligate anaerobes. Draw a tube showing a likely distribution of aerotolerant bacteria in a tube of thioglycolate broth.

c. A sample of bacteria from a suspected *Clostridium* infection was placed in thioglycolate broth. What pattern would be expected? Explain your choice.

7. Examine the following graphs, which show data on cervical cancer in Australia.

![Graphs showing incidence and mortality rates of cervical cancer in Australia from 1983 to 2019.](image)

a. What general trend is apparent in the incidence of cervical cancer in the period from 1983 to 2019?

b. What general trend is apparent in the mortality rate for cervical cancer in the period from 1983 to 2019?

c. Which age group shows the most marked ‘jump’ in incidence compared to the preceding age group?

d. Cervical cancer immunisation was introduced in Australia in 2007 for 13-year-old females. Would the impact of this immunisation program be expected to have an immediate impact on cervical cancer incidence?

The vaccination for cervical cancer is actually a vaccination against a virus known as human papilloma virus or HPV. This accounts for over 90 per cent of cervical cancer cases. The current HPV vaccine Gardasil 9 protects against nine strains of HPV.

e. In 2013, the HPV vaccine was extended to males. Why might males need the HPV vaccination when they are not at risk of cervical cancer?
8. *Listeria monocytogenes* causes the bacterial disease listeriosis, which is usually not serious in most healthy people, but can cause miscarriages and may be fatal in elderly people and in people whose immune systems are weakened. *L. monocytogenes* infection most commonly occurs via consumption of contaminated food. Unusually, *L. monocytogenes* can grow at temperatures as low as 0 °C, although relatively slowly. The generation time (doubling time) of *L. monocytogenes* growing in dairy products was found to be about 30 hours at 4 °C, about 2 hours at 21 °C and about 0.8 hours at 35 °C.

a. Starting with 50 *Listeria* cells in contaminated milk, about how many bacterial cells would be expected to be present after a period of 16 hours:
   i. when the milk is stored at 21 °C
   ii. when the milk is left in the summer sun at 35 °C
   iii. when the milk is stored in the refrigerator?

b. Which of these situations is most similar to what can happen if *Listeria* bacteria gain entry to the human body?

c. Why is correct food storage an important public health consideration?

6.6 Exercise 2: Exam practice questions

**Resources**

- **Teacher-led videos** Teacher-led videos for every exam question

**Section A — Multiple choice questions**

*All correct answers are worth 1 mark each; an incorrect answer is worth 0.*

*Use the following information to answer Questions 1 and 2*

**Source:** VCAA 2018 Biology Exam, Section A, Q32 and 33

The table below compares how eight diseases spread and the number of people likely to be infected by one other infected person.

<table>
<thead>
<tr>
<th>Disease</th>
<th>measles</th>
<th>whooping cough</th>
<th>rubella</th>
<th>polio</th>
<th>smallpox</th>
<th>mumps</th>
<th>severe acute respiratory syndrome (SARS)</th>
<th>Ebola</th>
</tr>
</thead>
<tbody>
<tr>
<td>How it spreads</td>
<td>airborne droplets</td>
<td>airborne droplets</td>
<td>airborne droplets</td>
<td>airborne droplets</td>
<td>airborne droplets</td>
<td>airborne droplets</td>
<td>airborne droplets</td>
<td>bodily fluids</td>
</tr>
<tr>
<td>Number of people infected from one other person</td>
<td>1 to 4</td>
<td>12 to 17</td>
<td>6 to 7</td>
<td>5 to 7</td>
<td>5 to 7</td>
<td>4 to 7</td>
<td>2 to 4</td>
<td>1 to 4</td>
</tr>
</tbody>
</table>

Data: © 2018 Thomson Reuters

**Question 1**

**Source:** VCAA 2018 Biology Exam, Section A, Q32

What would be the most effective method of preventing the spread of measles during an outbreak?

A. Wash hands thoroughly after going to the toilet.
B. Establish a ‘clean needle’ exchange program.
C. Vaccinate all infected people.
D. Isolate all infected people.
Question 2
Source: VCAA 2018 Biology Exam, Section A, Q33
Based on the information in the table, which one of the following statements is correct?
A. Ebola is the most contagious disease.
B. Polio and smallpox have a similar infection rate.
C. More people would die from measles than any other disease shown.
D. The fecal–oral route is the most effective means of spreading pathogens.

Question 3
Source: VCAA 2018 Biology Exam, Section A, Q36
Chagas' disease, a potentially life-threatening illness in humans, is caused by the protozoan parasite *Trypanosoma cruzi*. The disease is found mainly in Latin American countries, where the parasite is spread by an insect called a triatomine.
In this example, the role of the triatomine is to
A. introduce a virus into the protozoan parasite.
B. infect the insect with Chagas' disease.
C. introduce a gene into a bacterium.
D. enable *T. cruzi* to enter the host.

Question 4
Source: VCAA 2017 Biology Exam, Section A, Q37
Yellow fever is a viral disease that is transmitted primarily by mosquitoes.
An outbreak of yellow fever was reported to have occurred in an area of Brazil in January 2017. This outbreak was reported to be spreading to other areas within Brazil.
Which one of the following is a correct statement about this outbreak of yellow fever?
A. This outbreak of yellow fever is considered to be a pandemic.
B. Infected individuals who travel to other areas of Brazil will not increase the spread of the disease.
C. This outbreak of yellow fever is occurring in populations with high vaccination rates for yellow fever.
D. Elimination of mosquito breeding sites in areas with yellow fever will reduce the number of individuals affected.

Question 5
Source: VCAA 2018 Biology Exam, Section A, Q16
Lupus is a condition that results in the increased secretion of antibodies that attach themselves to healthy cells in a patient’s body. The accumulation of these antibodies causes inflammation, joint pain, rash, fatigue and fever.
Lupus is an example of
A. a parasitic reaction.
B. an autoimmune disease.
C. an immune deficiency disease.
D. a complement protein response.
Question 6
Malaria is caused by a parasite known as Plasmodium, which normally spreads to humans by mosquito bites. When a mosquito bites a human, the protist enters the bloodstream.

Using the information given above, it can be concluded that

A. protists must be non-cellular pathogens.
B. the mosquito is a vector.
C. the mosquito must also show symptoms of malaria.
D. malaria is an incurable disease.

Question 7
Source: VCAA 2018 Biology Exam, Section A, Q29

The graph below shows the death rates from acquired immune deficiency syndrome (AIDS) and also the number of people infected with the human immunodeficiency virus (HIV). Before 1995 many people infected with the virus went on to develop AIDS, which led to their deaths.


Based on the information in the graph, what is the most likely reason for the change in death rates, even though infection rates continued to climb after 1995?

A. People had access to new antiviral drugs.
B. People were educated about what caused HIV infection.
C. People infected with HIV were isolated from the rest of the public.
D. A widespread vaccination program for HIV was introduced within a targeted population.

Question 8
Antibiotics are chemicals that are

A. effective against animal cells.
B. synthesised naturally by protozoans.
C. have bactericidal or bacteriostatic actions.
D. cannot bind to viruses because of a lack of genetic information.
Question 9
Which of the following is not a way to identify a viral pathogen?

A. Physical methods such as x-ray crystallography
B. Molecular methods to find specific nucleic acid sequences
C. Immunological methods using capture antibodies
D. Phenotypic methods by growing the viruses in on different agar plates

Question 10
Monoclonal antibodies currently used clinically

A. can protect against a wide variety of viruses and bacteria.
B. can reduce the inflammation associated with rheumatoid arthritis.
C. are derived from the plasma of individuals already immune to these organisms.
D. have broad specificity for many antigens.

Section B — Short answer questions

Question 11 (11 marks)
SARS or severe acute respiratory syndrome was first reported in China in November 2002. It took just a few months for this highly contagious and sometimes fatal respiratory illness to spread through 26 countries in Asia, North and South America and Europe. This outbreak ceased in 2004. The causative agent was a coronavirus (a different strain as to the coronavirus that caused COVID-19).

a. Does this suggest that SARS was an existing or a new virus? Explain. 2 marks
b. Identify a factor that might have contributed to the speed of this disease’s spread. 1 mark
c. Would this event be identified as a SARS epidemic or a SARS pandemic? Explain. 2 marks

In Singapore, there were 238 cases of SARS with 33 deaths. Across all countries affected by SARS, there were 8096 cases with 774 deaths.
d. Compare the mortality rates between Singapore and other countries. 1 mark
e. Which, if any, of the following agents might have been tried in the treatment of SARS: penicillin or monoclonal antibodies? Explain. 2 marks

Read the following:
When SARS was first reported, its cause was not known. A key task was to find the causative agent and the top suspect was a coronavirus, now known as SARS coronavirus. Scientists in the Netherlands demonstrated that the SARS coronavirus was indeed the causative agent of SARS.

f. Why is identifying the causative agent of a new disease important? 1 mark

After SARS, changes to public health practices and procedures were introduced in the affected countries in order to minimise future epidemics of SARS in the future. One change in Taiwan was to replace handshakes (for greeting people) with courtesy bows.

g. Would this change be expected to reduce the risk of transmission of SARS? 1 mark
h. Suggest three other possible changes that might have been introduced. 1 mark
Question 12 (10 marks)

Source: VCAA 2020 Biology Exam, Section A, Q10

Measles in Samoa

Measles is one of the most contagious viruses affecting humans. Measles spreads when an infected person coughs or sneezes and the virus is breathed in by another person, or by direct contact with bodily fluids. In a susceptible population — people who have neither been vaccinated nor had measles previously — one person with measles could infect 12 to 18 other people.

The Pacific island nation of Samoa had a significant measles outbreak in 2019. This started when a person who had measles arrived in Samoa by plane in August 2019. In the following months, over 5000 measles cases were recorded and more than 70 people died.

A measles outbreak was declared by the Samoan Government in October 2019. On 15 November the Samoan Government declared a 30-day state of emergency as the number of measles cases continued to rise and more people died. Ninety per cent of the deaths were among children less than five years old. More than one in five Samoan babies aged six to 11 months contracted measles during the outbreak and more than one in 150 babies in this age group died. Fewer deaths occurred in babies who were less than six months old.

Prior to the measles outbreak in Samoa, the vaccination rate for measles for five-year-old children in the country had fallen to 31% in 2018. One of the responses of the government to the outbreak was a mandatory vaccination program for all people. By early December 2019, 90% of the population had been vaccinated.

In Australia a measles-containing vaccine (MMR vaccine) is recommended for children aged 12 months of age or older. A single dose of the measles vaccine provides protection for between 95% and 98% of recipients, while two doses protects 99% of vaccinated people. In 2018 in Australia, 95% of five-year-old Australian children were fully vaccinated.


a. Is the measles outbreak discussed in the article above best described as an epidemic or a pandemic? Give your reasoning. 2 marks

b. Consider the Samoan children who were less than five years old during the measles outbreak. Of this group, what age were the children who were least likely to die from measles? Explain why children of this age would be less likely to die. 2 marks

People who are vaccinated are unlikely to be affected by the measles virus.

c. i. What is the percentage difference between vaccinated five-year-old children in Samoa and Australia in 2018? 1 mark

d. ii. The MMR vaccine contains antigens for measles, mumps and rubella. What form of immunity is given when a person is vaccinated with the MMR vaccine? 1 mark

e. iii. Some children, for example those undergoing chemotherapy, cannot be vaccinated. Explain how high vaccination rates can also protect unvaccinated individuals. 2 marks

f. Describe two strategies, other than vaccination, that could reduce the transmission of measles. 2 marks

Question 13 (9 marks)

Source: VCAA 2019 Biology Exam, Section B, Q9

Zika fever is a rapidly emerging viral disease. It is most commonly transferred from one person to another by the Aedes species of mosquito.
Zika fever in people was discovered in Uganda in 1947. It was thought that a bite from a mosquito had transferred the virus from monkeys to humans.

The symptoms of Zika fever are usually mild and 80% of infected humans do not show symptoms. Infection of pregnant women, however, can cause severe defects in their babies.

a. One way that diseases, such as Zika fever, are thought to occur is when a pathogen infects humans from an animal host. Identify one social or economic factor that could lead to this transfer between hosts. 1 mark

b. When scientists attempt to identify a particular disease, they can look for specific antibodies in infected humans. Scientists trying to identify Zika fever infections found that testing for the antibodies produced against the Zika virus often gave them incorrect results. This was because the antibody tests that had been developed could not always identify the difference between the antibodies produced against the Zika virus and the antibodies produced against other viruses. Explain why making a correct identification of a viral pathogen is important in the control of a disease. 3 marks

c. Explain why the antibody tests could not identify the difference between the antibodies produced against the Zika virus and the antibodies produced against other viruses. In your response, refer to the structure of the antibody. 2 marks

d. Aedes mosquitoes are not found on every continent. They cannot fly great distances. Vaccines are currently being trialled for the Zika virus. Describe three different approaches, other than vaccination, that government health officials could use to reduce the spread of the Zika virus. 3 marks

Question 14 (3 marks)

Source: VCAA 2010 Biology Exam, Section B, Q8a and b

Measles is a highly contagious, serious disease caused by an RNA virus. There were regular epidemics of the disease until the introduction of mass vaccination. The following graph indicates the incidence of measles in Victoria from 1962 to 1979.

![Graph showing the incidence of measles in Victoria from 1962 to 1979 with a downward arrow indicating mass vaccination began.]

a. What was the time period between successive epidemics? 1 mark

b. An uninfected person without immunity has a 90 per cent chance of catching measles if they live in the same house as a person with the disease. If a child is suspected of having measles, a serum sample is taken and tested for measles-specific IgM and IgG antibodies. What conclusion could be made if high levels of these antibodies were found and what action would be taken? 2 marks
Question 15 (5 marks)

A traditional treatment for cancer is chemotherapy, which involves using strong chemical drugs to kill cancer cells. While the treatment can be effective in killing the cancer cells, the drugs cause many side effects in patients.

Monoclonal antibodies are a relatively new kind of treatment used for treating cancers.

a. Explain how monoclonal antibodies work in killing the cancer cells. 2 marks

b. Name the type of macromolecule monoclonal antibodies are made of. 1 mark

c. Some monoclonal antibodies, such as brentuximab, are used to deliver a chemotherapy drug to treat cancers like Hodgkin lymphoma. Suggest a name for these type of monoclonal antibodies and explain how they work. 2 marks

6.6 Exercise 3: Biochallenge

Resources

eWorkbook  Biochallenge — Topic 6 (ewbk-8087)
Solutions  Solutions — Topic 6 (sol-0662)

Past VCAA examinations

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Test maker

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Online Resources

Below is a full list of rich resources available online for this topic. These resources are designed to bring ideas to life, to promote deep and lasting learning and to support the different learning needs of each individual.

- **eWorkbook**
  - 6.1 eWorkbook — Topic 6 (ewbk-1885)
  - 6.2 Worksheet 6.1 Comparing epidemics and pandemics (ewbk-7849)
  - 6.3 Worksheet 6.2 Identifying pathogens (ewbk-7853)
  - 6.3 Worksheet 6.3 Controlling the spread of pathogens (ewbk-7855)
  - 6.4 Worksheet 6.4 Vaccination programs and protecting your pet (ewbk-7859)
  - 6.5 Worksheet 6.8 Exploring monoclonal antibodies (ewbk-7867)
  - 6.6 Worksheet 6.9 Reflection — Topic 6 (ewbk-7871)

- **Video eLessons**
  - 6.3 Sandwich ELISA (eles-4364)
  - 6.4 Memory cells and vaccination (eles-4365)
  - 6.5 Immunisation in Australia (eles-0126)
  - 6.6 Herd immunity (eles-4367)

- **Weblinks**
  - 6.2 Timeline of COVID-19
  - 6.3 Types of ELISA
  - 6.4 Victorian immunisation schedule
  - 6.5 Lymphoma Australia — Monoclonal antibodies

- **Exam question booklet**
  - 6.1 Exam question booklet — Topic 6 (eqb-0017)

- **Teacher resources**
  - There are many resources available exclusively for teachers online.

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