Infectious Disease Study Notes

TOPIC 1 - Cause of Infectious Disease

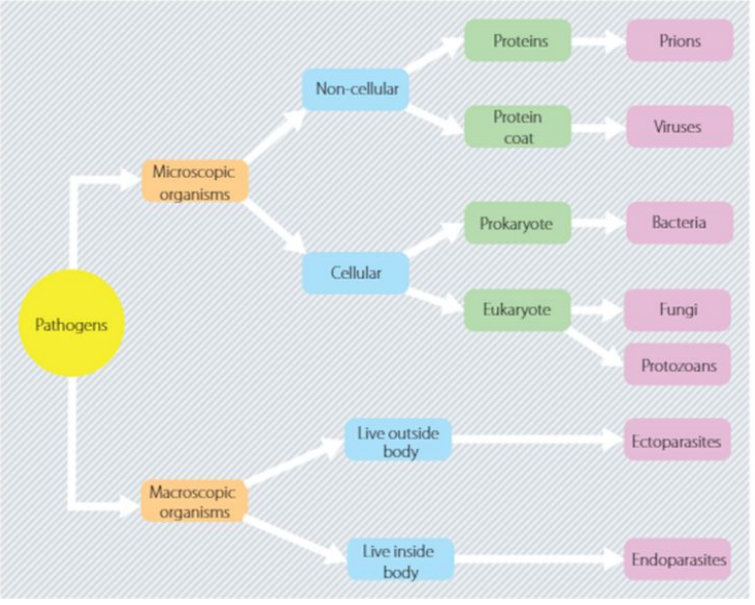
Inquiry Question: How are diseases transmitted?

1.1 Pathogens

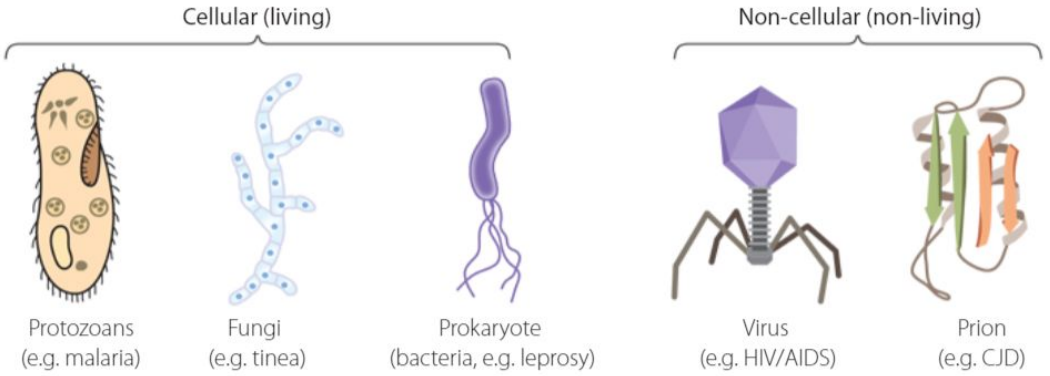
- *Describe a variety of infectious diseases caused by pathogens, including microorganisms, macroorganisms and non-cellular pathogens, and collect primary and secondary-sourced data and information relating to disease transmission, including:*
  - *Classifying different pathogens that cause disease in plants and animals*
  - *Investigating the transmission of a disease during an epidemic*
  - *Design and conduct a practical investigation relating to the microbial testing of water or food samples*
  - *Investigate modes of transmission of infectious diseases, including direct contact, indirect contact and vector transmission*

Disease:

- Definition → any condition that harms a living organism and impairs its function
- Disease is classified into infectious and non-infectious
- Virulence → the severity or harmfulness of a disease
- Infectious disease:
  - A disease that is caused by a **pathogen** which can be transmitted from one organism to another is an infectious disease
  - A pathogen is an organism or biological molecule (e.g. protein) that acts as an infective agent. This means it can be passed from one organism to another. A pathogen is an organism which is capable of causing disease.
- Can be transferred through direct contact of a sick person, contaminated food or water, airborne particles, touching contaminated surfaces, bites from insects or animals and exchange of bodily fluids (e.g. through sexual intercourse)
  - They are contagious
  - Examples → influenza, HIV and malaria
  - There are many different types of pathogens

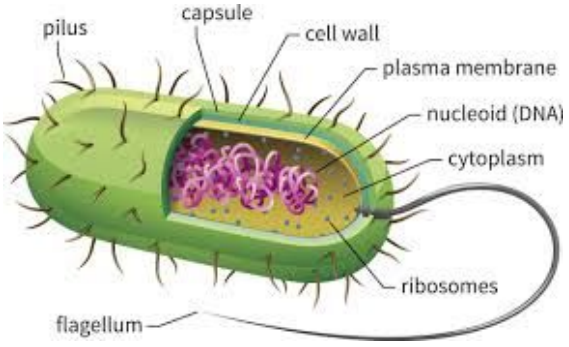


1.1.1 Classifying Pathogens



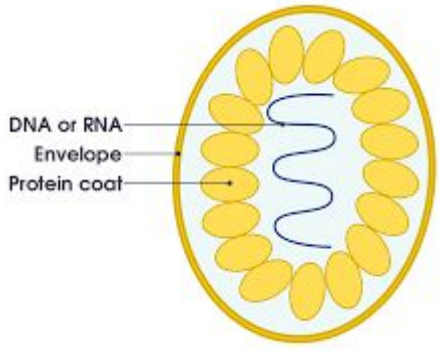
Bacteria (cellular & microscopic):

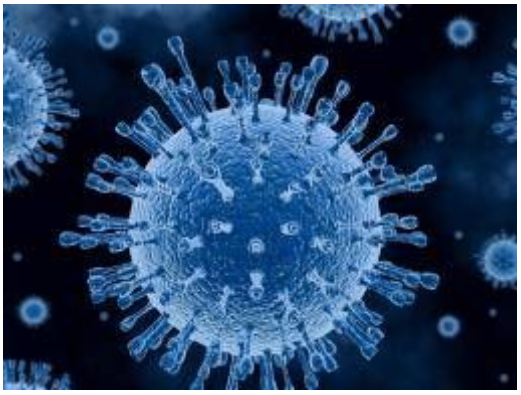
- Bacteria are single-celled, prokaryotic organisms. Pathogenic bacteria are classified according to shape. There are 4 types:
  1. Bacilli (rod-shaped)
  2. Cocci (spherically shaped)
  3. Spirochaetes (spirals)
  4. Vibrio (rod-shaped)
- Bacteria are not always pathogenic
- Bacteria reproduce using binary fission
- Bacteria have a cell wall but no membrane-bound nucleus or organelles.
- Their cell wall is composed of peptidoglycan, a substance made of protein and carbohydrate molecules.
- *Transmission method* → Bacteria can cause disease through reproduction within the host or by releasing toxins which are harmful to the host. Pathogenic bacteria overtake healthy bacteria or grow in tissues.
- *Immune system response* → The body reacts to disease-causing bacteria by increasing local blood flow (inflammation) and sending in cells from the immune system to attack and destroy the bacteria. Antibodies produced by the immune system attach to the bacteria and help in their destruction.
- *Treatments* → Commonly treated with antibiotics. Antibiotics target bacteria and kill them and the aim is to prevent multiplication.
- *Example* → Whooping cough (caused by Bordetella *pertussis* bacteria). Once Bordetella pertussis bacteria get in the lungs, they stick to the lung's lining (mainly the cilia in the upper part of the respiratory system), where they make pertussis toxin. The toxins damage the cilia and cause the airways to swell.



Viruses (non-cellular & microscopic):

- Infectious and cause a number of different diseases.
- Viruses infect the living cells of other organisms and replicate inside the host cells.
- They are bundles of DNA or RNA with a protein coat, the protein coat enables the virus to recognise suitable host cells. The virus's genetic material is then inserted into the host. The cell produces new viruses → cannot reproduce without a host.
- The protein coat allows the pathogen to have surface proteins that enable it to bind to surface receptor proteins on the host cell via complementary binding. It can then enter the cell via endocytosis.
- Extremely small (20- 400nm)
- *Transmission method* → Can be transmitted very easily. Inhaling virus particles attack the cells of the new person (sinuses).
- *Immune system response* → The body rises in temperature to slow down the rate at which most of the body's chemical reactions occur. The immune system fights the infection until the virus is gone.
- *Treatments* → Best way to control viral diseases is through vaccines. Vaccines assist the immune system to deal with an attack. Vaccines are often used to defend against viral diseases by triggering a "false-alarm" immune response that will protect against the virus when there is a real attack.
- *Example* → Influenza A (caused by Influenza type A virus). Influenza is a highly contagious respiratory illness that can have severe symptoms. It is transmitted through air transmission via water droplets from sneezing or coughing. It can also be transmitted through inhalation or oral ingestion _after unknowingly touching _the virus (e.g. park bench).

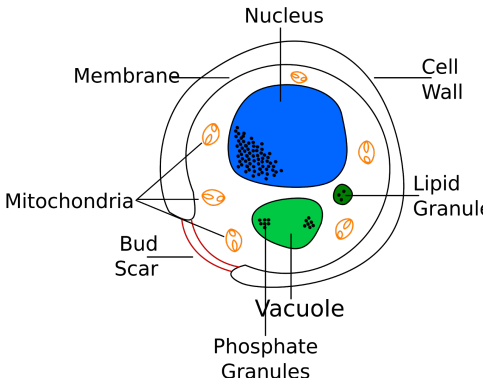


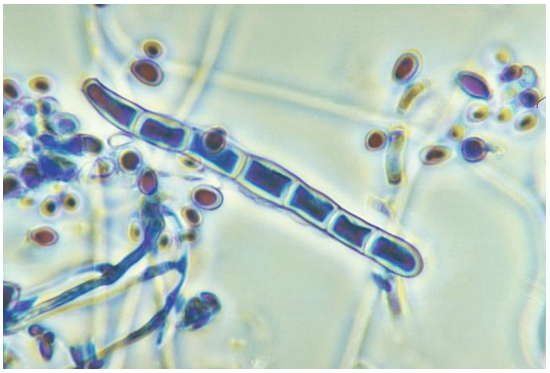


Fungi (cellular & microscopic):

- Similar to plants (rigid cell wall). Fungi are either saprophytes or parasites.
- Can be unicellular (yeast) or multicellular (mushrooms)
- Most species are made of long tubes known as hyphae. Intertwined hyphae are called mycelium.
- Reproduce by spreading spores that can release harmful enzymes
- They are dermatophyte pathogen they live on skin, nail or hair and absorb nutrients from environment by secreting digestive enzymes
- *Transmission method* → Easily spread through the air in water or by direct contact. Mostly affected on the skin, nails and hair. Species that infect humans are known as anthropophilic fungi.

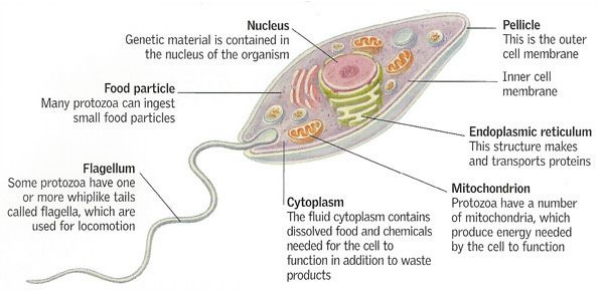
- *Immune system response* → Fungi are recognised by cells of the innate immune system (e.g. dendritic cells and macrophages) which bind components of fungal cell walls using pattern recognition receptors (PRRs) on their surface.
- *Treatments* → Antifungal agents work by preventing the formation of cell membranes.
- *Example* → Tinea (*dermatophytosis)* occurs in the feet, groin, underneath breasts and scalp. Easily spread in communal showers because the fungus likes warm, moist environments. It causes itching or burning, ring-shaped rash or blisters.





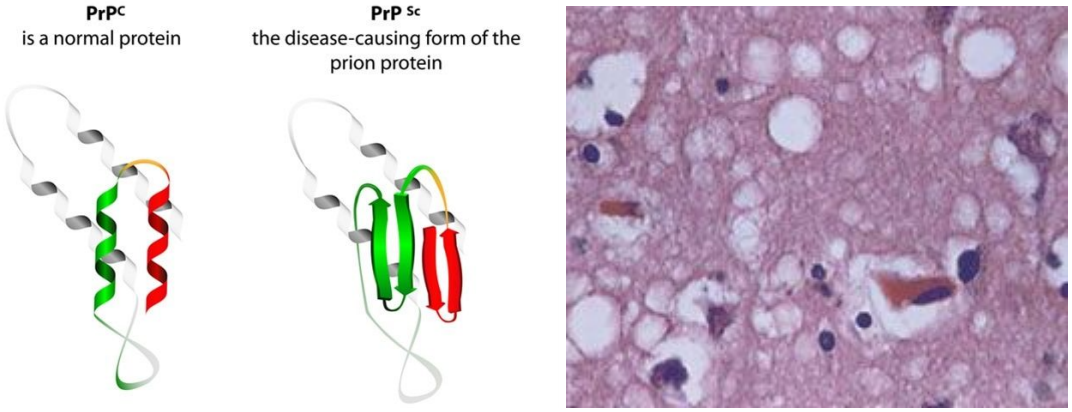
Protozoa (cellular & microscopic):

- Protozoa are single-celled, eukaryotic organisms. They get food from their surroundings (i.e. freshwater and marine environments).
- Pathogenic protozoa are known as parasites.
- Often infect humans when they are dormant.
- There are different types: intestinal, urogenital and blood and tissue
- Genetic material is enclosed in a nuclear membrane.
- Many types of protozoa are harmless to humans
- *Transmission method* → Spread among humans through female Anopheles mosquitoes. If a mosquito bites an infected person, it becomes infected and can then infect another human. Can't be directly transferred from person to person.
- *Immune system response* → Protozoa activate quite distinct specific immune responses, which are different from the responses to fungi, bacteria and viruses. Protozoa may be phagocytosed by macrophages, but many are resistant to phagocytic killing and may even replicate within macrophages.
- *Treatments* → Can be successfully treated with antibiotics however they have become resistant to the medication. Research is ongoing.
- *Example* → Malaria: caused by female Anopheles Mosquitoes which spread pathogenic *plasmodium*. Malaria invades and reproduces inside the red blood cells. The cells rupture and the protozoa are released into the bloodstream where they attack other red blood cells.



Prions (non-cellular & microscopic):

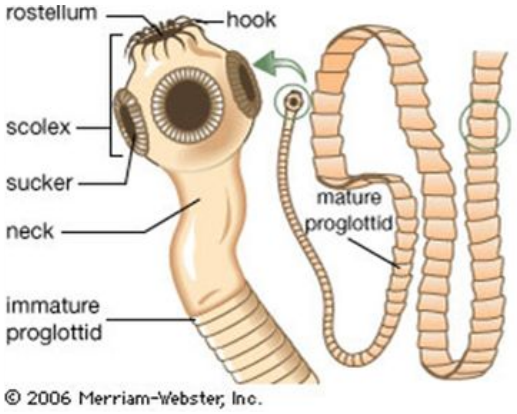
- Prions are infectious, self-reproducing proteins which can cause all different diseases.
- Prions have no nucleic acids (also don't contain any RNA or DNA meaning they have no genetic material) and are able to reproduce without nucleic acid.
- They infect the lining of neural cells and eventually destroy them. They cause cells to burst which brings on infection of other cells.
- Abnormal prions are folded slightly differently but have the same chemical composition as normal PrP.
- Cause neurodegenerative diseases
- Have a very long incubation period (5-20 years) but can progress rapidly after first clinical signs appear
- *Transmission method* →
    1. Contaminated food is ingested.
    2. Prion infectivity is accumulated in lymphoid tissue.
    3. Prions spread throughout the lymphatic tissue and the enteric nervous system, finally reaching the CNS. There they infect the neurons and then are broadcast to other tissues for replication.
- *Immune system response* → The immune system doesn't react to prions because, in their undistorted form, they are present in the body from birth.
- *Treatment* → There is no treatment/cure
- *Example* → CJD/mad cow disease: Rare degenerative brain disorder which is fatal. It affects nearly 1 in a million people. After onset, it causes rapid deterioration. Humans contract CJD after ingesting beef. Creutzfeldt-Jakob disease may occur spontaneously, be inherited or be transmitted by contact with infected tissue, such as during a transplant or from eating contaminated meat.



Macroparasites (cellular):

- Parasites that are visible to the naked eye. They include helminths. The parasite only spends part of its life inside a host and spends most of its time multiplying outside of it.
- Has a nucleus
- Multi-cellular
- Can directly cause disease and can also be vectors in the transmission of diseases
- 2 main types:
    1. Endoparasites→ live inside the host's body (e.g. flatworms)
    2. Ectoparasites → live outside the host's body (e.g. leeches)

- *Transmission method* → Transmission through direct contact, consumption of secondary hosts or endoparasitic transmission by vectors.
- *Immune system response* → The specific immune response to parasites leads to the production of antibodies. Infection by protozoan parasites is associated with the production of IgG and IgM.
- *Treatment* → Medications that work effectively. There are preventative measures such as sanitation.
- *Example* → *Taeniasis* (from tapeworm). Taeniasis is a parasitic infection from tapeworms. The eggs/larvae grow in your intestine. Most people with the disease are asymptomatic. Transmitted by eating food/drink contaminated with poo that has microscopic tapeworm eggs. Also from eating raw meat from infected animals.



1.1.2 Transmission During an Epidemic

Definition → a disease that is prevalent over a whole country or the world; it affects great no. of people/animals, spreads to new areas

<u>Cholera (19th Century London)</u>:

- Cholera is a water-borne bacteria that causes severe diarrhea to the point where people can die within a few hours to a few days
- Dr John Snow was the first doctor to pinpoint the source of the disease
- In the 1850s, Snow stopped an outbreak of Cholera
- Soho → Bad sewer system, people dumped waste into the River Thames which was also the main water source for London at the time. There was an increase in population and therefore more waste meaning more waste in the river.
- Nothing was known about Cholera at the time
- Cholera is highly infectious, causes severe diarrhea which leads to dehydration and cholera
- It wasn't known that bacteria and viruses were at the root of diseases and instead it was believed it was caused by 'bad air'
- Snow believed that Cholera was caused by ingesting something that had been contaminated (not bad air)
- Snow suspected that the Broad St pump was contaminated (there were white flecks in the water) and the outbreak started in that area. He asked where people had gotten their water from and he pinpointed the water pump for the root of the disease.

- Snow took his evidence to officials and they agreed with him, the handle was taken off so that people couldn't use the pump
- Snow found areas with downstream water supply and discovered that there were 14 times more deaths from Cholera during the outbreak. Downstream water means it went all through the city and it was much more contaminated.
- Microbes can cause disease
- Snow's outbreak management strategies are still being used:
    - Mapping outbreaks in the community → can be used to see where the outbreaks are happening

<u>Horse Influenza (2007, Australia):</u>

- Horse flu is an exotic equine disease
- Equine influenza virus is an orthomyxovirus which affects horses and donkeys
- It doesn't infect humans
- It is caused by two mains strains of EIV known as equine-1 (H7N7) and equine 2 (H3N8)
- Symptoms include a fever, watery nasal discharge, hacking cough, loss of appetite
- Transmission:
    - It is highly contagious
    - Can be spread directly between infected horses through nasal secretions and other body fluids
    - Can be spread indirectly through humans who carry the virus from an infected horse to other horses via contaminated shoes, clothing, grooming equipment, food and water buckets
- Management of the outbreak:
    - The NSW Chief Veterinary Office imposed a statewide lockdown on movement of horses. This eventually became nation-wide
    - A management centre was set up to coordinate management at the disease control headquarters in NSW
    - Horse properties were quarantined throughout NSW
    - The spread of the disease was mapped and by the end of August it was clear that the virus had spread to the Central Coast and Hunter Valley. Areas of high density horse stocking meant there was fast spreading disease.
    - With the lockdown of horse movements and quarantine procedures, the outbreak was controlled by December 2008
- Control of future outbreaks:
    - The Australian Veterinary Association suggests that mass vaccination of Australian horses is not a justifiable option
    - The equine influenza virus mutates in the same way that the human influenza virus and so a vaccination wouldn't confer against new strains of the virus
    - Restriction of the importation of live horses to hose from approved countries
    - Subject imported horses to strict biosecurity measures (quarantining the horses)
    - Public education, particular for those working in the horse industry, is vital for early detection
    - Provide biosecurity training for all involved in the importation of horses into Australia, including grooms, truck drivers, cleaners and airline staff

1.1.3 Investigation of Microbial Testing

Practical Investigation → Microbial Food and Water Testing

Background Information:

- Micro-organisms can be found anywhere e.g. food, water, air
- Some microorganisms can cause disease, some are beneficial to humans and some have no effect on all
- Individual micro-organisms are too small to be seen with the naked eye but when many organisms are clumped together they form a colony. Colonies can be observed and seen with the naked eye (e.g. mould on bread)
- Bacteria and fungi usually reproduce by means of microscopic spores which will then develop into colonies under the right conditions
- Many micro-organisms will reproduce in a lab if there are suitable conditions (warmth, moisture and nutrients). After the dishes have been incubated, the plates have the ability to be macroscopically observed
- Colonies are usually able to be distinguished by their size, shape, surface profile and colour
- Bacterial colonies can be distinguished from fungal colonies by observation. Bacterial colonies are usually quite small, shiny and coloured whereas fungal colonies are generally quite large and generally fluffy.
- Sterile techniques are essential in microbiological work

Sterilisation Techniques:

- When opening the petri dish:
  - When opening a petri dish, place the dish on a table and lift the lid at an angle (no more than 45 degrees).
  - Do not breathe over the dish and work as quickly as possible
  - After closing the dish, seal with tape
- Sterilising with heat:
  - Before using any equipment such as the inoculating loop, test tube or probe, pass it through the blue flame of a Bunsen burner

Terms:

- Pure culture → a population of cells or multicellular organisms growing in the absence of other species
- Colony → a visible mass of microorganisms all originating from a single mother cell
- Streaking → a technique used to isolate a pure strain from a single species of microorganisms
- Aseptic techniques → prevents cross contamination

Experiment:

Aim/Purpose:
This practical investigation involves inoculating nutrient agar plates with food or water samples and incubating at 30 degrees for 3 days. The purpose of this experiment was to

conduct an investigation relating to microbial testing of food samples (yoghurt and cheese) as well as air and water. Also aiming to find or identify microorganisms present within the samples. The use of sterilisation techniques are also being used and are necessary for this experiment

Materials:

- Disinfectant
- Incubator
- Sterile nutrient agar plants: 1 for control, 1 for air, 1 for water, 1 for cheese and 1 for yoghurt
- Bunsen burner
- Matches
- Inoculating loop
- Sticky tape
- Markers
- Water
- Cheese
- Yoghurt

Method:

1. Sterilise the workbench area with alcohol and wipe down
2. Set up bunsen burner on the mat
3. Collect other materials (matches, Petri dishes etc.)
4. Place 5 sterile Petri dishes that contain nutrient agar on the bench
5. Label each Petri dish with control, air, water, yoghurt and blue cheese. Also, add date and name to the petri dish
6. Close and seal the control agar plate with sticky tape
7. Leave the air agar plate open for 15 minutes then close and seal with sticky tape
8. Sterilise your inoculating loop by passing it through a flame
9. Dip the inoculating loop into your food type (yoghurt, water and blue cheese) and wipe it gently over the surface of an agar plate using the streak method
10. Close and seal each agar plate with sticky tape
11. Place all 5 Petri dishes in an incubator set to 30°C and leave for a few days

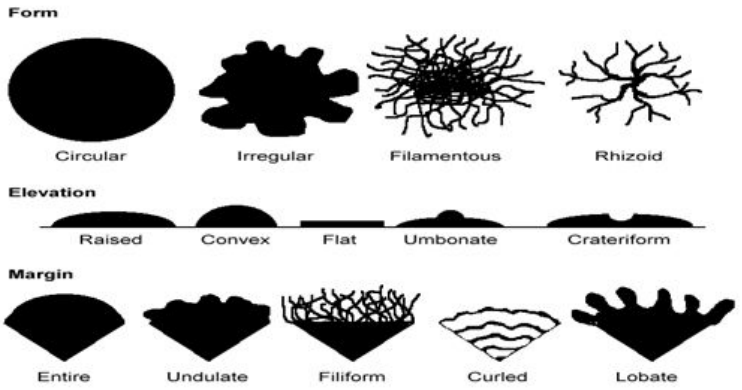
Risk Assessment:

Hazard	**Prevention**	**Treatment**
Bunsen burner - leading to burns on the skin (i.e. hands)	Be careful around the bunsen burner.	- Immediately inform the teacher of injury - Run the burn under water for at least 20 minutes
Having the incubator too high (impact on human health)	Only setting the incubator to a temperature of 30 degrees (no higher)	

Transmission of bacteria from food samples	Wear personal protective equipment (i.e. gloves)	- Inform teacher

Results:

Sample tested	**Bacteria**		**Fungi**	
	Number of colonies	**Number of types**	**Number of colonies**	**Number of types**
Control	3	1	-	-
Air	4	2	-	-
Water	48	1		
Cheese	276	2	3	1
Yoghurt	321	2	-	-



Variables:
Control → agar plate with no food/water/air samples, same temperature, same agar, same size agar plate
Independent Variable → sample type (cheese, air, yoghurt, water)
Dependent Variable → number of colonies

Analysis of Data:

Reliability: This experiment is reliable as it was repeated four times and each trial produced consistent results.

Accuracy: This experiment has a low level of accuracy since measurements of the cheese, yoghurt and water were varied amongst trials. An estimate was also taken of the colonies, further decreasing the validity of the experiment.

Validity: This experiment is of high validity as the method tested the aim. The controlled variables were kept the same (e.g. temperature and incubation period) and the independent variable was the only one changed.

Interpreting Plates → Although bacterial and fungi colonies have many characteristics and some can be rare, there are a few basic elements that you can identify for all colonies:

- Form - What is the basic shape of the colony? For example, circular, filamentous, etc.
- Elevation - What is the cross-sectional shape of the colony? Turn the Petri dish on end.
- Margin - What is the magnified shape of the edge of the colony?
- Surface - How does the surface of the colony appear? For example, smooth, glistening, rough, dull (opposite of glistening), rugose (wrinkled), etc.
- Opacity - For example, transparent (clear), opaque, translucent (almost clear, but distorted vision, like looking through frosted glass), iridescent (changing colours in reflected light), etc.
- Chromogenesis (pigmentation) - For example, white, buff, red, purple, etc.
- 3 additional elements of morphology should be examined only in a supervised laboratory setting: consistency, emulsifiability, and odour.

1.1.4 Transmission of Pathogens

- An understanding of transmission methods is critical to the control of disease outbreaks. For a disease to spread between organisms, a 'chain of infection' must be present:
  - A host that is susceptible to the disease
  - A pathogen that is capable of causing the disease
  - A mode of transmission → a way for the pathogen to get from host to host
- There are three modes of transmission, or ways that a pathogen can get from host to host:
  - Direct contact → transfer of the pathogen via exposure to infected skin or body secretions
  - Indirect contact → transfer of the pathogen to a new host via a non-living object
  - Vector transmission → transfer of the pathogen via another organism, such as an arthropod

<u>Direct Transmission:</u>

- This involves individuals physically transferring the pathogens to each other
- Kissing, touching, intercourse, direct infection/contact with an open wound, contact with nasal/oral secretions

<u>Indirect Transmission:</u>

- This involves objects being contaminated with the pathogen and transferring it - the contaminated object is known as a fomite
- Used tissues, objects with traces of saliva or feces, contaminated medical equipment, airborne pathogens and those carried in food and water

<u>Vector Transmission:</u>

- Involves pathogen transfer by an infected animal to a new host

- Insects such as mosquito's carry malaria parasite, Ross River Fever and Dengue fever virus
- Mammals such as bats carry Rabies virus, Lyssavirus and possibly coronavirus
- Birds - bird flu (avian influenza)

1.2 Robert Koch and Louis Pasteur

- *Investigate the work of Robert Koch and Louis Pasteur to explain the causes of transmission of infectious diseases including:*
    - *Koch's postulates*
    - *Pasteur's experiments on microbial contamination*

Previous Theory → Spontaneous Generation:

- The theory of spontaneous generation was put forward by ancient Greek philosophers and remained widely accepted until the 19th century
- This theory suggested that life could come into existence from non-living matter (e.g. old bread could spontaneously grow mould or old meat could suddenly have maggots in it)
- Due to the belief in spontaneous generation, when microbes were first observed in the blood of people suffering disease, the microbes were thought to have been created by the disease. The belief also fitted with religious views of the time meaning people were satisfied to accept it

Robert Koch:

- Koch was a German microbiologist working in the late 1800s
- He is known as the founder of modern bacteriology as he was able to correctly identify the microbial origins of many diseases (e.g. anthrax, cholera and tuberculosis)
- Most notable achievement → Developing the procedure for isolating and identifying diseases causing microbes. This method directly linked microbial growth as a causative agent in disease progression.
- Koch formulated a systematic method for biological research. These are known as Koch's Postulates
- Koch and Pasteur were actually both working on anthrax around the same time in France and Germany. Koch was able to isolate a rod shaped bacteria from sick sheep suffering with anthrax, purify it and infect healthy animals. These animals then developed symptoms that were common to anthrax and Koch was the first to determine that a particular bacteria caused a specific disease.
- Koch's Postulates:
    1. In all organisms suffering from disease, the micro-organisms must be present in abundance
    2. Micro-organisms must be isolated from the diseased organism and grown in pure culture
    3. When a healthy organism is inoculated with the pure culture, it must develop the same symptoms as the original sick organism

4. Isolate and re-grow the micro-organism from the newly infected organism. If it is identical to the micro-organism in step 2, it has been identified as the cause of the disease

- Koch developed these postulates while working on the bacteria that causes tuberculosis and cholera and created one of the first diagnostic methods for identifying the microorganism responsible for disease → Shows significant contribution to the field of science. This allowed further research.
- The Postulates have been superseded by technology and more accurate methods of identification including DNA sequencing
- The Postulates don't work for all bacteria or viruses (especially if the patient as asymptomatic)
- Modern-day example using Koch's Postulates:
  - Stomach ulcers → people believed that it was previously caused by stress. These scientists disproved this.
  - Barry Marshall and Robin Warren used Koch's Postulates in the most severe way to prove that Helicobacter pylori was the bacteria responsible for stomach ulcers
  - Marshall drank the bacteria and developed the stomach ulcers and proved that the bacteria caused it. He then took antibiotics and was cured.

<u>Louis Pasteur:</u>

- Pasteur was a French microbiologist who worked in the 1800s
- He proved that microbes caused fermentation (beer/wine), spoilage (food) and rotting
- Developed the now commonly used technique of pasteurisation
- Thoughts of the time:
  - The theory of spontaneous generation was believed. This theory states that living things can originate directly from non-living matter (e.g. rats from garbage)
  - Widespread belief in this theory prevented people from understanding what caused disease and how it was transmitted
- Pasteur's work in fermentation enabled him to identify that something he couldn't see (microbes) were present when beer or wine were fermented
- He also proposed that heating milk to a high temperature and pressure before bottling would prevent the milk from souring → this is now known as pasteurisation
- Pasteur's 1862 experiment:
  - Filled a swan-necked and a straight-necked flask with broth. Swan-necked remained clear, open flask became cloudy and smelly
  - Disproved spontaneous-generation theory (that disease occurs spontaneously), proved decay and disease were caused by air-borne *microbes*—germ theory.
- Swan-Necked Flask Experiment:
  - Placed yeast broth in 2 flasks with an S shaped top
  - Both flasks were heated for a prolonged period of time to kill any mirco-organisms in or on the glass
  - He broke off one of the tops to make it a straight neck
  - The flasks were cooled slowly
  - If there were germs in the air, they would fall into the flask with the straight neck and contaminate it, causing decay

    - The S shaped neck trapped the microbes in the bend and therefore no bacteria grew
- Discovered attenuated (weakened) pathogens could cause immunity, showing relationship between anthrax spores and anthrax infection.
- Developed vaccines for chicken cholera, anthrax, rabies, and identified specific parasites responsible for silkworm disease

1.3 Disease in Agriculture

- *Assess the causes and effects of diseases on agricultural production, including:*
    - *Plant diseases*
    - *Animal diseases*

Types:
- Types of disease in agriculture: endemic (consistently present), exotic (introduced).
- Factors that can contribute to infectious disease development include host factors (susceptibility, immune system), pathogen factors (availability, adaptations, virulence factors), and environmental factors (hygiene and density)
- Factors increasing risk of disease today include increasing mobility of human populations, industrial agriculture, deforestation, irrigation, climate change, pesticide resistance, loss of genetic diversity, and inexperienced farmers.

1.3.1 Plant Diseases

- Plant pathogens include: fungi, bacteria, protozoa and viruses
- Example → Rust: fungus invades stem tissue of plants and destroys leaf tissue, reducing photosynthetic capacity. It produces spores which spread to other parts of the plant and other plants until the whole crop is covered. Rust destroyed 15 million tonnes of wheat worldwide annually
- Plant disease symptoms: death of plants, necrosis (tissue destruction), abnormal growth, discolouration and wilting
- Disease is any abnormal condition that harms an organism and lowers its ability to function effectively
- Plant disease will occur if there is a pathogen present, if there is a susceptible host, if there is a favourable environment for the pathogen to reproduce
- Vector transmission - such as an insect or bird may transmit the pathogen from one plant to another as it feeds and moves around

Causes:
- Plant pathogens (as listed above) can cause disease
- There can also be abiotic factors such as drought or frost that can impact the health of a plant
- Examples of pests which greatly affect agriculture:
    - Fruit flies: macro-parasite which infects fruits and vegetables
    - Potato cyst nematode: microscopic round worm which eats potato, tomato and eggplant roots
    - Sharka: plum pox virus which infects fruits such as cherries and plums

Effects:

- Infectious diseases affect the ability for plants to carry out normal functions and therefore have a significant impact on the yield and quality of agricultural products
- Due to a reduction in productivity and costs associated with prevention, plant disease cost Australia millions of dollars annually
- Agriculture is a significant industry in Australia and the reduction in its efficient impacts trading abilities
- Estimated that pathogens cause nearly 12.5% of crop losses
- Plant disease can also have significant social impacts i.e. the Irish Potato Famine (death of nearly 1 million people)
- Plant diseases can negatively affect biodiversity in natural ecosystems → particularly when they have been transported from foreign countries
- Australia has strict biosecurity laws and practices in order to maintain our status as a relatively unaffected and safe nation
- Main effects:
    - Death of the plant/crop
    - Abnormal growths
    - Destruction or discolouration of plant tissues
    - Wilting
    - Reduced yield
    - Loss of trading opportunities
    - Economic loss for farmer

Example - Powdery Mildew Disease in Pea Plants:

- This is the most common form of plant disease
- Powdery mildew, plant disease of worldwide occurrence that causes a powdery growth on the surface of leaves, buds, young shoots, fruits, and flowers.
- Fungal spores can travel through the air with the wind or with vectors and transfer easily from one plant to another
- The spores land on the plant, germinate (if conditions are favourable) and the hyphae begin to grow. The hyphae invades the plant tissue including the xylem and phloem (consuming the plant's nutrients). The fungus begins to thrive while the plant deteriorates. The fungus continues to reproduce, form spores and the cycle continues.
- Impact on agriculture:
    - Highly significant impact on crops. In Victoria, pea plants that contract this disease have wilting and defoliating in the leaves (meaning they’re destroyed) and this means they are unable to photosynthesise. Without photosynthesis the plant dies and ultimately there are larger scale flow-on-effects.
    - Local scale impact: this results in loss of up to 20% of the crop yield which can be devastating to the livelihood of farmers. This in turn will increase the price of peas and be passed onto the consumer.
    - Global scale impact: Farmers can lose international trade deals and opportunities due to the lower yield and higher price

- Can be prevented through ensuring there is enough spacing between plants to provide enough airflow around all parts of the plant. It is also important that the plants aren't over fertilised.
- Can be cured by potassium bicarbonate– Similar to baking soda, this has the unique advantage of actually eliminating powdery mildew once it's there. Potassium bicarbonate is a contact fungicide which kills the powdery mildew spores quickly. In addition, it's approved for use in organic growing.

(Powdery Mildew Disease)

1.3.2 Animal Diseases

- Animal pathogens: fungi, bacteria, viruses, arthropods, helminths.
- Impacts: Animal deaths, economic loss to farmer, loss of trading opportunities, human illness (zoonoses), low growth rates, loss of fertility, loss of economic value of individual animals

<u>Causes:</u>

- Animal diseases may be caused by a number of different infectious agents including bacteria, viruses, protozoa and macro-parasites
- Diseases which are of particular concern to Australia biosecurity are:
  - Avian influenza (bird flu): a severe viral disease affecting poultry. There is no treatment
  - Foot and mouth disease: a highly contagious viral infection affecting cloven-hoofed animals, often leading to significant morality levels in young animals
  - Bovine Spongiform Encephalopathy (mad cow disease): a fatal neuro-degenerative disease caused by prions

<u>Effects:</u>

- Economic impacts:
  - Australia's livestock industry is fundamental to the growth of the Australian economy in our recent history → contributed about $15 billion in export revenue. Animal disease means this figure could be much lower thus negatively affecting the economy
  - A major outbreak of foot-and-mouth disease could cost the Australian economy around $50 billion

- Food security: Animal disease may severely impact agriculture which has significant impacts upon at-risk populations facing poverty or malnutrition
- Health risks: Animal diseases have the potential to infect humans too. This may affect farmers and handlers as well as those who consume the products

Example - Foot Rot in Sheep:

- Ovine (sheep) footrot is a serious disease which has long been dreaded by sheep owners.
- It is a disease which causes severe economic loss, suffering due to lameness and disruption to normal farm operations. The economic losses result from reduced body weight and growth, decreased wool production and restrictions to marketing opportunities
- It is a contagious disease caused by **bacteria** (*Dichelobacter nodosus)*
- It can cause pain and discomfort for the sheep or affected organism
- It has a number of strains and an outbreak may involve one or several strains
- This disease is able to break down the connective tissue between the horn and flesh of the hoof. It mostly affects the skin between the toes
- Can be spread from foot to foot via pasture or mud (still requires favourable conditions of warmth and moisture)
- It requires warm, moist conditions for ideal multiplication. The bacteria can only survive away from the foot for a maximum for 7 days
- It can be treated with dry heat, sunlight, cold and different chemicals
- Short term immunity can be achieved with vaccines
- Susceptibility factors include:
  - Foot shape and structure
  - The Merino breed is particularly susceptible
- Sheep with footrot aren't allowed to be sold or bought thus meaning the market can be negatively affected
- There are also issues for farmers (who usually have a large flock) meaning they have to locate the root cause of the footrot, find infected sheep and treat them. This can be a lengthy process and also has an economic impact.
- There can be impacts on trading and therefore affects not only the income of the individual farmer but the broader economy

1.4 Adaptations of Pathogens

- *Compare the adaptations of different pathogens that facilitate their entry into and transmission between hosts*

- For an organism to cause disease it must:
  1. Enter the host
  2. Multiply in host tissues
  3. Resist or not stimulate host defence mechanisms
  4. Damage the host

- Pathogens have developed an array of strategies or adaptations to enable them to adhere to, gain entry to and persist in their host (these strategies are referred to as virulence factors)

Pathogen (Entry)	Adaptation
Prion (Spread between animals through body fluids like feces, saliva, blood, or urine, either through direct contact or indirectly through environmental contamination of soil, food or water.)	- Prions are misfolded proteins that bind to neurons and degrades them → this stops the transmission of messages - These misfolded proteins are resistant to high temperatures so they don't denature, they are able to resist high pressure and intestinal environment. This means they can be ingested and survive the harsh digestive system - The host's B lymphocytes are thought to play a role by secreting factors that enable prions to invade follicular dendritic cells in lymphoid tissue - From lymphoid tissue, prions invade nervous tissue through the autonomic nerves and travel to the brain - Prions can also 'piggyback' on other proteins such as ferritin (in meat) to facilitate movement through the stomach
Virus (Transmission can occur through indirect or direct contact with contaminated surfaces or organisms)	- Viruses adapt to their hosts by evading defense mechanisms and taking over cellular metabolism for their own benefit. They then replicate in order to spread the infection. - Viruses are able to adapt to vaccines. Viruses continue replication and spread to other hosts, ensuring the continuity of the virus as they rely on the host to survive. - A virus can evolve to vaccines by altering the shape of an antigen, making a vaccine less effective against the virus - Viruses used adhesion and they must enter the nucleus of the host cell to facilitate replication of the viral genome - The viral surface proteins adhere to host cell surface receptors - Invasion also occurs within a virus's virulence factors. Receptor-mediated endocytosis (movement of the virus into the cell) is involved. - Enveloped viruses (e.g. influenza) are enclosed within an envelope formed from the host cell membrane as they move into the cell. They can mutate and evolve frequently to produce new antigens. - Non-enveloped viruses (e.g. polio virus) form a pore in the host cell membrane and deliver the viral genome through it - Some viruses use the cell's normal membrane-forming processes, follow a route through the endoplasmic reticulum and Golgi body and then bud off the surface
Bacteria (Transmission can occur through indirect or direct contact with contaminated surfaces or organisms)	- Bacterial evolution: the genetic changes that a bacterium accumulates during its lifetime, which come from adaptations in response to environmental changes - Due to their short generation times and large population sizes, bacteria has the ability to evolve rapidly. Bacteria evolve so quickly because their huge populations offer many opportunities for mutations and because they undergo horizontal gene transfer

	which involves the movement of DNA between organisms other than from parents. - Bacteria's 'generation time' is around 20 minutes meaning the time they take to grow and produce offspring - Bacteria develop antibiotic resistance, resistance genes are found in plasmids. They acquire resistance from mutations during replication or through horizontal gene transfer. Antibiotic resistance can occur relatively quickly. - Bacteria can survive under extreme conditions (temperature and pressure). To do so, the enzymes must adapt to have the right level of stability and flexibility (e.g. under high pressure, the enzyme is compressed and becomes more rigid). The DNA gives instructions for the enzymes so mutations may assist in bacteria - Bacteria can acquire new genetic material from other bacteria (horizontal gene transfer), or even viruses and plants. This means they can evolve suddenly + rapidly rather than slowly adapting - Pili and fimbriae help with **adhesion**. Pili is a hair like structure found on the surface of bacteria.he short attachment pili or fimbriae are organelles of adhesion allowing bacteria to colonize environmental surfaces or cells and resist flushing. - Adhesions on the surface of the bacterial cell resist washing action secretions such as urine, mucus, cilia - Translocation of bacterial proteins cause host cell membrane engulfment of bacteria - Bacterial cells also form a biofilm - In terms of **invasion** enzymes such as collagenase break down cell contents - Capsules are used to resist phagocytosis - Toxins are also secreted to damage host cells (endotoxins and exotoxins) - **Helicobacter pylor**i is a type of bacteria that causes stomach infections and ulcers in humans. The mucous membrane contains antibodies to bind to pathogens to prevent them from invading the body and also contains lysozyme which aids in the breaking down of bacterial cell walls. The H.pylori bacteria uses its flagella and chemotaxis to move through the mucous membrane and bind to the epithelial cells of the stomach.
Fungi (Fungi reproduce by spreading microscopic spores. These spores are often present in the air and soil, where they can be inhaled or come into contact with the surfaces of the body, primarily the skin)	- Fungus can adapt to have the ability to secrete necrotic factors which are enzymes that break down portions of the cell membrane. This allows hypha to enter the host cell's cytoplasm. - Fungi have heat shock proteins that allow them to tolerate body temperatures of 37°C - Fungi have adapted to develop a cell wall and capsules which protect fungi from host attacks - Fungi have adapted to increase the surface area of their gills which has increased the amount of spores that can disperse and - produce meaning they can survive for longer in the host - Fungi have adapted to have a thick cell wall, this has allowed for the spores to survive for longer periods on surfaces as well as

	providing better protection from adverse environments - In terms of adhesion, fungi are assisted by cell wall or capsule molecules that permit adhesion to host cells - In terms of invasion, thermotolerance is involved meaning heat shock proteins are synthesised to cope with body temperature (higher than air temperature) - Fungi cell wall and capsules protect them from host cell attacks - Secretion of enzymes causes damage to host cells and provides nutrients for the fungus
Protozoan (Transmission through direct, faecal-oral, vector-borne and predator-prey transmission, sexual transmission)	- For the most part, parasitic protozoans live in a fairly constant environment. Many protozoans respond to adverse environmental conditions by encysting: they secrete a thick, tough wall around themselves and effectively enter a quiescent state comparable to hibernation. - *Toxoplasma gondii:* microtubule protrusion into host cell facilitates entry and formation of a vacuolar membrane gives protection from lysosomes - *Trypansoma cruzi:* uses in receptor-mediated attachment, recruits lysosomes to fuse with cell membranes. Pathogen enters vacuole made of lysosomal membrane then deactivates the enzymes
Macro-parasite (Transmission through contact with contaminated soil or water, or through the consumption of intermediate hosts)	- An example of a macro-parasite is hookworms larvae. They are able to penetrate the skin such as between toes via hair follicles. If they are able to successfully enter the host, they will be carried to the heart and lungs by the bloodstream. - Through coughing and swallowing, hookworm larvae will enter the small intestines, the site where they mature and develop eggs. The adaptation in this is shown through the hookworms long chances of survival and receiving maximum benefit from the host but also have used their hooks to increase chance of survival through hooking onto small intestines etc. - During the time the hookworm remains in the body and intestines, it can cause many diseases such as by penetrating intestinal walls with their hooks - Hookworms can secrete proteins that reduce host cell immune responses. Third larval stage in soil invades host via hair follicles and migrates through circulation to lungs and intestines - Ticks have highly specialised mouthparts which are inserted into host skin to attach. The tick is anchored in the skin by 'attachment cement'. Biologically active molecules are secreted in saliva to prevent vasontricion and to prevent the host from forming a clot or initiating an inflammatory response.

Pathogen (Transmission)	Adaptation

Water	- Bacteria and protozoa can have a flagellum (tail) to help them swim through the water - Can be resistant to chlorine - meaning they survive the chemical that should kill them e.g. Staphylococcus aureus
Air	- These pathogenic agents are in air droplets as a result of sneezing or coughing, passing from one organism to another. - These pathogens are capable of floating in air due to light weight and can survive suspended in the air for long periods of time, before infecting animals via the upper or lower respiratory tract. - Diseases that are commonly spread through air transmission include bacterial meningitis, SARS, and influenza.
Oral	- A framework of fecal-oral transmission: Enteric pathogens can be transmitted between humans by the fecal-oral route via direct contact or indirect contact via contaminated fluids, including surface water, food, and carriers such as fomites - Main causes of fecal–oral disease transmission include lack of adequate sanitation (leading to open defecation), and poor hygiene practices. - If soil or water bodies are polluted with fecal material, humans can be infected with waterborne diseases or soil-transmitted diseases. - Fecal contamination of food is another form of fecal-oral transmission. - Washing hands properly after changing a baby's diaper or after performing anal hygiene can prevent foodborne illness from spreading
Vector	- Vector transmission occurs when a living organism carries an infectious agent on its body (mechanical) or as an infection host itself (biological), to a new host. - This occurs commonly through arthropods (e.g. mosquitos, flies, ticks etc) as well as some plants and fungi and mammals such as birds and pigs - Vector transmission relies heavily on macroparasites, as these parasitic organisms are the way in which vector transmission occurs. - These macroparasites have adaptations that have allowed them to be most efficient and successful in transmitted pathogens into the host as well as surviving in the host. For example Tapeworms have many adaptations such as strong suckers and hooks for attachment to the lining of the small intestine. They're also thin and flattened and have a very large surface area for absorption of nutrients
Sexual	- Sexual transmissions happen during sexual intercourse have the ability to enter the uterus; they are also able to survive in the placenta and transmit disease when organisms consume the placenta. An example of this is HIV virus.

TOPIC 2 - Responses to Pathogens

Inquiry Question: How does a plant or animal respond to infection?

2.1 Plant Responses

- *Investigate the response of a named Australian plant to a named pathogen through research. For example:*
    - *Fungal pathogens*
    - *Viral pathogens*

Species to be investigated → *Musa (Musa acuminata banksia* and *Musa jackeyi)*
Pathogen → Banana Bunchy Top Virus (BBTV)

Features of *Musa*:

- Bananas are a large herbaceous flowering plant that grow from a corm which is a swollen stem-based covered with scale leaves
- The plant consists of an apparent trunk that is actually large leaves rolled over one another. A sucker will shoot from the corm to grow into another banana plant. Inside the rolled part of a leaf, there is a bud that will produce flowers which form a large spike that produces bananas

Viral Pathogen:

- Banana bunchy top virus (BBTW) is a single-stranded DNA viral disease of bananas that is transmitted from plant to plant by aphids (small sap-sucking insects)
- There can also be transmission when transplanting occurs in an infected plant. The infected plant gets moved near other uninfected plants and the uninfected ones become infected.
- The virus stunts leaf growth making young leaves appear yellow and 'bunched' and usually prevents the plant from producing fruit
- The virus affects phloem tissue and when the infected cells die they are lighter in colour causing the area near the leaf stem to have a streaky appearance. The suckers of infected plants will also be diseased.
- There has been research into resistant varieties of bananas
- Most control measures involve controlled the aphid vectors (e.g. using chemical treatments and monitoring alternate vector feeding sites)
- Biosecurity measures are also used to prevent the transportation of infected fruit and plant material
- BBTV has a significant agricultural impact and outbreaks impact on quality production and trade.

Banana Plant Response:

- The pathogen means that a bunch isn't able to grow from the plant or a bunch is produced with very little fruit
- The banana plant responds by bunching it's leaves and any new leaves that grow are much shorter than previous ones

- Infected plant are never able to recover from bunchy top and has to be destroyed if it is found to be infected
- Symptoms usually appear in the second leaf to emerge after inoculation and consist of a few dark-green streaks or dots on the minor veins on the lower portion of the lamina. The streaks form 'hooks' as they enter the midrib and are best seen from the underside of the leaf in transmitted light. The 'dot-dash' symptoms can sometimes also be seen on the petiole.
- The following leaf may display whitish streaks along the secondary veins when it is still rolled. These streaks become dark green as the leaf unfurls.
- Successive leaves become smaller, both in length and in width of the lamina, and often have chlorotic, upturned margins. The leaves become dry and brittle and stand more erect than normal giving the plant a rosetted and 'bunchy top' appearance.
- A technique known as RNA silencing is employed by plants, where plants recognize the viral genetic material and copy it so other cells can respond to the virus

2.2 Physical and Chemical Barriers

- *Analyse responses to the presence of pathogens by assessing the physical and chemical changes that occur in the host animal cells and tissues*

<u>Physical Barriers:</u>

- Skin: Consists of outer epidermis, dermis, hypodermis. Good blood supply = access for WBCs, RBCs, platelets. Epidermis is covered in keratin (waterproof protein = extra barrier). Upper epidermis = barrier of dead skin cells.
- Mucous membrane: Line body cavities. Features—cilia (to remove particles), secrete protective substances (mucus traps and flushes away foreign substances)
- Tight junctions: Line blood vessels to prevent diffusion of pathogens.
- Peristalsis: Alimentary canal (mouth to anus) contracts, moving food and preventing bacteria from reproducing.
- Vomiting, diarrhoea, increased urination: expel harmful substances and pathogens.

<u>Chemical Barriers</u>

- Urine: Antimicrobial peptides secreted along urinary tract prevent bacteria binding to cells and break down bacterial cell
- Sweat: Secretes lysosomes that lyse (break down) bacterial cell walls
- Saliva: Has a flushing action and antimicrobial molecules.
- Tears: Produced by lacrimal glands, contains antimicrobial substances.
- Gastric secretions: Hydrochloric acid’s high acidity discourages growth and survival of microbes

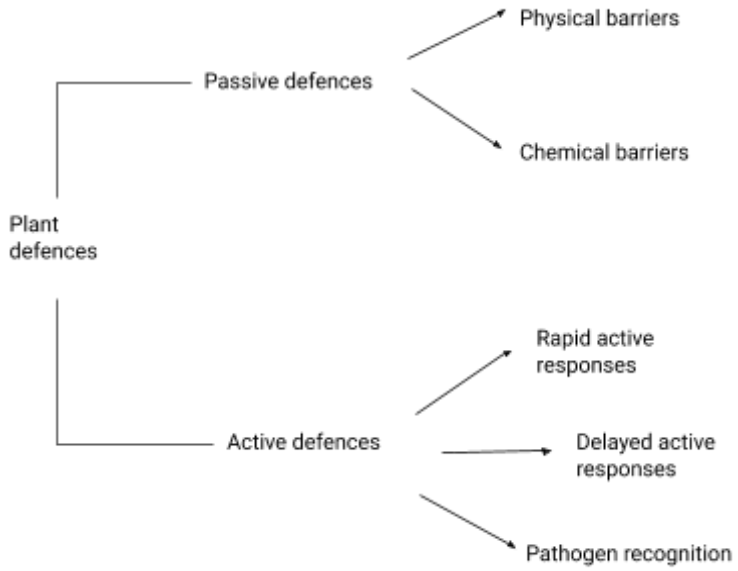
2.2.1 Plant

Passive	Active

• *Physical barriers*- thick cuticle, cell walls and small stomata, all inhibit pathogen entry
  ○ Bark- thicker layer of protection
  ○ Vertical hanging does not allow pathogen reservoirs to build up
  ○ Small stomata reduces the port of entry for pathogens
• *Chemical barriers*- the presence of chemical compounds in the tissues of plants can reduce fungal and bacterial growth and ward off vectors of viruses
	• *Pathogen recognition*- can detect certain physical and chemical signals
	• *Rapid active response*- recognition causes changes in cell membrane permeability. Oxidative burst, cell wall apposition, apoptosis
	• *Delayed active responses*- limits the spread of pathogens. Example is the repair of wounds in the bark through cork cell production. Salicylic acid plays a role in the plant's memory of a pathogen

<u>Plant Barriers:</u>

- In both natural and cultivated environments, plants have inherent disease-resistance strategies. These defences can either be passive (chemical or physical) or active (after the pathogen has been recognised)
- If a plant is able to prevent a pathogen from invading its tissue or prevent the pathogen from reproducing then it will be resistant to that pathogen → This process depends on a complex interaction between the plant and the pathogen at the time of infection



Passive Defences → Plants have two major types of passive defences against pathogen invasion: physical barriers and chemical barriers.

<u>Physical Barriers:</u>

- Physical barriers include:
  - Thick cuticle
  - Cell walls
  - Small stomata

- Some pathogens secrete enzymes down the cuticle and so plants with thicker cuticles are better able to withstand this.
- Bark offers plants extra protection against pathogens that otherwise might invade and try to each the food source (sap) in the phloem beneath the bark
- Vertical hanging leaves (that don't accumulate a water film) reduce the likelihood of pathogen reservoirs building up on the outside of the leaves
- Stomata open up during humid weather conditions and rainstorms which helps to regulate water in the plant but this also means pathogens can enter at this time

Chemical Barriers:

- Chemical barriers such as the presence of chemical compounds in the tissues of plants, can reduced fungal and bacterial growth and ward off vectors of viruses
- Examples of chemicals include:
  - Glucosides
  - Saponins
  - Citronella → repels insects
- Plants may also produce enzymes that break down pathogen-derived toxins
- Chemical receptors on plant cells can detect that presence of a pathogen and activate the next stage of defence

Active Defences → When its passive barriers are breached, the plant is now at grave risk of harm. The next line of defence involves more targeting responses by the plant. Three major groups of responses are involved: recognition of the pathogen, rapid response and delayed response.

Pathogen recognition:

- Plants are able to recognise pathogens by detecting certain physical and chemical signals including fragments from the cell walls of bacteria and fungi
- Genes within the cells of the plant regulate plant responses

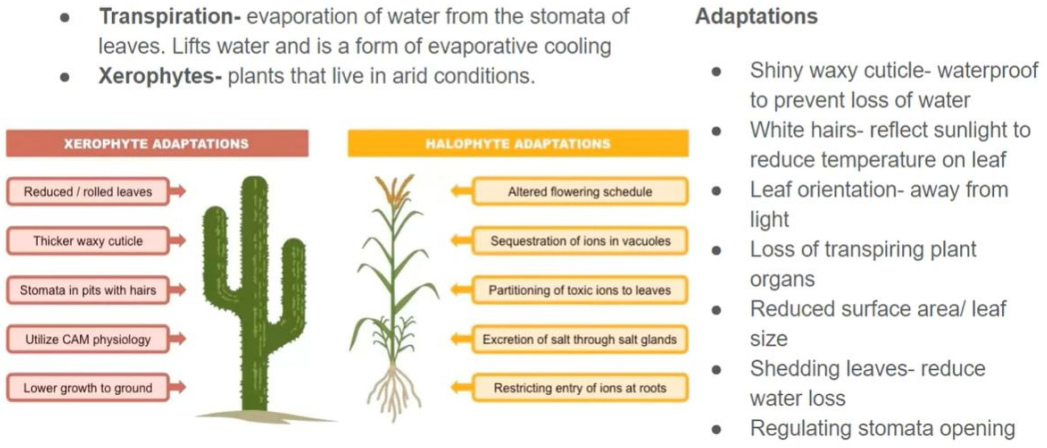
Rapid active response:

- Usually takes minutes - days
- Recognition of a pathogen by proteins on the surface of cells in plants causes changes in the permeability of the plant cell membrane
- This means ions have move into the cell and this triggers defence responses by activating the expression of certain genes
- The release of hydrogen peroxide in an oxidative burst can kill microbes directly. This release of hydrogen peroxide if often used in experiments as a chemical indication of a plant immune response
- Another response is reinforcement of the cell wall with aggregates of material in the cytoplasm near a defect in the wall → this is known as cell wall apposition
- A third response is programmed cell death (apoptosis) which causes a cluster of dead plant cells to accumulate around the pathogen to isolate it, followed by the secretion of antimicrobial compounds

Delayed active response:

- Usually takes days
- Delayed active responses limit the spread of the pathogen
- One important strategy is to repair wounds in the bark through cork cell production and gum secretion
- Lysozyme-like chemicals are also released and have an antimicrobial action
- Salicylic acid may act as a signalling agent of subsequent infections and play a role in the plant's memory of a particular pathogen → This is known as systemic acquired resistance and limits the severity of subsequent infections with that pathogen

Adaptations in plants:



2.2.2 Animals

Physical and Chemical Response:

- Pathogen presence:
  - Invasive pathogens will be recognised immediately by phagocytes (macrophages and neutrophils), they are ingested and destroyed by the process of phagocytosis
  - In the process these phagocytes release chemicals such as hydrogen peroxide and nitric oxide which helps them engulf and digest the pathogen
  - These phagocytes will then release cytokines and histamines to assist with the inflammatory response
- Phagocytosis → is the process by which a cell uses its plasma membrane to engulf a large particle

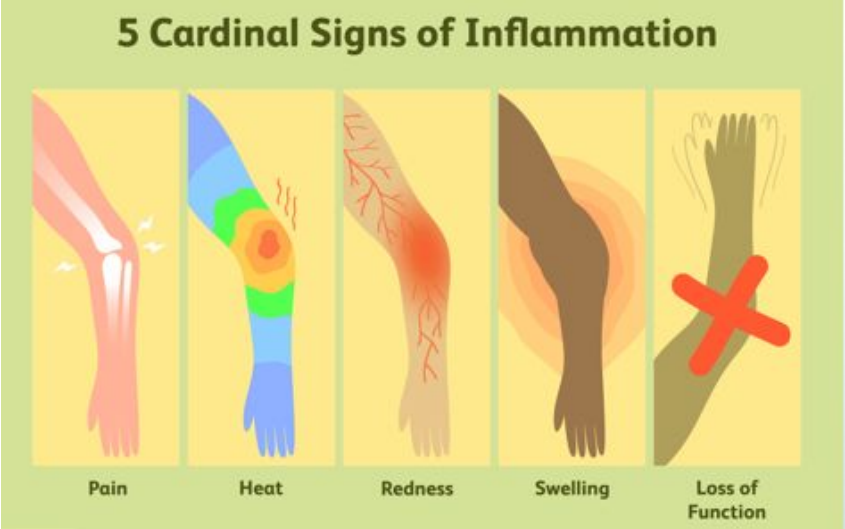
Role of Inflammation:

- Inflammation brings plasma proteins and phagocytes to the site of infection (to destroy the pathogen)
- Inflammation provides a physical barrier which prevents further spread of the infection (makes host aware)
- Inflammation also promotes the repair of damaged cells
- Histamines are also involved in the inflammatory response and have a central role as a mediator of itching. Histamines increase the permeability of the capillaries to white

blood cells and some proteins, to allow them to engage pathogens in the infected tissues.

The inflammatory response (initiated within minutes of infection or injury) includes:

1. Pain - nerve pain or pain from chemical response
2. Heat
3. Redness
4. Swelling
5. Loss of function



<u>Process of Inflammation:</u>

- The blood vessels dilate to increase blood flow to affected area (allows more red and white blood cells and complement proteins)
- There is increased permeability of blood vessels to that the white blood cells and complement proteins can move out of the bloodstream and into tissues easily
- Physical changes:
  - Increased diameter of blood vessels
  - Increased blood flow and volume to the affected area
  - This results in redness, heat and swelling to the area or tissues affected (visibly seen/felt by host)
  - As white blood cells and defense proteins move out of the now wider blood vessels and into the issue, they accumulate and build up in the site of the infection and this causes the swelling and pain we feel in the site of infection
- Chemical changes:
  - When the blood vessels are activated it causes the cells lining this area to release adhesion chemicals. These help the white blood cells that are flowing into the area to ‘stick’ or bind to the site of infection
  - Once the endothelial cells in the blood vessels have been activated, they also release proteins and chemicals that support blood clotting

- This helps reduce the loss of blood but also creates a border and prevents the pathogen from spreading out of the tissue and into the bloodstream (this prevents sepsis)

Redness	**Heat**	**Swelling**	**Pain**	**Loss of function**
Caused by dilation of arterioles/increased blood flow	Increased chemical activity and increased blood flow to skin surface	Caused by accumulation of blood and damaged tissue cells	Direct injury of nerve fibers, pressure of hematoma on nerve endings. Chemical irritants - bradykinin, histamine, prostaglandin	Increased pain of swelling

Summary of Physical and Chemical Changes:

Chemical changes	**Physical changes**
Hydrogen peroxide and nitric oxide produced by phagocytes helps to kill pathogen	Increased diameter of blood vessels which results in increased blood flow
Phagocytes release cytokines that initiate the inflammatory response	Increased permeability of blood vessels and this therefore allows more RBC and WBC flow through vessels into tissue
Adhesion proteins and chemicals are secreted by endothelial cells lining the blood vessels during inflammation	Increased body and tissue temperature to support inflammation and destroy pathogen
Proteins and chemicals that initiate blood clotting are secreted by endothelial cells lining the blood vessels during inflammation	Development of blood clots

Physical Responses (Examples):

Granuloma's (Sealing off the pathogen)

- Sometimes cells die to seal off an area of tissue that is infected and is not being successfully defended by the body. If the infected cells are surrounded by a wall of dead cells, this prevents the infection from spreading to other areas and infecting them.
- This wall of dead cells forms a capsule known as a granuloma. The cells inside the granuloma die, causing the destruction of the pathogens that are infecting them.
- The debris inside the granuloma is destroyed by macrophages that have surrounded the 'walled off' area
- The bacteria that cause tuberculosis and leprosy (Mycobacterium spp.) typically caused granuloma formations

- Granulomas in the lungs are referred to as tubercles (thus tuberculosis)
- Granuloma formation is part of the second line of defence

Vomiting (response to toxin in digestive system):
- Vomiting (emesis) is a reflex action coordinated by the vomiting centre (chemoreceptor trigger zone) of the brain
- It happens in response to many different signals, one of which is the presence of pathogens in the gut (gastroenteritis)
- It is the body's way of expelling harmful substances. Interestingly, hypersalivation occurs before vomiting in order to protect your tooth enamel from stomach acid

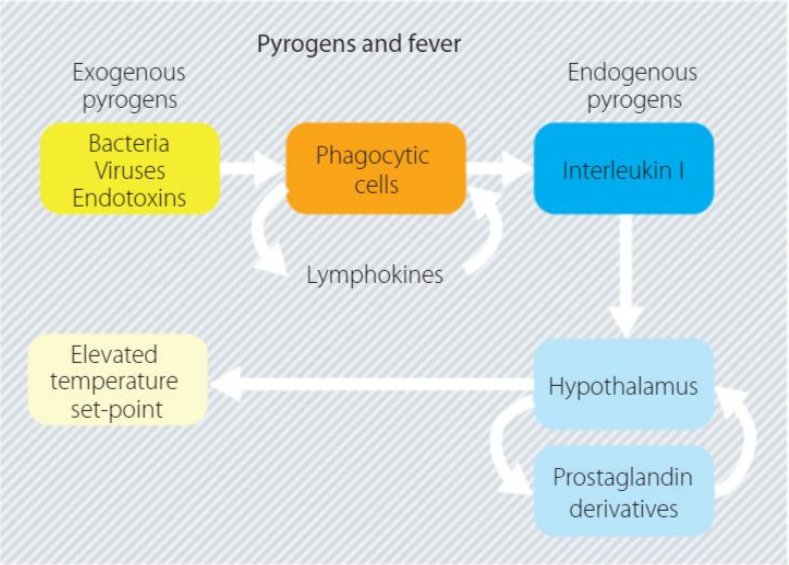
Frequent urination (symptom of UTI):
- When the bladder lining is attacked by a pathogen, a common response by the body is inflammation (*cystitis*) and the need to pass frequent small amounts of urine (*pollakiuria)*
- This is thought to be a response by the body to help flush out pathogens

<u>Chemical Responses:</u>

The Complement System (Innate Immunity):
- A group of around 30 soluble proteins that assist other defence mechanisms in destroying extracellular pathogens.
- These proteins are usually inactive (when we are healthy) but when a pathogen breaks through the barriers to infection, the complement system becomes activated
- These complement proteins can stimulate phagocytes to become more active, attract phagocytes to the site of the infection or destroy the membranes of the invading pathogen
- Complement proteins are manufactured in liver cells and macrophages
- These proteins circulate in the blood and are a part of the initial response to infection
- During the third line of defence, some pathogens bind to proteins in the blood called antibodies
- Complement proteins are attracted to pathogen-antibody complexes and bind to them as well. A layer of complement proteins now coats the antigen-antibody complex. This acts as a signal for phagocytes and other lymphocytes called B cells (third line of defence) to destroy the pathogen
- This enhancement process is called opsonization. Some complement proteins can 'punch' holes in microbial cell membranes, causing the cell contents to leak out. All these processes form part of the innate immune response to pathogens
- They also 'flag' antigens for removal, this enhances the activity of phagocytes and antibodies

Pyrogens and its role in fever:
- The hypothalamus is a part of the brain that contains a special cluster of cells responsible for regulating body temperature
- It acts like a thermostat to initiate responses to keep the body temperature within a certain set range. Normal body temperature of humans is 37 degrees

- The body may react to pathogens by altering the hypothalamic set point of body temperature and allowing the tissue to heat up. It does this by releasing 'fever-causing' chemicals known as pyrogens
- Humans experience this elevation in body temperature as a fever. The purpose of a fever is to kill or limit the growth of pathogens
- It may also enhance the activity of white blood cells and thereby strengthen the response of the presence of the pathogen
- The scientific name for fever is pyrexia. Fever is usually accompanied by sweating, chills, muscle aches and general weakness
- Although a temporary and mild fever is a normal response to pathogen invasion, very high fever for a prolonged period is a cue to seek further medical advice as it may be a sign of significant illness and elevated blood temperature in the brain can cause seizures
- An unexplained fever in a child, especially younger than three months is cause for investigation by a doctor



Cytokines (Innate Immunity):

- Cytokines are chemical messengers that are produced during an infection and they promote the development and differentiation of T and B lymphocytes for the third line of defence
- One example is interleukin (IL). These chemicals form a link between the innate and adaptive immune systems.
- A burst of cytokines occurs as infected cells signal to nearby uninfected cells to also release cytokines.
- Interferons are another example of cytokines. They act as a chemical signal to viruses to stop replicating. They do this by signalling to uninfected cells to destroy RNA and reduce protein synthesis.
- Infected cells are also signalled to undergo apoptosis (programmed cell death)
- Cytokines play a role in the feelings of lethargy, muscle pain and nausea that is experienced if there is an infection present. The implication of this is that the animal

isolates itself and rests and is therefore prevented from spreading the infection to other animals

TOPIC 3 - Immunity

Inquiry Question: How does the human immune system respond to exposure to a pathogen?

3.1 Innate and Adaptive Immune Systems

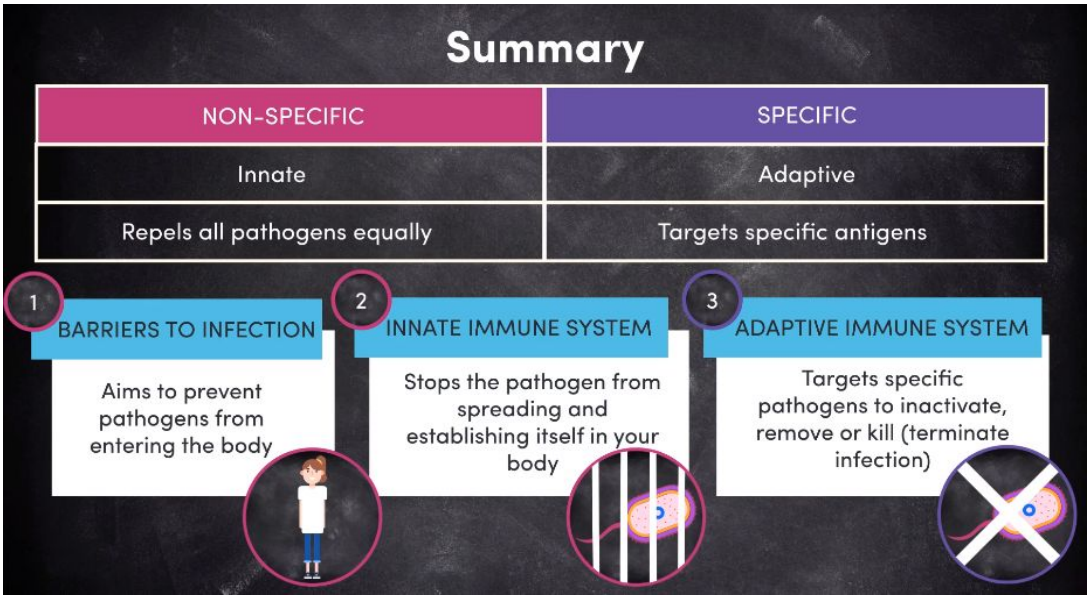
- *Investigate and model the innate and adaptive immune systems in the human body*
- *Explain how the immune system responds after primary exposure to a pathogen, including innate and acquired immunity*

Protecting the Body:

NONSPECIFIC DEFENSE MECHANISMS		SPECIFIC DEFENSE MECHANISMS (IMMUNE SYSTEM)
First line of defense	Second line of defense	Third line of defense
• Skin • Mucous membranes • Secretions of skin and mucous membranes	• Phagocytic white blood cells • Antimicrobial proteins • The inflammatory response	• Lymphocytes • Antibodies

There are two types of immunity:

1. Innate (non-specific)
    - First line and second of immune response
    - Relies on mechanisms that exist before infection
2. Adaptive (specific)
    - Third line of response (if innate fails)
    - Relies on mechanisms that adapt after infection
    - Handled by T- and B- lymphocytes
    - One cell determines one antigenic determinant



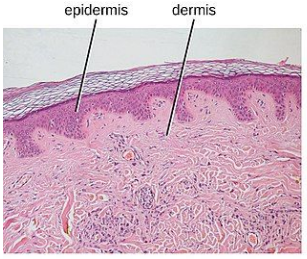
3.1.1 Innate Immunity

Innate immunity refers to nonspecific defense mechanisms that come into play immediately or within hours of an antigen's appearance in the body. These mechanisms include physical barriers such as skin, chemicals in the blood, and immune system cells that attack foreign cells in the body.

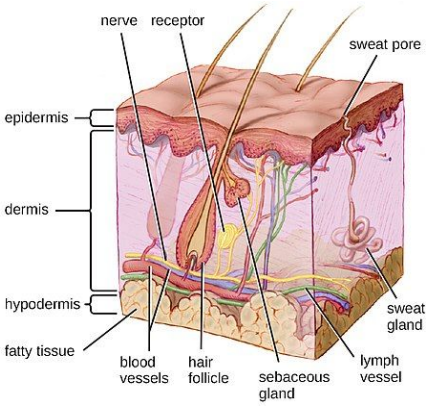
<u>First Line of Defence:</u>

- There are physical and chemical barriers in the first line of defence:
  - Non-specific natural barriers which restrict entry of a pathogen
  - Protects the body at all possible entry points
  - Main aim is to prevent pathogens entering the body
- There are several components of the 1st line:

1. Skin barrier:
   - The skin barrier has two layers (epidermis and dermis).
   - Epidermis: Thin outer layer of epithelial tissue which contains langerhans cells.
   - Dermis: Thick inner layer of connective tissue.
   - The skin covers the entire body. The dead outer cells are difficult for microbes to penetrate unless it's broken.
   - The sebaceous glands produce sebum which combine with our natural bacteria to prevent the growth of some harmful bacteria and fungi.
   - Skin cells are very tightly packed making it difficult for pathogens to get through. If the skin is broken, blood clotting quickly seals the wound to prevent entry of pathogens.



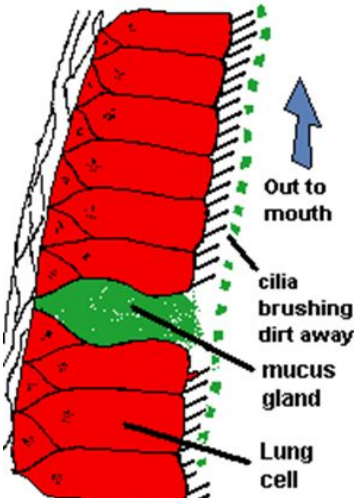
(a)



(b)

2. Mucous membranes (physical):
   - These line the respiratory, digestive, reproductive and urinary tracts with slimy mucous.
   - This allows for exchange of substances when needed. It protects against invasion by the presence of IgA, an antibody that reacts to potential pathogens.

3. Cilia (physical):
   - Cilia are minute hairs that protect respiratory surfaces.
   - They sweep mucous along to an opening where they can be coughed out or swallowed.
   - Cilia are found in the trachea, nose and bronchial tubes.



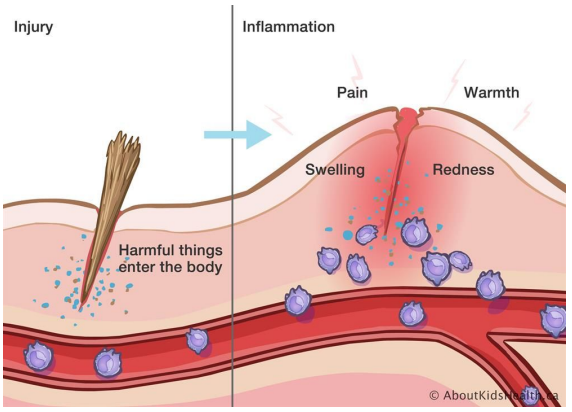
4. Chemical barriers:
    - Chemical barriers include stomach acid/gastric juice which is a mixture of hydrochloric acid, enzymes and mucus.
    - pH between 1.2-3 kills many microbes and destroys most toxins.
    - *Helicobacter pylori* neutralises stomach acid and can grow in the stomach, causing gastritis and ulcers.

5. Other secretions:
    - Urine → a sterile acidic liquid that cleanses the urethra and prevents growth of microorganisms
    - Saliva → washes microbes from teeth and mouth mucous membranes
    - Vaginal secretions → create acidic conditions which inhibit the growth of some bacteria and fungi

<u>The Second Line of Defence:</u>

- If the pathogen has managed to get past the first line of defence, there is a second set of mechanisms in our second line of defence
- These barriers keep most pathogens out of the body. If pathogens do manage to enter the body, the body's second line of defense attacks them. The second line of defense includes inflammation, phagocytosis, and fever

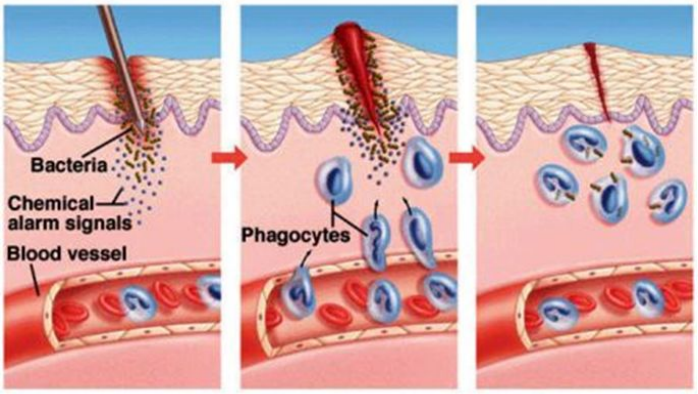
1. Inflammatory response:
    - After invasion of a pathogen or damage to cells, the area can become red, swollen, hot and painful
    - Once the infected cells have been damaged they release chemokines which then:
    - Attract neutrophils (stop the spread)
    - They act on mast cells (causing them to release histamine → causes dilation of the blood vessel and means more can pass through to the affected area)

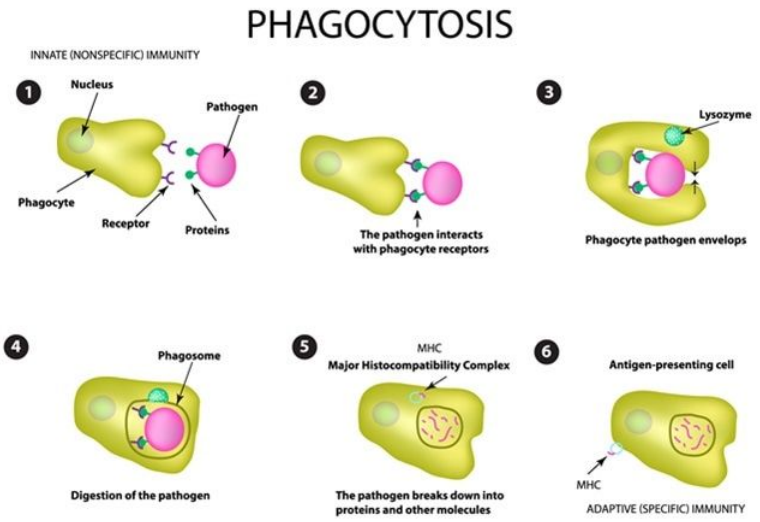


    - The purpose of inflammation is to destroy and remove pathogens. If destruction isn't possible, to limit effects by confining the pathogen and its products.
    - Heat within inflammation aims to slow the spread (messes with the enzymes of the pathogens) of the pathogen to the rest of the body → gives defences time to kick in. The increase in temperature also means that white blood cells can work more effectively to eliminate the pathogen.
    - The inflammatory response also repairs and replaces tissue damaged by pathogen and its products
    - Blood vessels dilate to increase blood flow to affected area which then increases the number of RBC and WBC (also **complement proteins**)

- There is increased permeability of blood vessels so that the WBC (such as phagocytes) and complement proteins can move out of bloodstream and into tissues easily
- Goal of inflammation:
  - To confine the pathogen to one area
  - Destroy the pathogen
  - Remove the pathogen, its products and any damaged tissue.

2. Phagocytosis (physical):
   - Carried out by phagocytes (WBCs) which move from the blood into the tissues to seek out, ingest and destroy pathogens
   - In early infection (hours-days) the cells present are called neutrophils
   - In chronic infection (weeks-months) the cells present are called macrophages
   - Both are phagocytes
   - Phagocytosis (multi-step process resulting in microbial death):
     1. Attachment
     2. Ingestion of pathogen and formation of a phagosome
     3. Fusion of pathogen with lysosome
     4. Digestion
     5. Release



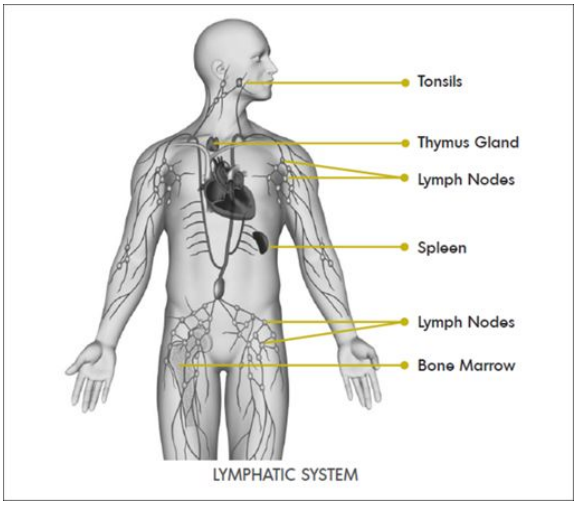


3. Neutrophils:
   - The neutrophils and macrophages recognise chemicals produced by the bacteria and migrate towards them
   - After investigating the foreign invader, they show pieces of the antigen on the cell membrane. This tells other cells what to look for so they can attack them

4. Fever (physical):
   - An increase in body temperature has been known since ancient times to be associated with infection and inflammation
   - Normal body temperature of humans is 37 degrees and the body may react to pathogens by altering the hypothalamic set point of body temperature and allowing the tissue to heat up. It does this by releasing ‘fever-causing’ chemicals known as pyrogens

- Humans experience this elevation in body temperature as a fever. The purpose of a fever is to kill or limit the growth of pathogens
- It may also enhance the activity of white blood cells and thereby strengthen the response of the presence of the pathogen

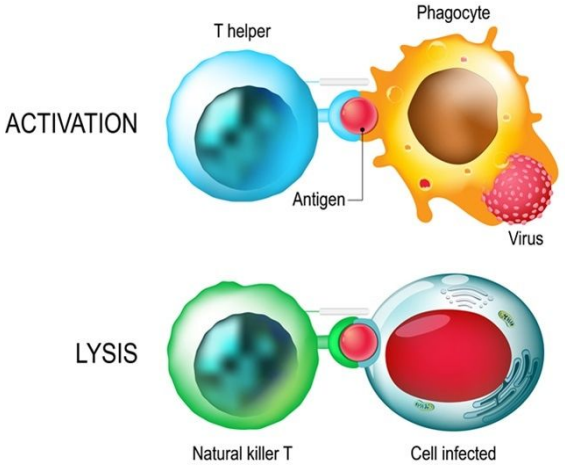
5. The Lymphatic System:
    - A system of nodes, capillaries and veins that drains fluid from tissue and returns it to the blood.
    - Lymph is a colourless fluid , similar to blood (without the red blood cells) that travels through the lymphatic system, joining the circulatory system at the heart.
    - Swollen lymph nodes indicate the body is fighting infection
    - Lymph nodes:
        - Act as filters, removing microbes, foreign particles, tissue debris and dead cells from circulation.
        - Lymphocytes formed in activated lymph nodes travel to the bloodstream so they can circulate around the body to fight infection



LYMPHATIC SYSTEM

6. Granuloma:
    - A granuloma is a cluster of cells that produce a covering to seal the pathogen in that area.
    - These cells die and are surrounded by macrophages, lymphocytes and a hard outer covering.
    - Granulomas are produced in tuberculosis and leprosy

7. Natural killer cells:
    - These are specialized white blood cells that can recognize when a cell is infected with a virus
    - They release a chemical while attached to the infected cell causing to undergo cell death – apoptosis
    - NK cells can also recognise some tumour cells and cause apoptosis in them as well



3.1.2 Adaptive Immunity

- If the innate immune system isn't able to expel the pathogen, adaptive immunity steps in
- After the first and second lines of defence, there is another (third line) to help protect the body
- The adaptive immune system is highly specific, providing specialised protection against pathogens which enter the body
- Includes B and T cells as well as other factors i.e antibodies
- Antigens are proteins found on the surface of pathogens. They are recognised as non-self. Antigens will trigger an immune response and by stimulating the B cells to produce antigen specific antibodies
- Humoral immunity is the aspect of immunity that is mediated by macromolecules found in extracellular fluids such as secreted antibodies, complement proteins, and certain antimicrobial peptides. Humoral immunity is so named because it involves substances found in the humors, or body fluids.

<u>Third Line of Defence:</u>

T Cells

- Produced in the bone marrow and mature in the thymus gland
- At maturation they are released into the blood, spleen, tonsils and lymph nodes
- Specific surface receptor proteins match with antigens and produce many clones of cytotoxic (killer) T cells specific to that antigen.
- They control **cell-mediated immunity** which is effective against
  - Bacteria and viruses that are inside the cells
  - Protozoa, fungi, flatworms and roundworms
  - Cancerous cells and transplanted foreign tissue

B Cells

- Produced and mature in the bone marrow
- At maturation they are released into the blood, spleen, tonsils and lymph nodes
- B cells have an antibody on their surface for a specific antigen. They have a short life, activated when they encounter an antigen. Upon activation they form plasma cells that produce antibodies.
- B cells control the **antibody-mediated (humoral) immunity** which defends the body against
  - Bacteria and viruses outside the cells
  - Toxins produced by the bacteria

- Antigen → any molecule that the body recognises as foreign and that triggers an immune response

B Lymphocytes (B cells):

- B cells are white blood cells that are formed (like all white blood cells) in the bone marrow
- B cells also mature in bone marrow (hence the name B cell)
- These B cells move into the lymph nodes (mall lumps of tissue that contain white blood cells, which fight infection, found in neck, groin and underarms) where they wait for phagocytes and other cells to present antigens to them
- This will active them to become a certain type of B cell
- B cells provide antibody mediated immunity

- Antigens activate the B cells to divide and differentiate into either plasma or memory cells
- This is humoral immunity

Plasma Cells (create antibodies):

- Plasma cells secrete immunoglobulins called antibodies that are compatible with the antigen
- B-cell response produces plasma cells
- It is like a lock and key fit
- The antibody binds to the antigen forming an antigen-antibody complex. This neutralises and destroys the antigen
- This binding destroys the antigen
- Plasma cells are found in bone marrow
- Clone themselves very quickly using mitosis
- Antibody strategies include:

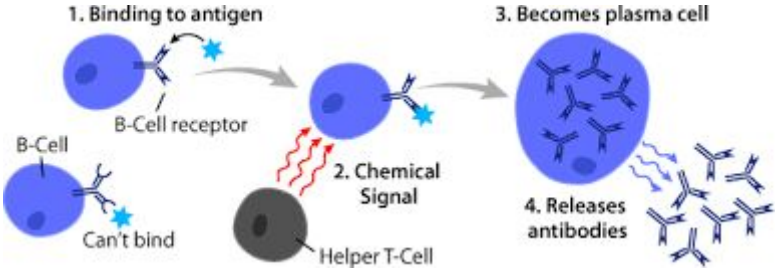
1. Neutralisation: deactivating a pathogen or toxin by blocking its active site. This mainly prevents the antigen from binding with its target
2. Precipitation: antibodies bind to soluble antigens causing them to form insoluble clumps (enhances phagocytosis as the clumps are more easily removed by the phagocytes)
3. Agglutination: antibodies bind to antigens on the surface of cells to form clumps of cells. Specifically pertains to cells instead of soluble antigens
4. Activating the complement system: this helps to disarm pathogens, enhance phagocytosis, inflammation and pathogen removal by cell lysis.

Shape of the antibody:

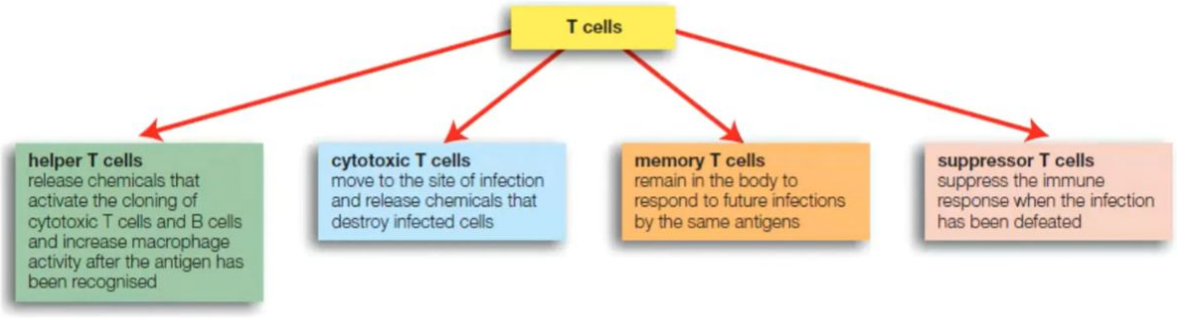
- The shape of the antibody is important as it forms the antigen-antibody complex
- This will help to significant other components of the immune system

Memory B-cells:

- At the time of infection and B-cell response is underway, some of the B-cells are made are called memory cells
- These circulate in our body for a very long time and provide us with immunological memory
- If you are re-infected with that same antigen, the memory B-cells will cause a rapid large scale production of the antibody required
- Memory cells provide long term immunity
- These cells remain dormant in lymph tissue but if the animal is exposed to the same antigen again, the memory cells recognise it and divide to produce antibody-producing plasma cells.
- The secondary response is faster, stronger and longer lasting due to the presence of memory B cells → symptoms are less severe



T lymphocytes (T cells):



- T cells are formed in the bone marrow they mature in the thymus - behind the sternum (hence T cells)
- T cells provide 'cell mediated immunity'
- They are very effective against body cells infected by virus
- Types of T cells:
  - Killer t cells (cytotoxic) → Destroy cells identified as 'non-self'. They form when the macrophage displays the antigen on its surface. The T cells bind to the infected one and infects the toxic chemical (perforin) into the cell and causes it to rupture
  - Helper t cells (CD4 T cells) → A helper T lymphocyte is a type of white blood cell that serves as a key mediator of immune function. Helper T cells play a central role in normal immune responses by producing factors that activate virtually all the other immune system cells. helper T cells activate B cells to differentiate into plasma cells so they can produce antibodies. Also activate cytotoxic T cells to divide and reproduce. Cytokines are also secreted by helper T cells. This then allows for an increase in the activity of phagocytes, helps to promote inflammation and stimulates the production of cytotoxic T cells. HIV specifically infects helper T cells, this has a negative impact on the immune system. Helper cells can active the B cells into two ways:
    1. Direct contact where the helper cell touches the B cell
    2. T cell produces a chemical called a cytokine and this reacts with the B cell membrane and activates it
  - Suppressor (regulatory) T cells: Turn off the immune response and suppress the production of antibodies
  - Memory T cells: Like memory B cells, memory T cells remain in the body after the primary exposure to the antigen. If our body encounters that same pathogen later in life there will be a rapid, large scale response to it

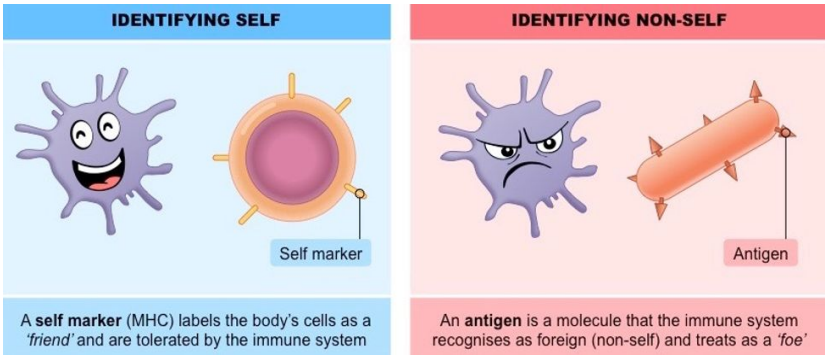
Interactions in the Immune System:

- Humoral **response (antibody mediated):** Antibodies are involved in attacking pathogens that our outside the cells i.e. in the bloodstream or body fluids
- Steps involved:
  1. Antigen binds to B cell
  2. Helper T cell activates B cell
  3. B cell divide and produce plasma cells
  4. Antibodies are made by the plasma cells
  5. These antibodies circulate through the blood neutralising pathogens, activating more phagocytes and activating the complement system (a series of proteins that enhance the immune response)
  6. Finally memory cells are made and provide long term immunity
- Cell mediated response: activated when the pathogen has entered the host cells or tissues
- The T cells need to be activated so they can release cytokines (chemicals) that destroy the antigen
- Antigens then bind to T cells
- Interleukins (chemicals) activate T cells to begin functioning
- T cells divide and produce cytotoxic T cells which destroy the antigens

These two systems are interrelated. B cells can't function without T cells. Helper T cells induce B cells to divide, resulting in large numbers of B cells dedicated to destroying the antigen. T cells stimulate production of antibodies by the plasma B cells.

Steps - Immune Response:

1. Pathogen enters the body and is recognised as non-self by the antigens on its surface



2. Inflammation leads to increase in diameter of blood vessels and in turn increased blood flow to the site as well as increased permeability allowing WBC to move into the infected area
3. Non-specific responses phagocytosis (macrophages and neutrophils) occurs and simultaneous release cytokines that signal more WBC to help fight infection
4. Phagocytes present the antigen to the B and T cells in the lymph nodes - where antigen specific B and T cells are selected an reproduce by clonal selection

5. B cells differentiate into plasma cells and start secreting antibodies to bind and immobilise foreign cells. Simultaneously cytotoxic T cells are attacking pathogenic cells with cytotoxins like perforin.
6. Memory T and B cells are produced
7. The pathogen is cleared from the site of infection and suppressor T cells come in and dampen the immune response as the infection is resolved
8. The memory B and T cells remain in circulation providing long term immunity

TOPIC 4 - Prevention, Treatment and Control

Inquiry Question: How can the spread of infectious diseases be controlled?

4.1 Disease Spread

- *Investigate and analyse the wide range of interrelated factors involved in limiting local, regional and global spread of a named infectious disease*

There are three different levels we can target to control the spread of disease: local, regional and global.

	Local	**Regional**	**Global**
Individual-level	- Limiting person to person spread by employing good hygiene practices - Covering mouth and nose while coughing and sneezing - Washing hands with soap and water - Wearing PPE such as mask and gloves - Social distancing and isolating	- Limiting person to person transmission through border protection (e.g. borders are closed for COVID-19, Queensland, WA and SA) - Screening new arrivals before entering a state - Although this is disruptive and difficult to implement (in the case of COVID-19) it is a necessary strategy	- Limiting person to person transmission through travel bans and restrictions - Screening and quarantining of arrivals in hotels/hospitals to ensure the incubation period is covered and the person is tested negative
Community-level	- Public health campaigns (e.g. Stay COVID Safe) on TV and radio which educate people on mass about how to stay safe and reduce transmission - Public health and community measures to conduct widespread testing for early detection of the virus - Closure of businesses,	- Quarantining areas with in the state (e.g. WA has sectioned off their state into 3 areas and people are not permitted to move out of their section of the state) - Widespread surveillance of case numbers to identify hotspots - Promoting prevention	- Equality in the distribution of medication and vaccines (e.g. not apparent for COVID-19, disadvantaged countries not receiving mediation/ventilators) - Global guidelines for infection control to be followed (e.g. WHO finding origin, transmission, how did it

	shops and schools - Preparation of hospitals and equipment for any new cases of the disease (e.g ventilators for COVID-19) - Use of vaccination campaign or antiviral medication to protect health care workers (not yet for COVID-19)	and control practices within the community (e.g. education groups of people)	become a pandemic) - Global surveillance to determine the path of transmission (e.g. COVID-19 was first seen in China then the spread was monitored across the world)

4.2 Methods for Preventing Disease

- *Investigate procedures that can be employed to prevent the spread of disease:*
    - *Vaccination including passive and active immunity*
    - *Quarantine*
    - *Hygiene practices*
    - *Public health campaigns*
    - *Use of pesticides*
    - *Genetic engineering*

4.2.1 Vaccination

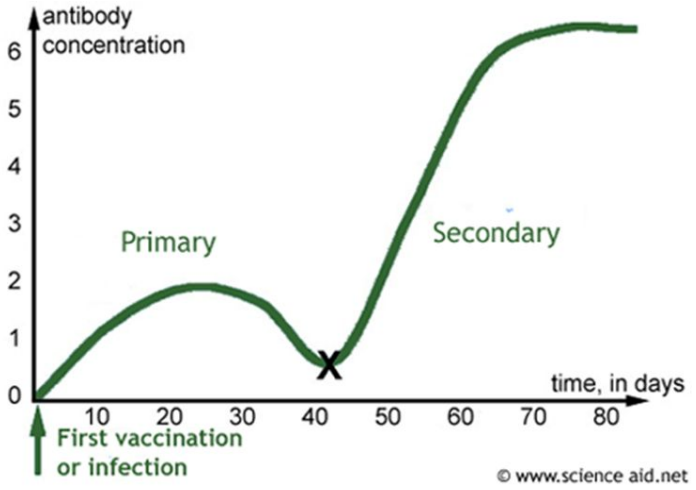
- Definition → The process of making people resistant to infection caused by a pathogen
- It involves receiving an injection or oral dose of vaccine that provides immunity
- Aims to prevent the infectious disease from developing and spreading throughout the community. Also aims to provide antibodies and memory cells
- What is a vaccine:
    - Preparation of live, dead or broken up pathogens that are injected so that immunity to a disease is developed (minus the symptoms). Allows the body to recognise the pathogen, not a big enough dose to make you sick but big enough for the body to recognise the pathogen.
    - Two types:
    1. Active immunisation (the body being challenged and body making memory cells and antibodies)
    2. Passive immunisation (given antibodies)

<u>Types of Vaccine:</u>

- Attenuated: live strains that are grown in the lab to be harmless (e.g. measles)
- Killed/dead pathogens: killed by heat or chemicals (e.g. typhoid)
- Fragments: part of the cell wall or virus capsid
- Toxoid: Toxin molecule is made harmless by heat or chemicals (e.g. tetanus)

<u>Active Immunisation:</u>

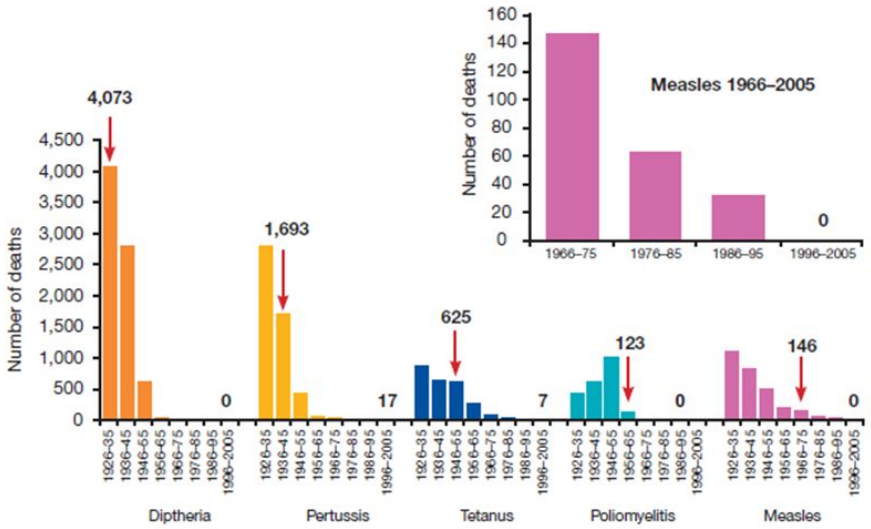
- Injection of antigen which causes the body to actively produce antibodies and provide long term immunity
- Memory cells are produced in the process and provide long term immunity
- Steps:
    1. Once vaccinated your body will produce specific antibodies to that antigen (this is the primary response).
    2. The memory cells will be circulating throughout the body and if exposed to that antigen a large scale, a rapid immune response will be activated
    3. The memory B cells will produce huge amounts of antigen-specific antibody to combat the pathogen and prevent the disease from affecting you



<u>Passive Immunisation:</u>

- The injection of antibodies to a specific pathogen
- Only provides a person with short term immunity
- Is able to last for up to 3 months before it is broken down in the body
- Example → hepatitis A (administered prior to travel)

Since the introduction of vaccinations (in Australia):



Examples of Vaccination Programs:

- Diseases such as smallpox, diphtheria and polio are now uncommon because of successful vaccination programs

Smallpox:

- Smallpox was the first disease for which a vaccine was developed. Edward Jenner did this in 1796. The vaccination program that was started in the 1960s was so successful that the World Health Organisation (WHO) has declared it eradicated.
- Famous for his vaccination against smallpox.
- This disease killed one in three of those who caught it and badly disfigured those who survived it.
- He was fascinated by an old wives tale that said milk maids could not get smallpox but could get a milder version called cowpox!
- Testing this theory: He took some pus from cowpox blisters found on the hand of a milkmaid. He injected a young boy with the pus in increasing doses over a few days. He then injected the boy with smallpox virus! The boy became ill, but recovered completely after a few days with no side effect World's first effective vaccination!
- Jenner did not patent the vaccination, thereby allowing the masses to be vaccinated. Smallpox was officially declared eradicated in 1979 thanks to the work of Jenner

4.2.2 Quarantine

- Quarantine is a period of isolation to prevent the spread of contagious diseases plays an essential role in preventing the entry of pests and disease into Australia
- Control of quarantine in Australia is controlled by the Department of Agriculture, more specifically the Quarantine and Biosecurity department
- Inspect people, animals, plants, machinery and any other materials entering Australia
- Role of Department of Agriculture (Quarantine and Biosecurity)
  - Australia's Quarantine or Biosecurity program is an arm of the Department of Agriculture
  - It's role is to protect Australia's unique environment by helping mitigate the risk of the introduction and spread of exotic pests and diseases, often introduced through shipping
  - Prospective exporters or their Australian importer should first check for any important requirements for their products with the Department of Agricultures Import Conditions Database
- Because of strict quarantine laws, Australia's animals and plants do not have some of the serious diseases found elsewhere
- Strategies:

- Quarantine inspectors are on duty 24 hours a day at all major points of entry of ships and aircraft
- Check people entering as well as their belongings
- Check all cargo and mail entering the country
- Imported animals are isolated in quarantine for a period of time to ensure they are free of disease
- Imported plant seeds are inspected for the presence of weed seeds mixed in
- Imported vehicles and farm machinery are inspected and clean so no soil or plant matter enters

- Importance:
  - Because of our strict quarantine laws, Australia's animals and plants do not have some of the serious diseases found elsewhere
  - If harmful diseases enter Australia, they would cause huge financial losses in lost profits to many industries (especially agriculture)
  - It would also be costly to attempt to bring the disease under control once it has entered
  - The cost of quarantine is much less than these costs would be should the diseases enter Australia or travel across Australia
- Animals:
  - Foot and Mouth disease is widespread in Britain and Europe (outbreak 2001)
  - Mad cow disease and Rabies have never crossed Australian borders
- Plants:
  - Fire blight is a bacterial disease infecting apples and pears - not present in Australia. The bacteria has spread from North America to Europe, the Middle East, Central America and New Zealand. Australia's strict quarantine laws prohibit the entry of all plant material

Blight
Causes death of plant tissue

Eucalyptus Rust
Caused by a fungus

Gall
A growth or swelling caused by an invasion of pathogens

Caterpillars
Cause damage to the leaf

- Interstate Quarantine:

- Trying to prevent the spread of disease from one state to another
- Phylloxera → insect affecting grapevines is present in Eastern Australia but not in South or Western Australian. If it is therefore forbidden to transport vines across these borders.
- Fruit fly → insect affecting fruit causing serious damage. Fruit is forbidden from being transported across borders to prevent the spread of fruit flies

4.2.3 Hygiene Practices

- Washing hands, particularly with soap and water (if not available then hand sanitiser with an alcohol content of above 70%)
- Cleaning surfaces regularly with disinfectant
- Cleaning wounds
- Undertaking responsible food preparation

4.4.4 Public Health Campaigns

- Focus on prevention, promotion and protection rather than on treatment
- Focus on populations rather than individuals
- Focus on the factors and behaviours that cause illness and injury rather than the illness and injury itself
- Communicable Disease Control:
  - Certain diseases in Australia are classified as 'notifiable' (inform the government so they can keep track of what is happening) e.g. AIDS, Anthrax, measles.
  - Other diseases require a quarantine period e.g. Cholera, Rabies, Smallpox. Needle and syringe programs are also used in control of communicable disease.
- Health Promotion: Health promotion campaigns that address health risks such as sun exposure, poor nutrition and physical inactivity. (e.g. Healthy Harold, Slip Slop Slap)
- Organised immunisation: Immunisation clinics, school immunisation programs, immunisation education, public awareness, immunisation databases and information systems.
- Food standards and hygiene: Development, review and implementation of food standards, regulations and legislation as well as the testing of food by regularly agencies
- Screening programs: Breast cancer screening, cervical screening and bowel cancer screening programs
- Prevention of hazardous and harmful drug use: Reduce and prevent the overuse or abuse of alcohol, tobacco, illicit and other drugs of dependence

4.4.5 Use of Pesticides

- Widely used to treat materials brought into Australia
- Poison is sprayed to kill insects especially crops, homes and other areas
- However it is known that over use of pesticides can lead to resistance in a population

4.4.6 GMOs

- Genetically engineered crops to contain resistant genes (resistant to pests and diseases)

- Bt cotton is a disease resistant crop. They produce a poison as they grow which kills the cotton pest Heliothis
- Again, the organism can become resistant due to natural selection

4.3 Pharmatucial Treatments

- *Investigate and assess the effectiveness of pharmaceuticals as treatment strategies for the control of infectious disease:*
    - *Antibiotics*
    - *Antivirals*

4.3.1 Antibiotics

- Chemicals produced by microorganisms that kill or stop the growth of bacteria and fungi
- Many antibiotics have been discovered but only a few are effective against bacteria without harming the host

Penicillin:

- Discovered in 1928 by Alexander Flemming
- Australian, Howard Florey purified the Penicillium strain for use to produce the penicillin antibiotics and started large scale production
- Proved effective against staphylococcus

How do they work?

- Penicillin: destroy cells wall of bacteria
- Streptomycin: disrupts protein synthesis
- Amphotericin: destroys cell membranes
- Broad spectrum: kill many different types of bacteria (including non-pathogenic forms)
- Narrow spectrum: kill one or two specific bacteria

Importance:

- Large scale production of antibiotics occurred during and post WWII. This reduced world infant mortality and eradicated many deadly diseases
- The spread of bacterial infections can be controlled by the widespread use of antibiotics. This can then restrict the spread of disease to other cities or countries, reducing the incidence of epidemics

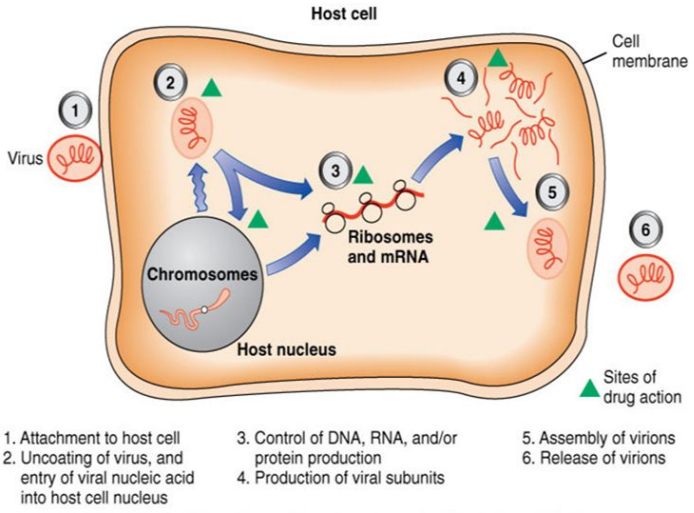
Antibiotic Resistance:

- Indiscriminate or incorrect use of antibiotics can act as a selecting agent on the bacteria, resulting in the evolution of multi-resistant strains that are difficult to kill
- This, in-turn can lead to a worldwide epidemic and the spread of disease, without a current treatment to prevent its spread
- Antibiotics are effective against many urinary tract infections, most ear infections and some sinus infections but are ineffective against all colds and flu, most coughs and most sore throats.

4.3.2 Antivirals

Viral Replication:

- A virus cannot replicate on their own but instead must attach to and enter a host cell
- It then uses the host cell's energy to synthesize protein (makes more of the virus), DNA and RNA



- Viruses are different to kill because they live inside cells
- This means that any drug that kills a virus may also kill the host cells - this is not beneficial to the host as it can cause serious harm

How do they work?

- **Doesn't destroy it but instead inhibits growth**
- Used to control viral infections by interfering with the virus life cycle and slowing it down
- This allows our immune system to 'catch up' and deal with the virus naturally
- The antiviral will also help with preventing further spread of the virus
- Able to enter the cells infected with virus
- Interfere with viral nucleic acid synthesis and regulation
- Some drugs interfere with ability of the virus to bind to cells
- Some drugs stimulate the body's immune system
- Best responses to antiviral drugs are in patients with complement immune system i.e. not immunocompromised
- A healthy immune system works synergistically with the drug to eliminate or suppress viral activity

Types Available:

- Cytomegalovirus (CMV)
- Hepatitis viruses (A-E)
- Herpes viruses (e.g. cold sores)
- Human immunodeficiency virus (HIV)
- Varicella (chicken pox and shingles)
- Influenza viruses (the flu)
- Respiratory syncytial virus (RSV)

4.4 Environmental Management and Quarantine Methods

- *Investigate and evaluate environmental management and quarantine methods used to control an epidemic or pandemic*

Ebola Virus (2014-16)

- Severe infectious disease, causes rapid death (50% death rate), spread through direct contact, a zoonose.
- Management incl. broad spectrum antibiotics, replacement of lost fluids.
- Admin control—organisation of response, allocation of tasks
- Environmental control—facilities for barrier nursing, hand hygiene, waste management (leak proof bags, covered bins), PPE (masks, gloves, waterproof boots, respirator, suit), surfaces sterilised every day.
- Quarantine—isolate patients in a single room/at least 3m between patient beds. Same clinical staff and equipment assigned to single patients. Visits restricted.
- Work with and educate the community on transmission and prevention.

4.5 Incidence and Prevalence Data

- *Interpret data relating to the incidence and prevalence of infectious disease in populations. For example:*
    - *Mobility of individuals and the portion that are immune or immunised*
    - *Dengue Fever in South East Asia*

Definitions:

- Incidence → the frequency of new cases of a disease over a specified period of time
- Prevalence → the proportion of a particular population affected by a disease
- Mortality rates → the number of deaths within a particular population as a result of a certain disease, over a specified period of time

4.5.1 Mobility of Individuals

- Incidence: New cases during a certain time
- Prevalence: Proportion of population with a disease at a certain time.
- Historical mobility
    - Silk Road → trade route from China to Europe this spread the Black Death.
    - Christopher Columbus → introduced 30 infectious diseases into the Americas e.g. smallpox, malaria.
- Modern mobility
    - Mobility in WWI spread the Spanish flu → killed more people than died in the war
    - HIV → originated in Democratic Republic of Congo. Increased, improved, cheaper travel options -> pandemic by 1980s.
    - Urbanisation → overcrowding, pressure on healthcare, increasing homeless population, poor living conditions which leads to the spread of disease e.g. TB, ebola.
- About 86% of the global population is immunised today.

4.5.2 Dengue Fever in South-East Africa

- Description:
    - Mosquito-borne tropical disease caused by dengue virus

- Spread by the Aedes types of mosquito
- Infection results in fever, headache, joint pain and fatigue
- May lead to development of dengue hemorrhagic fever or develop into dengue shock syndrome

- Viral illness
- Commonly found in Indonesia, Malaysia, Vietnam, Cambodia, Thailand, Philippines, Singapore
- A mosquito-borne viral illness caused by a flavivirus
- There are four different serotypes and the virus is carried by the *Aedes aegypti* mosquito
- It is found in tropical and subtropical areas
- Found in Northern Queensland, Western Australia and the Northern Territory
- Symptoms:
  - Range from asymptomatic to severe flu-like symptoms (aches, fever and fatigue)
  - Small proportion of cases develop severe dengue which involves hemorrhaging and multiorgan failure, then death can follow hen not treated correctly

<u>Epidemiology:</u>

- Dengue was identified in the 1950s ater epidemics in Thailand and the Philippines - today it has spread to most Asian countries and its incidence has been climbing ever since
- Also found in South America, Africa and Australia

<u>Incidence and Prevalence:</u>

- The incidence of dengue has grown dramatically around the world in recent decades
- A vast majority of cases are self-managed and hence the actual numbers of dengue cases are under-reported. Many cases are also misdiagnosed as other febrile illnesses.
- One modelling estimate indicates 390 million dengue virus infections per year (95% credible interval 284–528 million), of which 96 million (67–136 million) manifest clinically (with any severity of disease). Another study on the prevalence of dengue estimates that 3.9 billion people are at risk of infection with dengue viruses. Despite a risk of infection existing in 129 countries, 70% of the actual burden is in Asia.
- The number of dengue cases reported to WHO increased over 15 fold over the last two decades, from 505,430 cases in 2000 to over 2,400,138 in 2010 and 3,312,040 in 2015. Deaths from 2000 to 2015 increased from 960 to more than 40

<u>Incidence:</u>

- There are 390 million infections globally (per year)
- Current global estimates are that 3.9 billion people in 128 countries are at risk of infection
- 75% of the global population exposed to DF live in the Asia-Pacific region
- 2019 (worst year on record) → High number of cases were reported in Bangladesh (101,000), Malaysia (131,000) Philippines (420,000), Vietnam (320,000) in Asia.

- More than a million cases were reported in south-east Asia in 2019 with poorer households most at risk. The epidemic is exacerbated by poor infrastructure and lack of access to healthcare, with struggling health services overwhelmed by outbreaks.
- In the Philippines, there have been more than 1,000 deaths and 403,000 cases were reported in 2019 – a 98% increase in 2018. In Thailand 110 people died from dengue between January and October, with 106,000 cases reported. For the same period last year there were just 50,000

Prevalence:

- Found in tropical and sub-tropical climates
- Higher ratio of males than females hospitalised
- Typically affects children between the ages of 2-15 at a higher rate than adults
- Epicentres of outbreaks are located in major cities, mostly affecting urban and semi-urban areas
- Currently associated with the rainy season
- The rate is expected to increase due to viral evolution, climate change, globalisation, travel and trade factors
- Approximately a million people in South-East Asia

Distribution - Mobility (travel):

- Before 1970, only 9 countries had experienced severe dengue epidemics. The disease is now endemic in more than 100 countries in the WHO regions of Africa, the Americas, the Eastern Mediterranean, South-East Asia and the Western Pacific. The America, South-East Asia and Western Pacific regions are the most seriously affected, with Asia representing ~70% of the global burden of disease.
- Explosive outbreaks are occurring. The threat of a possible outbreak of dengue now exists in Europe; local transmission was reported for the first time in France and Croatia in 2010 and imported cases were detected in 3 other European countries.
- The largest number of dengue cases ever reported globally was in 2019. All regions were affected, and dengue transmission was recorded in Afghanistan for the first time.

Mortality Rates:

- Mortality rates: 22 million deaths globally per year
- Seasonal disease, first roughly 20 weeks of 2019:
  - Example → Malaysia: 50,000+ cases, 0.002% prevalence, 2x higher than last year.
  - Singapore → Almost 4000 cases, 0.0007% prevalence, 4x higher than last year.
- Climate change meant an increased spread.
- Dengue causes 10 million cases and 10,000 deaths per day.

4.6 Differing Strategies to Predict and Control Disease

- *Evaluate historical, culturally diverse and current strategies to predict and control the spread of disease*

4.6.1 Historical Strategies

Predicting Disease:

- There was very little understanding for the cause of disease so this meant minimal understanding for treatment, prevention or control
- Previously thought disease was caused by bad air
- Bernoulli was one of the earliest people to develop a mathematical model that showed if a person was vaccinated against smallpox then life expectancy was increased. This was found before the germ theory.
- The Epidemic Model (1972) was able to describe the relationship between susceptible, infected and immune people in a population
- Therefore they were able to determine possible spread and allowing for ways to control the disease to be implemented early and quickly

Controlling Disease:

- Widely believed that the Black Death, Malaria and Cholera were caused by 'bad air'
- Control strategies included:
  - Moving away from the bad air (swaps/sewage)
  - Using pomanders (perfumed wax) to repel the bad smell and fight infection

Examples:

- 460-370 BCE → Hippocrates (Greek physician) has the idea to collect and analyse data to predict and control disease. He believed that disease was a result of local conditions and collected data about the natural environment to determine when and where illness would occur.
- 69-30 BCE → Cleopatra used mosquito nets in her bedroom to protect her from being bitten during the night
- 1377 CE → The city Marseille uses quarantine to control the spread of disease by detaining individuals who had travelled from plague-infected areas for 40 days
- 1854 CE → John Snow (during the London cholera outbreak) used maps to record deaths and pinpoint the pathogen source

4.6.2 Culturally Diverse Strategies

Predicting Disease:

- There are many cultural and religious beliefs about health, disease, treatments and vaccination
- Cultural practices played a major role in the spread of Ebola in Africa (2013-2016):
  - African culture has very strong values placed on family and community (greetings involve close contact)
  - The elderly and ill are cared for by family

- Many infected with Ebola did not go to hospital for treatment because there is a believe that they could die from being away from loved ones
- Cultural practices for burial and mourning also involve very close contact with the corpse of the deceased.

Controlling Disease:

- Traditional Chinese medicine includes: acupuncture, herbal medicine, diet, massage and Tai Chi
- Ancient Chinese doctors established a pattern of warm disease that spread from people or households and treated them with specific herbs many still used today e.g. Ginseng and honeysuckle
- In Philippines uses traditional foods (e.g. garlic and onion) that contain quercetin to lower blood pressure

4.6.3 Current Strategies

Predicting Disease:

- Surveillance programs, notifiable diseases, public health intervention are all vital to maintaining control
- Mathematical modelling is used to predict:
  - Future occurrence of disease
  - How a disease will spread and progress
  - How intervention strategies may impact on incidence of cases
  - Hotspots of emerging cases
- Computer programing and algorithms allow for increased complexity and analysis of the data to get the most accurate picture of what is happening with the disease
- We still use mapping and contact tracing to predict where and when the next outbreak will occur

Controlling Disease:

- Australia has a national framework for communicable disease control and this helps with prevention, detection and response to disease
- National Notifiable Disease Surveillance System (NNDSS) → any confirmed cases of notifiable disease are investigated to ensure that it is contained and prevent further transmission
- Quarantine → For example, in 2003, there was an outbreak of severe acute respiratory syndrome and people were told to isolate in their houses.

Examples:

- **World Health Organisation (WHO)** → Uses both traditional surveillance methods and informal event-based data and coordinates international outbreak response using data from GOARN. Data sets that combine existing data on climate, vaccination and populating immunity are used to predict outbreaks while networks are established to improve communications among people during an epidemic
- **Global Public Health Intelligence Network (GPHIN)** → Event-based surveillance system that systematically scans a multitude of informal sources including news

reports, online newspapers, social media and internet-based searches. In 2002 GPHIN issued the first alert of unusual respiratory illness in Guangdong province which triggered an international response

- **Global Outbreak Alert and Response Network (GOARN) →** Established in 2002 by WHO and gatherers infectious disease intelligence in order to promptly detect and verify outbreaks, issue real time alerts and rapidly respond to global or national public health threats.

4.7 Aboriginal Protocols

- *Investigate the contemporary application of Aboriginal protocols in the development of particular medicines and biological materials in Australia and how recognition and protection of Indigenous cultural* and *intellectual property is important, for example:*
    - *Bush medicine*
    - *Smokebush in Western Australia*

- Aboriginal Australians are the custodians of a rich and detailed knowledge base of medicinal native Australian herbs, fruits and vegetables
- Traditionally, Aboriginal people lived healthy lives but there was sometimes a need to manage wounds (from burns, stings, bites)
- Substances from plants such as tannins, mucilage, oils, latex and alkaloids were used for medicine.
- The plant material was usually crushed and used as a poultice or infused with water to drink. Animal fat was often incorporated into the plant material. This increased the fat solubility of the plant substance and increased absorption rates into the issues.
- There has been a renewed interest in traditional Aboriginal medicinal knowledge. Databases are being compiled by different groups to ensure that these traditional approaches to disease control are not lost
- Scientists are now discovering that many bioactive compounds are contained in these traditional bush medicines. Some contain antimicrobial properties that are useful in managing certain infectious diseases.
- For example, alkaloid compounds from the Moreton Bay Chestnut (*Castanospermum austral)* or black bean are showing promise in the management of HIV/AIDS.
- It must be remembered that many of these plants contain potentially deadly compounds as well. Aboriginal people used specialised preparation techniques to minimise the harmful effects

<u>Smoke Bush (bush medicine example)</u>:

- In 1798, English botanist James Smith named the genus *Conospermum* meaning ‘cone seed’. These plants are commonly known as smokebush and grow mostly in south-west Western Australia
- Some species of this plant have very big and woolly white flowers that resemble drifting smoke
- These plants are a member of the Proteaceae family.
- Indigenous people have used smokebush for healing and scientists have now investigated the properties of this plant and its potential uses against cancer and HIV/AIDS

Bush medicine:

- Bush medicine is a new branch of horticulture that promises to be a fertile area for the development of new and effective treatment against a range of pathogens
- Scientists must separate the useful from the deadly before these treatments can be used commercially

Plant or Animal	**Traditional properties and uses as antimicrobials**	**Photo**
Emu bush leaves	- Has been valued for both medicinal and ceremonial purposes by Indigenous people in coastal parts of Australia. - The leaves have been used as a decoction for sores and wounds, an infusion for colds, headaches, chest pains and smoked to create a sterile environment for newborn babies and healing new mothers	
Gumbi Gumbi	- Gumbi Gumbi (pittosporum angustifolium) is found throughout the drier areas of Australia and is perhaps the most potent, yet versatile indigenous medicine. - It is used in a significant number of traditional medicinal applications, from the treatment of coughs and colds to eczema, and even used for lactagogue (milk let-down) activity.	
Tea tree leaves	- Grows in sand or clay around swampy and seasonally wet areas - Tea tree is none of the most widely known natural antiseptics in the world and has been used as a mainstream pharmaceutical since the 1920s - Traditionally it was crushed and the vapour was inhaled to treat headaches. It was also brewed as a tea for throat ailments and could be applied to wounds and superficial injuries - Today, it is widely used as a natural antiseptic with proven antimicrobial properties - A recent study found that antiviral agents is a promising combative to recurring herpes	

Kakadu plum fruit	- The world's highest source of Vitamin C and is an essential nutrient, rich in antioxidants - Vitamin C is involved in tissue repair and building collagen which plays a role in wound healing and anti-aging - It is also rich in iron and Vitamin E	
Witchetty grub	- Commonly known for being 'bush tucker' - Nutritionally witchetty grubs (*E. leucomochla*) are a great source of proteins and also contains good fats and vitamin C - They can also be used to treat burns and open wounds (once crushed and made into a paste)	

<u>Recognition and protection of Indigenous cultural and intellectual property:</u>

- Rights to develop the patent in Australia were licensed exclusively to a Victorian Pharmaceutical company (AMRAD). In order to gain access to rights over the plant for research, $1.65 million was paid to the WA Government
- Recognised that rights are sometimes only obtained so that Aboriginal culture can be exploited for monetary gain
- Patenting also represents a threat to Aboriginal communities and their traditional cultural practices. There is a possibility that the rights to use an entire species of flora may be sold to large multinational drug companies. This would prevent groups from using such plants subject to an exclusive agreement
- Essentially, the patenting of traditional medicinal plants may prevent Indigenous Australians from continuing to autonomously use their own cultural knowledge
- It is important that we understand the culture-specific rules associated with Indigenous knowledge (since they know the land and have done so for 65,000 years)
- Ownership manifests itself in very different ways across Indigenous and Western societies
- As Aboriginal Australians have used oral histories to pass their cultural information through generations, there may be complex rules governing the dissemination of information
- Some information may be sacred (meaning it is only allowed to be used by those within a group possessing certain authority). Customary laws and community values should be respected during any commercialisation process so that Indigenous knowledge may be protected as intended. This is particularly important in light of the limited control Indigenous people have over their land.