Edexcel GCSE Biology

Your notes

Defence Against Disease

Contents

Plant Defence Responses

Your notes

Chemical Barriers

- Plants have a range of **defence mechanisms** to infections and infestations
- These can be split into **chemical** and **physical** defences

Chemical defences

- Plants have chemical adaptations to prevent herbivores from eating them
  - Antiseptics or antimicrobial enzymes
  - Chemical poisons to deter pests that might eat them
  - Mechanisms to attract other insects as a **biological control**
- These same chemicals can sometimes be used to treat human diseases
  - Chemicals with **antimicrobial** properties can be extracted for human use such as in **antibiotics**
  - Herbal face creams can use plant extracts such as tea tree oil, mint and witch hazel to have an antibacterial effect
  - The pain relief drug, **aspirin,** originated from the bark of willow trees

Physical Barriers

Physical defences

- Plants also have several **physical adaptations** which provide protection
  - The **cellulose cell wall** not only provides support for the plant but also protection from microorganisms
  - The **waxy cuticle** of the leaf and stems acts as a barrier to microbes from entering the plant. The only place that they can enter in the leaf is through the stomata
  - **Bark** provides a tough layer around the stem of the plant to prevent pathogens from entering
  - As deciduous trees **lose leaves** in the winter the infection can be taken with them
  - **Thorns** or **hairy stems** also makes it more difficult for pests to access the plant tissue to feed

Plant Adaptions Table

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Adaptation	How does this work?	Example
Poisons	Some plants produce poisons to deter herbivores from eating them. Animals will quickly learn to avoid eating plants that make them feel unwell.	Foxgloves, deadly nightshade and yew.
Thorns	Make it unpleasant or painful for large herbivores to eat them.	Brambles, cacti and gorse
Hairy Stems	Hairy stems or leaves deter insects and larger animals from feeding on them or laying eggs on the stem or leaves.	Poppies. Can be combined with poisons, for example nettles.
Drooping or curling when touched	This is a rare but effective mechanism, when touched the leaves will automatically curl which can dislodge insects and frighten off larger species.	Mimosa pudica will curl and point leaves to the ground when an insect touches it.
Mimicry	Plants can droop to look as though they are diseased and trick animals into not eating them.They can also resemble larger insects to scare away any potential threats.	Passion flowers have evolved to mimic having butterfly eggs on its leaves so that butterflies do not lay their eggs. White deadnettle does not sting, but looks very similar to a stinging nettle.

Plant Diseases

Your notes

Detecting & Identifying Plant Disease

Higher tier only

- Plants can be infected with a range of **bacterial and viral pathogens**; such as the tobacco mosaic virus (TMV) and rose black spot fungus (see Viral Diseases & Fungal Diseases)
- Plants can also be infested with **insects** such as **aphid** which pierce the surface of the stem and feed off the sap in phloem causing physical damage and weakening the plant
- The symptoms of plant diseases can apply to **more than one disease**, which makes identifying them difficult
- Symptoms of diseases in plants include:

Plant Diseases Table

Symptom	Example
Stunted growth	Rose Black spot, tobacco mosaic virus, mineral deficiencies
Spots on leaves	Rose black spot
Areas decaying/rotting	Rose black spot, potato blight
Visible pests	Aphids, caterpillars
Discolouration of the leaves	Tobacco mosaic virus, magnesium deficiency
Growths	Crown Gall bacteria infection
Malformed stems and leaves	Aphid infestation

Detecting and identifying plant diseases in the field

- Studies of plant species in their natural environment might highlight the presence of certain diseases
- **Observations** by plant pathologists would be carried out and diseases identified based on symptoms
  - Chalara ash dieback causes leaf loss and bark lesions
  - Aphids cause physical damage to the stems of plants
- When a symptom of a disease has been detected, it is important to determine whether it is due to the proposed disease or an **environmental issue**, such as mineral ion deficiency
- Assessing the **distribution** of the plant populations also may indicate what type of pathogen is involved and/or how it is being transmitted
  - Patches of diseased plants may suggest infection through the **soil**
  - Random distributions may suggest **airborne transmission** such as the spores which cause Chalara ash dieback

Detecting and identifying plant diseases in the laboratory

- In order to do a more detailed assessment of plant disease, ecologists may take cuttings of plants to return to a laboratory for **chemical analysis**
- **Culturing** the pathogen from the sample taken may lead to accurate identification of the disease
  - **Monoclonal antibodies** can be used:
    - These are **antibodies** that are specific to the **antigens** on the pathogen
    - If the antigen is present in the infected plant sample, the antibodies will **bind** to them and allow accurate diagnosis of the disease
  - **DNA analysis** in the laboratory would help to identify the specific pathogen causing the problem

Your notes

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Human Defence Responses

Human Physical Barriers

- The human body has a number of mechanisms that are the first line of defence against an infection
- **Physical barriers** – structures that make it difficult for pathogens to get past them and into the body
  - **Skin** - covers almost all parts of your body to prevent infection from pathogens. If it is cut or grazed, it immediately begins to heal itself, often by forming a scab.
  - **Hairs and mucus in the nose** - these make it difficult for pathogens to get past them further up the nose so they are not inhaled into the lungs
  - **Mucus and cilia in the trachea and bronchi** - pathogens get trapped in mucus produced by cells in the airways of the lungs. Other cells lining the trachea and bronchi have cilia (microscopic hair-like structures) that waft mucus up to the back of the throat so it can be removed from the body (by coughing, blowing the nose, swallowing etc.)

Human Chemical Barriers

- **Chemical barriers** – substances produced by the body cells that trap or kill pathogens before they can get further into the body and cause disease
  - **Stomach acid** - contains hydrochloric acid which is strong enough to kill any pathogens that have been caught in mucus in the airways and then swallowed or have been consumed in food or water
  - **Lysozymes** - enzymes produced by the eyes and released in tears will breakdown and kill bacteria on or around the eye
  - Natural **bacterial flora** in the gut and vagina - protect against infection from pathogenic bacteria by outcompeting the pathogen
  - **Sebum** on the surface of the skin - kills bacterial and fungal pathogens

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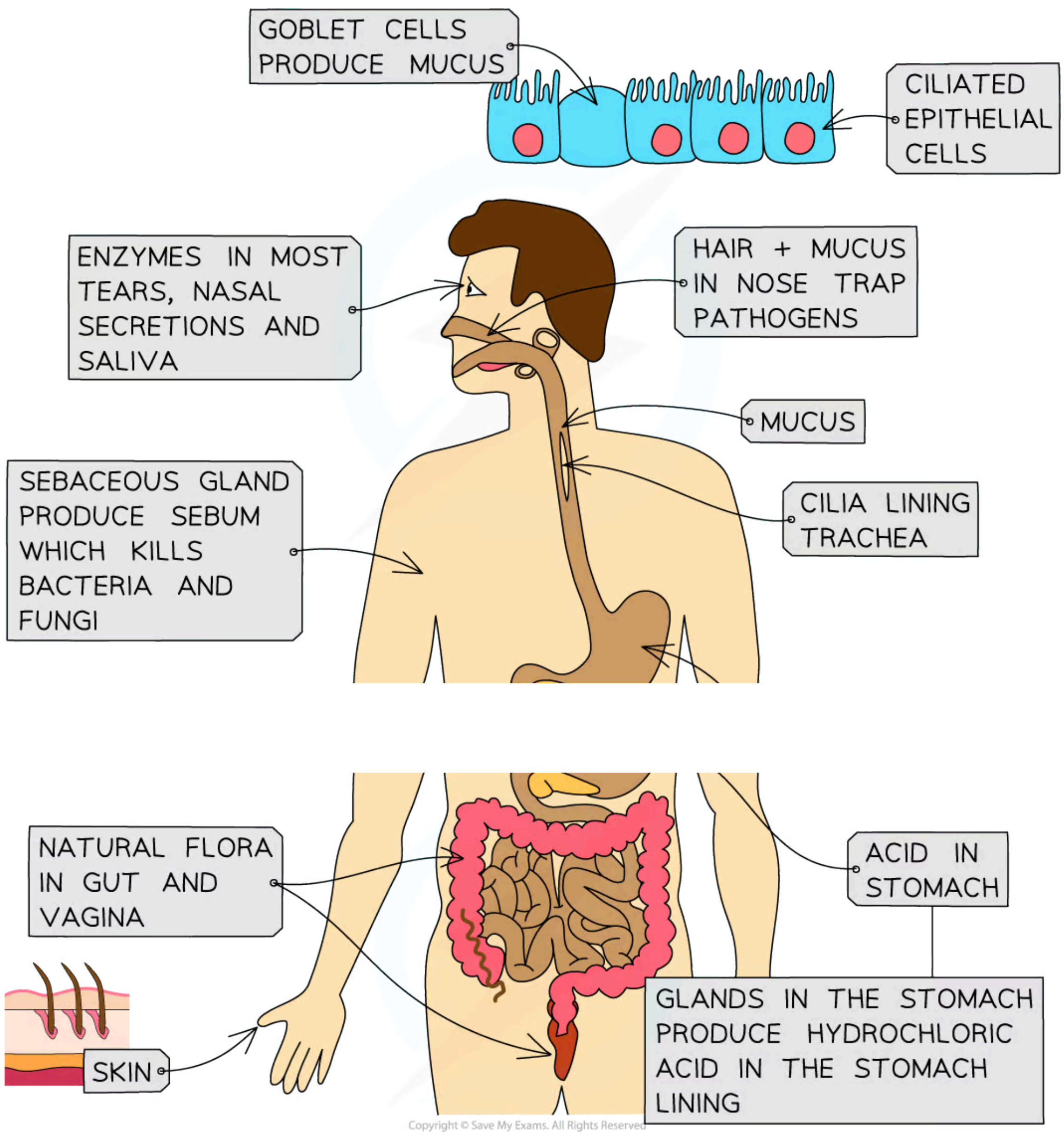

The first line of defence involves several chemical and physical barriers which prevent pathogens from entering the body

Immunity

Your notes

Non-Specific Immune Response

- White blood cells are part of the body's **immune system**
- These specialised cells defend against pathogenic microorganisms
- There are two main types of white blood cell:
  - **Phagocytes -** carry out phagocytosis
  - **Lymphocytes -** produce antibodies and antitoxins

Phagocytes

- Phagocytes carry out **phagocytosis** by **engulfing and digesting pathogens**
  - Phagocytes have a sensitive cell surface membrane that can detect chemicals produced by pathogenic cells
  - Once they encounter the pathogenic cell, they will engulf it and **release digestive enzymes** to digest it
  - This is a **non-specific** immune response as the response is **the same for any pathogenic cell**
- Phagocytes can be easily recognised under the microscope by their **multi-lobed nucleus** and their **granular cytoplasm**

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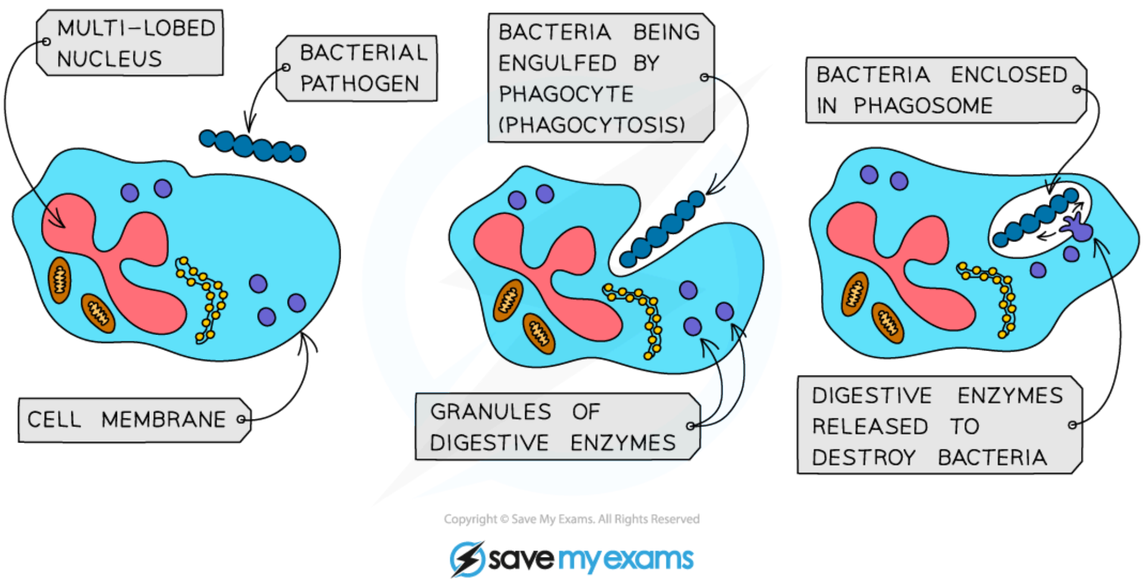

The process of phagocytosis

Specific Immune Response

Lymphocytes

- **B-Lymphocytes** can easily be recognised under the microscope by their **large round nucleus** which takes up nearly the whole cell and their **clear, non-granular cytoplasm**
- **B-Lymphocytes** produce **antibodies**
  - Antibodies are Y-shaped proteins with a shape that is **specific** (complementary) to the **antigens** on the surface of the pathogen
  - This is a **specific** type of immune response as the antibodies produced will only fit one type of antigen on a pathogen

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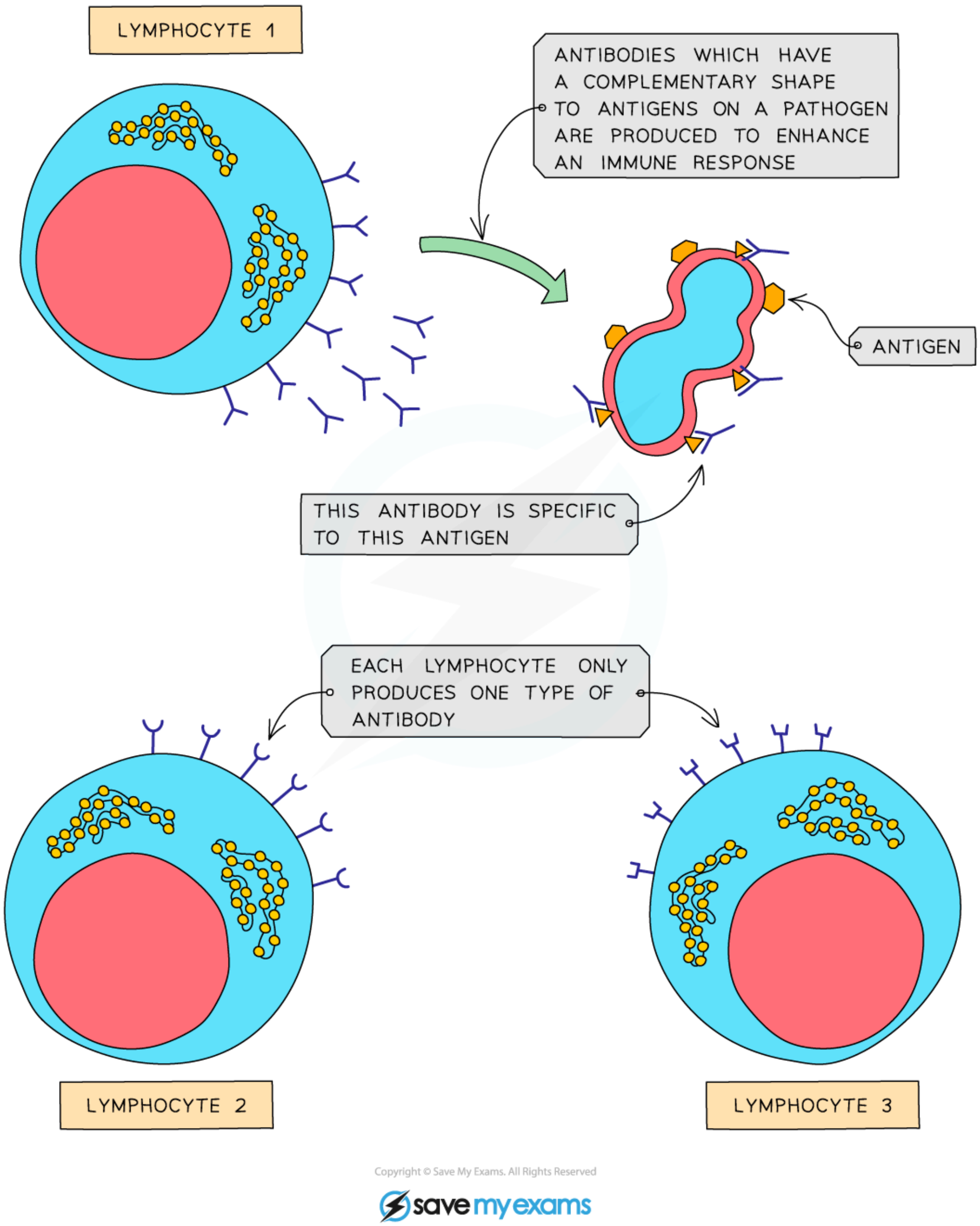

The lymphocytes produce antibodies that are specific to the antigen on the pathogen

- Antibodies attach to the antigens and cause **agglutination** (clumping together)
- This means the pathogenic cells cannot move very easily
- At the same time, **chemicals** are released that signal to **phagocytes** that there are cells present that need to be destroyed

Your notes

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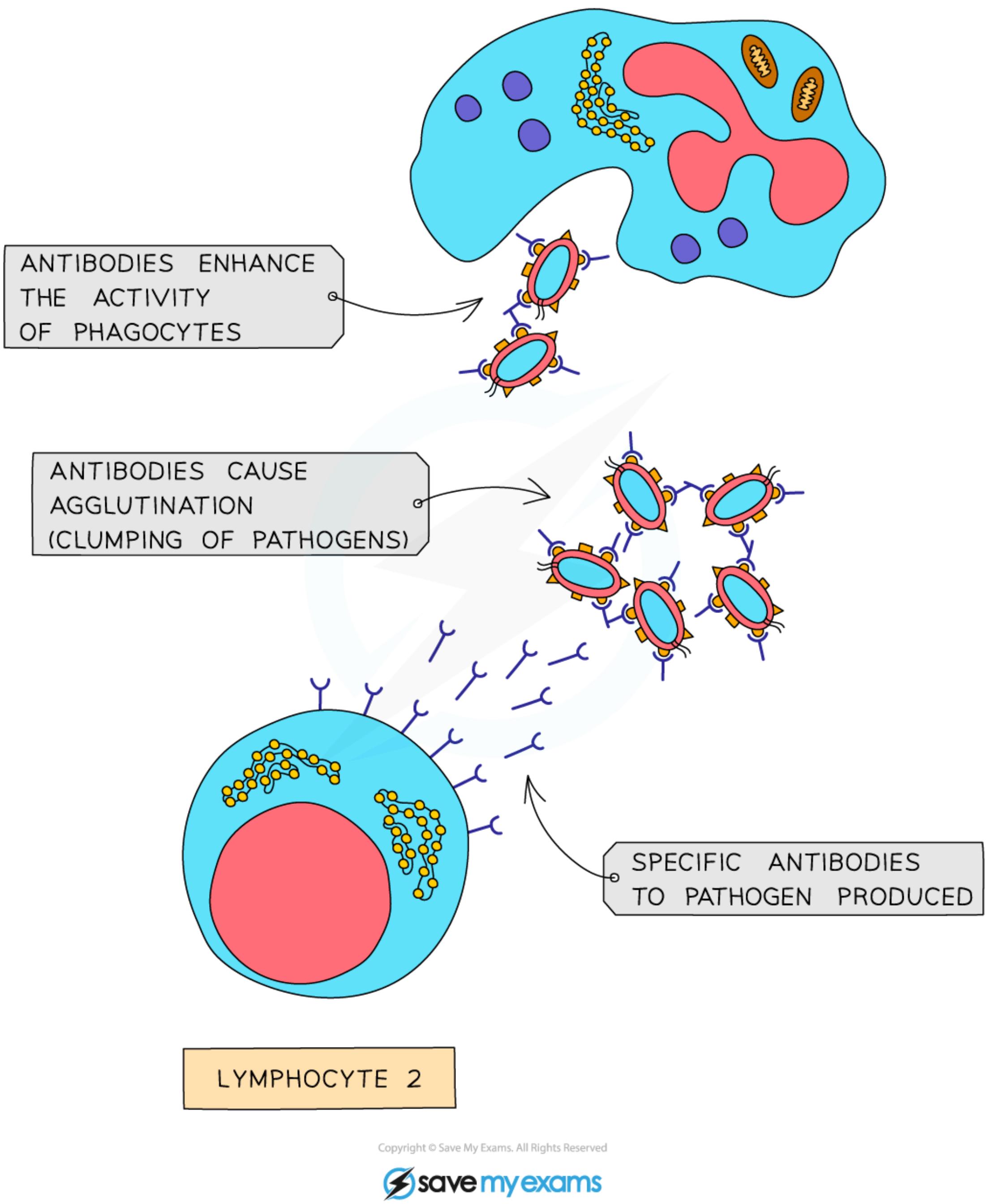

Agglutinated pathogens cannot move easily

- **Lymphocytes** also produce **antitoxins** to neutralise toxins released by pathogens

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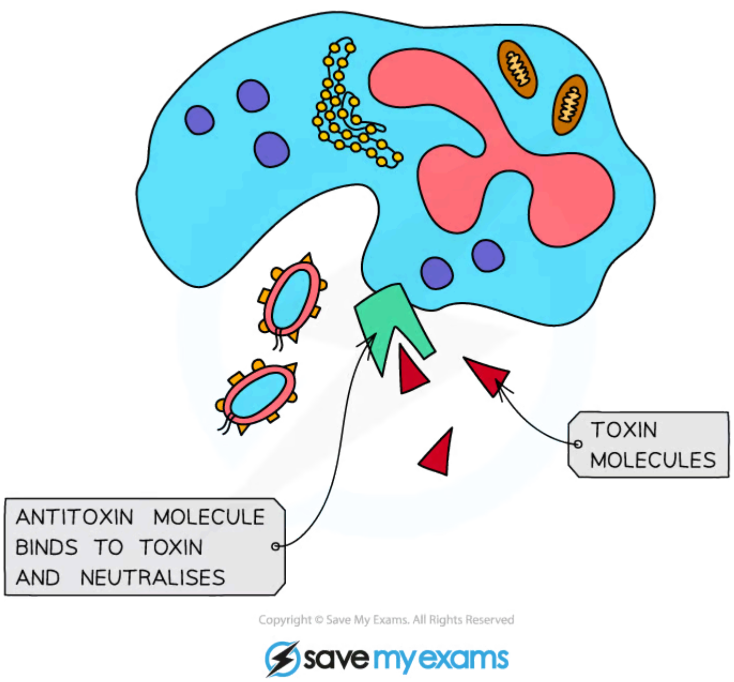


Lymphocytes produce specific antitoxins to specific pathogens

Response to infection

- The stages of infection and the subsequent immune response are as follows:

1. The pathogen enters the blood stream and **multiplies**
2. A release of **toxins** (in the case of bacteria) and **infection of body cells** causes **symptoms** in the patient
3. **Phagocytes** that encounter the pathogen recognise that it is an invading pathogen and **engulf and digest** (**non-specific response)**
4. Eventually, the pathogen encounters a **B-lymphocyte** which recognises its **antigens**
5. The lymphocyte starts to produce **specific antibodies** to combat that particular pathogen
6. The lymphocyte also **clones itself** to produce lots of lymphocytes (all producing the specific **antibody** required)
7. Antibodies cause **agglutination** of pathogens
8. **Phagocytes** engulf and digest the agglutinated pathogens

9. After the patient has recovered, they **retain antibodies** specific to the disease as well as **memory cells** (lymphocytes that recognise the pathogen)
10. If the patient encounters the same pathogen again, it will trigger a secondary immune response
11. Memory cells can produce much **larger quantities** of the required antibody in a much **shorter time** to fight off the pathogen before the patient suffers any symptoms

Your notes

Examiner Tips and Tricks

Make sure you know the difference between antigen, antibody and antitoxin:

- An **antigen** is a molecule found on the surface of a cell
- An **antibody** is a protein made by lymphocytes that is complementary to an antigen and, when attached, clumps them together and signals the cells they are on for destruction
- An **antitoxin** is a protein that neutralises the toxins produced by bacteria

Your notes

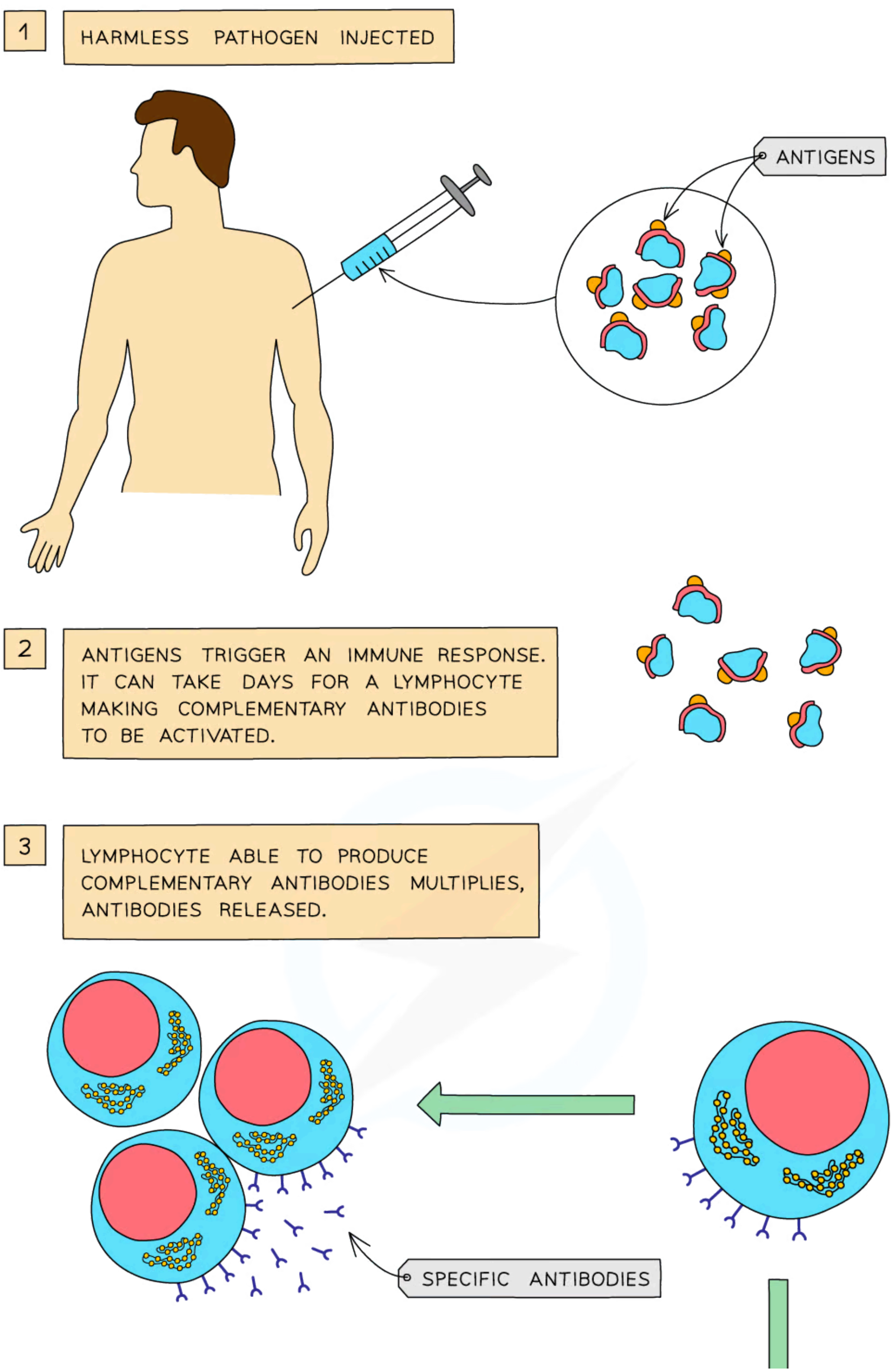
Vaccination

Vaccination

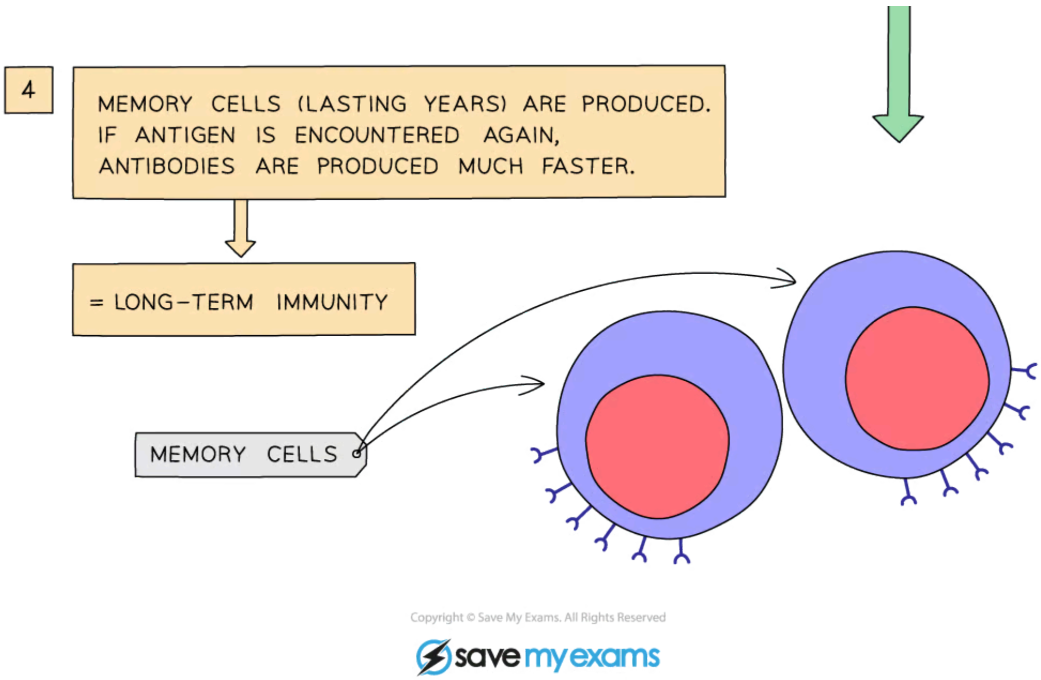
- Vaccines are used to **induce immunity** to infectious diseases
- A vaccine contains **harmless** versions of a pathogen
- There are several different methods by which scientists ensure that vaccines contain harmless pathogens such as:
  - **Killing** the pathogen
  - Making the pathogen **unable to grow or divide** (**attenuated** vaccine)
  - Using **fragments** of pathogens, which include the necessary **antigens** (rather than whole cells)
- A vaccine may be administered **orally, nasally** or via an **injection**

How vaccines work

- Once in the bloodstream, the antigens contained within the vaccine can trigger an immune response in the following way:
  - **Lymphocytes** recognise the **antigens** in the bloodstream
  - The activated lymphocytes produce **antibodies specific** to the antigen encountered
  - **Memory cells and antibodies** subsequently remain circulating in the blood stream


1
HARMLESS PATHOGEN INJECTED
ANTIGENS
2
ANTIGENS TRIGGER AN IMMUNE RESPONSE. IT CAN TAKE DAYS FOR A LYMPHOCYTE MAKING COMPLEMENTARY ANTIBODIES TO BE ACTIVATED.
3
LYMPHOCYTE ABLE TO PRODUCE COMPLEMENTARY ANTIBODIES MULTIPLIES, ANTIBODIES RELEASED.
SPECIFIC ANTIBODIES

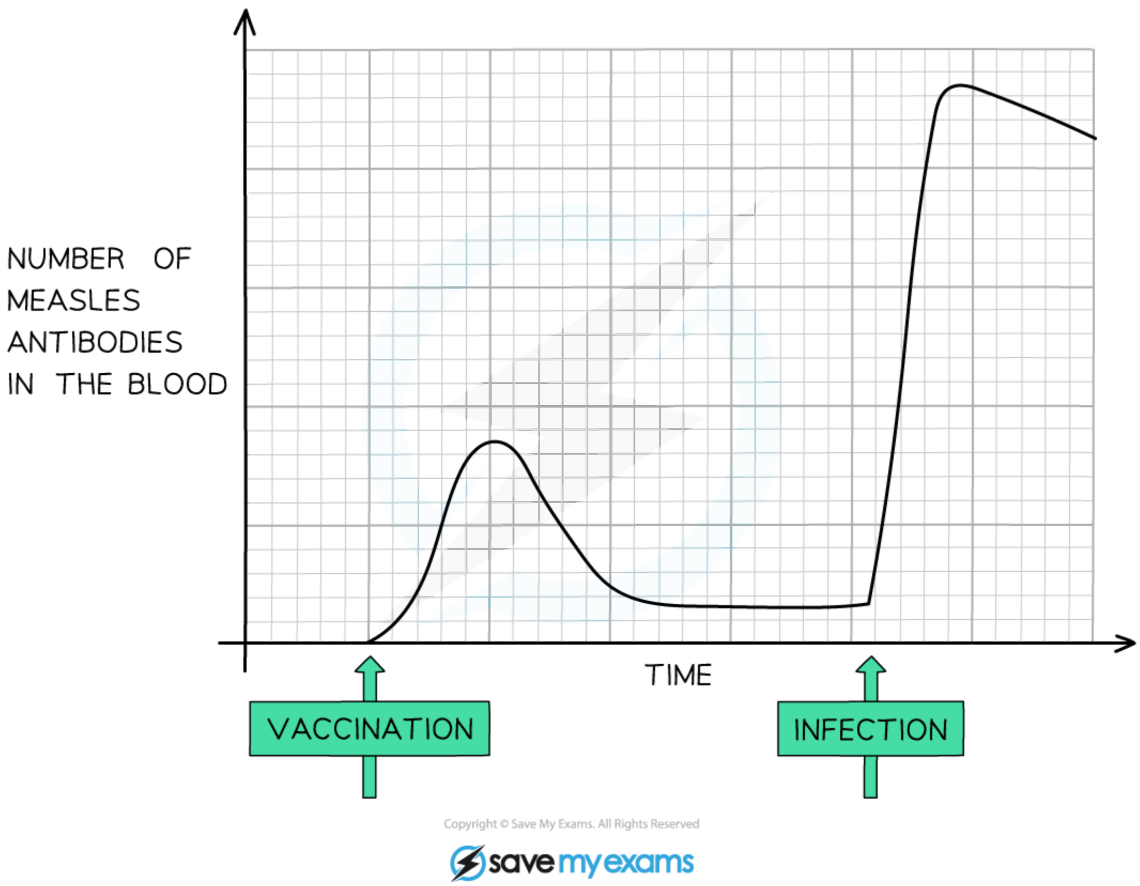
Your notes



The process of long-term immunity by vaccination

- Future infection by the same pathogen will trigger a response that is **much faster** and **much larger** compared to the initial response
- Due to the rapid nature of the response, the pathogen is unable to cause disease and the individual is said to be immune

Your notes



Graph showing the number of measles antibodies in the blood following vaccination. The secondary response is much faster and a greater number of antibodies are produced.

Advantages & Disadvantages of Vaccination

Advantages of vaccination

- Vaccines not only protect the vaccinated individuals, they also **reduce** the likelihood that an infected individual will **spread** the pathogen to others
  - If a **large proportion of the population** is vaccinated, it is unlikely that an unvaccinated individual will become infected with the pathogen
  - This concept is referred to as **herd immunity** and can **prevent the spread** of the disease
- Vaccines have **reduced the cases of certain diseases** drastically or even **eradicated** many diseases worldwide

  - This includes smallpox, measles, mumps and tetanus amongst many others
- There are hopes for the future eradication of several other diseases through **vaccination programs**
  - This includes polio, HIV, malaria and of course COVID-19

Disadvantages of vaccinations

- There are some disadvantages to vaccinations that reduce how effective vaccination programs can be
  - **Mutations** in the pathogen's DNA/RNA can result in significant changes to the antigen of the pathogen meaning that lymphocytes no longer recognise the pathogen
  - Vaccination doesnt always give **immunity**
  - **Side-effects** of vaccinations can reduce the uptake in the population

Advantages & Disadvantages of Vaccination Table

ADVANTAGES	DISADVANTAGES
• DISEASES THAT WERE ONCE COMMON ARE NOW FAIRLY RARE DUE TO WIDESPREAD VACCINATIONS. (FOR EXAMPLE POLIO, MEASLES) • **EPIDEMICS** CAN BE PREVENTED IF LARGE NUMBER OF THE POPULATION ARE VACCINATED	• THE VACCINE DOESN'T ALWAYS GIVE IMMUNITY • THERE CAN BE SIDE EFFECTS TO THE VACCINE, FOR EXAMPLE SWELLING OR A RASH TO MORE SEVERE REACTIONS SUCH AS SEIZURES