Immune System Notes

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An animal, during the course of its life, encounters and must defend itself from many potentially dangerous bacteria, viruses and other pathogens. To respond to these dangers the body has evolved two kinds of defence systems to enable the animal to counter these threats, these are the **general defence system** and the **specific defence system**.

The first form of defence is known as the general defence system at GCSE.

The general defence system: is a group of tissues and cells that protects the animal in general way against any potential pathogens that may be encountered.

The general defence system is made up physical barriers, chemical defences and phagocytes.
Let's look at the physical barriers first and see what each barrier does 😊

Physical Barriers

1. **The skin**: this is a physical barrier that prevents the entry of pathogens.
2. **Mucus membranes:** these secrete mucus which lines many body parts. The mucus traps pathogens and prevents them from entering the body.
3. **Nasal hairs:** these remove suspended micro-organisms from the air.
4. **Cilia:** are small hairs on the cells lining the trachea and bronchi. They waft mucus to the pharynx for swallowing to the stomach.

Chemical Barriers

1. **Stomach acid:** this kills pathogens that are swallowed, usually by denaturing their enzymes.
2. **Lysozyme enzyme**: an enzyme that is found in sweat and tears, this is able to destroy bacterial cell walls.
3. **Antimicrobial secretions**: the skin produces oils (sebum) that can kill pathogens.

Pathogens that penetrate the body's physical and chemical defences must face the Phagocytes…

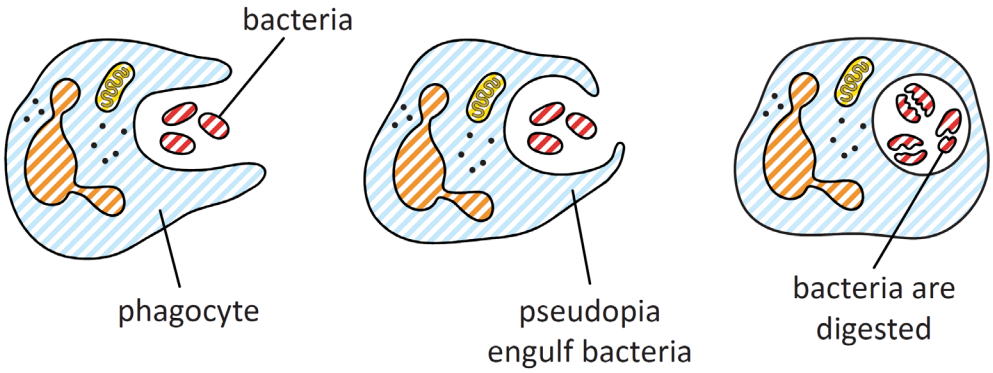
Phagocytes

Phagocytes: are white blood cells that engulf and destroy other cells. They can identify a pathogen by its antigen. The word phagocyte means "**cell eater**".

An antigen: a unique molecule (which is often a protein) on the surface of a pathogen or foreign cell that triggers an immune response.

The phagocytes can read each antigen a bit like how barcodes are read by a till in a shop. When they identify an antigen as "foreign" phagocytes can bind to the object and engulf it in a process known as phagocytosis.

Within the phagocyte, enzymes such as lysozyme, break down the pathogen in order to destroy it. As phagocytes do this to any and all pathogens that they encounter, they are considered part of the general defence system.



The Specific Defence System

If a pathogen is able to avoid the physical and chemical barriers as well as the phagocytes then that pathogen could make us ill. If that happens then we have a specific problem which needs a specific response…

The specific immune system: made up of lymphocytes which attack specific pathogens that have penetrated into the body. They do this by producing antibodies.

Lymphocytes

What are lymphocytes? They are a type of white blood cell that play an important role in the immune system. There are two different types of lymphocyte that we study for the GCSE. These are B Lymphocytes, often called B cells for short and T Lymphocytes, which are often called T cells for short 😊

A Lymphocyte

Just for Context 😊

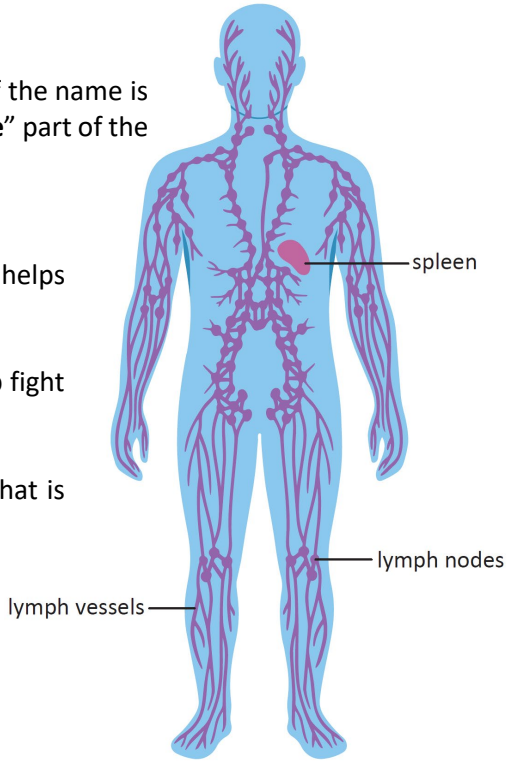
The following section is not on the GCSE specification but we are including it here so that you can place all of these structures in the body and understand this whole system a bit more.

Lymphocytes are called lymphocytes, but why? Well the "**lympho**" part of the name is because these cells are found mostly in the **Lymphatic system** and the "**cyte**" part of the name literally means cell. So, a lymphocyte is a lymph cell.

What is the lymphatic system? Good question!
The lymphatic system is a network of vessels, lymph nodes, and organs that helps fight infections and it also helps to maintain fluid balance in the body.

You could think of the nodes as mini forts packed with lymphocytes to help fight off infections.

So, it's like an entirely separate circulation system (but without a pump) that is involved in fighting pathogens. The figure shows the lymphatic system.



Ok… let's get back to the lymphocytes themselves 😊

What does each type of lymphocyte do? Let's look at each.

1. B Lymphocytes (B cells) are produced and mature in the bone marrow. Hence why they are called B cells. B cells produce antibodies that bind to specific antigens on pathogens, marking them for destruction by the phagocytes.

2. T Lymphocytes (T cells) are produced in the bone marrow but they mature in the thymus gland.
   T cells do not produce antibodies but they do help in other ways.
   - Helper T cells help to activate B cells and other immune cells when we meet a pathogen.
   - Killer T cells (cytotoxic T cells) destroy infected body cells.

What happens when an antigen is detected?
- Each B cell can produce antibodies against only one specific antigen.
- A B cell will come into contact with the antigen and then differentiate.
- The B cell differentiates into a memory cell and a plasma cell. These then increase in number by mitosis.

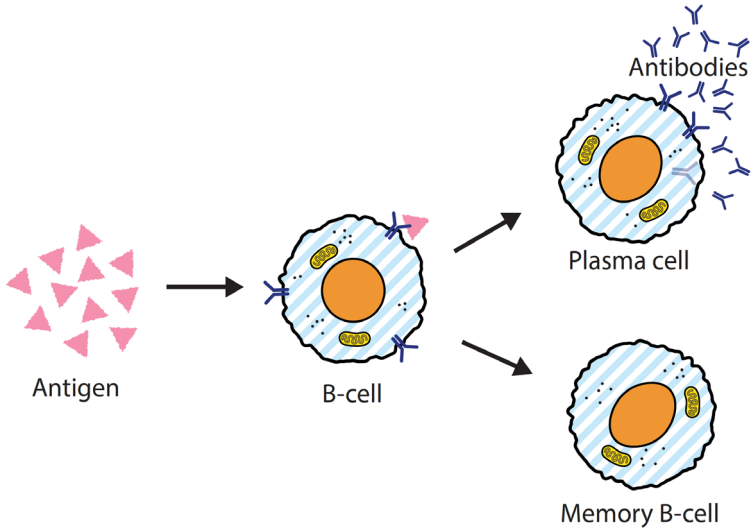
Memory Cells and Plasma Cells

So, when a B-cell differentiates into one memory cell and one plasma cell these have very different roles in defence…

Memory cells: are produced to **recognise a pathogen's antigen in future** if a person meets it again.
If they do meet the antigen again then the memory cell will differentiate into another memory cell and another plasma cell and these would increase in number by mitosis. This is a much faster response than the first time, this is known as the secondary response. Memory cells live for a very long time so they can provide long term immunity to a pathogen.

Exam note: DO NOT SAY MEMORY CELLS REMEMBER THE ANTIGEN. THEY DON'T. You will not receive a mark for saying that memory cells remember antigens. **They recognise them.**

Plasma cells: are lymphocytes that produce antibodies against the antigens of the pathogen.



The figure to the left shows a B-cell binding to an antigen and **differentiating** into a plasma cell and a memory cell.

The way our immune system reacts to a pathogen depends entirely on whether it is meeting the pathogen for the very first time, or if it recognises one it has met in the past. This is called the primary and secondary response.

Primary Versus Secondary Response

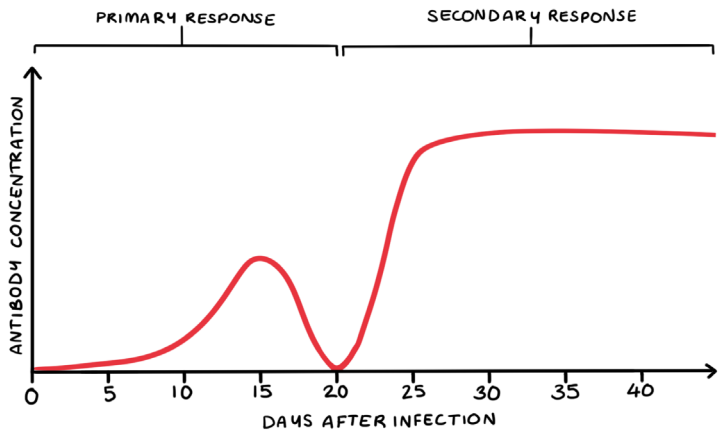
An exam question could ask you to compare a primary and secondary response to the same antigen.

The primary immune response: occurs when an antigen comes into contact with the specific defence system for the first time this response is relatively slow and can take over a week in some cases.

The secondary immune response: occurs the second time the animal is exposed to the same antigen. This is a much faster response, taking only a short time to produce larger quantities of antibodies.

Primary response to an antigen	Secondary response to an antigen
• It takes a long time to produce antibodies for the first time. • Antibody concentration is low. • Antibodies do not remain in the bloodstream for very long.	• Antibody production is quicker/faster than primary response. • Antibody concentration is much higher than primary response. • Antibodies remain in the blood for many months sometimes even years.

The graph to the right illustrates the difference between a primary and secondary response.



The First Vaccine

A vaccine: is a substance containing antigens from a specific pathogen that is introduced into the body to stimulate white blood cells to produce antibodies, leading to immunity without causing the disease.

The first vaccine was developed by Dr Edward Jenner in 1796. Dr Jenner noticed that milk maids would very often get a mild disease called Cowpox but they never developed Smallpox, a deadly disease.

He concluded (correctly) that the two diseases were closely related and that previously having the mild Cowpox gave lasting immunity to Smallpox.

Jenner then injected a boy with Cowpox pus. The boy developed Cowpox but recovered quickly. Jenner then injected the same boy with Smallpox pus. The boy did not develop Smallpox.

Advantages of Immunisation	Disadvantages of Immunisation
• Protects individuals against disease.	• Not guaranteed to work or provide 100% protection.
• Prevents epidemics and pandemics.	• Possible side effects.
• Prevents you spreading the disease to others.	• Costs to the NHS or to the individual.
• Prevents the potential greater cost of treating the infected patients.	

Herd immunity: occurs when the majority of individuals in a group are immunised. This provides protection to the few individuals who are not vaccinated by reducing their chances of meeting an infected person.

Antibiotics

How do antibiotics work? Antibiotics work by **disrupting the cell wall synthesis of dividing bacteria**.

What does disrupting cell wall synthesis mean? Bacterial cells have cell walls that help maintain their structure. If we mess up their ability to build these walls then they're left with only their cell membranes. These membranes can't regulate water properly. As a result, water moves into the cell by osmosis, causing the bacteria to burst and die. 😊

As animals do not have cell walls the antibiotics have no effect on animal tissues. Antibiotics are only effective against bacteria. They have no effect against a fungal or viral infection. Increasing antibiotic resistance is a concern. The first antibiotic Penicillin was discovered by Alexander Fleming from a mould called *Penicillium*.

Calculating areas on agar plates

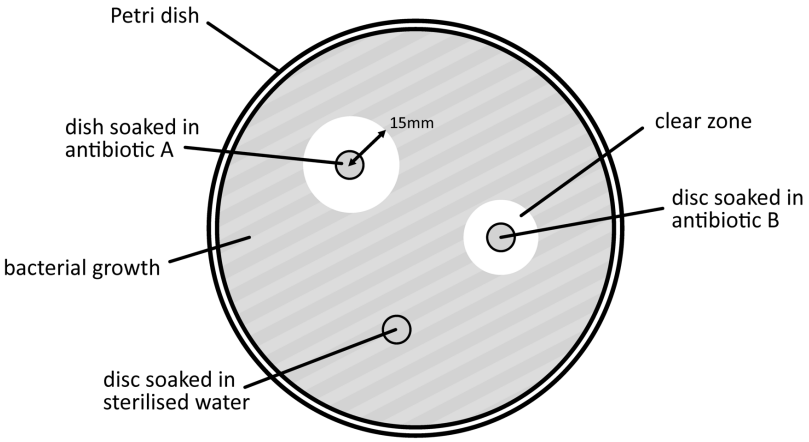
A number of these types of questions have come up in recent years. This is part of a policy of bringing more maths into biology examinations to have more of a problem-solving aspect in the papers.
These are quite straight forward. If you are comfortable calculating the area of a circle these should be no issue at all.

Area of a circle $= \pi r^2$

Exam note: please ensure it is the **radius** that you are using in the calculation as questions often give the diameter.

Example: the diagram below shows what a student sees on a petri dish after it has been prepared with a culture of bacteria and it was then incubated overnight.

The radius of the clear zone around the disc soaked in antibiotic A is 15 mm.
Calculate the area of this clear zone. Use the equation: area of clear zone $= 3.14 \times r^2$.



πr^2

$3.14 \times (15)^2 = 706.50$

To three significant figures $= 707\ mm^2$

Aseptic Technique

As we have just looked at the petri dishes and using them to find clear areas in agar jelly let's take this chance to look at aseptic techniques.

Aseptic techniques: refer to techniques used to prevent contamination by unwanted microorganisms when growing microorganisms.

What do we need to know about aseptic technique?

1. How each technique works.
2. Some of the apparatus used and why it's used.

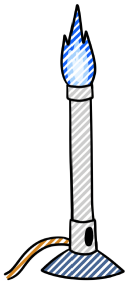
How each aseptic technique works!

Working near the Bunsen burner

This is one of the most common techniques used in microbiology.

Working near to a lit Bunsen burner means that you are working in a pocket of sterile air.

This helps to reduce the chance of contamination.

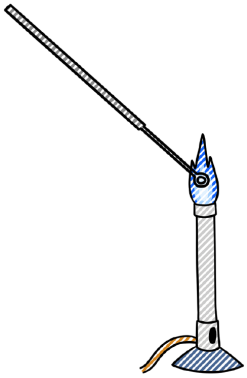


Use of an autoclave

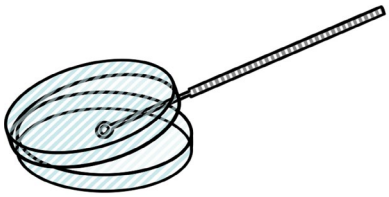
Autoclaves are machines that can create high temperatures and pressures. This is used to **sterilise** equipment such as petri dishes and agar jelly.

Sterile inoculation loop

An inoculation loop is often used to place microorganisms onto the agar jelly of a petri dish. It is very important that this loop be sterile before being placed into the microorganism that you want to culture.

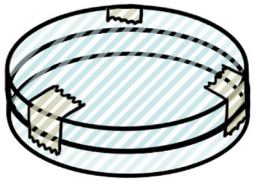


The loop can be sterilised by placing it into the roaring flame of a Bunsen burner and holding the loop there for a few moments. It is important not to put the loop down as this would contaminate the loop



Keep petri dishes and culture containers sealed

This is quite obvious. To prevent contamination, petri dishes and culture containers should be kept sealed when they are not in use.



Exam note: we should say that we only tape up the plate in a few places. Don't say "seal it completely airtight". If it is completely sealed, oxygen cannot enter, which encourages the growth of dangerous, disease-causing anaerobic bacteria!

Development of New Drugs

Today, most new drugs are made by chemists and other scientists in the pharmaceutical industry.

But before we can use new drugs… we have to make sure they **work** and **work safely**! 😊

Before a drug can be prescribed by a doctor at your local GP, it must be tested to ensure it meets **three** criteria:

Toxicity: Is it toxic? Is it harmful? What are the side effects?

Efficacy: Is it effective? Does the drug actually work to treat the disease?

Dosage: How much of the drug is needed to work safely against the disease?

In order to find out the answers to each of these questions we need to test the drug at different stages of its development. Let's look at the different stages of new drug development.

Stage 1: Pre-clinical testing

Where does this stage happen? In a laboratory.
What is the drug being tested on? Human cells, tissues, and live animals.
What is the point of this stage? To test for toxicity (safety) and efficacy.

Stage 2: Clinical Trials

Where does this stage happen? In hospitals/clinics.
What is the drug being tested on? Humans. The clinical trials then have a few different phases in them…

Phase 1: Very low doses are given to healthy volunteers – to make sure they don't die.
Purpose*:* To check for safety and side effects (not efficacy yet).

Phase 2: If the drug passes phase 1 and is safe, the drug is given to a small group of patients suffering from the illness.
Purpose*:* To test efficacy and find the optimum dosage of the drug.

Phase 3: If the drug passes phase 2 we then test it on a much larger group of patients to confirm our findings.

What can we do to prevent bias during the trials?

To ensure results are scientifically valid, trials use specific methods:

Note: Just a quick reminder that being valid means that the experiment has only one variable, only one thing that is changed and everything else is kept the same.

What is bias? Bias occurs when the results of a trial are influenced by personal opinions, expectations, or poor experimental design, rather than being a true reflection of what happened. If bias is present, the results are **not** valid. To prevent bias we could use a placebo, a double blind trial and peer review over the process. Let's look at each!

Placebo: a substance that looks like the real drug but contains no active ingredient (for example a sugar pill).
This controls for the psychological effect of taking medicine.

Double-blind trial: neither the patient nor the doctor knows who has received the active drug and who has received the placebo during the trial.
Why should we do this? To stop doctor bias when recording results and patient bias when reporting symptoms.

Peer Review: Before results are published, other scientists check the data to prevent false claims.