C3.2

Immune System

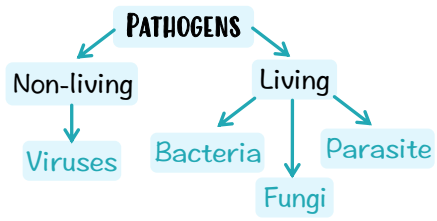
Section 1 — Defense Against Infectious Disease

Immune System – Network of organs that protect your body from **infections**.

Pathogens are disease-causing organisms. They include viruses, parasites, bacteria, fungi...

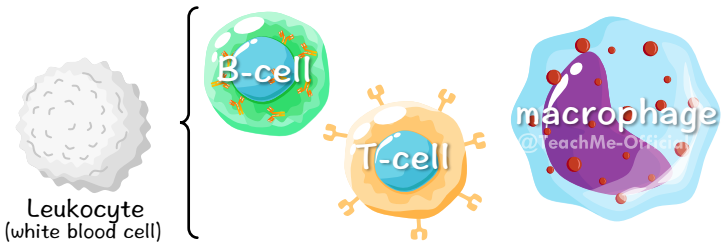
Our bodies have various "barriers" in place to prevent such pathogens from infecting us including first, second and third line of defense (see below).

(Disease causing organisms)



The best way to prevent an infection would theoretically be **quarantine**, however, that is no way of living – therefore our body has its own way of dealing with infectious pathogens.

Innate Immunity (non-specific)		Adaptive Immunity (specific)
I. First line of defense	II. Second line of defense	III. Third line of defense
Skin Mucous membranes	Blood clotting Phagocytes (macrophages)	Lymphocytes (T-cells & B-cells) Antibodies Memory B-cells

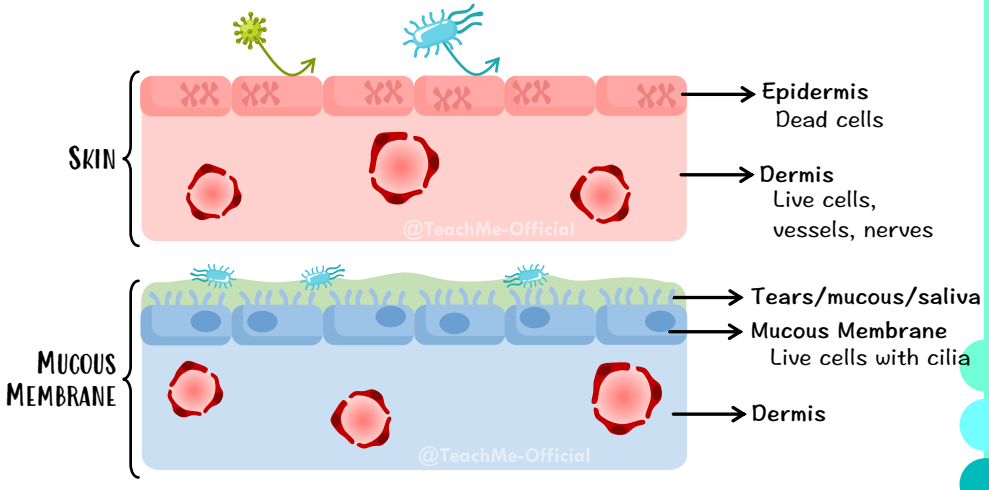


Leukocytes (white blood cells) are important cells which play a role in our immune system. It is important to notice that leukocytes are just a **general name** for many different types of cells. Some of which you learn about in this chapter such as **B-cells, T-cells and macrophages.**

First line of defense

The **skin** and **mucous membrane** are the first line of defense. The **skin**, with its thick layer of dead epithelial cells, forms a physical barrier against pathogenic invaders.

Mucous membranes are found at body openings such as the trachea, the nose, urethra, vagina; they produce secretions to trap pathogens and use their cilia, hair-like extensions, to sweep the pathogens out of the body.

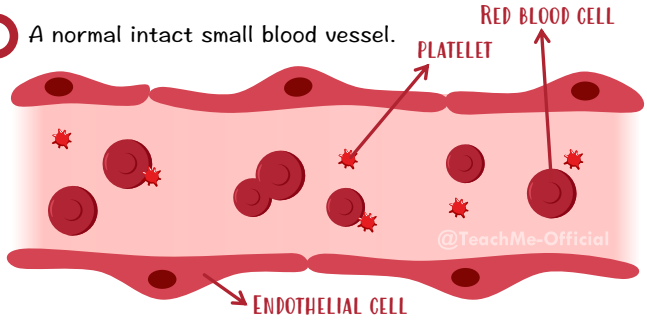


Second line of defense

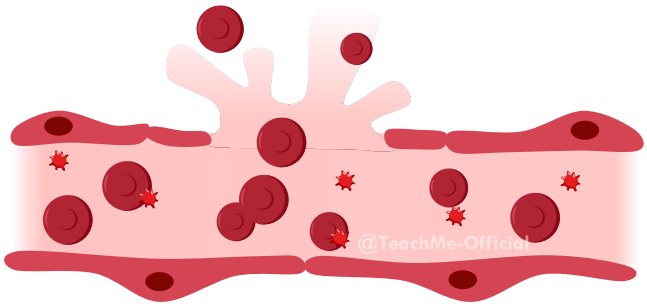
Blood Clotting If the skin or mucous membrane barrier is disrupted (for example by a cut), the pathogen now has a gateway to enter your body tissues or bloodstream. To prevent this from occurring, as part of the second line of defense, the body can make a blood clot to close the wound created by a cut (on page 2).

Immune System

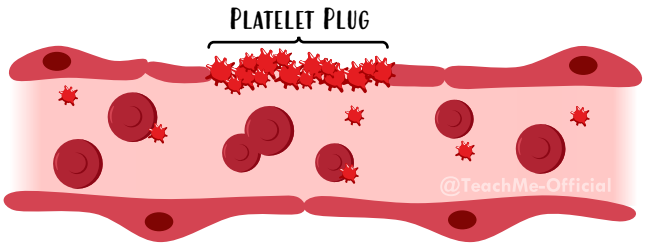
1. A normal intact small blood vessel.



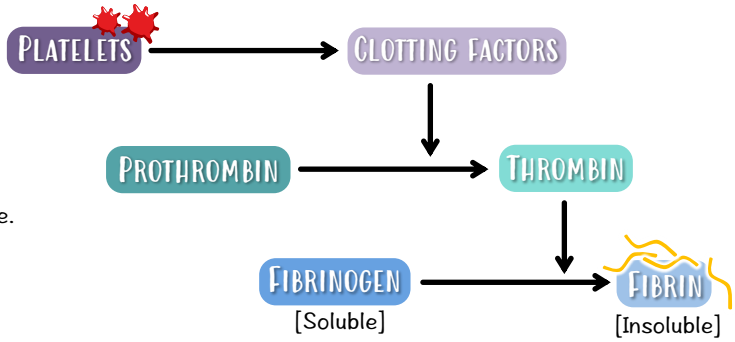
2. When a small blood vessel gets damaged, blood escapes. This increases the risk of pathogens entering our body.



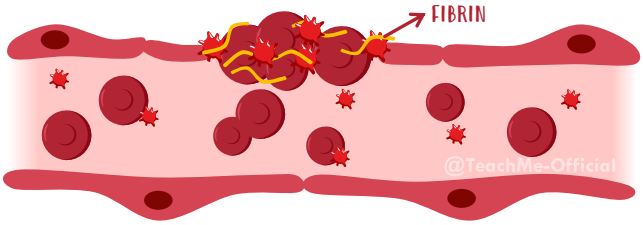
3. The damaged vessel cells release molecules which stimulate platelets to adhere to the damaged area and form what is called a **PLATELET PLUG** (or platelet clot).



4. Clotting factors released ··· convert **PROTHROMBIN** to **THROMBIN**. This newly activated enzyme catalyzes the conversion of the soluble **FIBRINOGEN** into the soluble **FIBRIN**. Fibrin (a fibrous protein) forms a mesh-like network to stabilize the platelet clot.

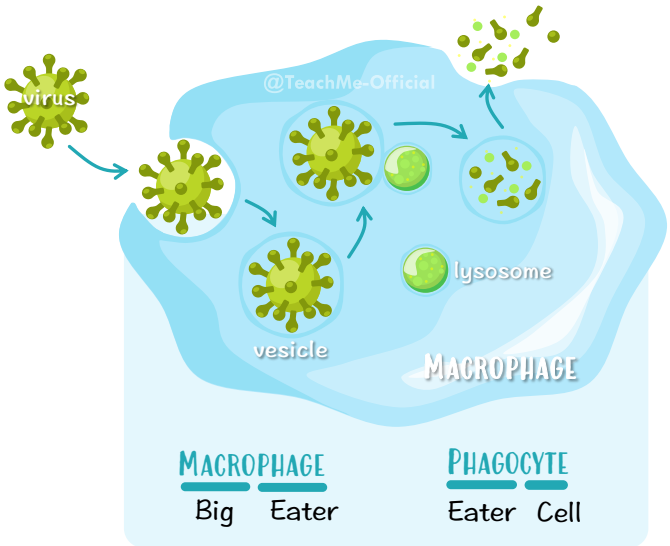


5. This mesh-work also allows cellular debris and red blood cells circulating to get trapped in the clot, rendering it more stable.



PHAGOCYTOSIS

Some pathogens may have made their way into the bloodstream regardless of blood clotting process. To help combat these pathogens from causing further replication and damage, special cells in our bloodstream will get involved.



Some leucocytes (white blood cells) such as **MACROPHAGES** are capable of capturing pathogens through a mechanism called phagocytosis. Such leucocytes are therefore considered as **PHAGOCYTES**.

PHAGOCYTOSIS is the action by which the cell, due to its amoeboid movement, extends its cytoplasm around a pathogen until it is engulfed through endocytosis. The pathogen is trapped inside the phagocyte within a vesicle which can join to a **LYSOSOME**, full of enzymatic enzymes, to digest the pathogen.

Bear in mind. This process is **NON-SPECIFIC** (part of innate immunity), meaning **ANY** pathogen that enters the body is targeted by this process. BUT, because it is **NON-SPECIFIC**, the attack is **NOT** as **EFFICIENT** at killing the particular cell. This bring us to adaptive immunity (see **PAGE 3**), which is part of the third line of defense.

Immune System

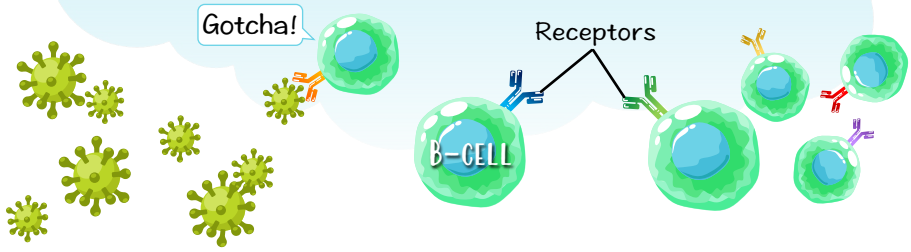
Third line of defense

When pathogens infect you, your innate immune system (like a macrophage) will start to attack them non-specifically, in the meanwhile, your adaptive immune system will start taking action (slower) to make antibodies which target that one specific pathogen that has entered your body. We call this **adaptive immunity** as your body adapts to **specifically** target that **one** pathogen (killing it more effectively than the innate system).

Adaptive immunity (Specific/acquired Immunity)

The leukocytes contributing to adaptive immunity are **B-lymphocytes** (**B-cell**) and **T-lymphocytes** (**T-cell**).

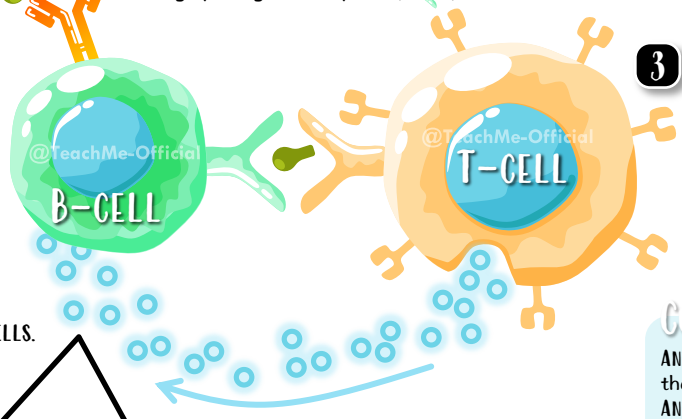
We have a multitude of B-cells in our body, each with a unique type of B-cell receptor, which can recognize **one** antigen (see image to the right). When we get infected, only the **B-cell** with a receptor that matches the antigen on the pathogen will bind to it and initiate the immune response.



1 The antigen ( ) on the pathogen is recognised as "non-self" by a B-cell receptor ( ) on the surface of a **B-cell**.

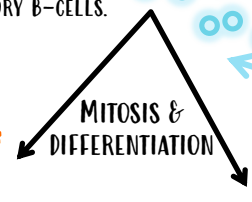
(pathogen)

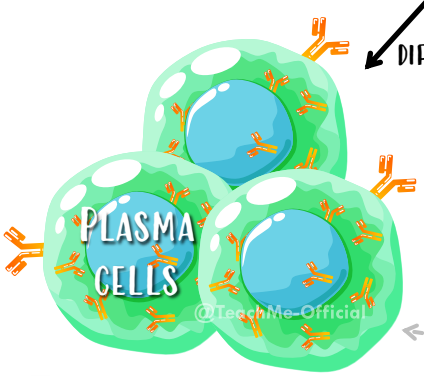
2 The **B-cell** presents the antigen on its surface B-lymphocyte receptor ( ).

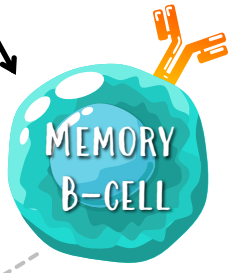


3 A T-cell controls the process by confirming the antigen is non-self. It then releases signal molecules called **cytokines** ( ) which go and activate the **B-cell**.

4 The activated B-cell now undergoes replication (by mitosis) to produce multiple copies of itself (**clones**) forming **plasma cells** and **memory B-cells**.







5 **Plasma cells** are specialized to produce large amounts of **antibodies*** ( ), which are **specific** to the antigen. These antibodies are released into the bloodstream.

6 Some of the B-cells become **memory cells** which are **long-lived cells**, they remain in the body after the infection is cleared. They allow us to "remember" the antigen, enabling a faster and stronger immune response if the same pathogen infects again.

reinfection

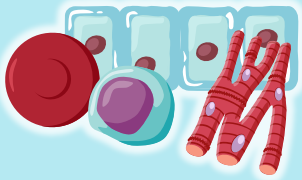
7 If you get **infected again** by the same pathogen, the memory B-cells become plasma cells **fast** to start producing antibodies.

See page 4
What is the purpose of **antibodies**?

Self Vs. Non-self

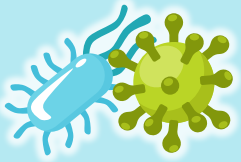
Any cell will present molecules on their surface called **antigens**. The immune system is specialized in detecting these antigens, targetting them to be destroyed. The cells of your own body (e.g. your liver cells, heart cells, skin cells etc···) also present antigens **but** your own immune system considers those as "self", and will therefore not attack your own cells.

Self antigens : on your own cells



Liver cells, heart cells, red blood cells···

Non-self antigens : Not on your own cells



Pathogens or other people's cells

ANTIbody **GEN**erating **S**ubstances

Common confusion!

Antigen – molecule recognized by the B-cell (belongs to the pathogen)
Antibody – molecule produced by the B-cell (targetting the antigen)

Immune System

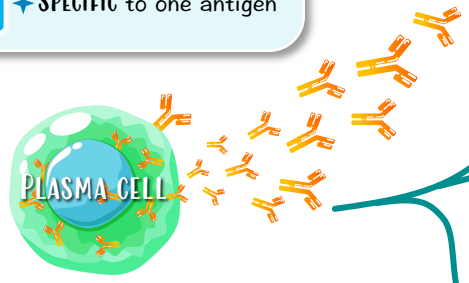
Antibody Structure

Binding sites (for the antigen)

- Made by B-cells
- Protein
- Y-shaped
- **Specific** to one antigen

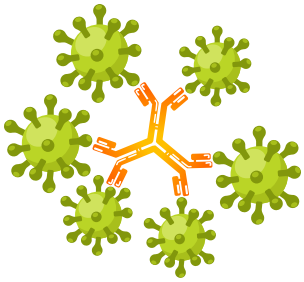
Purpose of Antibodies

The antibodies produced by the plasma cells are released into the bloodstream to efficiently target the **specific** pathogen they recognise and destroy it!



Agglutination

Antibodies can bind multiple pathogens it recognizes, creating a large clump, making it easier for phagocytes to engulf.

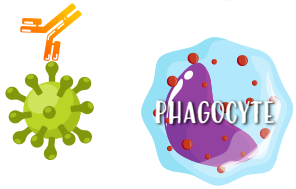


Destruction

Antibodies can help other cells target the pathogen to destroy it.

Opsonization (marking)

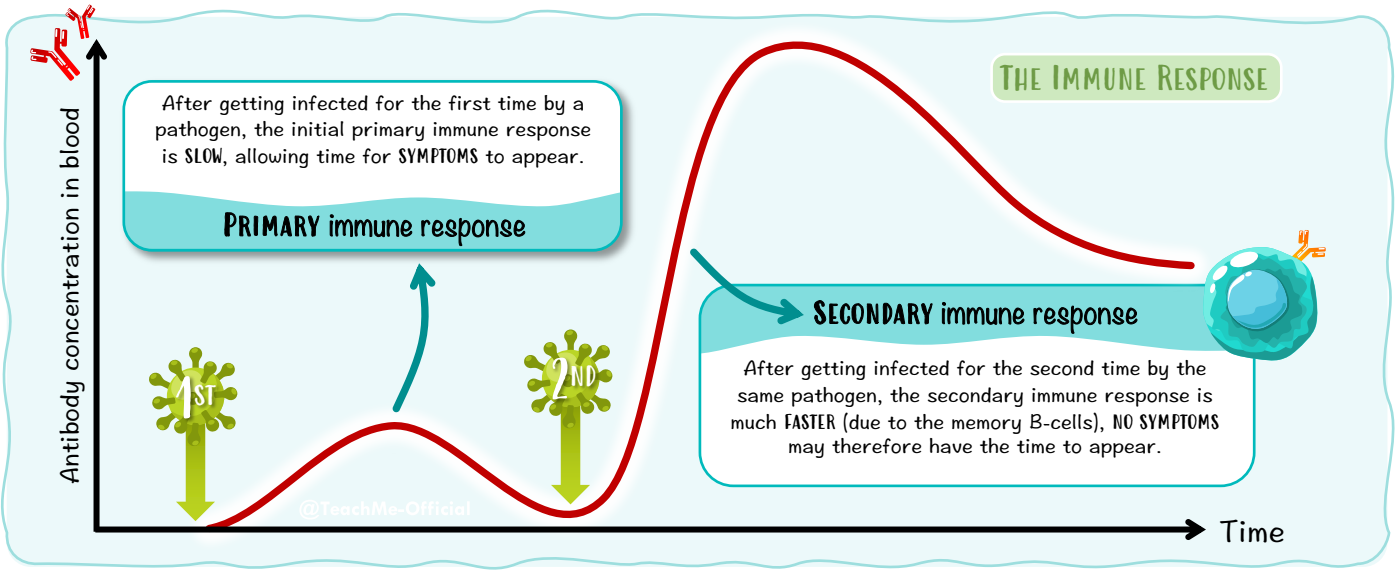
Placing an antibody on a pathogen allows it to become "marked" for easier recognition by phagocytes.



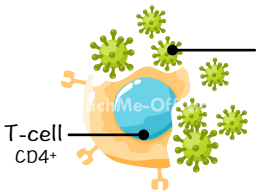
Did you know?

If you get infected with the flu, a certain antibody will be produced. If you get infected with measles, a **different** antibody will be produced.

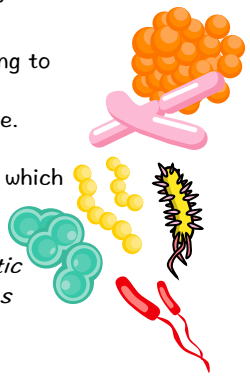
The Immune Response

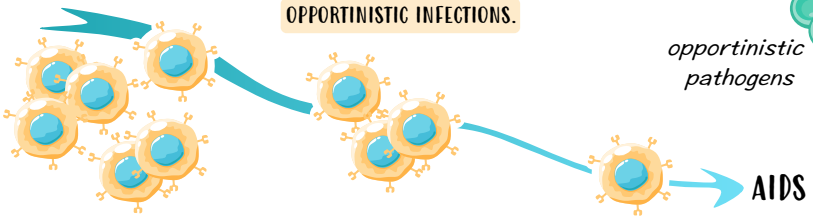


Human Immunodeficiency Virus (HIV) - a disease of the immune system



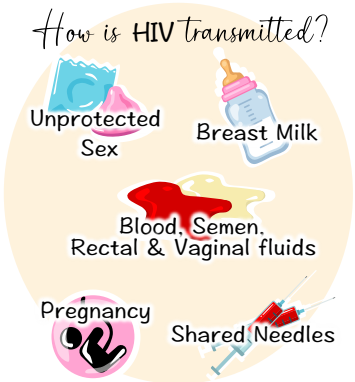
HIV is a virus which targets **CD4+ T-cells**, leading to their destruction. Without T-cells, we cannot complete **step 3** (page 3) in the immune response. Over time, the amount of T-cells decreases so drastically, that we get infected by pathogens which normally aren't strong enough to infect us: **opportunistic infections**.





When infected by this virus we are said to be infected with HIV, but after the T-cells number decreases below a certain threshold, we are said to have **AIDS**: Acquired ImmunoDeficiency Syndrome.

How is HIV transmitted?



Big Brain Tip!

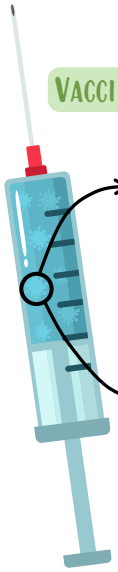
HIV – the virus
AIDS – the disease

CD4+ is a type of T-cell (you don't need to know more detail for the IB)

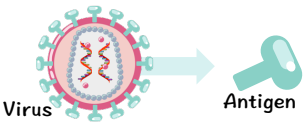
Immune System

VACCINES Vaccines have been developed to act as the "first exposure" to a pathogen (in a safe way). Different types of vaccines have been created;

DID YOU KNOW?
Vaccines do not prevent you from getting infected by a pathogen, but it reduces the immune response time and may prevent symptoms.

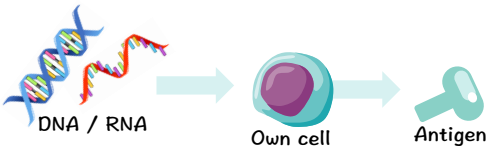


TRADITIONAL VACCINE (Inactivated)
Pathogen minus the disease-causing parts.

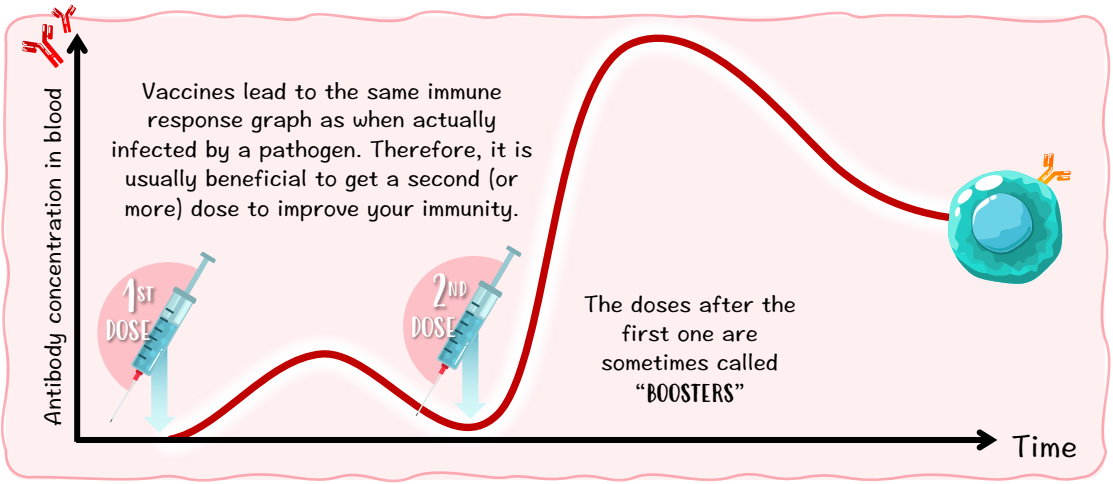


The ANTIGEN OF A VIRUS is isolated and injected into a person. This person's B-cell will identify it as foreign and will initiate an immune response (PAGE 3) leading to the production of SPECIFIC antibodies (state of immunity). But they have never actually been infected by the disease-causing virus (the disease-causing parts were removed).

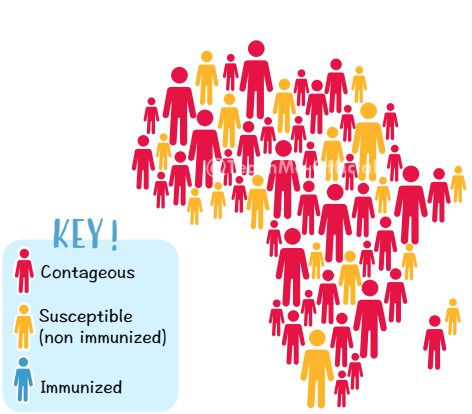
ADVANCED VACCINE
Pathogen DNA & RNA coding for antigens.



The DNA OR RNA OF A VIRUS which codes for its antigen is isolated and injected into a person. This person's own cells will use this DNA to create the antigen. B-cell will identify it as foreign and will initiate an immune response (PAGE 3) leading to the production of specific antibodies (state of immunity). But they also have never actually been infected by the disease-causing virus.



HERD IMMUNITY Herd immunity occurs when a significant proportion of a population becomes IMMUNE to a disease (either through vaccination or prior infection). This reduces the likelihood of disease transmission, protecting individuals who are NOT IMMUNE (some people may not be able to get vaccinated – even if they wanted to).



In a population with no immunity, CONTAGIOUS INDIVIDUALS can easily spread the disease to SUSCEPTIBLE INDIVIDUALS leading to outbreaks.

With some IMMUNIZED INDIVIDUALS, the spread slows, but SUSCEPTIBLE INDIVIDUALS remain at risk.

Herd Immunity achieved!
High levels of IMMUNITY prevent widespread transmission, as most people are IMMUNIZED, indirectly protecting those who are NOT IMMUNE.

[This is because the immunized people have lots of antibodies and therefor when they get infected the pathogen is quickly destroyed and not given the opportunity to grow. Thereby reducing the risk of infecting susceptible people.]

Immune System

Section 2

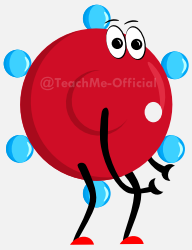
ABO Blood Groups

Blood groups are determined by the presence of different **ANTIGENS** present on the surface of red blood cells. The major blood groups are created by two antigens: **ANTIGEN A** and **ANTIGEN B**.

Self-antigens!

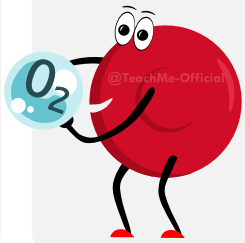
Blood Group A
Presence of antigen A

Blood Group B
Presence of antigen B



Blood Group AB
Coexistence of antigen A and B

Blood Group O
Absence of antigen A or B



BIG BRAIN TIP!
O – NO antigen

Antigen A
Antigen B

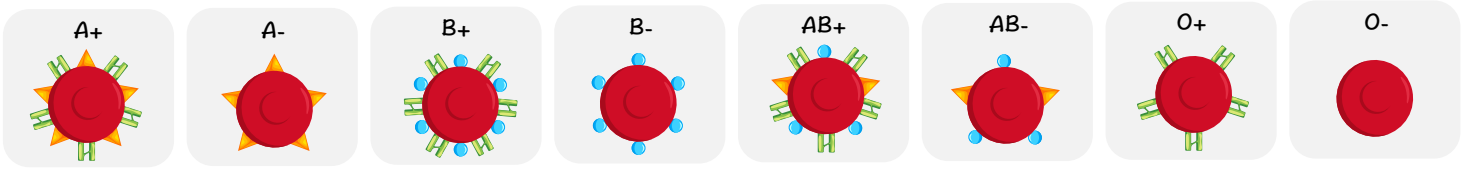
To prevent foreign blood from being present in our body, your immune system will produce antibodies against the antigens you do not have (non-self antigens from other people). For example, a blood group A person will have anti-B antibodies.

	Blood Group A	Blood Group B	Blood Group AB	Blood Group O
Antigens	Presence of antigen A 	Presence of antigen B 	Coexistence of antigen A and B 	Absence of antigen A or B NONE
Antibody	Anti-B Antibody 	Anti-A Antibody 	Absence of Anti-A or Anti-B antibody NONE	Anti-A AND Anti-B antibodies 

NOTE!
You will learn more about how we inherit blood groups in D3.2

Anti-A antibody
Anti-B antibody

An additional antigen, the **RH ANTIGEN**, may also be present. The presence of this antigen is indicated as "+" and its absence is shown as "-". This antigen may be present in conjunction with any of the above ABO blood groups.

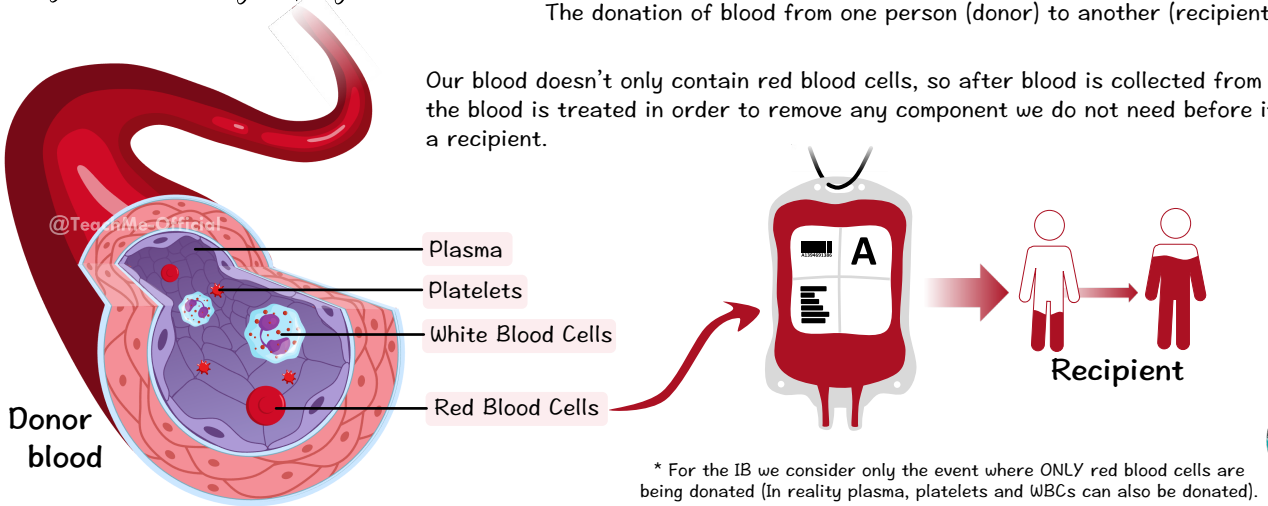


Rh Antigen

Why does blood grouping matter? → Blood Transfusion*

The donation of blood from one person (donor) to another (recipient).

Our blood doesn't only contain red blood cells, so after blood is collected from the donor, the blood is treated in order to remove any component we do not need before it is given to a recipient.

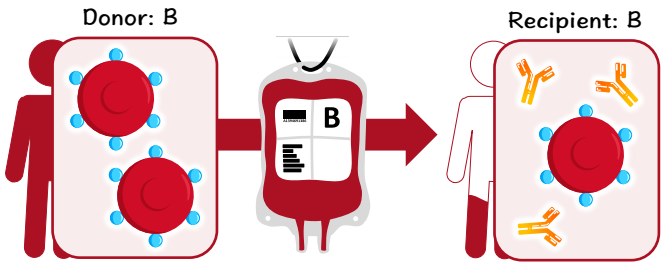


* For the IB we consider only the event where ONLY red blood cells are being donated (In reality plasma, platelets and WBCs can also be donated).

Immune System

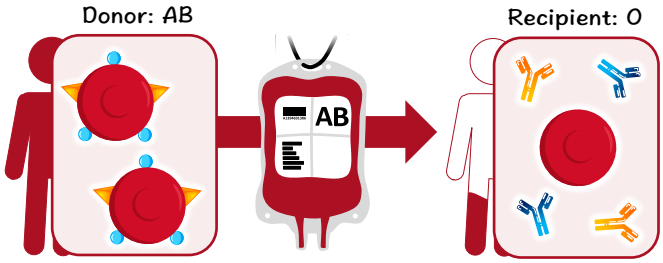
Blood Transfusion

Example 1 (ommiting the presence of Rh antigen)



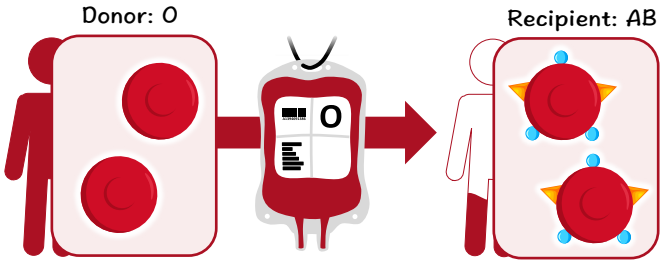
Recipient blood contains anti-A antibodies, donor's blood does not contain A antigens. Hence, the recipients' antibodies will not reject the donors RBCs. The transfusion is A MATCH.

Example 2 (ommiting the presence of Rh antigen)



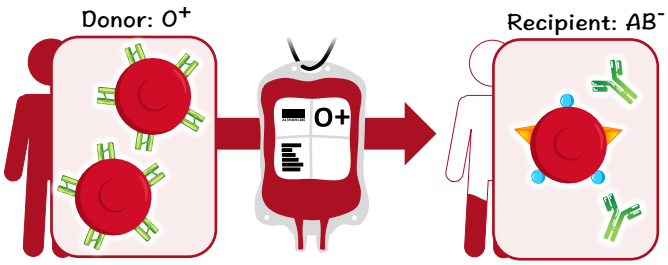
Recipient blood contains anti-A and anti-B antibodies, donor's blood contains A and B antigens. Hence, the recipients' antibodies will reject the donors RBCs. The transfusion is NOT A MATCH.

Example 3 (ommiting the presence of Rh antigen)



Recipient blood contains no antibodies, donor's blood contains neither A or B antigens. Hence, the recipient has no antibodies to reject the donors RBCs. The transfusion is A MATCH.

Example 4 (with presence of Rh antigen)



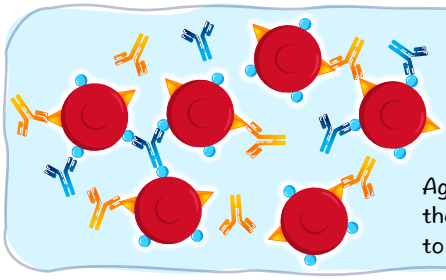
Recipient blood contains antibodies for Rh antigen, donor's blood contains neither A or B antigens **BUT** does contain Rh antigens. Hence, the recipients' antibodies will reject the donors RBCs. The transfusion is NOT A MATCH.

General Rules to Blood Transfusion

A person cannot receive any of the three antigens (A, B, Rh) that they do not already have.

- O- is a universal donor (No antigens to be reacted with).

- AB+ is a universal recipient (No antibodies to react with donated blood).
- All blood groups can accept from their own blood group. E.g. A, can accept A.



What happens when the transfusion is NOT A MATCH?

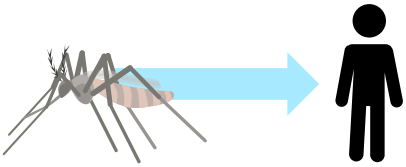
Agglutination (Clumping)

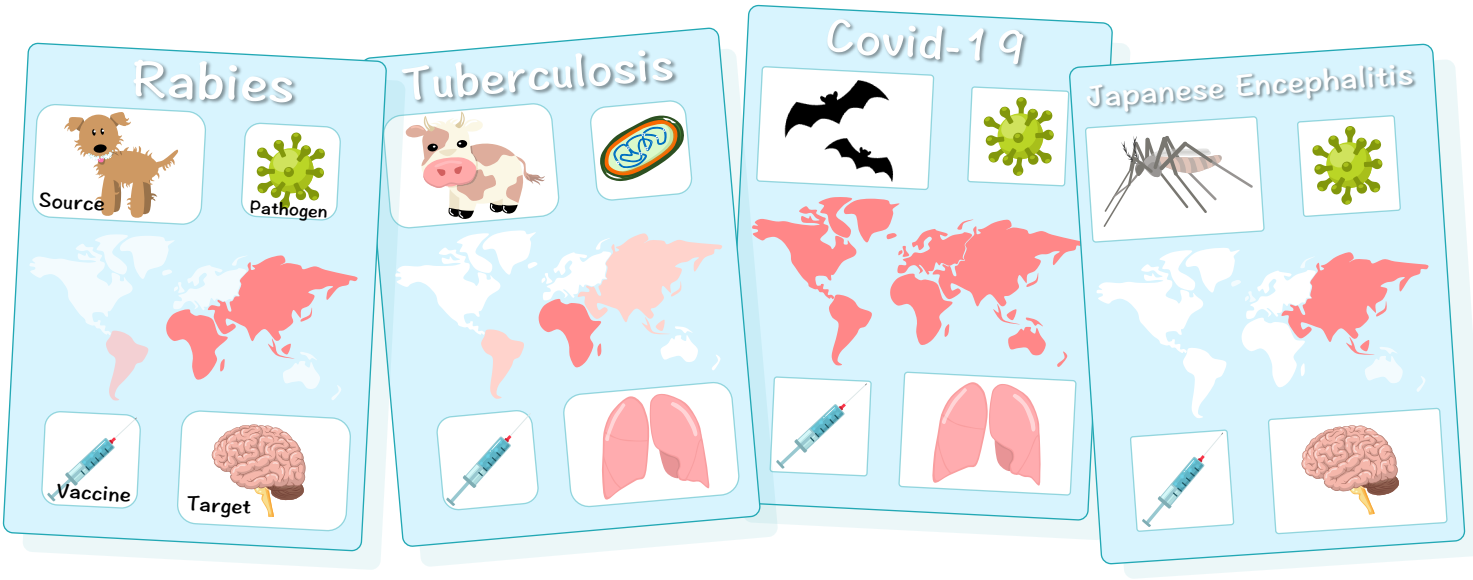
Agglutination happens when incompatible blood types mix. The recipient's antibodies bind to the donor's red blood cells via the antigens, causing them to clump. This phenomenon can lead to blockage of blood vessels (stroke, heart attack etc) and death.

Immune System

Section 3
Zoonotic Diseases

Many infectious diseases are specific to one species, with the pathogens being transmitted between organisms within the species. In the instance where a pathogen successfully gets transmitted **FROM ONE SPECIES TO ANOTHER**, we call them **ZOONOTIC DISEASES** – usually they are diseases transmitted from animals to humans.



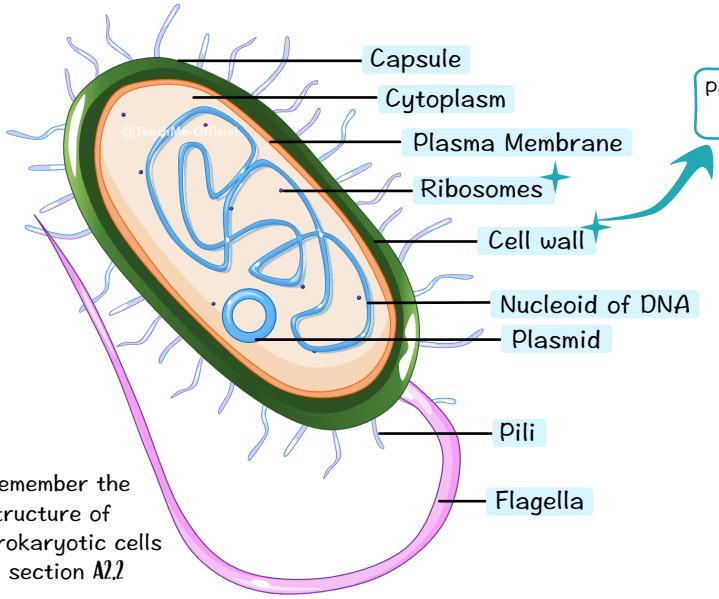


Section 4
Antibiotics V.S Antibodies

These two terms sound and look very similar! But they are very different. We know antibodies are little weapons made by plasma cells in response to an antigen from a pathogen encountered. On the contrary antibiotics:

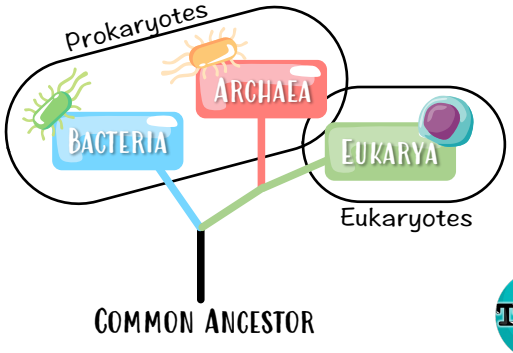
- Are made **ARTIFICIALLY** in a lab or by other microorganisms (stolen from organisms which naturally make them).
- Kill **ONLY BACTERIA** (not virus or other types of pathogens).
- Are **NON-SPECIFIC**, so can be used for more than one type of bacteria.
- Don't bind antigens. They destroy **CELL WALL** and prevents cellular functions (metabolism) of bacteria by targeting **RIBOSOMES**.

BIG BRAIN TIP!
AntiBODIES - Made by the "BODY"
AntiBIOTICS - Sounds like "ROBOTIC" (made by a scientist).



Remember the structure of prokaryotic cells in section A2.2

Prokaryotes contain 70S ribosomes which are different from eukaryotic 80S ribosomes. Therefore **ANTIBIOTICS DO NOT TARGET OUR (EUKARYOTIC) CELLS.**

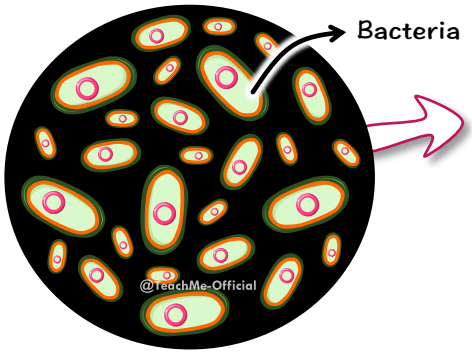


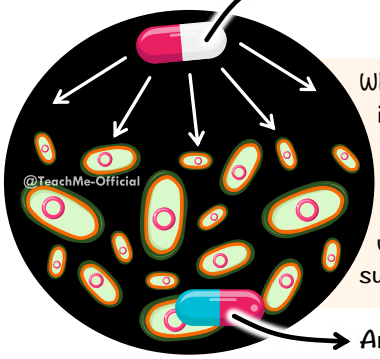
Immune System

Antibodies	Antibiotics
Made **NATURALLY** by the immune system of the body.	Made **ARTIFICIALLY** in a lab or made by other microorganisms (and then scientists essentially stolen from the organism that makes it).
Bind to antigen and kill the pathogen through various mechanisms.	Doesn't bind antigen, destroys cell wall, and prevents cellular functions (metabolism) of bacteria.
For any type of pathogen (virus, bacteria etc).	For bacteria **ONLY**.
They are **SPECIFIC** to a pathogen.	They are **NOT SPECIFIC** to a pathogen. Can kill more than one type of bacteria.
Examples: IgA, IgG, IgE···	Examples: Penicillin, Ampicillin···

Antibiotic Resistance and Sensitivity

When placed in a petri dish, the bacteria will grow freely.





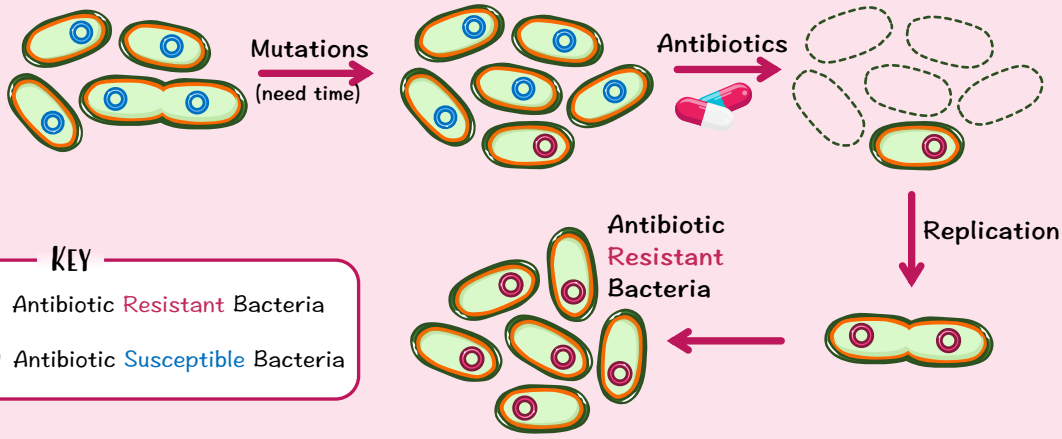
Antibiotic the bacteria are **SENSITIVE** to (can be killed by)

When placing different antibiotics in the petri dish, bacteria **SENSITIVE** to an antibiotic will die in the region surrounding it, while bacteria **RESISTANT** to an antibiotic will survive in the region surrounding it.

Antibiotic the bacteria are **RESISTANT** to (can't be killed by)

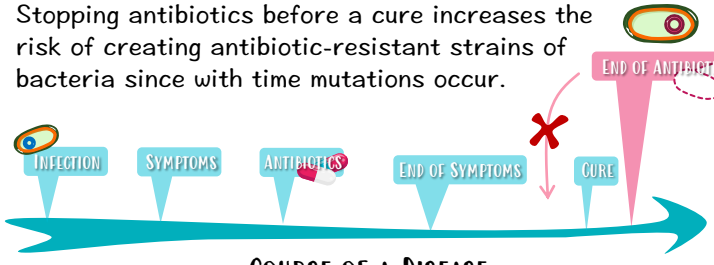
are sensitive to antibiotic & resistant to antibiotic.

How can a bacteria become resistant to an antibiotic?



Example of antibiotic-resistant bacteria: MRSA (Methicillin Resistant Staphylococcus Aureus)

Stopping antibiotics before a cure increases the risk of creating antibiotic-resistant strains of bacteria since with time mutations occur.



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