Lecture: **The Body's Control Mechanisms and Immunity**

Ref: CDC (Centers for Disease Control and Prevention)
WHO (World Health Organization)

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Web ref provided on slides
Images: From google image

The Body's Control Mechanisms and Immunity

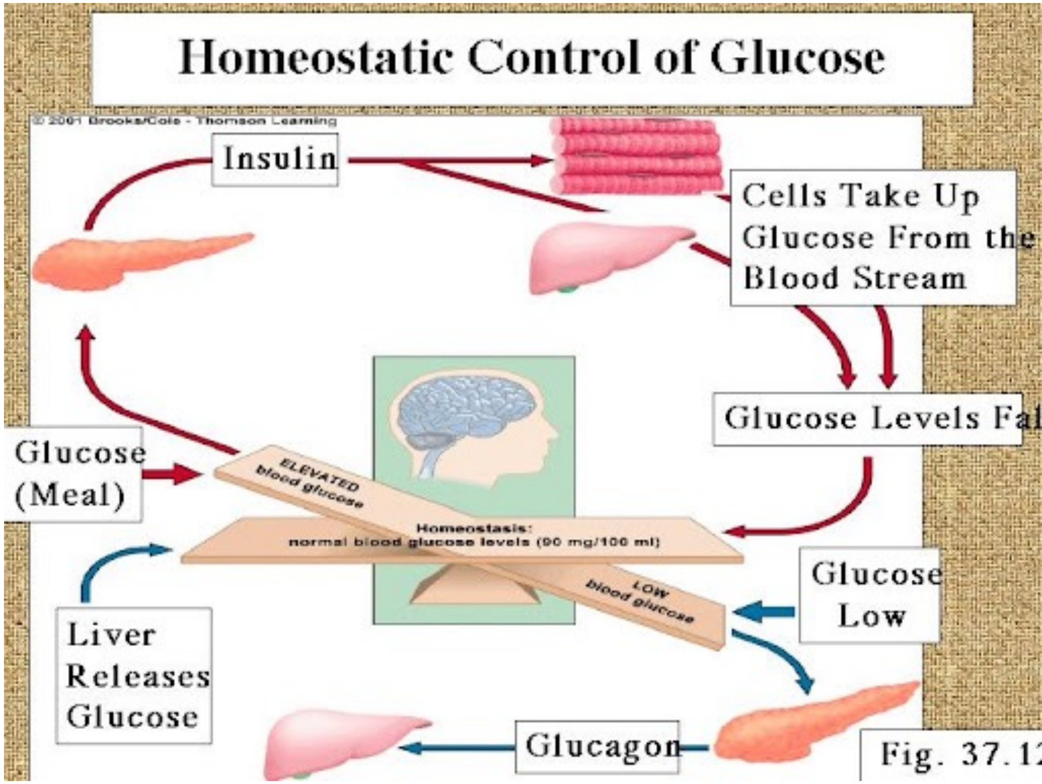
- **Homeostatic Control**
- **Disease as Homeostatic Imbalance**
- **Immune System**
- **The immune system and microbial infection**
- **Common disorders of the immune system**
- **Immunoglobulin Therapy**
- **Immunisation**
- **How do vaccines work?**
- **How COVID-19 Vaccines Work**

Ref: wikipedia

Homeostatic Control

Homeostasis is maintained by the body's responses to adverse stimuli, ensuring maintenance of an optimal physiological environment.

- Homeostatic control mechanisms have at least three interdependent components: a receptor, integrating center, and effector.
- The receptor senses environmental stimuli, sending the information to the integrating center.
- The integrating center, generally a region of the brain called the hypothalamus, signals an effector (e.g. muscles or an organ) to respond to the stimuli.
- Positive feedback enhances or accelerates output created by an activated stimulus. Platelet aggregation and accumulation in response to injury is an example of positive feedback.
- Negative feedback brings a system back to its level of normal functioning. Adjustments of blood pressure, metabolism, and body temperature are all negative feedback.



Ref: https://courses.lumenlearning.com/boundless-ap/chapter/homeostasis/

Homeostatic Control

Concept of Homeostasis

Homeostasis regulates an organism's internal environment and maintains a stable, constant condition of properties like temperature and pH. Homeostasis can be influenced by either internal or external conditions and is maintained by many different mechanisms. All homeostatic control mechanisms have at least three interdependent components for the variable being regulated:

- A sensor or receptor detects changes in the internal or external environment. An example is peripheral chemoreceptors, which detect changes in blood pH.
- The integrating center or control center receives information from the sensors and initiates the response to maintain homeostasis. The most important example is the hypothalamus, a region of the brain that controls everything from body temperature to heart rate, blood pressure, satiety (fullness), and circadian rhythms (sleep and wake cycles).
- An effector is any organ or tissue that receives information from the integrating center and acts to bring about the changes needed to maintain homeostasis. One example is the kidney, which retains water if blood pressure is too low.

The sensors, integrating center, and effectors are the basic components of every homeostatic response. Positive and negative feedback are more complicated mechanisms that enable these three basic components to maintain homeostasis for more complex physiological processes.

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Homeostatic Control

Positive Feedback

- Positive feedback is a mechanism in which an output is enhanced in order to maintain homeostasis. Positive feedback mechanisms are designed to **accelerate or enhance the output** created by a stimulus that has already been activated. Positive feedback mechanisms are designed to push levels **out of normal ranges**. To achieve this, a series of events initiates a cascading process that builds to increase the effect of the stimulus. This process can be beneficial but is **rarely used because it may become uncontrollable**. A positive feedback example is blood platelet accumulation and aggregation, which in turn causes blood clotting in response to an injury of the blood vessels.

Negative Feedback

- Negative feedback mechanisms **reduce output or activity** to return an organ or system to its normal range of functioning. Regulation of blood pressure is an example of negative feedback. Blood vessels have sensors called baroreceptors that detect if blood pressure is too high or too low and send a signal to the hypothalamus. The hypothalamus then sends a message to the heart, blood vessels, and kidneys, which act as effectors in blood pressure regulation. If blood pressure is too high, the heart rate decreases as the blood vessels increase in diameter (vasodilation), while the kidneys retain less water. These changes would cause the blood pressure to return to its normal range. The process reverses when blood pressure decreases, causing blood vessels to constrict and the kidney to increase water retention.

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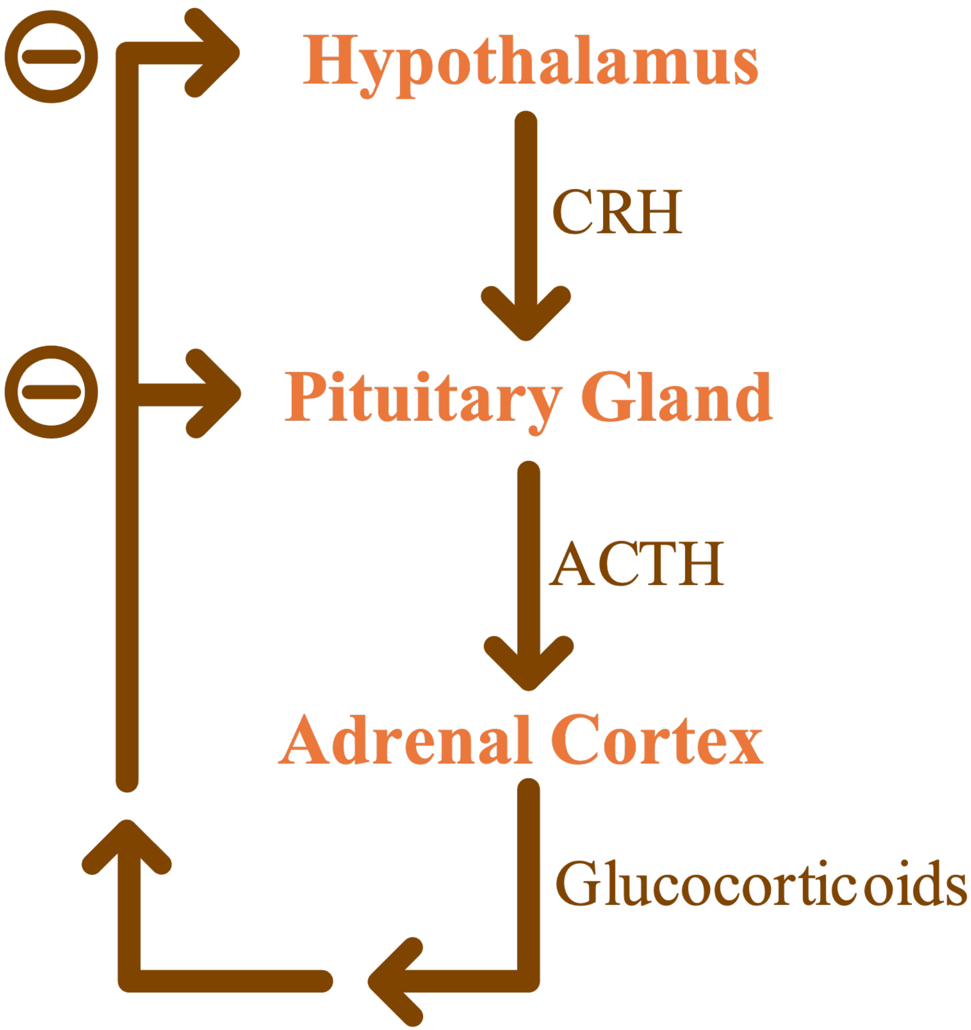
Homeostatic Control



Negative Feedback Loop: The hypothalamus secretes corticotropin-releasing hormone (CRH), which directs the anterior pituitary gland to secrete adrenocorticotropic hormone (ACTH). In turn, ACTH directs the adrenal cortex to secrete glucocorticoids, such as cortisol. Glucocorticoids not only perform their respective functions throughout the body but also prevent further stimulating secretions of both the hypothalamus and the pituitary gland

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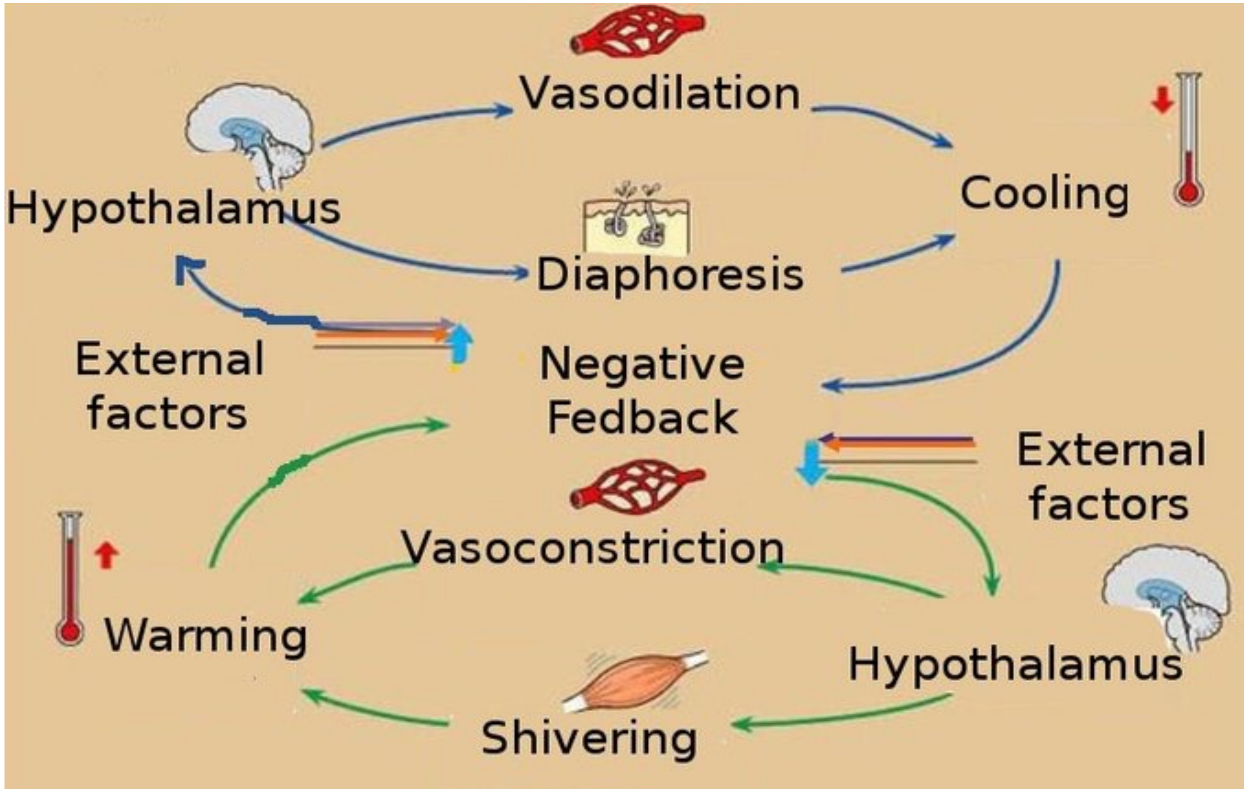
Homeostatic Control



- Temperature control is another negative feedback mechanism. Nerve cells relay information about body temperature to the hypothalamus. The hypothalamus then signals several effectors to return the body temperature to 37 degrees Celsius (the set point). The effectors may signal the sweat glands to cool the skin and stimulate vasodilation so the body can give off more heat.
- If body temperature is below the set point, muscles shiver to generate heat and the constriction of the blood vessels helps the body retain heat. This example is very complex because the hypothalamus can change the body's temperature set point, such as raising it during a fever to help fight an infection. Both internal and external events can induce negative feedback mechanisms.

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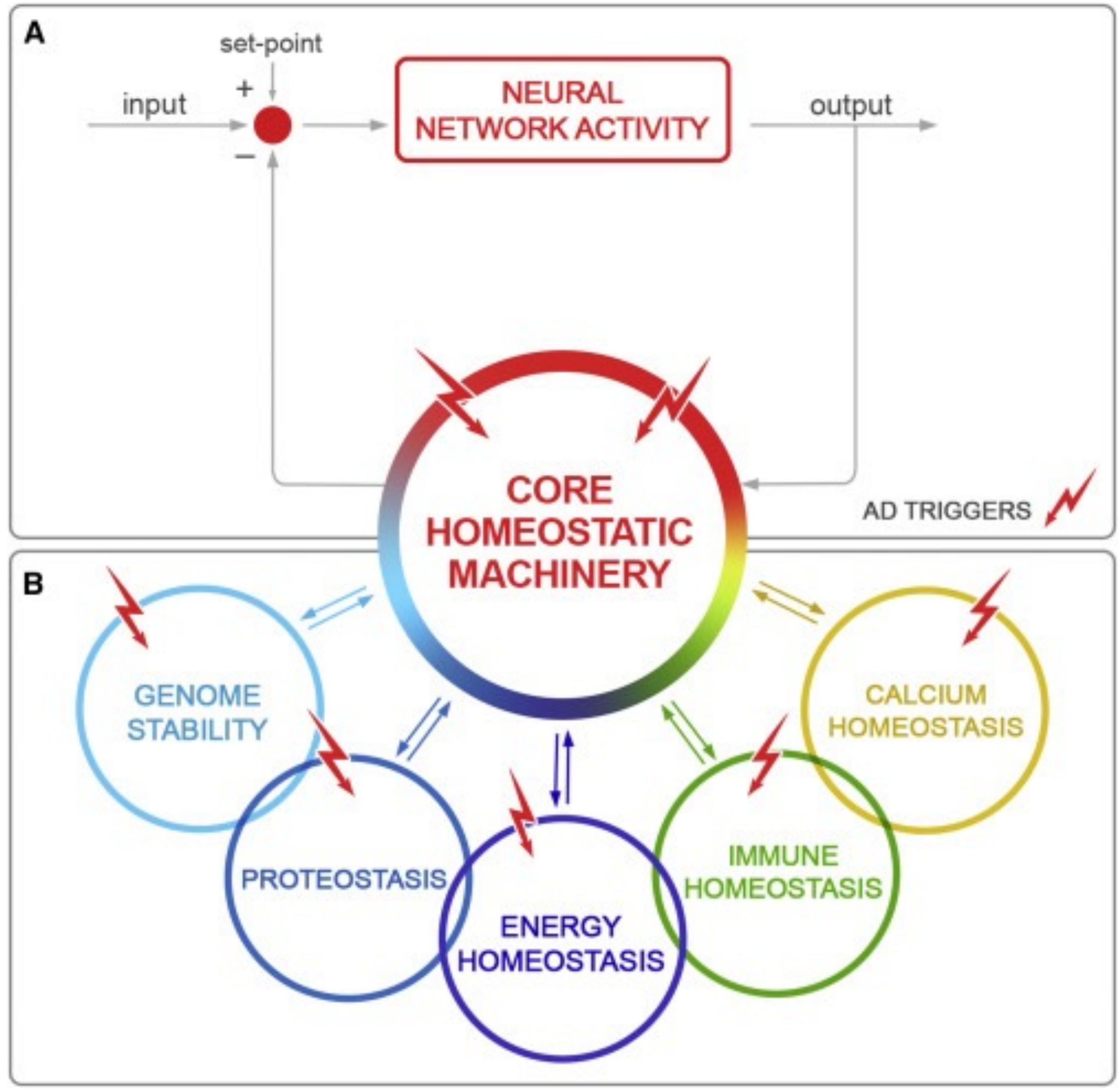
Disease as Homeostatic Imbalance

If positive and negative feedback loops are affected or altered, homeostatic imbalance and resultant complications can occur.

Disease is any failure of normal physiological function that leads to negative symptoms. While disease is often a result of infection or injury, most diseases involve the disruption of normal homeostasis. Anything that prevents positive or negative feedback from working correctly could lead to disease if the mechanisms of disruption become strong enough.



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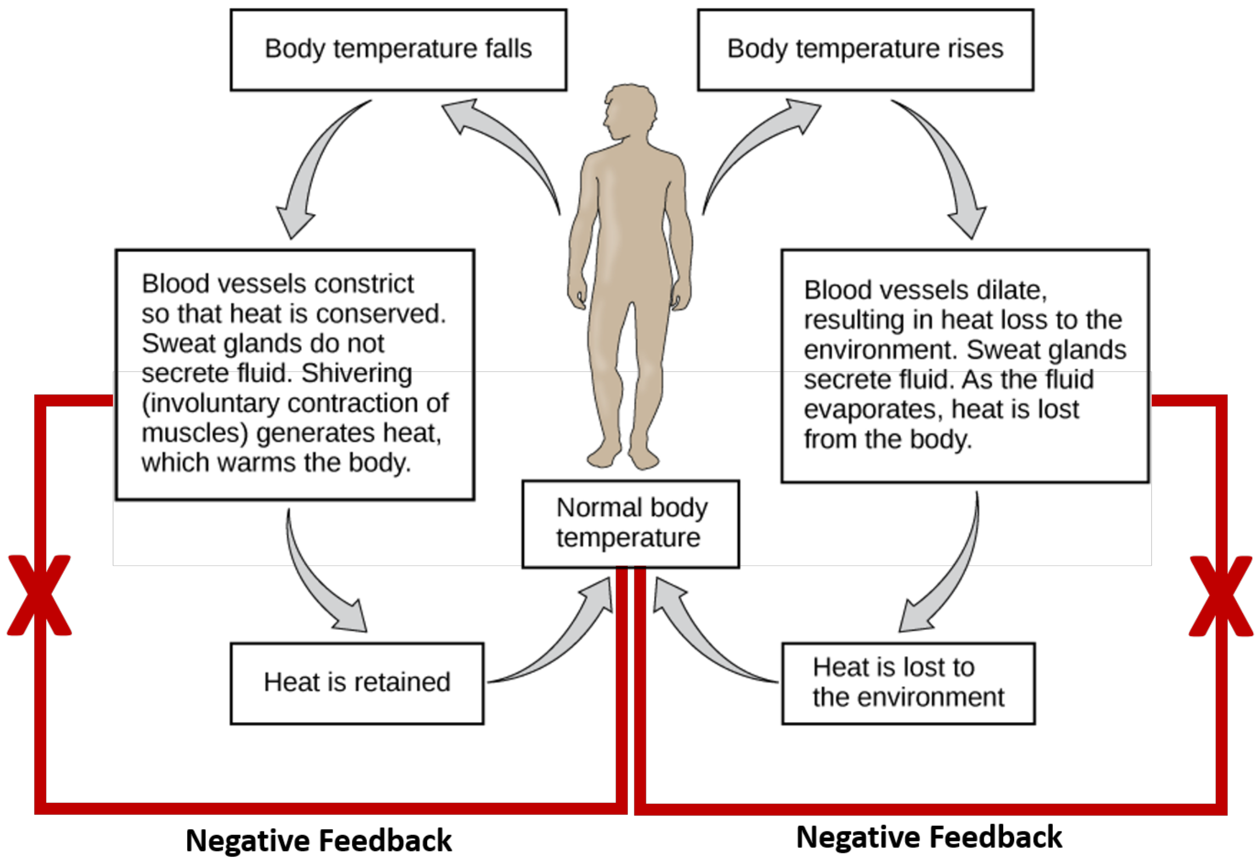
Disease as Homeostatic Imbalance

Aging is a general example of disease as a result of homeostatic imbalance. As an **organism ages, weakening of feedback loops** gradually results in an unstable internal environment. This lack of homeostasis increases the risk for illness and is responsible for the physical changes associated with aging. Heart failure is the result of negative feedback mechanisms that become overwhelmed, allowing destructive positive feedback mechanisms to compensate for the failed feedback mechanisms. This leads to high blood pressure and enlargement of the heart, which eventually becomes too stiff to pump blood effectively, resulting in heart failure. Severe heart failure can be fatal.



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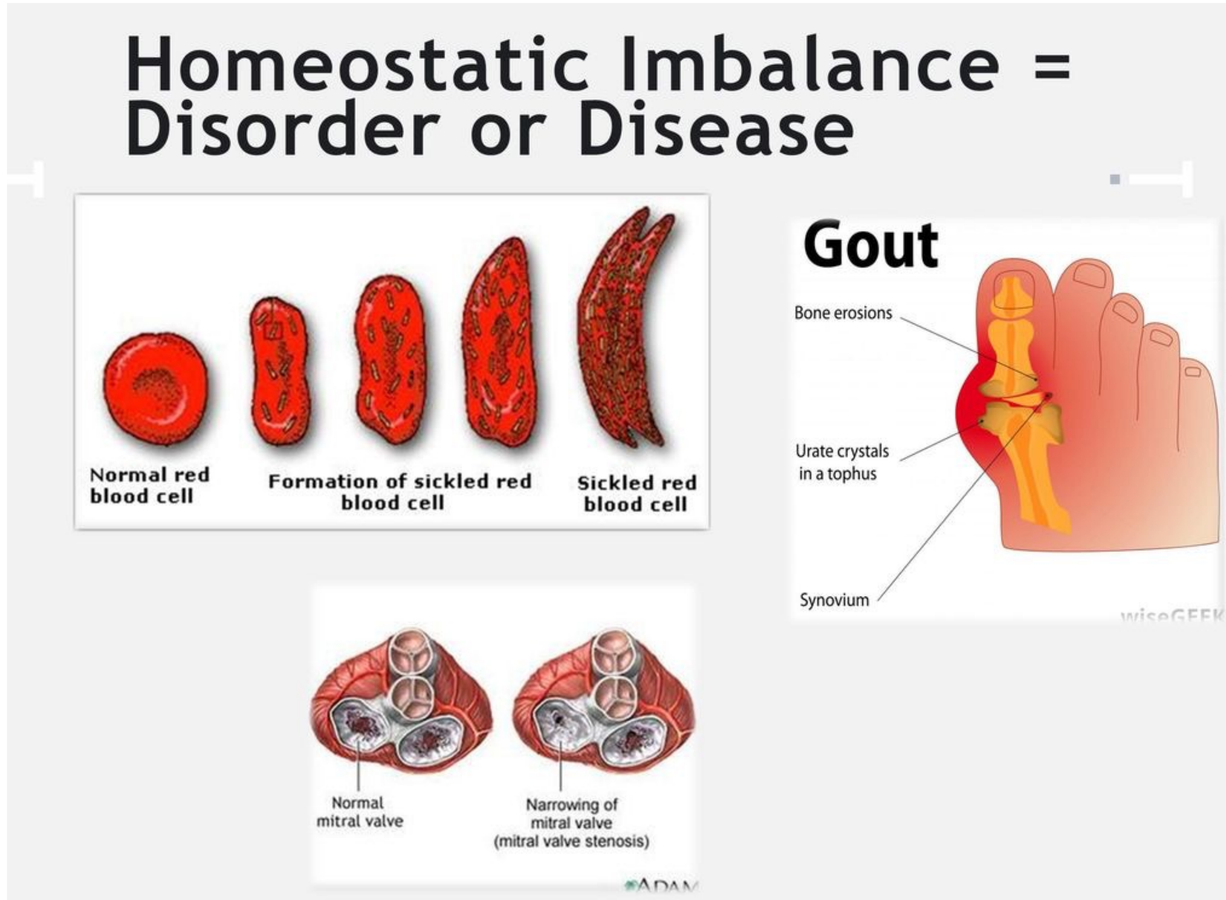
Disease as Homeostatic Imbalance

Diabetes: A Disease of Failed Homeostasis

- Diabetes, a metabolic disorder caused by excess blood glucose levels, is a key example of disease caused by failed homeostasis. In ideal circumstances, homeostatic control mechanisms should prevent this imbalance from occurring. However, in some people, the mechanisms do not work efficiently enough or the amount of blood glucose is too great to be effectively managed. In these cases, medical intervention is necessary to restore homeostasis and prevent permanent organ damage.



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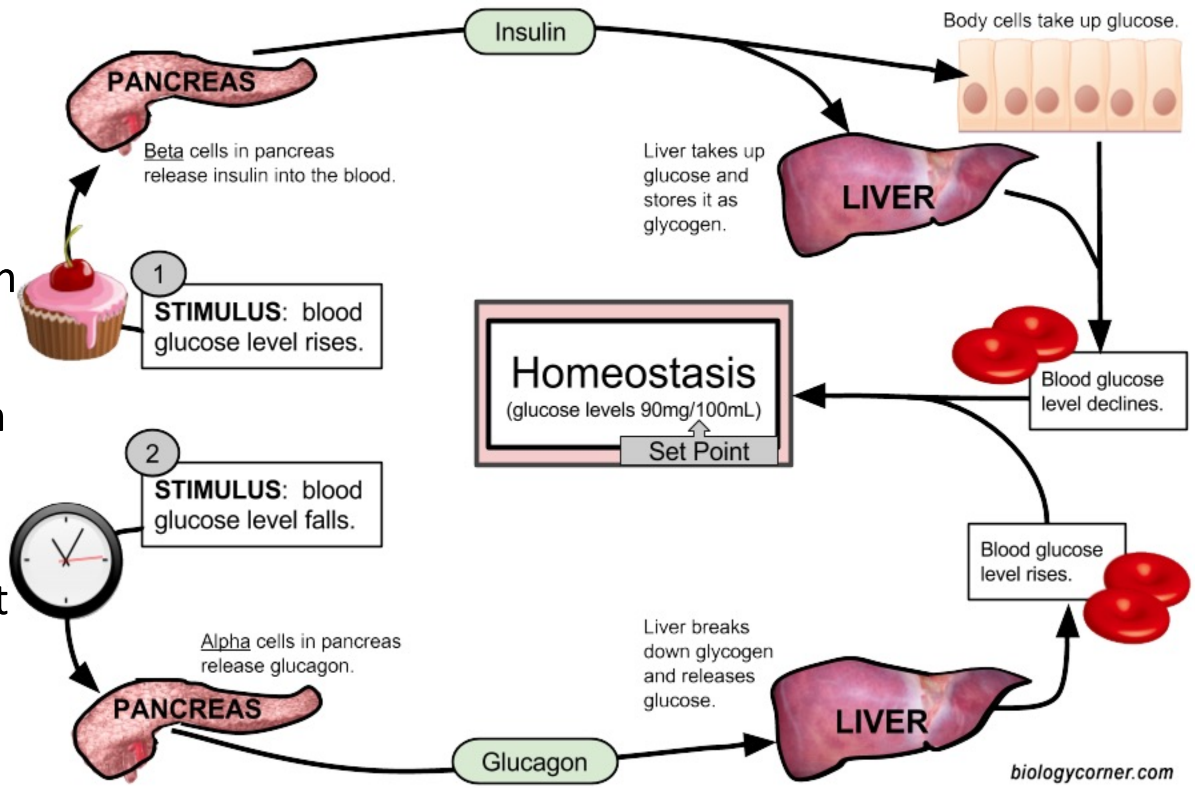
Disease as Homeostatic Imbalance

Blood Sugar Regulation

The human body maintains constant levels of glucose throughout the day, even after fasting. During long periods of fasting, glucose levels are reduced only very slightly. Insulin transports glucose to the body's cells for use in cellular metabolic function. The cells convert excess glucose to an insoluble substance called glycogen to prevent it from interfering with cellular metabolism. Because this ultimately lowers blood glucose levels, insulin is secreted to prevent hyperglycemia (high blood sugar levels). Another hormone called glucagon performs the opposite function of insulin, causing cells to convert glycogen to glucose and stimulating new glucose production (gluconeogenesis) to raise blood sugar levels. Negative feedback between insulin and glucagon levels controls blood sugar homeostasis.



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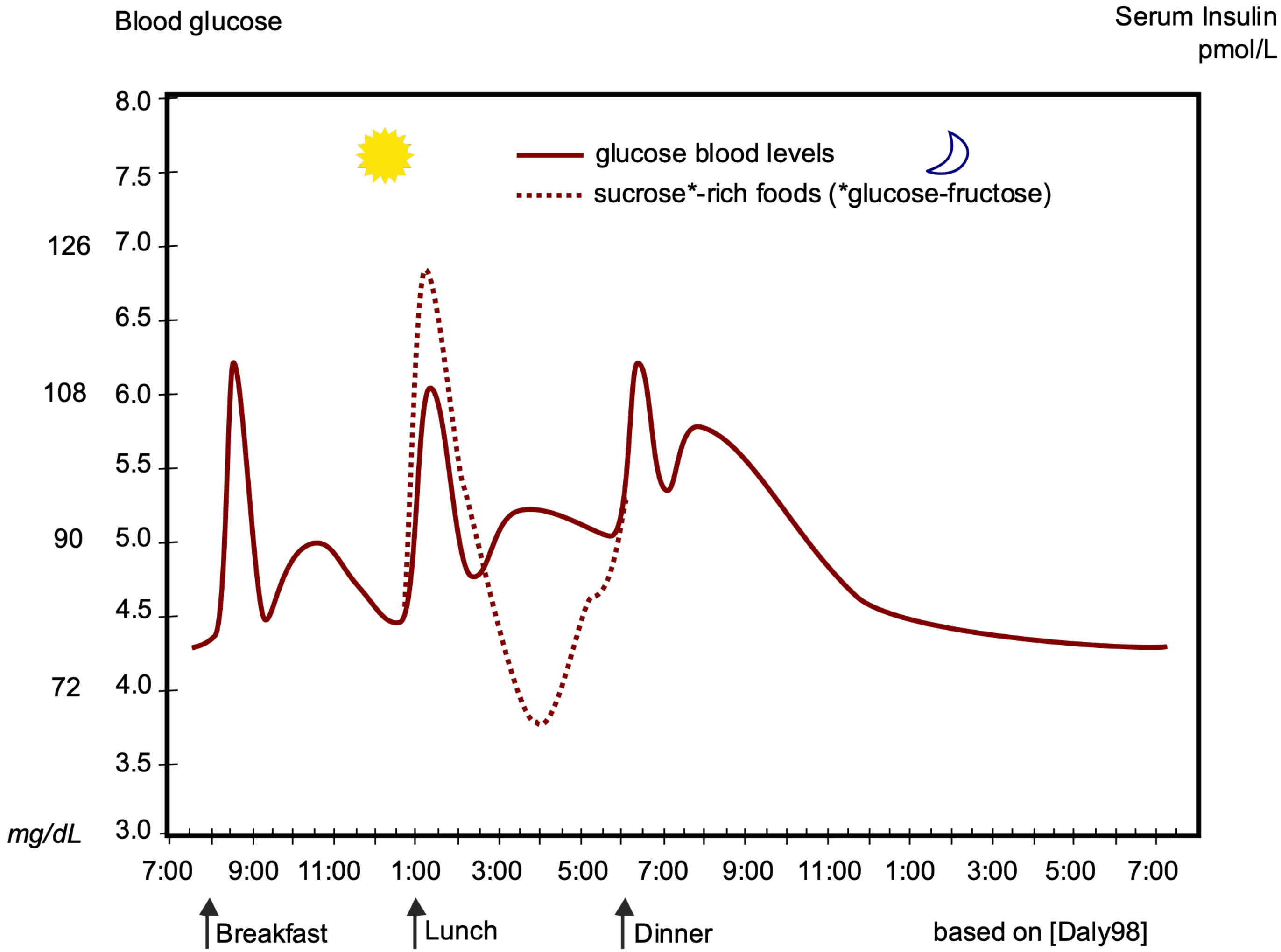
Disease as Homeostatic Imbalance



Homeostasis of Glucose Metabolism: This image illustrates glucose metabolism over the course of a day. Homeostasis may become imbalanced if the pancreas is overly stressed, making it unable to balance glucose metabolism. This can lead to diabetes.

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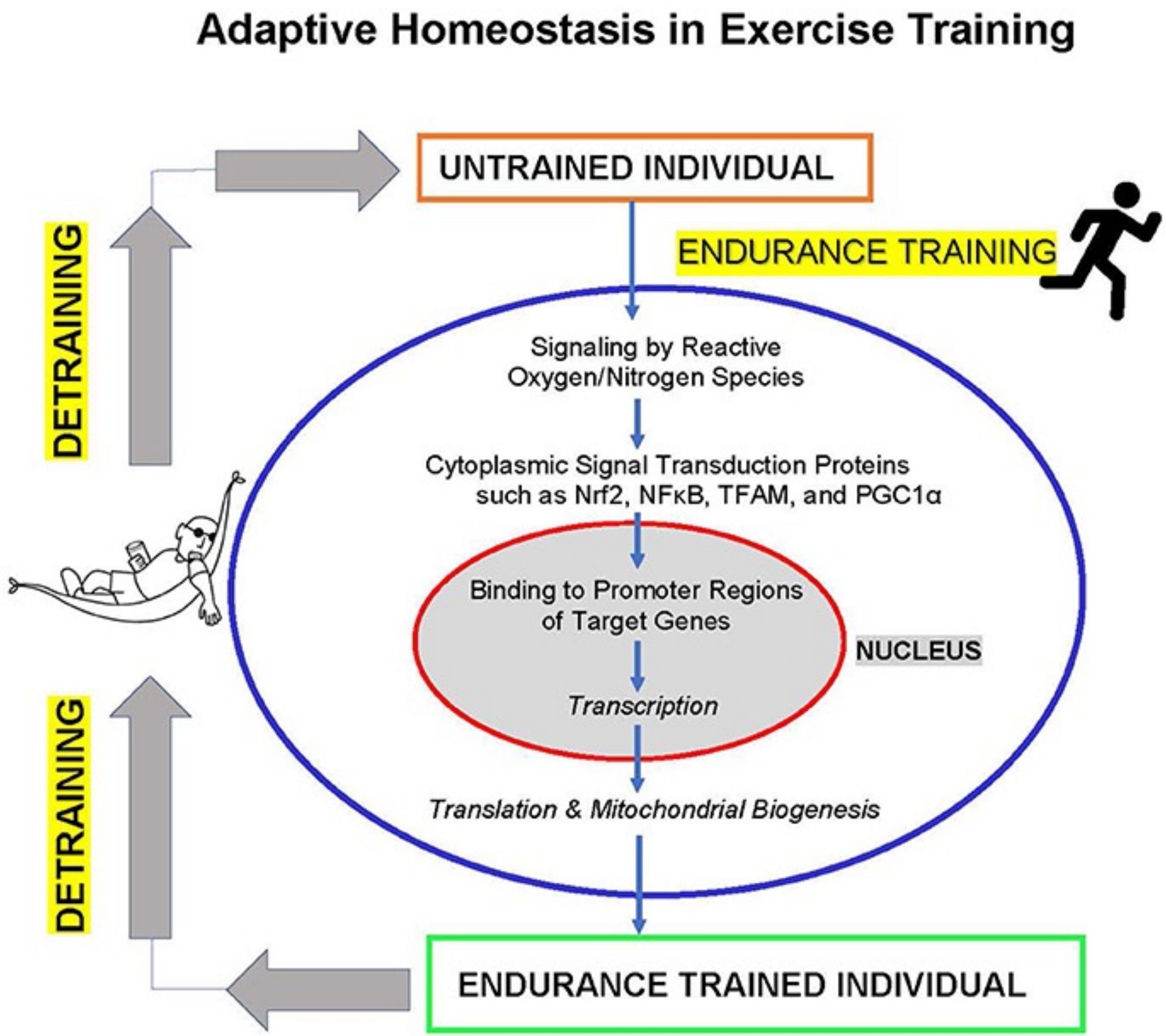
Disease as Homeostatic Imbalance

Causes of Homeostatic Disruption

People **with type 1** diabetes **do not produce insulin** due to auto-immune destruction of the insulin producing cells, while people with **type 2** diabetes have **chronic high blood glucose levels** that cause insulin resistance. With diabetes, blood glucose is increased by normal glucagon activity, but the lack of or resistance to insulin means that blood sugar levels are unable to return to normal. This causes metabolic changes that result in diabetes symptoms like weakened blood vessels and frequent urination. Diabetes is normally treated with insulin injections, which replaces the missing negative feedback of normal insulin secretions.



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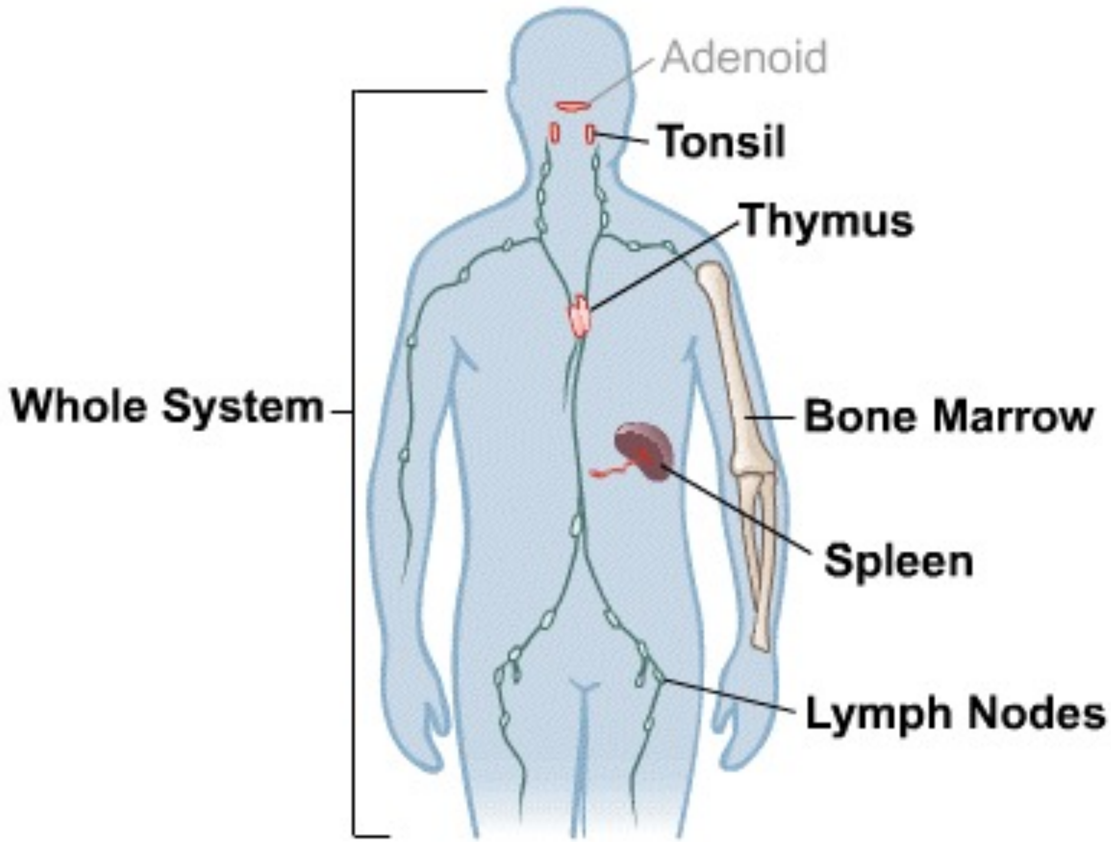
Immune System

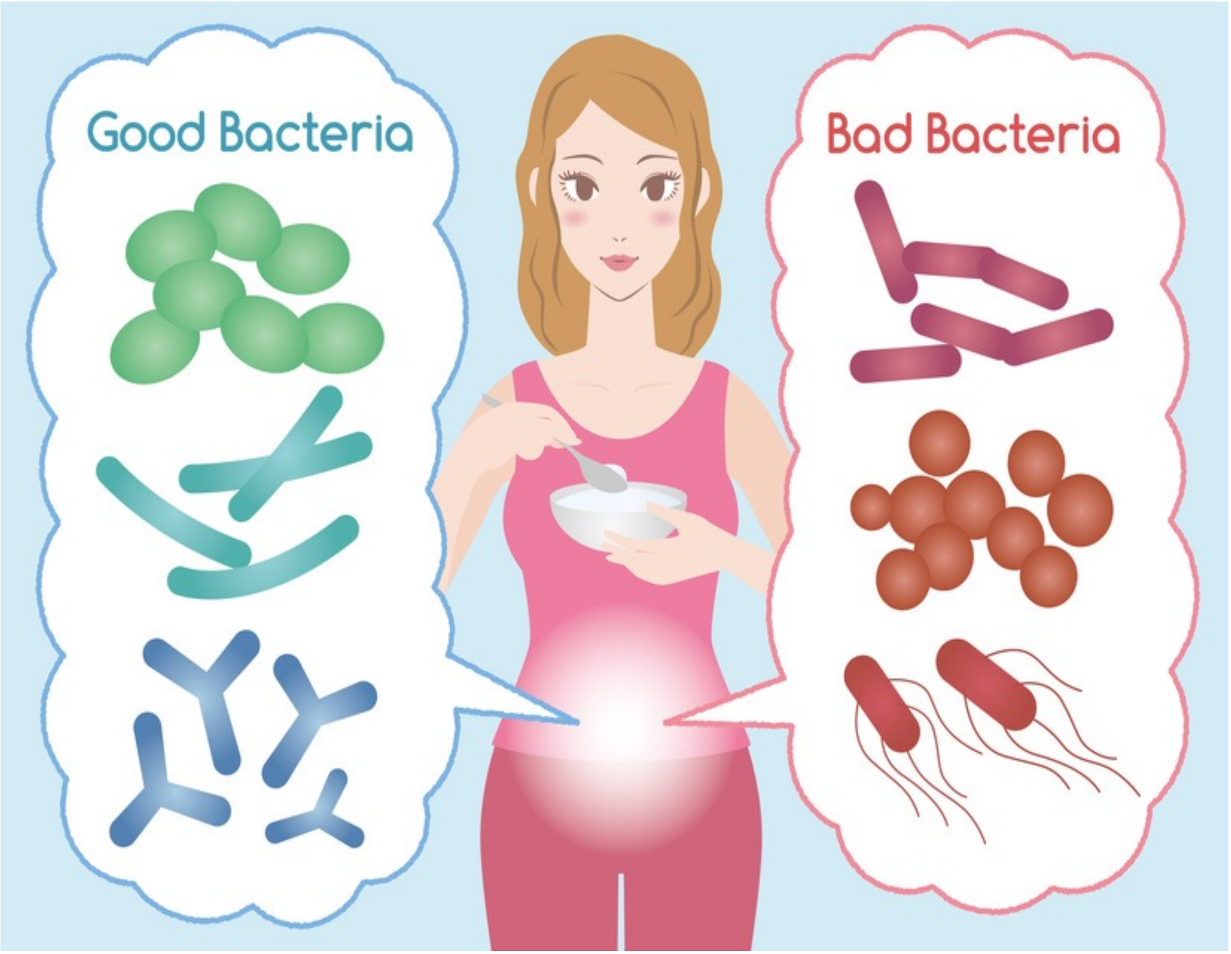
The immune system is made up of special organs, cells and chemicals that fight infection (microbes). The main parts of the immune system are: white blood cells, antibodies, the complement system, the lymphatic system, the spleen, the thymus, and the bone marrow. These are the parts of your immune system that actively fight infection.



Ref: https://www.betterhealth.vic.gov.au/health/conditionsandtreatments/immune-system

The immune system and microbial infection

- The immune system keeps a record of every microbe it has ever defeated, in types of white blood cells (B- and T-lymphocytes) known as memory cells. This means it can recognise and destroy the microbe quickly if it enters the body again, before it can multiply and make you feel sick.
- Some infections, like the flu and the common cold, have to be fought many times because so many different viruses or strains of the same type of virus can cause these illnesses. Catching a cold or flu from one virus does not give you immunity against the others.



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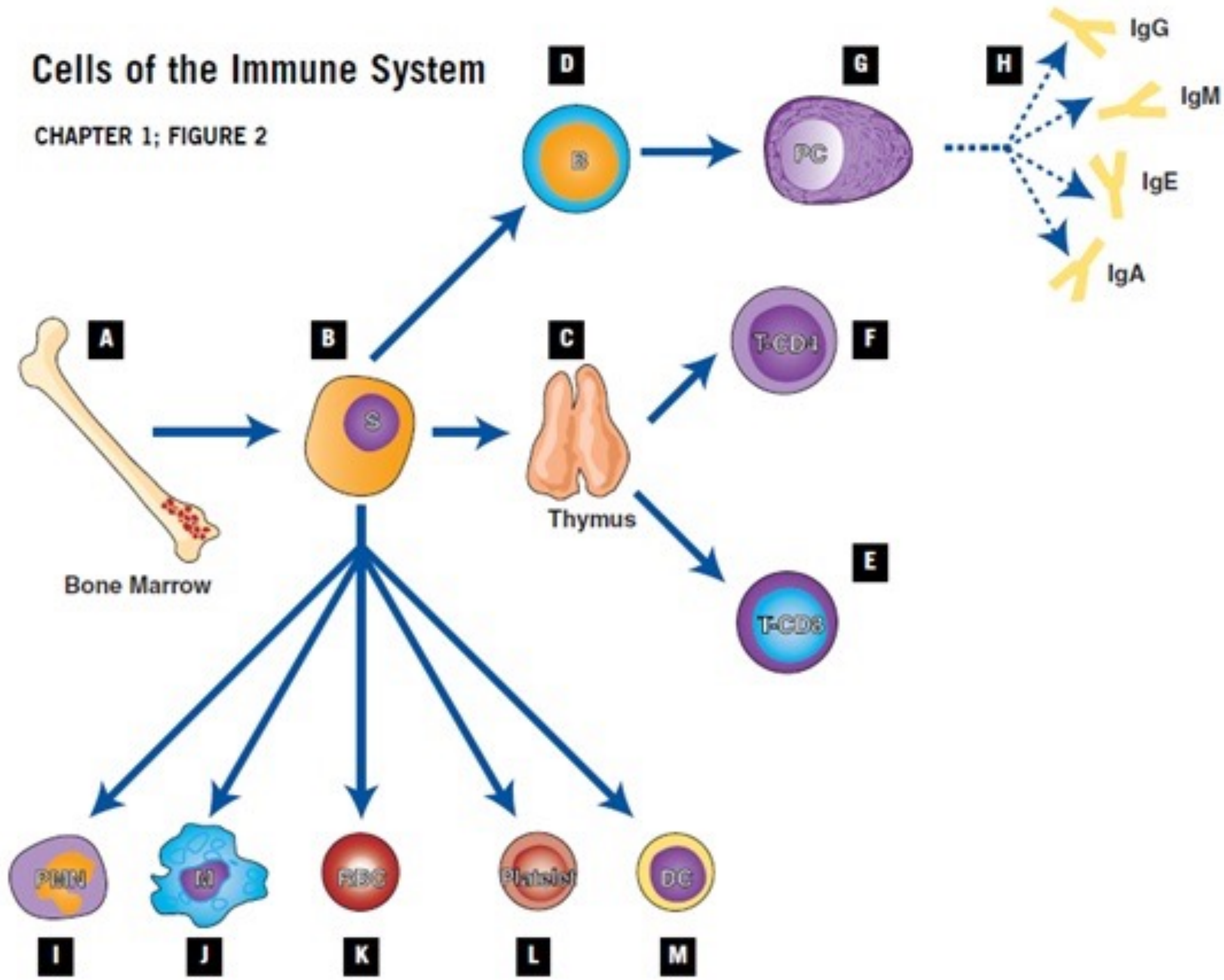
The immune system and microbial infection

The main parts of the immune system are:

- white blood cells
- antibodies
- complement system
- lymphatic system
- spleen
- bone marrow
- thymus



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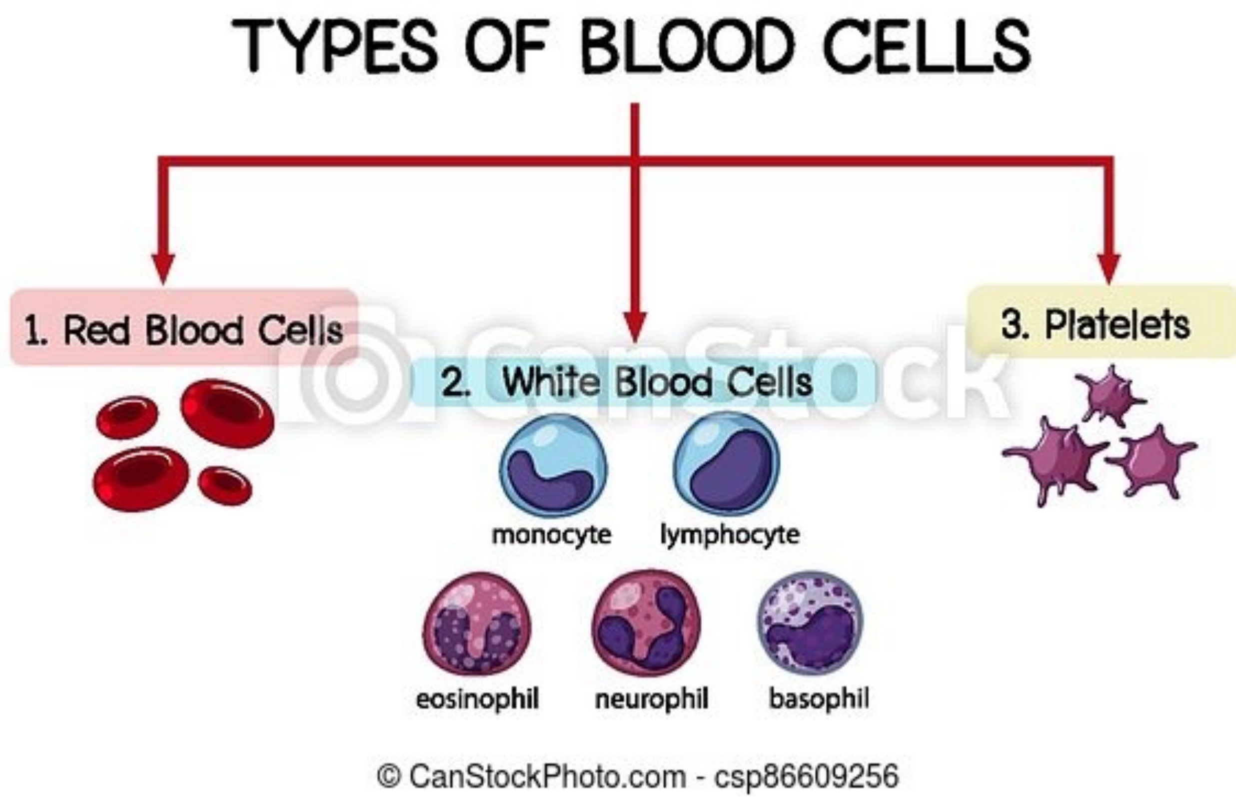
The immune system and microbial infection

White blood cells

- White blood cells are the key players in your immune system. They are made in your bone marrow and are part of the lymphatic system.
- White blood cells move through blood and tissue throughout your body, looking for foreign invaders (microbes) such as bacteria, viruses, parasites and fungi. When they find them, they launch an immune attack.
- White blood cells include lymphocytes (such as B-cells, T-cells and natural killer cells), and many other types of immune cells.



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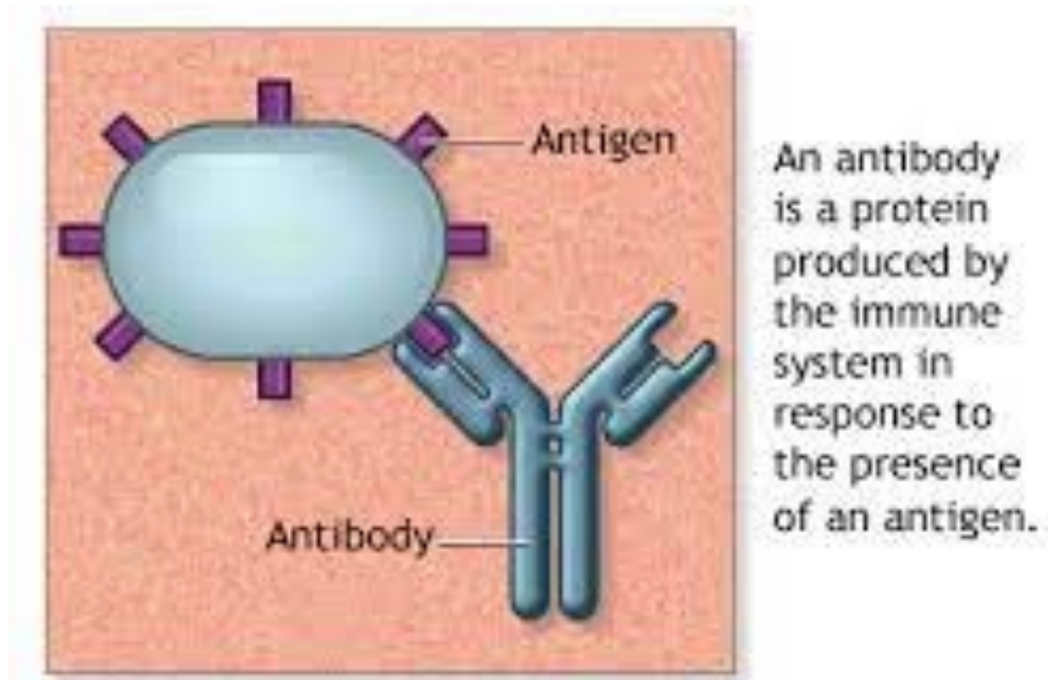
The immune system and microbial infection

Antibodies

- Antibodies help the body to fight microbes or the toxins (poisons) they produce. They do this by recognising substances called antigens on the surface of the microbe, or in the chemicals they produce, which mark the microbe or toxin as being foreign. The antibodies then mark these antigens for destruction. There are many cells, proteins and chemicals involved in this attack.

Complement system

- The complement system is made up of proteins whose actions complement the work done by antibodies.



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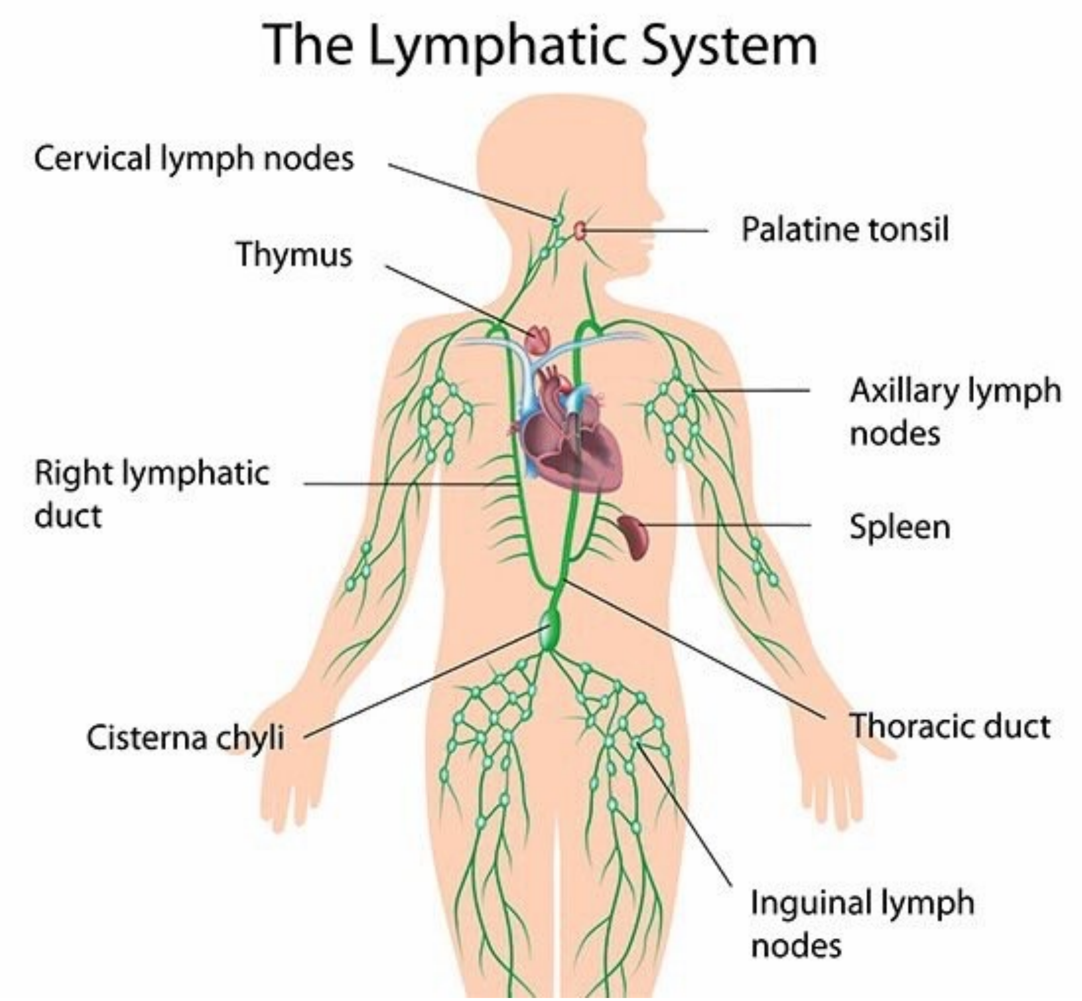
The immune system and microbial infection

Lymphatic system

- The lymphatic system is a network of delicate tubes throughout the body. The main roles of the lymphatic system are to:
- manage the fluid levels in the body
- react to bacteria
- deal with cancer cells
- deal with cell products that otherwise would result in disease or disorders
- absorb some of the fats in our diet from the intestine.

The lymphatic system is made up of:

- lymph nodes (also called lymph glands) -- which trap microbes
- lymph vessels -- tubes that carry lymph, the colourless fluid that bathes your body's tissues and contains infection-fighting white blood cells
- white blood cells (lymphocytes).



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The immune system and microbial infection

Spleen

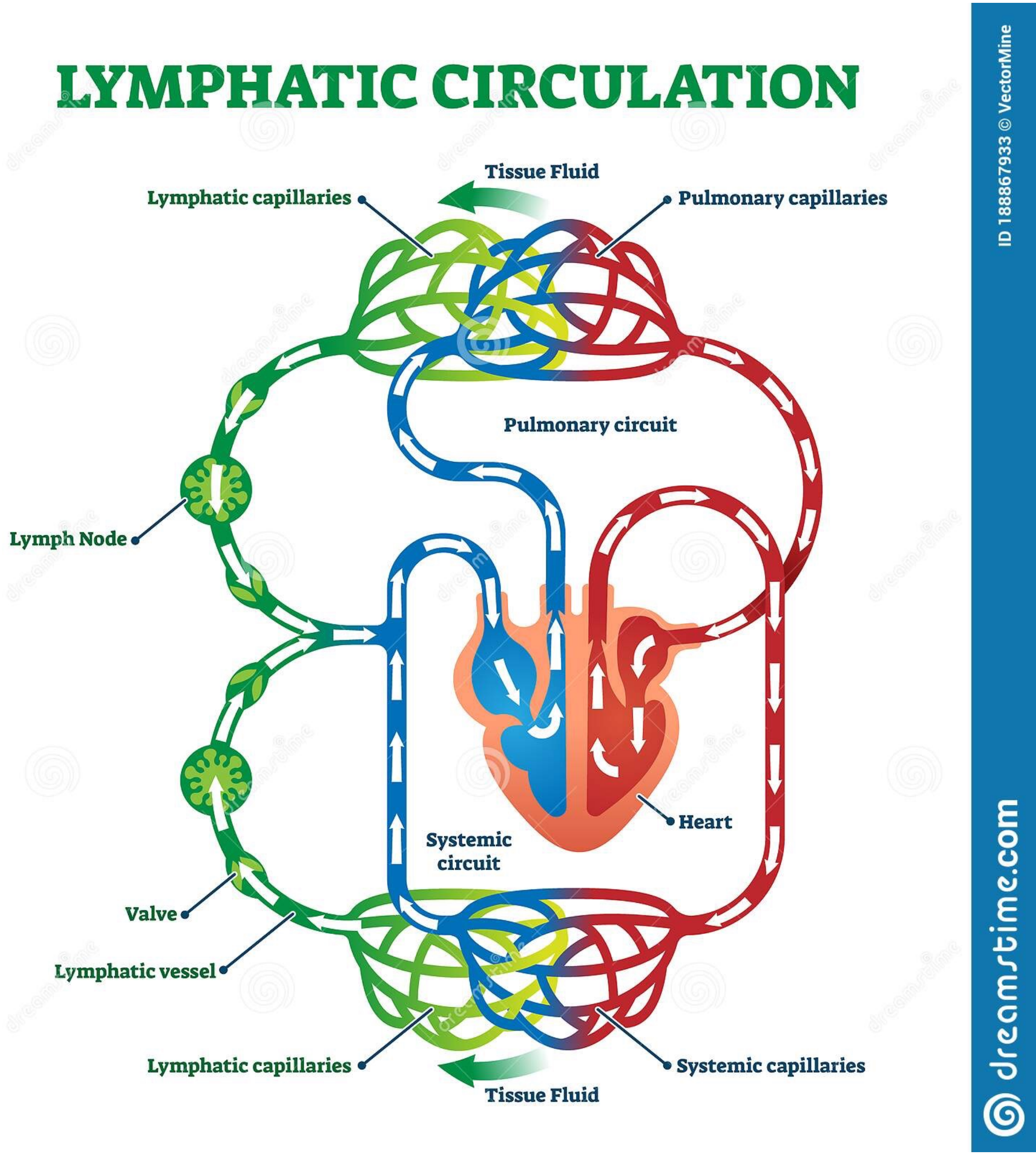
- The spleen is a blood-filtering organ that removes microbes and destroys old or damaged red blood cells. It also makes disease-fighting components of the immune system (including antibodies and lymphocytes).

Bone marrow

- Bone marrow is the spongy tissue found inside your bones. It produces the red blood cells our bodies need to carry oxygen, the white blood cells we use to fight infection, and the platelets we need to help our blood clot.

Thymus

- The thymus filters and monitors your blood content. It produces the white blood cells called T-lymphocytes.



Ref: https://www.betterhealth.vic.gov.au/health/conditionsandtreatments/immune-system

The body's other defences against microbes

As well as the immune system, the body has several other ways to defend itself against microbes, including:

- skin - a waterproof barrier that secretes oil with bacteria-killing properties
- lungs - mucous in the lungs (phlegm) traps foreign particles, and small hairs (cilia) wave the mucous upwards so it can be coughed out
- digestive tract - the mucous lining contains antibodies, and the acid in the stomach can kill most microbes
- other defences - body fluids like skin oil, saliva and tears contain anti-bacterial enzymes that help reduce the risk of infection. The constant flushing of the urinary tract and the bowel also helps.

Ref: https://www.betterhealth.vic.gov.au/health/conditionsandtreatments/immune-system

Common disorders of the immune system

It is common for people to have an over- or underactive immune system. Overactivity of the immune system can take many forms, including:

- allergic diseases - where the immune system makes an overly strong response to allergens. Allergic diseases are very common. They include allergies to foods, medications or stinging insects, anaphylaxis (life-threatening allergy), hay fever (allergic rhinitis), sinus disease, asthma, hives (urticaria), dermatitis and eczema
- autoimmune diseases - where the immune system mounts a response against normal components of the body. Autoimmune diseases range from common to rare. They include multiple sclerosis, autoimmune thyroid disease, type 1 diabetes, systemic lupus erythematosus, rheumatoid arthritis and systemic vasculitis.

Ref: https://www.betterhealth.vic.gov.au/health/conditionsandtreatments/immune-system

Common disorders of the immune system

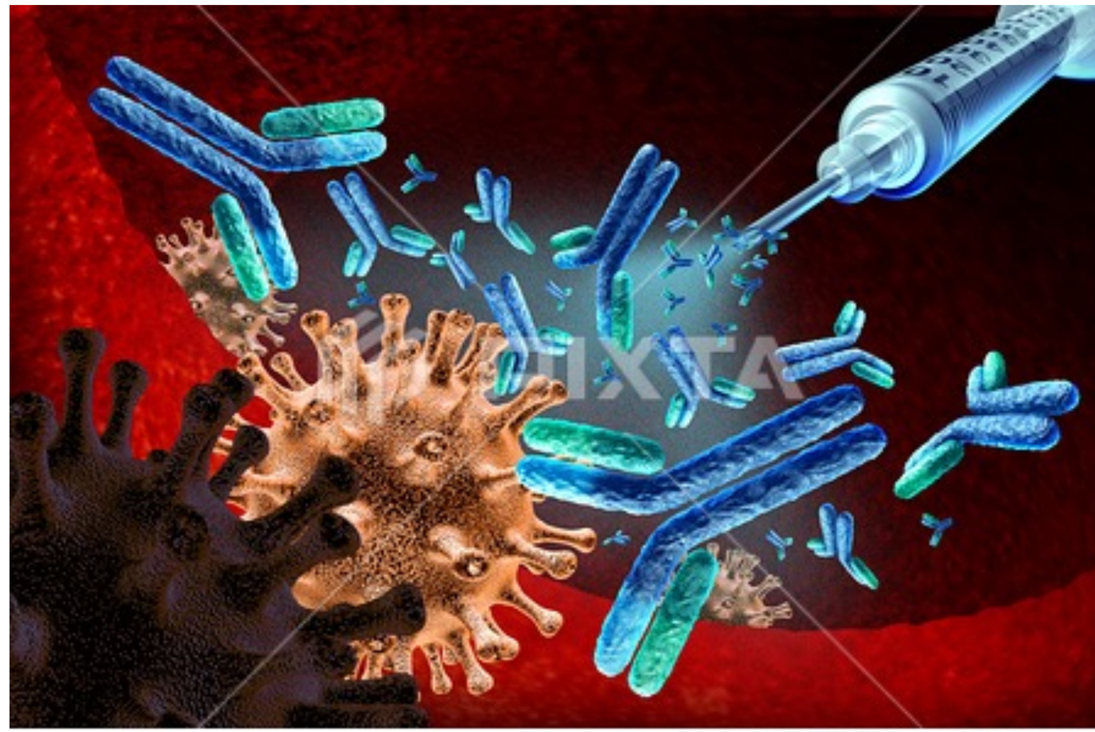
Underactivity of the immune system, also called immunodeficiency, can:

- be inherited - examples of these conditions include primary immunodeficiency diseases such as common variable immunodeficiency (CVID), x-linked severe combined immunodeficiency (SCID) and complement deficiencies
- arise as a result of medical treatment - this can occur due to medications such as corticosteroids or chemotherapy
- be caused by another disease - such as HIV/AIDS or certain types of cancer.
- An underactive immune system does not function correctly and makes people vulnerable to infections. It can be life threatening in severe cases.
- People who have had an organ transplant need immunosuppression treatment to prevent the body from attacking the transplanted organ.

Ref: https://www.betterhealth.vic.gov.au/health/conditionsandtreatments/immune-system

Immunoglobulin Therapy

- Immunoglobulins (commonly known as antibodies) are used to treat people who are unable to make enough of their own, or whose antibodies do not work properly. This treatment is known as immunoglobulin therapy.
- Until recently, immunoglobulin therapy in Australia mostly involved delivery of immunoglobulins through a drip into the vein – known as intravenous immunoglobulin (IVIg) therapy. Now, subcutaneous immunoglobulin (SCIg) can be delivered into the fatty tissue under the skin, which may offer benefits for some patients. This is known as subcutaneous infusion or SCIg therapy.



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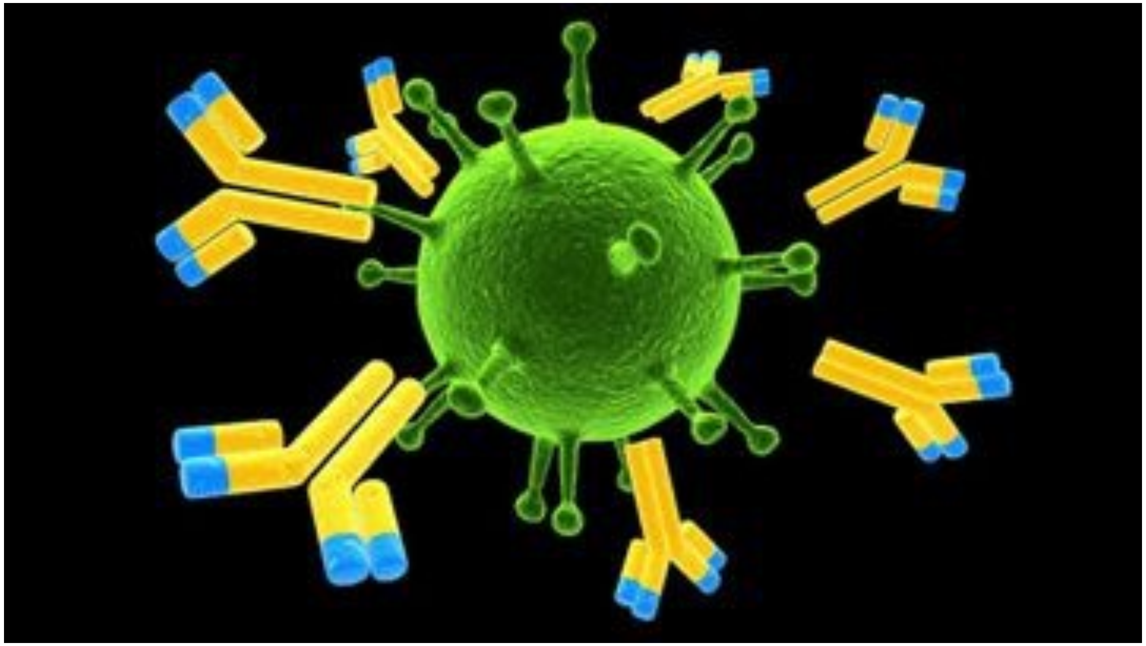
Immunoglobulin Therapy

- Subcutaneous immunoglobulin is similar to intravenous immunoglobulin. It is made from plasma – the liquid part of blood containing important proteins like antibodies.

Download the SCIg introduction fact sheet to read more about this type of treatment.

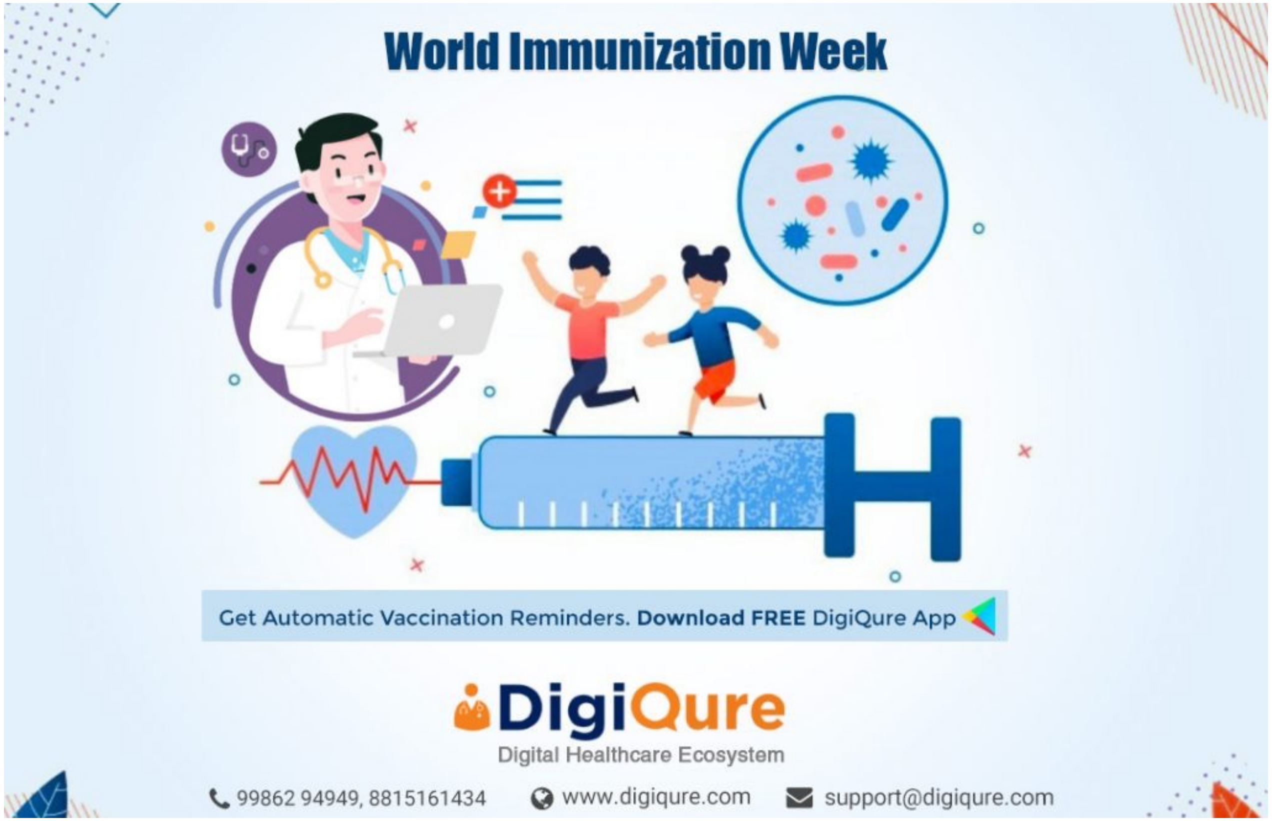
- Many health services are now offering SCIg therapy to eligible patients with specific immune conditions. If you are interested, please discuss your particular requirements with your treating specialist.



Ref: https://www.betterhealth.vic.gov.au/health/conditionsandtreatments/immune-system

Immunisation

Immunisation works by copying the body's natural immune response. A vaccine (a small amount of a specially treated virus, bacterium or toxin) is injected into the body. The body then makes antibodies to it. If a vaccinated person is exposed to the actual virus, bacterium or toxin, they won't get sick because their body will recognise it and know how to attack it successfully. Vaccinations are available against many diseases, including measles and tetanus.



Ref: https://www.betterhealth.vic.gov.au/health/conditionsandtreatments/immune-system

Immunisation

The immunisations you may need are decided by your health, age, lifestyle and occupation. Together, these factors are referred to as HALO, which is defined as:

- health - some health conditions or factors may make you more vulnerable to vaccine-preventable diseases. For example, premature birth, asthma, diabetes, heart, lung, spleen or kidney conditions, Down syndrome and HIV will mean you may benefit from additional or more frequent immunisations
- age - at different ages you need protection from different vaccine-preventable diseases. Australia's National Immunisation Program sets out recommended immunisations for babies, children, older people and other people at risk, such as Aboriginal and Torres Strait Islanders. Most recommended vaccines are available at no cost to these groups; can be an example for us to adopt from for our older people

Ref: https://www.betterhealth.vic.gov.au/health/conditionsandtreatments/immune-system

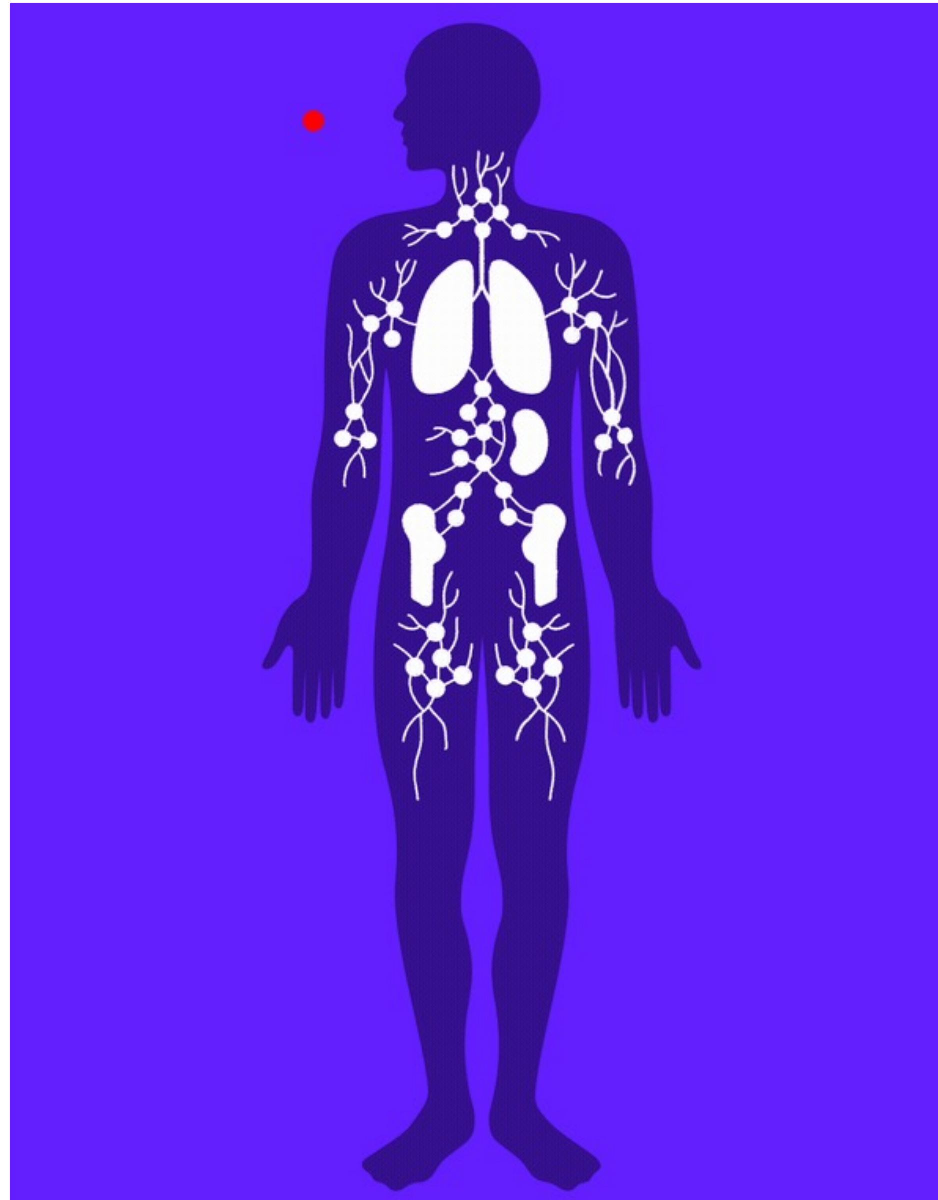
Immunisation

- lifestyle - lifestyle choices can have an impact on your immunisation needs. Travelling overseas to certain places, planning a family, sexual activity, smoking, and playing contact sport that may expose you directly to someone else's blood, will mean you may benefit from additional or more frequent immunisations
- occupation - you are likely to need extra immunisations, or need to have them more often, if you work in an occupation that exposes you to vaccine-preventable diseases or puts you into contact with people who are more susceptible to problems from vaccine-preventable diseases (such as babies or young children, pregnant women, the elderly, and people with chronic or acute health conditions). For example, if you work in aged care, childcare, healthcare, emergency services or sewerage repair and maintenance, discuss your immunisation needs with your doctor. Some employers help with the cost of relevant vaccinations for their employees.

Ref: https://www.betterhealth.vic.gov.au/health/conditionsandtreatments/immune-system

How do vaccines work?

- Germs are all around us, both in our environment and in our bodies. When a person is susceptible and they encounter a harmful organism, it can lead to disease and death.
- The body has many ways of defending itself against **pathogens** (disease-causing organisms). Skin, mucus, and cilia (microscopic hairs that move debris away from the lungs) all work as physical barriers to prevent pathogens from entering the body in the first place.
- When a pathogen does infect the body, our body's defences, called the immune system, are triggered and the pathogen is attacked and destroyed or overcome.

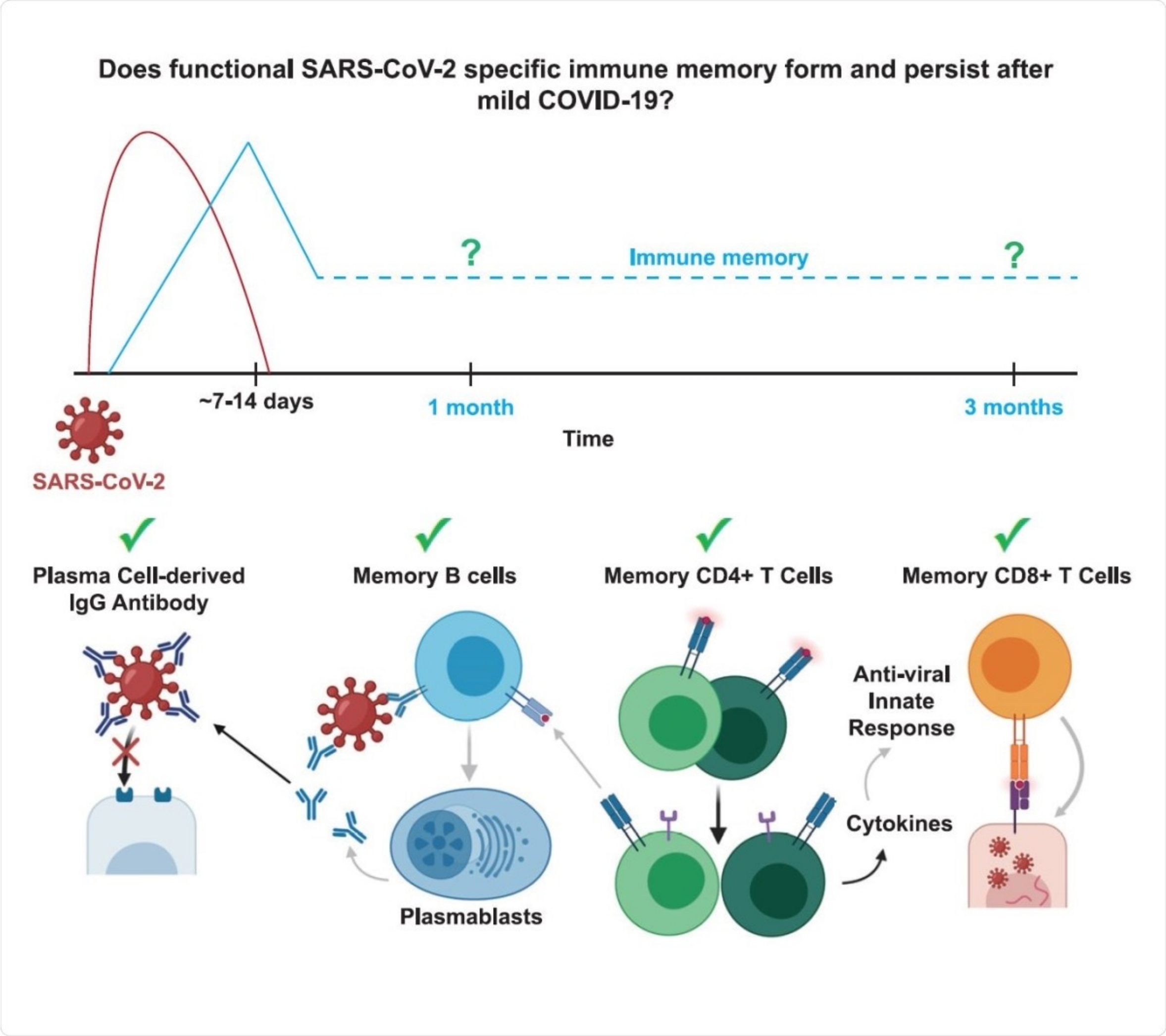


Ref: https://www.who.int/news-room/feature-stories/detail/how-do-vaccines-work

How do vaccines work?

The body's natural response

- A pathogen is a bacterium, virus, parasite or fungus that can cause disease within the body. Each pathogen is made up of several subparts, usually unique to that specific pathogen and the disease it causes. The subpart of a pathogen that causes the formation of antibodies is called an antigen. The antibodies produced in response to the pathogen's antigen are an important part of the immune system. You can consider antibodies as the soldiers in your body's defense system. Each antibody, or soldier, in our system is trained to recognize one specific antigen. We have thousands of different antibodies in our bodies. When the human body is exposed to an antigen for the first time, it takes time for the immune system to respond and produce antibodies specific to that antigen.



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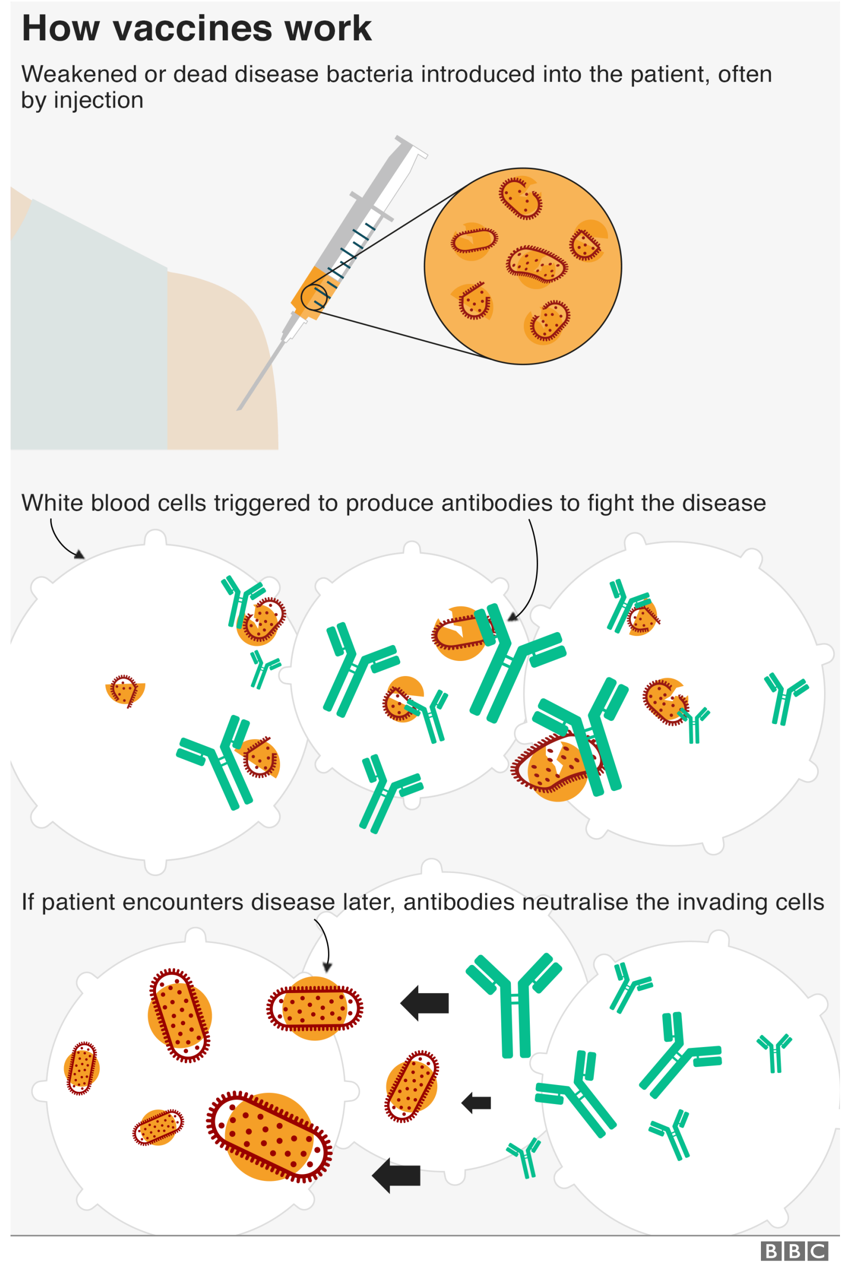
How do vaccines work?

- In the meantime, the person is susceptible to becoming ill.
- Once the antigen-specific antibodies are produced, they work with the rest of the immune system to destroy the pathogen and stop the disease. Antibodies to one pathogen generally don't protect against another pathogen except when two pathogens are very similar to each other, like cousins. Once the body produces antibodies in its primary response to an antigen, it also creates antibody-producing memory cells, which remain alive even after the pathogen is defeated by the antibodies. If the body is exposed to the same pathogen more than once, the antibody response is much faster and more effective than the first time around because the memory cells are at the ready to pump out antibodies against that antigen.
- This means that if the person is exposed to the dangerous pathogen in the future, their immune system will be able to respond immediately, protecting against disease.



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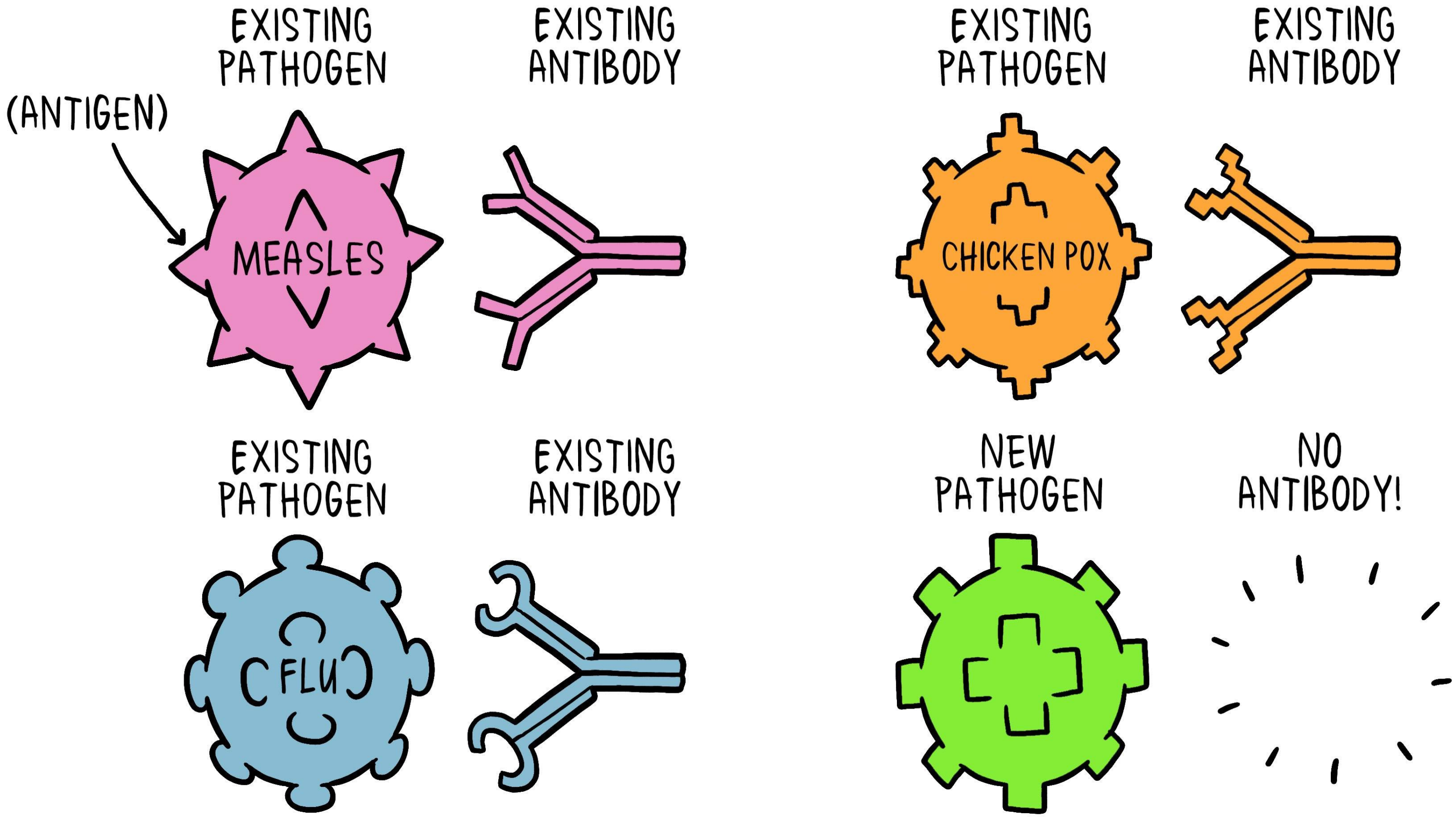
How do vaccines work?



When a new pathogen or disease enters our body, it introduces a new antigen. For every new antigen, our body needs to build a specific antibody that can grab onto the antigen and defeat the pathogen.

Ref: https://www.who.int/news-room/feature-stories/detail/how-do-vaccines-work

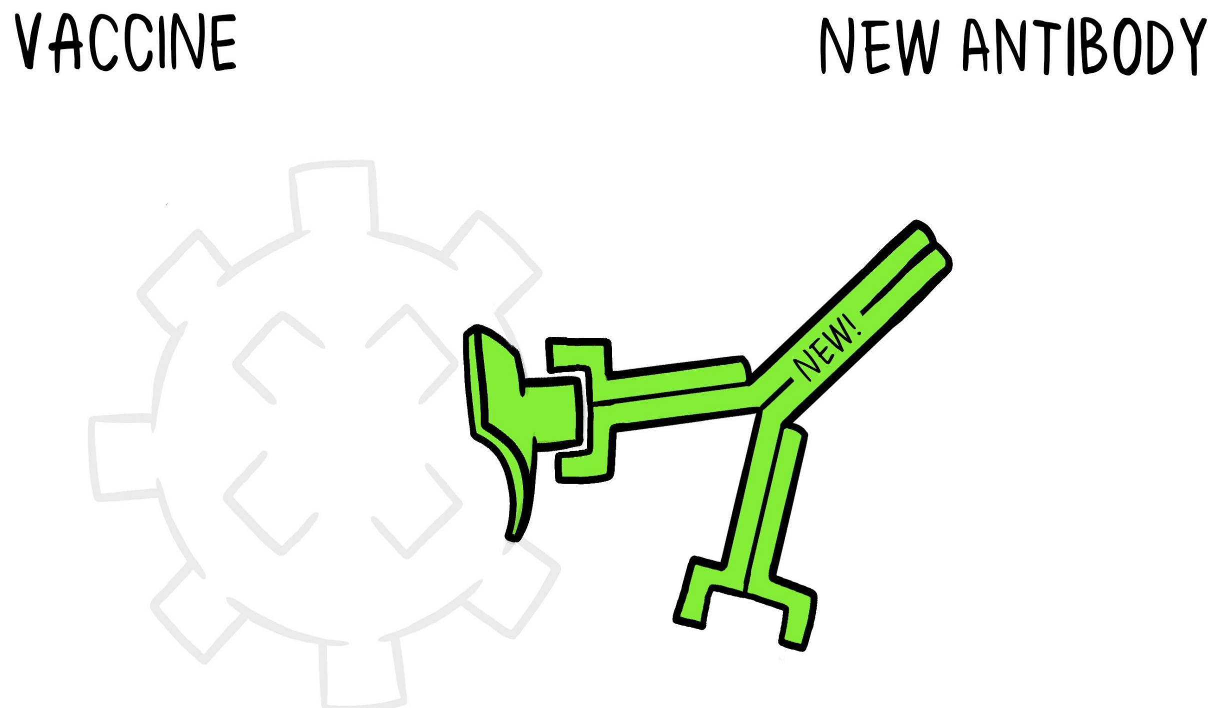
How do vaccines work?

How vaccines help

- Vaccines contain weakened or inactive parts of a particular organism (antigen) that triggers an immune response within the body. Newer vaccines contain the blueprint for producing antigens rather than the antigen itself. Regardless of whether the vaccine is made up of the antigen itself or the blueprint so that the body will produce the antigen, this weakened version will not cause the disease in the person receiving the vaccine, but it will prompt their immune system to respond much as it would have on its first reaction to the actual pathogen.
- Some vaccines require multiple doses, given weeks or months apart. This is sometimes needed to allow for the production of long-lived antibodies and development of memory cells. In this way, the body is trained to fight the specific disease-causing organism, building up memory of the pathogen so as to rapidly fight it if and when exposed in the future.

Ref: https://www.who.int/news-room/feature-stories/detail/how-do-vaccines-work

How do vaccines work?



A VACCINE is a tiny weakened non-dangerous fragment of the organism and includes parts of the antigen. It's enough that our body can learn to build the specific antibody. Then if the body encounters the real antigen later, as part of the real organism, it already knows how to defeat it.

Ref: https://www.who.int/news-room/feature-stories/detail/how-do-vaccines-work

How do vaccines work?

Herd immunity

- When someone is vaccinated, they are very likely to be protected against the targeted disease. But not everyone can be vaccinated. People with underlying health conditions that weaken their immune systems (such as cancer or HIV) or who have severe allergies to some vaccine components may not be able to get vaccinated with certain vaccines. These people can still be protected if they live in and amongst others who are vaccinated. When a lot of people in a community are vaccinated the pathogen has a hard time circulating because most of the people it encounters are immune. So the more that others are vaccinated, the less likely people who are unable to be protected by vaccines are at risk of even being exposed to the harmful pathogens. This is called herd immunity.
- This is especially important for those people who not only can't be vaccinated but may be more susceptible to the diseases we vaccinate against. No single vaccine provides 100% protection, and herd immunity does not provide full protection to those who cannot safely be vaccinated. But with herd immunity, these people will have substantial protection, thanks to those around them being vaccinated.
- Vaccinating not only protects yourself, but also protects those in the community who are unable to be vaccinated. If you are able to, get vaccinated.

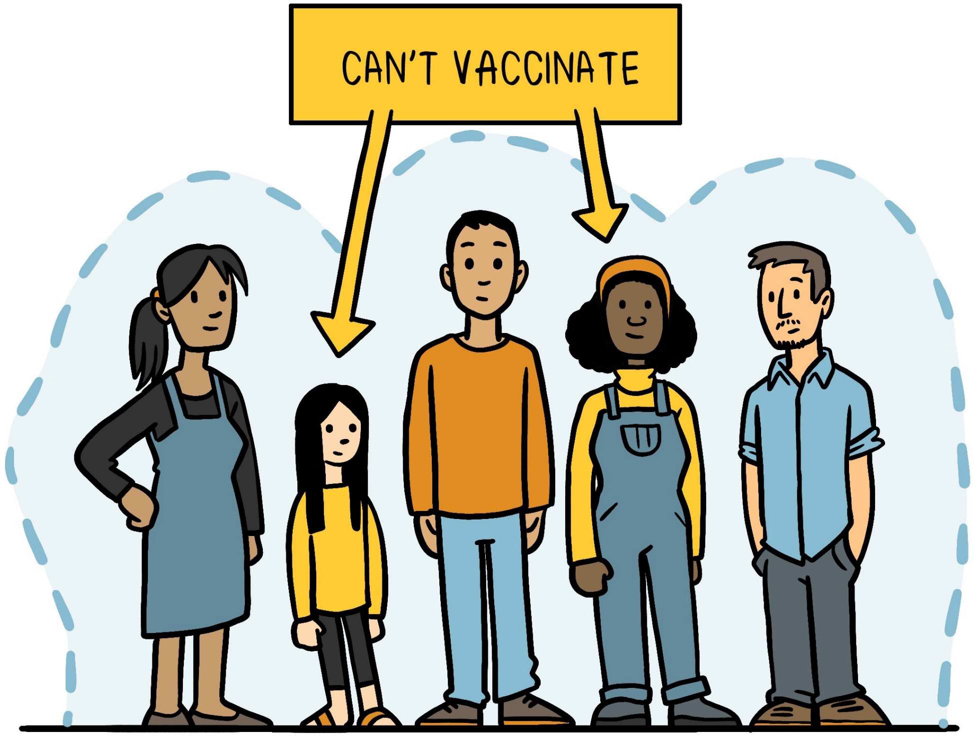
Ref: https://www.who.int/news-room/feature-stories/detail/how-do-vaccines-work

How do vaccines work?

A vaccine protects an individual...

Ref: https://www.who.int/news-room/feature-stories/detail/how-do-vaccines-work

How do vaccines work?



Community vaccination protects the whole community, even those who can't vaccinate.

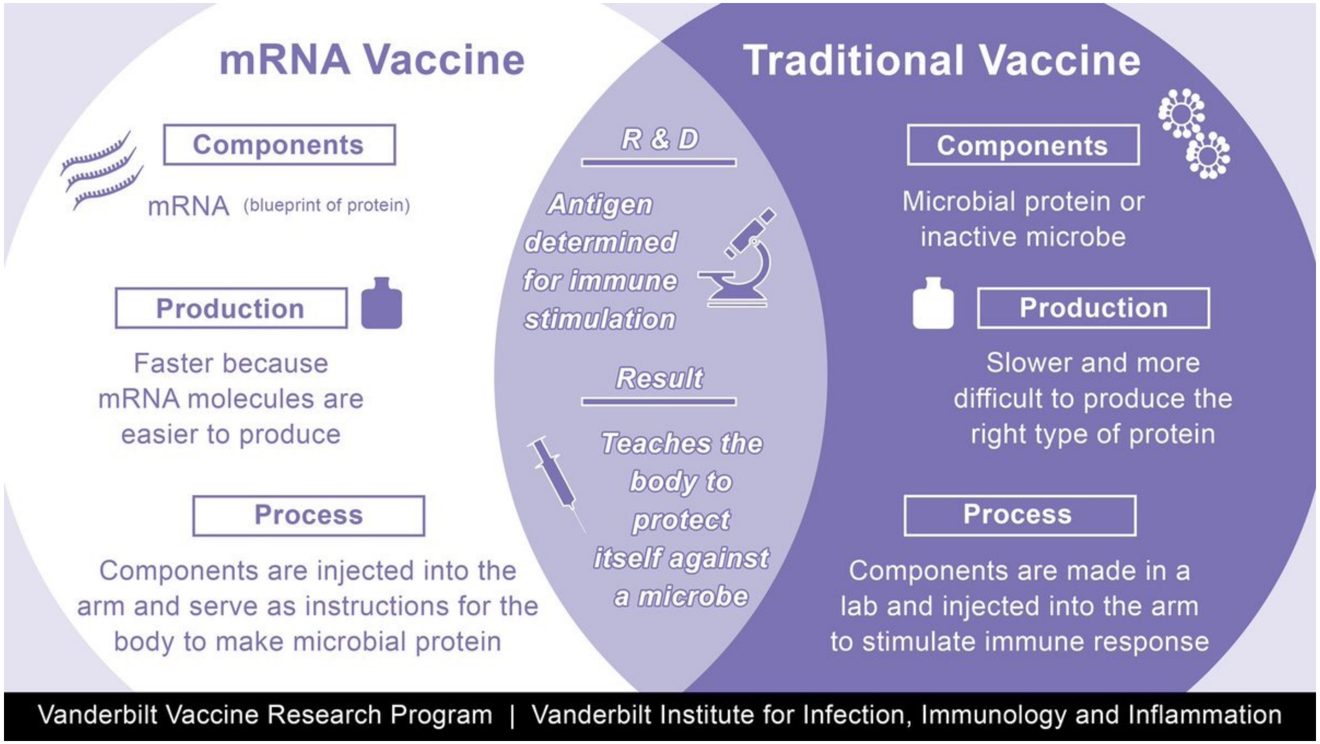
Ref: https://www.who.int/news-room/feature-stories/detail/how-do-vaccines-work

How COVID-19 Vaccines Work

- Different types of vaccines work in different ways to offer protection. But with all types of vaccines, the body is left with a supply of “memory” T-lymphocytes as well as B-lymphocytes that will remember how to fight that virus in the future.
- It typically takes a few weeks after vaccination for the body to produce T-lymphocytes and B-lymphocytes. Therefore, it is possible that a person could be infected with the virus that causes COVID-19 just before or just after vaccination and then get sick because the vaccine did not have enough time to provide protection.
- Sometimes after vaccination, the process of building immunity can cause symptoms, such as fever. These symptoms are normal and are signs that the body is building immunity.

Ref: https://www.cdc.gov/coronavirus/2019-ncov/vaccines/different-vaccines/how-they-work.html

Types of Vaccines



Below is a description of how each type of vaccine prompts our bodies to recognize and protect us from the virus that causes COVID-19. None of these vaccines can give you COVID-19.

- mRNA vaccines contain material from the virus that causes COVID-19 that gives our cells instructions for how to make a harmless protein that is unique to the virus. After our cells make copies of the protein, they destroy the genetic material from the vaccine. Our bodies recognize that the protein should not be there and build T-lymphocytes and B-lymphocytes that will remember how to fight the virus that causes COVID-19 if we are infected in the future.

Ref: https://www.cdc.gov/coronavirus/2019-ncov/vaccines/different-vaccines/how-they-work.html

Types of Vaccines

- **Protein subunit vaccines** include harmless pieces (proteins) of the virus that causes COVID-19 instead of the entire germ. Once vaccinated, our bodies recognize that the protein should not be there and build T-lymphocytes and antibodies that will remember how to fight the virus that causes COVID-19 if we are infected in the future.
- **Vector vaccines** contain a modified version of a different virus than the one that causes COVID-19. Inside the shell of the modified virus, there is material from the virus that causes COVID-19. This is called a "viral vector." Once the viral vector is inside our cells, the genetic material gives cells instructions to make a protein that is unique to the virus that causes COVID-19. Using these instructions, our cells make copies of the protein. This prompts our bodies to build T-lymphocytes and B-lymphocytes that will remember how to fight that virus if we are infected in the future.

Ref: https://www.cdc.gov/coronavirus/2019-ncov/vaccines/different-vaccines/how-they-work.html

Types of Vaccines

To be fully vaccinated, you will need two shots of some COVID-19 vaccines.

- **Two shots:** If you get a COVID-19 vaccine that requires two shots, you are considered fully vaccinated two weeks after your second shot. Pfizer-BioNTechand Moderna COVID-19 vaccines require two shots.
- **One Shot:** If you get a COVID-19 vaccine that requires one shot, you are considered fully vaccinated two weeks after your shot. Johnson & Johnson's Janssen COVID-19 vaccine only requires one shot.
- If it has been less than two weeks since your shot, or if you still need to get your second shot, you are NOT fully protected. Keep taking steps to protect yourself and others until you are fully vaccinated (two weeks after your final shot).

Ref: https://www.cdc.gov/coronavirus/2019-ncov/vaccines/different-vaccines/how-they-work.html