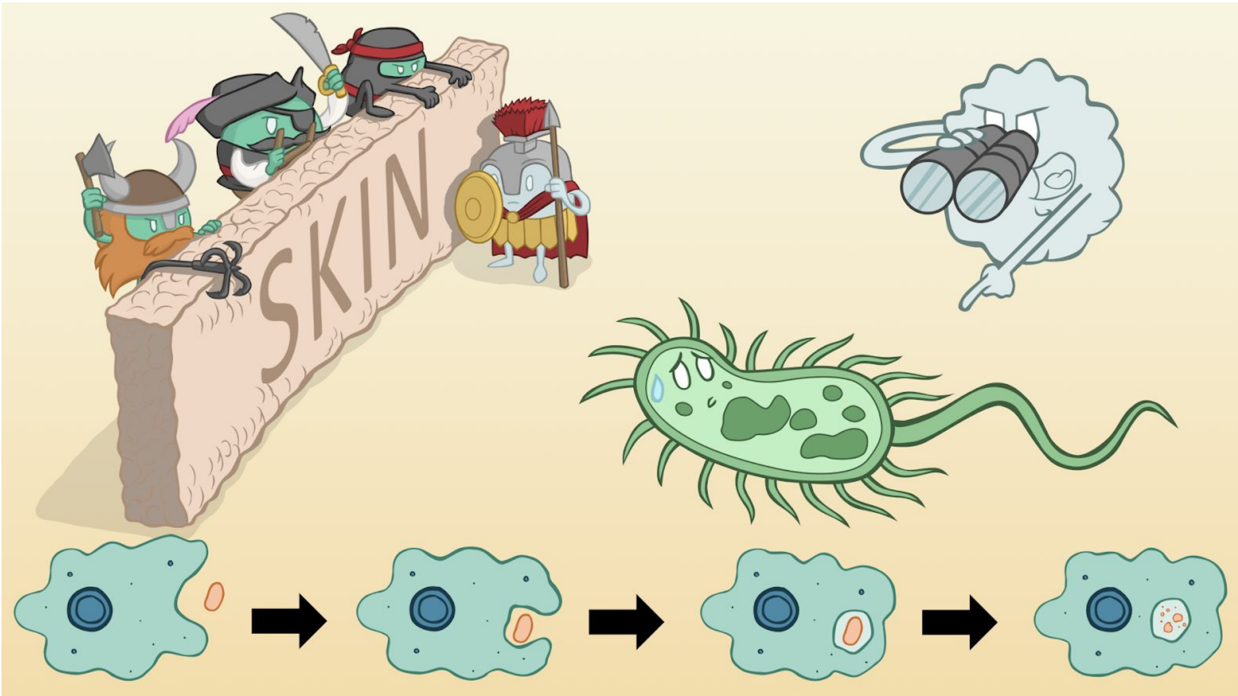


Introduction to the Immune System

Do you remember the last time you were sick? Chances are you remember having had a head cold or the flu, or maybe even a stomach virus. You might have thought that you were never going to recover, but in a few days, you were feeling yourself again. That is thanks to your **immune system!**

Some common pathogens are the Influenza virus that causes the Flu, or the bacterium *Streptococcus pneumoniae,* which causes Pneumonia.

What makes you sick?

Bacteria and viruses are usually to blame for bringing on nasty colds, fevers and fatigue, and many serious infections. There are other life forms that can infect you as well, such as parasites and fungi, and also non-living things like chemical toxins. Any microorganism that causes an infection is called a ***pathogen***.

How do you get sick?

Pathogens can spread in many different ways causing infections. They can be spread from sneezing, coughing, kissing, and touching contaminated areas. This is how the common cold is spread. Eating and drinking contaminated food and drinks, such as food poisoning. More chronic diseases can spread through the exchange of blood or sexual contact, like the HIV virus.

There are many ways pathogens spread from person to person, and each pathogen is different. Sometimes all we have to do to get sick is breathe in air-born particles!

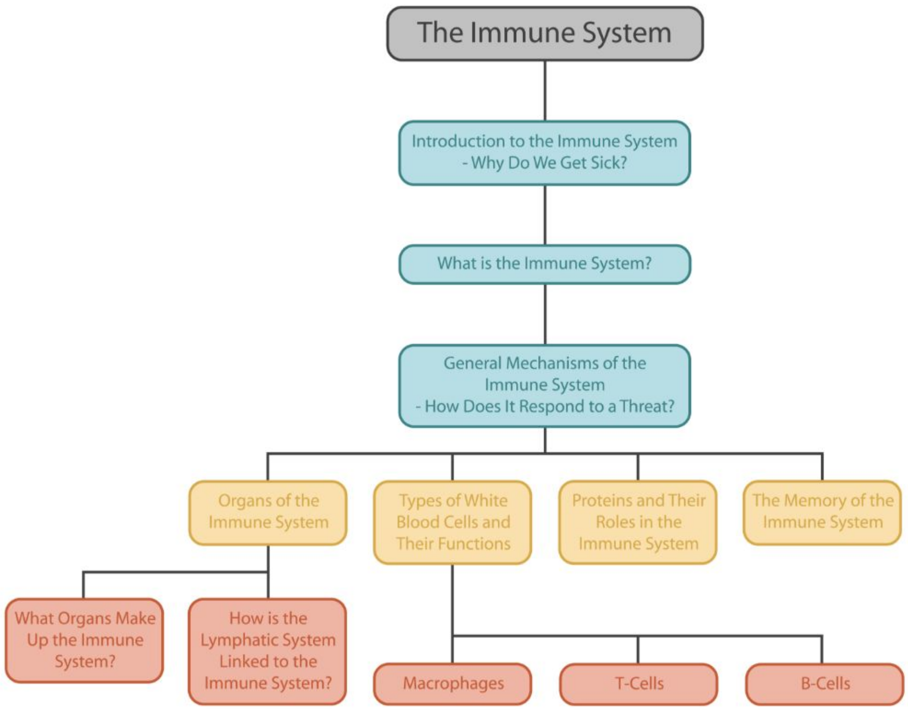
With so many points of entry and so many dangerous microbes out there, it seems that we should be sick all the time. Luckily, our immune system is working round the clock to fend off infections. It defends the body against outside particles and cleans the body of dead or old cells.

What is our Immune System?

The immune system is the body's own defense system against **pathogens** attacking the body. Various cells, organs, and other systems all over the body work together to form the immune system. Some components of the immune system work together to prevent the entry of pathogens. This forms our first line of defense. However, sometimes the pathogens pass through the first line of defense and enter our body. This is when our **innate immune system** and **acquired immune system** come into play.

A big part of our guard cells recognizing and destroying harmful cells is being able to determine which cells belong in the body and which cells do not.

As mentioned earlier the immune system is made up of a number of different cells and organs working and communicating with each other. This site contains extensive explanations of various components that play a part in the immune system. Use the chart below to guide your exploration of how the immune system works.



What happens if the Immune System malfunctions?

In the case of **autoimmune diseases** the immune system malfunctions. Rather than protecting the body from harmful particles, the immune system begins to attack healthy cells in the body. Examples of autoimmune diseases include Type I Diabetes and Lupus Erythematosus. Scientists are still unsure as to why the immune system does this, but have identified two main factors that could trigger this malfunction.

1. Environmental factors such as viruses, drugs, and chemicals.
2. Genetic factors

More on: What is the Immune System?

Again, the immune system is the body's own defense system against pathogens attacking the body. Various cells, organs, and other systems all over the body work together to form the immune system.

The bone marrow found in the center of our bones produces special blood cells called B and T white blood cells. These blood cells can identify, destroy, and remember pathogens that enter our body. Remembering the pathogen helps prevent infection in the future. The lymphatic system also plays a role in the immune system. All the waste materials from the destroyed pathogens are removed by the lymphatic system.

You might ask, how does each cell know what job to do? Are they just born that way? And how do they differentiate between "good" and "bad" cells, knowing not to attack your own healthy cells?

Think about all the hair cells, teeth cells, bone cells, the calcium in your bones, and even the friendly bacteria in your intestines. Imagine constantly remembering and monitoring each type of cell or tissue in your body. The B and T white blood cells go a step further. They vigilantly look for unknown particles that enter the body.

Distinguishing Self from Non-Self

All the materials and substances that belong in the body can be described by the term "self." On the other hand, the term "non-self" describes anything that is new and does not belong inside the body. Thus, the main function of the immune system is to distinguish between self and non-self cells and substances.

How does the immune system protect us from attack?

As you begin to explore the immune system, it is important to remember that our immune system has **learned to learn and remember.** As organisms evolved over millions of years, the immune system has developed its ability to *learn* and *remember* the billions of different cells and substances it comes into contact with every day. Without this ability to learn and remember, you would keep getting sick from the same thing over and over.

General Mechanisms

All organisms, including our body, live in a state of balance. Organisms eat and breathe to supply the body with energy needed to survive. As we eat and breathe our body also needs to protect itself from harmful organisms or substances that may enter through food, water, and air. We must eat and breathe to produce the energy needed to defend our body!

Harmful particles and substances use various methods to harm the healthy body cells.

- Some pathogens, like bacteria, may release toxins that destroy healthy cells.
- Other pathogens, like viruses, enter the body cells and use the cell's machinery to replicate itself.
- Sometimes, damaged or dead body cells can become harmful to the other cells.

The immune system is on constant watch to respond quickly and correctly to any three of these above instances.

The First Line of Defense

Like any other defense system, the first step is to prevent the entry of foreign attackers. Your skin forms the biggest barrier to stop pathogens from attacking. Think of it as a big stone wall protecting the castle on the inside. The skin shields your delicate organs and tissues from attack. Our nasal passages have hair-like structures called cilia that sweep the air breathed in for foreign particles like bacteria, pollen, and dust. This is why we sneeze! Saliva, the enzymes found in our tears, and mucous lining in the nasal passages, the lining of the lungs, intestines, urinary tract, and reproductive tracts all destroy pathogens that enter the body. Imagine the cilia and enzymes like soldiers, protecting the gates around the castle.

Sometimes the first line of defense by our immune system is not enough. In these instances, the immune system uses its innate and acquired defenses to destroy the unwanted visitors.

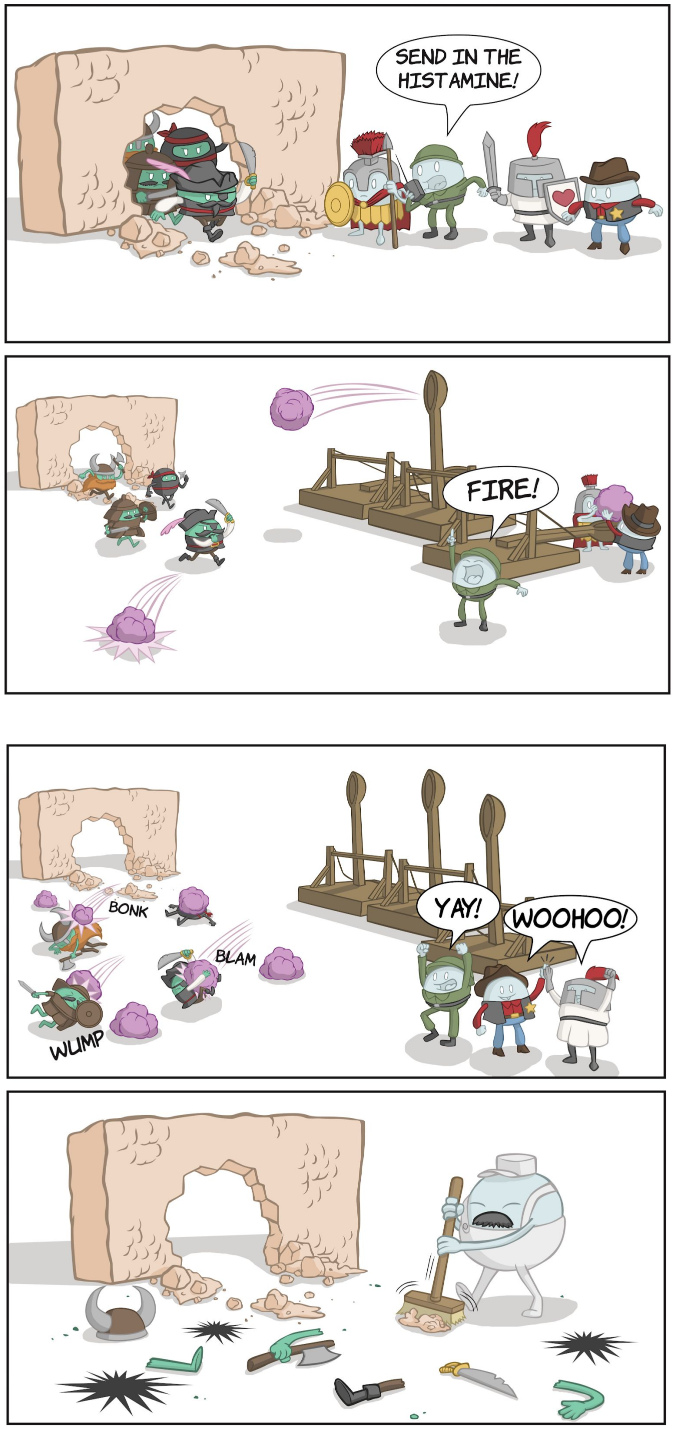
The Innate Immune System

If a foreign particle gets through the first line of defense, the body cells around it will release histamine. Histamine is an enzyme that increases the temperature of blood and causes it to flow faster. The higher blood temperature can kill some of the bacteria. As the blood flows faster, the white blood cells can arrive at the infection site faster.

Along with the red and white blood cells, blood also carries many proteins. These proteins are part of the **Complement System** that helps the immune system. Proteins in the blood react with other substances on the pathogen, activating the protein. The activated protein begins to break down the pathogen chemically causing them to burst (lysis). As the pathogen cell bursts, it releases another enzyme- **cytokines**.

Cytokines signal special swallowing cells called macrophages to the infected site. The macrophages eat and digest the pathogen cells destroying them.

It is important to understand that the proteins and macrophages work together at the same time to destroy the pathogen.



The first lines of defense, the proteins in the Complement System and the macrophages, are all part of the innate immune system. The innate defenses occur immediately after attack and are non-specific. This means it does not identify the attacker, it simply defends the body from non-self particles.

If the innate immune system is unsuccessful and the pathogen is not destroyed, then the **acquired immune system** is triggered.

The Acquired Immune System

The acquired immune system is a vital component that helps defend our body. It is able to identify harmful non-self particles, destroy them and remember them, too. This part of the immune system is described as "acquired" because it is constantly identifying new particles and saving this information to its memory for future use.

The acquired immune system consists of the macrophages, B and T white blood cells, and other cells more vulnerable to pathogens. The B and T cells save the information about the different pathogens that it encounters. This way they can fight off future infections using this saved information.

Together, the innate and acquired defenses of the immune system pose a double threat to pathogens!

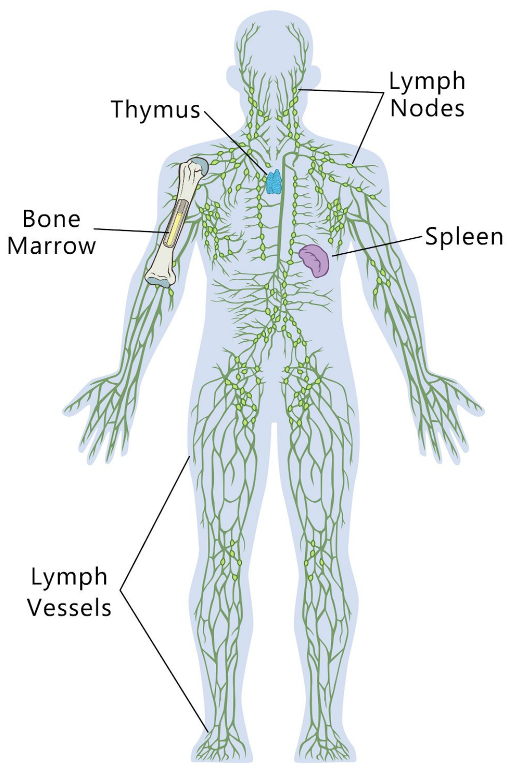
Passive Immunity

There is a third kind of immunity- passive immunity. Passive immunity comes from receiving antibodies from another person. This happens between a mother and her child since they share blood and also during lactation. This protection is immediate and very effective but does not last long.

Organs of the Immune System

The organs that make up the immune system include the bone marrow, the spleen, the thymus, and the lymph nodes and lymph vessels.

Bone marrow, the spongy tissue inside of the bone produces the white blood cells. All T cells, B cells, macrophages and others are first created in the bone marrow. B cells mature in the bone marrow, but T cells travel to the thymus to grow.



Just like blood travels through the blood vessels, the cells of the immune system have their own transportation system where they perform many functions. This is called the lymphatic system.

The lymphatic system is a network of vessels, lymph nodes, and organs throughout the body. The lymph vessels help the white blood cells travel around the body quickly and connects the lymph nodes and the blood stream.

White blood cells like macrophages and T cells concentrate in the lymph nodes, where they can quickly disable any bacteria or virus passing through. Here, B cells divide and multiply, sending a flood of antibodies through the blood and lymph vessels.

Unlike the circulatory system, the lymphatic system lacks a muscle (or organ) that facilitates its movement. The heart pumps blood throughout the body, but the lymphatic system depends upon the contraction of skeletal muscles for movement. This causes the lymphatic system to move much slower than the circulatory system.

A bad infection will cause a lot of activity in the lymph nodes, causing swelling. This is noticeable in some viral infections like Mononucleosis, where the lymph nodes in the neck are swollen and tender.

Stem cells are very important. Right now, scientists are researching how to use these stem cells to help cure diseases like Diabetes. Read on to Autoimmune Diseases and Diabetes to learn more about stem cells and regenerative medicine!

Macrophages

A macrophage is an important type of white blood cell. The function of a macrophage is to swallow foreign particles and smaller cells.

Macrophages carry out their function through a process called **phagocytosis.** This cell constantly roams around the body looking for and destroying dead cells and particles that do not belong in the body.

Macrophages cannot recognize specific target cells. So they are considered part of the **innate immune response.** They also help directly with the *specific* immune response.

Where and how are macrophages made?

Macrophages are a type of white blood cell called monocytes. These cells are produced from stem cells in the bone marrow. The new monocytes formed in the bone marrow are released into the bloodstream. Once it leaves the bloodstream it matures into either a *wandering macrophage* or a *fixed macrophage.*

- **Wandering macrophages** travel around the blood stream and the lymph system looking for unknown cells and particles to eat up.
- **Fixed macrophages** stick to and guard a specific location in the body that is at a higher risk of infection. For example, the lungs and intestines.

Therefore, macrophages are found all around your body in different tissues, lungs, skin, and organs of the immune system like the spleen, lymph nodes and bone marrow.

What role do macrophages play in the immune system?

- *In the innate immune system:* Macrophages travel around the body looking for non-self antigens it does not recognize. These cells are programmed to look for specific structures of proteins on the surface of other cells to distinguish between self and non-self particles. Macrophages look for and eat any foreign particles that live in the fibrous environment (extracellular matrix) between cells, as well as eat the debris of damaged or dead cells. Special receptor sites on the cell membrane enable the macrophage to receive chemical signals sent out by bacteria, attracting them to points of infection. This way macrophages will not hurt the healthy cells in our bodies! By themselves, macrophages are good at destroying bacteria, fungi, and different types of parasites (like worms). They also help fight off tumors.
- *In the acquired immune system: An* important function of the macrophages is that they can activate the acquired immune system! After a macrophage has eaten and digested a particle, it displays some of the broken down germ proteins (antigens) on its cell surface. These antigens act as identification signals for Helper T cells. Helper T cells can “read” these signals and tell what kind of particle the macrophage has eaten! If the T cell determines the macrophage has eaten something harmful (a pathogen), it can trigger a powerful reaction towards the specific pathogen.

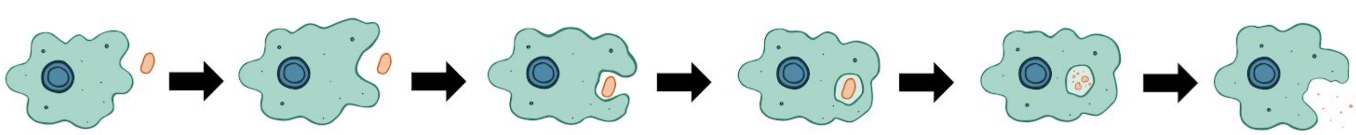
How do macrophages eat or engulf the harmful particles?

Phagocytosis (“phago”=eat, “cyte”=cell) is a fundamental biological process, where organisms, cells and/or particles are “eaten” or engulfed and digested.

When a macrophage encounters an outsider, it extends its cell membrane around the particle, drawing the particle into itself. It then forms a vesicle called a phagosome. Lysosomes inside of the macrophage release enzymes that break apart the captured particle inside of the phagosome.

Macrophages are not the only type of cells that function through phagocytosis. There are other important swallowing cells that make up the immune system, such as cells called granulocytes, neutrophils and dendritic cells. Macrophages are the biggest and most effective of the phagocytes.

Phagocytosis was **one of the earliest forms of metabolism**, meaning that it was first used to get food needed for energy. You can still see some organisms using phagocytosis for eating and digestion, like the amoeba from the Protista kingdom. The amoeba is a single-celled organism that can swallow other cells, then break down the cell and use it for energy—the same way that macrophages swallow and break down bacteria and harmful pathogens. This ancient swallowing ability has been retained by some cells in modern organisms, like the macrophages, for protection!



So, phagocytosis has evolved from a simple form of metabolism to being also a major part of our immune system, helping to keep us healthy!

B cells

B cells are another type of white blood cell. They are similar to the swallowing cells like macrophages but they are specific, meaning they can only attack one kind of intruder. B cells create **antibodies** during an immune response.

Where and how are B cells formed?

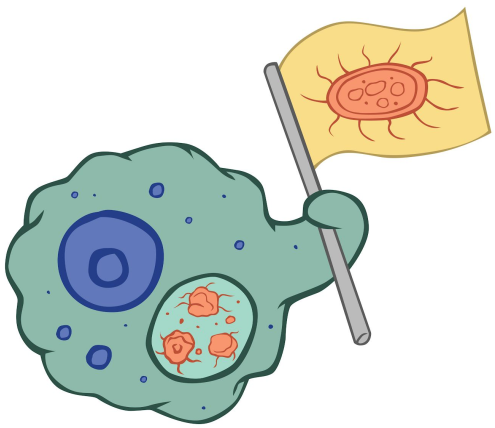
Like T cells, B cells are lymphatic cells that are born from stem cells in the bone marrow. But, unlike T cells, B cells stay in the bone marrow until they are mature. Once mature, they travel through the body, moving in and out of the lymph and blood streams and collecting in the lymph nodes.

The most important part of a B cell is its **receptor site**. This site is called an **antibody**. Each B cell is born with a specific site on their membrane that can bind to only one kind of harmful particle. So this receptor site allows the B cell to recognize and identify one kind of infectious foreign particle. It can do this by binding to the specific protein structure on the particle's surface. But, antibodies do a lot more, read on!

How do B cells function?

When a B cell finds a particle in the body that matches its unique receptor site, it attaches by its receptor site and digests it through a process similar to phagocytosis. It then displays the digested viral or bacterial pieces on its cell surface which attracts Helper T cells. If the Helper T cell also has a specific binding site that matches the digested bits on the B cell, then it *knows* that the digested particle is harmful! If it hadn't already been alerted (and activated) by a macrophage of the same threat, it now becomes activated.

The activated Helper T cell, in turn, activates the B cell, and this interaction causes the B cell to divide. After a few days, the young B cells will mature and differentiate into **plasma cells** and **memory B cells**.



- **Plasma cells** use their machinery to produce **antibodies**.
- **Memory B cells** remain in the body and "remember" the proteins the infectious particle had. So in the future if it encounters the same particles with the same antigens then it can launch a quicker and stronger response.

How do antibodies work?

Antibodies are "Y" –shaped protein structures made by B cells. They are made to specifically bind with one kind of infecting virus or bacteria. Think of how a lock and key work. The key has to match exactly into the lock for it to open the door. Likewise, the Y shaped antibody protein locks into a specific place on the infecting virus or bacteria**.** So, each type of virus or bacteria requires a different set of antibodies—antibodies made against the Influenza virus don't have any effect on, let's say, the Mononucleosis virus, although their symptoms are very similar!

Antibodies can work in three ways to fight against an infection:

1. They travel through the blood and lymph to the site of infection and attach themselves to the matching foreign particle. This causes the foreign particle to become immobile, preventing them from spreading or reproducing.
2. Antibodies make the foreign particle more attractive to macrophages and other phagocytes, who quickly come and eat the immobile particles.

3. Antibodies can also travel to the intestines or our external mucous membranes to stop their pathogen before more of it enters the body!

What do Memory cells do?

The other set of cells produced during B cell division are **memory B cells.** These continue to exist in the body long after the infection has been cleared. This way, they keep the antibody that recognizes the specific harmful outsider. In other words, they have the bacteria or virus on file! The next time it enters the body, the memory B cells will have all the information needed to start a quick antibody response and stop a chronic infection before it occurs. These B cells can stay circulating around your body for years, or possibly forever!

Memory B cells are the reason we can have vaccines and, unfortunately, allergies!

How do B cells recognize bacteria or viruses?

Specificity

Each piece of virus or bacteria that causes an infection has its own different genetic makeup. This genetic makeup is expressed in the proteins that are displayed either on its surface or on the surface of an infected body cell. These proteins are called antigens.

The whole goal of the B cell is to recognize the specific structure of these proteins, and manufacture antibodies that will “fit” their shape. Antibodies have specific binding sites allowing them to only bind to one kind of antigen. It’s like creating *thousands* of one type of key—per second—that will unlock one door. It is estimated that there are *10 million* different variations in protein structure that viruses and bacteria can express. So the body competes by producing *10 million* B cells that each have a uniquely-shaped receptor! Our B cells represent one way in which our immune system has adapted over time. These adaptations enable it to acquire and remember information about viruses, bacteria, and other harmful pathogens that threaten our well-being.

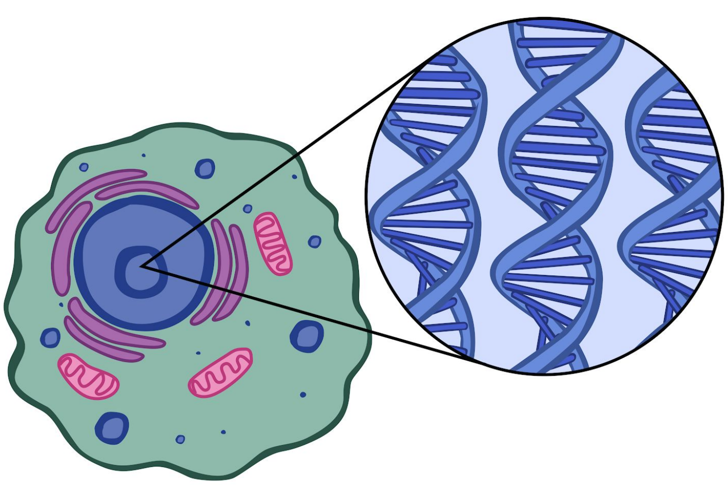
One of the Least Well Known But Major Players of the Immune System: Proteins

As you keep reading this page you will learn more about the innate immune system and the acquired immune system. But, before we can discuss these topics we must look at the importance of one player of the immune system that is not as well known: the proteins.

The proteins act on their own and form the complement system to the immune system. They help all the cells in the immune system communicate with each other. Furthermore, they play an important role in identifying each cell or germ.

Identifying cells and Proteins

All cells (human, bacterial and everything in between) hold some form of genetic material. The genetic material carries the information that tells the cell what to do. This genetic material codes for proteins that become part of the surface of the cell, its membrane. The proteins are called **antigens** in the context of the immune system.



All livings things are made of cells, from one cell to millions of cells – including us and the organisms we refer to as pathogens. In all organisms, each cell holds genetic material in the form of DNA in their nuclei. Combinations of different molecules called **nucleic acids** make up who we are—they encode for every aspect of our bodies. The formation of our organs, bones, muscles and tissues as a fetus and the color of our hair, eyes and skin, and even our own immune system—are all expressions of our unique DNA. Even though we each have our own variations of DNA, which is most noticeably expressed in physical features, each species has a different set of DNA. This is true except for viruses, which only have RNA (one strand of ribo-nucleic acids instead of two). Likewise, there are millions of different bacteria, viruses, and infectious organisms that exist in the world and each one has a different genetic makeup.

DNA holds the information, but how does the body use it?

Each cell builds proteins from the different combinations of amino acids encoded in the DNA. Proteins carry out many functions in each cell in the body and they play a major role in the immune system. At any point, each cell in your body is producing proteins from its DNA. These proteins can stay inside the cell, become a part of the cell's membrane and even go out of the cell.

Proteins are characterized by having complex 3D shapes, but the shapes depend on their composition. Since each protein usually has a unique composition, **proteins can be distinguished by shape** (and by other molecular interactions).

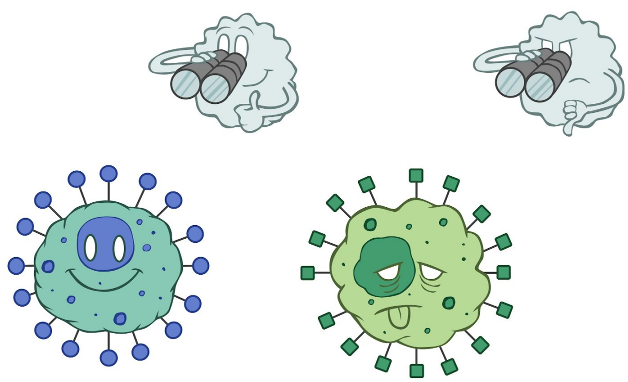
> If a virus infects a healthy human cell, the virus injects its own genetic material into the cell. This causes the cell to make proteins from the genetic material of the virus! Thus, the proteins a cell produces are a pretty good indicator of how the cell is doing.

The type of protein a cell makes depends on two factors:

1) The type of cell making the protein. For example, a brain cell has different functions to a heart cell. Thus, the proteins the brain cell makes will be different from the proteins made in the heart cell.

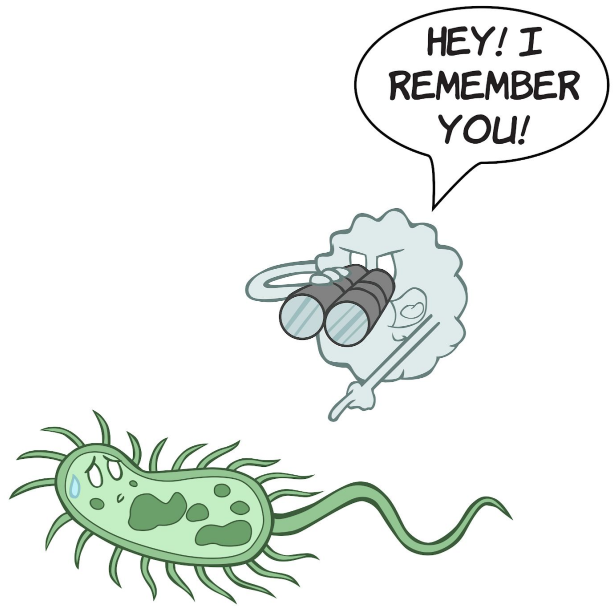
2) The circumstances under which the protein is being made, for example, the proteins a cell makes when it is healthy, is different from when it is lacking essential nutrients or is ready to divide.

Self antigens are proteins made by a cell during its natural life. "Self" means belonging to the cell. The proteins made by an infected cell are called **nonself antigens**. This means the proteins do not belong in a healthy body. The immune system recognizes the nonself proteins and destroys them.



Memory in the Immune System

During an immune response, B and T cells create memory cells. These are copies of the specific B and T cells that responded to a threat. These cells remain in the body, holding information about each threat and how to fight against the threat. This gives our immune system **memory**. So the immune system is able to prepare a quicker and more powerful response if it comes across the same threat again.



Our immune system's capacity for memory allows us to develop **immunities**. When our immune system knows what a germ looks like, it can stop any new infections before we get sick again. That means we are immune to that particular germ.

Our immune system's capacity for memory allows us to gain immunity through vaccines. However, it can also get us in trouble with autoimmune disorders or with allergies.

Vaccines

There are thousands of bacteria and viruses in the world, some of which your body has never seen before. That's why we get vaccines. Vaccines help protect us from these bacteria and viruses. When you go to the doctor to get a vaccine, you are actually injected with a form of whatever virus or bacteria you are trying to prevent! Scientists today have engineered vaccines that are very safe. Some vaccines don't even use the whole virus or bacteria, but simply a part of it. Your B cells pick up the vaccine and begin making antibodies and memory cells against it. The next time your body comes across that virus or bacteria, your B cells will be ready to produce the right antibodies against it.

Ever wonder why it takes days, sometimes weeks to get over a cold? Remember that you produce millions of different B cells. With so many different cells to produce, it's impossible to make a lot of each. Your body only has so much energy and space. Whenever an infectious outsider is introduced, the right B cell has to be weeded out. Not only that, that B cell has to divide and produce antibodies. With the common cold, the body needs a few days to get its B cells in full operation. But with more chronic diseases, like Tuberculosis or Hepatitis, the body benefits from the introduction of a vaccine. That way it will already have many of the necessary B cells and antibodies needed to prevent infection.

Allergies

The Functions of Histamine

On a general level, histamine is a chemical neurotransmitter produced by the body during an allergic reaction, most noticeably causing skin, nose, throat and lung irritation (itchiness, redness, swelling, rash, cough and flem, mucosa) in response to various allergens: insect bites or topical irritants, dust pollen, food allergies. These reactions are part of the inflammatory response, which is an important part of the overall immune response. Other functions: histamine helps regulate physiological function in the gut, helps to regulate sleep, and aids the sexual response.

Let's look at these functions one by one, beginning with how histamine functions as a chemical neurotransmitter.

Histamine as a Neurotransmitter: A neurotransmitter is a chemical that is passed between neurons in the nervous system. When a neuron releases molecules of a chemical neurotransmitter, it passes from what is called the "presynaptic nerve terminal" or the end of the neuron, through the "synapse" or the gap between neurons, and is finally taken up by a "receptor" area on the receiving neuron. That neuron then continues to pass the neurotransmitter, resulting in a reaction. The constant stimulation of neurons causes reactions in the body which are specific to the type of neurotransmitter that is passed.

Histamine is grouped with a class of neurotransmitters called “Small Molecule Neurotransmitter Substances,” alongside Serotonin, Epinephrine (adrenaline) and Dopamine.

Histamine in Allergic Reactions: There is always a small amount of histamine circulating through your body at any given time. When a foreign substance is introduced, such as the toxic chemicals of an insect bite or the oil of poisonous plants like poison ivy, the body releases larger amounts of histamine to the site of infection. In individuals who are allergic to certain types of food like strawberries or foods containing sulfur, the body can release very large quantities of histamine which can result in shock and sometimes death. The body cannot handle large amounts of histamine. As a result, the body will counter-act histamine by producing Epinephrine (adrenaline) which helps to de-activate histamine. Sometimes high levels of adrenaline can result in unwanted anxiety and panic attacks. Medication like Benadryl or other antihistamines help to clear some histamine from the body for relief. This is why, whenever you are sick with a head cold, you want to take medicine that contains antihistamine, to relieve swelling resulting from infection inside the nasal cavity and stimulate fluid secretion.

What is the purpose of histamine in allergic reactions? : The histamine reaction in relation to the immune response (in both allergic reactions and immune reactions) serves two main functions: 1. It causes what is called “vasodilation.” Vasodilation occurs when the muscular walls that surround blood vessels are relaxed, causing the interior of the blood vessel to widen. 2. It induces fluid secretion at the site of infection. Both of these responses are an important part of the inflammatory response. Vasodilation allows white blood cells to move easily to the site of infection. Fluid secretion is important in ridding the body of infectious agents or allergens. It is also known, at a molecular level, that histamine helps to stimulate certain macrophage responses as well as Helper T cell responses, and so it is purported through the latter that histamine also helps induce antibody response.

Histamine in Digestion: Histamine plays a role in gastric secretion by helping to induce the production of acid in the stomach.

Histamine in Sleep: The body regulates the amount of histamine in circulation and maintains a careful balance. This is most important with keeping the body awake and alert. *Antihistamines* are known to cause drowsiness and sleep.

Autoimmune Diseases

Autoimmunity occurs when the immune system attacks healthy cells and tissues in the body. **When this autoimmunity starts to harm the body it is called an autoimmune disease.**

It seems counter-productive for our immune system to attack our own bodies. Yet, scientists think that there is a naturally occurring level of autoimmunity that is going on all the time in humans and other higher animals. Scientists still do not completely understand why the immune system does this, or why only certain individuals are affected while others are not. However, they can conclude that genetics, drugs, viruses, and certain chemicals seem to be associated with autoimmune diseases.

There are over 80 different types of immune disorders. Some of the most common are Lupus Erythematosus, thyroid disorder, Multiple Sclerosis, arthritis, Celiac Disease, and Type I Diabetes, to name a few. Some of these diseases affect only a specific organ or tissue in the body, thus being **localized**. While others can affect the whole body, and are termed **systemic**. Localized diseases attack a specific area of the body, like tissues and joints, the nervous system, the blood, and the pancreas for example. Metabolism, muscular movement, brain function—these are just some of the body's major functions that can be de-regulated by autoimmune disorders. Your whole body is an interconnected system. So, if one organ or individual system is attacked it will affect many other functions in the body.

Studies have found women are more likely to be diagnosed with an autoimmune disease compared to men. Some scientists believe that women have more complex immune systems than men, and so are more susceptible to complications, usually set off by pregnancy.

Type I Diabetes is an autoimmune disease where a rare error occurs and the immune cells attack some special cells in the pancreas. Keep reading to find out more about Type I Diabetes.

TYPE I DIABETES

Type I Diabetes affects approximately 5% to 10% of the general population. It usually begins during childhood. The specific cause for Type I Diabetes has yet to be found. But scientists believe genetics and environmental factors play a role. Like many other autoimmune disorders, if someone has family members that are diabetic, they have a greater chance of developing diabetes than someone who has no family history of diabetes.

Scientists believe environmental factors, like certain chemicals and viral infections, begin or exacerbate Type I Diabetes. Also, there is evidence linking Type I Diabetes to other autoimmune diseases like anemia, thyroid disease, and Addison's disease.

Pathogenesis: what happens inside the body of someone who has Type I Diabetes?

In Type I Diabetes, the immune system becomes *intolerant* of the Islet cells in the pancreas and trigger an immune response against it. The pancreas is a vital organ in the digestive system that secretes enzymes to break down food, and regulates the blood sugar level. The Islet cells in the pancreas secrete **insulin**. It is a hormone that allows cells to use the sugar in food to make energy. In the case of Type I Diabetes, the T cells of the immune system attack, destroy, and activate antibodies against the Islet cells. Thus, preventing the body from producing insulin and regulating its blood sugar level.

It is unusual for the body to mistake healthy cells for infected ones. There are many steps taken to prevent this. T cells are the mediators and regulators of the immune system. They activate the antibody response and stimulate phagocytosis. If they mistakenly recognize healthy body cells as infected, they activate other cells of the body to attack as well. To prevent this, when T cells are maturing in the thymus, they get evaluated before they are released into the body. If they are designed to recognize and attack body cells, then they are automatically destroyed—about **90% of T cells are destroyed in the thymus before traveling to the body!**

If the thymus destroys malfunctioning T cells, then how is Type I Diabetes caused? Keep reading to learn about the major theories of what causes Type I Diabetes.

Possible Causes of Type I Diabetes

Diabetes Type I is not a new disease. There are records of Type I Diabetes existing in ancient Egypt. Today, there are several explanations being considered, including viruses, drugs and chemicals. But there is significant evidence that Type I Diabetes usually results from a combination of both pre-disposed genetics and environmental factors.

Modern Treatments for Type I Diabetes

There is currently no cure for diabetes, but there are a few available treatments, and a lot of options being researched! Right now, there are two popular types of treatment for patients with Type I Diabetes:

1. *Insulin replacement therapy:*

The majority of individuals that live with Type I Diabetes undergo insulin replacement therapy. This means that everyday, many times a day, they must inject a very specific amount of insulin *into their blood streams. This insulin makes up for what their dead insulin-making cells cannot produce. Although many diabetic patients can lead healthy lives with insulin replacement therapy, it is a painstaking method to treat the disease. Despite having to constantly monitor blood sugar levels and administer many shots daily, sometimes this treatment is not effective enough. It is difficult to imitate the delicate balance of the pancreas. If the shot contains too little or too much insulin, or a shot is missed, the patient runs the risk of developing further health complications.*

2. Islet cell transplant:

*Instead of constantly injecting the body with insulin, some doctors are in favor of transplanting new islet cells or even a new pancreas into the diabetic patient. Doing so potentially replaces the insulin-producing islet cells and restores the body's metabolism of glucose. Islet cells are transplanted into the liver, where they are able to produce insulin. Recent studies show that one year after the operation, 58% of Islet cell transplant patients were insulin independent. But there are many problems with this method. Not only is this a costly procedure, it often takes two or more donors for a successful transplant, so there is a long waiting list. Also, the transplanted islet cells can fail to function after a few years. However, the biggest risk is that the transplant can be attacked by the immune system—this is called **rejection**. **Rejection is a risk with all transplants.** Any cells that are transplanted into one person's body from another person's are likely to be attacked by the white blood cells of the immune system. They recognize the cells as foreign, and so will again destroy the islet cells! To counteract rejection, transplant patients must take **immunosuppressant drugs** for the rest of their lives to allow their new islet cells to function. Immunosuppressant drugs usually weaken the whole immune system. This causes the patient to experience fatigue and sickness and is likely to develop other health problems. Sometimes it is better for the diabetic patient to avoid transplants.*

Current treatment methods like islet cell transplants and insulin injection both help the diabetic patient, but they cannot cure the disease. Scientists are now looking to regenerative medicine for the answers!

Regenerative Medicine Treatment

Modern medicine offers a few options to help reduce the symptoms of diabetes but as of now it doesn't offer a cure. So, researchers are looking at a relatively new and promising field of **regenerative medicine**. Instead of replacing cells and organs in sick individuals, the idea of regenerative medicine is to re-grow the body's own natural cells that were destroyed. In patients with Type I Diabetes, scientists are studying how to regenerate the insulin-producing islet cells of the pancreas.

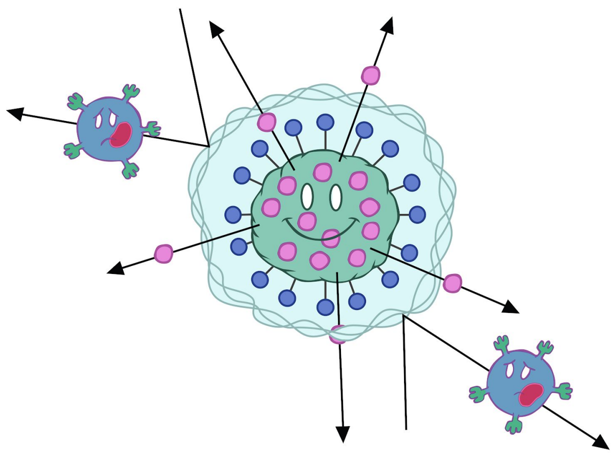
What role do stem cells play?

The key to re-growing cells is to use **stem cells**. Stem cells are special self-renewing cells found in certain areas in the body. These cells have the ability to mature into different cells, organs, tissues, and muscles.

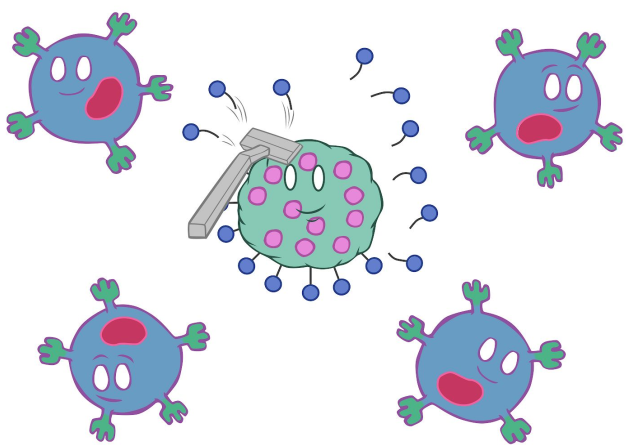
Scientists are experimenting with harvesting and cultivating stem cells that could mature into islet cells. These cells can then be transplanted into patients with Type I Diabetes. For example, some researchers at Stanford University believe that stem cells from the brain can mature into islet cells.

Even with new insulin-producing cells from the individual's own body, an autoimmune reaction against them is still a problem. As defined earlier, in Type I Diabetes the body attacks its own cells. So it's T cells and other white blood cells are still programmed to attack any new cells introduced to the body. Instead of taking damaging immunosuppressant drugs, scientists are developing two methods to resolve this problem.

One is to place the re-grown beta cells into special protective capsules that would not allow the immune system to detect the cells. The capsules would be designed to let insulin out and allow blood sugar in.



Another idea is to “shave” off the proteins on the surface of the insulin-making cells that seem to be activating the autoimmune reaction. Since cells use the proteins on their surfaces to read each other and take specific actions from these signals, the proteins on beta cells could be responsible for telling T cells to attack the insulin-producing cells. Getting rid of some of these proteins might prevent the immune system from attacking.



Hopefully, scientists will soon be able to create insulin-producing cells from stem cells as well as prevent an autoimmune reaction and cure people with Type I Diabetes.

TYPE II DIABETES

It is estimated that over 200 million people in the world today are living with Type II Diabetes. This number is significantly more than those living with Type I Diabetes. Although Type II Diabetes has some of the similar effects of Type I, its cause is different from Type I Diabetes. **Type II is not an autoimmune disorder nor is it connected to autoimmunity.** In Type II Diabetes the body also can't use insulin properly. Instead of being unable to produce it, **the body seems to produce too much**.

Diabetes Type II is not well understood yet but doctors agree that a few things seem to be associated with it like **hyperglycemia** (too much sugar in the blood) and **insulin resistance**. The latter, insulin resistance, is when cells in certain tissues, like the muscle, liver and fat cells, stop responding to insulin in the body. This can result in both insulin and sugar accumulating in the blood! Too much insulin and glucose in the blood can become toxic. Also, if the cells don't take up enough sugar either, the cells starve. These problems over time can affect the health of whole organs and leave the individual very weakened.

Studies indicate Type II Diabetes is linked to genetics, environmental factors, diet and lifestyle, and is specifically linked to obesity.

Type II Diabetes develops over time, and seems to affect older adults, the overweight, and some ethnic groups. Lately, there have been more and more cases of Type II Diabetes affecting children and even individuals who are not overweight. **However, doctors agree that this type of diabetes can be controlled and even prevented through diet, exercise, and regular medical check ups.**

Metabolism and the Immune System

Life forms can be made up of only one cell or millions of cells. Millions of years ago, life consisted mostly of one-celled organisms. Yet, over time, a variety of bigger and more complex organisms emerged.

Single-celled organisms, like bacteria, are efficient at surviving in very specific and harsh environments! For example, some bacteria are able to live on the ocean floor where there is no sunlight, while others live in hot springs. More complex organisms need more energy but are also more able to move and interact with their environment. This helps them seek food and comfort, use more specialized ways of protecting themselves or muscles and legs that allow them to move greater distances with greater control.

Life has evolved over millions of years. Life exists as a myriad of shapes and forms, from one-celled organisms like bacteria to organisms with millions and millions of cells, like human beings! But in every size, shape and form, **life is always in a constant balancing act of getting food for energy and protecting ourselves from things that might disrupt and infect our bodies.** These basic needs give rise to the most fundamental processes in our bodies: metabolism and the immune system!

Metabolism

All organisms, regardless of their size, and all the cells that compose them, need energy to survive. **Metabolism** is the process through which a life form gets energy from its environment and uses it to live. Metabolism includes eating food, breaking it down into nutrients, getting the nutrients to each cell of the body and each cell's processes that utilize this food energy.

IMMUNE SYSTEM

The immune system is not a simple organ with a simple function. It is a group of cells and tissues that work together to protect the body. The immune system carries out the challenging task of identifying what belongs to the body (the self) from those that may be harmful- like old, dead cells or **outsider** particles like some kinds of bacteria or viruses. Our immune system has to be intelligent to deal with the magnificent variety of unknowns in the world.

Metabolism and the immune system share a common purpose, somehow they must swallow other particles, one for energy, one to stop a harmful invader. Keep reading to discover the role of the swallowing cells in both!

SWALLOWING CELLS: THE BASIC UNIT

When life first began, all organisms were single-celled. These cells could get all their energy from the ocean or the sun. They absorbed and digested what they could, individually. Over time, these small single-celled organisms evolved into bigger cells. These bigger cells had the ability to swallow other smaller cells and digest them for energy. Hence becoming the **swallowing cells**. These cells were able to get energy a lot faster! These swallowing cells became central to the development of more complex digestion and immune systems we see in organisms today.

CELL COOPERATION AND SPECIALIZATION

Millions of years ago, cells started to be able to work together. This cooperation allowed the cells that make up these tiny animals to start specializing, and carrying out different roles. Some cells, on the outside of the animal become tougher to protect the animal, like a sort of skin. Some swallowing cells became really good at absorbing food and took over eating. In small animals, this works well, as all the cells were close to the eating cells, so they can easily share energy with their neighboring cells.

Cell cooperation involves cells being able to communicate with each other. This communication is at the basis of almost all processes in your body! For example, your immune cells use chemicals to work together, and your neurons and muscle cells send electrical signals from one to another.

Some swallowing cells became good at moving around and sniffing out harmful cells or particles. This is the beginning of a simple **immune system**!

Even in modern animals, the ancient ability to swallow certain cells and small debris has been retained by some special cells. So, in addition to digesting food, swallowing cells can destroy things that may be harmful to an organism, such as some kinds of bacteria, viruses, or old dead cells. So what was once a form of nutrition became a form of protection, too!

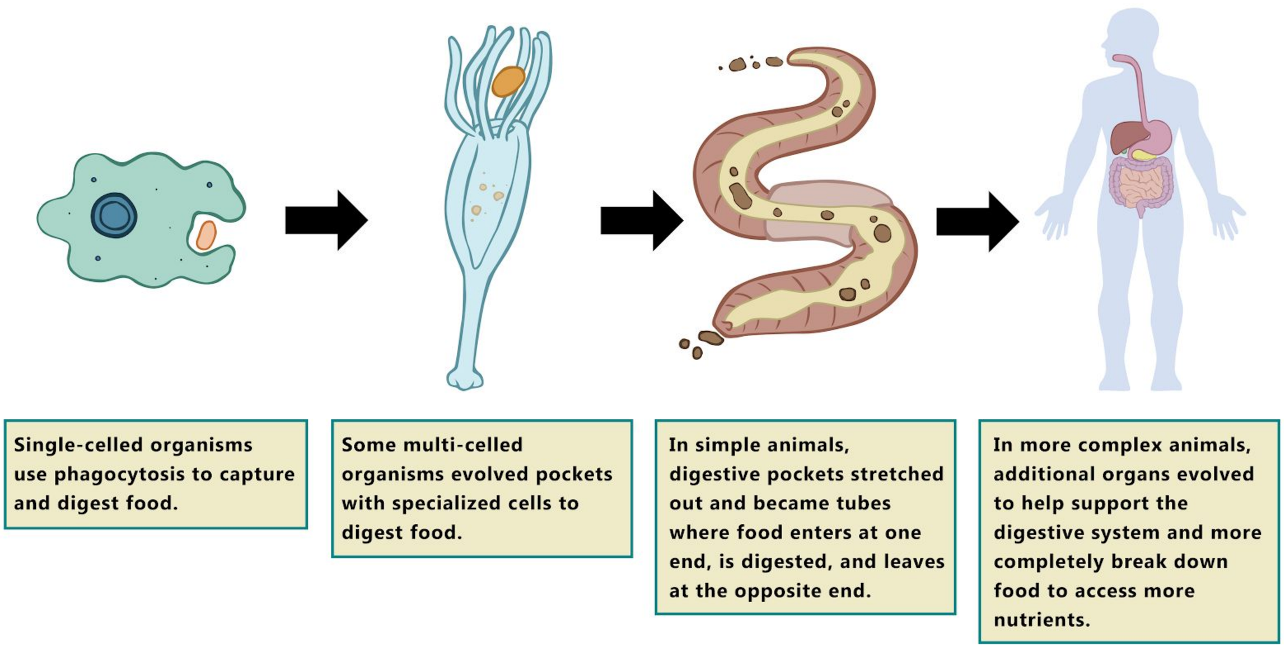
These swallowing cells are found in the immune system of human beings, too! They are called **macrophages** and **B cells**.

EVOLUTION OF METABOLISM

Over time more complex organisms with more and more cells appeared. Since these organisms had more cells they needed specialized ways to get more energy and spread the energy to other cells.

Some organisms evolved with special pockets to break down the food in one area. Others evolved with a passageway to make the distribution of energy easier. Eventually, this passage evolved into a complex system with special organs similar to the digestive system we see today.

Look at the diagram below to learn more about the evolution of metabolism.



The digestive tube, being very good at absorbing broken down food, is also a big point of entry for outsiders! So, lots of immune cells are found very close to digestive tubes.

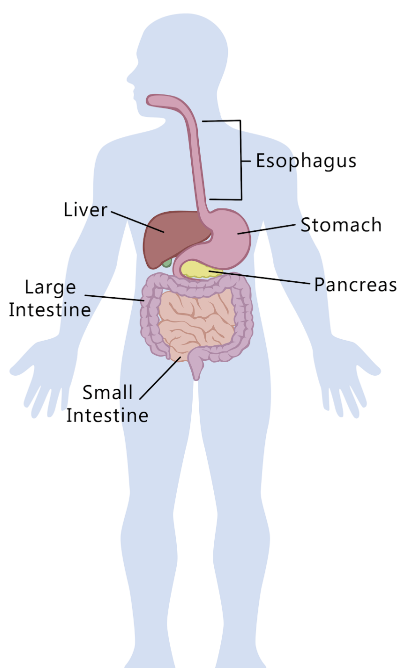
As organisms became more complex and **specialized,** with many different types of cells, the harder the immune system's job became. Think of the human body, how many different cells and particles can you think of that belong to your body? Skin cells, hair cells, eye cells, bone cells and even the calcium in your teeth! So, the **immune system** needed to become more complex! New types of cells, like B cells and T cells, and tissues, like the lymphatic system, evolved to work together and be more efficient and specific. Once the immune system has discovered a particle or dead cell in your body, it calls a team of special swallowing cells that set to work breaking it down, like food!

Metabolism, Sugar, and Diabetes

Your body needs a great deal of energy to complete your day-to-day activities. For example, you need energy to do homework, play soccer, or even read a book! For any of these activities, even when you're just sleeping, all of your cells need energy to continue being healthy and to function correctly.

METABOLISM

Your body is constantly busy getting energy. The cells store the food energy and then spend it, maintaining themselves and doing fun things! **All the processes in your body that involve getting or spending energy are known as your metabolism**. A high metabolism occurs when your body is both getting a lot of energy and using a lot of energy. Whereas a low metabolism occurs when the body neither has nor is able to use a lot of energy.



So where does your body get all this energy from? Eating a healthy diet helps provide your body with a great deal of its energy. The food you eat is broken-down into smaller parts like sugars, fats and proteins and other nutrients in a process called **digestion**. As the food travels through the digestive tract it gets broken-down into smaller pieces. In the small intestine the nutrients such as carbohydrates, proteins, and fats are absorbed by the blood. The blood carries the nutrients all over the body so that cells can use them.

A special chemical, called insulin, helps cells absorb sugar from the blood stream. Sugar is one of the main sources of energy for the body so without insulin, most of the cells in your body would not get ANY energy!

Our body has a carefully regulated mechanism to deal with the amount of sugar in our body. Too much and too little can be harmful! Our body constantly decides how much sugar each cell needs, how much sugar to have in our bloodstream for quick use and how much sugar to store for later.

However, there are certain instances where the regulatory mechanism malfunctions. An example of such an instance is the case of **Diabetes.**

In a person diagnosed with **Diabetes, the body does not produce enough insulin or the body cells stop responding to insulin.** In both these instances the cells can not absorb sugars and the sugar level in the blood starts to rise. As a result, the body gets tired, dehydrated and blood pressure lowers. Many other health problems can occur as well.

SO IF IT IS SUGAR OUR BODY NEEDS TO GET ENERGY, WHY CAN'T I JUST EAT TONS OF SUGAR?

If you gave a human a lot of sugar their metabolism level will not be sustained and would drop quickly! Despite the human body needing sugar to gain energy, too much sugar can actually overwhelm the body. The body has a specific and delicate mechanism that controls the use and storage of its sugars. Too much sugar stresses out this mechanism. As a result causing the regulation mechanism to malfunction.

Getting too much or too little sugar can both be significant problems. But getting too much sugar is a more common problem seen in both adults and children.

THERE ARE “GOOD” SUGARS AND “BAD” SUGARS TO LOOK OUT FOR.

The Good Sugars

Natural sugars are examples of “good sugars” your body can easily store and use. They even have other health benefits such as boosting your immune system, strengthening the power of your pancreas and ridding your body of toxins that may make you feel sluggish and unhealthy. These kinds of “healthy sugars” are found in some fruits like apples, pears and blueberries, vegetables and legumes like yams and beans, nuts and foods containing whole grains.

The Bad Sugars

While there are many “good sugars” out there, you have to watch out for the sugars that aren't so good for you! The main sugar to watch out for is called “**refined sugar**”. It is also known as “white sugar” and most people use it everyday! It is present not only in obvious foods like candy and soda, but also in other foods like breads, lunch meats, ketchup, canned vegetables and fruits!

WHY ARE THE BAD SUGARS SO BAD?

When a bar of candy is digested, white sugar is broken down by the body into very simple sugars in an unusually quick manner. This causes a person's sugar levels in their blood to rise drastically (hyperglycemia), and causes an equally quick response of big insulin-production from the pancreas. This uncontrolled production of insulin can lead to removing too much sugar from the blood! In this situation, the body gives order to release sugar that is in storage in the liver to replenish the sugar in the bloodstream. If these imbalances happen a lot, they can really wear out our sugar control mechanism! This can lead to health problems like diabetes and hypoglycemia, as well as a lot of trauma to the pancreas!

People with diabetes are prone to experience the sharp highs and lows described above, since the lack of insulin leaves the body in a state of stress, usually with too much sugar in their bloodstream. So, when a diabetic eats, their body will immediately have a harder time dealing with the added sugars.

The balance of sugar in your body is directly related to the kinds of foods you eat. A healthy, balanced diet lets your body have an easy time digesting and using its energy.