**The Immune System**

**Introduction**

**The immune system** is a collaboration of multiple cells and proteins, which each has a specific role in identifying or attacking foreign substances. These cells and proteins work together to prevent infection in the body. The immune cells and proteins do not form a single organ or tissue. Still, it is a system that is distributed throughout the body to allow for prompt responses to a foreign substance. The immune cells can travel through the bloodstream and the lymphatic vessels, which are similar to blood vessels but carry lymph rather than blood. The immune system has one primary function: to defend your body from infections to keep you alive and healthy. There are many ways your body detects pathogens and many ways to fight them off.

The idea of immunity started with **Edward Jenner** back in 1796 when he discovered the vaccination for smallpox. With the widespread epidemic of smallpox in Europe, Dr. Jenner tested a long-lasting theory that milkmaids were unable to contract the smallpox disease due to the constant exposure to cowpox. Dr. Jenner tested this theory by taking samples from a milkmaid’s hands and injecting it into a young boy, who did not get smallpox. After testing his theory on many family members and friends, he published his findings in 1788 for what we now know as vaccinations.

**Components of the Immune System**

 The cells of the immune system are used to distinguish between healthy and unhealthy cells. Unhealthy cells are detected by cues recognized by the immune system, which are called danger-associated molecular patterns (DAMPs). These specific patterns are perceived as harmful, and the immune system starts working. Cells can be unhealthy from wounds or infections, or they can be damaged from non-infectious agents such as the sun or cancer. Infected cells are recognized by a set of signals called pathogen-associated molecular patterns (PAMPs). After the signal from the unhealthy or infected cell is recognized by the immune system, the cells begin to dispose of the harmful agent. It is essential to know the functions of each element of the immune system, for each has a significant role in the immune system.

 The skin is typically the first line of defense for most microorganisms. Many immune cells can be found in the layers of the skin and produce antibacterial properties to keep unwanted microorganisms out of the body. Bone marrow produces **stem cells** that then develop into multiple types of cells, such as those of the innate and adaptive immune system. The myeloid progenitor stem cell produces the cells of the innate immune system- **macrophages, dendritic cells, neutrophils, basophils, eosinophils, and mast cells.** The lymphoid progenitor stem cell produces the cells of the adaptive immune system- **T cells, B cells,** and **natural killer cells.** Immune cells travel consistently throughout the bloodstream to monitor the threat of pathogens and other infections to the body. White blood cells (immune cells) can be an indicator of a problem if the cell count is too high or too low. The **lymphatic system** is important for the communication between body tissues and the blood stream. The lymphatic system contains many vessels and tissues that contain lymph, and lymphoid organs- such as lymph nodes, thymus, and spleen. Mucosal tissues are common places pathogens can enter the body, so there are necessary immune cells located in mucosal tissues to detect pathogens.

Key components of the Immune System:

* Bone marrow: Where immune cells are produced as stem cells.
* Thymus: This organ is in the chest area where immature T cells develop into mature T cells.
* Lymphocytes: B cells, T cells, and natural killer cells.
* B cells: Lymphocytes, which are produced in the bone marrow, differentiate into plasma cells and produce immunoglobulins.
* Immunoglobulin: Extremely specialized antibodies
* Cytotoxic T cells: Responsible for killing infected cells.
* Helper T cells: Specialized to provide necessary information cytotoxic T cells and B cells to do their job.
* Dendritic Cells: Important for the presentation of an antigen to cells of the immune system.

**Location**

While it is essential to know how the immune system functions daily to keep the body healthy, it is also necessary to understand where the immune cells are active.

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* Immune cells travel consistently throughout the bloodstream to monitor the threat of pathogens and other threats to the body. White blood cells (immune cells) can be an indicator of a problem if the cell count is too high or too low.
* The lymphatic system is vital for the communication between body tissues and the bloodstream. The lymphatic system contains many vessels and tissues that carry lymph and lymphoid organs- such as lymph nodes, thymus, and spleen.
* Mucosal tissues are familiar places pathogens can enter the body, so there are necessary immune cells located in mucosal tissues to detect pathogens.

**Innate Immunity**

**Stem Cell**: The primary immune cell that can differentiate into all cells that make up the immune system.

**Mucosal Membranes:** lining of the body’s cavities such as eyes, ears, mouth and intestines.

**Pathogen:** Microorganism that can cause disease or harm.

**Phagocytes:** Cell that is able to engulf or destroys unfamiliar particles.

**Apoptosis:** programmed cell death**.**

**Mast cell:** Found in connective tissue.

**KEY TERMS**

 The most basic form of immunity is the innate immune system which is naturally present form of immunity that is not due to previous exposure to a **pathogen** (either by infection or vaccination). Everyone is born with a natural immune system that is built by evolutionary processes that allow cells inside your body to recognize foreign invaders. These cells then take the necessary steps to get rid of an infection or disease, which typically causes immediate inflammatory responses and results in a neutralization of pathogens. The innate immune system includes macrophages, dendritic cells, NK cells, and granulocytes. This form of immunity is prompt and persistent- even infants have active innate immunity.

The first line of defense for innate immunity includes the skin and **mucosal membranes**. These barriers are the first to sense a pathogen or harm to the body and call on the internal innate immune system. The innate immune system takes immediate responses to get rid of a pathogen; this includes fever, chemical signals, and inflammation. **Phagocytes** are typically the first to get to a pathogen There are a couple of different types of phagocytes in the innate immune system.

**Neutrophils** are the most common phagocyte of white blood cells. The role of neutrophils is to respond to the site of infection to engulf pathogens. They are present in the bloodstream and have short life spans because they self-destruct after consuming the pathogens. Dead neutrophils make up the main components of puss.

**Macrophages** have cytoplasmic extensions that allow it to capture a pathogen and engulf it. The macrophage releases the consumed pathogen and will continue this cycle to get rid of foreign pathogens in the body. Macrophages are also essential to produce cytokines, which is vital for adaptive immunity. Monocytes are a phagocytic cell that turns into a macrophage once in tissue.

**Natural killer (NK) cells** are present in blood and lymph to get rid of unwanted pathogens. They can identify infected and cancerous cells due to these cells lacking the protein MHC 1, which is present in healthy cells. Unlike neutrophils and macrophages, NK cells do not engulf pathogens; they inject an enzyme into the contaminated cell to trigger **apoptosis**. NK cells can kill your natural cells if they have been contaminated with an infection or become cancerous.

The first line of defense barriers is responsible for the initial inflammatory response for a wound or pathogen. This inflammatory response triggers **mast cells** to release chemicals, such as histamine, to alert the innate immune cells. Neutrophils are first released from the bone marrow into the bloodstream to reach the site of infection and are the first to reach the pathogens. Since they are the first at the infection site and self-destruct, they run out rather quickly. Macrophages soon replace the neutrophils and start to engulf the pathogens. For minor injuries and illnesses, neutrophils and macrophages can get rid of the pathogens.

For more significant injuries and illnesses, pathogens quickly start to outnumber the phagocytes and require help. This results in the hypothalamus to increase body temperature, which results in the metabolic rate of healthy cells to increase to fight off the infection.

**Adaptive Immunity**

 After the innate immune system recognizes a foreign pathogen that cannot be overcome by phagocytes, the adaptive immune system starts to kick in. The adaptive immune system takes longer to activate, but it keeps a "memory" of these pathogens. The memory of the adaptive immune system allows the immune system to fight off a known infection more efficiently than the first exposure. The adaptive immune system includes B cells, T cells, and antibodies. The primary function of the adaptive immune system is to recognize antigens, fight them off, and maintain immunological memory. The ability to adapt to new infections or diseases is a significant advantage of the adaptive immune system. There are two vital components of adaptive immunity: humoral immunity and cellular defenses. Humoral immunity allows your body to build and have protection by facing pathogens either randomly or on purpose. Cellular defense immune response comes into play when neither the innate immune system nor the adaptive immune system can fight off an antigen.

B cells are specialized lymphocytes that produce antibodies. When they confront a foreign substance, B cells develop into plasma cells that then produce. There are five major types of antibodies: IgG, IgA, IgM, IgD, and IgE. Each of these immunoglobulin classes has particular functions.

* IgG: Formed in large quantities, able to travel to bloodstream and tissues, and can cross the placenta to give antibodies from mother to child.
* IgA: Produced near mucous membranes found in bodily secretions to protect the respiratory and gastrointestinal tracts.
* IgM: First to be formed for infection and essential for the first few days of disease.
* IgD: Regulates B cell function.
* IgE: Responsible for allergic reactions.

B cells are a significant component of the adaptive immune system and learn how to differentiate between antigens and healthy bacteria in the body. B cells have hundreds of receptors, and each receptor is specific for one antigen. Once a B cell encounters a pathogen that matches its receptor, it replicates to acquire more receptors to fight off the infection; these are called effector cells. Effector cells are armed with a robust endoplasmic reticulum to produce the needed antibodies to attack the antigen.

**Cytokine**: Signaling protein.

**Major Histocompatibility complex**: a protein that displays a cell’s peptide fragments.

**Complement system**: Enhances inflammation, attacks the pathogen's membrane, and ultimately kills the pathogen.

**Opsonization:** Marking a cell for death by phagocytes.

The cells that are replicated for the specific infection but are not used for the current infection, then turn into memory cells. These memory cells allow the body to be prepared to fight off the specific antigen more effectively if it ever occurs again. If an antigen is presented again, the cells are prepared to fight off the infection faster and more reliable than the first time around.

 Antibodies are used in multiple different ways to prevent infections. The primary function of B cells is to produce antibodies, which attach to the antigen and call for **opsonization.** Another ability of antibodies is they can connect to antigens and block all their binding sites to prevent infection, and this is calledneutralization. All these antibodies result in a signal to the innate immune system, which allows phagocytes to dispose of the antigen. Antibodies attached to some infected cells can activate the **complement system**. Bacteria that are coated with antibodies are easier for neutrophils to consume rather than bacteria without antibody coating. These procedures by antibodies prevent invasive bacteria from effectively causing infections.

All nucleated blood cells have a **major histocompatibility complex** (MHC) class 1 protein on their surface, but professional antigen-presenting cells contain macrophages, dendritic cells, and B cells which contain the protein MHC 2. T cells contain two different groups: helper T cells and cytotoxic T cells.

**Helper T cells** cannot kill antigens, but they help throughout the process by alarming other cells that there is an antigen present, which is signaled by cytokines. Helper T cells are a lot like B cells, where they have specific receptors for specific antigens and replicate to make effector and memory cells. On the other hand, cytotoxic T cells are the ones that kill antigens. Cytotoxic T cells are signaled by the cytokines produced by helper T cells.

**Cytotoxic T cells** contain receptors that are specific for defined antigens, like B cells and antibodies. Once the cytotoxic T cell finds a cell with the matching receptor, it attaches to the infected cell and releases enzymes to trigger apoptosis. These cells that are killed are displaying their infection on their MHC 1 to alert the cytotoxic T cells to kill them. The cytotoxic T cells can detach from the infected cell and continue to find antigens.

 **Regulatory T cells** help the body control the regulation of recognizing healthy cells and infected cells. These cells are important to help regulate the cells that are needed during an infection. For example, if neutrophils and macrophages can get rid of an infection, B cells and T cells are not required.

**Cytokines** are useful in the immune system due to their ability to help with the development, regulation, and differentiation of the cells. However, the dysregulation of cytokines can lead to health problems such as autoimmune diseases. Not all autoimmune diseases are caused by problems in the immune system, but there are several that are caused by the cells of the immune system attacking the normal, healthy cells in the body. Type 1 diabetes is a common form of an autoimmune disease in which the cells in the immune system attack healthy cells in the pancreas. The pancreas is responsible for producing insulin, which is essential for regulating blood sugar levels. While people with Type 1 diabetes lack the necessary insulin, people who have Celiac's disease experience a problem when gluten is in the small intestine. The cells of the immune system attack the lining of the gastrointestinal tract, which causes inflammation and can lead to more severe problems. These are two examples of how this dysregulation of the immune system can lead to autoimmune diseases and how it affects the health of the human.

Adaptive immunity is the basis of vaccinations. Vaccinations are used to expose an individual's immune system to a specific antigen, which allows the adaptive immune system to build the necessary memory cells to fight off the infection if it ever is presented to the body again. Most vaccinations contain dead cells from a virus, but some contain minimal amounts of viable cells. Most forms of infections do not change much over time, so one or two encounters with the vaccination typically are enough to maintain your immunity, such as measles or smallpox. Other viruses, such as the flu, change drastically year to year, which is why most people recommend getting the flu shot once each year.

**Immunodeficiencies**

 Immunodeficiency is the inability of the immune system to protect the body from infection due to the lack of a component or substance necessary for proper function. Immunodeficiencies are as varied as the cells and functions within the immune system. Some immunodeficiencies affect one element of the system, while others affect multiple aspects. There are components of the immune system that can be compensated for if there is an immunodeficiency present. Still, in some cases, a person will have difficulties protecting itself from infections due to the immune system lacking a necessary component that cannot be replaced by another accessible cell.

**Support the Immune System**

 Now that the basics and location of the immune system have been discussed, it is crucial to know how to take preventative actions to help protect the immune system. The immune system's role is to protect the body from infections and diseases, and it typically does a good job fighting off pathogens, but there are times it fails. So, what can someone do to improve the functions of the immune system?

 The entire immune system requires a balance between many different areas of the body, so the answer isn't as simple as it may seem. Since there are many aspects of the entire system, it is not a single act that can prevent someone from getting sick. Instead, several suggestions are supported by many scientists and doctors. Essential information everyone hears from a doctor or healthcare provider regularly might include:

* Consume proper nutrients
* Don't smoke
* Wash your hands thoroughly and regularly
* Exercise regularly
* Drink alcohol in moderation
* Minimize stress
* Get adequate sleep

While the above steps seem to be basic knowledge, many do not follow through with the suggestions that could help prevent the cause and spread of many diseases and infections. For example, the Center for Disease Control and Prevention states the proper way to wash hands is to use warm water and bacterial soap. While cleaning, it is vital to scrub all areas of the hands (including between fingers and under nails) for at least 20 seconds. Twelve researchers observed roughly 3,700 people in a public restroom, and the results exhibit only 5% of the population washed their hands properly. Roughly a third of people washed their hands without soap, and approximately 10% skipped out on washing their hands at all. Overall, the spread of infections and diseases is reduced by proper handwashing, and the immune system would be exposed to lower amounts of pathogens, which would lead to less risk of infection.

Not only is it important to consume proper nutrients for overall health, but the immune system also relies on nutrients to develop its necessary cells to function to its highest ability. Nutrients are a vital part of the development and functionality of the immune system cells. When the cells of the immune system are unable to develop and function correctly, the human body would be susceptible to infection, making it vital to consume nutritional foods regularly.

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