

Summary: The Immune System

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1 Categorization of immunities

The **immune system** prevents humans from constantly falling ill as a result of exposure to **pathogens**—bacteria, fungi, viruses, etc. . . — in our environment. More specifically, an *inherent* or **innate immunity** exists in all animals that are active even before infection takes place.

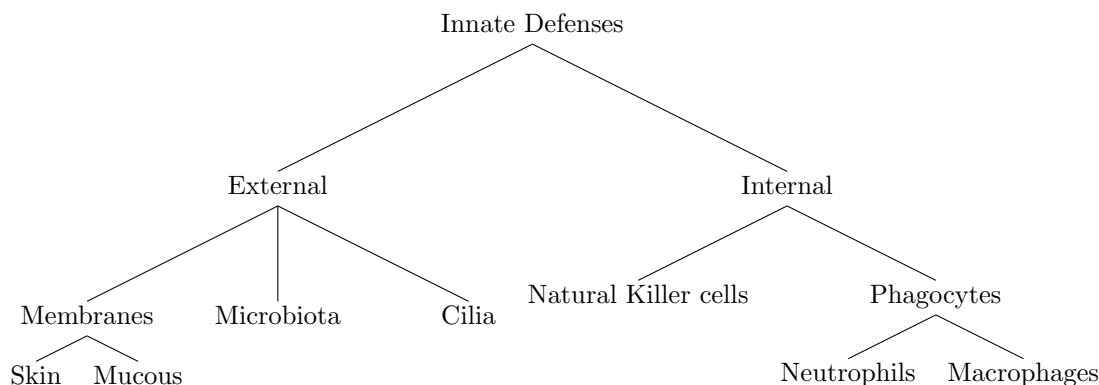
In the case of the invertebrate, innate immunity is the only mode of infection deterrent available to the host. Yet, the innate immunities that invertebrates possess are often effective in combating infection. For example, externally, an invertebrate has an exoskeleton, which keeps out bacteria and viruses through a simple physical barrier. Internally, antimicrobial molecules in conjunction with chemically inhospitable conditions lower the chance of infection. Furthermore, generalized immune cells exist within the organism that are capable of digesting foreign substances (i.e., pathogens that have already entered the body).

In contrast to invertebrates, vertebrates have both *innate* and **adaptive immune** systems. Some innate immune systems possessed by humans include:

- Skin and mucous membranes
- Microbiota on the skin and mucous membranes
- Cilia placed throughout airways
- **Natural killer cells**: cells that recognize cancerous or infected cells and release chemicals that result in their death
- **Phagocytes**
- **Defensive proteins** (e.g., interferons which interfere with viral infections)
- **Complement system**: a group of different proteins that act in conjunction with other defense mechanisms

Within the phagocyte family of innate immunities, there exist two general classifications: **neutrophils** and **macrophages**. The former of the two classifications describes the most common type of white blood cell which enters tissues at the site of infection and circulate in the blood. The latter, the macrophage “big eater” refers to a class of large phagocytes that “float” within the interstitial fluid, ingesting any viruses or bacteria that they come across. Each of these phagocytes shares a surface receptor that binds to foreign molecules found in/on a large range of pathogens (e.g., double- stranded RNA, flagellin).

As such, with consideration to each of the aforementioned types of innate defenses, a categorization tree could be composed as such:



2 The inflammatory response and disinfection

Whenever a tissue is damaged, an **inflammatory response** is evoked with the effect of disinfecting and cleaning injured tissue. Take, for example, the penetration of the skin by a splinter, allowing for the potential for a bacterial infection. In this situation, the following will occur:

1. Macrophage cells are activated by the intruding bacterial cell. These cells will then produce signaling molecules that increase blood flow in the affected region, allowing for **mast cells**—white blood cells originating from connective tissues—to be brought to the scene of injury.
2. Mast cells at the site of infection release **histamine** ($C_5H_9N_3$), causing surrounding capillaries to become “leaky.” After dilating, plasma from the “leaky” capillaries is brought, alongside platelets to form clots along the affected tissue.
3. Neutrophils engulf bacteria, alongside any non-functional body tissues

Usually, inflammation is restricted only to the region in which tissues were damaged. But, in the circumstance where inflammation becomes systemic, can harm the host organism. Such a response usually occurs when microorganisms enter the bloodstream, releasing toxins throughout the body.

3 Adaptive immunity

In contrast to the more general innate immune mechanisms that have been defined thus far, **adaptive immunity** or *acquired immunity* describes an immune response that is highly specialized in its target pathogen, and is activated only *after* exposure to a pathogen. Generally, an adaptive immune response is triggered by a pathogen, but adaptive responses are not limited **only** pathogens. As such, when a molecule triggers an adaptive immune response, it is referred to as an **antigen**. Keeping in mind this naming scheme, we can refer to a countering protein originating from blood plasma as an “**antibody**” (antigen = antibody-generating). Due to the specialized nature of adaptive immune responses, antibodies are only effective with consideration to the antigen for which they were produced.

Though exposure to antigens is generally the principal mechanism by which antibodies are produced, antibodies can be obtained for a specific pathogen by inducing an adaptive immune response through, for example, vaccination. Both natural and artificial adaptive immune responses, resulting in the production of antibodies for a desired antigen are considered forms of **active immunity**, as they require an individual’s immune system to produce antibodies on its own behalf. **Passive immunity**, on the other hand, is obtained when premade antibodies are given to an organism (e.g., through the placenta or breast milk).

The name **lymphocyte** is given to a white blood cell responsible for this type of immunity, adaptive immunity—be it artificially or naturally induced adaptive immunity.

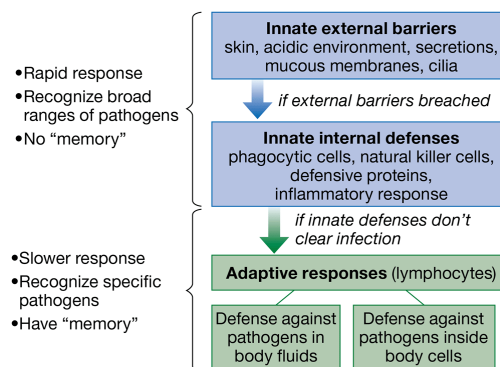


Figure 1: Various types of immune responses

4 The lymphatic system

In both the case of innate and adaptive immunity, the **lymphatic system** serves as an instrumental component to the survival of the organism in question. More specifically, the lymphatic system serves as a “filter” for infectious material, and, as such, has two main functions:

1. fighting infection
2. returning tissue fluid to the circulatory system

The lymphatic system is composed of various **lymph nodes**—masses of lymphocytes and macrophages—and **lymphatic vessels** which contain **lymph**. The latter of these structures, the lymphatic vessel, serves to return fluid to the blood after filtration—specifically, to the circulatory system through vessels that fuse with veins in the chest. The former, on the other hand—the lymph node—aids in the circulation of lymph, which carries various toxins picked up from infection sites in the body. Once lymph has circulated to each of the lymph organs, macrophages are able to ingest the unwanted material as part of the body’s immune response.

4.1 Types of lymphocytes

As was previously mentioned, **lymphocyte** are responsible for adaptive immunity. However, even within the disambiguation, “lymphocyte”, there exists two specialized kinds of defensive cells: B cells and T cells. However, each of these kinds of cells are derived from the general classification, “lymphocyte”, and are differentiated from immature stem cells inside their respective housings—the bone marrow for B cells, and the thymus for the T cell.

Each of these cells serve different purposes, and are specialized for specific kinds of infections. More specifically, the T cell is responsible for what is termed the “cell-mediated immune response”—action against infected cells. B cells, on the other hand, are responsible for the “humoral immune response” —action against free-floating antigens.

Generally, the humoral and cell-mediated immune responses can be described in terms of the pathogen or antigen that they target. In other words, we can define the humoral and cell-mediated responses as such:

- **Humoral immune response:** targets bacteria and viruses in the body fluids. Results in the secretion of free-floating antibodies into the lymph and blood
- **Cell-Mediated immune response:** defends against infections inside body cells. Results in the destruction of body cells infected with bacteria or viruses.

As has been recognized thus far, the general term “lymphocyte” can be used to refer to a T cell or a B cell. However, the disambiguation “T cell” in and of itself can be further divided into more specific categories. For example, the defensive T cell functions directly in the humoral immune response by ingesting infected body cells. Other T cells might simply promote phagocytosis, rather than defensive T processes.

4.2 Structure of a lymphocyte

In the process of differentiation, protein molecules are attached to the surface of a lymphocyte. These proteins are **antigen receptors**, which allow a lymphocyte to bind to a specific type of antigen. Usually, antibodies released as a result of a lymphocyte’s actions will bind on to the **epitope** of the antigen at the lymphocyte’s **antigen-binding site**, which has a shape complementary to that of the epitope.

Keeping in mind that antigen receptors are attached to B and T cells before contact is ever made with the target antigen, a large variety of lymphocytes exist in most humans.

Once the structure of a lymphocyte has developed, resulting in differentiation, a lymphocyte must be expelled to the bloodstream and to the spleen, lymph nodes, and the lymphatic system.

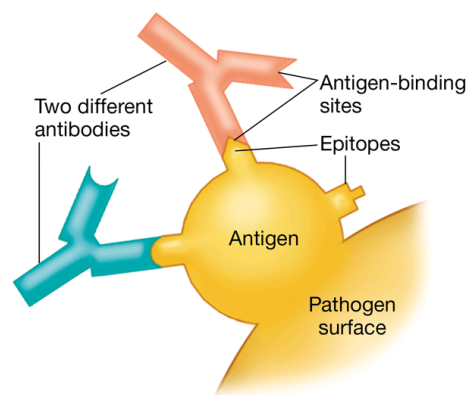


Figure 2: Antibodies binding on to an epitope.

