Summary: The Immune System

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1 Categorization of immunities

The **immune system** prevents hummans 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.

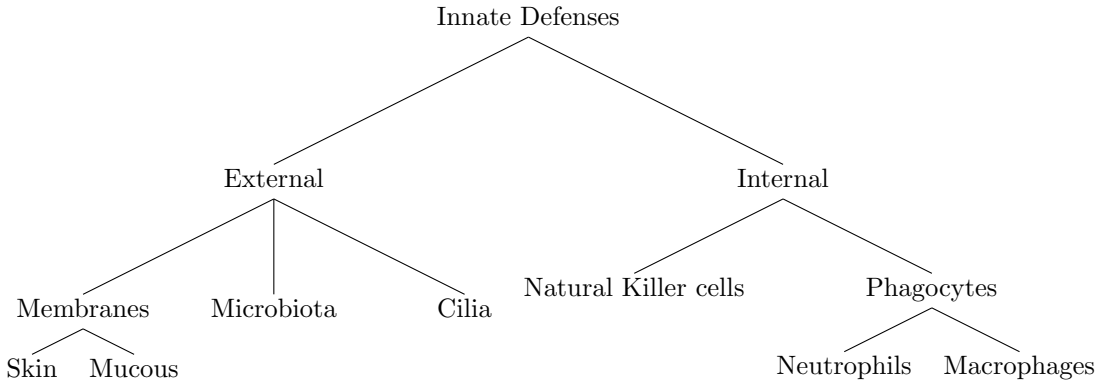
In the case of the invertebrate, innate immunity is the only mode of infection deterrent available to the host. Yet, the innate immunities that invertebrates posess are often effective in comabing infection. For example, externally, an invertebrate has an exoskeleton, which keeps out bacteria and viruses through a simple physical barrier. Internally, antimicrobial molecules in conjunction with chemically unhospitable 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 posessed by humans include:

- Skin and mucous membranes
- Microbiota on the skin and mucous membranes
- Cilia placed throughout airways
- **Natural killer cells**: cells that recognize canerous 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.

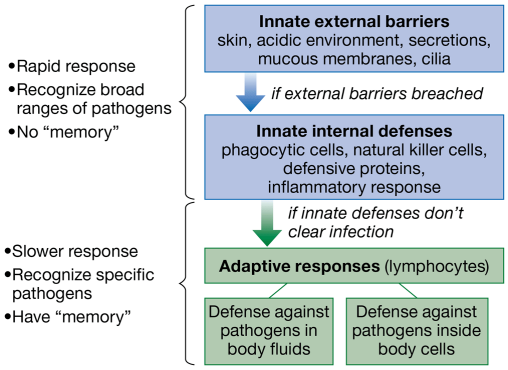


Figure 1: Various types of immune responses

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 immmunity**, 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.

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 lympatic 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.

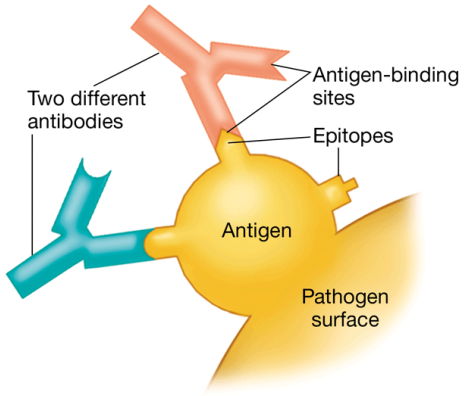


Figure 2: Antibodies binding on to an epitope.

4.3 Clonal selection as a result of lymphocyte binding

4.3.1 Types of clonal lymphocyte binding cells

Once a lymphocyte cell binds to an antigen, the cell proliferates, forming various clones of cells capable of responding to the aforementioned antigen.

Of these "clone" cells, two categories exist: **effector cells** that take effect immediately, neutralizing an infectious agent, and **memory** cells that wait for the next encounter with such an agent.

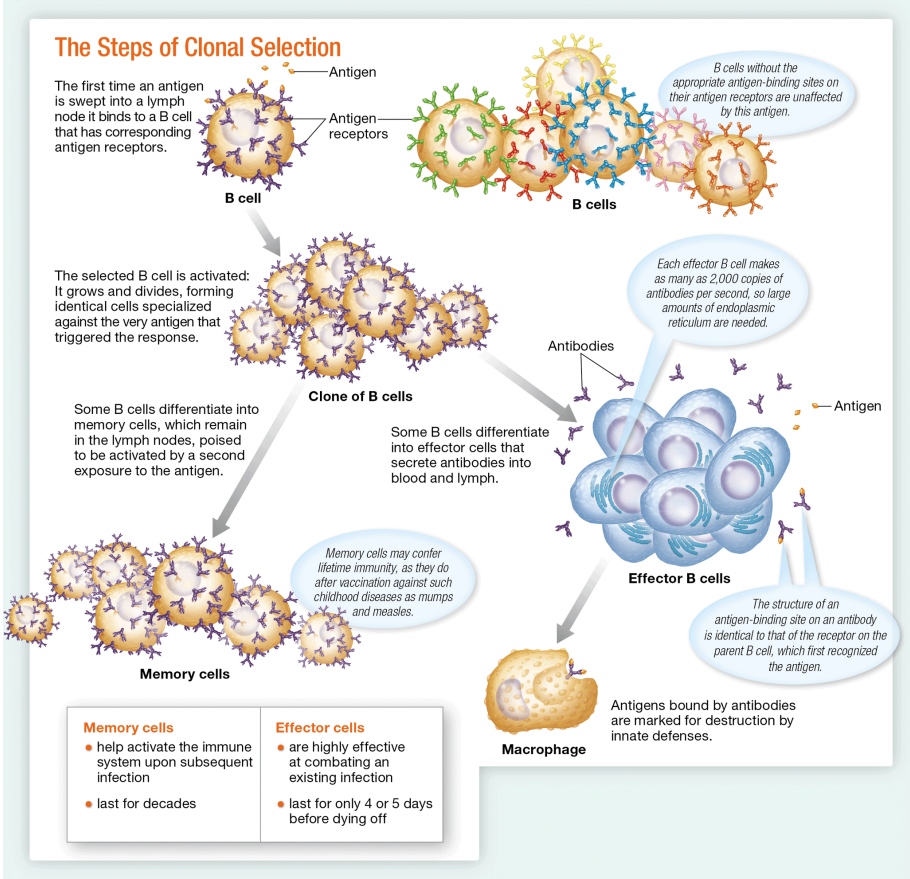
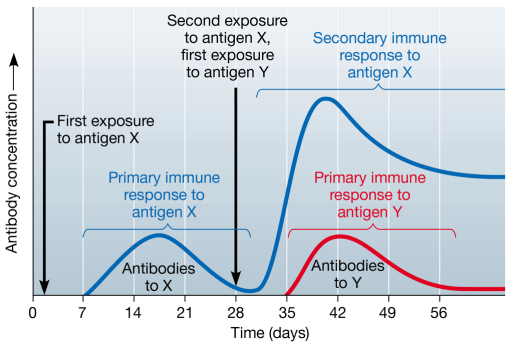


Figure 3: The process by which "selected" cells are cloned

4.3.2 Differences between the primary and secondary responses

As is suggested by the nature of the aforementioned "cloning" process, generating a sufficient number of "selecting" cloned cells at the primary immune response takes a significantly longer amount of time than in the case of a sequential response—the secondary immune response. This is caused by the fact that, once an infectious agent has arrived within an organism, enoguh "cloned" cells have been produced for the same response to be evoked without waiting for the production of such "cloned" selecting cells on the next encounter with an effective agent. In other words, these "selecting" cells are stockpiled, in hopes that, when an agent is next encountered, there will be a sufficient quantity to neutralize the threat.



5 The role of antibodies in immunity

5.1 The structure of an antibody

An important distinction must be made between the role of an antibody and, for example, a B or T cell. Or, that is to say that a common misconception lies in the function of the antibody. An antibody does not serve to harm an infectious agent. But, rather, an antibody simply "marks" an agent for destruction. The action of agent destruction is carried out by various other components of the immune system, but not by the antibody. Again, by forming a chemical bond between the *antigen-binding site*, antibodies simply form a complex that can be easily recognize by other components in the immune system.

More specifically, the role of the antibody in the humoral immune resp onse is twofold:

1. Recognizing and binding to an antigen
2. Assisting in—but not necessarily carrying out—the elimination of such an antigen

the antibody satisfies these stipulations not by function, but as a side-effect of its structure: each antibody consiss of four Y-shaped polypeptide complexes.

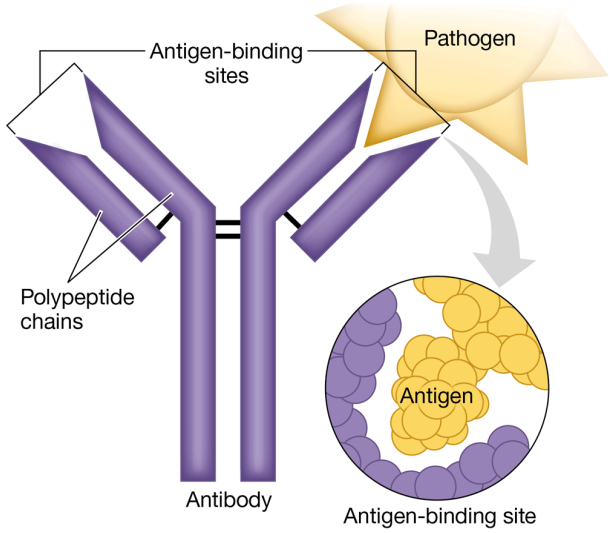
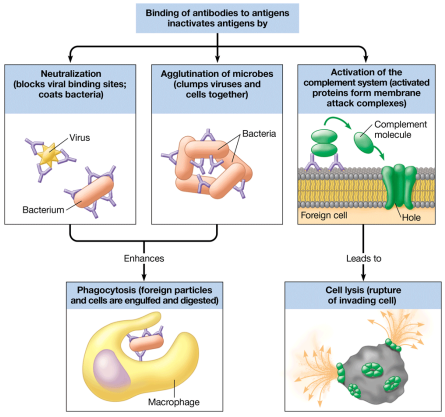


Figure 4: The structure of a typical antibody.

5.2 Components of the innate immune system can work in conjunction with specific recognition

In order to dispose of an infectious agent, the humoral immune response must look to the innate immune system: the complement system and macrophages are responsible for attacking invading agents. More specifically, during the neutralization phase, antibodies bind to the agent, letting macrophage cells easily recognize the intruding entity. Of course, this results in the ingestion of the agent by a macrophage. However, the macrophage is not the sole path to the destruction of a harmful agent: once activated as a result of antibody bindings, members of the complement system can act to "poke holes" in the membrane of the invading cell or agent, causing it to swell and lyse.



6 Helper and cytotoxic T cells

Once a pathogen has entered a body cell, the cell-mediated immune response produced by the "cytotoxic T cell" must battle the pathogen. However, cytotoxic T cells don't act of their own volition. But, rather, a **helper T cell** triggers the humoral and cell-mediated immune responses by signaling to initiate the production of antibodies that neutralize pathogens or activate cytotoxic T cells. In other words, the helper T cell is essentially a central coordinator for the entire immune system—that is, excluding external innate barriers. Without helper T cells, no immune response is evoked from the body outside of its autonomous, innate, external barrier functions— which are, of course, not functional, but structural in their utility.

In order for a helper T cell to activate, several requirements must be met:

- The antigen receptor of the T cell must be active—that is, it must be able to bind to the agent or molecule in question
- The antigen must be displayed on the surface of an antigen-presenting cell (e.g., marcophages, B cells)

In practice, these requirements could be met in the following sequecne of events:

1. A macrophage ingests a foreign particle and breaks the particle into its foreign antigens
2. **Self proteins**, or proteins belonging to the macrophage bind to the foreign antigens
3. The macrophage display a **self-nonself complex**—a combination of the self protein and the foreign antigen—on its surface
4. A helper T cell recognizes the self-nonself complex

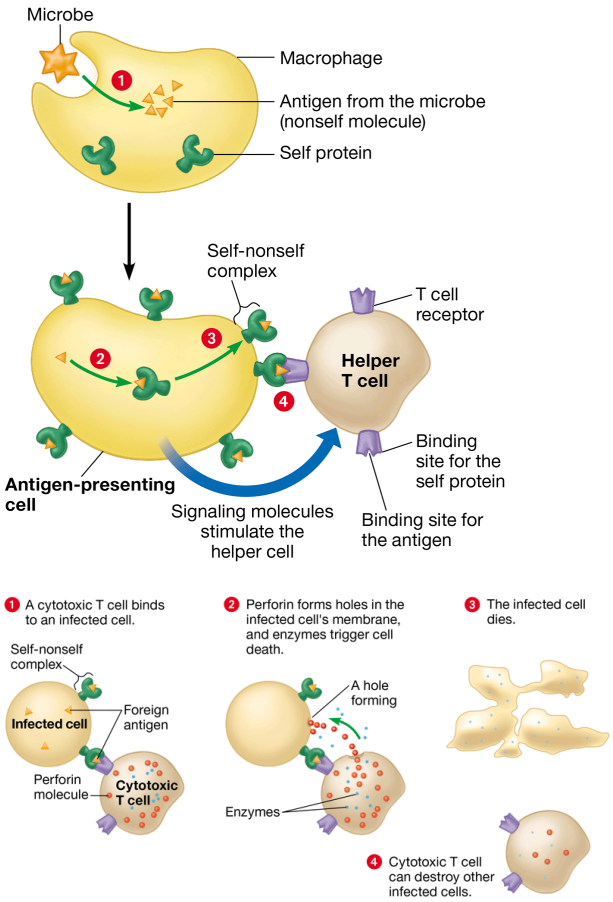


Figure 5: Self-nonself recognition (top), Agent breakdown (bot)