

A Model of the Immune System

This demonstration introduces students to some of the components of the immune system and generally explains and demonstrates their functions and interactions. It is important to tell the students that the immune system is very complex, and that much more is going on than what they will see in the lesson. In fact, the immune system is one of the hottest areas of study in medical science today. Many students have heard of T-cells in relation to AIDS, and have a hazy idea of some of the cells and processes involved in the immune response. This activity will build on that background knowledge and hopefully clarify some things.

Grade level: 6 through 8 -- can be enriched and used in high school.

Materials:

- 8 foot long rope (clothesline rope is fine)
- Bacteria: tennis balls (3), and/or 2-3 3" diameter styrofoam balls
- Viruses: marbles (3), or small decorative fabric balls
- T cells: 1" thick foam cut in "T" shape, about 2x2 inches. Cut 3 pieces, and paint or put some kind of colored tape on each piece so that you have 3 different colors. Label them "K", "H", and "R".
- B cells: 1" thick foam cut in "B" shape (3 pieces) Each "B" should be partially slit to conceal several peppercorns. (B-cells with antibodies)
- Phagocyte: sock to be used as a puppet

Procedure:

1. Review the fact that germs (or pathogens) can cause disease, and that they are so small that they can be seen only with powerful microscopes. Ask students if they know 2 common names of germs—bacteria and viruses.
2. Discuss how pathogens enter our bodies. What is our first line of defense? (skin). When we do have a cut or scratch, we have heard that germs are "killed in our blood". What does that mean? Ask where else pathogens might enter our bodies. Our eyes, ears, nostrils, and mouth are all openings into our bodies. It is significant that there are many lymph nodes concentrated near these areas.
3. Introduce the functions of the Immune System.
 - A healthy immune system can destroy nearly all types of pathogens.
 - It can create millions of specific antibodies to attack specific bacteria and viruses.
 - Our immune system recognizes "self" and "non-self" cells.

4. Conduct the following demonstration of the immune system at work. (The students should sit or stand in a circle around an area of floor where you conduct the demonstration.)
 - a. Hold the two ends of the rope in one hand so the rope forms a circle, showing the skin as a barrier to keep germs out. Discuss: as long as the skin remains uninjured, it holds the body's insides in and keeps the rest of the world safely out.
 - b. Open the break in the rope, and compare it to a break in the skin. Now pathogens can enter. Have students say some ways that breaks in the skin occur. (cuts, scratches, burns, abrasions, surgery, tattoos, ear-piercing, IV drugs, etc.) Review proper care for breaks in the skin. (Washing with soap and water, using antibiotic ointment, etc.)
 - c. Lay the rope on a flat surface where it can be seen by the students and roll the tennis balls and styrofoam balls into the circle through the break in the skin. These balls represent bacteria. They are large and plentiful. Roll in the marbles, representing viruses, and note that they are much smaller than bacteria.
 - d. Explain that our blood contains white blood cells that fight germs. Some of these cells (**phagocytes**) surround and "eat" germs in tissues and blood. Use the sock puppet to demonstrate the action of the phagocytes by engulfing a virus or bacteria in your sock-covered hand
 - e. Other white blood cells, called Lymphocytes, attack specific germs or make antibodies that destroy these germs. Both T-cells and B-cells are Lymphocytes. (All Lymphocytes originate in **Bone marrow**, and B-cells mature there; but T-cells migrate to the **Thymus** and mature there. Hence, "B" and "T".) There are several kinds of T-cells.

Helper T-cells are the first cells to identify the specific pathogen in the body. They identify a pathogen alone, or one that has been picked up by a phagocyte or a B cell. Helper T-cells mobilize forces and direct the battle just as coaches direct players on a team.

Add a "H" T-cell to the circle.

Killer T-cells attack and destroy cells infected by viruses, and they also kill cancer cells. (Unfortunately, killer T-cells are also responsible for the rejection of organ transplants.)

Add a T-cell marked "K" to the circle.

And still other T-cells slow and stop the attack by the B-cells and Killer T-cells. These **Regulatory T-cells** help prevent autoimmune diseases and organ rejection by stopping the other T-cells from attacking self cells.

Add the "R" T-cell to the circle.

Emphasize the similarity to a team or squadron where the helper T-cell is the captain, running the command center.

- f. Another kind of Lymphocyte is the **B-cell**.
Add B-cells to the circle. B-cells produce chemicals called Antibodies which destroy pathogens. Helper T-cells activate B-cells by telling them to make specific antibodies for the pathogen that has invaded.
Pick up a B-cell and let the peppercorns fall out into the circle. Each antibody is specific to a particular virus or bacteria. "Attack" a virus or bacteria with a peppercorn, and remove it from the circle. After an infection is over, some B-cells "remember" how to make that specific antibody and will start producing it rapidly if the same germ re-infects the body.

Note: The Lymphocytes are concentrated in the lymph nodes, where they "hang out", waiting for something to happen. What does happen is that the phagocyte circulates through the node, showing a piece of the germ it has just "eaten", and the T-cells and B-cells go into action. When a B-cell recognizes an antigen, it attaches to it and presents this to a T-cell. The T-cell then directs the B-cell to begin cloning itself into plasma cells to make antibodies. A few of the cloned cells will become "memory cells", able to respond quickly if the same antigen presents itself at a later date.

- h. Ask students, "What happens when the "command center of a real battle is destroyed?" When germs attack T-cells that control the body's immune response, they cripple the body's ability to fight off infection. HIV attacks helper T-cells, so that they cannot recognize an invader, nor can they direct the other components of the immune system to begin to work.

What's Going On? Overview

Non-specific defense mechanisms

The skin and mucous membranes are primary defense mechanisms against pathogens. However, even the best defenses can be breached by opportunistic invaders. Bacteria and viruses may enter the body through a cut or other skin opening. They may even overcome the antimicrobial secretions of skin and mucous membranes. Cell surface "markers" of the invader differ from the markers on our own cells. Our immune system can recognize these "non-self" markers, and will mount an immune response.

When a microbe penetrates the first line of defense, the body's second line of defense springs to action. Several types of white blood cells, collectively called *phagocytes*, attack and kill pathogens. The largest of these, the *macrophage* ("big eater") enter tissues to search for invaders. They are very effective, long lived phagocytes, and engulf pathogens in a vacuole that fuses with a macrophage lysosome and kills the microbe.

Specific defense mechanisms

The body's third line of defense, key to the immune system's success, are *lymphocytes*. Lymphocytes are produced in the bone marrow, and number about one trillion. "B" lymphocytes mature in the bone marrow and "T" lymphocytes mature in the thymus, located behind the breastbone. B cells make antibodies, and T cells orchestrate, coordinate, and regulate the immune response.

Mature lymphocytes are concentrated in the lymph nodes, where they "hang out", waiting for something to happen. A critical event that occurs here is the activation of Helper T cells. This activation is critical because activated Helper T cells stimulate antibody production and cause Killer T-cells to proliferate. HIV infects and kills Helper T cells (also known as CD4+ cells), which explains the "crash" of the immune system due to an active HIV infection.

Activation of Immune Cells

After a macrophage has ingested and killed an invader, it displays the antigen fragments on the outside of its cell membrane. (*An antigen is a foreign molecule that causes an immune response – in this case, bits of the invader*). As the displaying macrophage circulates through the lymph nodes, it attracts an unactivated Helper T cell. The interaction of the two cells "activates" the Helper T cell, and it can go on to stimulate other immune cells (see below).

A resting Killer T cell may also recognize a foreign antigen displayed on a cell surface (for example, a body cell invaded by a virus or bacterium that is displaying parts of the invader) and bind to it. This binding activates the Killer T cell, so that it can destroy the infected cell. Activated Helper T cells can instruct the proliferation of the activated Killer T cells to fight an infection.

When a foreign invader circulates through a lymph node, one of the B cells will recognize it, engulf and destroy it, and display a piece of it. This activity attracts an activated Helper T-cell and this T cell directs the B-cell to begin cloning itself into *plasma cells* that make large numbers of antibodies. The antibodies will seek out and destroy that particular invader. A few of the cloned cells will become "memory cells" that will be able to respond quickly if the same invader presents itself at a later date.

Antibodies have several antigen binding sites. As the antibodies encounter many copies of the antigens, large clumps of antigen/antibody complexes are formed. Several mechanisms exist to eliminate this complex from the body. In one common scenario, a macrophage will encounter this large clump, ingest it and destroy it.

Concluding Note

There are many other components of the human body's immune system that we can't cover here. We encourage you to undertake further exploration of this important and fascinating topic. We've included some great web sites to aid you in your explorations. Enjoy!

Web Resources for additional Information:

Immune System Overview

National Institutes of Allergy and Infectious Disease:

<http://www.niaid.nih.gov/final/immun/immun.htm>

How Stuff Works: <http://science.howstuffworks.com/immune-system.htm>

BBC Health: <http://www.bbc.co.uk/health/immune/>

Allergies

American Academy of Allergy, Asthma, and Immunology:

<http://www.aaaai.org/patients/topicofthemoth/1101/default.stm>

Online Biology Book excerpt: Great images and links:

<http://www.emc.maricopa.edu/faculty/farabee/BIOBK/BioBookIMMUN.html>

Autoimmune Disorders

Discovery Channel Health:

<http://health.discovery.com/encyclopedias/537.html>

Yahoo Health Encyclopedia:

<http://health.yahoo.com/health/ency/adam/000816/overview>