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Alicia Cepaitis, MS
Chief Creative Nerd
Science Prof Online
Online Education Resources, LLC
alicia@scienceprofonline.com

Tami Port, MS
Creator of Science Prof Online
Chief Executive Nerd
Science Prof Online
Online Education Resources, LLC
info@scienceprofonline.com

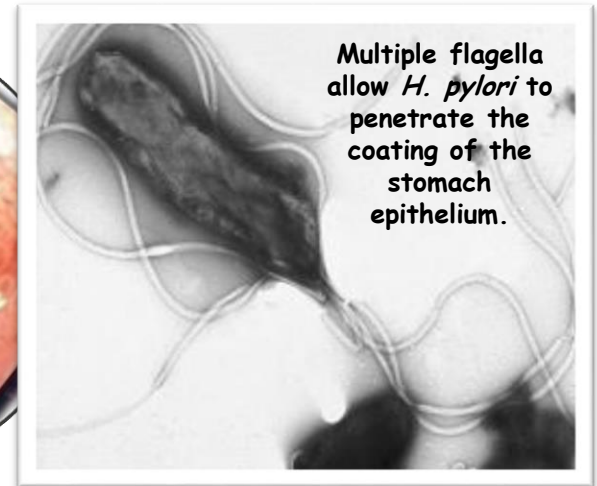
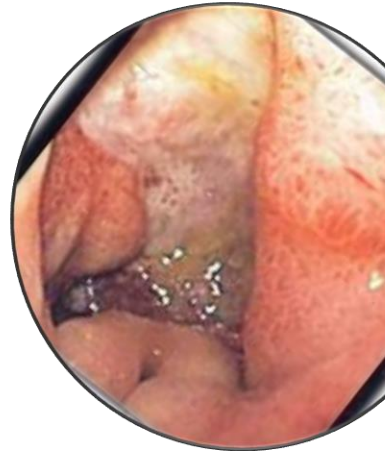
Immunology



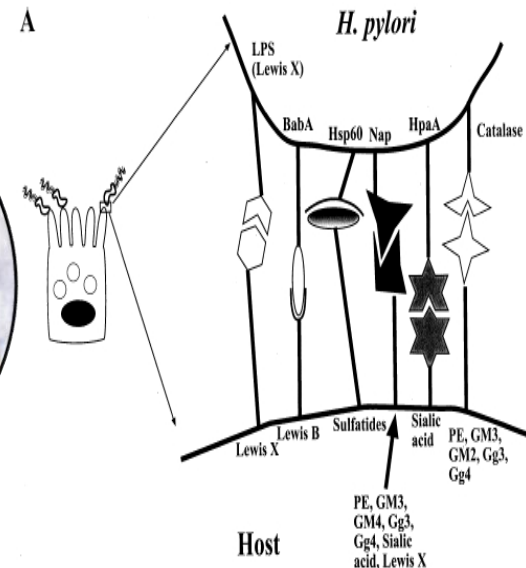
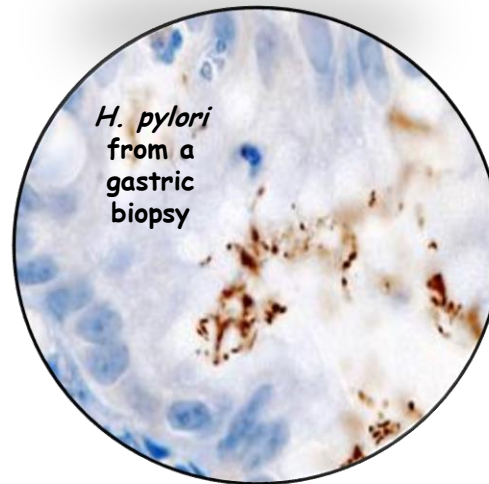
It Isn't Easy Being a Pathogen

What a pathogen must do in order to cause disease:

1. Gain access to the body.
2. - Attach to and/or enter cells of its host.
 - Receptors on pathogen must fit, lock-and-key, with receptor sites on host cell.
3. Reproduce while avoiding host's immune system long enough to produce harmful changes.



Multiple flagella allow *H. pylori* to penetrate the coating of the stomach epithelium.



Normal Flora

- Protect the body by competing with potential pathogens.
- This is called **microbial antagonism**.
- Normal microbiota protect us by:
 - Consuming nutrients that would otherwise be available to pathogens.
 - Sometimes change the **pH** of the area they inhabit in ways that help them and hinder competing microbes.
 - Presence stimulates certain parts of the second line of immune defense, helping the body defend itself from invaders.
 - Normal flora of the intestines improve our overall health by producing several types of vitamins.



Innate Immunity

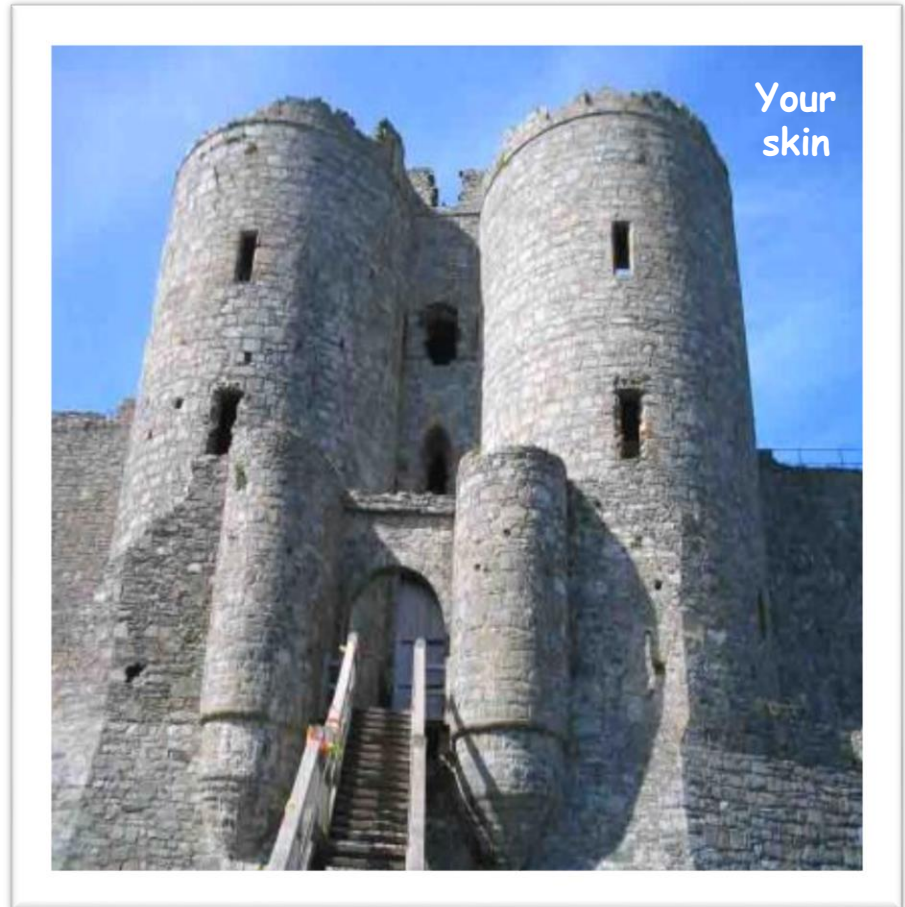
- First two lines of immune defense considered together.
- **Q:** Why do you think that they are called innate immunity?
- Innate immunity is **nonspecific**, meaning that these lines of defense work against a wide range of pathogens.



First Line of Defense

Nonspecific

- Structures, chemicals, processes that work to *prevent pathogens entering the body.*
- Includes the skin and mucous membranes of the respiratory, digestive, urinary, and reproductive systems.



First Line of Defense

Skin - Physical Components of Defense

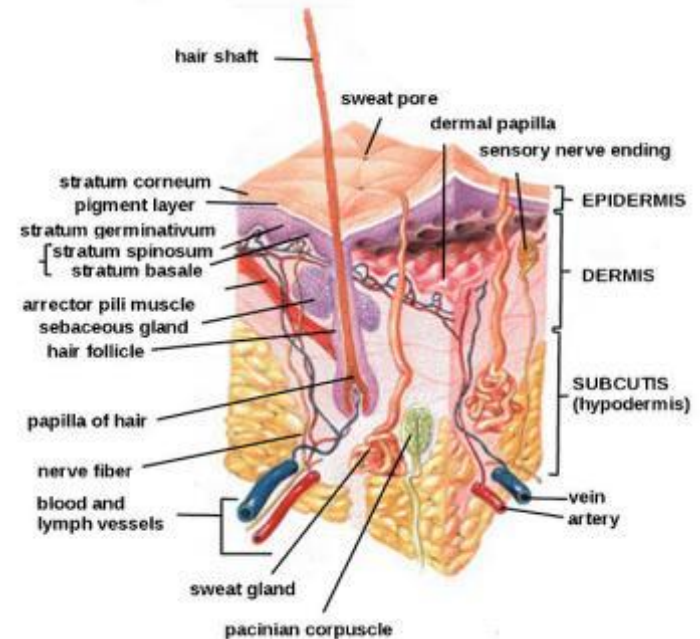
Two major layers:

1. epidermis

- Outer layer composed of multiple layers of tightly packed cells
 - Few pathogens can penetrate these layers
 - Shedding of dead skin cells removes attached microorganisms
- Epidermal dendritic cells phagocytize pathogens.
 - These cells extend out among other cells of the epidermis, forming a network to intercept invaders.

2. dermis

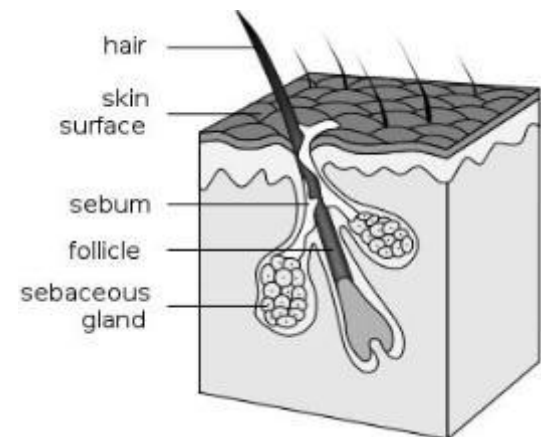
- Contains protein fibers called collagen
 - Give skin strength and pliability to resist abrasions that could introduce microorganisms



First Line of Defense

Skin - Chemical Components of Defense

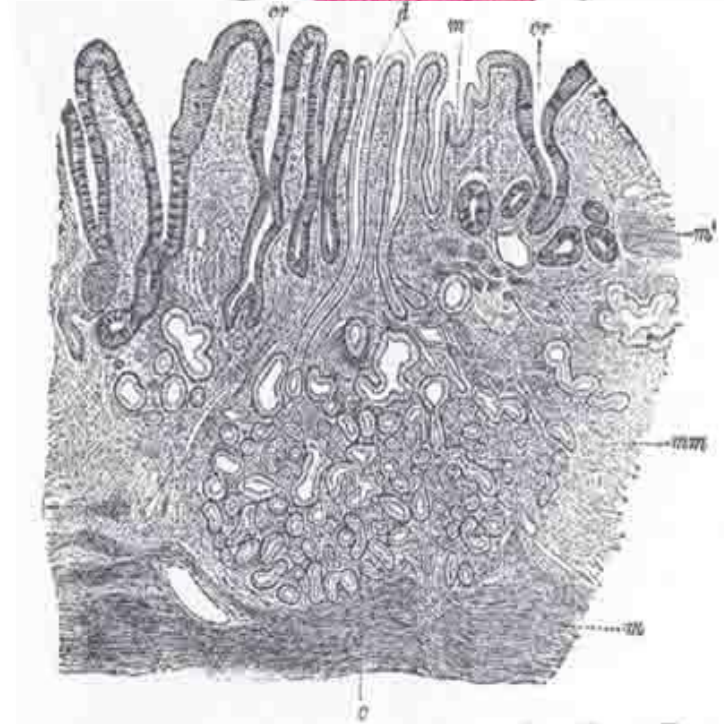
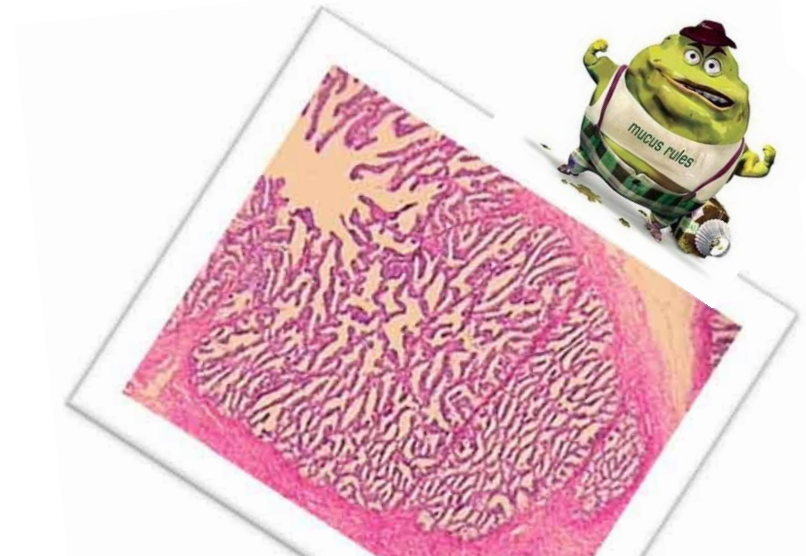
- **perspiration** secreted by sweat glands
 - Salt- inhibits growth of pathogen by drawing water from their cells
 - Antimicrobial **peptides**
 - Lysozyme- destroys cell wall of bacteria
- **sebum** secreted by sebaceous (oil) glands
 - Helps keep skin pliable and less likely to break or tear
 - Lowers **pH** of skin to a level inhibitory to many bacteria



First Line of Defense

Mucous Membrane

- Line all body cavities open to the outside environment.
- Unlike surface epidermal cells, epithelial cells are living.
- Epithelial cells packed tightly to prevent entry of pathogens, but often only one cell layer thick, so pathogens sometimes breach the barrier.
- Continual shedding of cells carries attached microorganisms away
- Besides producing mucus, mucous membranes also produce lysozyme and other antimicrobial peptides.
- OMG U R Nasty > Every day you swallow and digest about 1 liter of mucus.

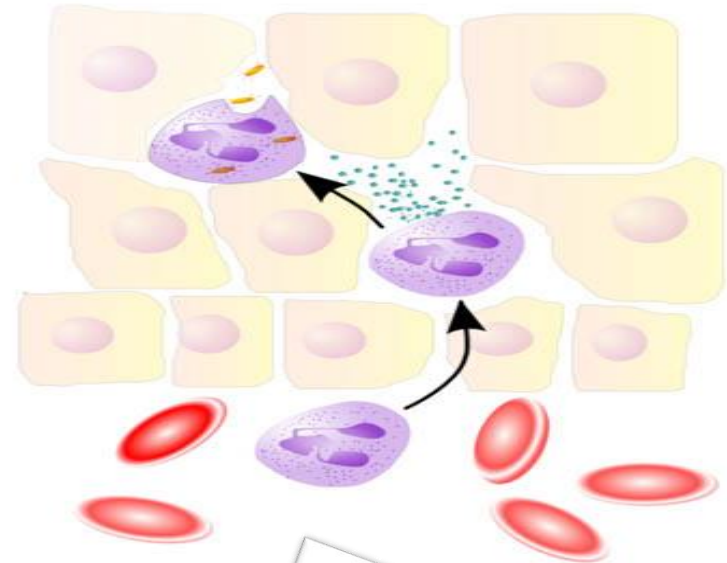


First Line of Defense

Second Line of Defense

Nonspecific

- Operates when pathogens penetrate skin or mucous membranes.
- Cells, antimicrobial chemicals, and processes, but no physical barriers.
- Many of these components are contained or originate in the blood.

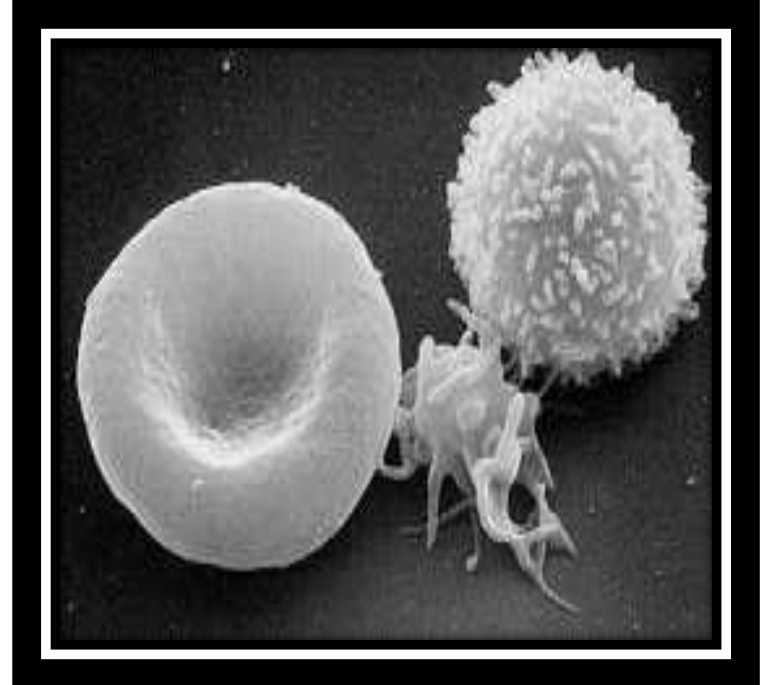


Second Line of Defense

Formed Elements

Three types of formed elements:

- **erythrocytes** - red blood cell, carry oxygen & carbon dioxide in the blood.
- **platelets** - involved in blood clotting (also called thrombocytes).
- **leukocytes** - white blood cells; involved in defending the body against invaders.
 - 2 groups
 - Granulocytes
 - Agranulocytes



Scanning electron micrograph
of formed elements

RBC (*left*)

platelet (*center*)

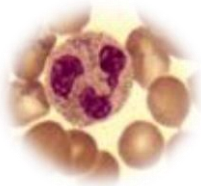
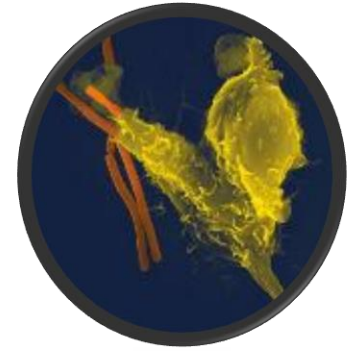
leukocyte (*right*)

Second Line of Defense

Leukocytes > Granulocytes

Category of white blood cells characterized by presence of **granules** in their cytoplasm.

3 types:



Neutrophils - Most abundant white blood cell. Predominant cells in pus, accounts for its whitish appearance. Respond quickly following tissue injury. Hallmark of acute inflammation.

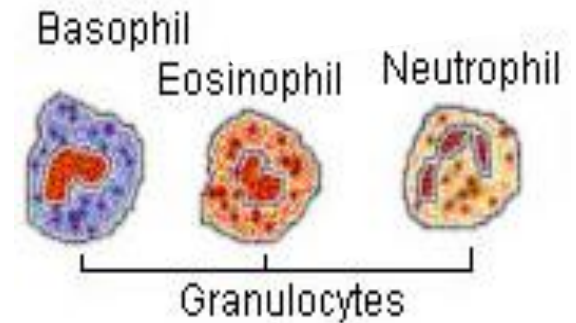


Basophils - Least common granulocyte. When activated, release histamine and other inflammatory chemicals.



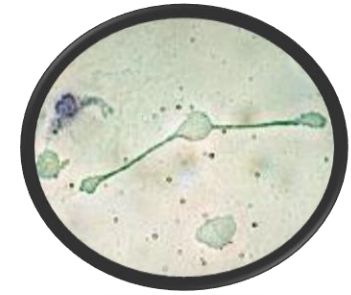
Eosinophils - Main effector cells in allergic responses & asthma. Also fight helminth (worm) colonization.

Neutrophils and **eosinophils** can *phagocytize* pathogens.

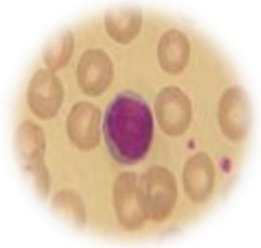


Second Line of Defense

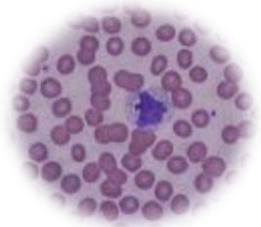
Leukocytes > Agranulocytes



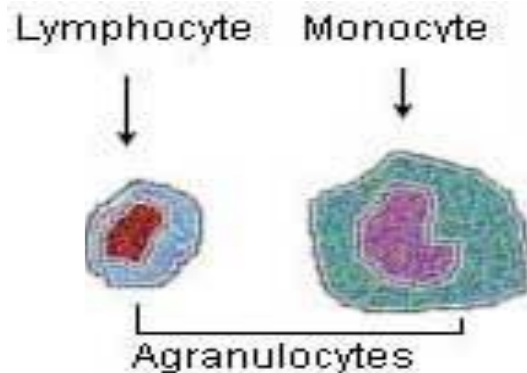
2 types:



Lymphocytes - most involved in specific immunity
(3rd line of immune defense),



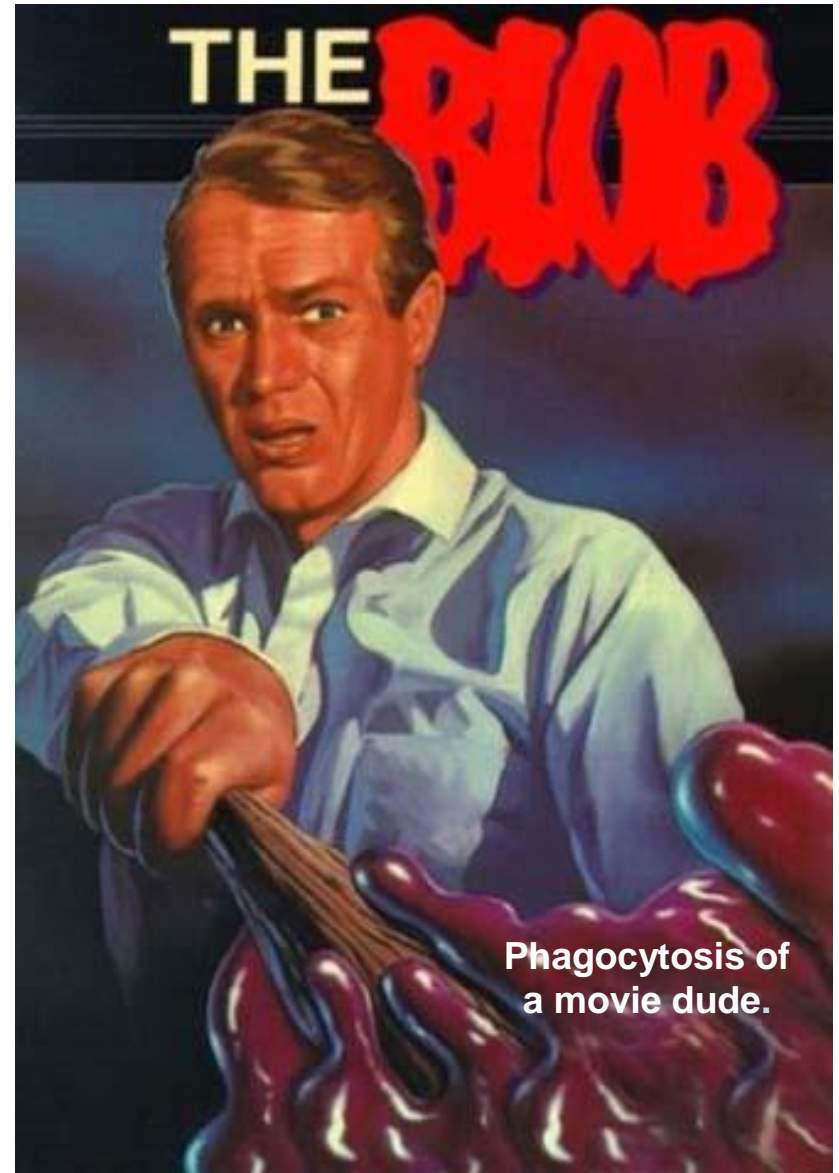
Monocytes - leave the blood and mature into **macrophages** (phagocytic cells of the second line of defense).



Second Line of Defense

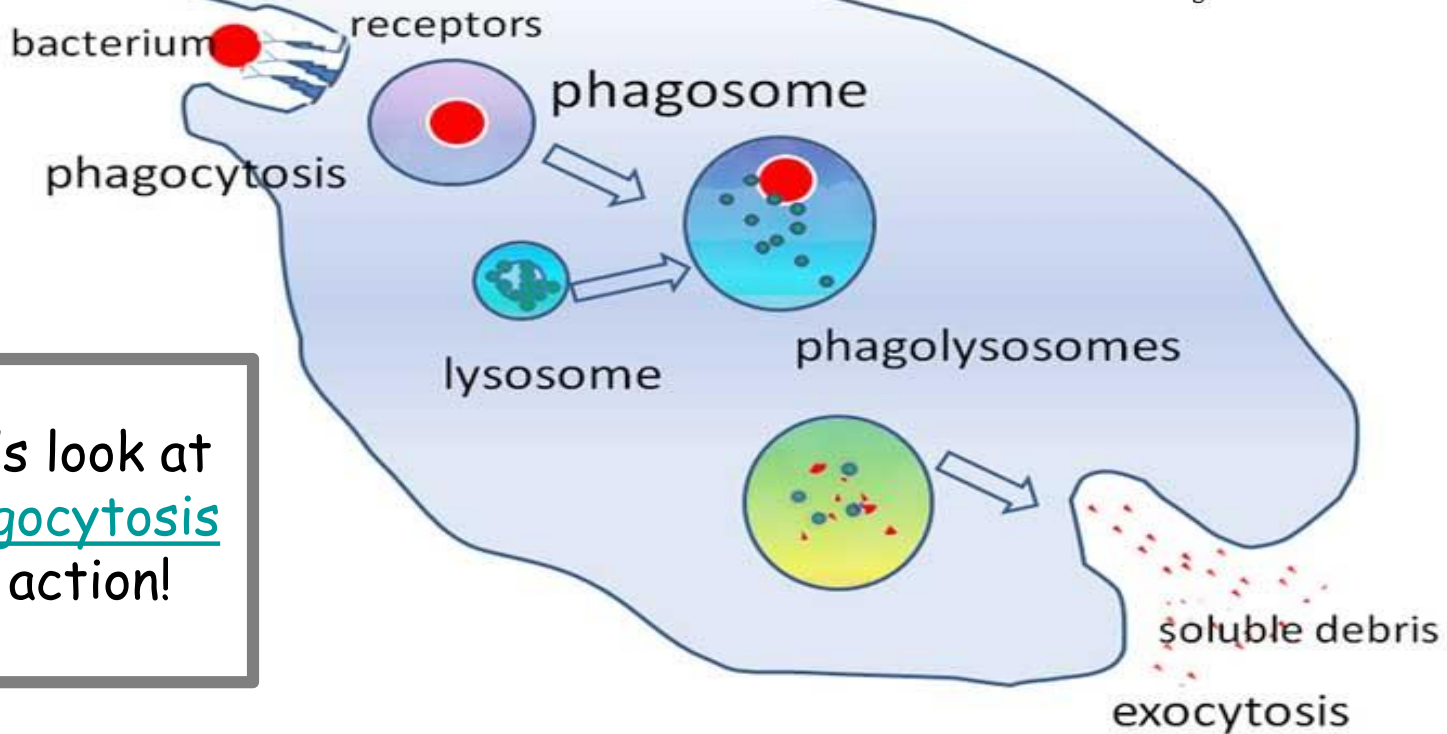
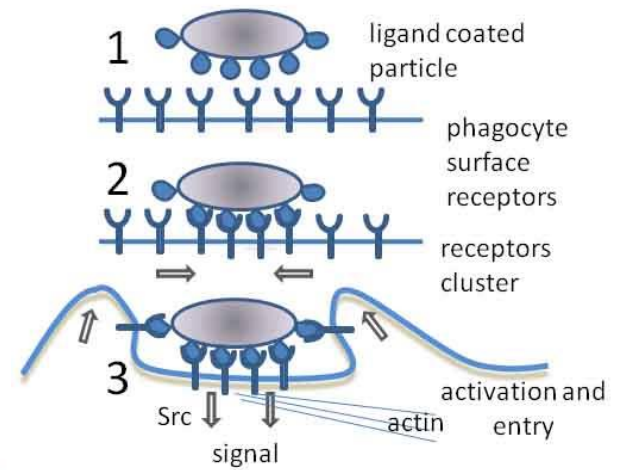
Components of the Second Line of Defense

- Leukocytes
 - **Phagocytosis**
How phagocytes ingest and destroy foreign matter such as microorganisms or debris.
 - Extracellular killing by leukocytes
- Nonspecific chemical defenses
- Inflammation
- Fever



Second Line of Defense

Leukocytes: Phagocytosis



Let's look at phagocytosis in action!

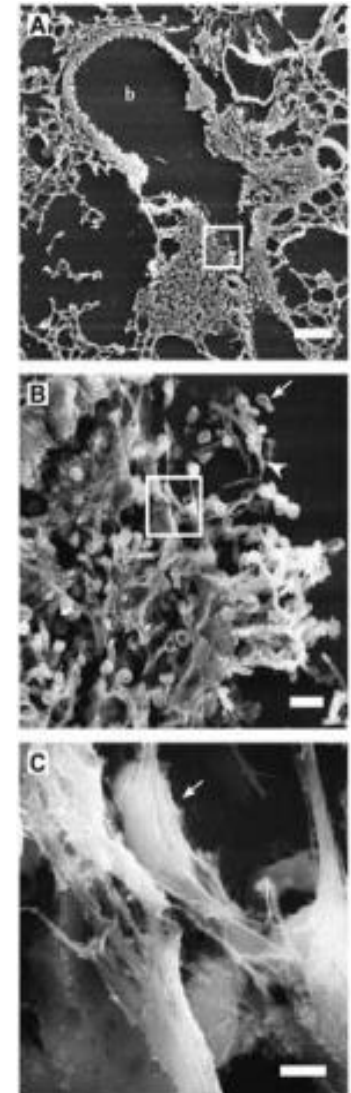
Second Line of Defense



Leukocytes: Extracellular Killing

3 Cell Types That Kill Extracellularly:

- **natural killer lymphocytes** (NK cells)
 - Secrete toxins onto surface of virally infected cells & tumors.
 - Differentiate normal body cells because they have membrane **proteins** similar to the NK cells.
- **eosinophils**
 - Mainly attack parasitic worms by attaching to their surface.
 - Secrete toxins that weaken or kill worm.
 - Elevated eosinophil levels, is often indicative of a helminth (parasitic worm) infection.
- **neutrophils**
 - Can create the active ingredient in bleach to kill nearby microbes.
 - Fibers called neutrophil extracellular traps (NETs) can ensnare and kill bacteria and fungi. Secrete antimicrobial proteins.

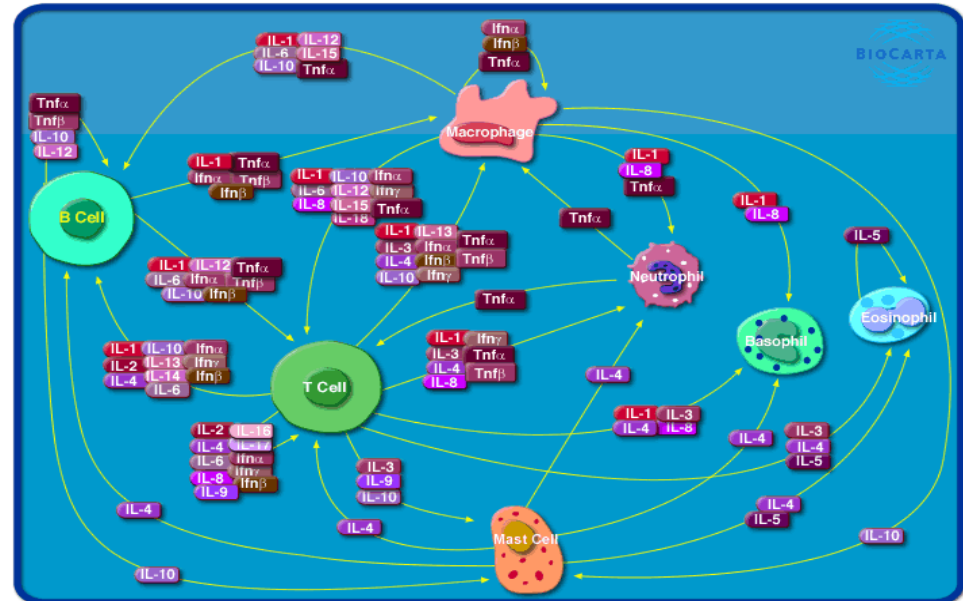
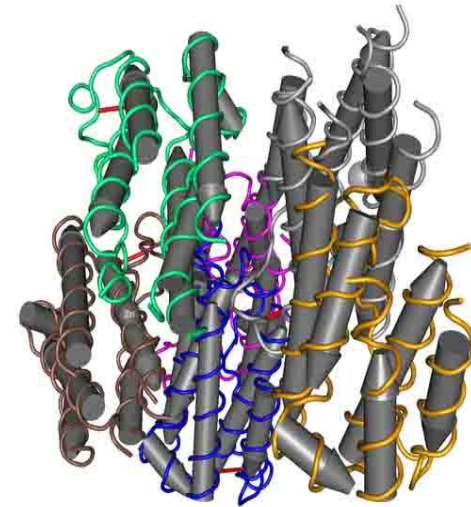


Second Line of Defense

Image: Natural killer cell (yellow) attacking a cancer cell (red), Dr. Rupert Handgretinger, University Hospital of Tübingen; Mouse lung cell **NETS** engulfing fungus PLoS.

Components of the Second Line of Defense

- Leukocytes
 - Phagocytosis
 - Extracellular killing by leukocytes
- Nonspecific chemical defenses
 - Lysozyme, Defensins & Cytokines (including interferons and interleukins).
 - Augment phagocytosis
 - Some attack pathogens directly
 - Some enhance features of nonspecific resistance
- Inflammation
- Fever



Second Line of Defense

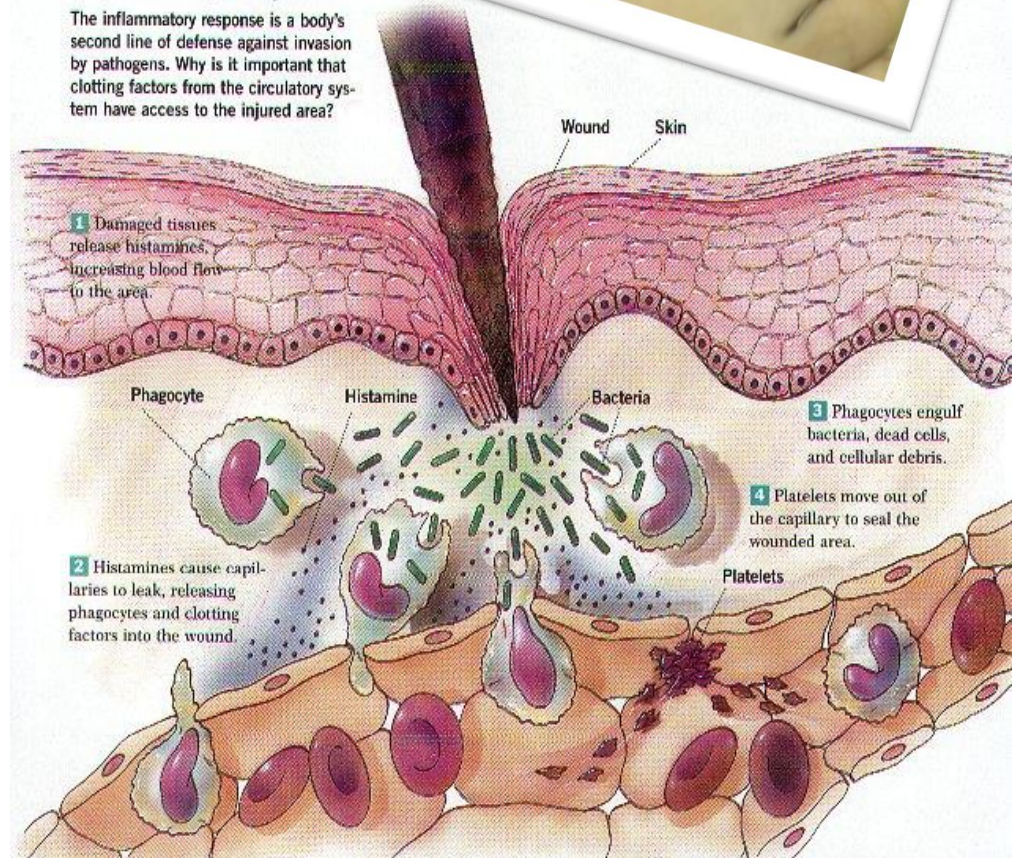
Components of the Second Line of Defense

- Leukocytes
 - Phagocytosis
 - Extracellular killing by leukocytes
- Nonspecific Chemical Defenses
 - Ex. Lysozyme, Defensins & Cytokines
- Inflammation
 - Nonspecific response to tissue damage.
 - Damages cells release histamines which increase vasodilation.
 - Heat, swelling, pain
- Fever



Steps of the Inflammatory Response

The inflammatory response is a body's second line of defense against invasion by pathogens. Why is it important that clotting factors from the circulatory system have access to the injured area?



Second Line of Defense

Components of the Second Line of Defense



- Leukocytes
 - Phagocytosis
 - Extracellular killing by leukocytes
- Nonspecific Chemical Defenses
 - Ex. Lysozyme, Defensins & Cytokines
- Inflammation
 - Nonspecific response to tissue damage.
 - Damages cells release histamines, which increase vasodilation.
 - Heat, swelling pain
- Fever

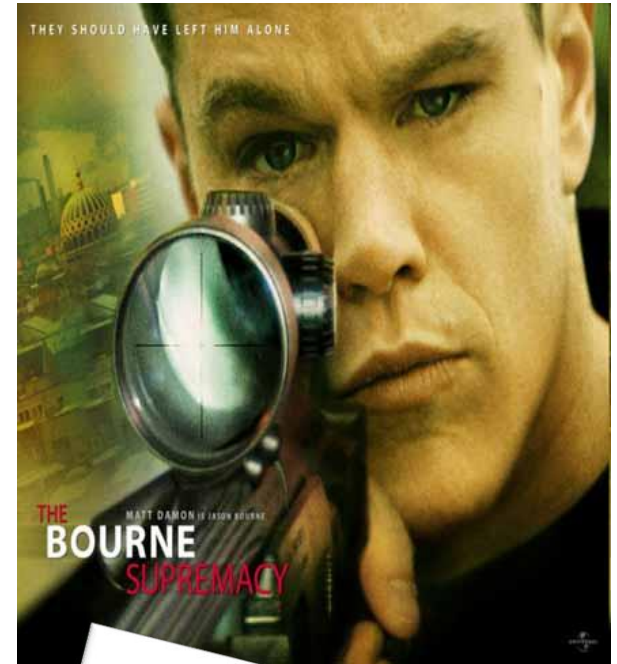
- ✓ Body temp above normal range of 36.5-37.5 °C (98-100 °F).
- ✓ Results when chemicals called pyrogens trigger the hypothalamus to increase body's core temperature.
- ✓ Various types of pyrogens
 - ❖ Bacterial toxins
 - ❖ Cytoplasm of bacteria released by lysis
 - ❖ Antibody-antigen complexes
 - ❖ Interleukin-I (IL-1 a cytokine)
- ✓ Benefits
 - ❖ Speed of immune system reaction increased
 - ❖ Inhibits growth of some temp sensitive microorganisms

Second Line of Defense

Third Line of Defense

Acquired

- The body's ability to recognize and defend itself against distinct invaders.
 - Is a "smart" system.
 - Also called **specific** and **adaptive** immunity.
 - "Memory" allows it to respond rapidly to additional encounters with a pathogen.
 - If nonspecific immune system has *warriors*, then acquired immunity has more sophisticated *special agents* and *assassins*.
- Two types of specific immunity:
 - **Naturally acquired** = immune response against antigens encountered in daily life.
 - **Artificially acquired** = response to antigens introduced via vaccine.
- **Q:** How does the body recognize invaders?



Third Line of Defense

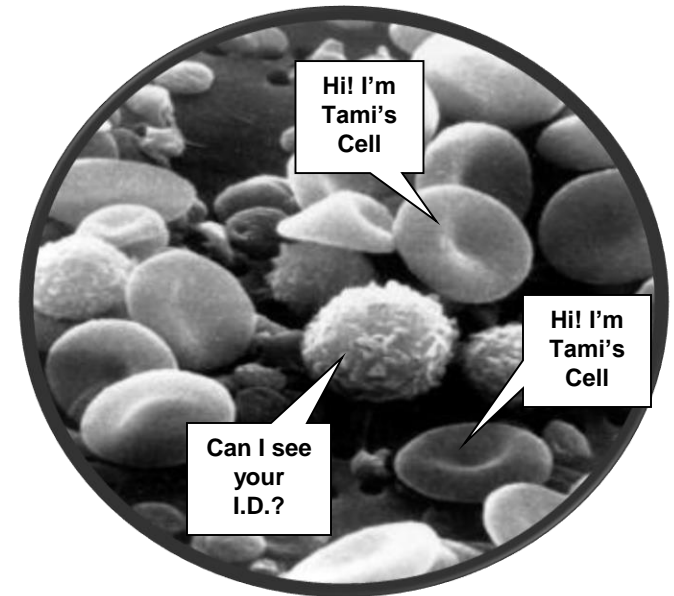
Antigens

- Body does not direct immune response against whole bacteria, fungi, protozoa or viruses.
- Foreign molecules trigger a specific immune response.
- These foreign molecules are called **antigenic determinants** (a.k.a. epitopes or antigen fragments). There may be several different antigenic determinants on an antigen molecule.
- Include components of **bacterial cell walls**, capsules, pili, and flagella, as well as proteins of **viruses**, fungi and protozoa.
- Food and dust can also contain antigenic particles.
- Enter the body by various methods:
 - Through breaks in skin & mucous membranes
 - Direct injection, as with a bite or needle
 - Through organ transplants and skin grafts

HELLO
my name is

Antigens Are Like Name Tags

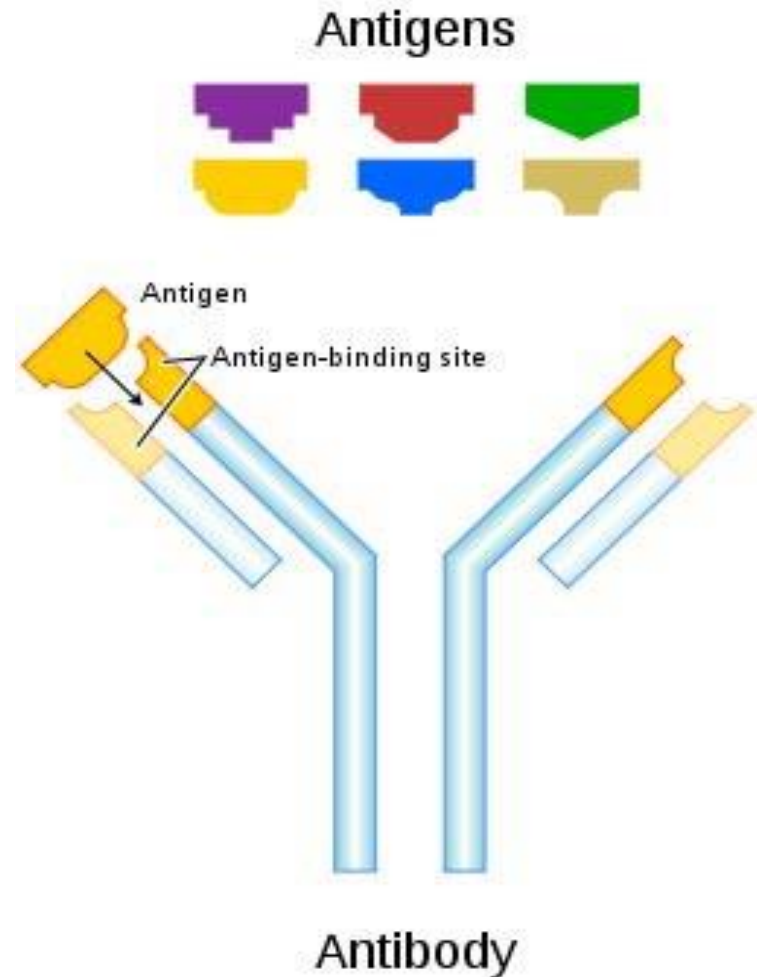
Antigenic particles are often associated with a specific characteristic of an organism, so are detected as foreign when they get inside another organism that doesn't have that characteristic.



Third Line of Defense

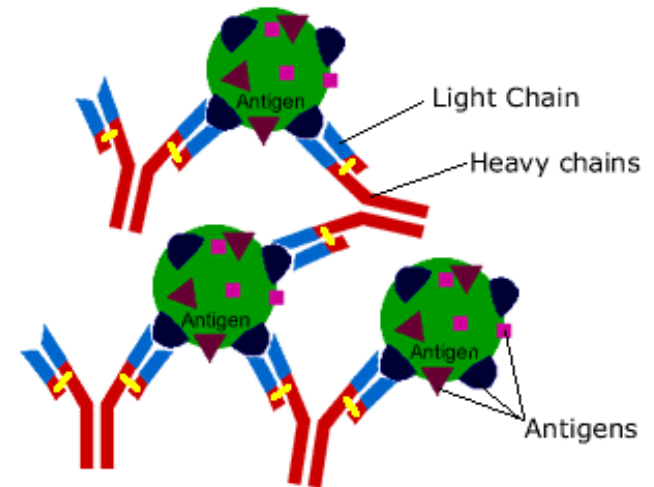
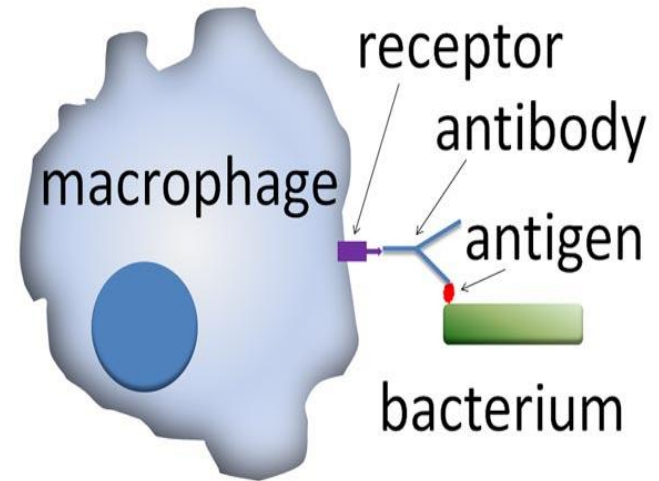
Antibodies

- Also called immunoglobulins (Ig).
- Proteinaceous molecules that bind antigens at the antigen-binding site.
- Considered part of the humoral immune response since bodily fluids such as lymph and blood were once called humors.



How Antibodies Work

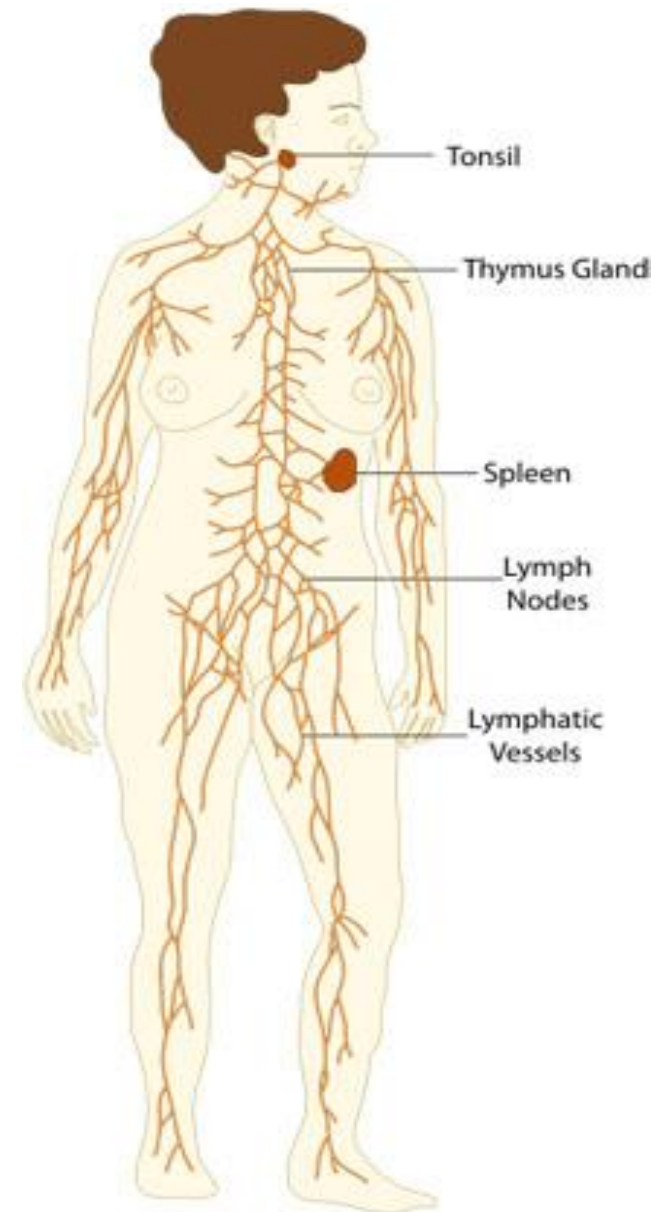
- Some act as **opsonins**, markers to identify antigens for phagocytes and stimulate phagocytosis.
- Some work as **antitoxins** (i.e. they neutralize toxins for e.g. those causing diphtheria and tetanus).
- Some attach to bacterial flagella making them less active and easier for phagocytes to engulf.
- Some cause **agglutination** (clumping together) of bacteria making them less likely to spread



Q: But where do **antibodies** come from?

Lymphatic System

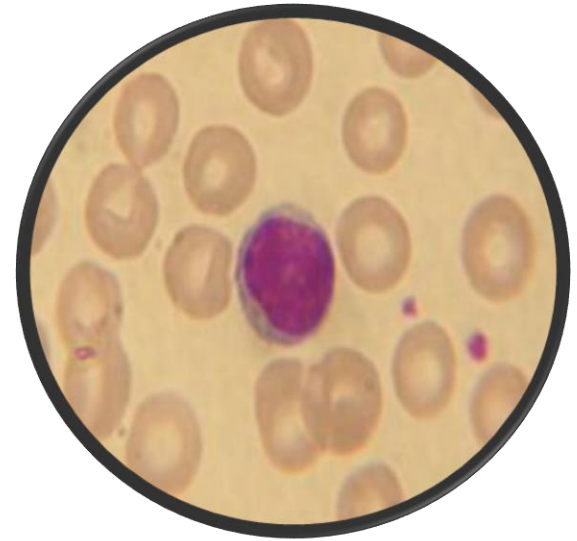
- Screens tissues of the body for foreign antigens.
- Composed of lymphatic vessels and lymphatic cells.
- One-way system that conducts lymph from local tissues and returns it to the circulatory system.
 - Lymph is a liquid with similar composition to blood plasma.
 - Comes from fluid leaked from blood vessels into surrounding tissues.
- Lymph nodes house white blood cells called **lymphocytes** that recognize and attack foreign antigens present in lymph.



Third Line of Defense



Lymphocytes



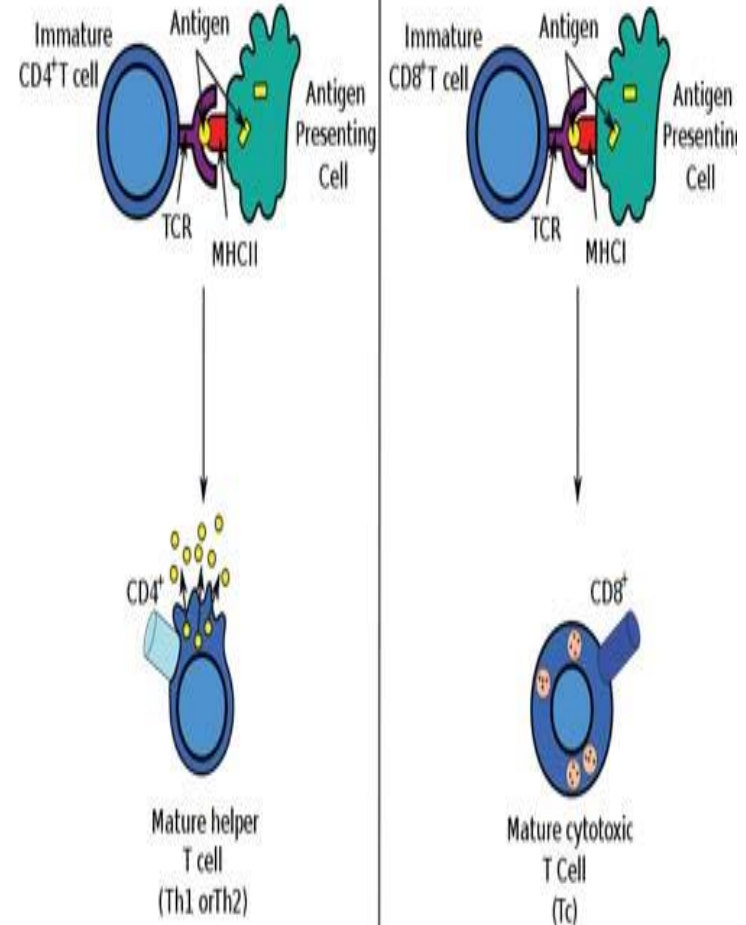
- WBCs of specific immunity. Smallest [leukocytes](#). Have huge nucleus surrounded by thin rim of cytoplasm.
- Produced from blood stem cells in the red bone marrow.

Two main types:

- **B cells** mature in bone marrow, then concentrate in lymph nodes & spleen.
- **T cells** mature in thymus.
- B and T cells mature then circulate in the blood and lymph.
- Circulation ensures they come into contact with pathogens and each other.

T Lymphocytes (T cells)

- Produced in red bone marrow and mature in thymus.
- Circulate in the lymph and blood and migrate to the lymph nodes (and other areas of the lymph system).
- Part of the **cellular immune response** (aka cell-mediated immune response) because these cells act directly against various antigens
 - Endogenous invaders (intracellular pathogens inside the body's cells)
 - Abnormal body cells such as cancer cells
- Types
 - **cytotoxic** or **killer** T cells (T_C)
 - Destroy compromised body cells
 - **helper** T cells (T_H)
 - Activate B-cells



Third Line of Defense: Cell-mediated Immune Response

What Is an Antigen Presenting Cell?

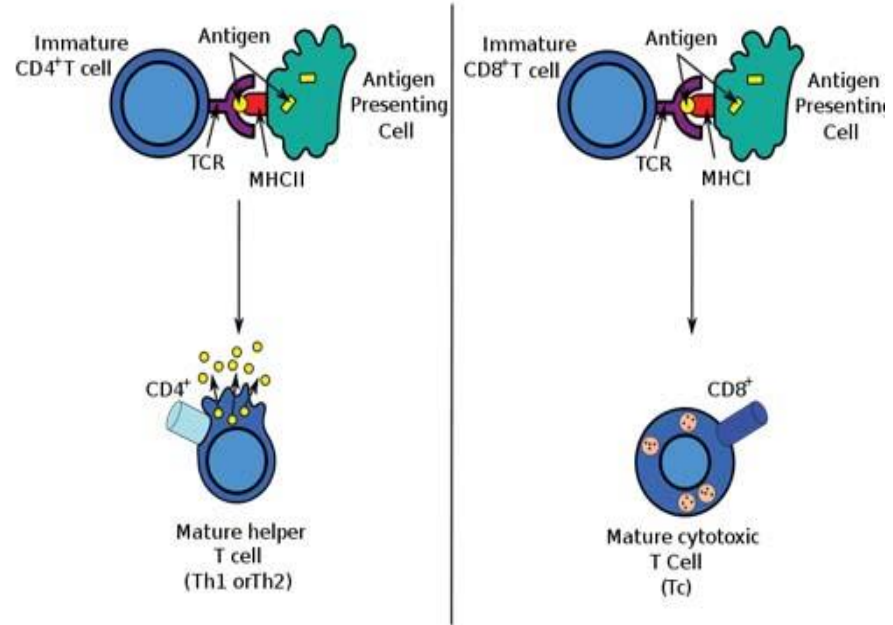
Consider your WBCs a **security force** for your body and any non-self antigens as **pictures of a bad guy**.

The larger the force, the more likely one of the officers will run into a "bad guy" and help the body apprehend it.

Any WBC that can grab and present an antigen to another, is called an antigen presenting cell (APC).

There are "professional" (WBC) APC cells, such as **B cells**, **macrophages** and **dendritic cells**.

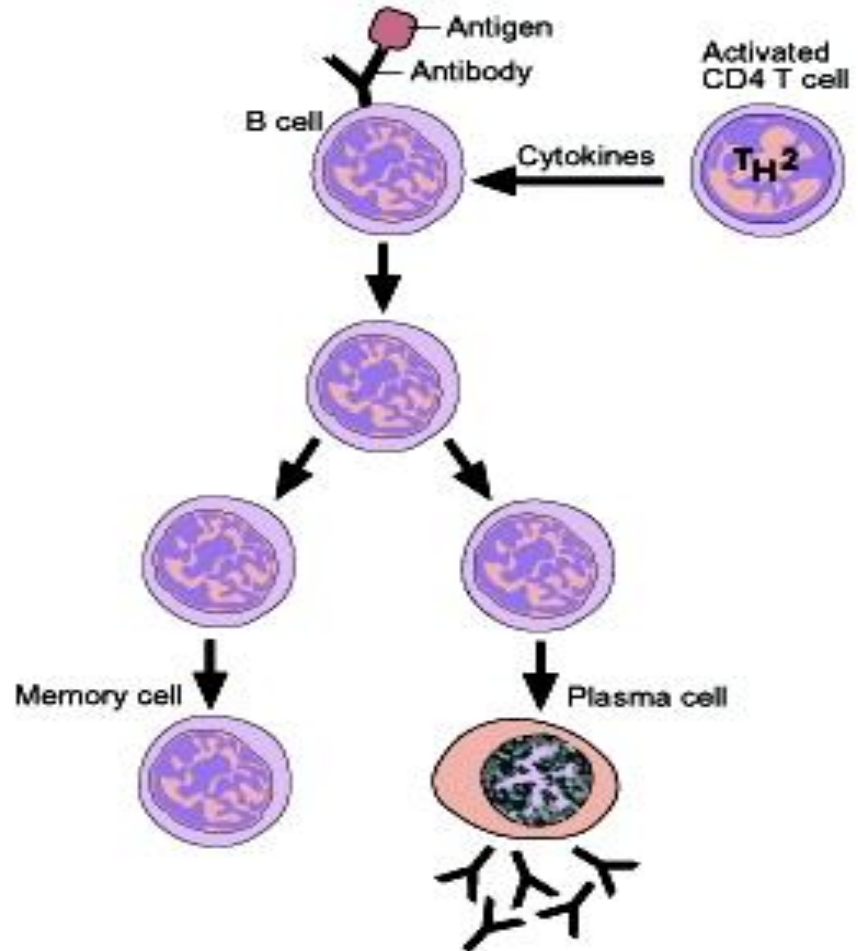
There are also other cells in the body (non-WBCs) that are "non-professional" APC cells, such as fibroblasts (in skin), some epithelial and endothelial cells & glial cells (in brain).



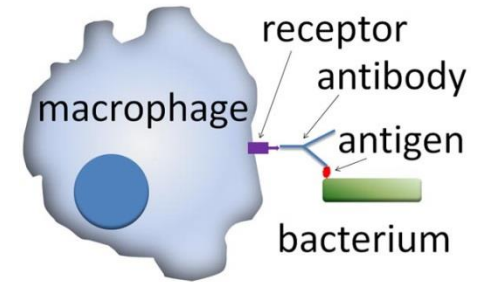
B Lymphocytes (B cells)

Activated B-lymphocytes produce either:

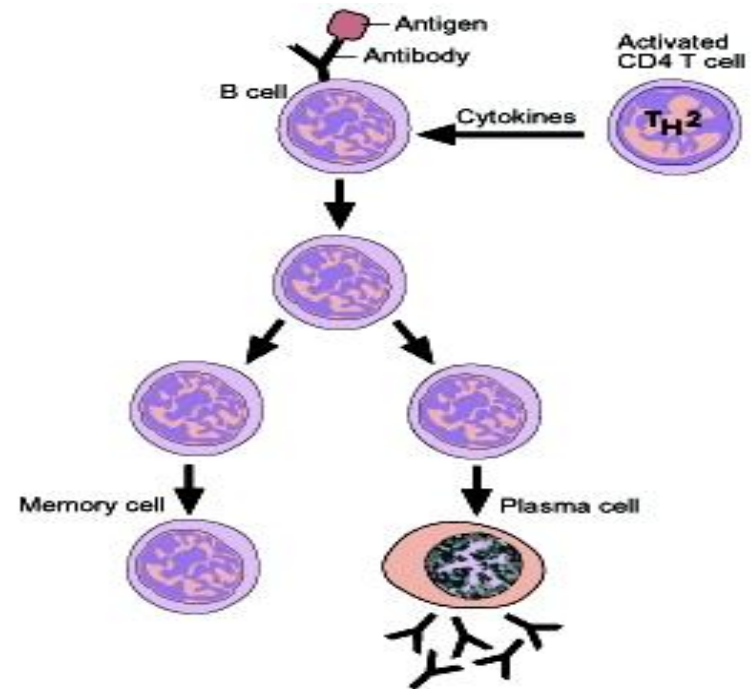
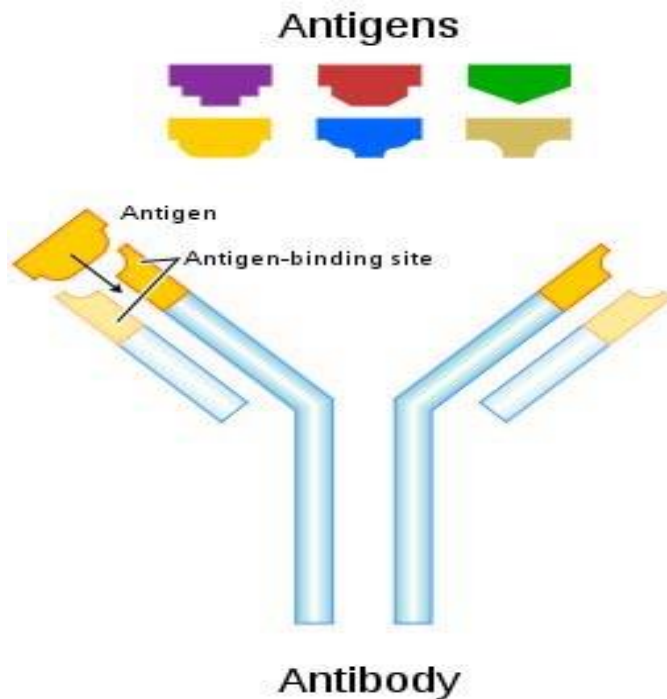
- **Plasma cells** make antibodies to a pathogen.
- **Memory cells** remember the same pathogen for faster antibody production in future infections.



REVIEW!



Animated lesson on Humoral Immune Response



Confused?



Here are links to fun resources that further explain acquired immunity:

- [Immunology: Innate & Acquired Immunity](#) Main Page on the Virtual Cell Biology Classroom of [Science Prof Online](#).
- [Phagocytosis](#) animation and quiz by McGraw-Hill.
- [Immune System](#) "Who Wants to Be a Millionaire" game.
- [Immune System](#) animation and quiz by McGraw-Hill.
- ["Fever"](#), song by Peggy Lee & ["Assassin"](#) song by John Mayer
- [Cellular Immune Response](#) & [Humoral Immune Response](#) narrated animation and quiz from W. H. Freeman.
- [Immune System Defender](#), online game from the Nobel Prize website. Use your force of white blood cells to destroy invading bacteria, before they overpopulate and cause disease.
- [Immune System Game](#), a collection of online fun and educational games about immunology.

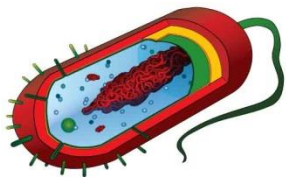
Are microbes intimidating you?



Do yourself a favor. Use the...

Virtual Microbiology Classroom (VMC) !

The VMC is full of resources to help you succeed,
including:



- practice test questions
- review questions
- study guides and learning objectives

You can access the VMC by going to the Science Prof Online website

www.ScienceProfOnline.com