# Pathogens and the immune system

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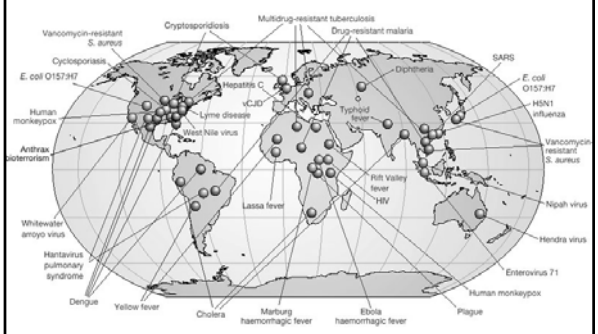
BRC 511 / 530-lab

Lecture 8
BIOE 301-Bioengineering and World Health

## Review of lecture 7

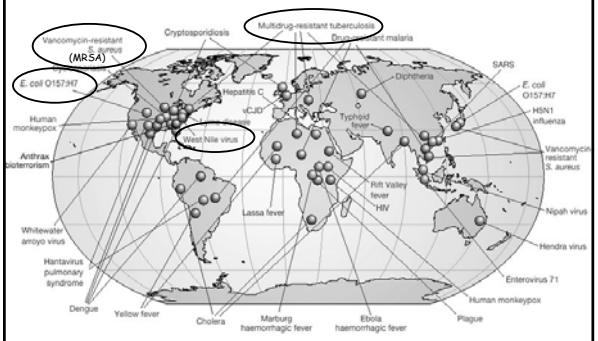
- Science
  - "**Science** is the human activity of seeking natural explanations for what we observe in the world around us."
- Engineering
  - Systematic design, production and operation of technical systems to meet practical human needs under specified constraints
  - Six steps of the engineering design method

## Infectious diseases: a global health problem

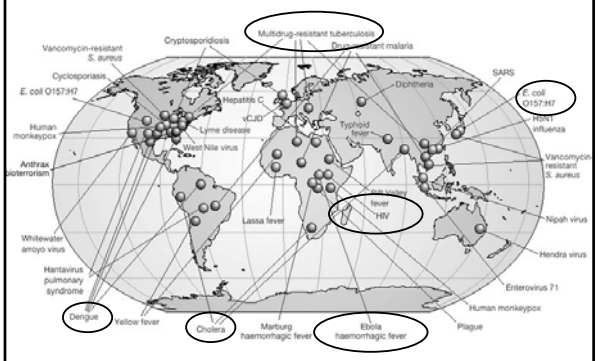



(From Morens, D., et al , 2004)

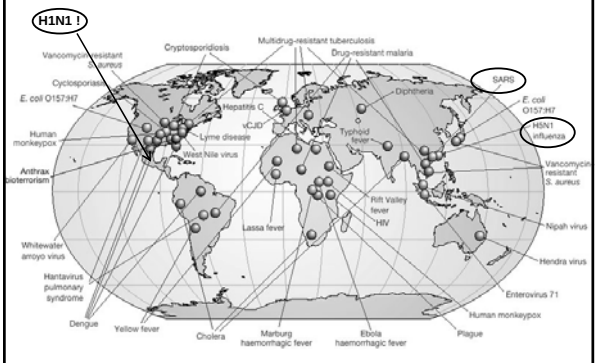
## Infectious diseases: a global health problem




## Infectious diseases: a global health problem




## Infectious diseases: a global health problem



## How can technology help?

### Science

1. Understanding biology: pathogens & disease
   immune system

### Engineering

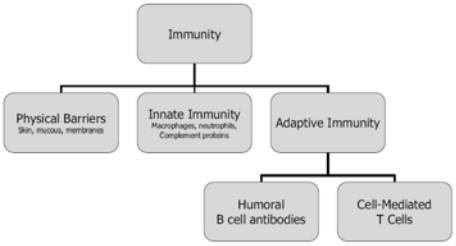
2. Developing vaccines: from idea to product
   - vaccine design
   - production
   - testing safety & effectiveness

3. Addressing challenges for vaccine development:
   - Developed vs. developing countries
   - The AIDS vaccine challenge

## Lecture map

1. The players: Types of pathogens
   Cells of the Immune system

2. Types of Immunity

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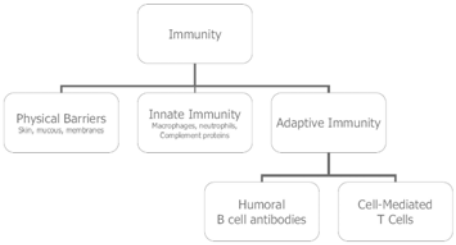



## Types of pathogens

*Mycobacterium tuberculosis*
*Staphylococcus aureus*
*Escherichia coli O147:H7*
*Vibrio cholera*
*Bordetella pertussis (whooping cough)*

Bacteria


*SARS- Severe Acute Respiratory Syndrome*
*Influenza (Flu)*
*HIV (AIDS)*
*Hepatitis C virus*
*Ebola/ Marburg viruses*

Viruses

*Plasmodium sp. (Malaria)*
*Cryptospridium*

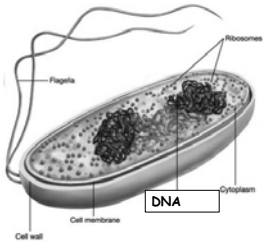
Parasites

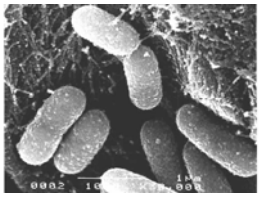
*Candida albicans*

Fungi

## Bacteria

- Cells with membrane and cell wall (usually)
- Can survive & reproduce outside host
- Can be killed or inhibited by antibiotics
- Responsible for >90% of hospital infections

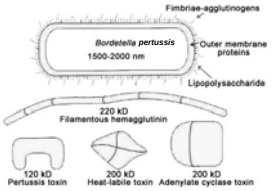


Size ~ 1 µm

## How do bacteria cause disease?

- Invade host
- Reproduce
- Produce toxins which disturb function of normal cells

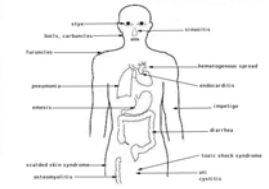


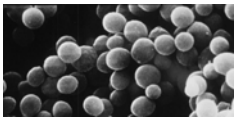


Paralyze cilia & inhibit clearance of respiratory secretions
= whooping cough

## How do bacteria cause disease?

*MRSA: Methycillin Resistant Staphylococcus aureus*

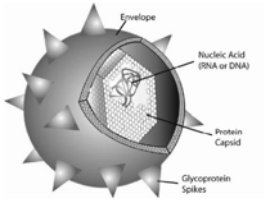


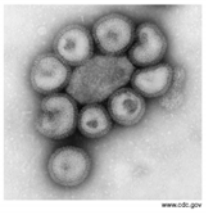


http://www.npr.org/templates/story/story.php?storyId=15453093

## Viruses

- Nucleic acid core surrounded by protein capsid, and for some viruses an envelope
- Use host intracellular machinery to reproduce
- They cannot be killed with antibiotics, but antivirals may inhibit different stages of their life cycle in the host
- >50 viruses that can infect humans



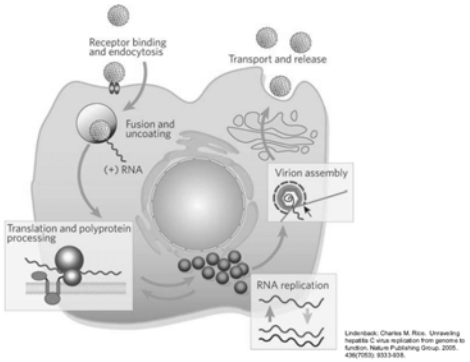



Size ~ 0.1 µm = 100nm

## How do viruses cause disease?

1. Virus invades host cell
   - Binds to cell membrane receptors
   - Endocytosis brings virus into cell
2. Virus takes over cell
   - Use viral nucleic acid and host cell resources to make new viral nucleic acid and proteins
3. More virus is released from host cell
   - Virus causes host cell to lyse OR
   - Viral particles bud from host cell surface

## How do viruses cause disease?




## The Human Immunodeficiency virus (HIV)

Viral components:

-nucleic acid core (RNA)
-protein capsid
-envelope
-Glycoproteins

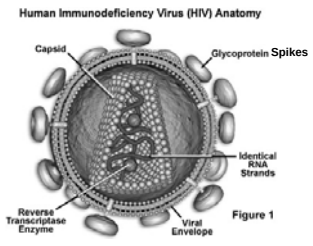
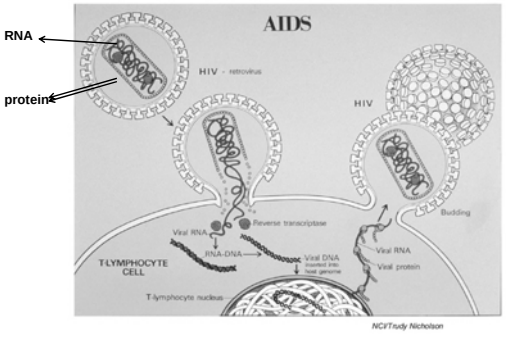
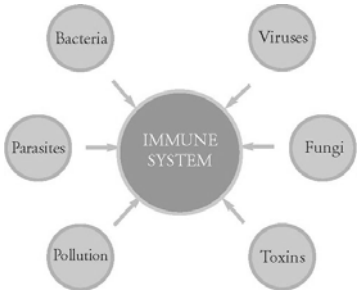



Figure 1

## The Human Immunodeficiency virus (HIV)



## How are we protected against pathogens?

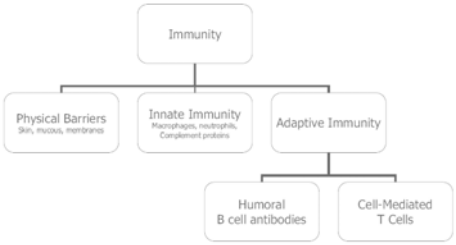



## Role of the Immune System

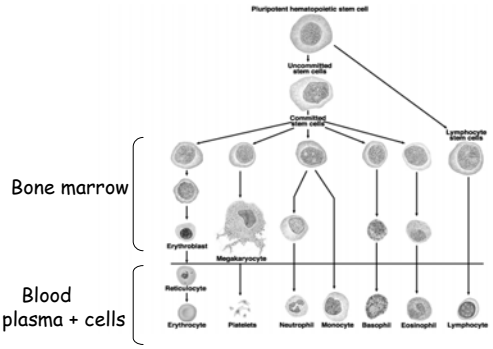
- Defend the body against pathogenic organism
- Recogize self vs. non-self
- Eliminate microbial agents
  - nonspecific mechanisms of the **innate immune system**
  - specific mechanism of the **adaptive immune system**
- Display immunologic memory
- Tolerance of self-antigens

## Lecture map

1. **The players:** Types of pathogens
   **Cells of the Immune system**
2. Types of Immunity



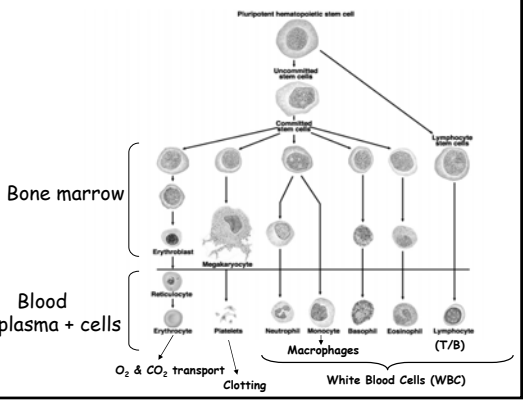

## Cells of the immune system




Bone marrow

Blood
= plasma + cells

## Cells of the immune system

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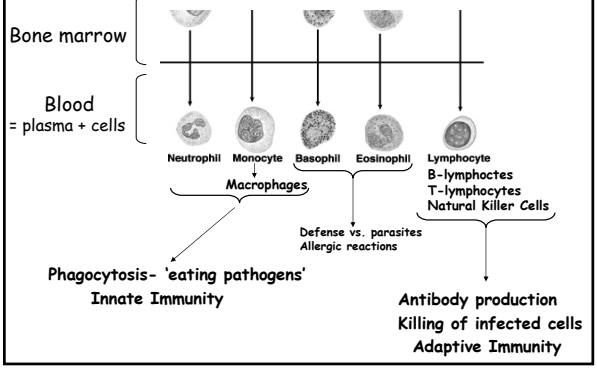


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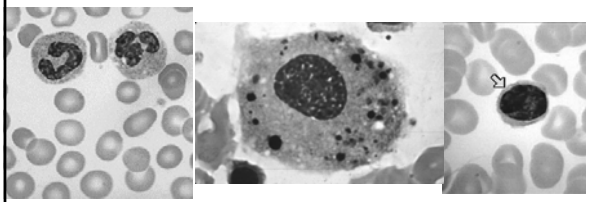

Neutrophil Macrophage Lymphocyte

**Phagocytosis- killing**

**B-lymphocytes**
**T lymphocytes**
**NK cells**

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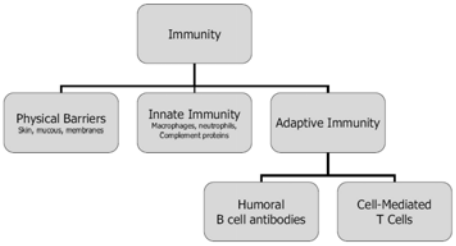


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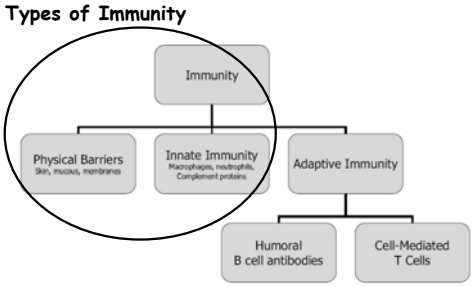
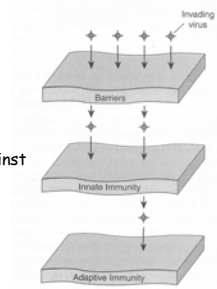



## Types of Immunity

Physical Barriers
- skin (2 square meters!)
- mucose membranes (400 square meters!)

Innate Immune System
- General inflammatory response against pathogens outside of the cell

Adaptive Immune System
- Can adapt to defend against any specific invader inside or outside of the cell
- Important when innate immunity cannot defend against the attack
- Provides 'Immune Memory'




## What happens when you get a splinter?

## What happens when you get a splinter?

- Pathogen makes it past a physical barrier
- Symptoms?
  - Red, swollen, hot, pus
- What causes these symptoms?
  - The Innate immune system is kicking into gear!
- Usually innate immune system can take care of it

## The Innate Immune System: 3 main weapons

-Activated Macrophages
- Phagocyte ('eat') invading pathogens
- Produce chemicals that:
  - increase blood flow (redness & heat)
  - cause 'fluid leaking' (swelling)
  - recruit neutrophils (pus)
- Present antigen to adaptive immune system

-Complement proteins
- Present in tissue and blood
- Attach to surface of bacteria and viruses targeting them for phagocytosis
- Recruit other immune cells from blood

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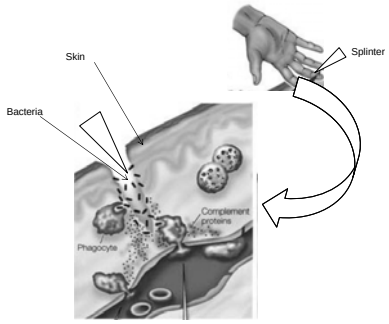


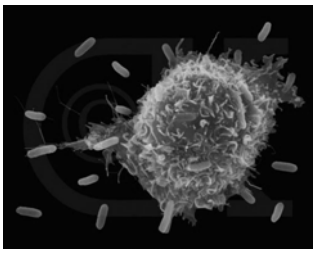

Macrophage attacking *E.coli* SEM x 8,800 ©Denis Kunkel

## Question:

- Can you find the toxins, bacteria and viruses in your kit?
- Based on your understanding of the innate immune system, represent a macrophage during phagocytosis of an invading bacteria


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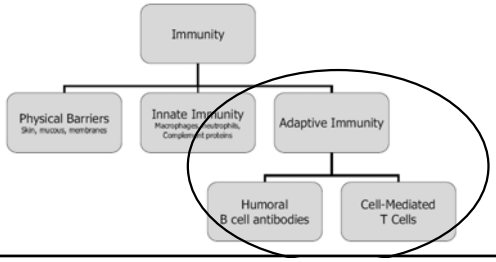



## The Adaptive Immune System

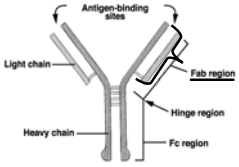
- Recognizes antigens (molecular signatures) specific for each pathogen
- Effective against both intra- and extracellular pathogens
- Two main components:

Humoral immunity
- Relies on Antibodies produced by **B**-lymphocytes
- Fights pathogens outside of cells

Cell-mediated Immunity
- Relies on specific receptors on the surface of **T**-lymphocytes
- Fights pathogens inside of cells

## What is an antibody?

- Bridge between:
  - Pathogen
  - Tool to kill it
- Antibodies have two important regions:
  - Fab region:
    - Binds antigen
    - Binds surface of virus infected cell
  - Fc region:
    - Binds macrophages and neutrophils, induces phagocytosis
    - Binds natural killer cell, induces killing

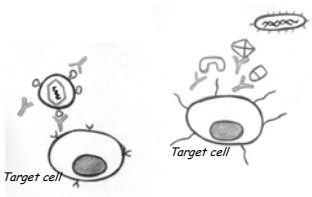



## The Adaptive Immune response: humoral immunity

How do antibodies work?

1. **Neutralization**: Blocking the biological activity of toxin or pathogen *ie. Blocking access*
2. **Bridge:** Bringing together pathogens and phagocytes

## The Adaptive Immune response: humoral immunity




**1. Neutralization**


**2. Bridge: pathogen-phagocyte**

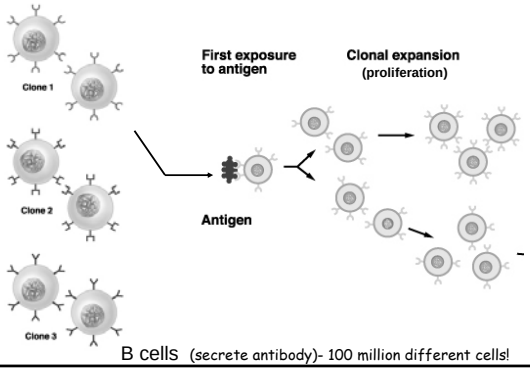
## Question:

- Which components of your kit are most like antibodies?
- Arrange the components of the kit to demonstrate how these antibodies "bridge" a pathogen and the tool to kill it?


## The Adaptive Immune response: humoral immunity

- How are antibodies made?
  - B cells
    - Lymphocytes that make antibodies
    - Have B cell receptors on surface
    - 100 million different types of B cells, each with different surface receptors
    - B cell receptors are so diverse they can recognize every organic molecule
  - When a B cell binds antigen:
    - Proliferates - In one week, clone of 20,000 identical B cells
    - Secretes antibody

## Clonal selection and proliferation




B cells (secrete antibody)- 100 million different cells!

## The Adaptive Immune response: cell-mediated immunity

- How do we kill virus once inside the cell?
  - Antibodies cannot get to it
  - Need T cells
- T Cells
  - Recognize protein antigens
  - When bind antigen, undergo clonal selection
  - Three types of T Cells:
    - Killer T Cells (Cytotoxic T Lymphocytes – CTLs)
    - Helper T Cells (orchestrate adaptive immune response)
    - Regulatory T Cells

## How do T Cells recognize Virus-Infected Cells?

- All cells have **M**ajor **H**istocompatibility **C**omplex (MHC) molecules on surface
- T Cells inspect MHC proteins and use this as a signal to identify infected cells

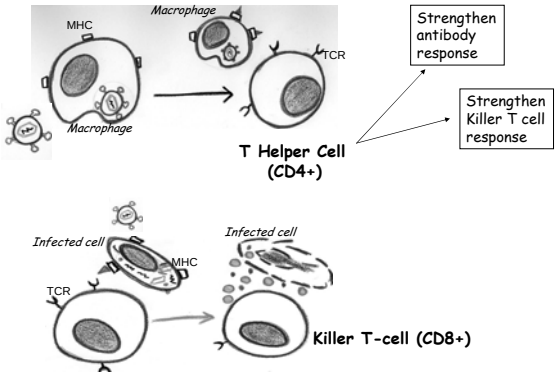
➢ Antigens (bits of pathogens) get loaded into MHC molecules:

- When virus invades target cell, fragments of viral protein are loaded onto MHC proteins
- 'Profesional' Antigen Presentation Cells (APCs= phagocytes of innate immunity)

## Question:

- Demonstrate how the T cell can identify a virus infected cell: antigen presentation
- Why is this component of the adaptive immune system a significant advance over the innate immune system?

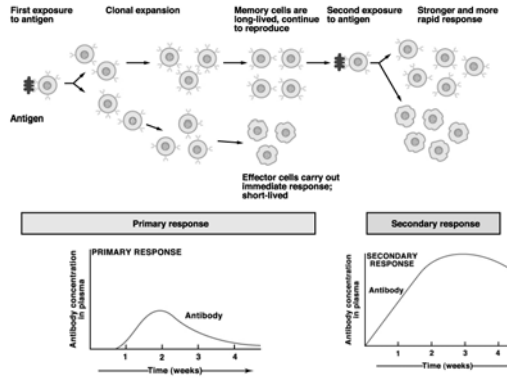
## Antigen presentation and cellular immunity




## Immunologic Memory

- **First time** adaptive immune system is activated by an antigen:
  - Build up a clone of B cells and T cells
  - Takes about a week
  - After infection is over, most die off
  - Some remain – memory cells
- **Second time** adaptive immune system is activated by that antigen:
  - Memory cells are easier to activate
  - Response is much faster – no symptoms

## Immunologic Memory



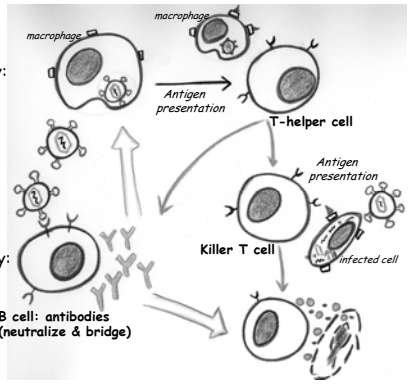
The adaptive Immune Response

Putting it together…

## The Adaptive immune response

1. Cellular Immunity:

2. Humoral Immunity:




## Summary of lecture 8

- Pathogens: Bacteria and Virus
- Levels of Immunity:
  - Barriers → First line of defense
  - Innate → Inflammation
    - Phagocytes
    - Complement
  - Adaptive → Immunologic memory
    - Antibody mediated immunity
    - Cell mediated immunity → Pathogens within cells
    - Diversity to recognize 100 million antigens

The end.

## What happens when you get a splinter?