Homeostatic Disruptions and the Immune System
Disruptions to Dynamic Homeostasis

• Disruptions at the molecular and cellular level affect the health of the organism = death and disease

Examples include:
– Dehydration
– Pathogens
– Toxins
– Allergens
Pathogens

- Infectious agent that causes disease
- Microorganisms (bacteria, parasites, fungi) and viruses
Toxins

• Biologically produced poison

Examples include:
- bee stings
- black widow spiders
- botulinum toxin
Allergens

• Any substance (antigen) that causes an allergic reaction (hypersensitive immune response)

Common allergens:
- pollen
- pet dander
- antibiotics
- foods
- insect stings
Defense Mechanisms
Pathogens (such as bacteria, fungi, and viruses)

**INNATE IMMUNITY**
(all animals)
- Recognition of traits shared by broad ranges of pathogens, using a small set of receptors
- Rapid response

**Barrier defenses:**
- Skin
- Mucous membranes
- Secretions

**Internal defenses:**
- Phagocytic cells
- Natural killer cells
- Antimicrobial proteins
- Inflammatory response

**ADAPTIVE IMMUNITY**
(vertebrates only)
- Recognition of traits specific to particular pathogens, using a vast array of receptors
- Slower response

**Humoral response:**
- Antibodies defend against infection in body fluids.

**Cell-mediated response:**
- Cytotoxic cells defend against infection in body cells.
Animal Nonspecific Defenses (Innate Immunity)

- Physical and chemical barriers (skin, mucous membranes, stomach acids, enzymes, “good” bacteria)
- Inflammation and swelling (mast cells, macrophages, and neutrophils)
Plant Nonspecific Defenses

• Plants have molecular recognition systems that trigger systemic responses
• Infection triggers chemical responses that destroy infected and adjacent cells, results in a localizing effect

Example: Hypersensitive Response in Plants
Vertebrate Specific Defenses (Acquired or Adaptive Immunity)

• Develops only after exposure to a pathogen
• Involves an antigen-antibody interaction
• Two types of specific immune responses:

1. Humoral Response

2. Cell-Mediated Response
Very Important Cells

- Phagocytic cells (macrophages, dendritic cells)
- Natural Killer Cells
- B cells
- Helper T cells
- Cytotoxic T cells
Macrophage

- Responsible for nonspecific and specific defenses
- Engulfs and digests any foreign debris that does not match the healthy cells of the body (bacteria, viruses, cancer cells, “marked” cells)
Natural Killer Cells – Born to Kill!

- Do not require activation
- Detect abnormal surface proteins of virus-infected cells and cancer cells
- Cause cell death (do not engulf cells)
B cells and T cells (lymphocytes)
B cells

• Plasma B cells (effector cells) produce antibodies
T Cells

- Helper T cells and cytotoxic T cells (effector cells)
B Cell and T Cell Antigen Receptors

- ~100,000 antigen receptors per cell
Antigen-Antibody Interaction
Antigen-Antibody Interaction

- **Antigen**: any substance that causes the immune system to produce antibodies ("antibody-generating")

- **Antibodies**: Y-shaped proteins that are produced by **B cells**, identify and neutralize pathogens (antigens), specific shapes to antigens
Humoral Versus Cell-Mediated Response

The humoral immune response:
- B cell makes antibodies which bind to antigens in body fluid.

The cell-mediated immune response:
- T cell binds to infected body cell and self-nonself complex.
Humoral Response

That one looks delicious!
Humoral Response

- Defends against pathogens in the body fluids (blood, lymph, interstitial fluids)
- Involves B cells
- B cells secrete antibodies against specific antigens
Humoral Response (Primary)

1. B cells with different antigen receptors
   - Antigen receptor on the cell surface

2. Antigen molecules
   - First exposure to the antigen

3. Cell activation: growth, division, and differentiation
   - Antibody molecules
   - Endoplasmic reticulum
   - Plasma (effector) cells secreting antibodies
   - First clone
   - Memory cells
Humoral Response (Secondary)

- Second exposure to the same antigen
- Memory cells
- Antibody molecules
- Clone of plasma (effector) cells secreting antibodies
- Second clone
- Clone of memory cells
What do antibodies do?

1. Mark cell for destruction by immune cells
2. Block receptors
3. Deliver toxic payload
Primary and Secondary Immune Response
Cell-Mediated Response

T-cell: B-cells! Over here! I found them!

B-cell: You nark! I thought we were friends!

Oh god, which antibody do I use!? I've never seen this one before!
Cell-Mediated Response

- Attack body cells that have been infected with pathogens
- Involves T cells (Helper T cells and Cytotoxic T cells) and B cells
Cell-Mediated Response

- Antigen presented by macrophage
- T cell antigen receptor
- Cytotoxic (killer) T cell
  - Cell-mediated immunity (attack on infected cells)
- Helper T cell
  - Cytokines
- B cell
  - Humoral immunity (secretion of antibodies by plasma cells)
- Antigen processing
- Self-protein
- Cytokines
T Cells

Helper T cell

Cytotoxic T cell
Helper T Cells

Three ways to “help” the immune response:

• Stimulate **B cells** to produce more antibodies to the specific antigen

• Activate and increase the number of **macrophages**

• Activate **cytotoxic (killer) T cells** for the cell mediated response
Cytotoxic (Killer) T Cells

- Target and destroy cells infected with pathogens
MHC (Major Histocompatibility Complex)

1. A fragment of foreign protein (antigen) inside the cell associates with an MHC molecule and is transported to the cell surface.

2. The combination of MHC molecule and antigen is recognized by a T cell, alerting it to the infection.

Figure 43.9b
CD4

- Accessory protein that helps to bind the helper T cell to “presented” antigen on the surface of the macrophage
HIV and Helper T Cells

(a) Structure of HIV.

(b) HIV infecting a CD4 T cell. The gp120 spike of HIV attaches to a CD4 receptor with CCR5 or CXCR4 coreceptors. The HIV capsid then enters the cell by fusion, leaving its envelope behind.
Dengue Virus Life Cycle

Malaria: Human Host

Cloning an Army of T Cells