

## Regulating the Internal Environment

### Maintaining Homeostasis



---

---

---

---

---

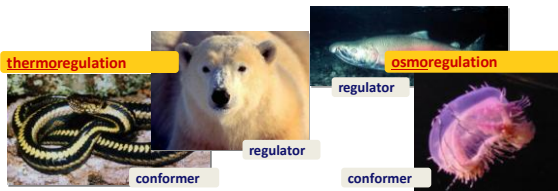
---

---

---

## Conformers vs. Regulators

- Two evolutionary paths for organisms
  - regulate internal environment
    - maintain relatively constant internal conditions
  - conform to external environment
    - allow internal conditions to fluctuate along with external changes



---

---

---

---

---

---

---

---

## Homeostasis

- **Keeping the balance**
  - animal body needs to coordinate many systems all at once
    - temperature
    - blood sugar levels
    - energy production
    - water balance & intracellular waste disposal
    - nutrients
    - ion balance
    - cell growth
  - maintaining a “steady state” condition

---

---

---

---

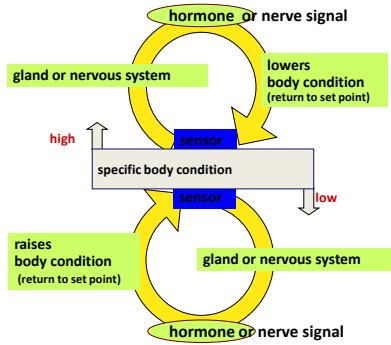
---

---

---

---

## Negative Feedback Loop



---

---

---

---

---

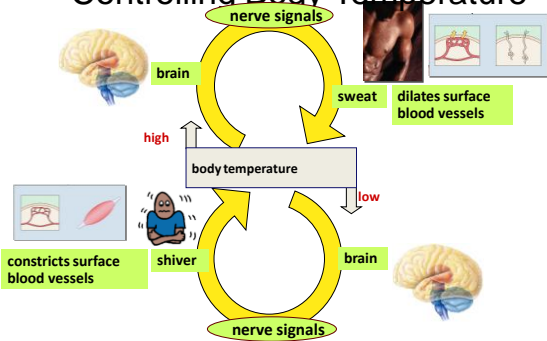
---

---

---

## Nervous System Control

### Controlling Body Temperature



---

---

---

---

---

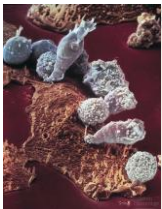
---

---

---



## Immune / Lymphatic System



---

---

---

---

---

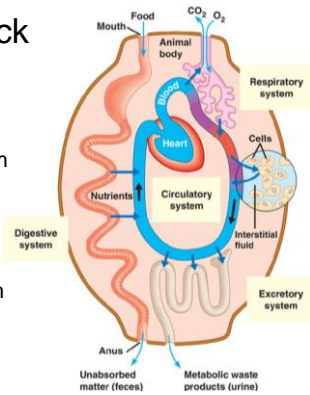
---

---

---

## Avenues of attack

- Points of entry
  - digestive system
  - respiratory system
  - urogenital tract
  - break in skin
- Routes of attack
  - circulatory system
  - lymph system




---

---

---

---

---

---

---

---

## Why an immune system?

- Attack from outside
  - lots of organisms want you for lunch!
  - animals are a tasty nutrient- & vitamin-packed meal
    - cells are packages of macromolecules
    - no cell wall
      - traded mobility for susceptibility
  - animals must defend themselves against invaders
    - viruses
      - HIV, flu, cold, measles, chicken pox, SARS
    - bacteria
      - pneumonia, meningitis, tuberculosis
    - fungi
      - yeast ("Athlete's foot"...)
    - protists
      - amoeba, Lyme disease, malaria
- Attack from inside
  - defend against abnormal body cells = cancers




---

---

---

---

---

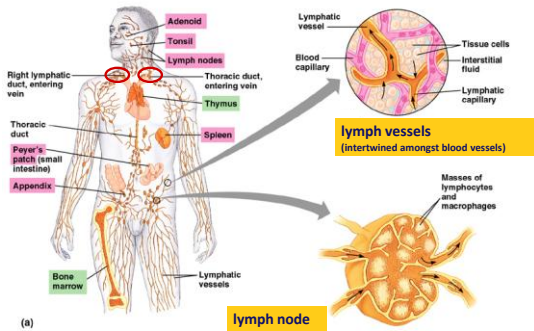
---

---

---

## Lymph system

**Production & transport of leukocytes**  
Traps foreign invaders




---

---

---

---

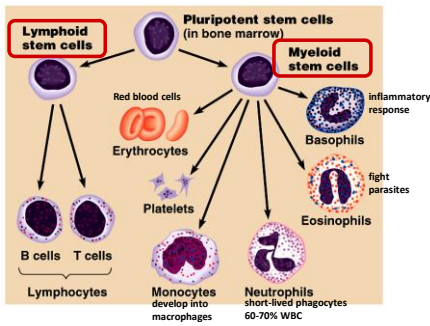
---

---

---

---

## Development of Red & White blood cells




---

---

---

---

---

---

---

---

---

---

## Lines of defense

- 1st line: **Barriers**
  - broad, **external** defense
    - "walls & moats"
    - skin & mucus membranes
- 2nd line: **Non-specific patrol**
  - broad, **internal** defense
    - "patrolling soldiers"
    - **leukocytes = phagocytic WBC**
      - **macrophages**
- 3rd line: **Immune system**
  - specific, **acquired immunity**
    - "spies"
  - **lymphocytes & antibodies**
    - **B cells & T cells**



Bacteria & insects  
 inherit **resistance**.  
 Vertebrates  
 acquire **immunity!**

---

---

---

---

---

---

---

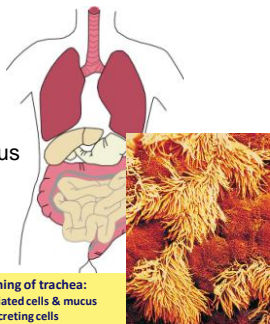
---

---

---

## 1st line: External defense

- Physical & chemical defenses
  - non-specific defense
- external barrier
  - epithelial cells & mucus membranes
    - skin
    - respiratory system
    - digestive system
    - uro-genital tract



Lining of trachea:  
ciliated cells & mucus  
secreting cells

---

---

---

---

---

---

---

---

---

---

## 1st line: Chemical barriers on epithelium

### ▪ Skin & mucous membrane secretions

- sweat
  - pH 3-5
- tears
  - washing action
- mucus
  - traps microbes
- saliva
  - anti-bacterial = "lick your wounds"
- stomach acid
  - pH 2
- anti-microbial proteins
  - lysozyme enzyme
    - digests bacterial cell walls




---

---

---

---

---

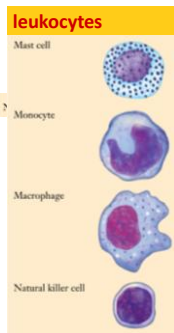
---

---

---

## 2nd line: Internal, broad range patrol

- Innate, general defense
  - rapid response
- Patrolling cells & proteins
  - attack invaders that penetrate body's outer barriers
    - **leukocytes**
      - **phagocytic** white blood cells
    - complement system
      - anti-microbial proteins
    - inflammatory response




---

---

---

---

---

---

---

---

## Leukocytes: Phagocytic WBCs

- Attracted by chemical signals released by damaged cells
  - enter infected tissue, engulf & ingest microbes
    - **lysosomes**
- **Neutrophils**
  - most abundant WBC (~70%)
  - ~ 3 day lifespan
- **Macrophages**
  - "big eater", long-lived
- **Natural Killer Cells**
  - destroy virus-infected cells & cancer cells




---

---

---

---

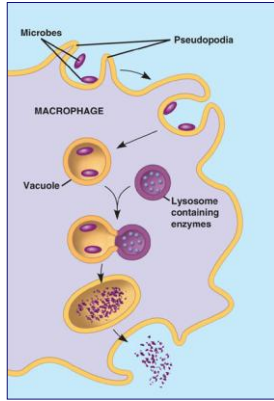
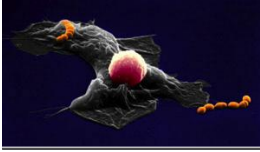
---

---

---

---

# Phagocytes




---

---

---

---

---

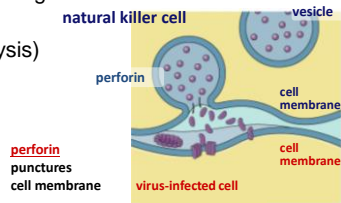
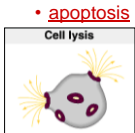
---

---

---

## Destroying cells gone bad!

- Natural Killer Cells perforate cells
  - release **perforin** protein
  - insert into membrane of target cell
  - forms pore allowing fluid to flow into cell
  - cell ruptures (lysis)




---

---

---

---

---

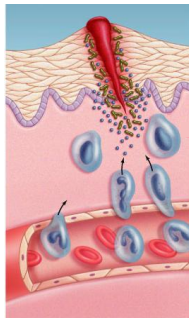
---

---

---

## Inflammatory response

- Damage to tissue triggers local non-specific **inflammatory response**
  - release **histamines** & **prostaglandins**
  - capillaries dilate, more permeable (leaky)
    - increase blood supply
    - delivers WBC, RBC, platelets, clotting factors
    - fight pathogens
    - clot formation
    - accounts for swelling, redness & heat of inflammation & infection




---

---

---

---

---

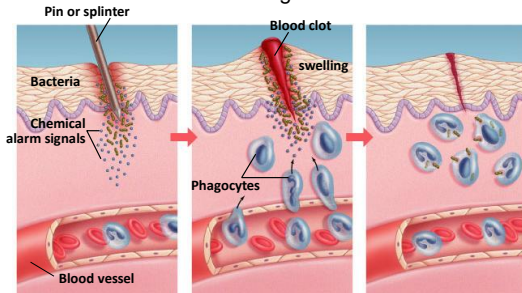
---

---

---

## Inflammatory response

- Reaction to tissue damage




---

---

---

---

---

---

---

---

## Fever

- When a local response is not enough
  - systemic response to infection
  - activated macrophages release interleukin-1
    - triggers hypothalamus in brain to readjust body thermostat to raise body temperature
  - higher temperature helps defense
    - inhibits bacterial growth
    - stimulates phagocytosis
    - speeds up repair of tissues
    - causes liver & spleen to store iron, reducing blood iron levels
      - bacteria need large amounts of iron to grow




---

---

---

---

---

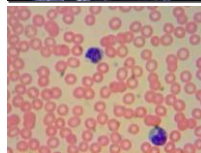
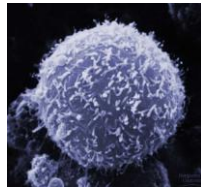
---

---

---

## 3rd line: Acquired (active) Immunity

- Specific defense
  - lymphocytes
    - B lymphocytes (B cells)
    - T lymphocytes (T cells)
  - antibodies
    - immunoglobulins
- Responds to...
  - antigens
    - specific pathogens
    - specific toxins
    - abnormal body cells (cancer)




---

---

---

---

---

---

---

---

## How are invaders recognized: Antigens

- **Antigens**
  - proteins that serve as cellular name tags
    - **foreign antigens** cause response from WBCs
      - viruses, bacteria, protozoa, parasitic worms, fungi, toxins
      - non-pathogens: pollen & transplanted tissue
- **B cells & T cells respond to different antigens**
  - B cells recognize **intact antigens**
    - pathogens in blood & lymph
  - T cells recognize **antigen fragments**
    - pathogens which have already infected cells




---

---

---

---

---

---

---

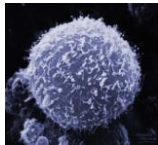
---

---

---

## B cells

- **Humoral response** = "in fluid"
  - defense against attackers circulating freely in blood & lymph
- **Specific response**
  - produce specific **antibodies** against specific **antigen**
- **Types of B cells**
  - **plasma cells**
    - immediate production of antibodies
    - rapid response, short term release
  - **memory cells**
    - long term immunity




---

---

---

---

---

---

---

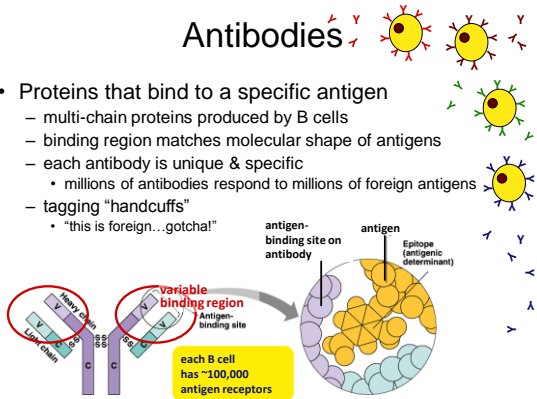
---

---

---

## Antibodies

- **Proteins that bind to a specific antigen**
  - multi-chain proteins produced by B cells
  - binding region matches molecular shape of antigens
  - each antibody is unique & specific
    - millions of antibodies respond to millions of foreign antigens
  - tagging "handcuffs"
    - "this is foreign...gotcha!"




---

---

---

---

---

---

---

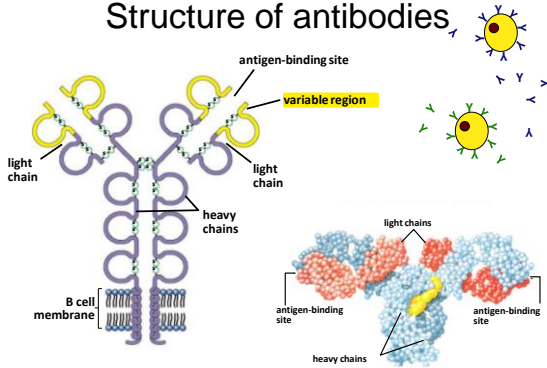
---

---

---



## Structure of antibodies



---

---

---

---

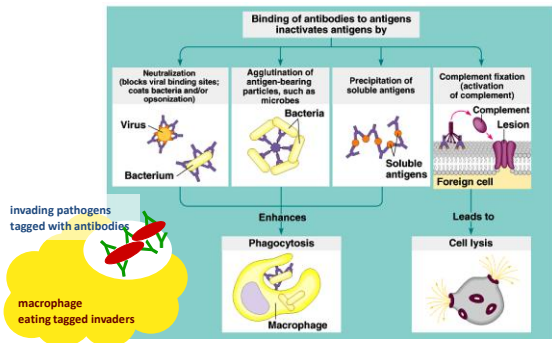
---

---

---

---

## How antibodies work



---

---

---

---

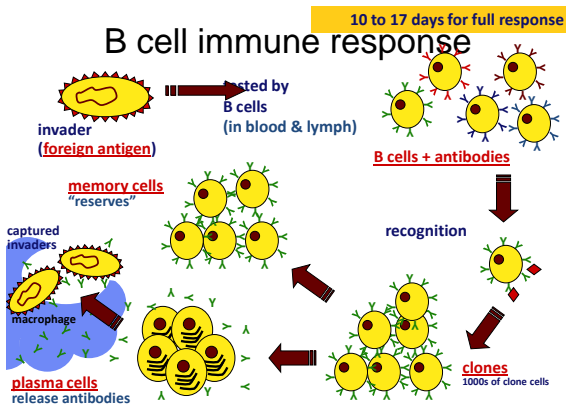
---

---

---

---

## B cell immune response



---

---

---

---

---

---

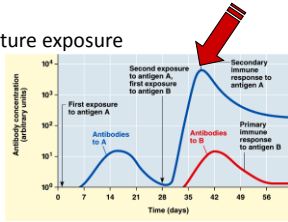
---

---

# Vaccinations



- Immune system exposed to harmless version of pathogen
  - stimulates B cell system to produce antibodies to pathogen
    - “active immunity”
  - rapid response on future exposure
  - creates immunity without getting disease!
- Most successful against viruses




---

---

---

---

---

---

---

---

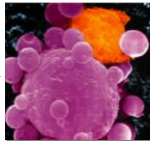
---

---

What if the attacker gets past the B cells in the blood & actually infects some of your cells?

You need trained assassins to kill off these infected cells!

Attack of the Killer T cells!




---

---

---

---

---

---

---

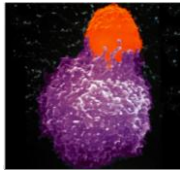
---

---

---

## T cells

- Cell-mediated response
  - immune response to infected cells
    - viruses, bacteria & parasites (pathogens) within cells
  - defense against “non-self” cells
    - cancer & transplant cells
- Types of T cells
  - helper T cells
    - alerts immune system
  - killer (cytotoxic) T cells
    - attack infected body cells




---

---

---

---

---

---

---

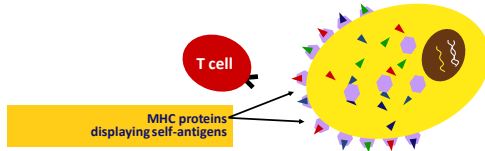
---

---

---

### How are cells tagged with antigens

- Major histocompatibility (MHC) proteins
  - antigen glycoproteins
- MHC proteins constantly carry bits of cellular material from the cytosol to the cell surface
  - “snapshot” of what is going on inside cell
  - give the surface of cells a unique label or “fingerprint”



---

---

---

---

---

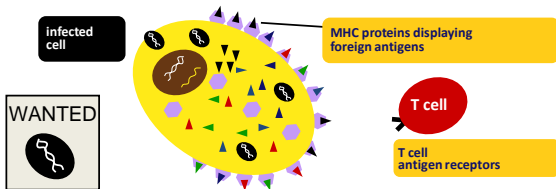
---

---

---

### How do T cells know a cell is infected?

- Infected cells digest pathogens & MHC proteins bind & carry pieces to cell surface
  - antigen presenting cells (APC)
  - alerts Helper T cells



---

---

---

---

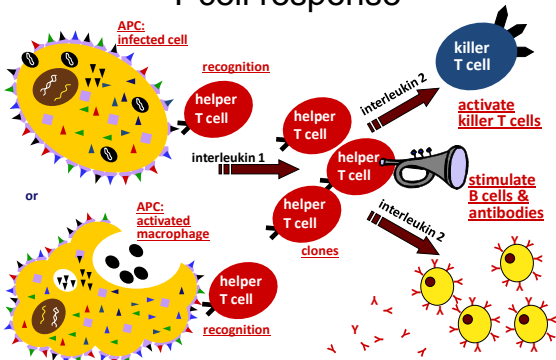
---

---

---

---

### T cell response



---

---

---

---

---

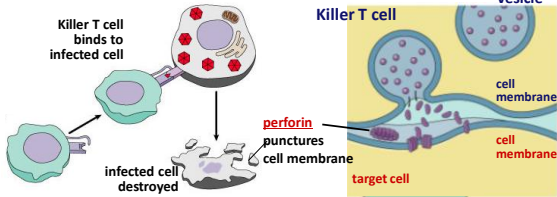
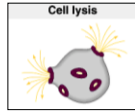
---

---

---

## Attack of the Killer T cells

- Destroys infected body cells
  - binds to target cell
  - secretes perforin protein
    - punctures cell membrane of infected cell



---

---

---

---

---

---

---

---