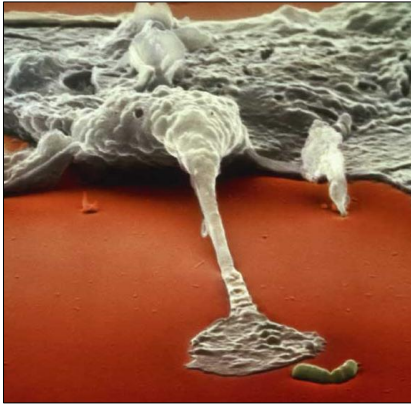


Chapter 20:
The Immune System



Pathogens:
Microscopic organisms
that cause disease

- Viruses
- Bacteria
- Fungi
- Protists

Chapter 20: Immune System

How Does a Body Defend Against Invasion?

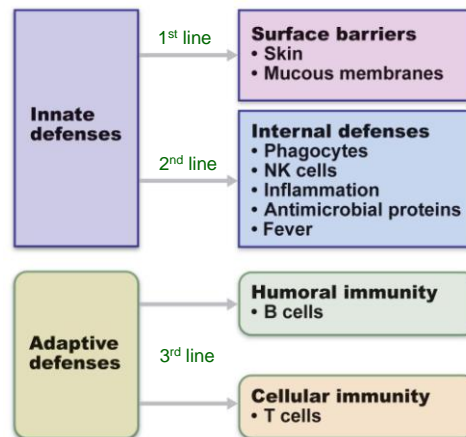
1) **Innate** (nonspecific) **defenses:**

- Rapid responders
- Do not distinguish threat

Two systems linked together...

2) **Adaptive** (specific) **defenses:**

- Slow responders
- Defend against particular threats



Marieb & Hoehn – Figure 20.1

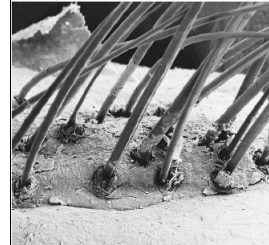
Innate (nonspecific) Defenses:

1) **Surface Barriers:**

- Prevent microbes from entering body

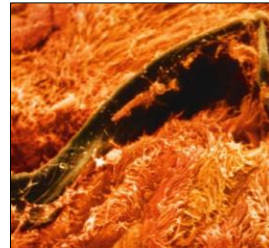
A) **Skin:**

- Multiple layers / keratinized cells / desmosomes
- Inhospitable environment
 - Dry, nutrient-free zone
 - Sweat / oil gland secretions (low pH; antibiotics)
 - Skin sloughs off



B) **Mucous membranes** (e.g., digestive tract):

- Secrete mucus (traps microbes):
 - Anti-bacterial enzymes
 - Cilia sweep up mucus (swallowed)



How Does a Body Defend Against Invasion?

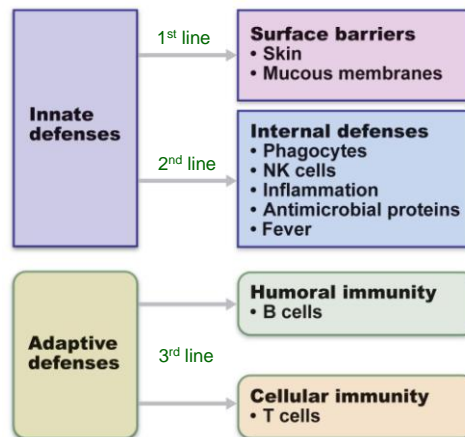
1) **Innate** (nonspecific) **Defenses:**

- Rapid responders
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Two systems linked together...

2) **Adaptive** (specific) **Defenses:**

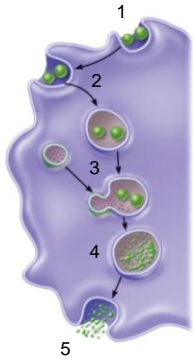
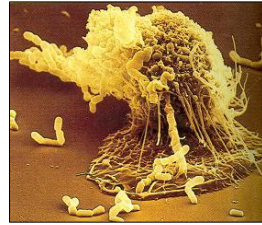
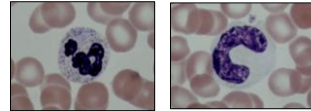
- Slow responders
- Defend against particular threats



Innate (nonspecific) Defenses:

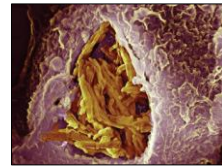
2) **Phagocytes:**

- 'First line of cellular defense'
- A) **Macrophages** (free / fixed):
 - Large phagocytic cells; derived from **monocytes**
- B) **Neutrophils** (microphages):
 - Phagocytize cellular debris / invading bacteria



Events of **phagocytosis:**

- 1) Phagocyte adheres to pathogen / debris
- 2) Phagocyte engulfs pathogen (phagosome)
- 3) Lysosome fuses with phagosome
- 4) Hydrolytic enzymes digest pathogen
- 5) Waste material released via exocytosis



Respiratory burst:
Free radical production
(nitric oxide / superoxide)

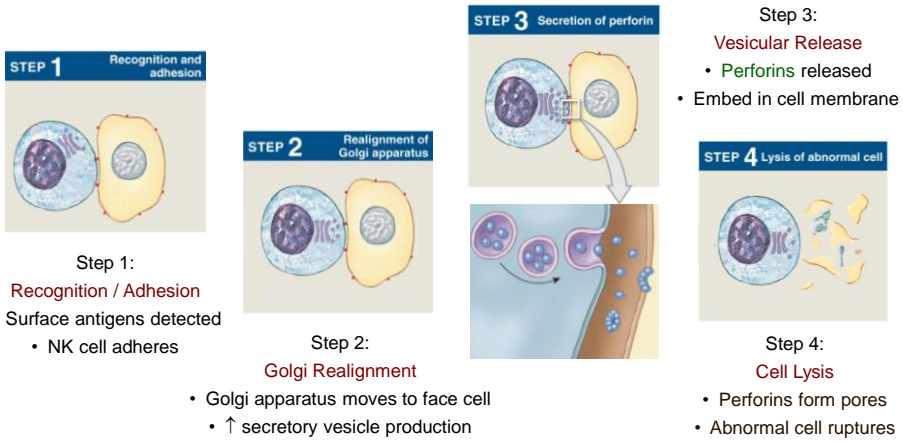
Lifespan of phagocytes
relatively short (~ hours / days)

Marieb & Hoehn – Figure 20.2

Innate (nonspecific) Defenses:

3) **Natural Killer Cells:**

- Highly versatile; recognize a variety of antigens (viral / tumor-specific)
- Rapid responders (only need contact with abnormal cell)

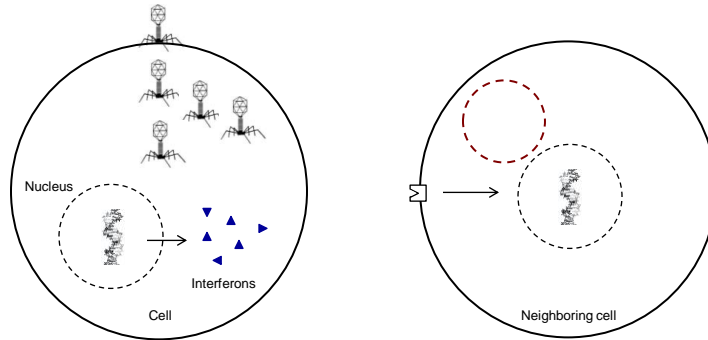


Innate (nonspecific) Defenses:

4) **Antimicrobial proteins:**

A) **Interferons:**

- Small proteins released by lymphocytes / macrophages / virus-infected cells
- Triggers production of anti-viral proteins in healthy cells (slow spread of infection...)

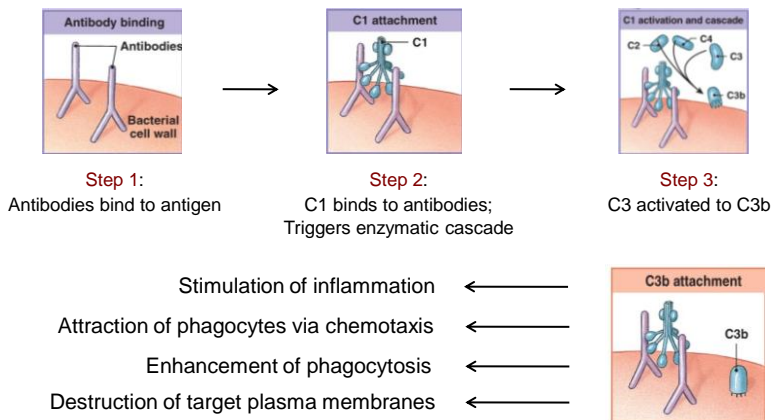


Innate (nonspecific) Defenses:

4) **Antimicrobial proteins:**

B) **Complement:**

- Special proteins (~ 20) found in blood plasma (**complement system**)
- Assist the action of antibodies (B cells):



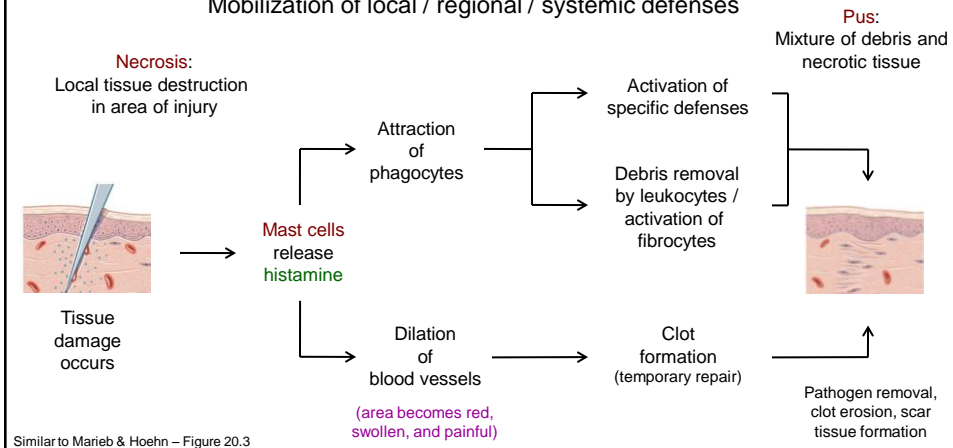
Innate (nonspecific) Defenses:

Cardinal signs and symptoms of inflammation

5) **Inflammation** ("to set on fire"):

tumor rubor calor dolor

- Localized tissue response that produces swelling, redness, heat, and pain
- Triggered by multiple stimuli (e.g., impact / abrasion / infection / chemical irritation)
- Effects = Temporary repair of injured site; inhibition of pathogen spread
Mobilization of local / regional / systemic defenses



Innate (nonspecific) Defenses:

Within limits, a fever is beneficial to the body...

6) **Fever**:

- Maintenance of body temperature above 37.2°C (99°F)
- Triggered by circulating **pyrogens** (proteins); released by active macrophages
- Function: Inhibit virus replication / bacterial growth
Triggers liver / spleen to sequester iron / zinc (necessary for bacterial growth)
Increases body metabolism (↑ 1°C = 10% metabolic increase)

How Does a Body Defend Against Invasion?

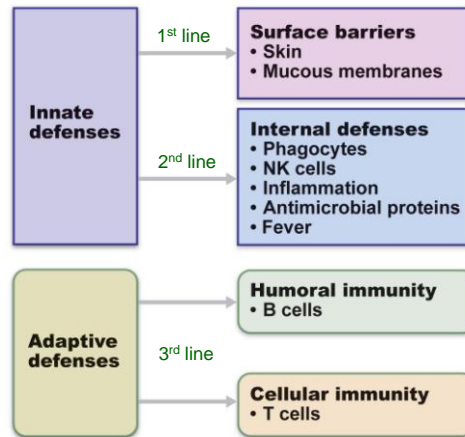
1) Innate (nonspecific) Defenses:

- Rapid responders
- Do not distinguish threat

Two systems linked together...

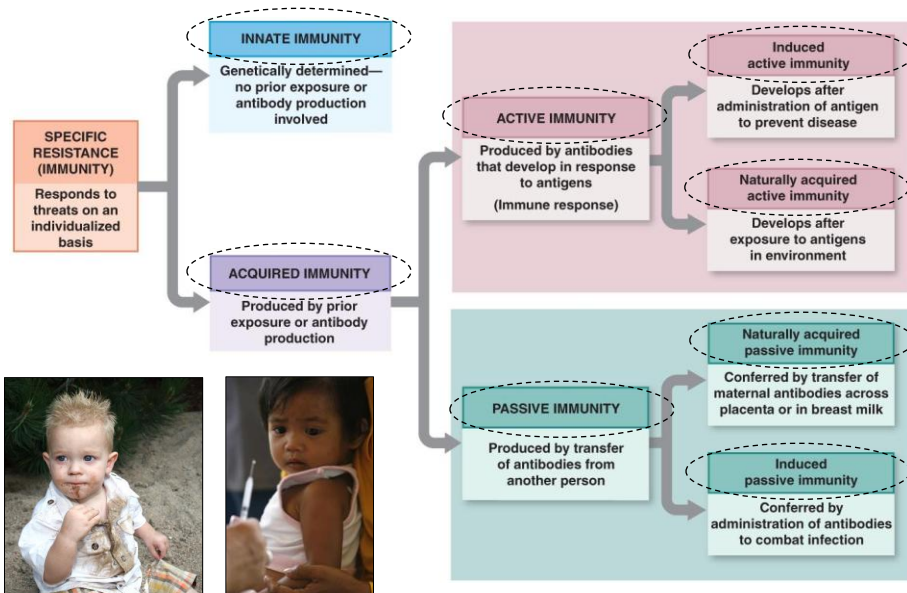
2) Adaptive (specific) Defenses:

- Slow responders
- Defend against particular threats



Marieb & Hoehn – Figure 20.1

Adaptive (Specific) Defenses:



General Properties of Adaptive Defense System:

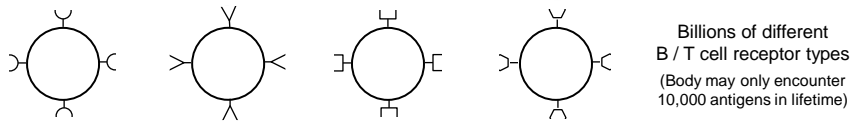
1) **Specificity:**

- System designed to target specific antigen (B / T cells have specialized receptors)



2) **Versatility:**

- System designed to respond to multiple antigens (diverse B / T cell populations)



3) **Memory:**

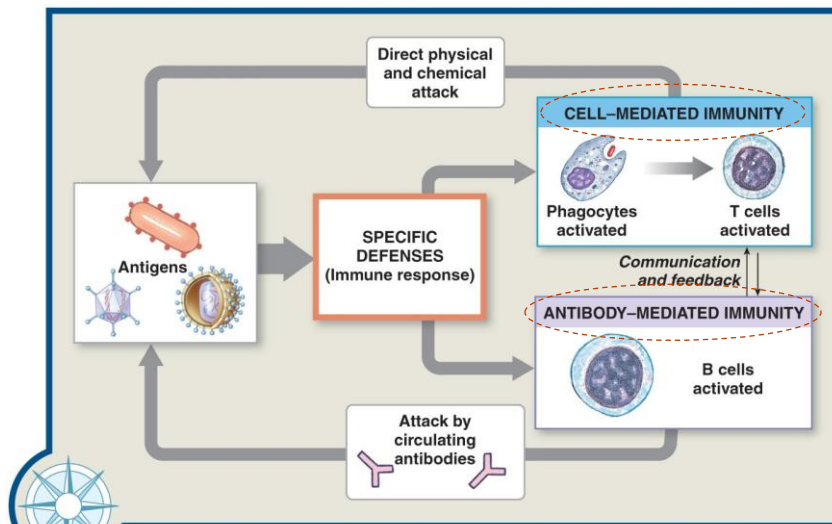
- System designed to 'remember' specific antigen invasions

4) **Tolerance:**

- System designed to 'ignore' normal tissue antigens ('self' recognition)

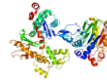
Overview of Adaptive Defense Response:

Defense against abnormal cells and pathogens inside cells



Defense against antigens and pathogens in body fluids

Proteins are the strongest antigens



Antigen:

- Substances that mobilize the adaptive defenses and provoke an immune response

Antigen = “Antibody generating”

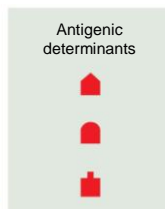
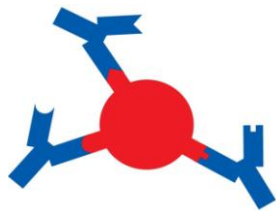
A) **Complete antigen**

- Able to stimulate proliferation of lymphocytes and react with activated lymphocytes / antibodies

B) **Incomplete antigen** (or hapten)

- Not able to stimulate proliferation of lymphocytes but will be reactive to lymphocytes / antibodies (e.g., penicillin / animal dander)

- **Antigenic determinant:** Portion of antigen recognized by immune system

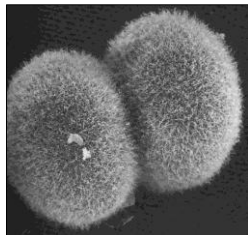


- Most antigens have multiple antigenic determinants on their surface
- Different antigenic determinants may mobilize different lymphocyte populations

Marieb & Hoehn – Figure 20.7

Self-Antigens:

- Protein molecules located on the outside of cells that are not foreign to your own immune system, but are strongly antigenic to other individuals



Skin graft rejection

Major Histocompatibility Complex (MHC) Proteins

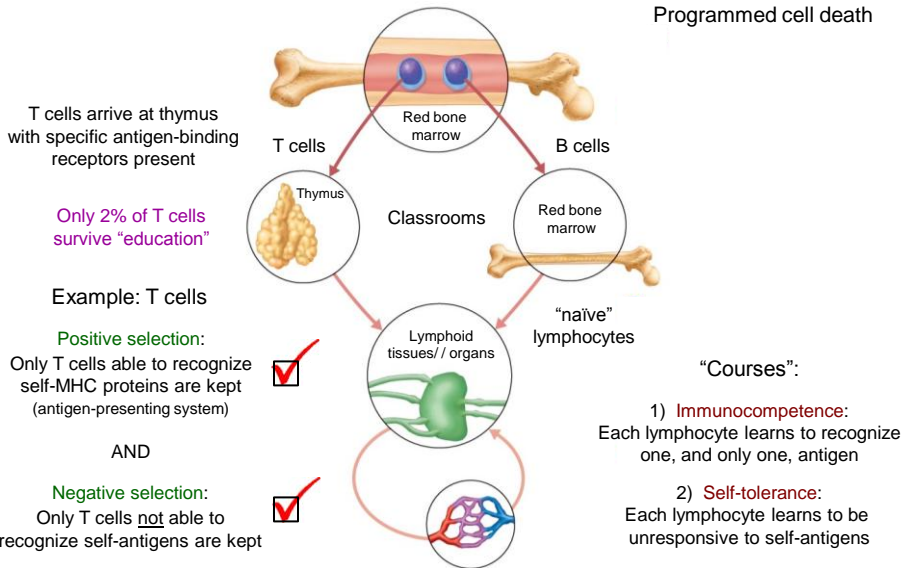
- Unique glycoproteins found on surface of cells that act as antigen-presenting agents:
 - **Class I** MHC proteins: All body cells
 - **Class II** MHC proteins: Select body cells



Antigen

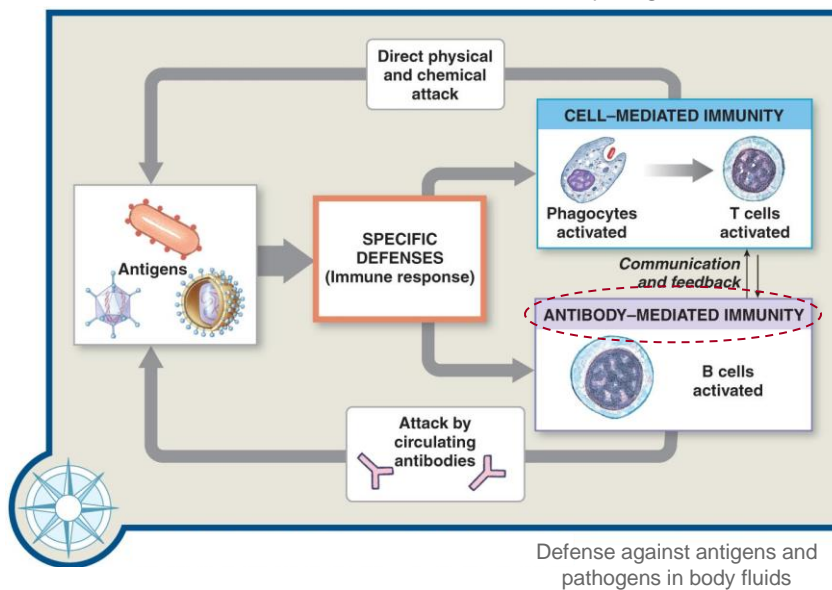
MHC proteins have a deep groove that allows peptides to be displayed

Lymphocyte "Education":



Overview of Adaptive Defense Response:

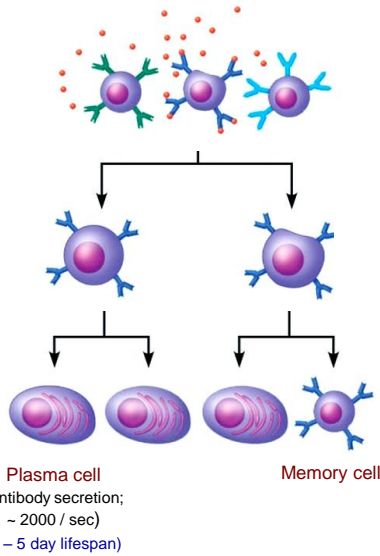
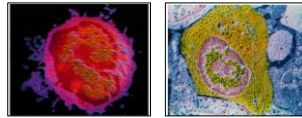
Defense against abnormal cells and pathogens inside cells



B cell → Plasma cell

Antibody-Mediated Immunity (B cells):

Clonal Selection:



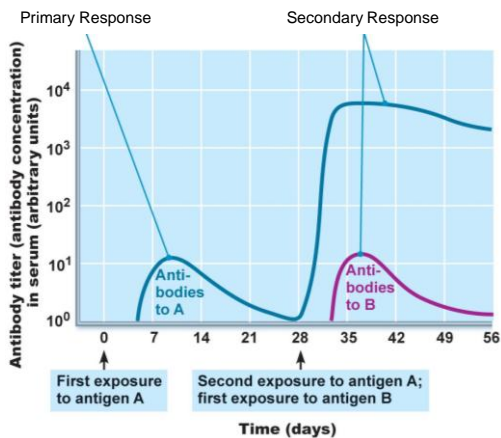
Step 1:
Antigen bind to antibodies
on a specific B cell

Step 2:
B cell multiplies rapidly producing
large population of genetically
identical cells (i.e., clones)

Step 3:
B cell 'clones' differentiate into
plasma cells and memory cells

Antibody-Mediated Immunity (B cells):

Responses to Antigen Exposure:



Primary Response:

- Level of antibody peaks ~ 1 – 2 weeks
- Rapid decline

Secondary Response:

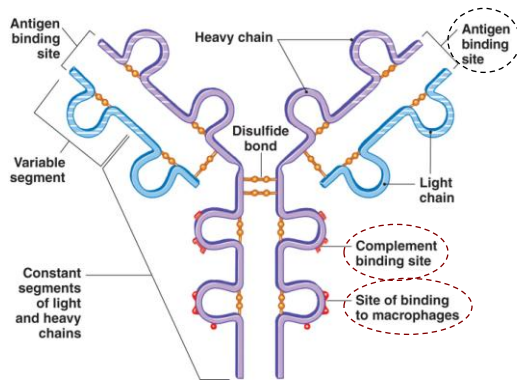
- Rapid and massive response
 - **Memory cells** 'remember' antigen
- Pathogens overwhelmed quickly

Immunization



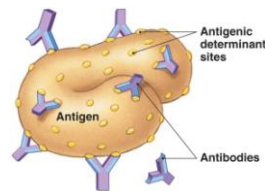
Antibody-Mediated Immunity (B cells):

Antibody Structure:



Antibody (immunoglobulin):
 Protein that binds to specific antigens and promotes their destruction / removal

- Y-shaped
- 4 chains (2 light; 2 heavy)
 - Variable / constant regions
- **Antigen binding site**
 - High specificity



Remember:
 Antibodies bind to specific regions on antigens (antigenic determinant sites)

Similar to Marieb & Hoehn – Figure 20.14

Antibody-Mediated Immunity (B cells):

Classes of Antibodies:

- Determined by differences in structure of heavy-chain constant regions

Largest class
 (80% of antibodies)



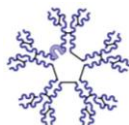
1) **IgG:**
 Attack viruses, bacteria, and bacterial toxins



2) **IgE:**
 Stimulate histamine release from mast cells



3) **IgD:**
 Activates B cells; located on B cell surface



4) **IgM:**
 Circulate as starbursts; attack bacteria

A single plasma cell can switch from making one type of antibody to making another type of antibody (same antigen specificity)

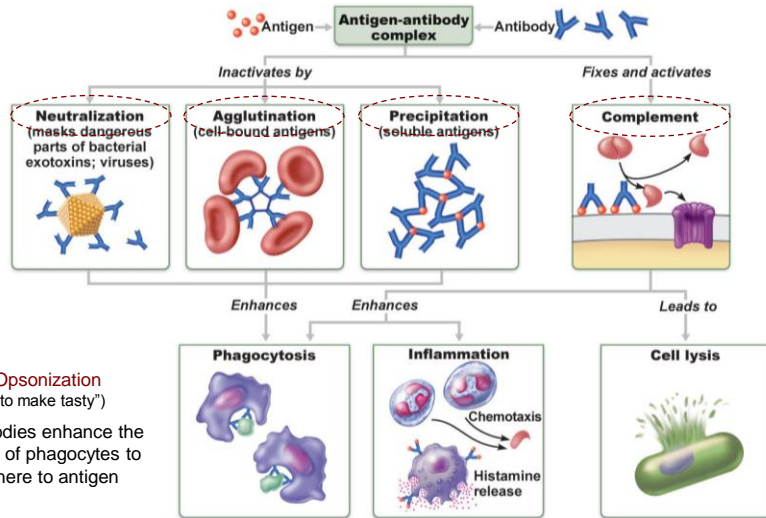


5) **IgA:**
 Found in secretions; attack external pathogens

Antibody-Mediated Immunity (B cells):

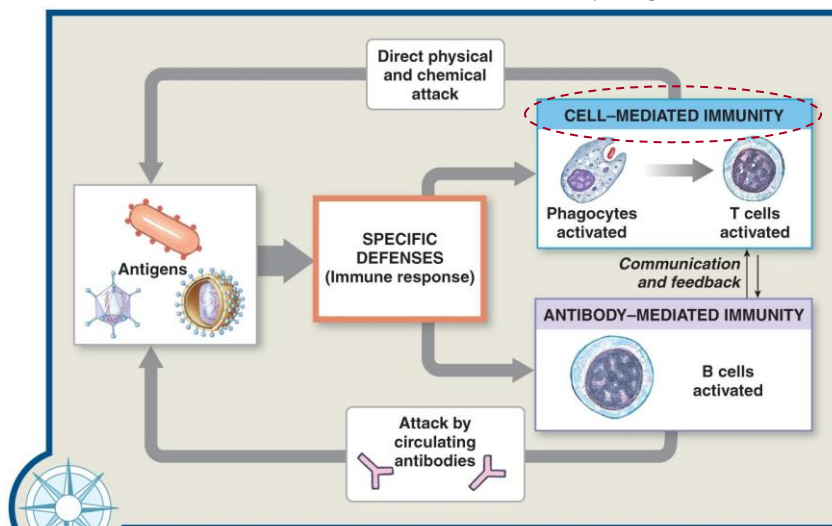
Antibodies do not directly destroy pathogens – Instead, they prepare them for destruction by innate defenses

Functions of Antigen-Antibody Complexes:



Overview of Adaptive Defense Response:

Defense against abnormal cells and pathogens inside cells



Defense against antigens and pathogens in body fluids

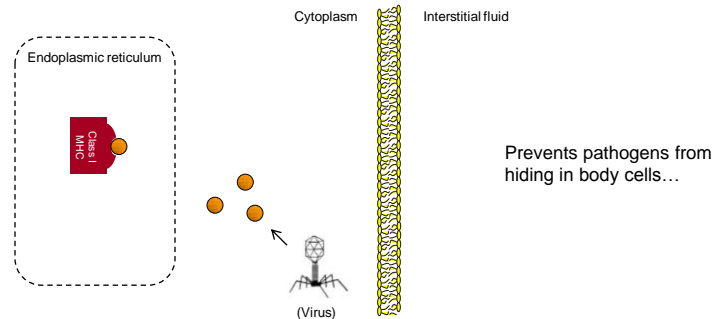
Cell-Mediated Immunity (T cells):

Before response can begin, T cells must be activated by antigen exposure

- Antigen fragments displayed by **MHC proteins**:

Class I MHC presentation:

- Displayed by virtually all cells in body
- Display antigens produced in cells (**endogenous antigens**)



Cell-Mediated Immunity (T cells):

Before response can begin, T cells must be activated by antigen exposure

- Antigen fragments displayed by MHC proteins:

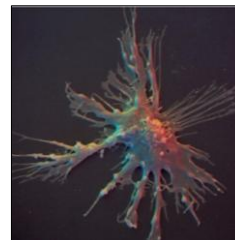
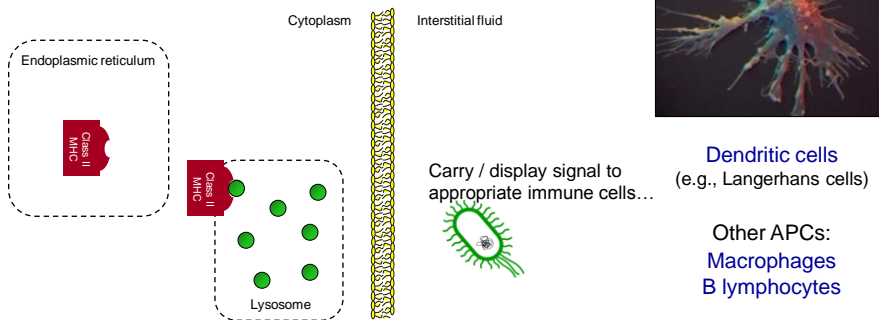
Antigen-Presenting Cells:

- Engulf antigens and present fragments on surface for T cells to recognize

Class II MHC presentation:

- Displayed only by APCs
- Display antigens engulfed from outside APCs

exogenous antigens



Dendritic cells
(e.g., Langerhans cells)

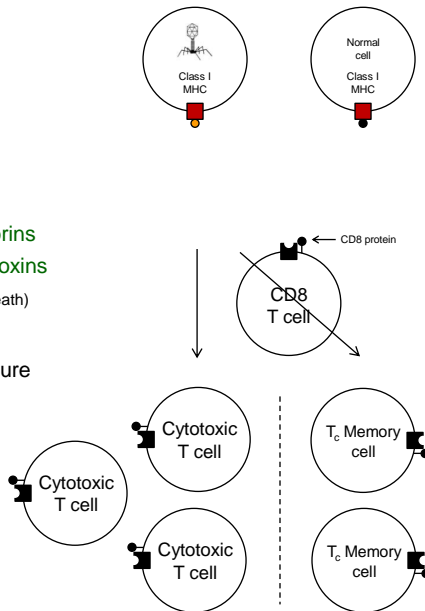
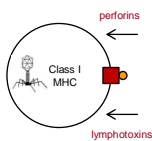
Other APCs:
Macrophages
B lymphocytes

Cell-Mediated Immunity (T cells):

Activation of T cells:

CD8 T cells:

- Recognize MHC-antigen complex (Class I); rapidly divide to form:
 - Cytotoxic T cells** (rapid deployment)
 - Disrupts plasma membrane via **perforins**
 - Disrupts cell metabolism via **lymphotoxins**
 - Stimulates apoptosis (programmed cell death)
 - T_C Memory cells** (remain inactive)
 - Activate only if antigen appears in future



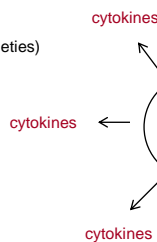
Cell-Mediated Immunity (T cells):

Activation of T cells:

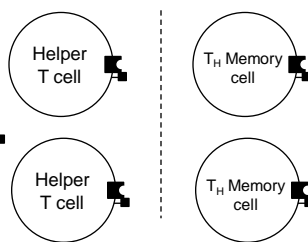
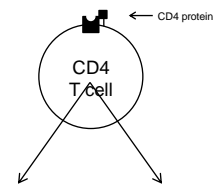
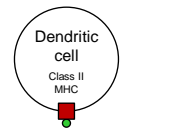
CD4 T cells:

- Recognize MHC-antigen complex (Class II); rapidly divide to form:
 - Helper T cells** (rapid deployment) – Release **cytokines**
 - T_H Memory cells** (remain inactive)
 - Activate only if antigen appears in future

- Stimulate T cell divisions (T_H / T_C varieties)
- Attract / stimulate macrophages
- Attract / stimulate NK cells
- Promote B cell activity



Antigen-presenting cell (APC)





Rheumatoid arthritis

Immune Disorders:

1) **Autoimmune Disorders** (rare)

- Immune response inappropriately targets normal body cells / tissues

2) **Immunodeficiency Diseases** (rare)

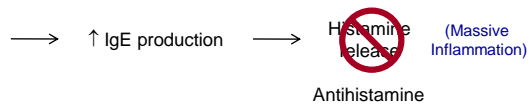
- Immune system fails to function at full effectiveness
 - a) Problems with embryological development of immune system (e.g., SCID)
 - b) Infection with virus that depresses immune function (e.g., HIV)
 - c) Exposure to immunosuppressive agents (e.g., radiation / drugs)

3) **Allergies** (common)

- Inappropriate / excessive immune responses to antigens



Allergic rhinitis



Anaphylaxis: Allergen affects mast cells throughout body