

The Immune System and Defenses

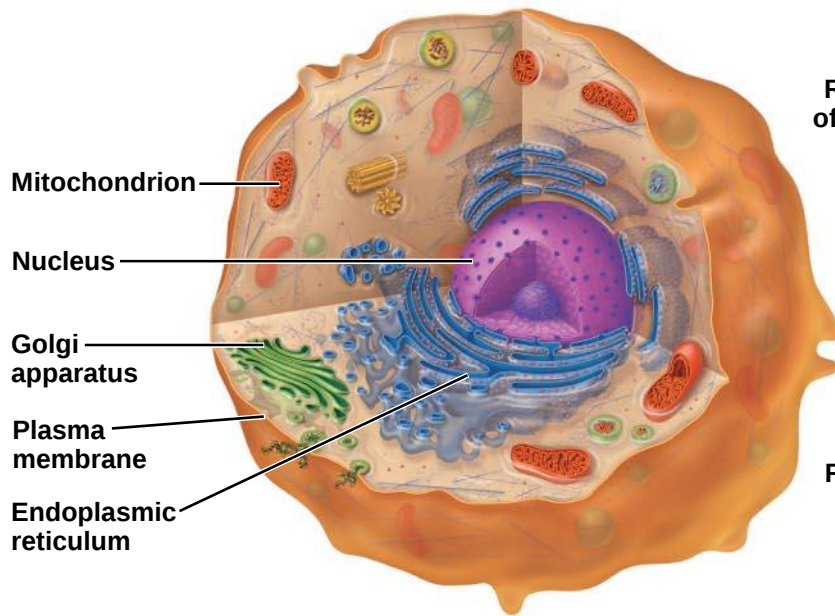


Overview of the Body's Defense Mechanisms

- Defense mechanisms include
 - Barriers to entry of pathogens
 - (Pathogens = disease-producing microorganisms)
 - Skin, stomach acid, tears, vomiting
 - Nonspecific defense mechanisms
 - Phagocytosis, inflammation
 - Specific defense mechanisms
 - Immune response
 - antibodies
 - T cells

Pathogens Cause Disease

- Disease-causing agents include
 - Living organisms
 - Bacteria
 - unicellular prokaryotes
 - Fungi
 - unicellular and multicellular eukaryotes
 - Parasites
 - unicellular and multicellular eukaryotes
 - Nonliving infectious “particles”
 - Viruses
 - Prions



Mitochondrion

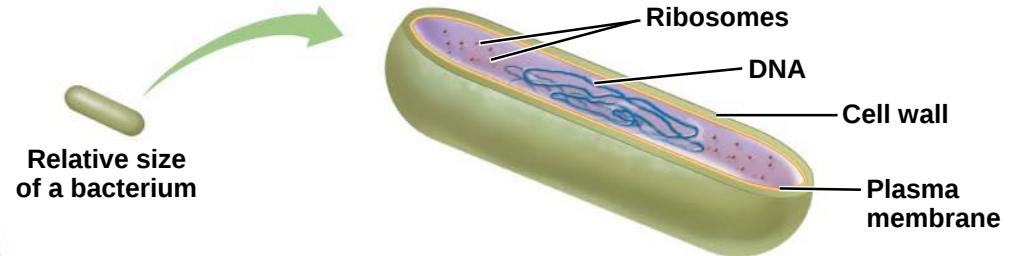
Nucleus

Golgi apparatus

Plasma membrane

Endoplasmic reticulum

a) Eukaryotic cell. Eukaryotic cells have a membrane-bound nucleus and well-defined membrane-bound organelles.



Relative size of a bacterium

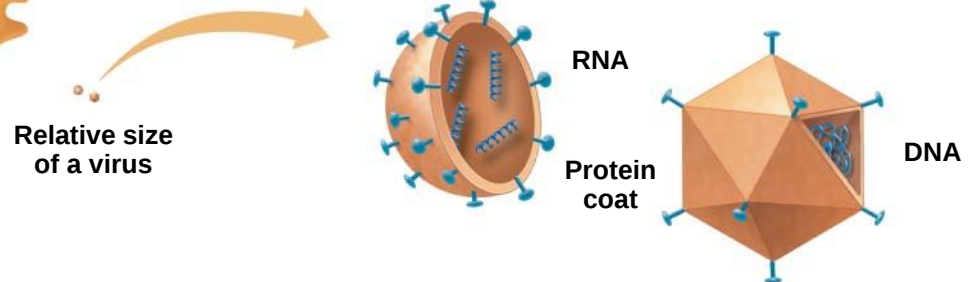
Ribosomes

DNA

Cell wall

Plasma membrane

b) Bacterial cell. Bacteria have a single strand of DNA and free-floating small ribosomes within their cytoplasm. Their plasma membrane is surrounded by a rigid cell wall.



Relative size of a virus

RNA

Protein coat

DNA

c) Viruses. Viruses consist of a protein coat surrounding either RNA or DNA.

Bacteria: Single-celled Living Organisms

- Characteristics
 - Prokaryotic
 - Single-celled
 - Use a variety of resources for growth and reproduction
- Infections
 - Pneumonia, tonsillitis, tuberculosis, botulism, toxic shock syndrome, syphilis, Lyme disease, etc.
- Generally treated with **antibiotics**

Viruses: Tiny Infectious Agents

- Extremely small, much smaller than bacteria
- Living? Open to debate
 - Unable to reproduce outside of a host cell
 - No metabolic activity
- Structure
 - Contain DNA or RNA, not both
 - DNA/RNA is surrounded by a protein coat
- Diseases
 - AIDS, hepatitis, encephalitis, rabies, influenza, colds, warts, chicken pox

Prions: Infectious Proteins

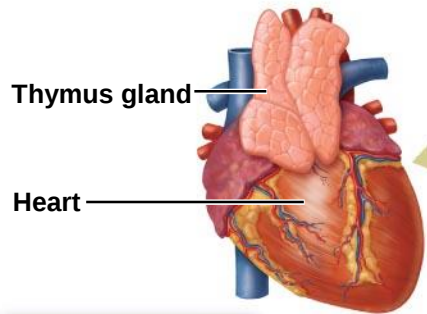
- Infectious proteins
- Normal brain proteins that are not folded correctly
 - The mis-folding becomes self-propagating, filling and disabling the cell with protein debris
- Resist cooking, freezing, drying
- Diseases
 - Bovine spongiform encephalitis (BSE, “mad cow disease”)
 - Creutzfeldt-Jakob disease (CJD)

Transmissibility, Mode of Transmission, and Virulence Determine Health Risk

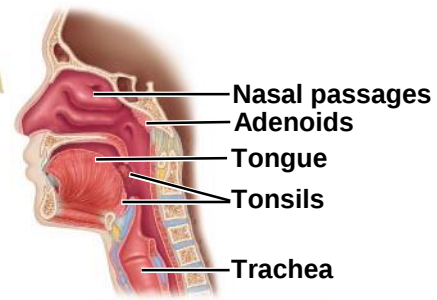
- Transmissibility
 - How easily a pathogen is passed from person to person
- Mode of transmission
 - Respiratory, fecal–oral, body fluids
- Virulence
 - How much damage is caused by the infection

Lymphatic System Defends the Body

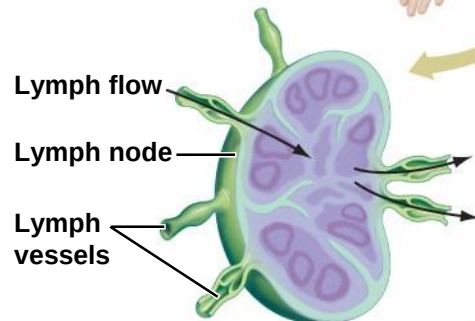
- Functions
 - Maintenance of blood volume in cardiovascular system
 - Transport of fats and fat-soluble material from digestive system
 - Filtration of foreign material to defend against infection



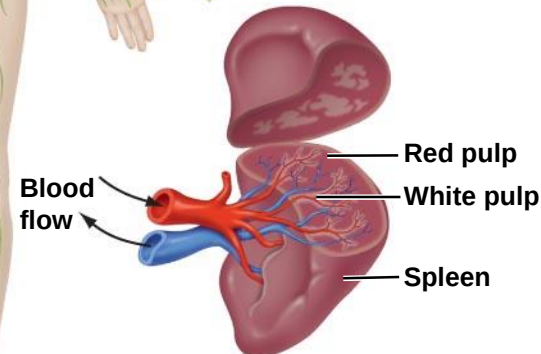
Lymphocytes mature in thymus.



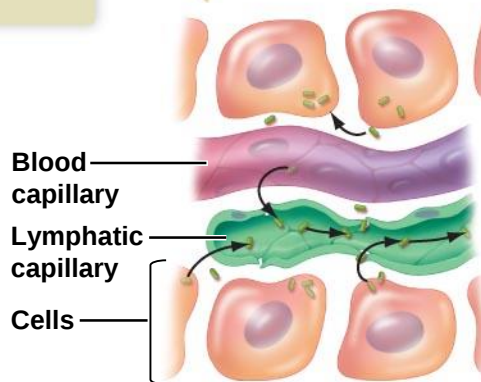
Tonsils protect the throat.



Macrophages cleanse lymph; lymphocytes activate defense mechanisms.



Spleen removes damaged blood cells and microorganisms from blood.



Lymphatic vessels transport fluid, bacteria, and viruses.

Keeping Pathogens Out: The First Line of Defense

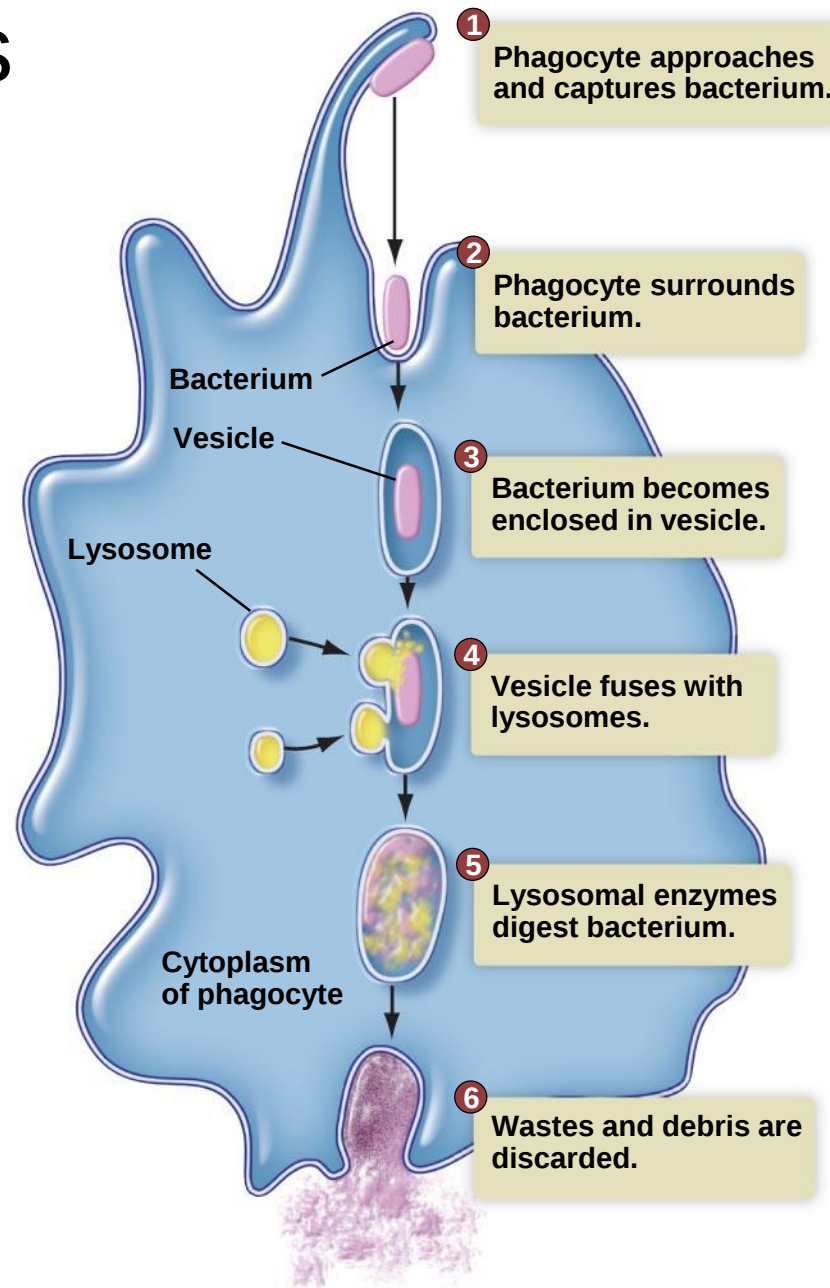
- **Skin**, an effective deterrent
- **Tears and saliva** – contain lysozyme (antibacterial enzyme)
- **Ear wax** – entraps microorganisms
- **Mucus** – entraps microorganisms
- **Stomach** – highly acidic, inhibits microorganisms
- **Vagina** – slightly acidic, inhibits some microorganisms
- **Vomiting, urination, and defecation** – remove microorganisms
- **Resident bacteria** – outcompete pathogens

Nonspecific Defenses:

Phagocytes Engulf Foreign Cells

- **Phagocytic cells**
 - white blood cells that surround and engulf invading bacteria
 - Neutrophils, macrophages, eosinophils

Phagocytes Engulf Foreign Cells



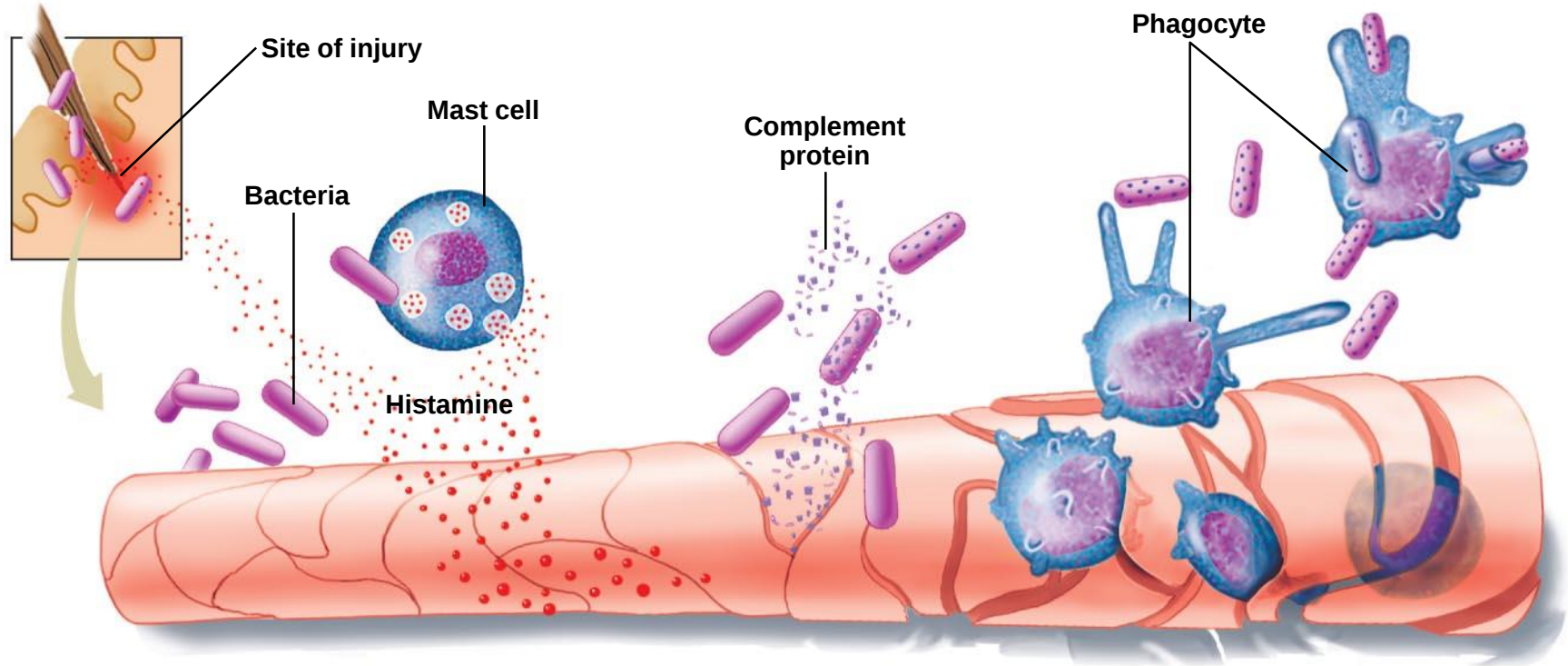
b) Steps in the process.

Nonspecific Defenses:

Phagocytes Engulf Foreign Cells

- **Phagocytic cells**
 - white blood cells that surround and engulf invading bacteria
 - Neutrophils, macrophages, eosinophils
- **Inflammation**
 - Redness, warmth, swelling, pain

Inflammation Response



1

Damaged cells and mast cells in the area release histamine and other substances. Histamine dilates blood vessels and makes them leaky.

2

Complement proteins from plasma diffuse out of leaky capillaries. They mark the bacteria for destruction and sometimes kill them.

3

Attracted by histamine and other chemicals, phagocytes squeeze through the leaky capillary walls and begin attacking and engulfing bacteria and debris.

Nonspecific Defenses:

Phagocytes Engulf Foreign Cells

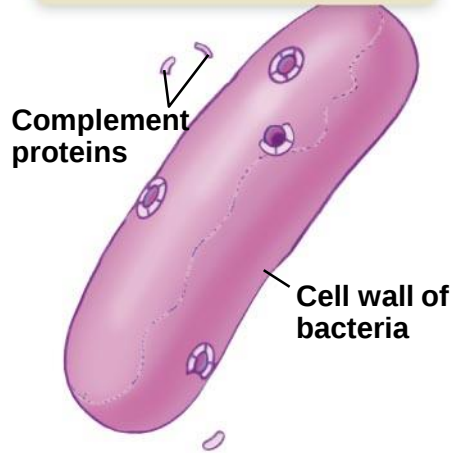
- **Phagocytic cells**
 - white blood cells that surround and engulf invading bacteria
 - Neutrophils, macrophages, eosinophils
- **Inflammation**
 - Redness, warmth, swelling, pain
- **Natural killer cells**
 - a type of lymphocyte that attacks tumor cells and virus-infected cells

Nonspecific Defenses: Phagocytes Engulf Foreign Cells

- **Complement proteins**
 - lyse invading bacteria

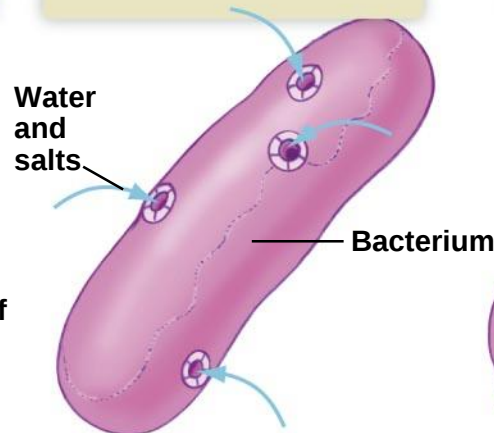
1

Activated complement proteins form complexes of proteins that create holes in the bacterial cell wall.



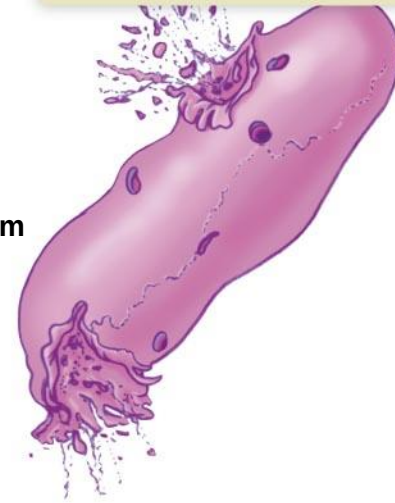
2

Water and salts diffuse into the bacterium through the holes.



3

The bacterium swells and eventually bursts.



Photomicrograph of an intact bacterium



A bacterium after lysis by activated complement proteins

Complement Proteins

Nonspecific Defenses:

Phagocytes Engulf Foreign Cells

- **Complement proteins**
 - lyse invading bacteria
- **Interferons**
 - antiviral proteins
- **Fever response**

Specific Defense Mechanisms: Third Line of Defense (The Immune Response)

- Characteristics
 - Recognizes and targets specific pathogens and foreign substances
 - Has “memory” – “remembers” initial exposure and responds more quickly and aggressively on subsequent exposures
- Able to distinguish between
 - Self cells and foreign invaders
 - Healthy cells and abnormal (tumor) cells

Specific Defense Mechanisms: Immune Response Targets Antigens

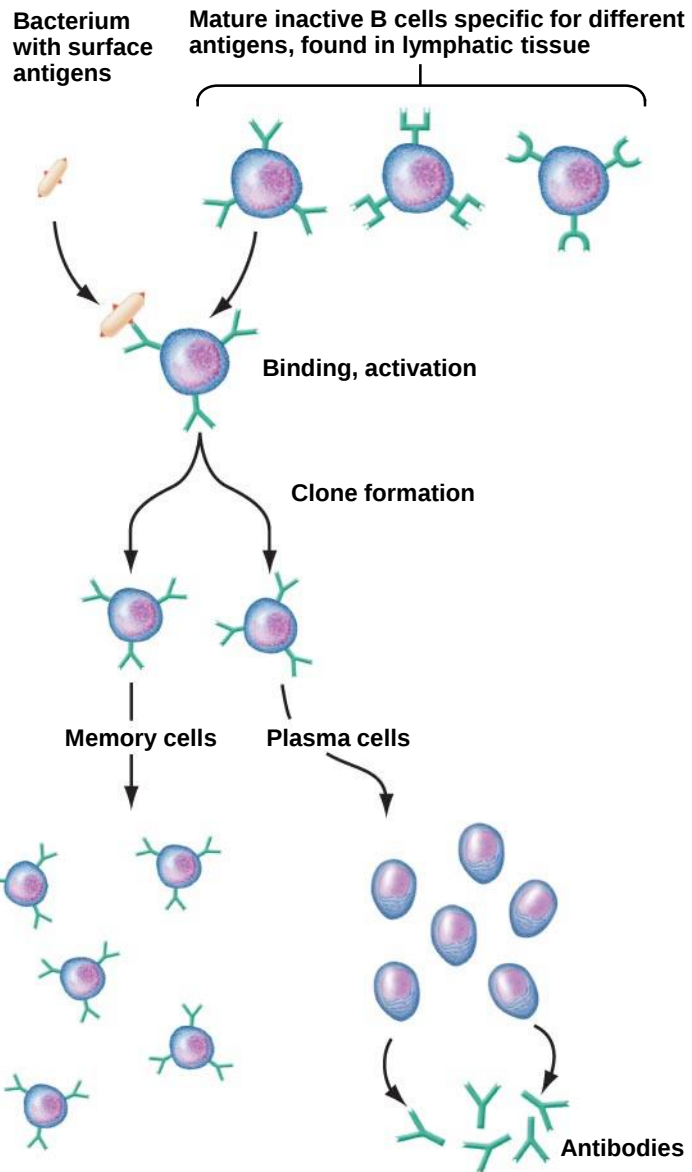
- Antigen
 - any substance that triggers an immune response
 - MHC (major histocompatibility complex) proteins
 - Self-antigens that are on human cell surfaces enabling recognition of “self”
 - Enable immune system to distinguish “self” from “nonself”

Specific Defense Mechanisms: Lymphocytes Are Central to Specific Defenses

- B lymphocytes
 - Antibody-mediated immunity
 - **Antibodies:** proteins made by B lymphocytes that bind with and neutralize specific antigens
 - Active against viruses, bacteria, and soluble foreign molecules
 - B cells activated when they recognize an antigen

Specific Defense Mechanisms: Lymphocytes Are Central to Specific Defenses

- T lymphocytes
 - Cell-mediated immunity
 - Directly attack foreign cells
 - Coordinate the immune response
 - Active against parasites, viruses, fungi, intracellular bacteria, cancer cells, cells with “nonself” MHC



Key idea

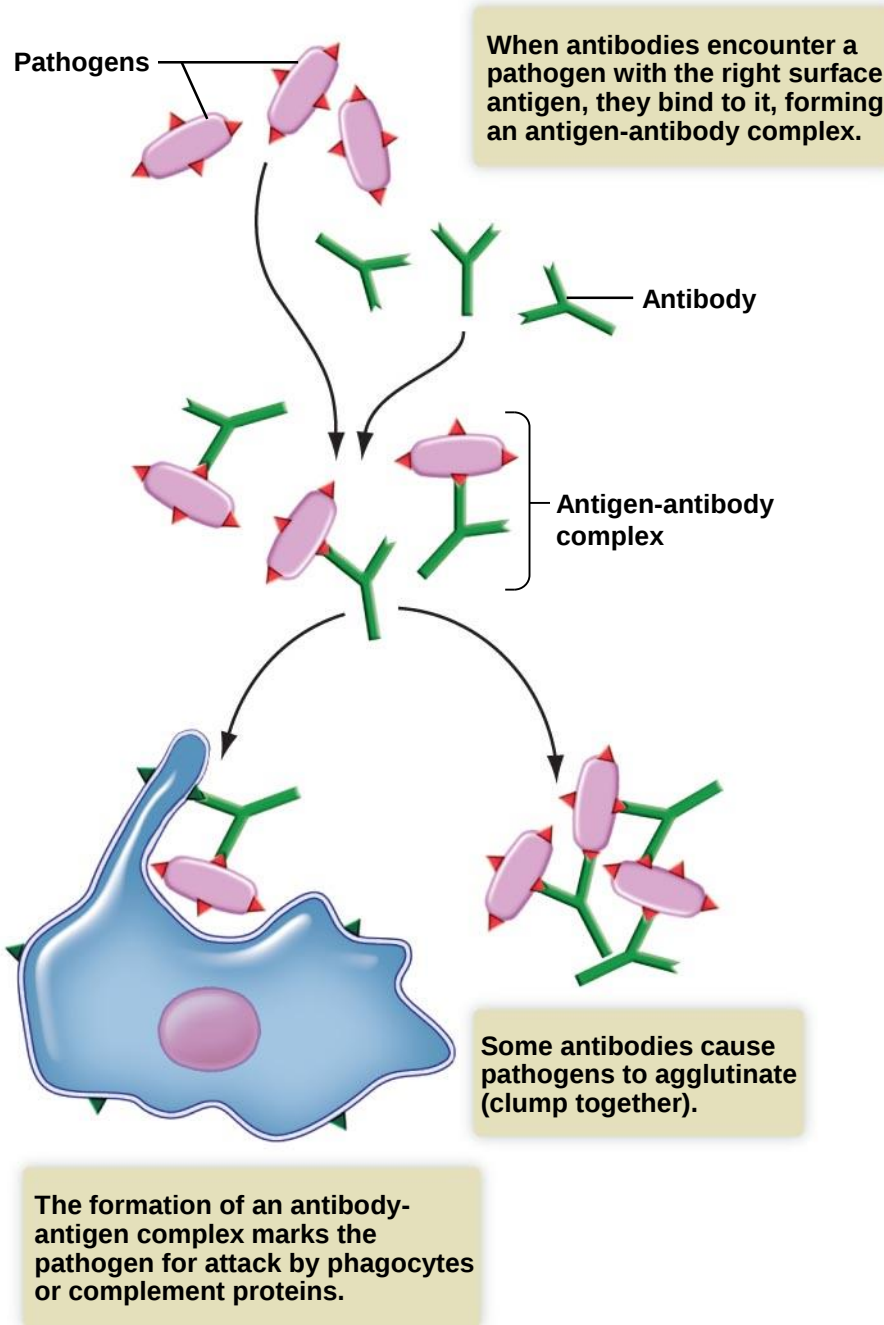


Memory cells store information until the next exposure to the same antigen.

Plasma cells secrete antibodies into circulation.



Key idea



T Cells: Cell-Mediated Immunity

- **Helper T cells**

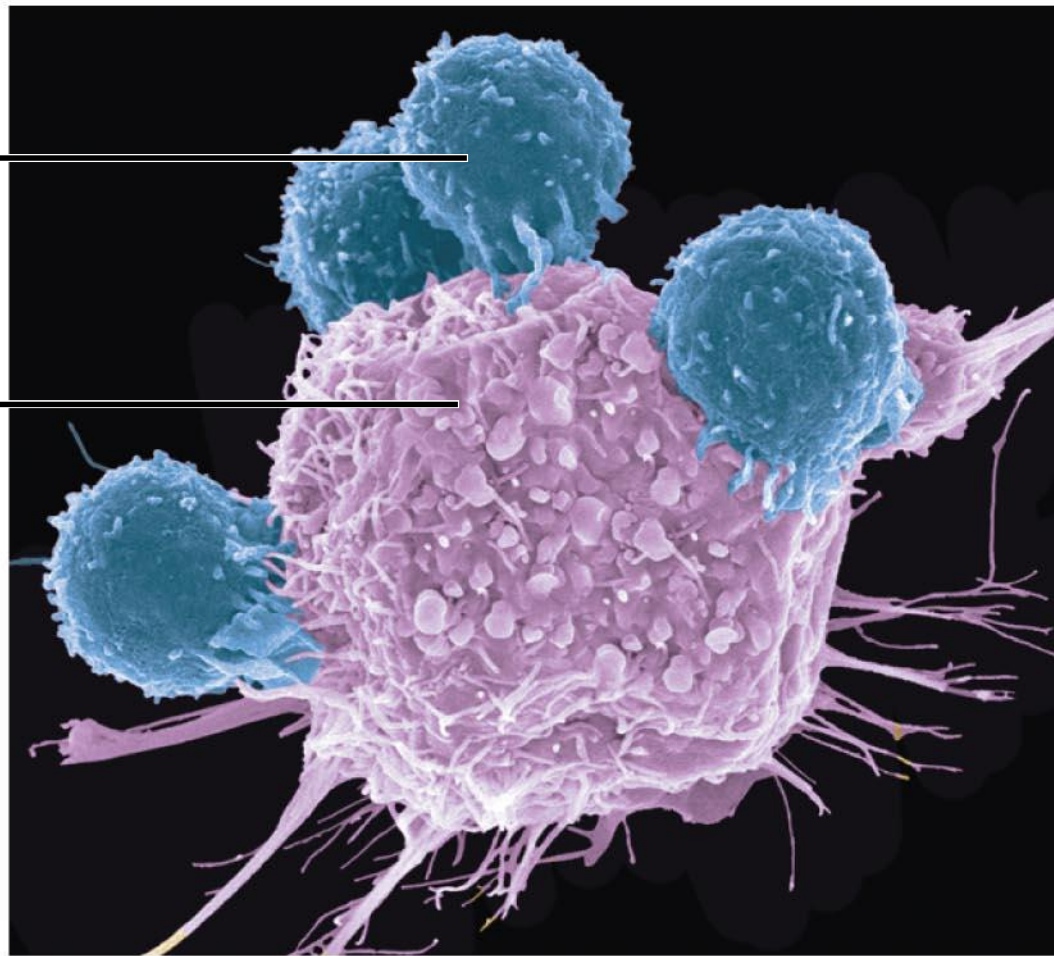
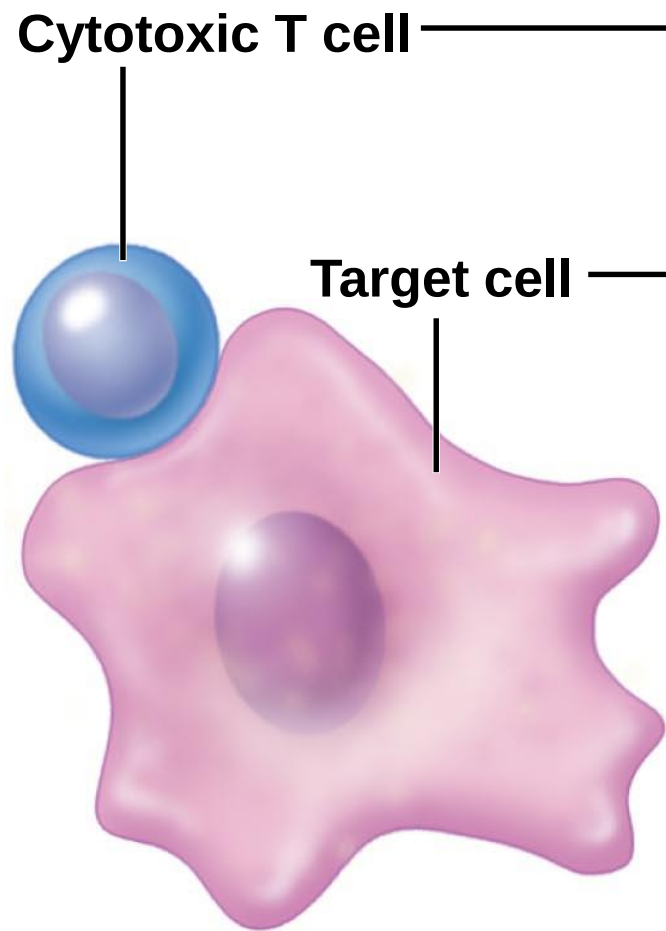
- Secrete cytokines, which stimulate other immune system cells
- Play a key role in directing the immune response

- **Cytotoxic T cells**

- Directly attack and destroy abnormal (tumor or viral-infected) cells and foreign cells

- **Memory T cells**

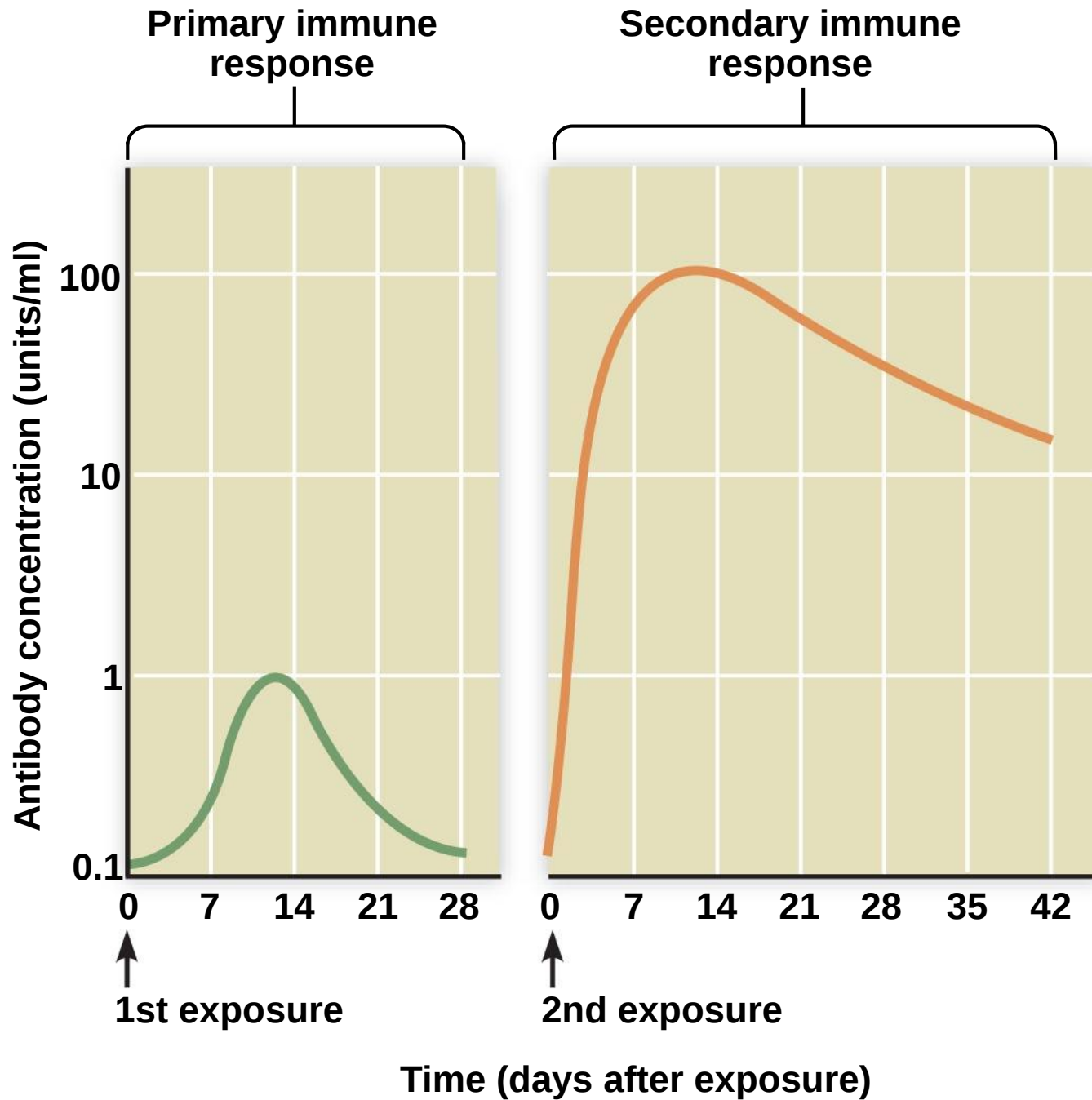
- Reactivate during later exposures



a) Cytotoxic T cells (blue) attaching to a target cell (pink).

Immune Memory Creates Immunity

- Primary immune response
 - Occurs on first exposure to antigen
 - Characteristics
 - Lag time of 3–6 days for antibody production
 - Peak at 10–12 days
- Secondary immune response
 - Occurs on second and subsequent exposure to antigen
 - Characteristics
 - Lag time in hours
 - Peak in few days



Medical Assistance in the War Against Pathogens: Immunization

- A strategy for causing the body to develop immunity to a specific pathogen
- **Active immunization**
 - Intentionally expose individual to a form of the antigen that doesn't produce disease
 - Also known as **vaccination**
- **Passive immunization**
 - Administer protective antibodies to an individual

Medical Assistance in the War Against Pathogens: Antibiotics Combat Bacteria

- Antibiotics kill bacteria or inhibit their growth
- Antibiotics are selectively toxic for bacteria by targeting features of bacterial cells that are different from eukaryotic cells
- Antibiotics are not effective against viruses

Inappropriate Immune System Activity Causes Problems: Allergies

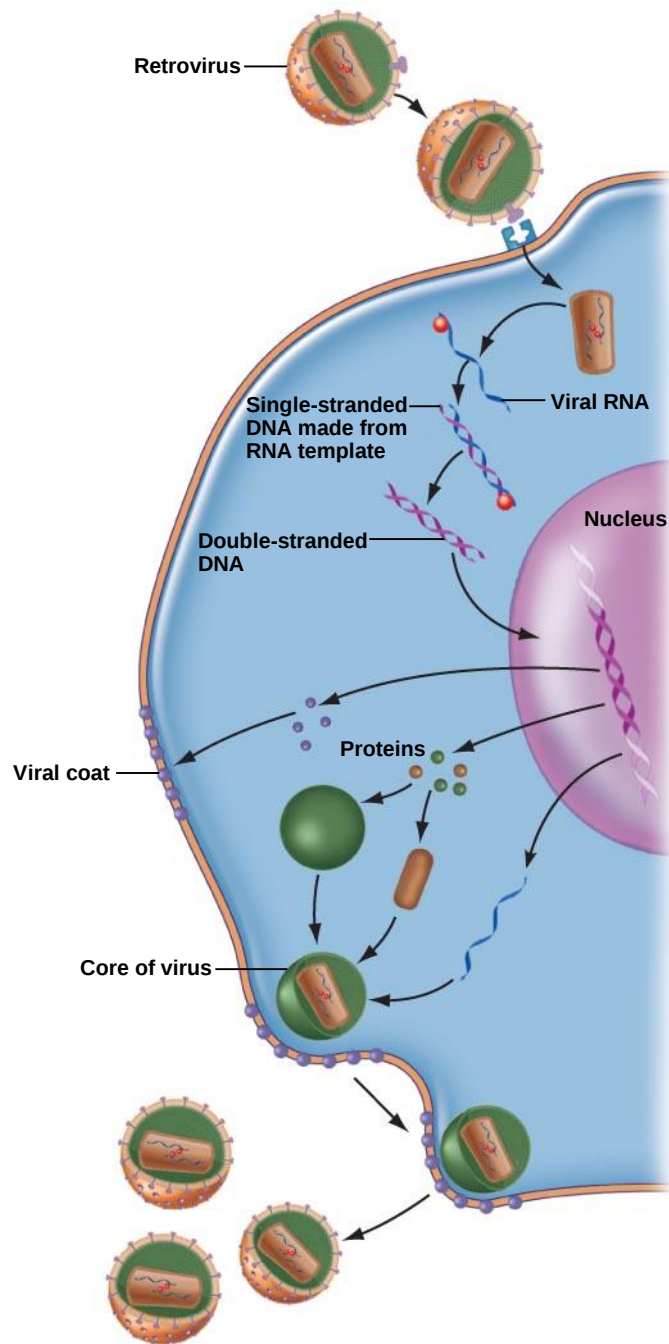
- Allergies are hypersensitivity reactions
 - Inappropriate response to an allergen
- Treatment of allergies
 - Antihistamines – treatment of mild to moderate reactions
 - Epinephrine injection – treatment of anaphylactic shock
 - Allergy shots

Inappropriate Immune System Activity Causes Problems: Autoimmune Disorders

- Inability of immune system to distinguish “self” from “nonself”
- Autoantibodies and cytotoxic T cells target the body’s own tissues
- Examples
 - Lupus erythematosus (LE or lupus)
 - Inflamed connective tissue
 - Rheumatoid arthritis
 - Inflamed synovial membrane

Immune Deficiency: The Special Case of AIDS

- AIDS
 - Acquired Immune Deficiency Syndrome
- Caused by infection with HIV (Human Immunodeficiency Virus)
- HIV targets helper T cells
- Transmission via body fluids (blood, semen, breast milk, vaginal secretions)



AIDS Develops Slowly: Phase I

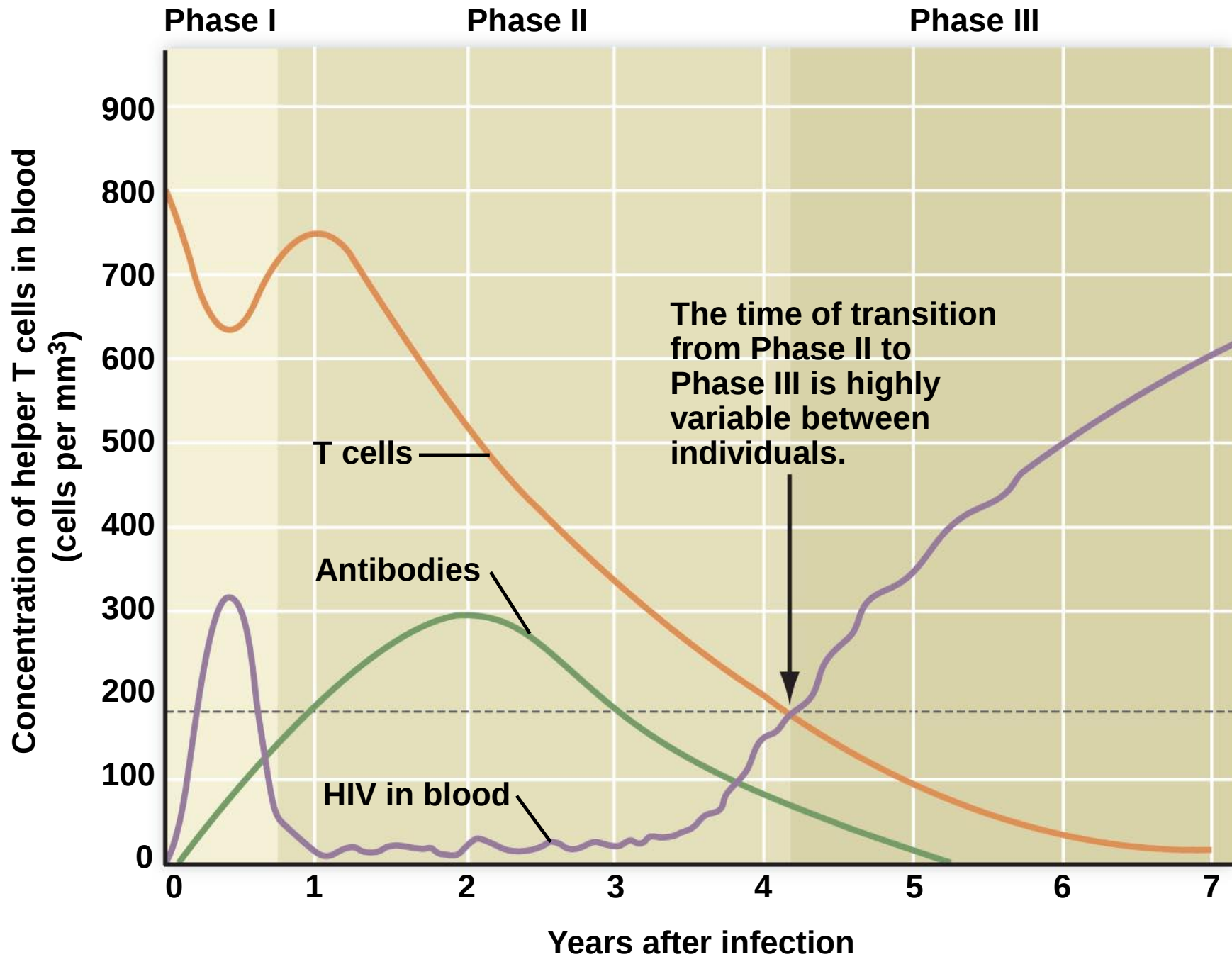
- Phase I
 - May last a few weeks to a few years
 - Brief period of flu-like symptoms
 - Swollen lymph nodes
 - Chills
 - Fever
 - Fatigue
 - Body aches
 - Most people don't exhibit recognizable symptoms
 - Virus is multiplying, antibodies are made but are ineffective for complete virus removal

AIDS Develops Slowly: Phase II

- Phase II
 - Occurs within 6 months to 10 years
 - Opportunistic infections present
 - Helper T cells affected, numbers are decreasing
 - If untreated, 95% will progress to next phase (AIDS)

AIDS Develops Slowly: Phase III (AIDS)

- Phase III: Clinical AIDS
 - Helper T cells fall below 200 cells/mm³
 - Opportunistic infections and cancers present
 - Tuberculosis
 - Pneumonia
 - Meningitis
 - Encephalitis
 - Kaposi's sarcoma
 - Non-Hodgkins lymphoma
 - If untreated, nearly always fatal



Risky Behaviors Increase Your Chances of Getting AIDS

- Males (3/4 of new cases)
 - Sex with other men
 - Sharing needles during intravenous drug use
 - Heterosexual sex with HIV-infected female
- Females (1/4 of new cases)
 - Sex with HIV-infected male
 - Sharing needles during intravenous drug use

Sex Can Be Safer

- Abstinence
- Reduce number of sexual partners
- Choose sexual partners with low-risk behavior
- Avoid high-risk sexual practices
 - Anal-genital sex is a high-risk practice
- Use latex or polyurethane condoms or barriers
- GET TESTED

New Treatments Offer Hope

- HIV Drugs
 - Reverse transcriptase inhibitors: AZT
 - Protease inhibitors: ritonavir, saquinavir
 - Maraviroc: new drug
 - Blocks entry of HIV into T cells
 - Early treatment may delay or prevent clinical AIDS
- Vaccine
 - Under development and testing
 - Challenge: Virus mutates rapidly