

# Chapter 24

## The Immune System



PowerPoint Lectures for  
***Biology: Concepts & Connections, Sixth Edition***  
***Campbell, Reece, Taylor, Simon, and Dickey***

**Lecture by Edward J. Zalisko**

# Introduction: *The Kissing Disease?!?*

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- Mononucleosis (mono)
  - Caused by Epstein-Barr virus (EBV)
  - 95% of humans infected by adulthood
  - Infected children show few symptoms
  - Half of infected adolescents/young adults get mono
  - Symptoms include
    - Fever
    - Sore throat
    - Swollen lymph glands

# Introduction: *The Kissing Disease?!?*

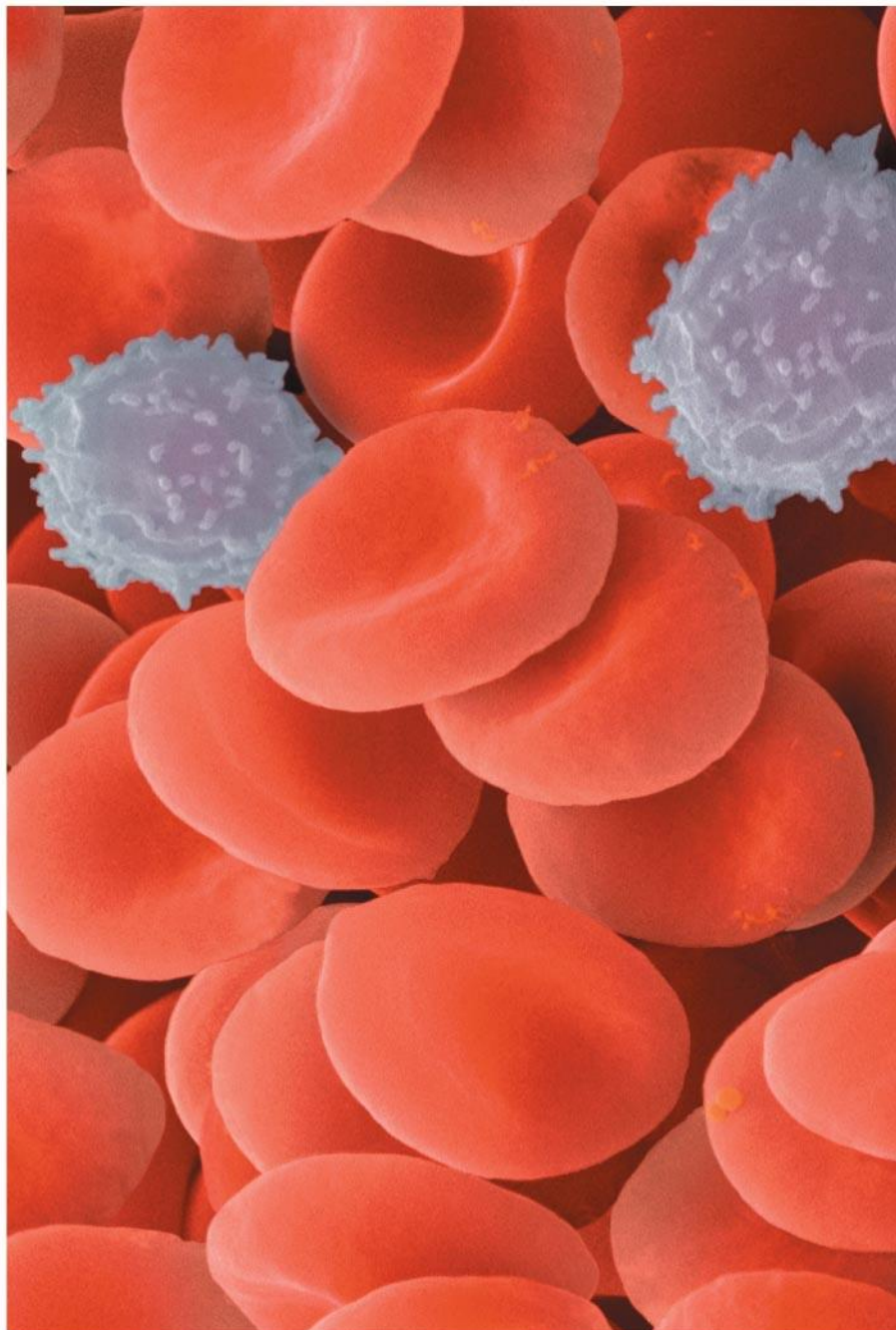
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- There is no vaccine for mono
- There is no effective treatment for mono
- Rest, fluids, and pain relievers assist recovery
- Mono is almost never fatal

# Introduction: *The Kissing Disease?!?*

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- Mono is spread by saliva
  - Kissing
  - Shared dishes or utensils
- EBV infects B cells, weakening the immune system
- Infections are life-long but rarely cause symptoms again
  - An infected person acquires long-lasting immunity against EBV
  - An infected person can spread the disease







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# INNATE DEFENSES AGAINST INFECTION

## 24.1 Both invertebrates and vertebrates have innate defenses against infection

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- Innate defenses—first line of defense
  - Found in all animals
  - Includes
    - Skin
    - Mucous membranes
    - Phagocytic cells
    - Antimicrobial proteins
  - Same response to invaders each time



## 24.1 Both invertebrates and vertebrates have innate defenses against infection

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- Invertebrates have only innate immunity
- Vertebrates have innate and acquired immunity

**Innate immunity (24.1-3)**  
Response is the same whether  
or not pathogen has been  
previously encountered

**Acquired immunity (24.4-15)**  
Found only in vertebrates;  
previous exposure to pathogen  
enhances immune response

**External  
barriers**

**Internal  
defenses**

- Skin/exoskeleton
- Secretions
- Mucous membranes

- Phagocytic cells
- NK cells
- Defensive proteins
- Inflammatory response (24.2)

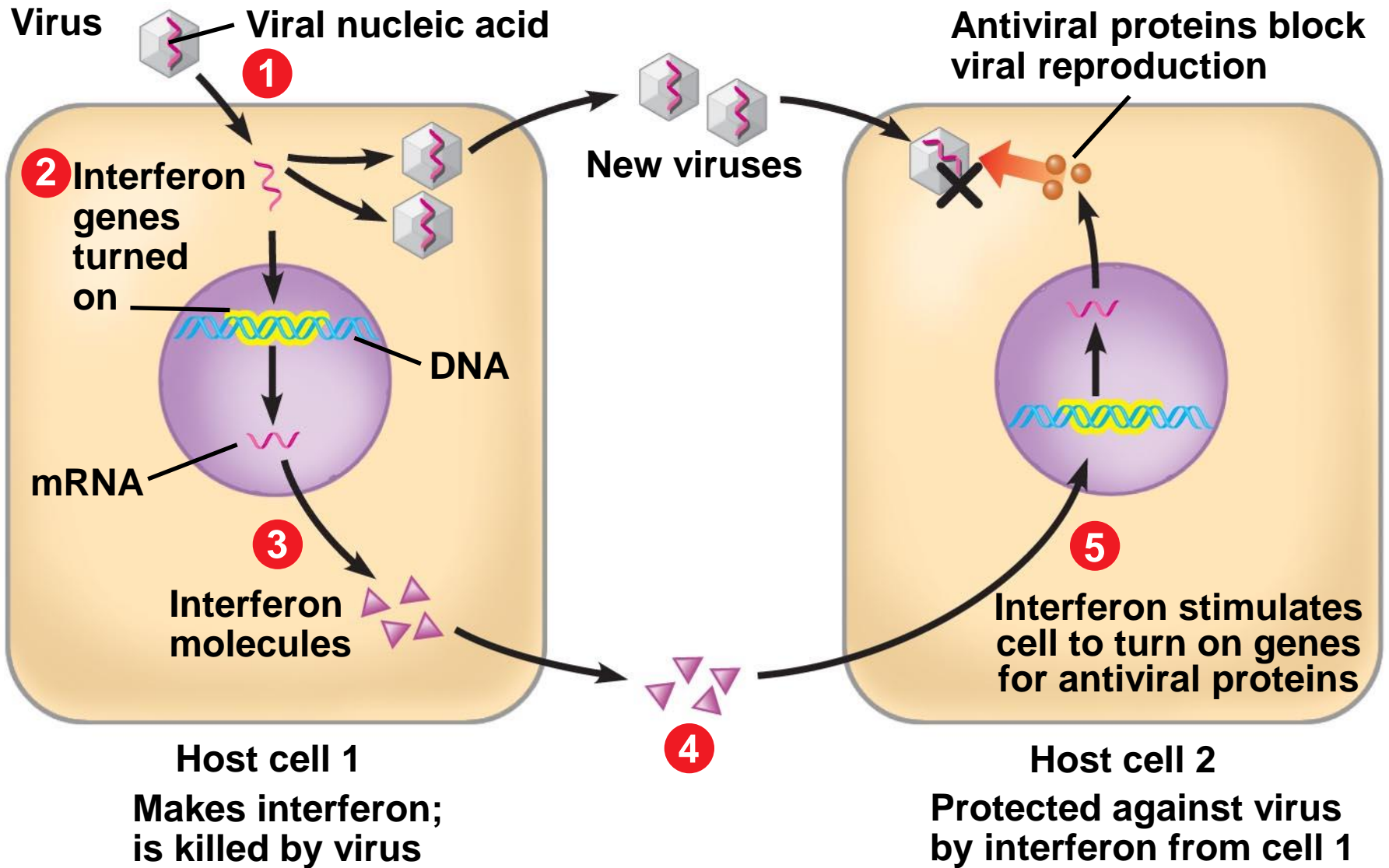
- Antibodies (24.8-10)
- Lymphocytes (24.11-14)

**The lymphatic system (24.3)**

## 24.1 Both invertebrates and vertebrates have innate defenses against infection

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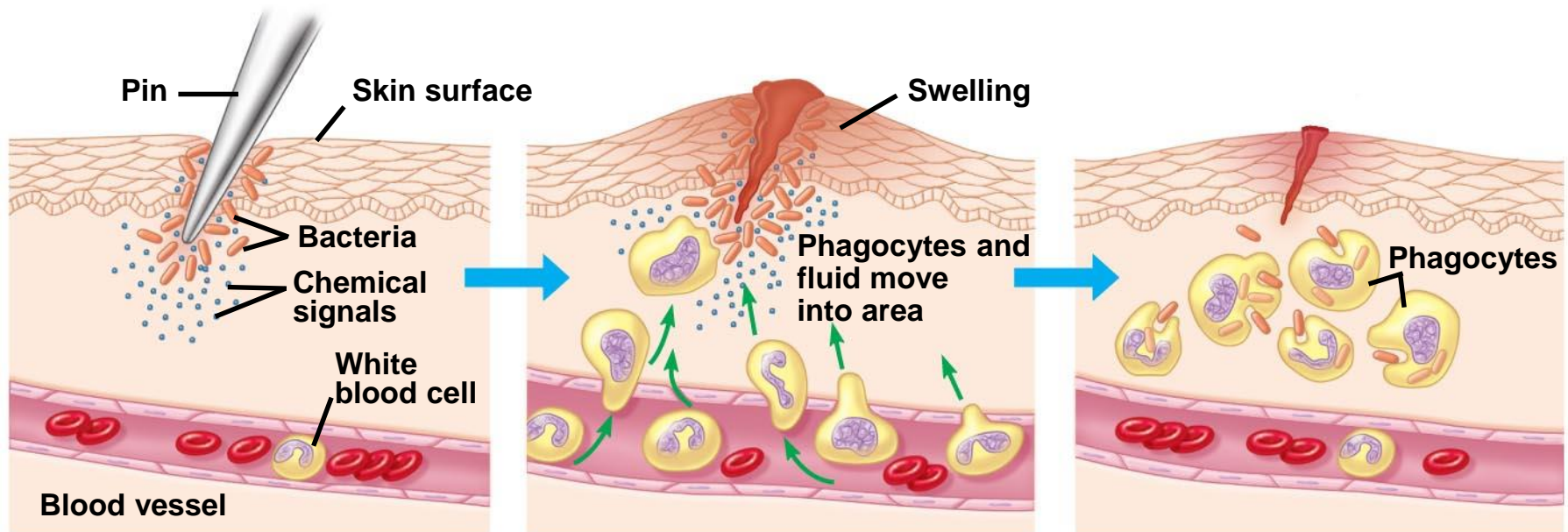
- **Interferons** are proteins produced by virus-infected cells
  - Interferons help other cells resist viruses
  - Found only in vertebrates



## 24.2 The inflammatory response mobilizes innate defenses

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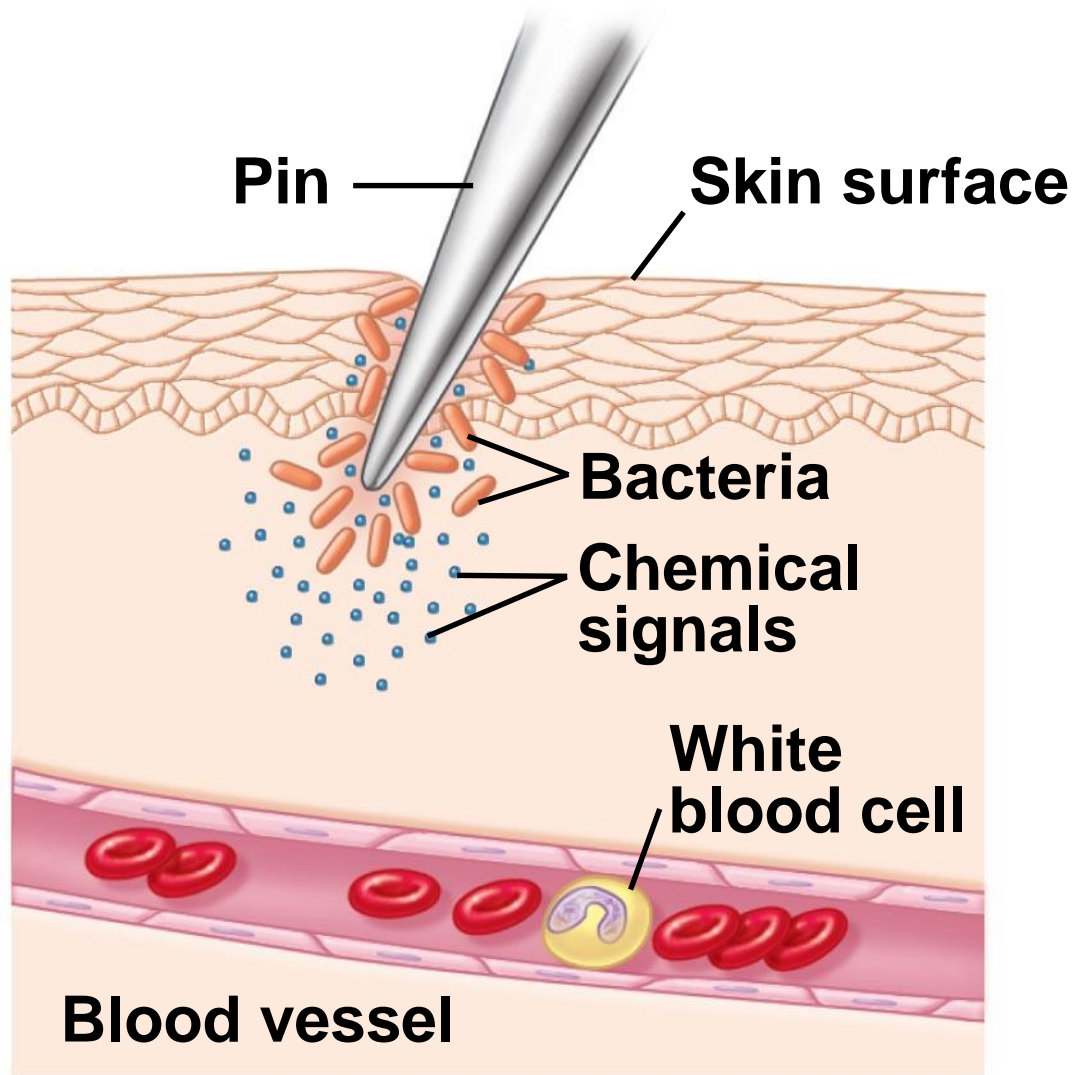
- Tissue damage triggers the **inflammatory response**
- The inflammatory response can
  - Disinfect tissues
  - Limit further infection



**1 Tissue injury; release of chemical signals such as histamine**

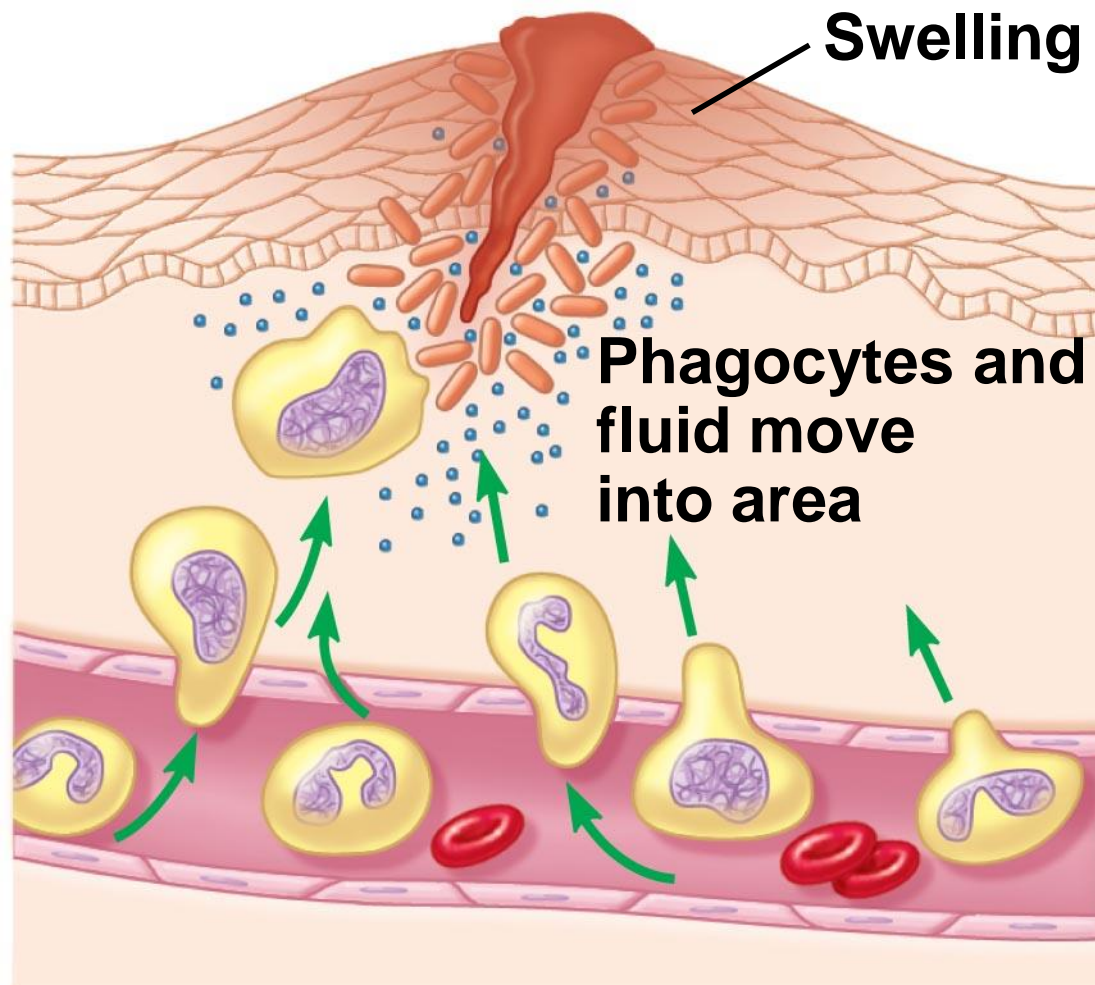
**2 Dilation and increased leakiness of local blood vessels; migration of phagocytes to the area**

**3 Phagocytes (macrophages and neutrophils) consume bacteria and cell debris; tissue heals**

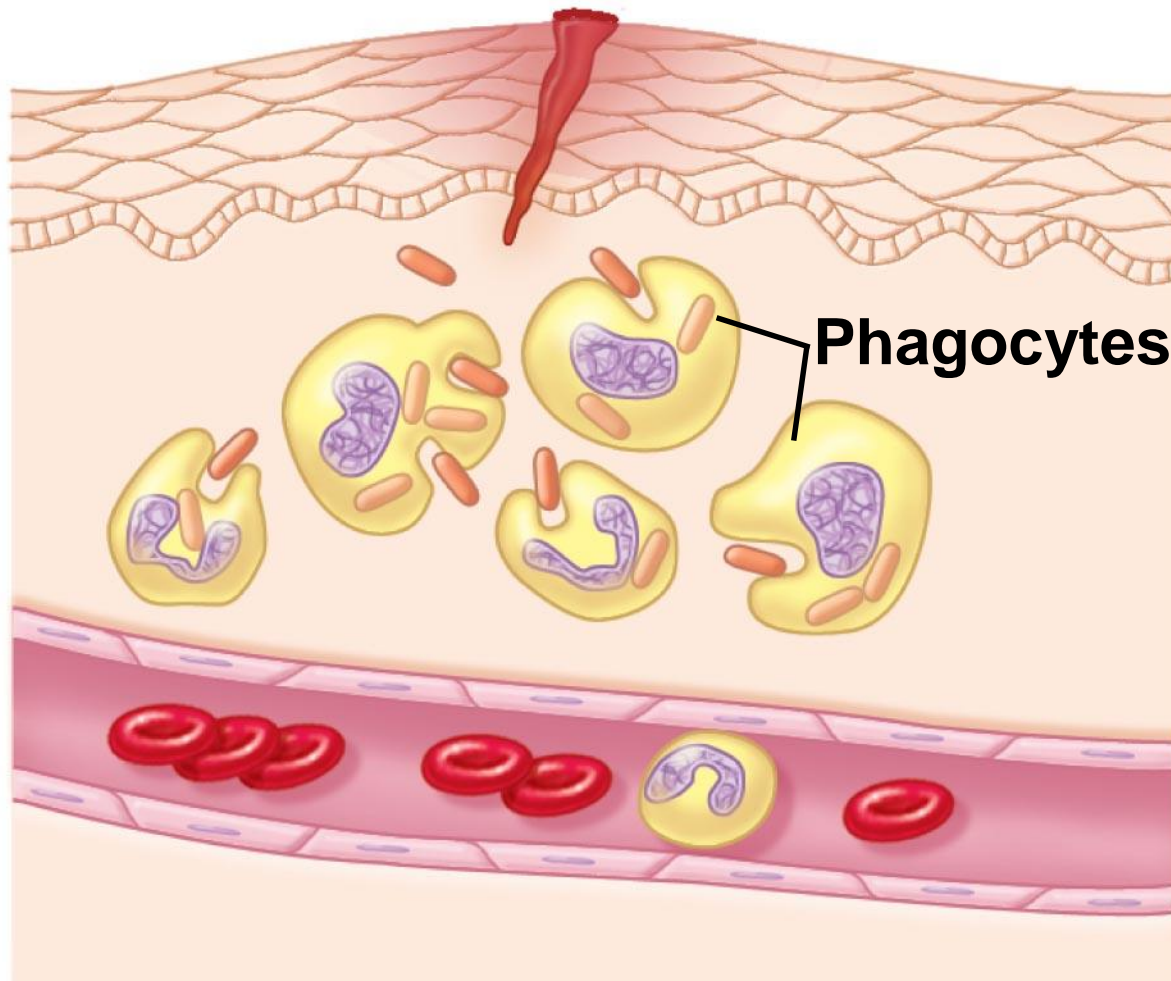


- 1 Tissue injury; release of chemical signals such as histamine**





- 2 Dilation and increased leakiness of local blood vessels; migration of phagocytes to the area**



- 3 Phagocytes (macrophages and neutrophils) consume bacteria and cell debris; tissue heals**

## 24.3 The lymphatic system becomes a crucial battleground during infection

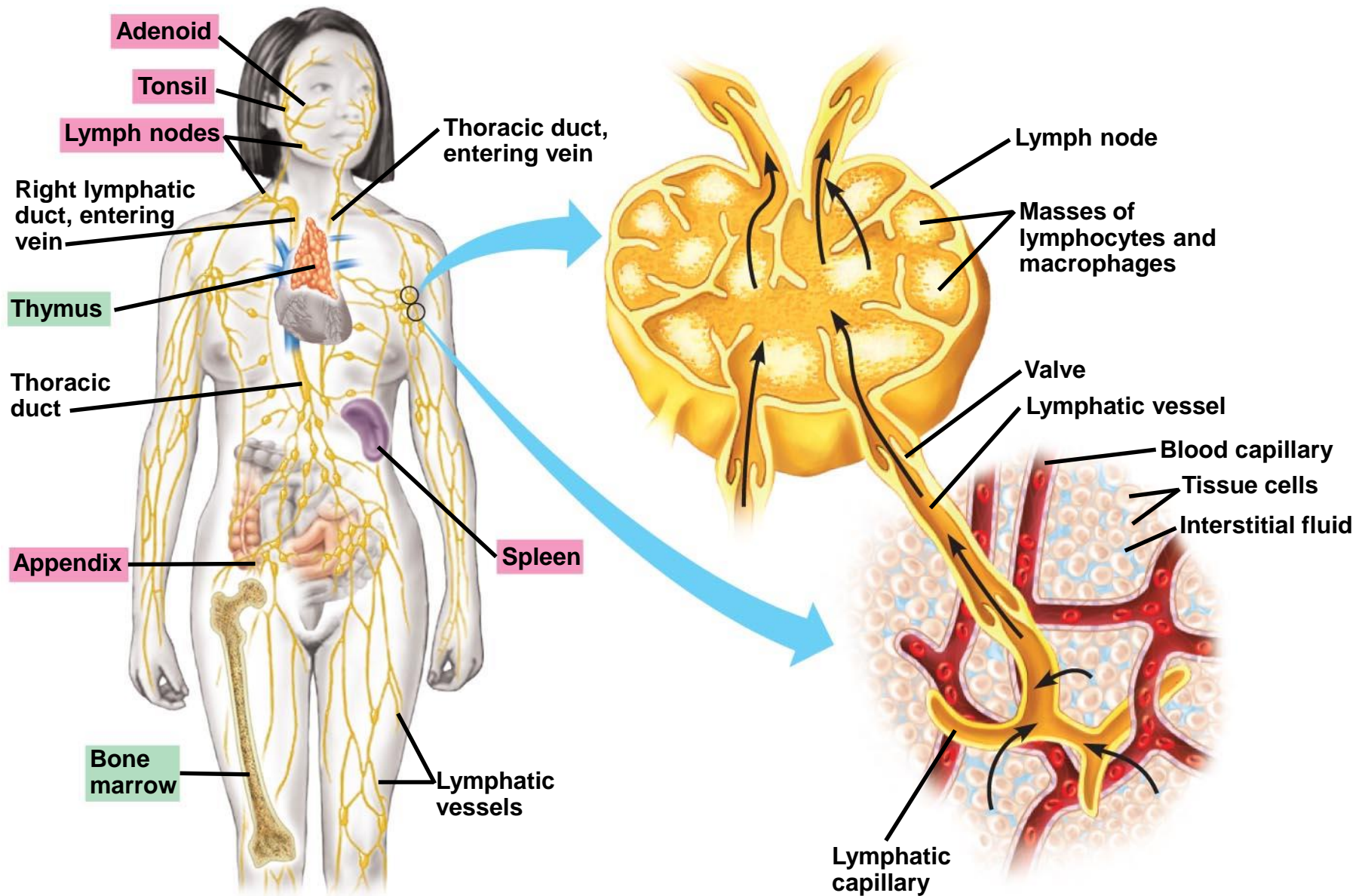
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- The **lymphatic system** is a network of
  - Lymphatic vessels
  - Organs
- Lymphatic vessels
  - Collect fluid from body tissues
  - Return it as **lymph** to the blood
- Lymph organs
  - Such as the spleen and lymph nodes
  - Are packed with white blood cells that fight infections

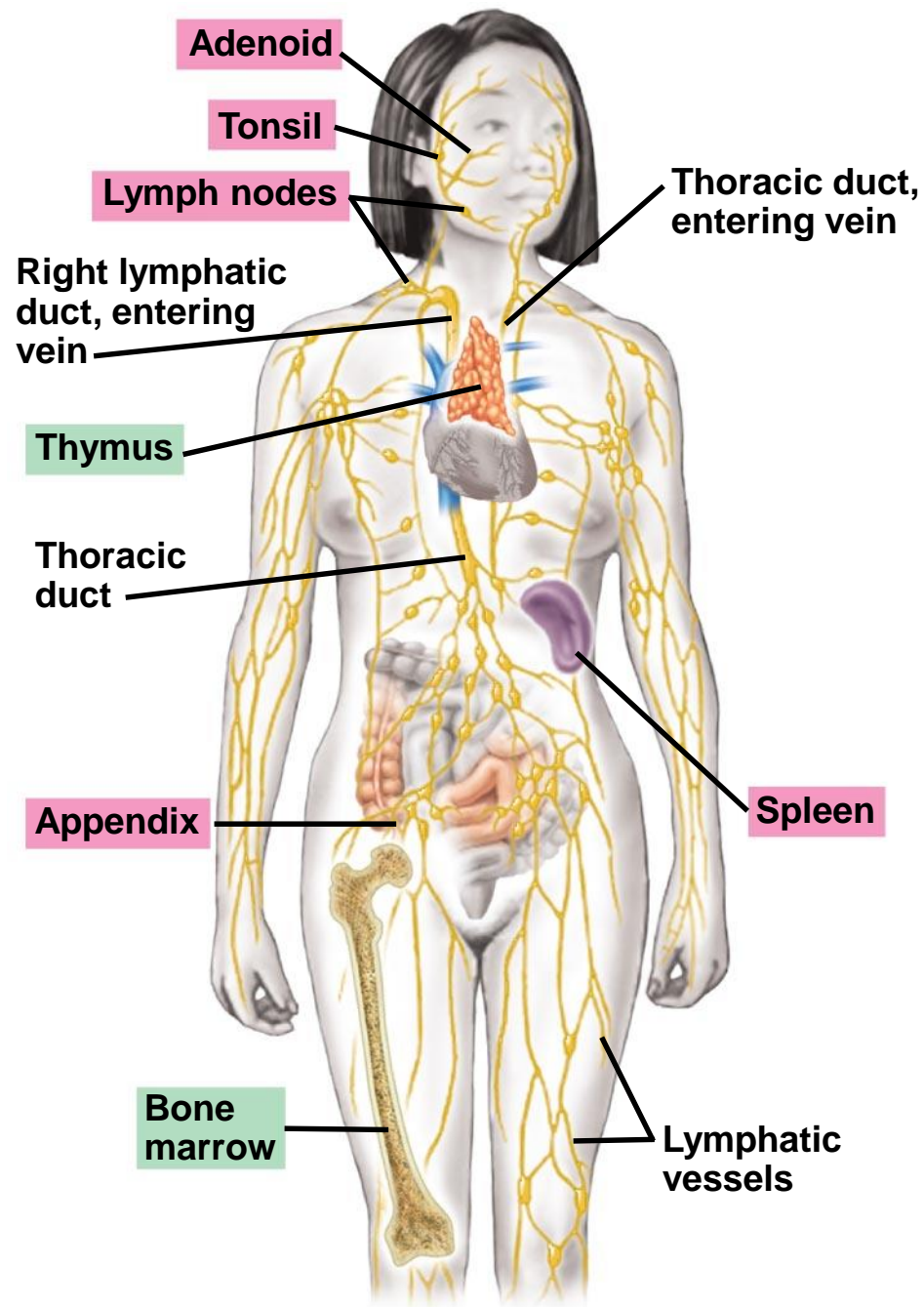
## 24.3 The lymphatic system becomes a crucial battleground during infection

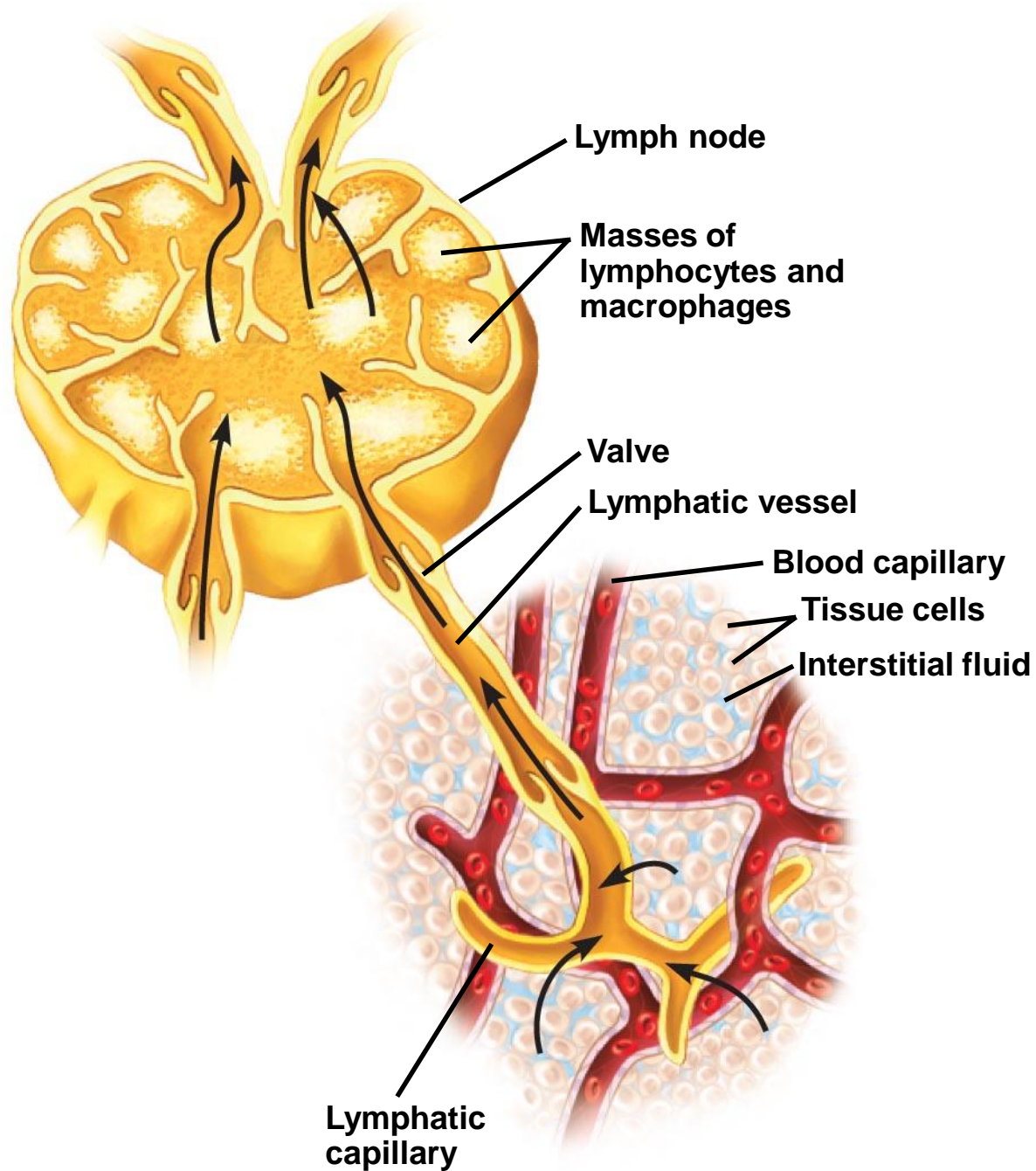
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- As lymph circulates through lymphatic organs it
  - Collects
    - Microbes
    - Parts of microbes
    - Microbe toxins
  - Transports them to lymphatic organs
    - Macrophages in lymphatic organs engulf the invaders
    - Lymphocytes may mount an acquired immune response











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# ACQUIRED IMMUNITY

## 24.4 The acquired immune response counters specific invaders

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- Our immune system
  - Responds to foreign molecules called **antigens**
- The acquired immune system
  - Reacts to antigens
  - And “remembers” an invader

## 24.4 The acquired immune response counters specific invaders

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- Infection or vaccination triggers **active immunity**
- We can temporarily acquire **passive immunity** by receiving premade antibodies



## 24.5 Lymphocytes mount a dual defense

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- Two kinds of **lymphocytes** carry out the immune response
  - **B cells**
    - Secrete antibodies
    - Mount the **humoral immune response**
  - **T cells**
    - Attack cells infected with bacteria or viruses
    - **Cell-mediated immune response**

## Humoral immune response

Bone marrow

Stem cell

Immature lymphocytes

Antigen receptor

B cell

## Cell-mediated immune response

Thymus

Via blood

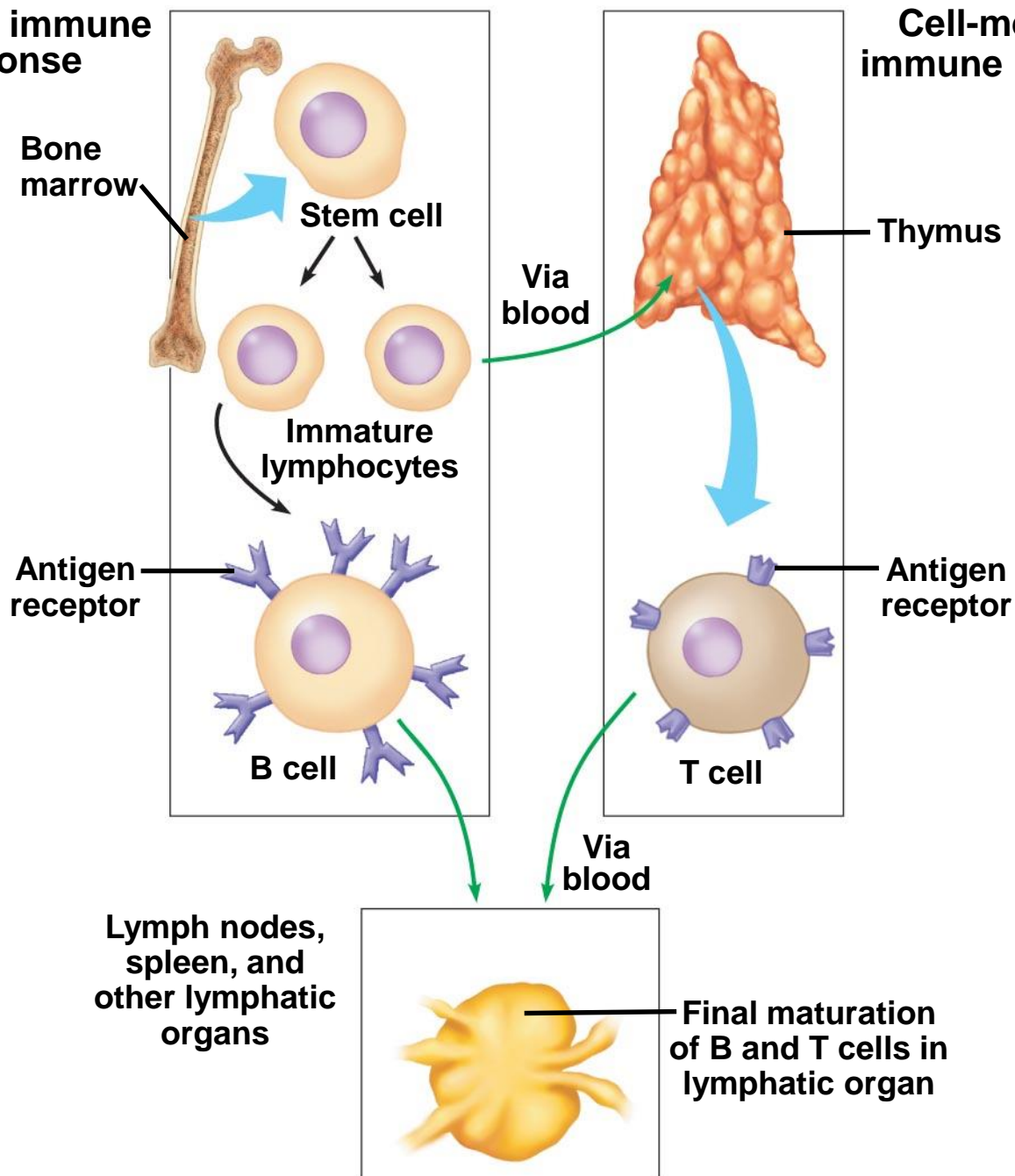
Antigen receptor

T cell

Via blood

Lymph nodes, spleen, and other lymphatic organs

Final maturation of B and T cells in lymphatic organ

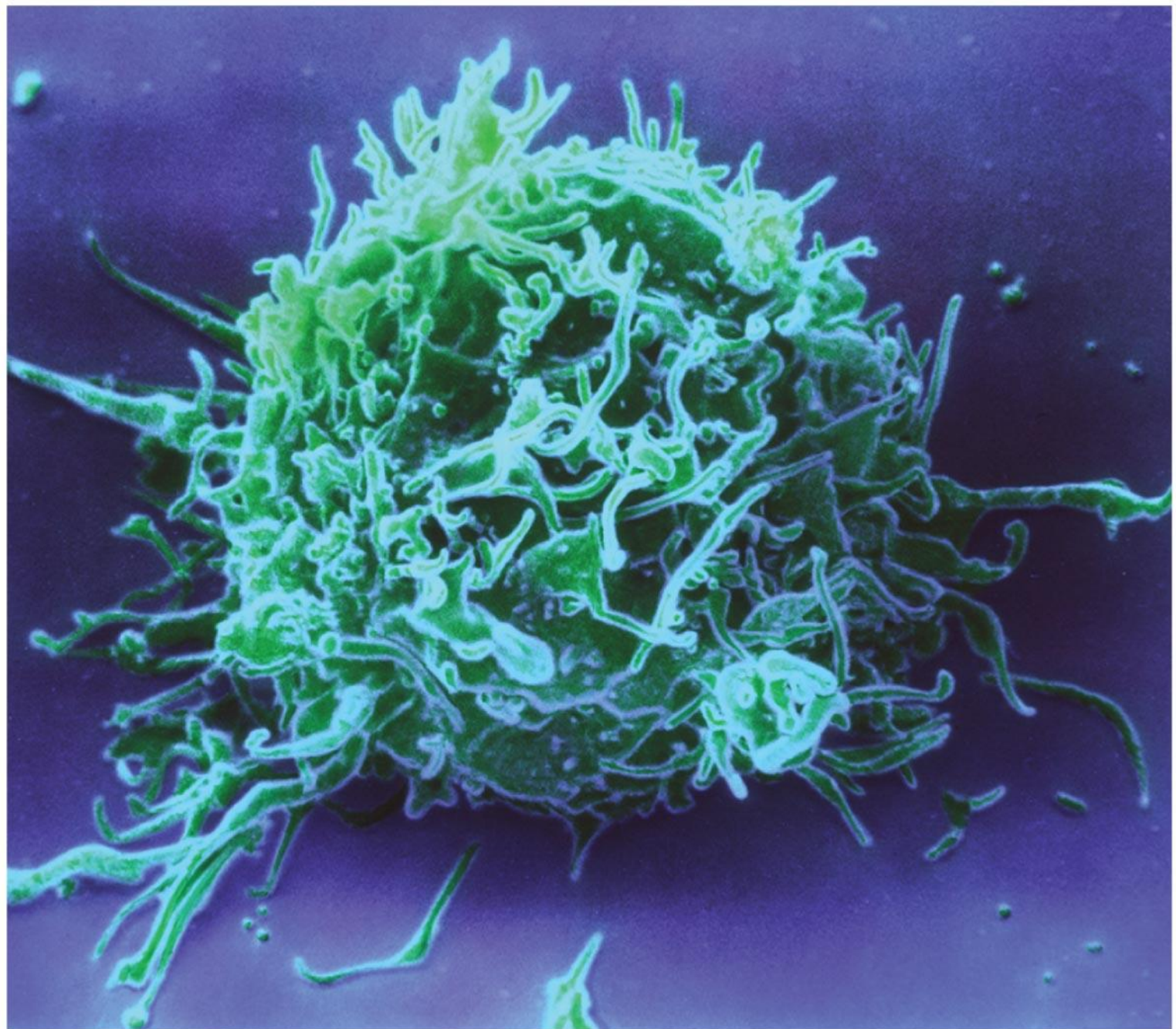


## 24.5 Lymphocytes mount a dual defense

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- Millions of kinds of B cells and T cells
  - Each with different membrane receptors
  - Wait in the lymphatic system
  - Where they may respond to invaders





## 24.6 Antigens have specific regions where antibodies bind to them

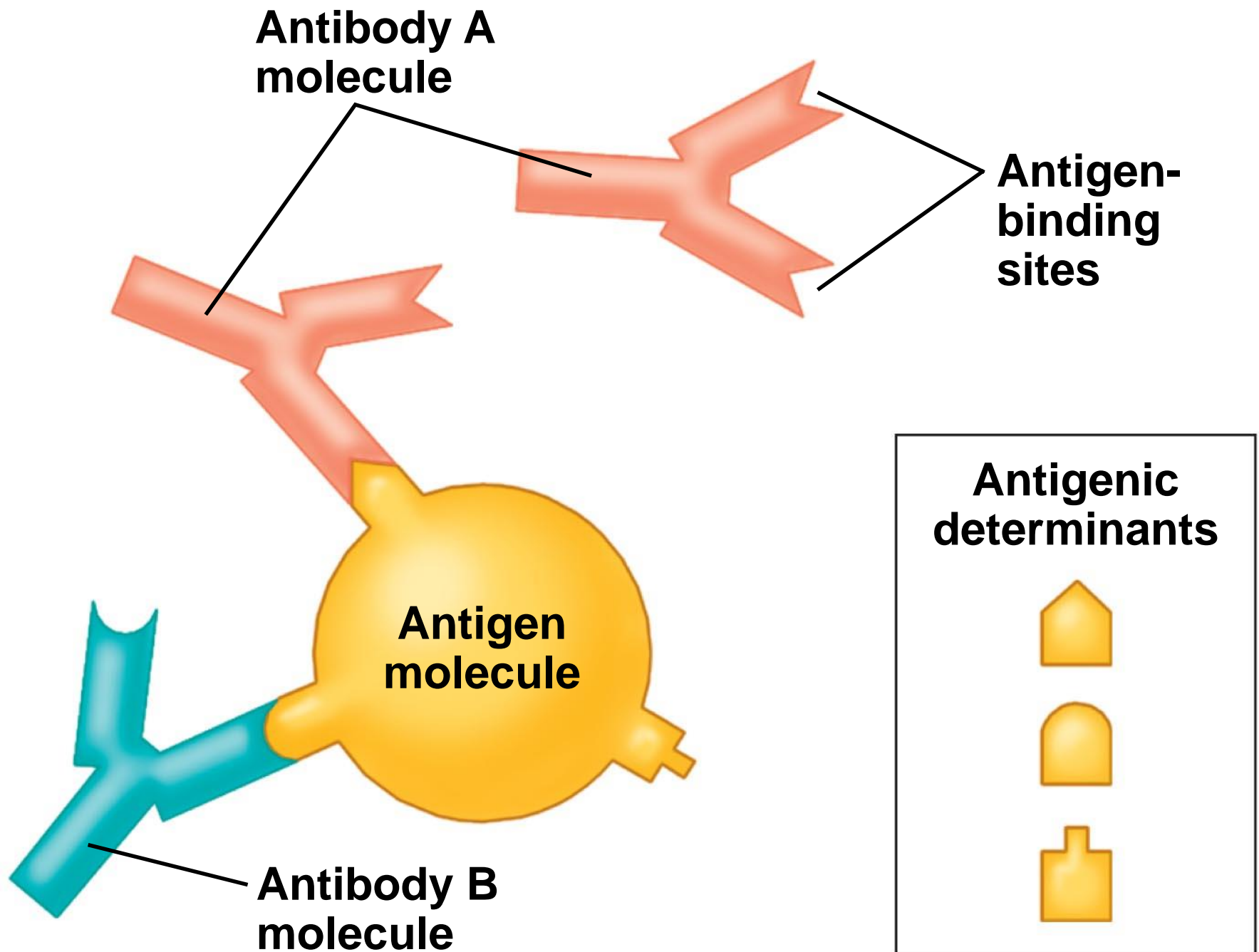
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- **Antigens**

- Not usually part of the host
- Most are proteins or large polysaccharides on the surfaces of
  - Viruses
  - Foreign cells

- **Antigenic determinants**

- Specific regions on an antigen
- To which antibodies bind



## 24.7 Clonal selection musters defensive forces against specific antigens

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- When an antigen enters the body
  - It activates only a small subset of lymphocytes
  - Those with complementary receptors
- The selected lymphocyte cells multiply into clones of short-lived effector cells
  - Specialized for defending against the antigen that triggered the response
  - And into memory cells that confer long-term immunity

## 24.7 Clonal selection musters defensive forces against specific antigens

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- The steps of **clonal selection**
  - **Primary immune response**, clonal selection
    - Produces **effector cells**
    - **Memory cells** that may confer lifelong immunity
  - **Secondary immune response**
    - Memory cells are activated by a second exposure to the same antigen
    - This initiates a faster and stronger response

**PLAY**

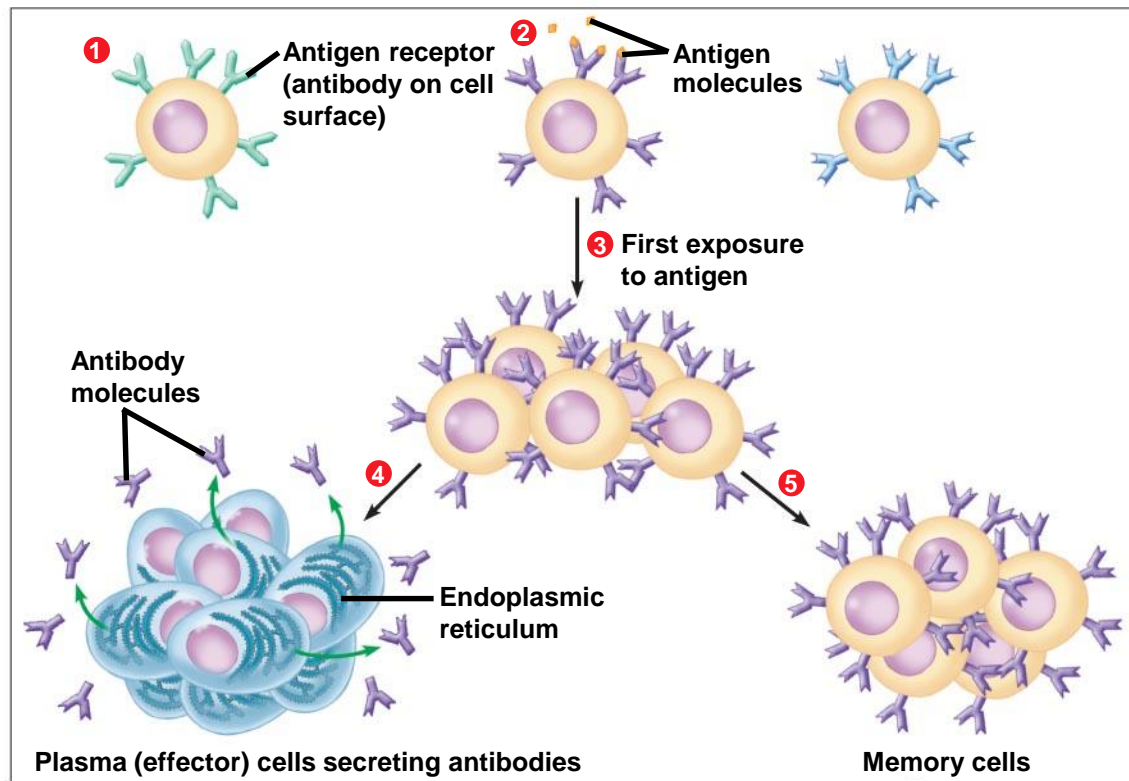
Animation: Role of B Cells



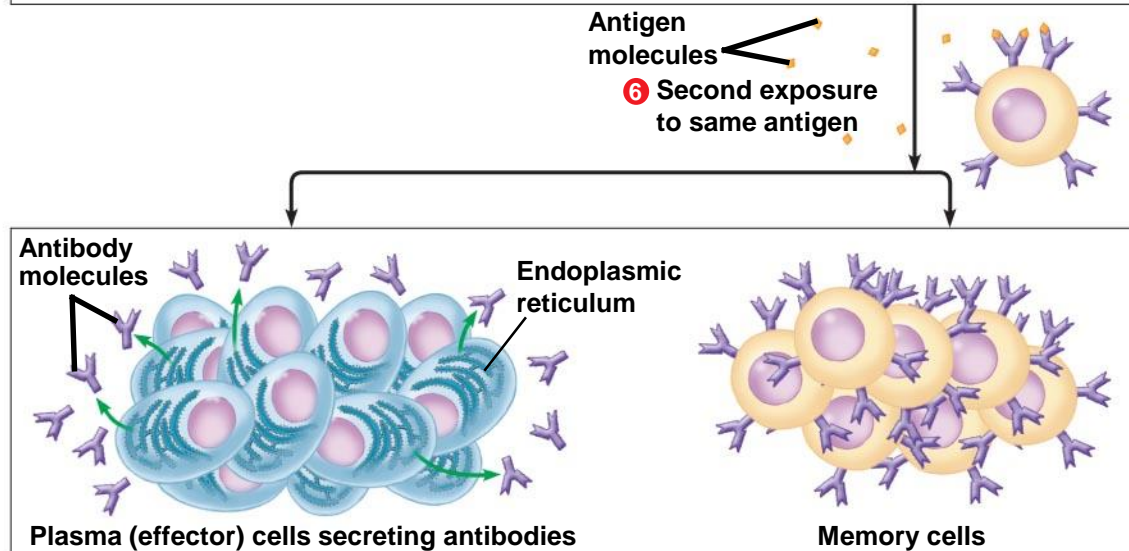
**Primary immune response**  
B cells with different antigen receptors

**Cell activation: growth, division, and differentiation**

**First clone**

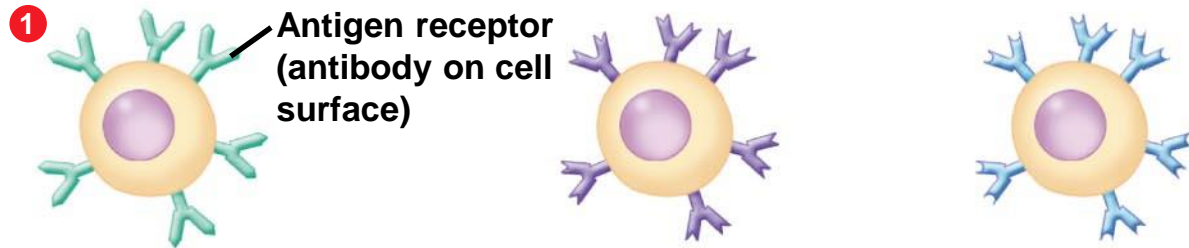


**Secondary immune response (May occur long after primary immune response.)**  
**Second clone**



**Primary immune  
response**

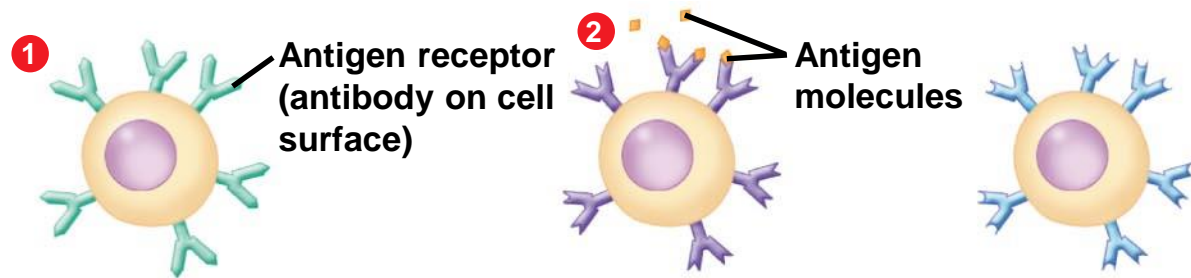
**B cells with  
different  
antigen  
receptors**





**Primary immune  
response**

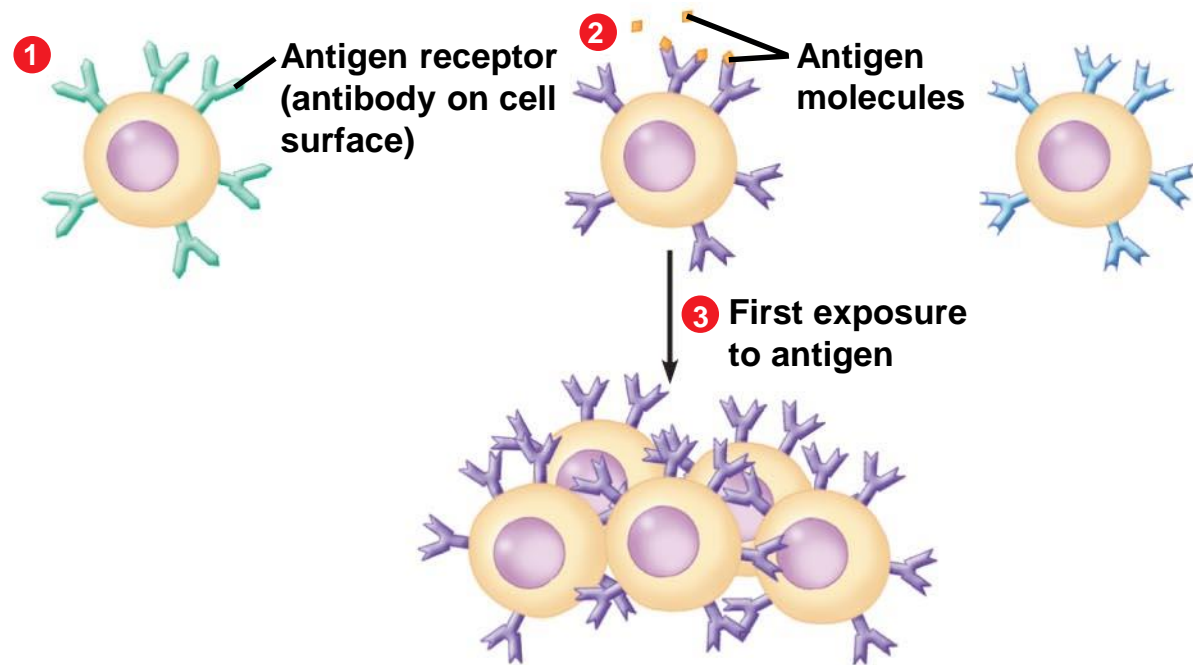
**B cells with  
different  
antigen  
receptors**



**Primary immune response**

**B cells with different antigen receptors**

**Cell activation: growth, division, and differentiation**

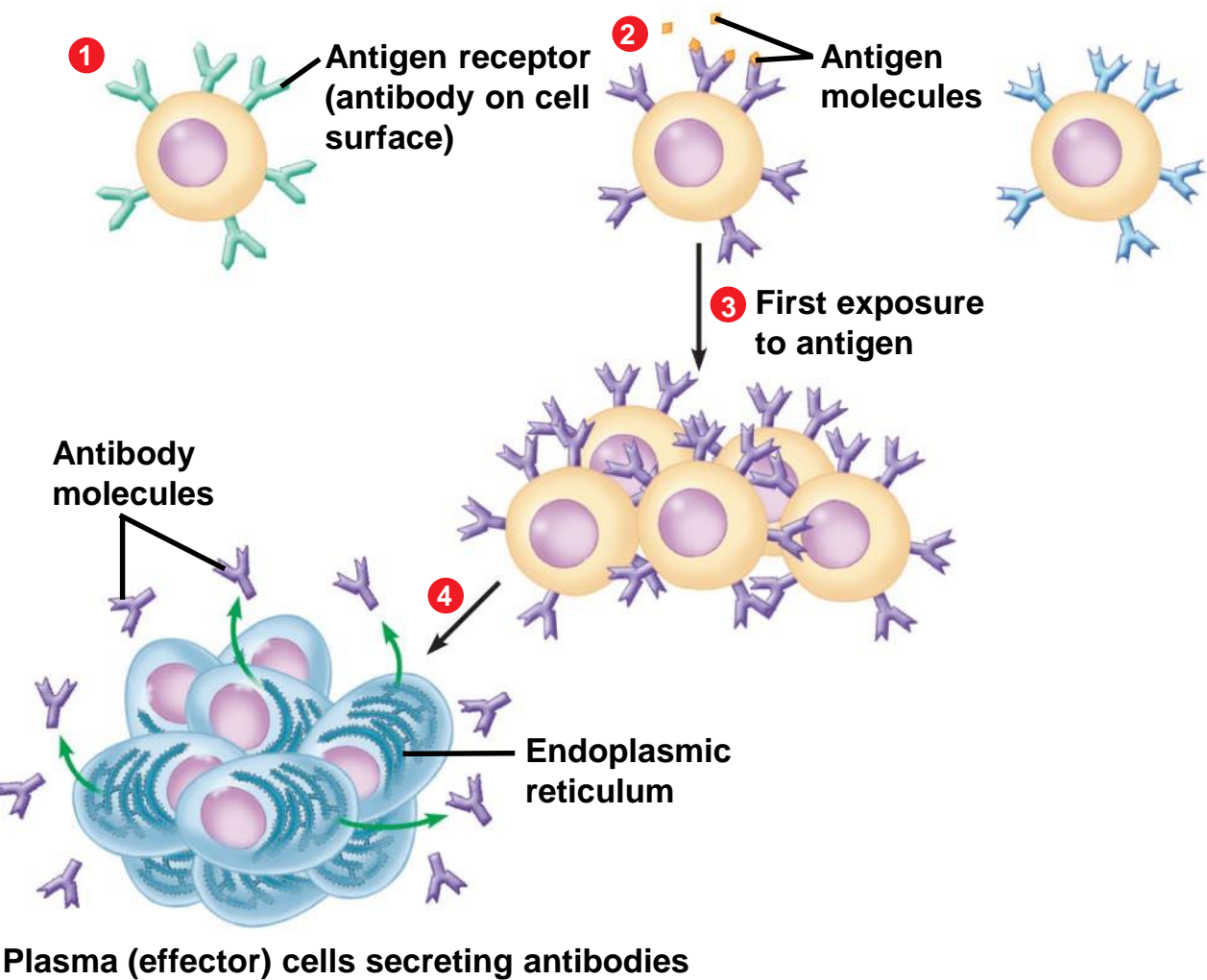


Primary immune response

B cells with different antigen receptors

Cell activation: growth, division, and differentiation

First clone

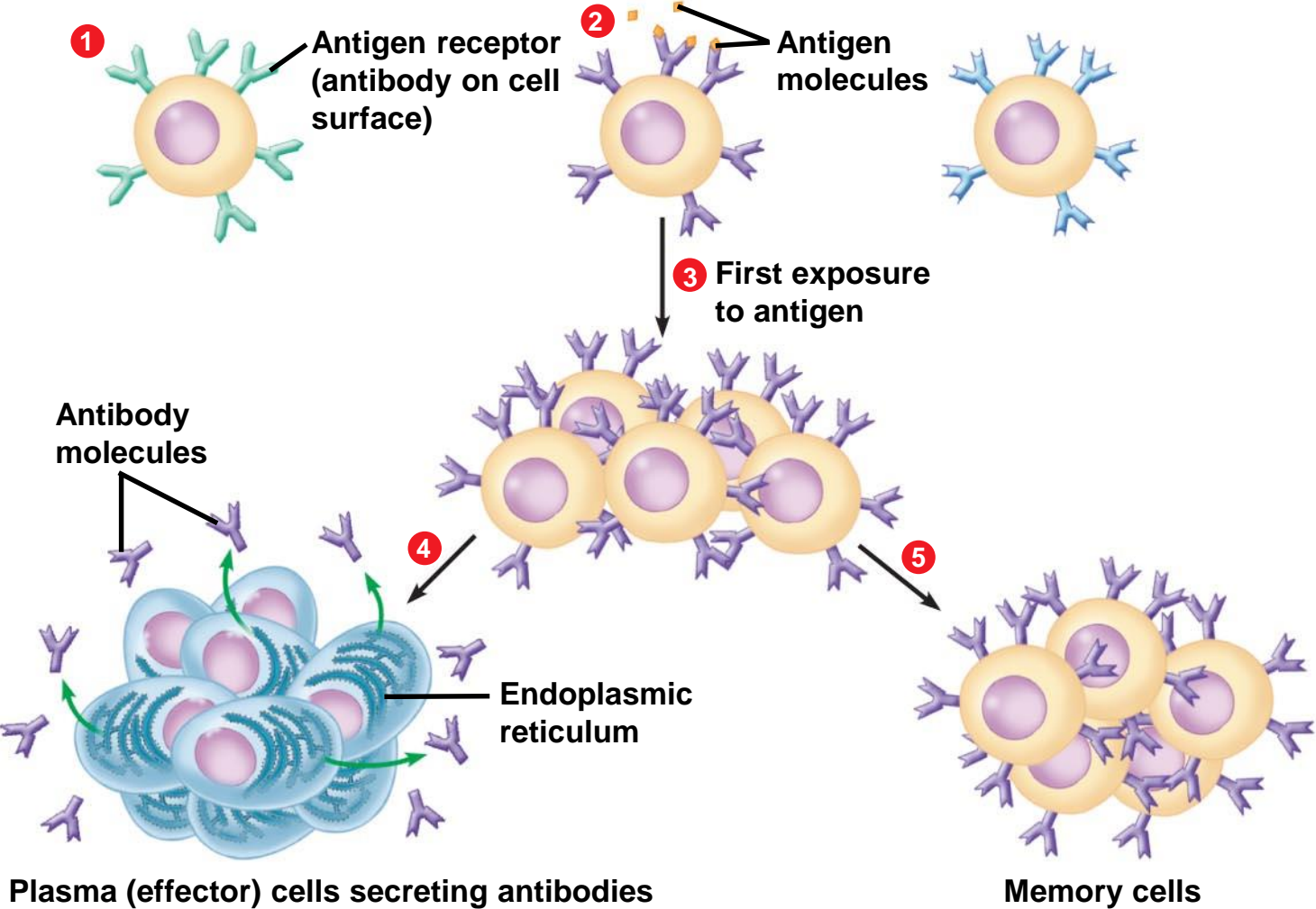


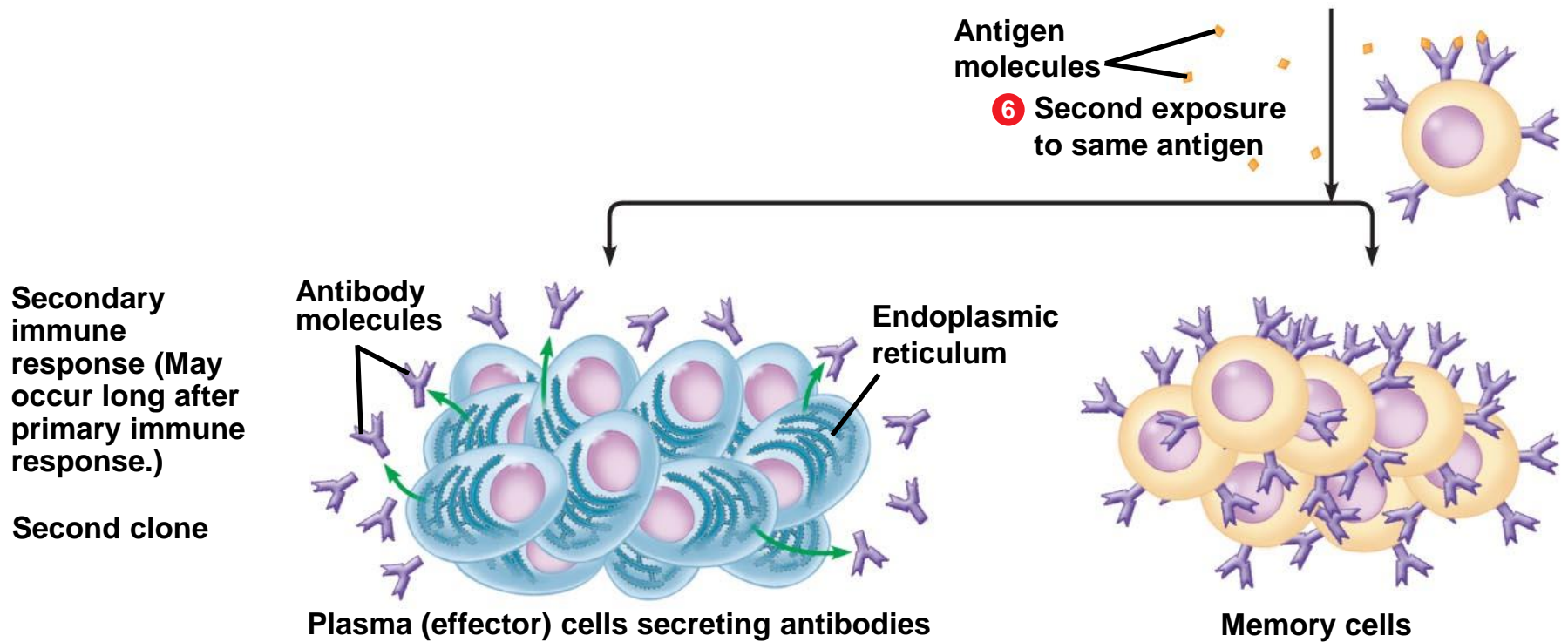
Primary immune response

B cells with different antigen receptors

Cell activation: growth, division, and differentiation

First clone

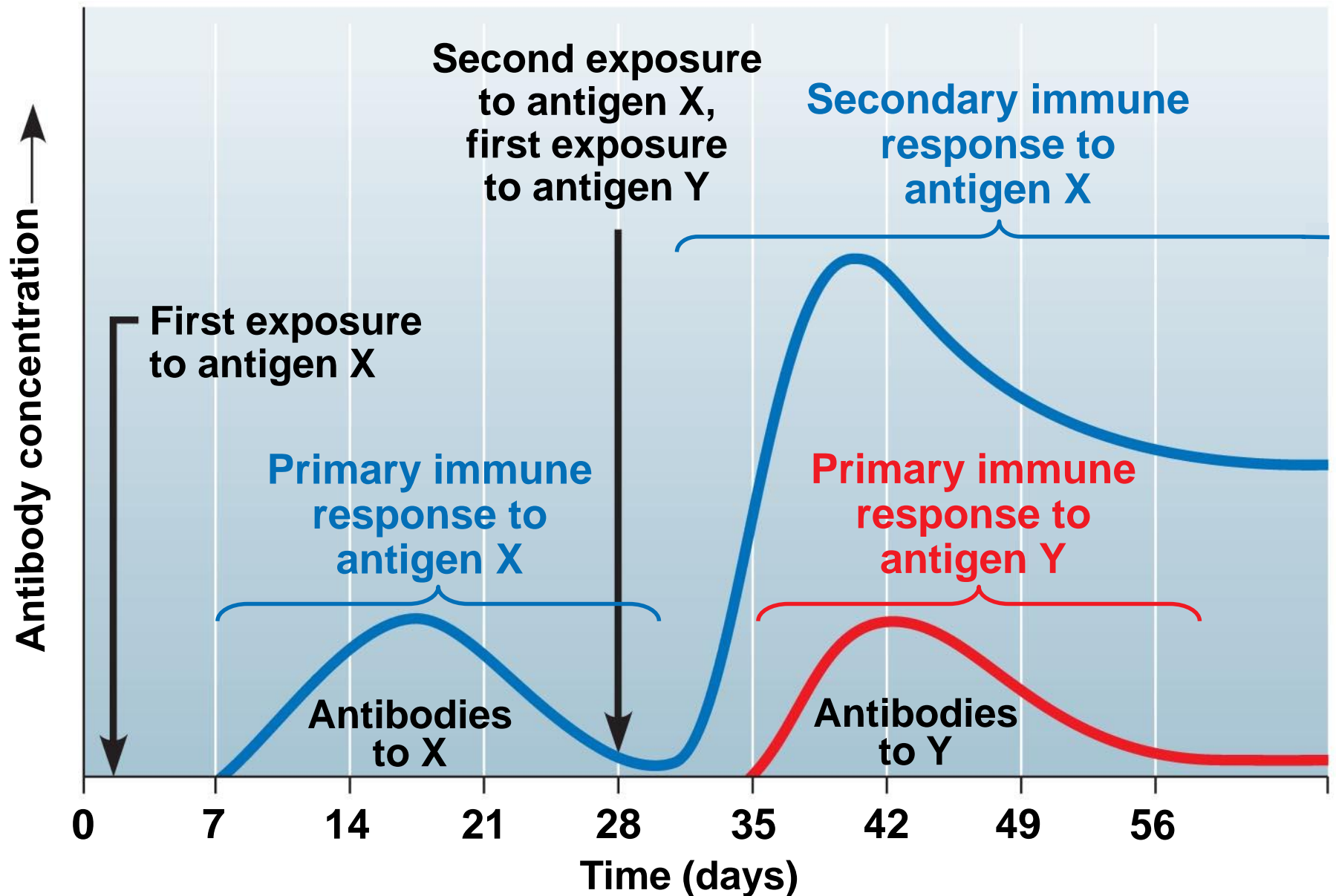




## 24.7 Clonal selection musters defensive forces against specific antigens

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- Primary vs. secondary immune response
  - The primary immune response
    - Occurs upon first exposure to an antigen
    - Is slower than the secondary immune response
  - The secondary immune response
    - Occurs upon second exposure to an antigen
    - Is faster and stronger than the primary immune response

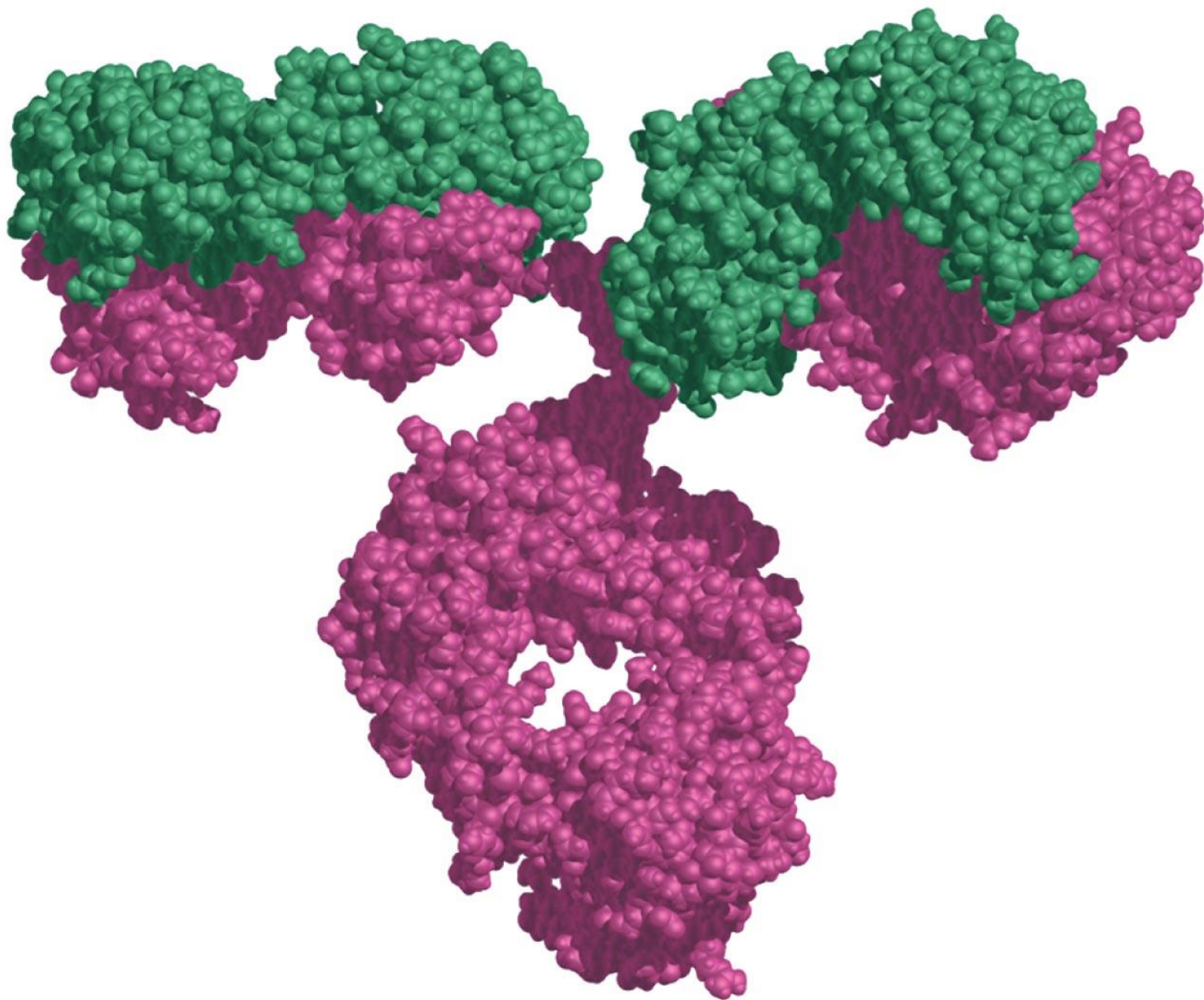




## 24.8 Antibodies are the weapons of the humoral immune response

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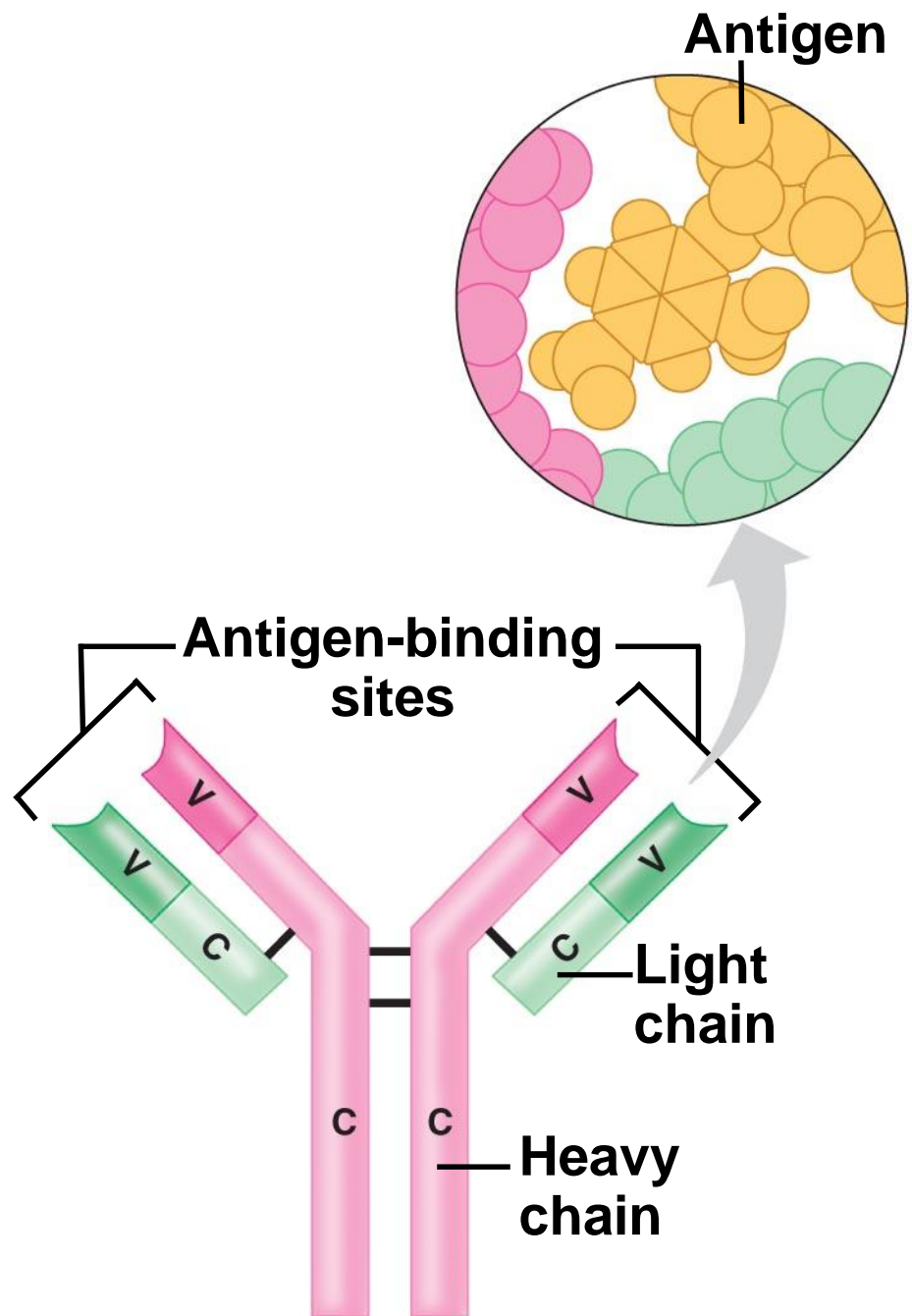
- Antibodies
  - Are secreted by plasma (effector) B cells
  - Into the blood and lymph



## 24.8 Antibodies are the weapons of the humoral immune response

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- An antibody molecule
  - Is Y-shaped
  - With two **antigen-binding sites**
  - Specific to the antigenic determinants
  - That elicited its secretion



## 24.9 Antibodies mark antigens for elimination

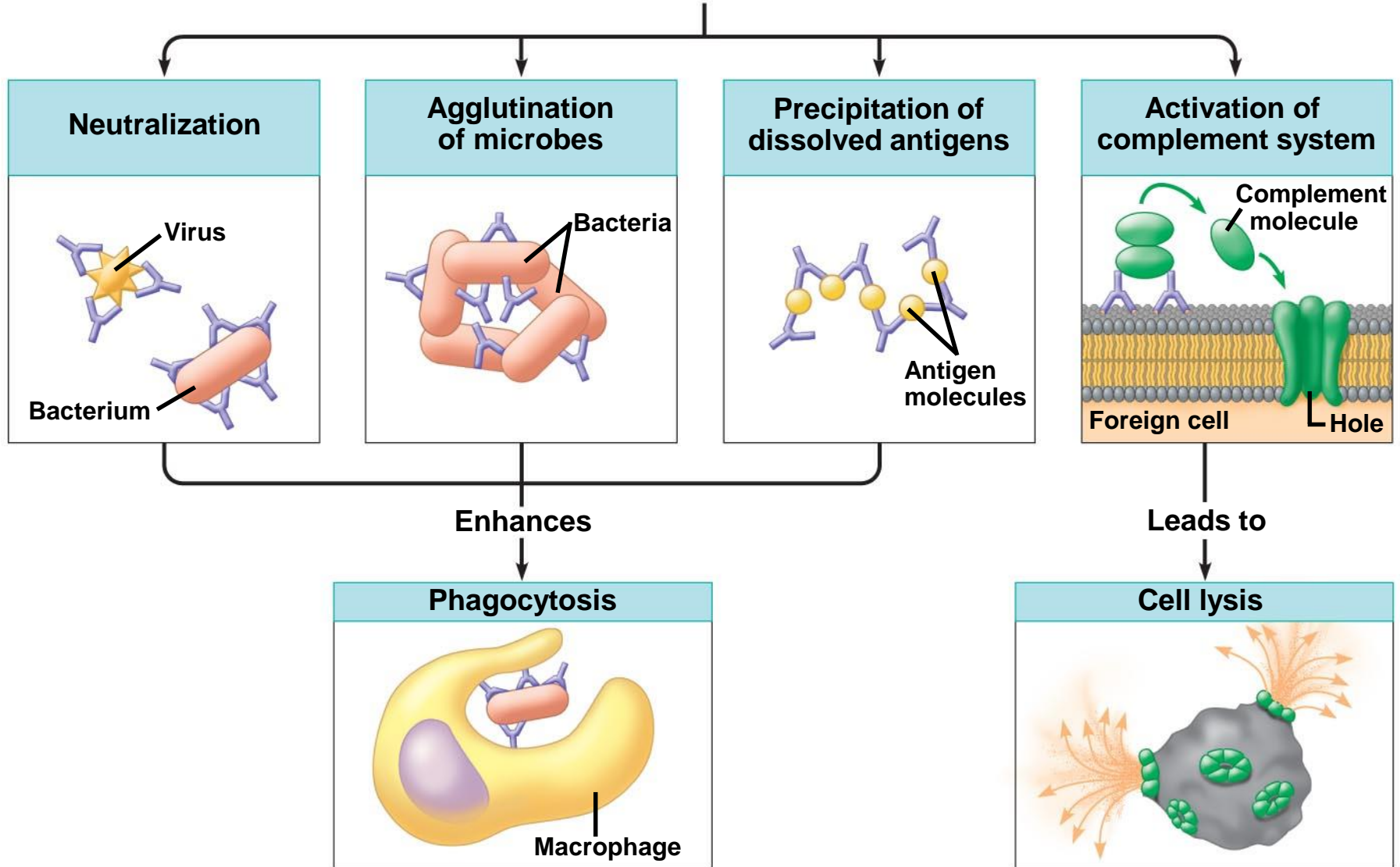
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- Antibodies promote antigen elimination through several mechanisms
  - Mark invaders
  - Which triggers mechanisms to neutralize or destroy invaders

**PLAY**

Animation: Antibodies

## Binding of antibodies to antigens inactivates antigens by

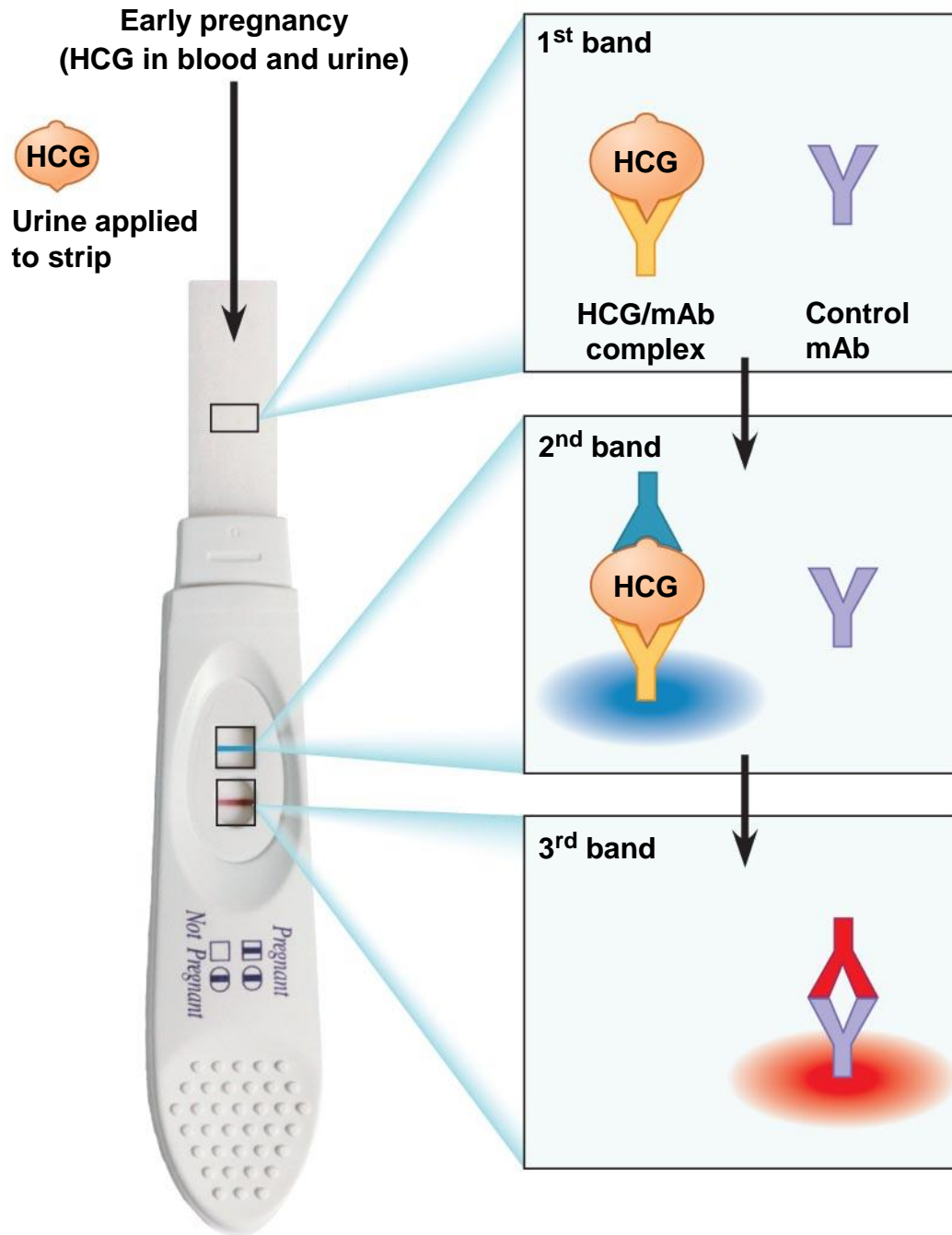




## 24.10 CONNECTION: Monoclonal antibodies are powerful tools in the lab and clinic

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- **Monoclonal antibodies (mAb)**
  - Name means all antibody-producing cells come from one cell
  - Produced by fusing
    - B cells specific for a single antigenic determinant with
    - Easy to grow tumor cells



## **24.10 CONNECTION: Monoclonal antibodies are powerful tools in the lab and clinic**

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- Monoclonal antibodies are useful in
  - Research
  - Diagnosis
  - Treatment of certain cancers

## 24.11 Helper T cells stimulate the humoral and cell-mediated immune responses

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- **Helper T cells and cytotoxic T cells**
  - Are primarily responsible for the cell-mediated immune response
  - Helper T cells also stimulate the humoral response

## 24.11 Helper T cells stimulate the humoral and cell-mediated immune responses

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- In the cell-mediated immune response, an **antigen-presenting cell** displays
  - A foreign antigen (a **nonself molecule**) and
  - One of the body's own **self proteins**
  - To a helper T cell

## 24.11 Helper T cells stimulate the humoral and cell-mediated immune responses

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- The helper T cell's receptors
  - Recognize the self–nonself complexes
  - The interaction activates the helper T cells
- The helper T cell can then activate
  - Cytotoxic T cells and
  - B cells

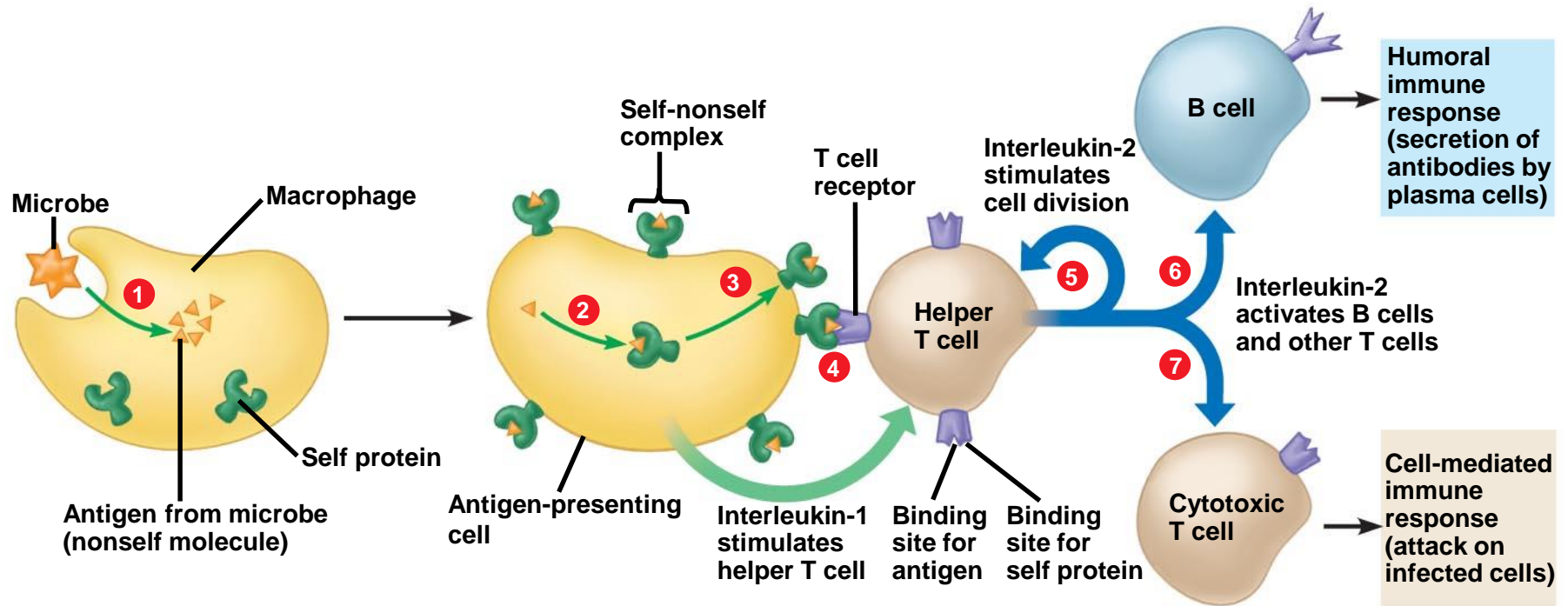
**PLAY**

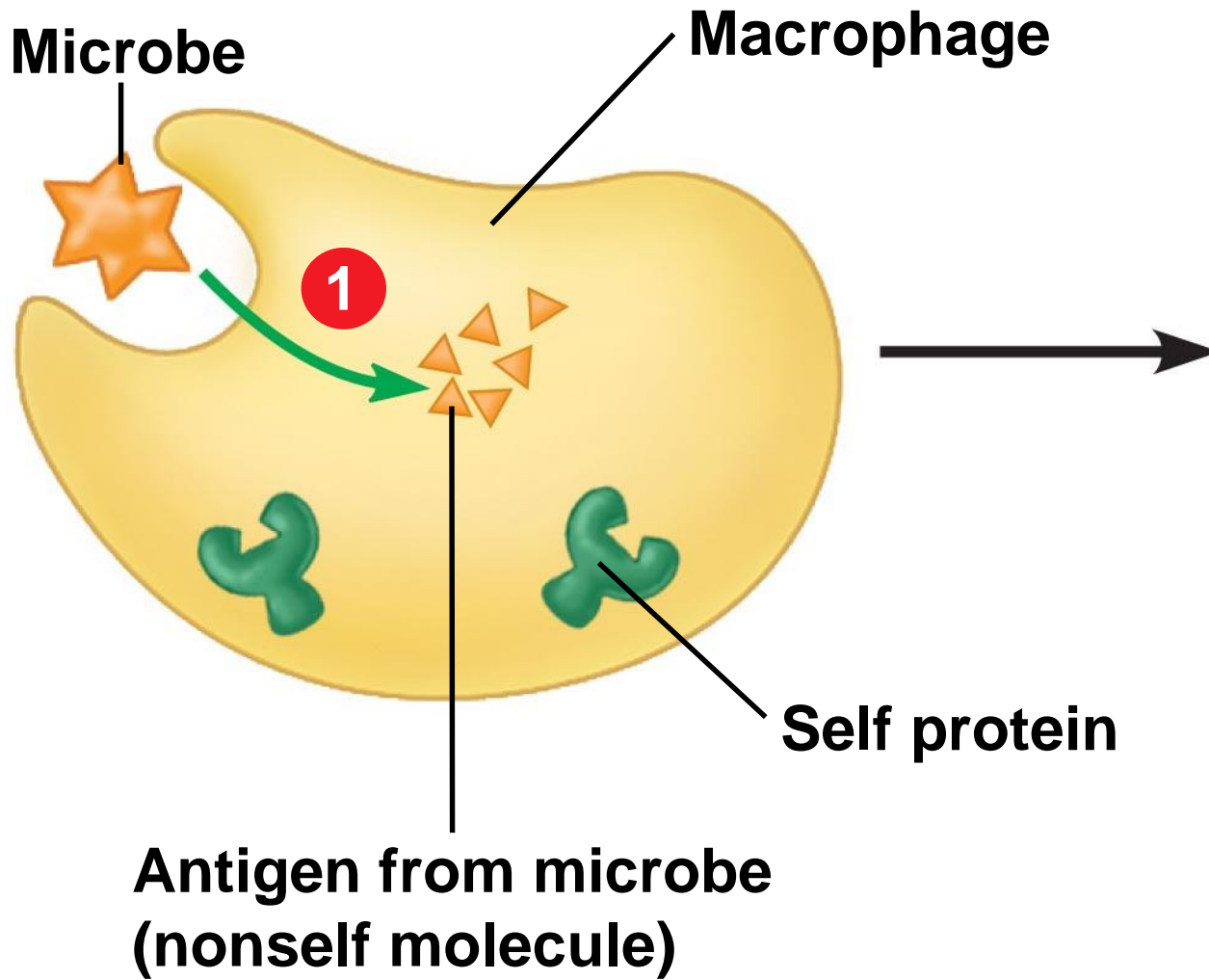
Animation: Helper T Cell

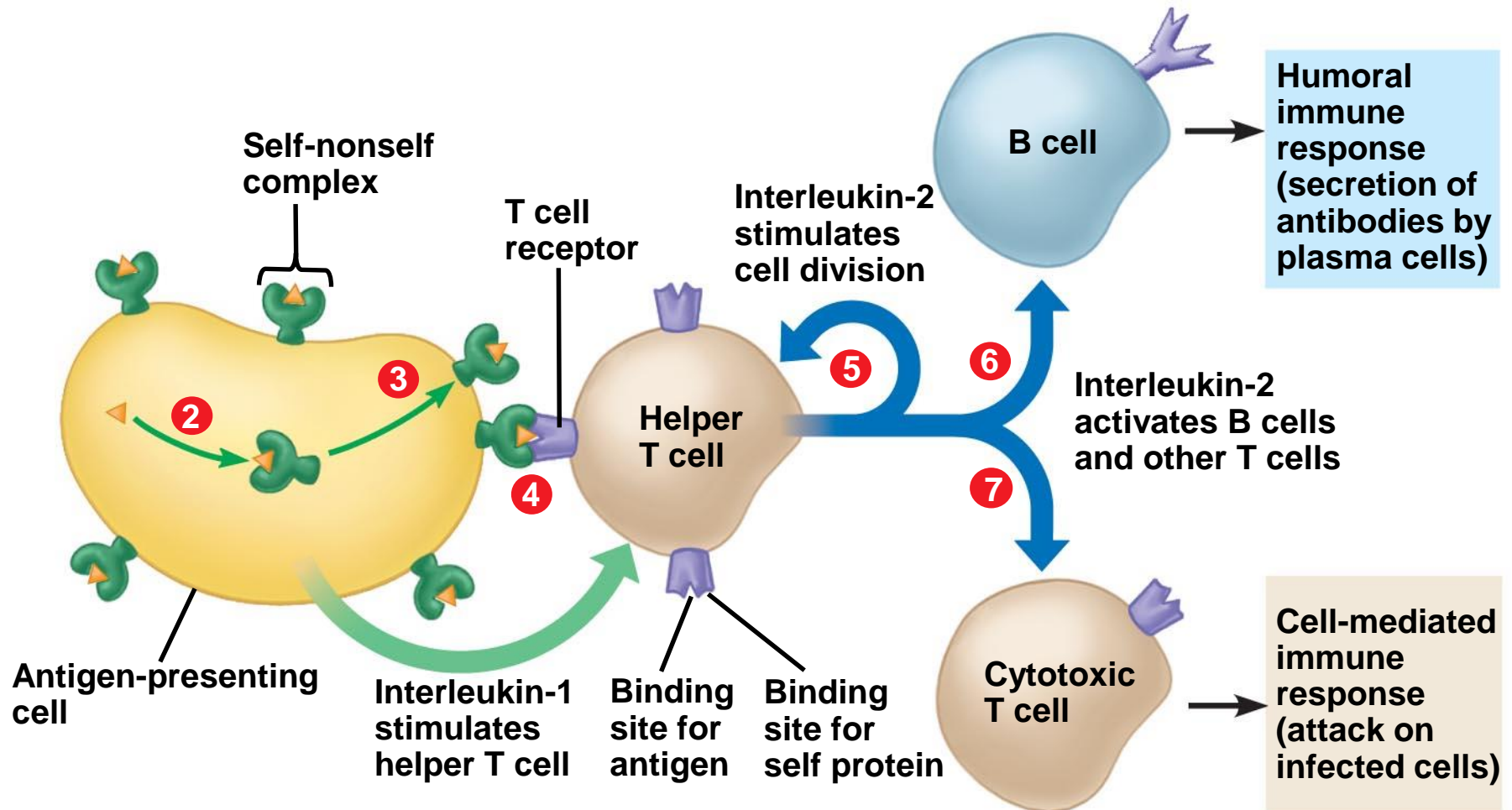
**PLAY**

Video: T Cell Receptors









# 24.12 Cytotoxic T cells destroy infected body cells

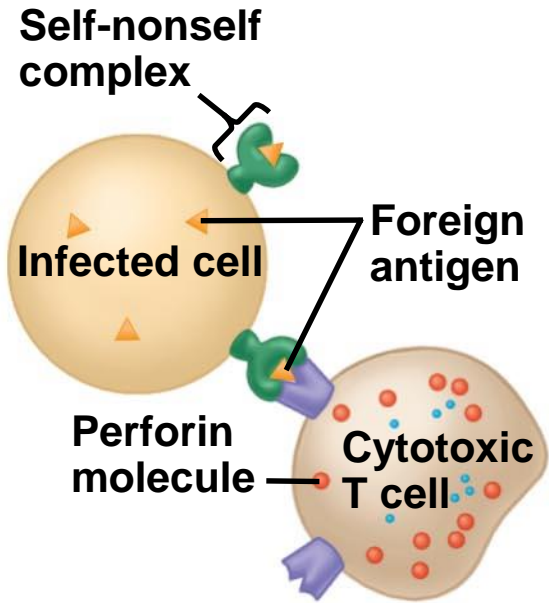
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- Cytotoxic T cells
  - Are the only T cells that kill infected cells
- Cytotoxic T cells
  - Bind to infected body cells
  - Destroy them

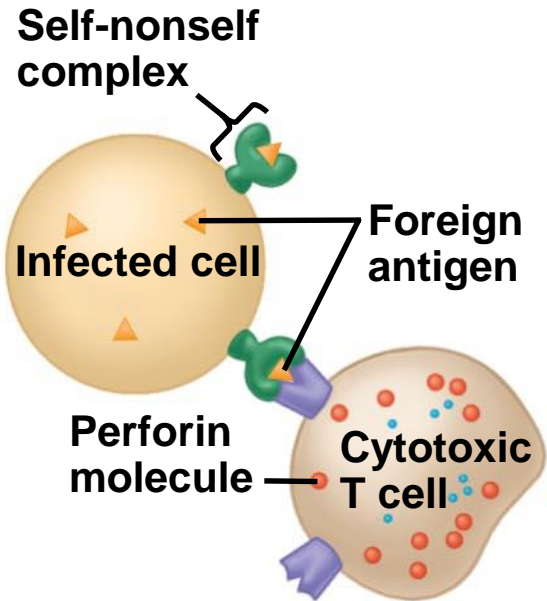
**PLAY**

Animation: Cytotoxic T Cells

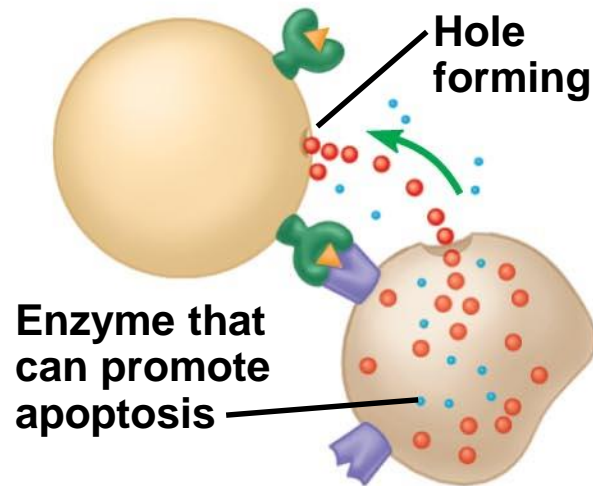
**1 Cytotoxic T cell binds to infected cell**



**1 Cytotoxic T cell binds to infected cell**

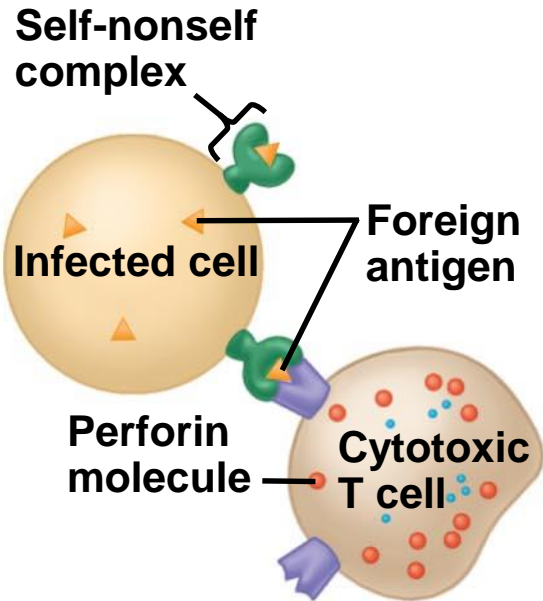


**2 Perforin makes holes in infected cell's membrane and enzyme enters**

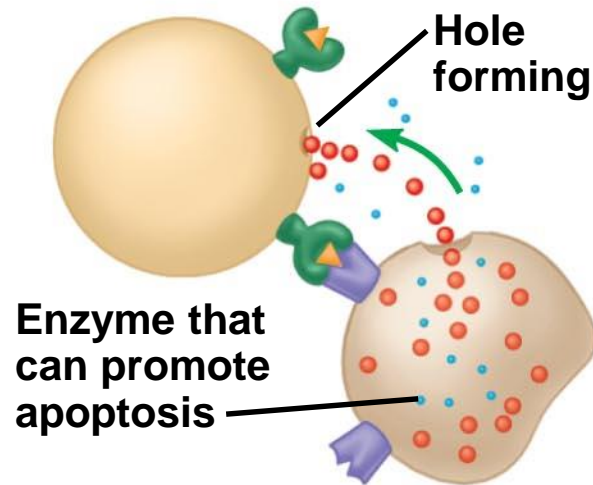




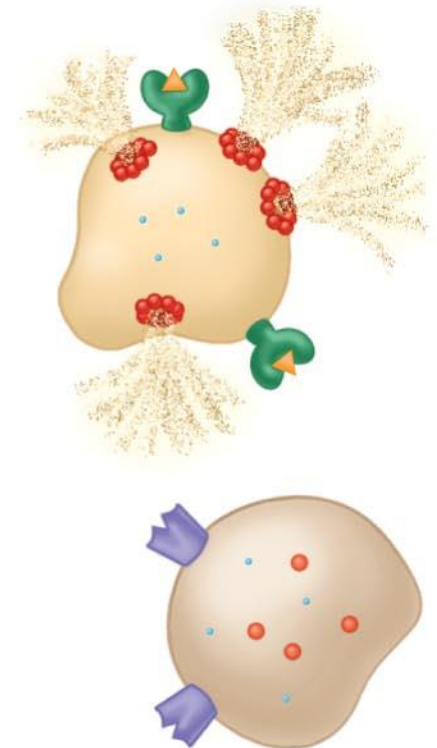
**1 Cytotoxic T cell binds to infected cell**



**2 Perforin makes holes in infected cell's membrane and enzyme enters**



**3 Infected cell is destroyed**



## 24.13 CONNECTION: HIV destroys helper T cells, compromising the body's defenses

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- **AIDS (acquired immunodeficiency syndrome)**
  - Results from infection by **HIV (human immunodeficiency virus)**
  - Between 1981 and 2007 AIDS killed more than 27 million people
  - In 2006, 4.3 million people were newly infected with HIV, including 400,000 children under age 15
  - Most AIDS deaths occur in nonindustrialized nations
  - In some African nations, about 40% of adults are HIV positive

## 24.13 CONNECTION: HIV destroys helper T cells, compromising the body's defenses

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- The AIDS virus usually attacks helper T cells impairing the
  - Cell-mediated immune response and
  - Humoral immune response
  - Opening the way for **opportunistic infection**

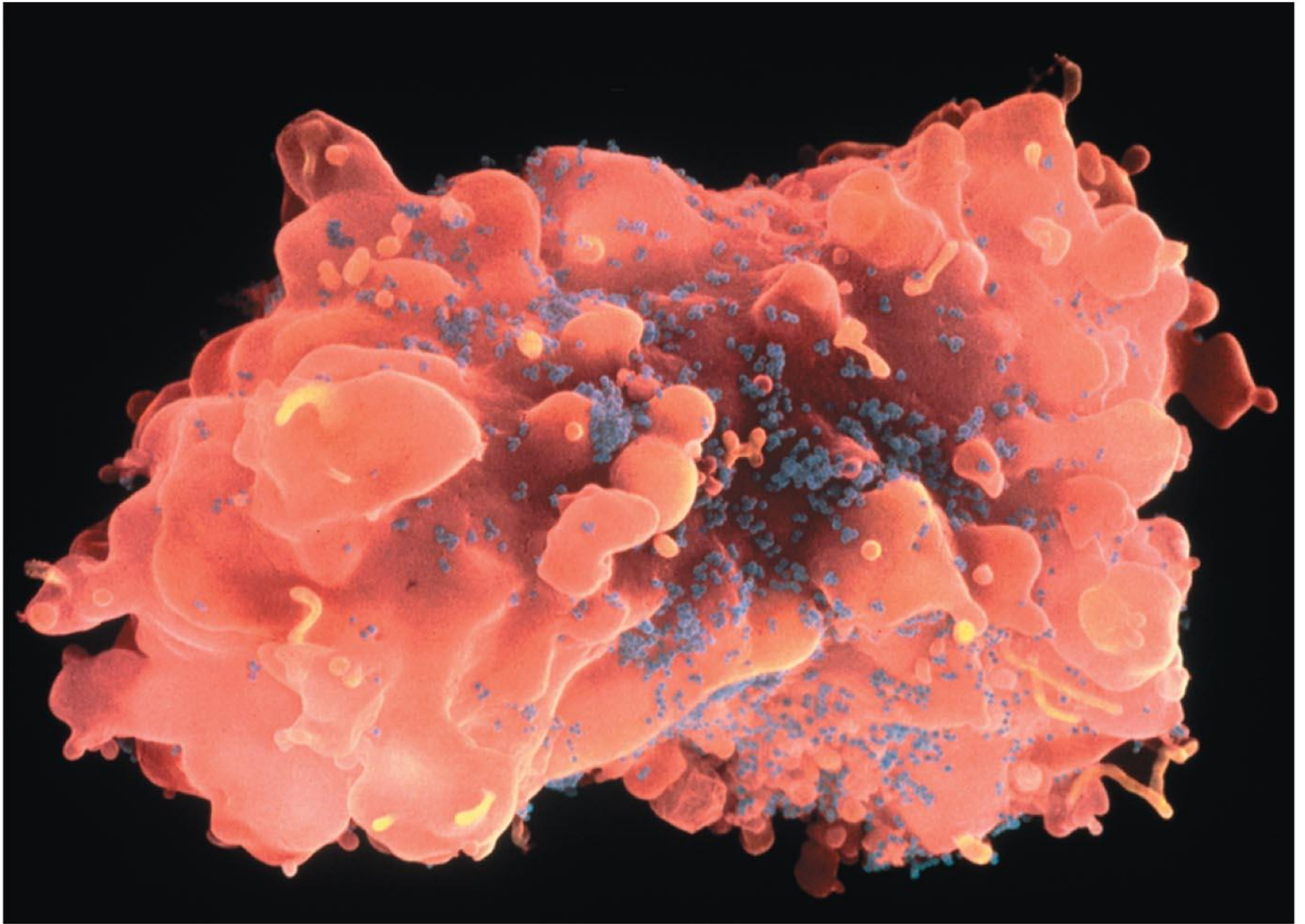
## 24.13 CONNECTION: HIV destroys helper T cells, compromising the body's defenses

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- AIDS patients typically die from
  - Opportunistic infections and
  - Cancers
  - That would normally be resisted by a person with a healthy immune system

**PLAY**

Animation: HIV Reproductive Cycle



## **24.14 EVOLUTION CONNECTION: The rapid evolution of HIV complicates AIDS treatment**

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- HIV mutates faster than any pathogen ever studied
- New strains may be resistant to AIDS drugs
- Drug-resistant strains now infect new patients

## **24.14 EVOLUTION CONNECTION: The rapid evolution of HIV complicates AIDS treatment**

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- The evolution of the AIDS virus is the number one obstacle to eradicating AIDS
- Current drugs are unable to
  - Eliminate HIV from a patient
  - Cure AIDS



## 24.15 The immune system depends on our molecular fingerprints

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- The immune system normally reacts
  - Only against nonself substances
  - Not against self

## 24.15 The immune system depends on our molecular fingerprints

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- Transplanted organs
  - May be rejected
  - Because the transplanted cells lack the unique “fingerprint” of the patient’s self proteins
- Donors are used that most closely match the patients tissues
- Transplants between identical twins do not typically have this problem

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# DISORDERS OF THE IMMUNE SYSTEM

## 24.16 CONNECTION: Malfunction or failure of the immune system causes disease

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- In **autoimmune diseases**

- The immune system turns against the body's own molecules
- Examples include
  - Lupus
  - Rheumatoid arthritis
  - Insulin-dependent diabetes mellitus
  - Multiple sclerosis

## 24.16 CONNECTION: Malfunction or failure of the immune system causes disease

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- In **immunodeficiency diseases**
  - Immune components are lacking
  - Recurrent infections are frequent
- The immune system may be weakened by
  - Physical stress
  - Emotional stress
  - Students are more likely to be sick during a week of exams

## 24.17 CONNECTION: Allergies are overreactions to certain environmental antigens

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### ■ Allergies

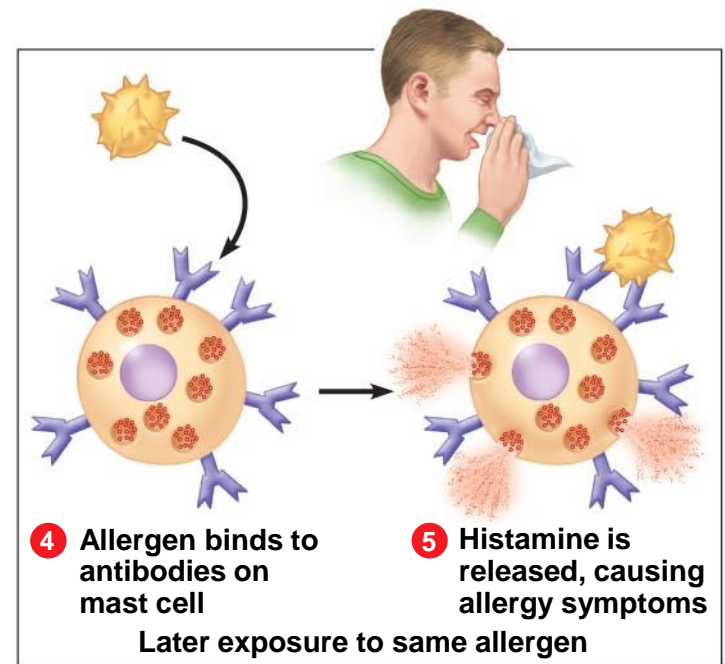
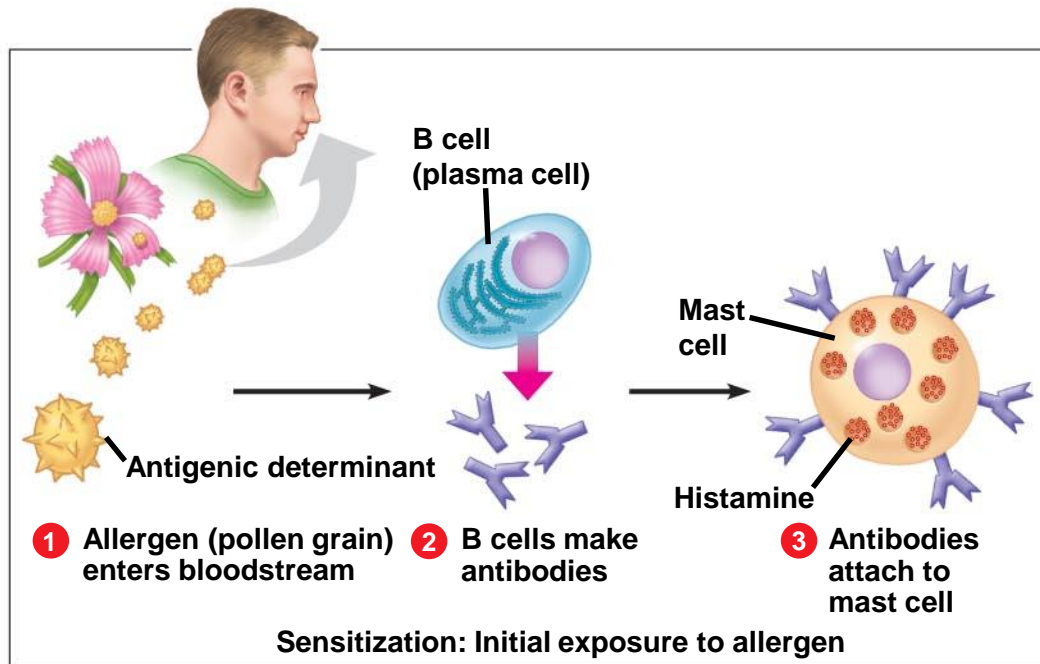
- Are hypersensitive (exaggerated) responses
- To antigens (**allergens**) in our environment

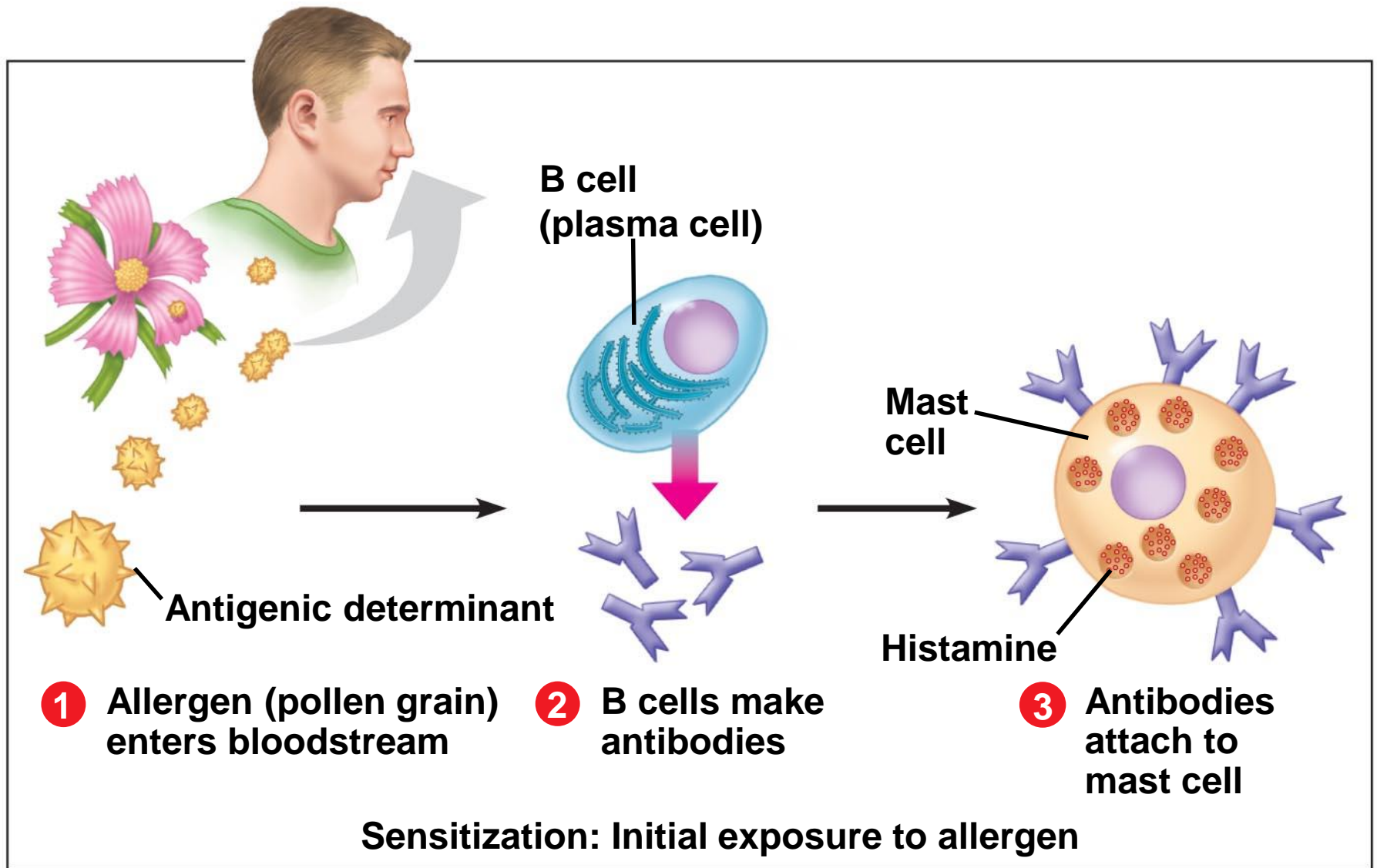
## 24.17 CONNECTION: Allergies are overreactions to certain environmental antigens

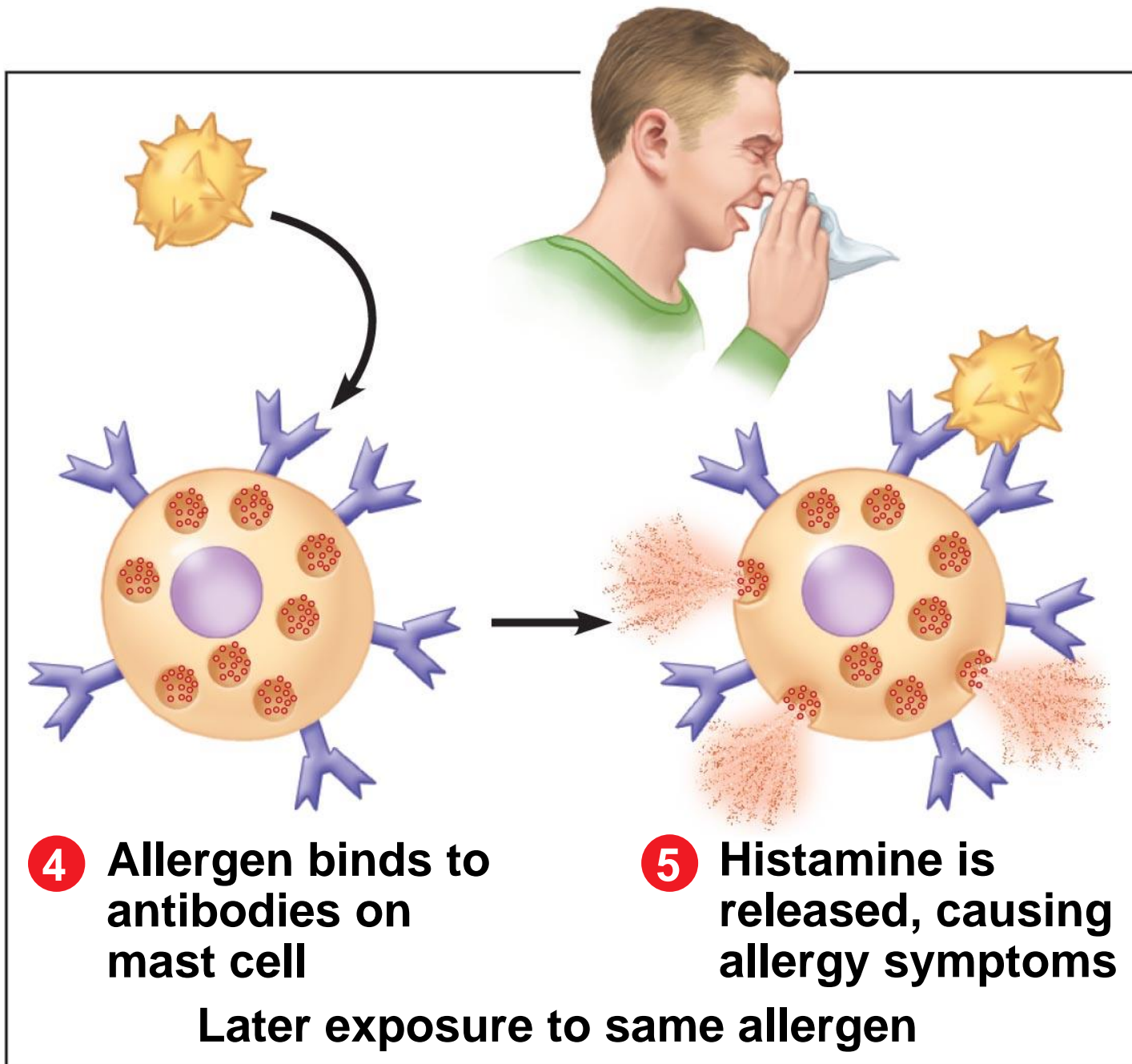
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- Allergic reactions typically occur
  - Very rapidly in response to
  - Tiny amounts of an allergen
- Allergic reactions can occur in many parts of the body
  - Nasal passages
  - Bronchi
  - Skin









## 24.17 CONNECTION: Allergies are overreactions to certain environmental antigens

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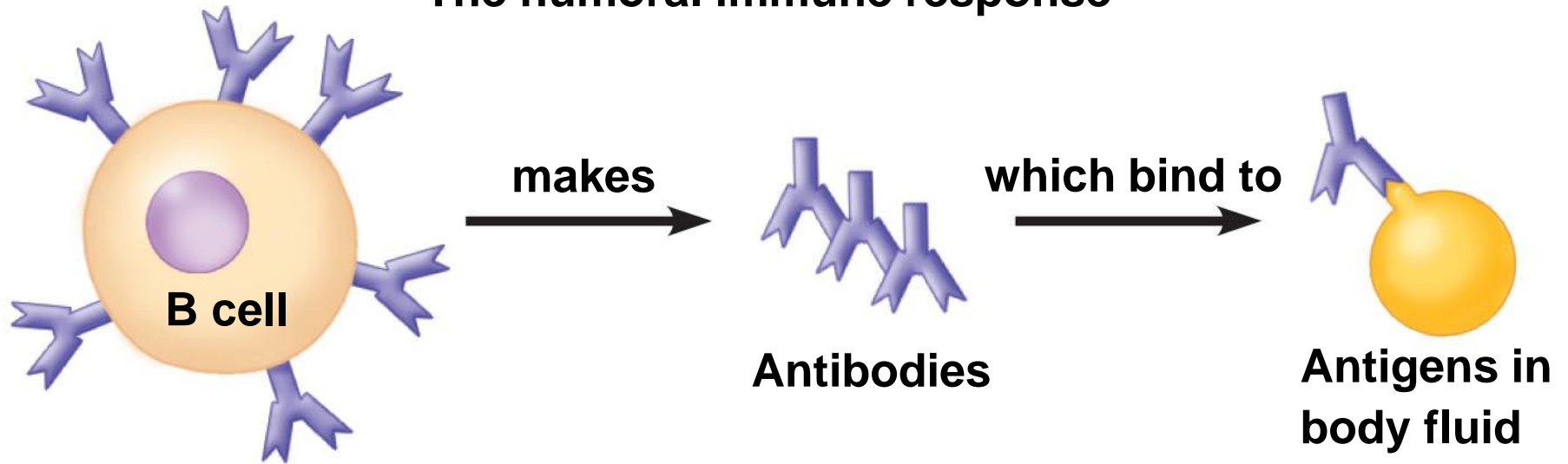
### ■ **Antihistamines**

- Interfere with histamine's action
- Provide temporary relief
- Often make people drowsy

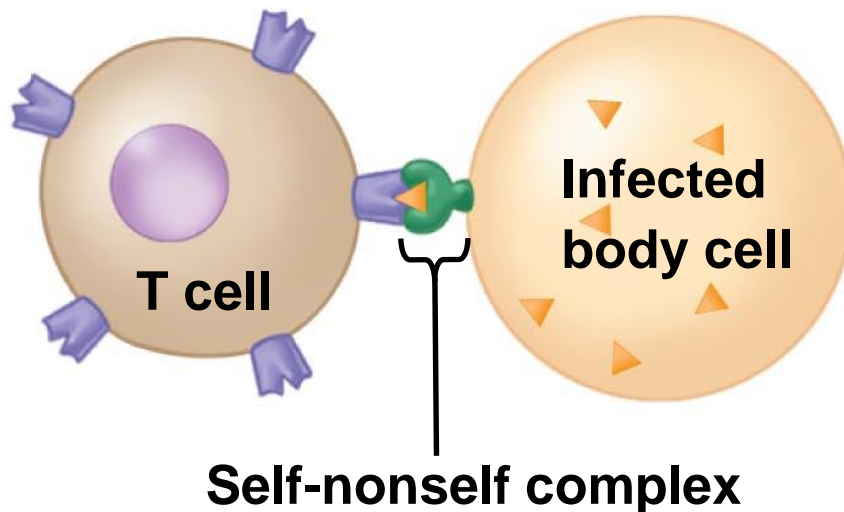
### ■ **Anaphylactic shock**

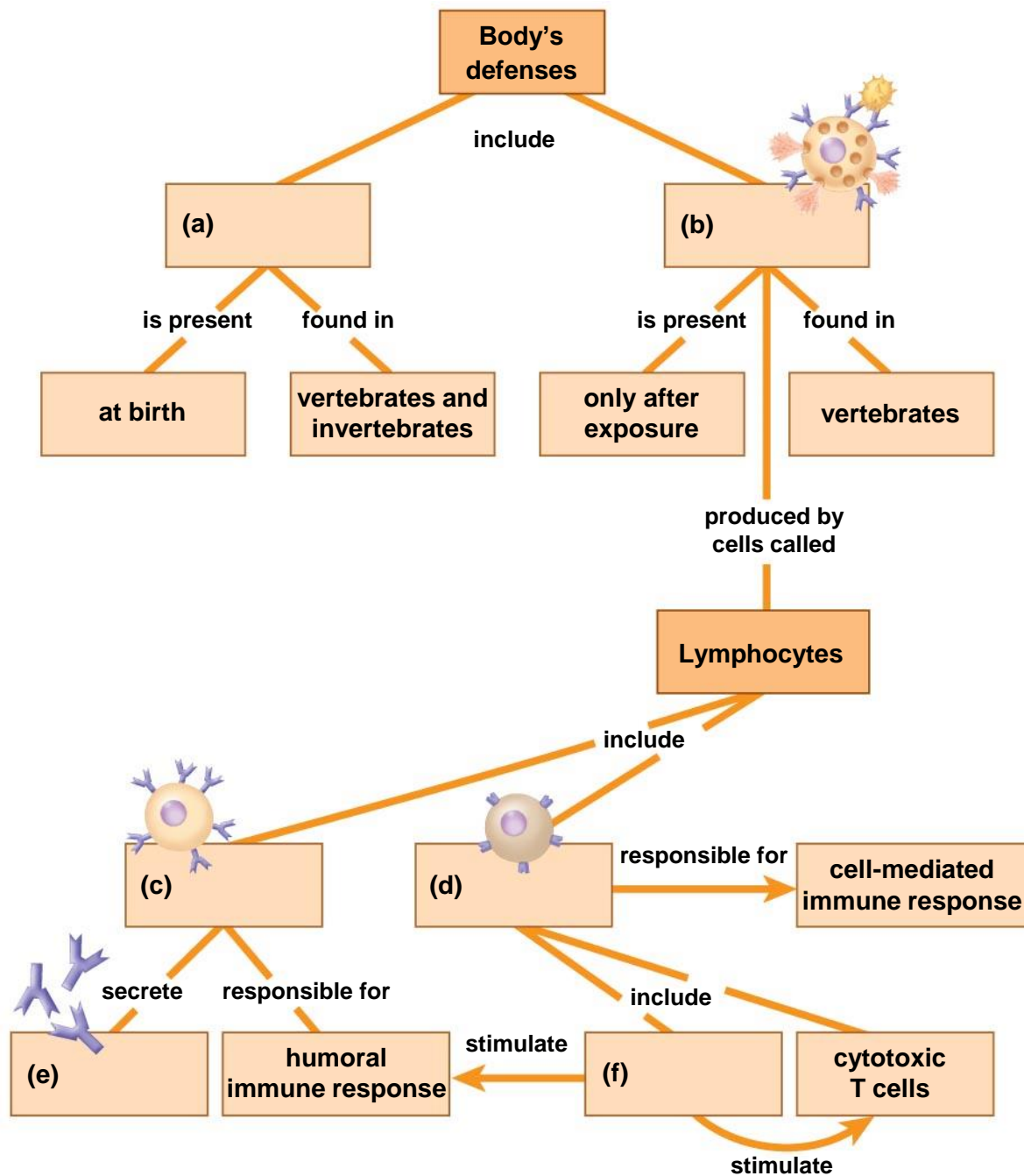
- Extreme life-threatening allergic reaction
- Can be treated with injections of epinephrine

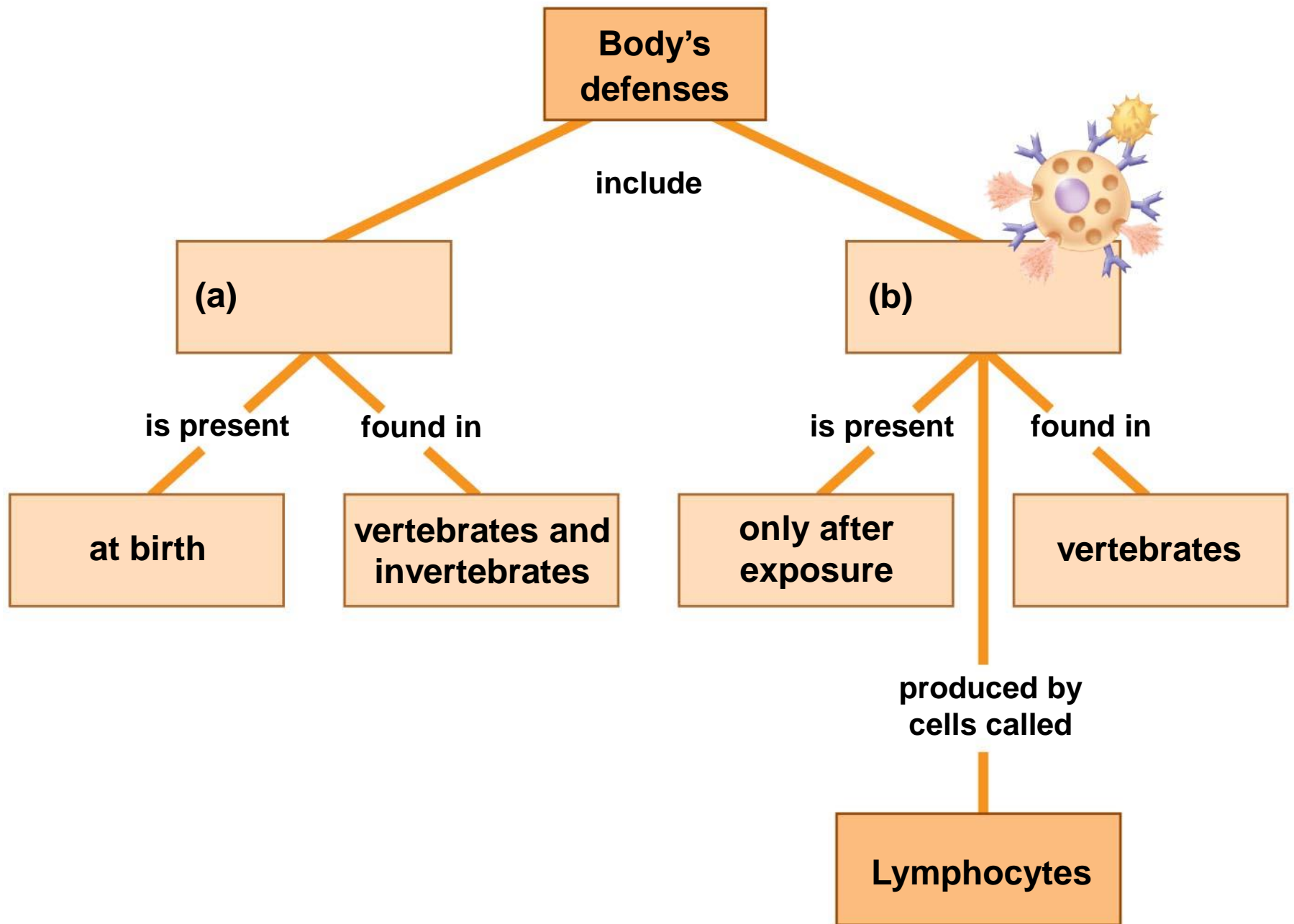
## The humoral immune response



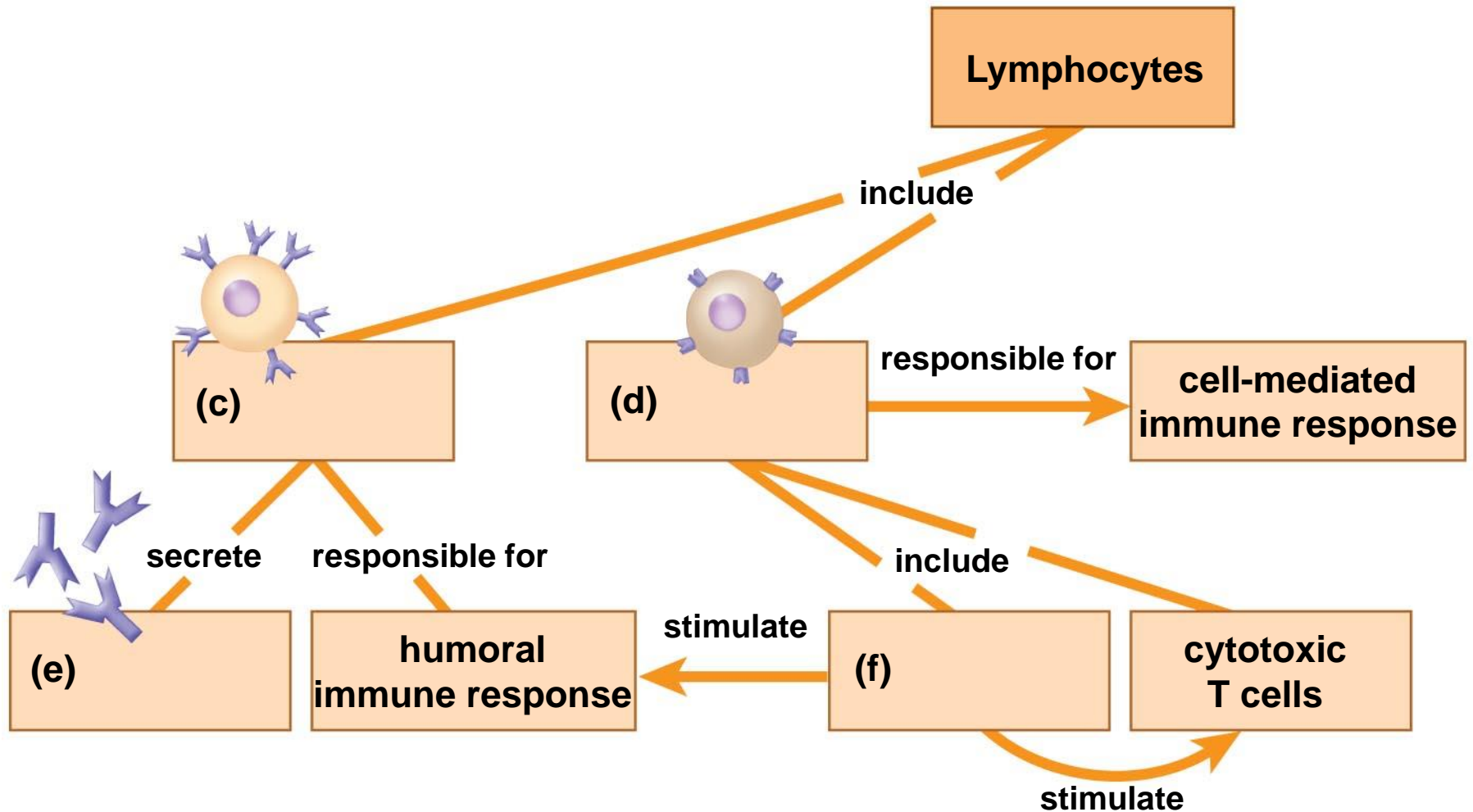
## The cell-mediated immune response











# You should now be able to

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1. Describe the causes, symptoms, and treatments for mononucleosis
2. Describe the structure and functions of the lymphatic system
3. Describe the specific nature of an immune system response
4. Define antigen, antibody, passive immunity, and active immunity

# You should now be able to

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5. Distinguish between the humoral immune response and the cell-mediated immune response
6. Explain how an antigen and antibody interact
7. Compare a primary immune response to a secondary immune response
8. Relate the structure of an antibody to its functions
9. Describe the production of and uses for monoclonal antibodies

# You should now be able to

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10. Describe the specific functions of helper T cells and cytotoxic T cells
11. Explain how HIV infects cells, multiplies, and causes disease
12. Explain the causes of immunodeficiency diseases and allergies