

# Lecture 20 Immune System

## §1 The Immune System

### 1. Immune system

The **immune system** is the body's defense against infectious diseases, which are caused by various disease-causing **pathogens** (病原体), including viruses and microorganisms.

### 2. Two levels of immunity

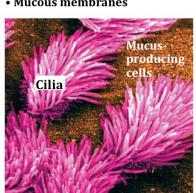
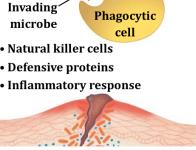
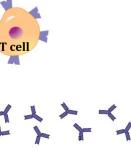
#### 1<sup>o</sup> Innate defenses (先天防御)

- ① in born immunity
- ② the response is immediate
- ③ does not change with prior expose
- ④ covers two lines of innate defenses.
  - { external barriers
  - { internal defenses

#### 2<sup>o</sup> Adaptive defenses (适应性防御)

- ① a third line of defense
- ② activated by exposure to specific invaders
- ③ delayed (take time)
- ④ highly specific

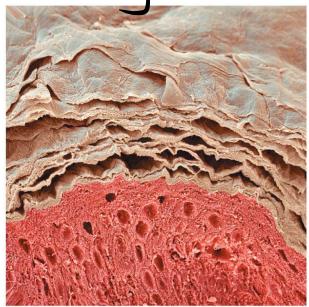
### Overview of the Body's Defense

THE BODY'S DEFENSES		
Innate Defenses (always deployed)	Adaptive Defenses (activated by exposure to specific pathogens)	
<b>External innate defenses</b> <ul style="list-style-type: none"><li>• Skin</li><li>• Secretions</li><li>• Mucous membranes</li></ul>  <p>Cilia Mucus-producing cells Colored SEM</p>	<b>Internal innate defenses</b> <ul style="list-style-type: none"><li>• Phagocytic cells</li><li>• Invading microbe</li><li>• Phagocytic cell</li><li>• Natural killer cells</li><li>• Defensive proteins</li><li>• Inflammatory response</li></ul> 	<ul style="list-style-type: none"><li>• Lymphocytes</li><li>• B cell</li><li>• T cell</li><li>• Antibodies</li></ul> 
<b>The Lymphatic System</b> (involved in internal innate defenses and adaptive defenses)		

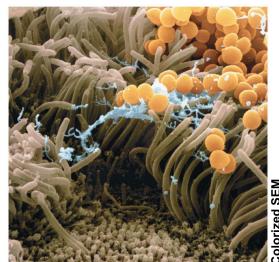
## §2 External Innate Defenses

### 1. Physical barriers

- 1° a tough outer skin layer generally impenetrable (无法通过的)
- 2° mucous (黏液) membranes covered with sticky mucus.
- 3° wax in the ear canal, which traps particles before they can get deep inside.
- 4° Secretions (like tears, sweat, and saliva) with antimicrobial chemicals
- 5° strong stomach acids



(a) Skin forms a protective barrier.



Cilia on cells in the nasal cavity sweep mucus (blue) and trapped bacteria (yellow) out of the body.

## §3 Internal Innate Defenses

### The Body's Second Line of Defense

INTERNAL INNATE DEFENSES	
White Blood Cells	
Phagocytic cells (吞噬细胞) (engulf foreign cells or substances): Neutrophils, macrophages, dendritic cells and monocyte	Natural killer cells (destroy infected and cancerous body cells)
Defensive Proteins	
Interferon (干扰素) (protect body cells against viral infection)	Complement proteins (补体) (cause invading microbial cells to lyse)

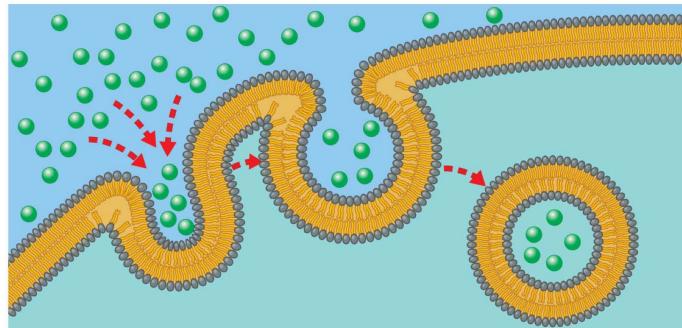
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### 1. White blood cells

- 1° phagocytic cells (吞噬细胞)

- ① engulf foreign cells or molecules

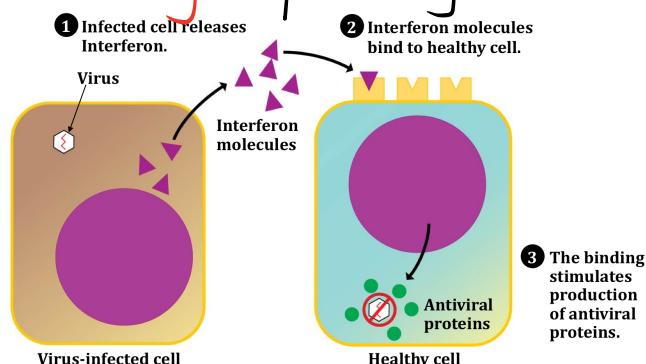
- ② engulf debris from dead cells
- 2º natural killer (NK) cells (自然杀伤细胞)
- ① recognize virus-infected cells
  - ② release chemicals that kill diseased cells.
- Endocytosis --- Phagocytosis**



## 2. Defensive proteins

### 1º Interferons (干扰素)

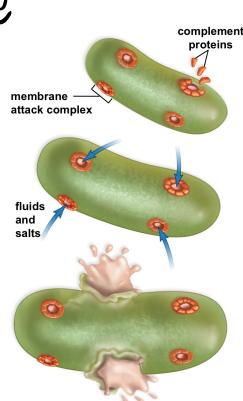
*indirectly* help healthy cells resist damage



Interferons may be administered to treat certain viral infections, such as hepatitis C.

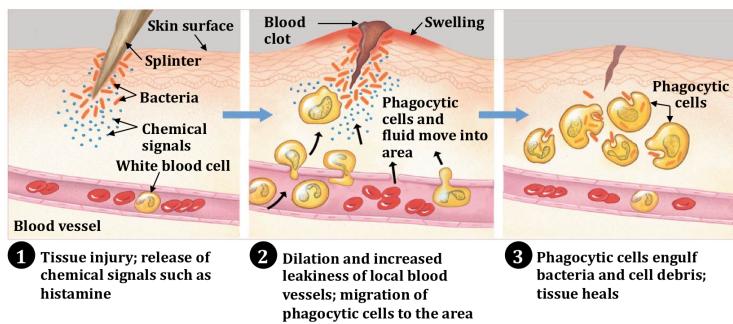
### 2º Complement proteins (补体)

attack pathogens *directly*, causing invading microbial cells to lyse



### 3. Inflammatory response (炎症反应)

- 1° a coordinated set of **nonspecific** defences in response to injury or infection
- 2° damage cells release chemicals that
  - ① increase blood flow to the damaged area
  - ② turn the wound red and warm



红、肿、热、痛 (redness, swelling, warmth, pain)

- If the cause of inflammation cannot be eliminated, as occurs in tuberculosis 肺结核 and some types of arthritis, the inflammatory reaction may persist and become harmful rather than helpful.
  - Anti-inflammatory drugs, such as aspirin and ibuprofen,
    - dampen the normal inflammatory response and
    - reduce swelling and fever.

## §4 The Lymphatic System

### 1. Components

The **lymphatic system** consists of

- 1° a branching network of **vessels**
- 2° numerous **lymph nodes** (淋巴结)
- 3° several other **organs**

Lymphatic vessels carry **lymph** (淋巴), a fluid that is similar to interstitial fluid surrounding body cells.

## 2. Functions

- 1<sup>o</sup> return tissue fluid to the circulatory system
- 2<sup>o</sup> fights infection

## §5 Adaptive Defense

### 1. Lymphocytes (淋巴细胞)

#### 1<sup>o</sup> B cells

- ① mature in bone marrow (骨髓)
- ② is responsible for antibody-mediated immunity (体液免疫)

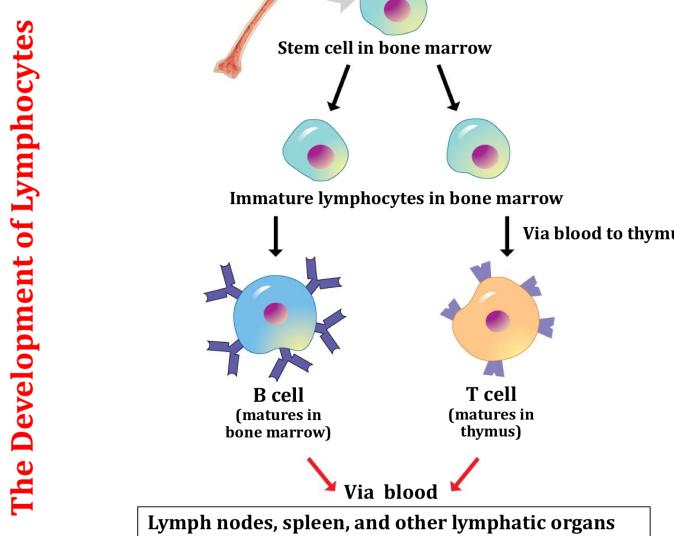
#### 2<sup>o</sup> T cells

- ① mature in thymus (胸腺)
- ② is responsible for cell-mediated immunity (细胞免疫)

#### 3<sup>o</sup> B cells and T cells eventually make their way to

##### ① lymph nodes

##### ② other lymphatic organs



### 2. Antigens (抗原)

- 1<sup>o</sup> molecules on the surfaces of viruses or foreign cells

2º elicit a response from a lymphocyte.

## §b Adaptive Defense: Step 1: Recognizing the Invaders

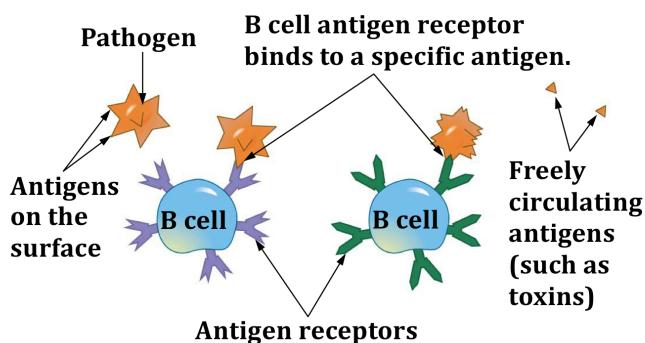
### 1. Antigen receptor (抗原受体)

1º B cells and T cells have antigen receptors on their surface that can bind to an antigen.

2º Each cell has about 10000 copies of an antigen receptor

### 2. Antigen recognition by B cells

Antigen receptors on B cells recognize **intact** (完整的) antigens that are on the **surface of pathogen** or **circulating freely** in body fluid.

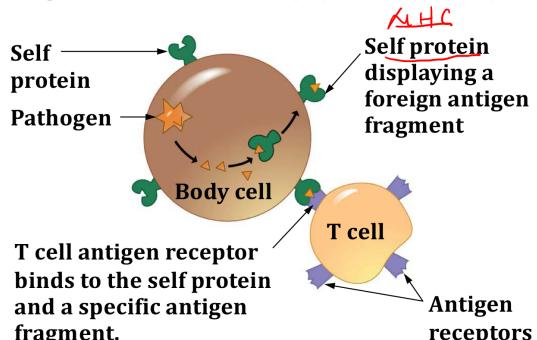


### 3. Antigen recognition by T cells

Antigen receptors on B cells recognize **fragments** of antigens.

The fragments must be **presented** on the surface of body cells by **special proteins (MHC)**.

(Major Histocompatibility complex)



- The fragments of antigens that T cells recognize originate from pathogens that have entered a body cell.
- A T cell bearing a receptor with specificity for this antigen fragment binds to both the antigen and self protein.
- This three-part interaction among a self protein, an antigen fragment, and an antigen receptor is required for a T cell to function.

## §7 Adaptive Defense: Step 2: Cloning the Responders

### 1. Cloning of B cells

1. Once a pathogen enters the body, antigens on its surface bind with a B cell that has complementary antigen receptors. Other lymphocytes without the appropriate binding sites are not affected.
2. The binding activates the B cell — it grows, divides, and develops further. This produces clones of B cells specialized for defending against the very antigen that triggered the response.

### 2. Effector cells (效应细胞)

1° Short-lived

2° Take action and secrete antibodies

3. Some of the newly produced B cells are short-lived cells that have an immediate effect against the antigen and are therefore called effector cells. They secrete antibodies (抗体).

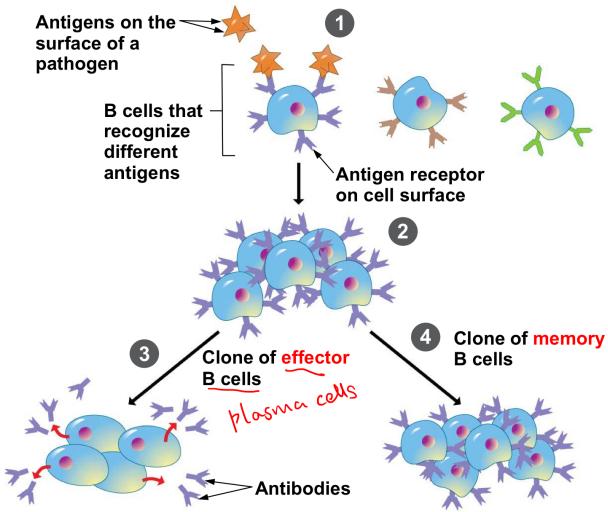
- During the first response to an antigen, called the **primary immune response**, it takes several days for clonal selection to produce effector cells. The response peaks about **two to three weeks** after the first exposure and starts to decline.

### 3° Memory cells (记忆细胞)

1° Long-lived

2° Secondary immune response

4. Clonal selection (无性选择) produces **long-lived memory cells** that help fight subsequent exposures to a specific antigen.
- If memory cells are exposed to a previously encountered antigen, they rapidly give rise to new effector cells and memory cells, a process known as the **secondary immune response**.



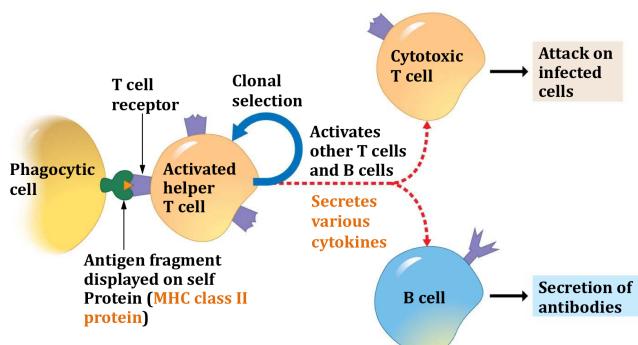
## §8 Adaptive Defense: Step 3: Responding to Invaders

- While the antibody response from B cells helps to eliminate pathogens in the blood and lymph,
- cytotoxic T cells** destroy pathogens within body cells and
- helper T cells** do not directly carry out attacks on pathogens but aid in stimulating both the B cells and the cytotoxic T cells in their responses.

### 1. The helper T cell response

Stimulate B cells and cytotoxic T cells

- Each helper T cell
  - is only activated when a particular white blood cell type presents the antigen.
- Once activated, helper T cells give rise to a population of
  - effector helper T cells** (which respond to infection by stimulating the activity of B cells and cytotoxic T cells) and
  - memory helper T cells** through clonal selection.

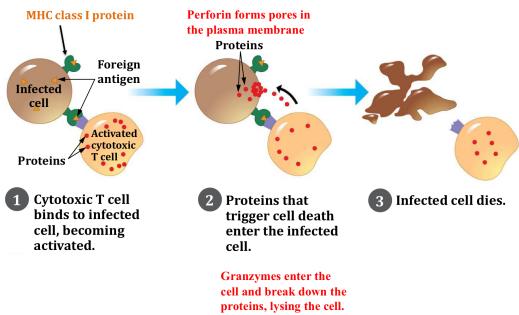


- The human immunodeficiency virus (HIV) infects helper T cells.
  - **HIV infection causes helper T cell numbers to decline significantly.**
  - If not treated, HIV infection results in acquired immune deficiency syndrome (AIDS).
  - Individuals with AIDS lack a completely functional immune system and die from exposure to other infectious agents.

## 2. The cytotoxic T cells response

$1^{\circ}$  actually kill the infected cell

- The cytotoxic T cell response defends against pathogens that have entered body cells.
- Cytotoxic T cells are the only T cells that actually kill infected cells.
- They identify infected body cells because foreign antigen fragments are "advertised," or bound to a self protein.



## 2. Immune rejection (免疫排斥)

- The cytotoxic T cell response does not always work in a person's favor.
- **Immune Rejection:** When an organ is transplanted from a donor into a recipient, the newly transplanted cells contain self proteins that do not match those on the recipient's cells and the recipient's cytotoxic T cells tag the transplanted cells as foreign and kill them, ultimately causing organ rejection.

To minimize organ rejection,

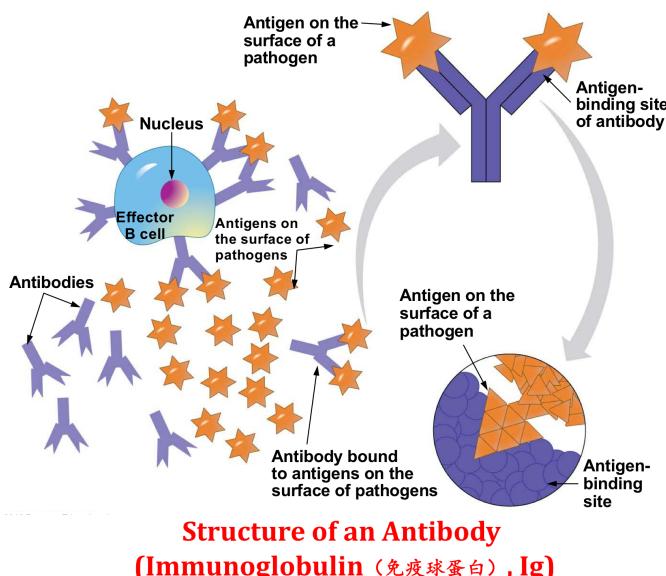
- doctors look for a donor with self proteins that match the recipient's as closely as possible and
- drugs are administered to suppress the immune response. **Organ recipients are often on immunosuppressants (免疫抑制剂) for life.**

*↑  
production of  
certain cytokines by T cells*

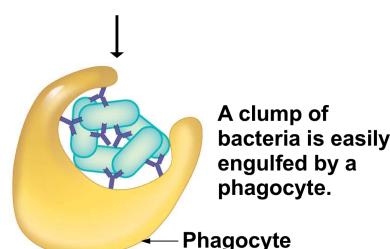
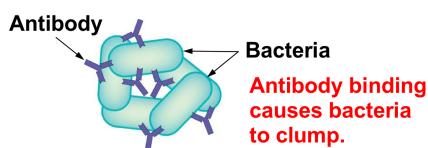
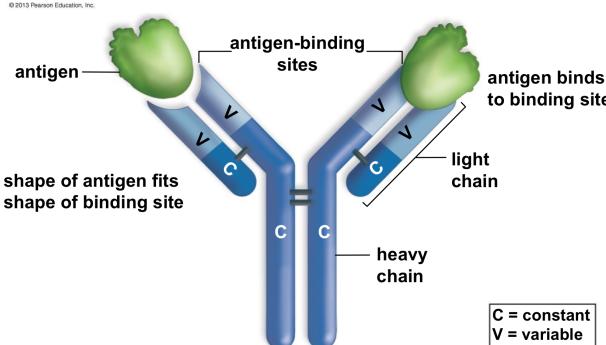
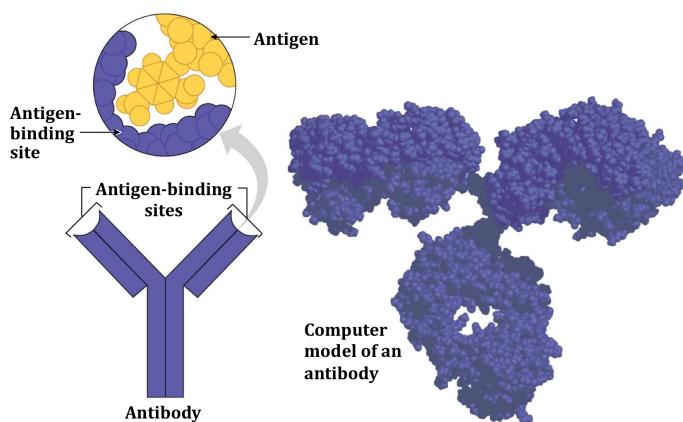
## 3. The B cell response

Antibody: enhance phagocytosis (噬菌作用)  
block pathogen from entering a cell.

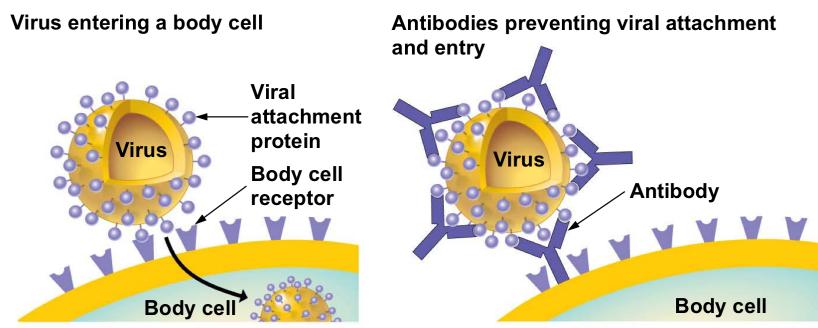
- By secreting antibodies into the blood and lymph, B cells defend primarily against pathogens circulating in body fluids.
- Antibodies can facilitate pathogen destruction.
- Antibodies may serve as physical barriers that prevent pathogens from entering body cells.



**Structure of an Antibody  
(Immunoglobulin (免疫球蛋白), Ig)**



**(a) Antibodies enhance phagocytosis.**



(b) Antibodies block a virus from entering a body cell.

## §9 Adaptive Defense : Step 4: Remembering Invaders

- Memory cells can last decades in the lymph nodes, ready to be activated by a second exposure to the antigen.
- If the antigen is encountered again, the secondary immune response will be
  - more rapid,
  - of greater magnitude, and
  - of longer duration than the primary immune response.

