Big Idea 2: Biological systems utilize free energy and molecular building blocks to grow, to reproduce and to maintain dynamic homeostasis.

Enduring understanding 2.D: Growth and dynamic homeostasis of a biological system are influenced by changes in the system's environment.

Essential knowledge 2.D.4: Plants and animals have a variety of chemical defenses against infections that affect dynamic homeostasis.

a. Plants, invertebrates and vertebrates have multiple, nonspecific immune responses.

Students should be able to demonstrate understanding of the above concept by using an illustrative example such as:

-Invertebrate immune systems have nonspecific response mechanisms and may possess pathogen-specific defense responses.

-Plant defenses against pathogens include molecular recognition systems with systemic responses; infection triggers chemical responses that destroy infected and adjacent cells, thus localizing the effects.

-Vertebrate immune systems have nonspecific defense mechanisms against pathogens.

Main Idea

- *Life is faced with a number of threats.*
  - *These threats include biotic factors like predators, pathogens, and parasites.*
  - *Even extreme abiotic factors can threaten the life.*
- *Living organisms defend themselves by using four general strategies protective barriers, fleeing, hiding, or fighting back.*
  - *Plants however can not flee or hide.*

Preface to Plant Defenses

- ***Plants face threats at both the organismal level and at the cellular.***
  - ***Herbivores attack the organism itself.***
  - ***Pathogens and parasites attack the cells of the organism.***
- **This presentation will address defense mechanisms against herbivory and defense against pathogens separately.**

Plant Defenses against Herbivores

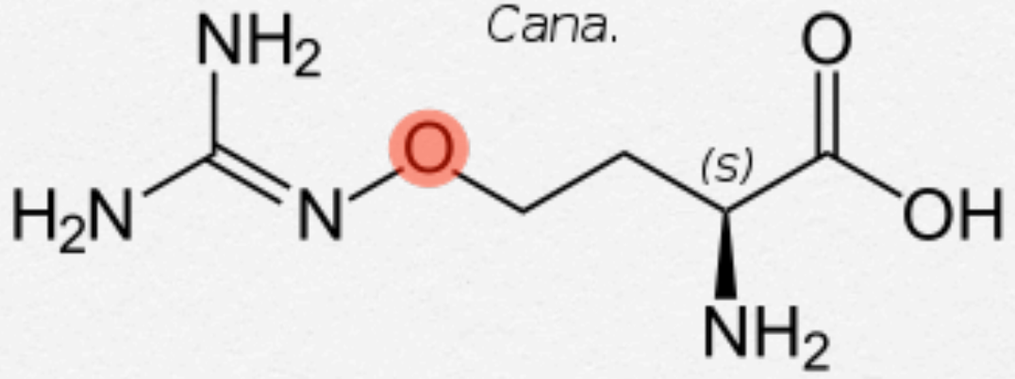
- **PROTECTIVE & PHYSICAL BARRIERS**

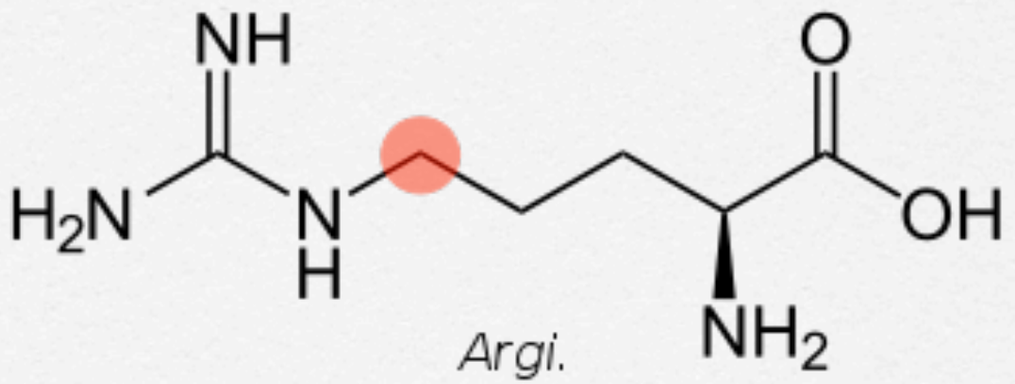
- **Plant barriers include bark, spines, thorns, trichomes (hairs).**

Plant Defenses against Herbivores

- **CHEMICAL DEFENSES**
- **Plants can produce distasteful or toxic chemicals.**
  - Canavanine is a chemical that resembles the amino acid arginine.
  - It is different enough that organisms that build proteins with it have misshapen proteins.
  - These misshaped proteins do function properly and the organism dies.

Canavanine vs Arginine



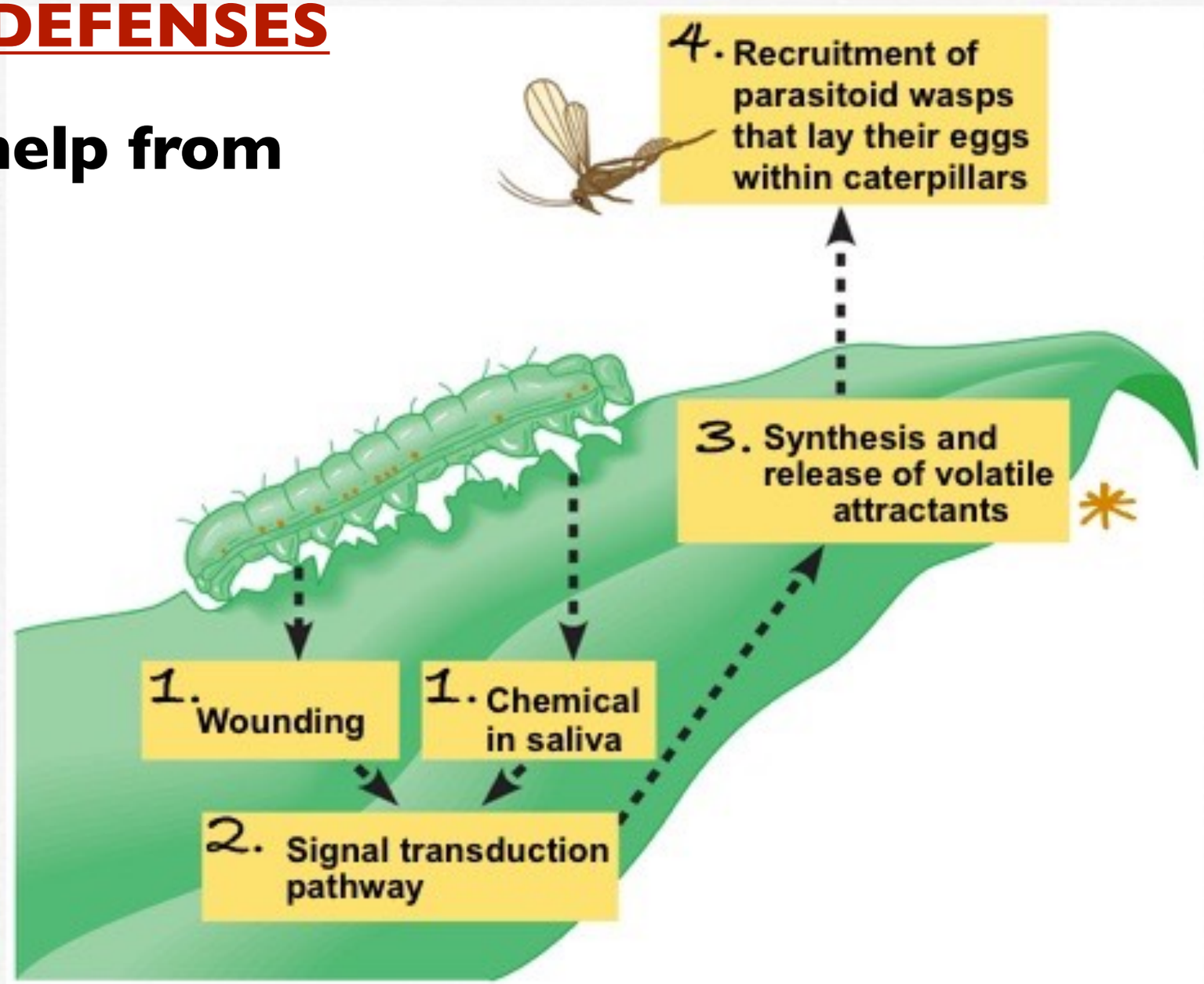


Structure Dictates Function

Plant Defenses against Herbivores

- **RECRUITMENT DEFENSES**
- **Plants can elicit help from other species.**

* These volatile attractants can also warn nearby plants, so that they might make biochemical changes that make them less susceptible themselves



Plant Defenses against Pathogens

- **1st Line of Defense- PHYSICAL BARRIERS**
- Remember the first and most fundamental barrier is the plasma membrane and cell wall itself.
- **Plant barriers include the periderm and epidermis (basically bark).**
  - Unfortunately these barriers are not impenetrable.
- **2nd Line of Defense- CHEMICAL ATTACK**
- Chemicals destroy pathogens and prevents its spread from site of infection.
- Similar to animals, plants can recognize certain pathogens

Host-Pathogen Coevolution

- **Virulent** pathogens kill the host.
- **Avirulent** pathogens do not kill the host.

Which of the two is more common? Why?

Host-Pathogen Coevolution

- **Virulent** pathogens kill the host.
- **Avirulent** pathogens do not kill the host.

Which of the two is more common? Why?

Avirulent is more common; if not then the host and pathogen would perish together

Host-Pathogen Coevolution

- **Oddly enough this host-pathogen coevolution illustrates yet another example of "Trade-Offs" common in nature.**
  - Complete resistance is energetically very expensive to the plant
    - this would make less able to compete for other resources
  - No resistance is energetically very inexpensive to the plant but would kill the plant
  - Thus we find a compromise between pathogen and host.
    - The best pathogens gain access to plant to perpetuate itself but does not severely damage the plant.

Do you think the same applies to bacterial and viral infections of animals?

Host-Pathogen Coevolution

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Do you think the same applies to bacterial and viral infections of animals?

YEP!

Gene for Gene Recognition

- **Plants have hundreds of resistance genes (R) that code for pathogen derived molecules called effectors**
  - It is simple...if the plant does not have the R genes to recognize the pathogen then the pathogen redirects its metabolism to its advantage BUT if the plant has the R genes to recognize the pathogen then an arsenal of defenses are released.
  - See next slides

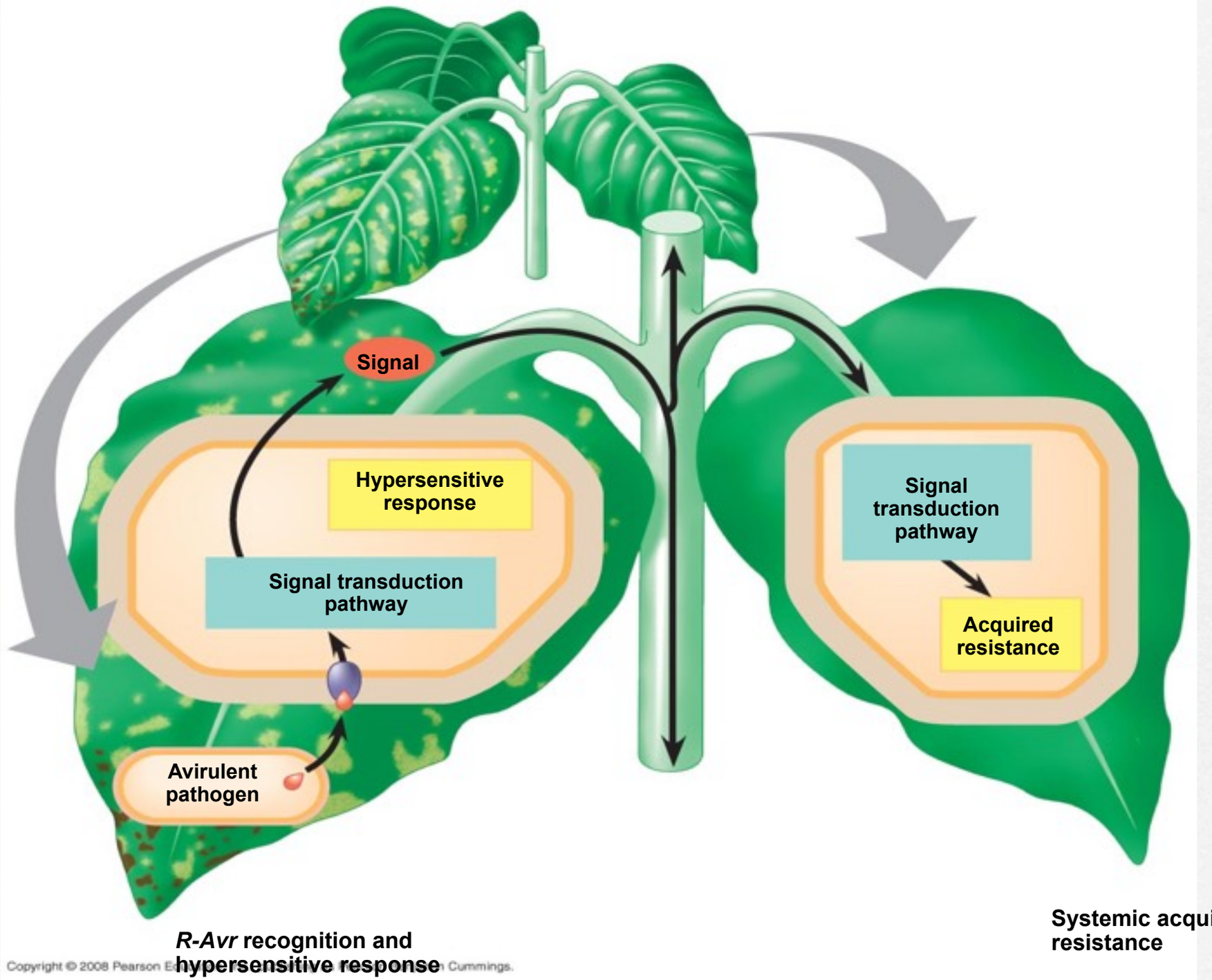
The Hypersensitive Response

- **Hypersensitive Response** is a defense response that causes tissue death near the infection site, thus restricting spread of pathogen.
  - Chemical attack occurs
    - ***phytoalexins*** *that have fungicidal and bactericidal properties along with hydrolytic enzymes are released*
  - Area is sealed off
    - lignin and cross-linking of molecules reinforces the cell wall to hinder spread of infection
  - Infected cells destroy themselves
    - infected cells under go apoptosis to save other cells

Systemic Acquired Resistance

- **Systemic Acquired Resistance** arises from a plant wide expression on defense genes.
  - It is non-specific and provides protection that lasts for days
  - It is a chemical "alarm call" for the entire plant
  - *Methylsalicyclic acid* is produced around infection site, carried by phloem to rest of plant, *methylsalicyclic acid* is converted to ***salicyclic acid*** which promotes the production of proteins specific against the attacking pathogen.

Systemic Acquired Resistance



R-Avr recognition and hypersensitive response

Systemic acquired resistance

Essential knowledge 2.D.3: Biological systems are affected by disruptions to their dynamic homeostasis.

b. Mammals use specific immune responses triggered by natural or artificial agents that disrupt dynamic homeostasis.

Students should be able to demonstrate understanding of the above concept by using an illustrative example such as:

The mammalian immune system includes two types of specific responses: cell mediated and humoral.

In the cell-mediated response, cytotoxic T cells, a type of lymphocytic white blood cell, “target” intracellular pathogens when antigens are displayed on the outside of the cells.

In the humoral response, B cells, a type of lymphocytic white blood cell, produce antibodies against specific antigens.

Antigens are recognized by antibodies to the antigen.

Antibodies are proteins produced by B cells, and each antibody is specific to a particular antigen.

A second exposure to an antigen results in a more rapid and enhanced immune response.

Animal Defenses against Pathogens

<u>Specific</u> Internal Defenses.

- ACQUIRED or ADAPTIVE IMMUNITY: 4 Characteristics
  - 1. Immense diversity- of lymphocytes & receptors (millions)
  - 2. Self Tolerant- should not attack own cells
  - 3. Proliferation- activation of immune response creates many more T cells and B cells
  - 4. Immunological Memory- stronger and more rapid response to a previously encountered antigen

Animal Defenses against Pathogens

<u>Specific</u> Internal Defenses.

- ACQUIRED or ADAPTIVE IMMUNITY: lymphocytes provide ***specific*** defenses against infection.
    - it is the bodies second line of defense
    - it again involves lymphocytes
        - (general=white blood cells) (specifically T cells and B cells)
    - it looks for and recognizes ***antigens***

Adaptive immunity is found only in vertebrates

Animal Defenses against Pathogens

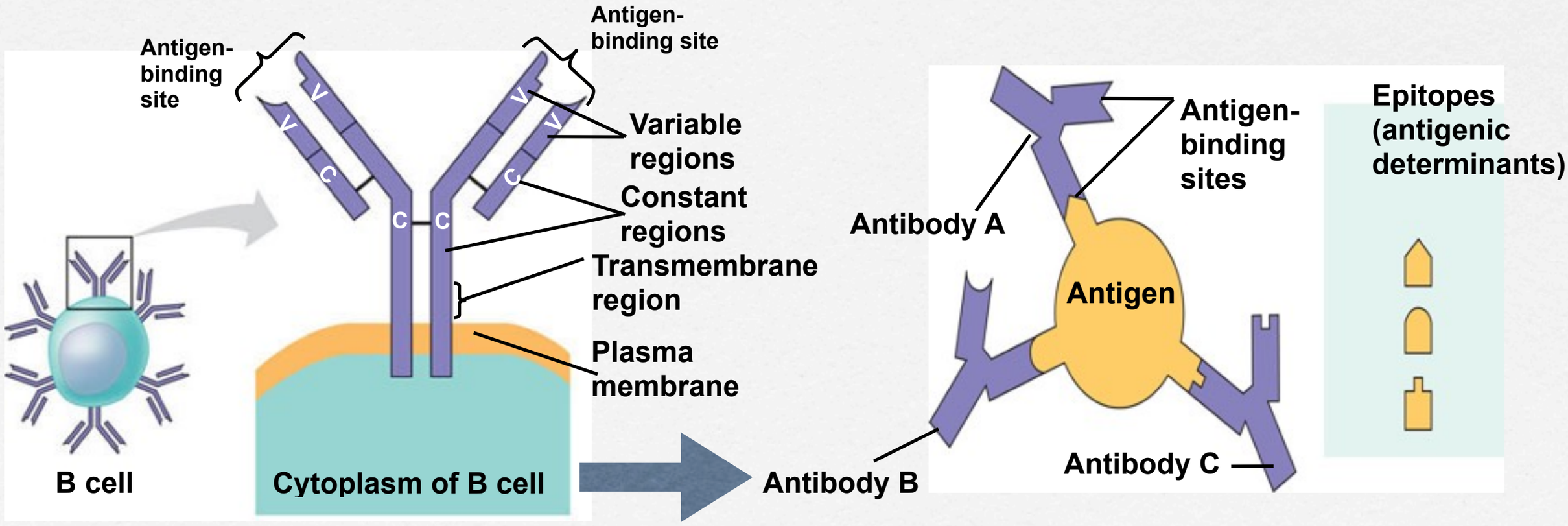
Antigens

- An antigen is foreign molecule that is recognized by T cells and B cells as "not self"
- The lymphocytes recognize and bind to antigens by the "shape" of the antigen

Animal Defenses against Pathogens

B Cells

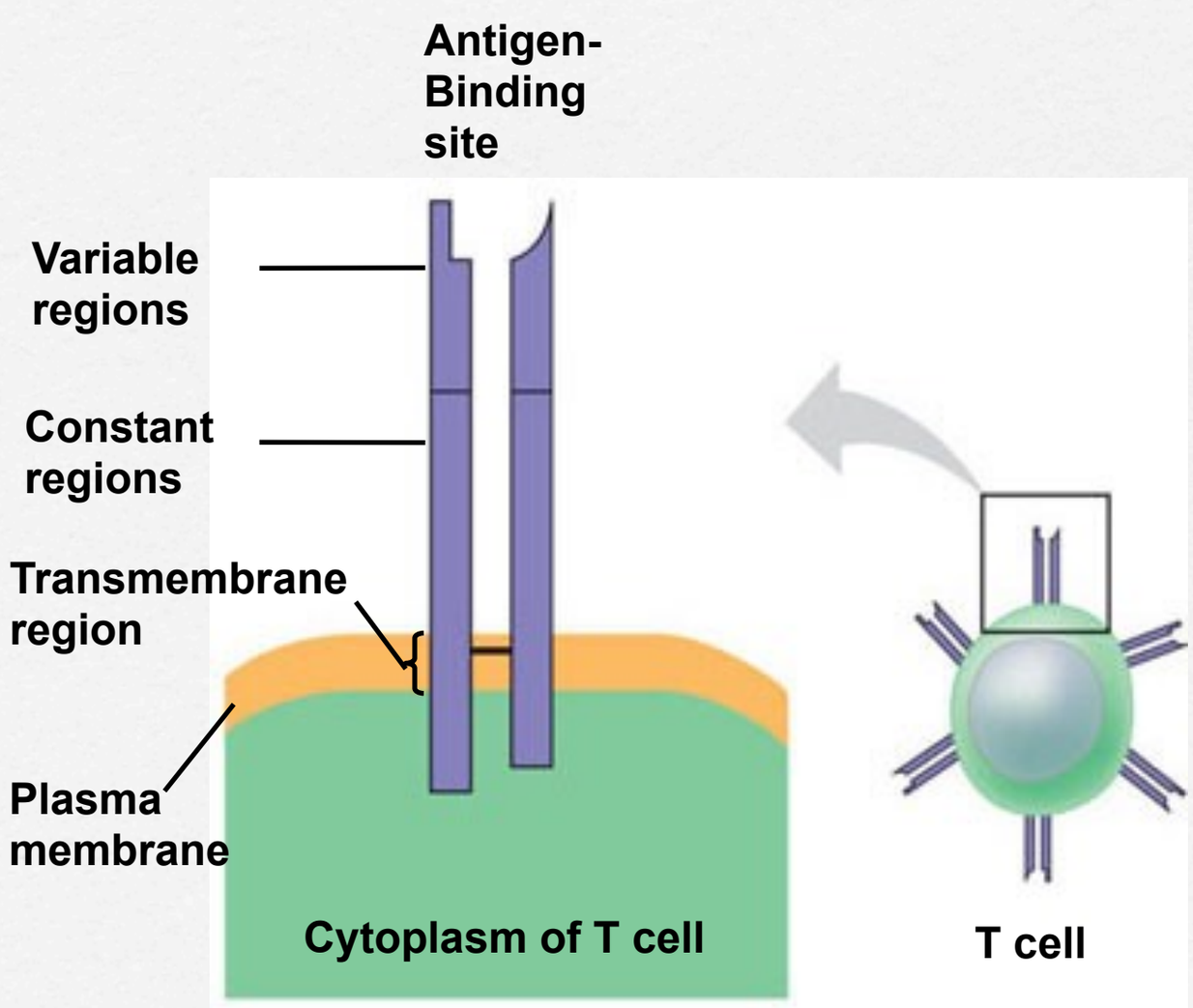
- B cells bind to epitopes of "whole" or "intact" antigens that are circulating in body fluids
- Once B cells recognize the antigen, they produce and secrete antibodies that identically shaped to B cell antigen receptors



Animal Defenses against Pathogens

T Cells

- T cells bind only to fragments of antigens that are displayed on the surface of host cells
- The antigen presentation requires another protein called the major histocompatibility complex (MHC)

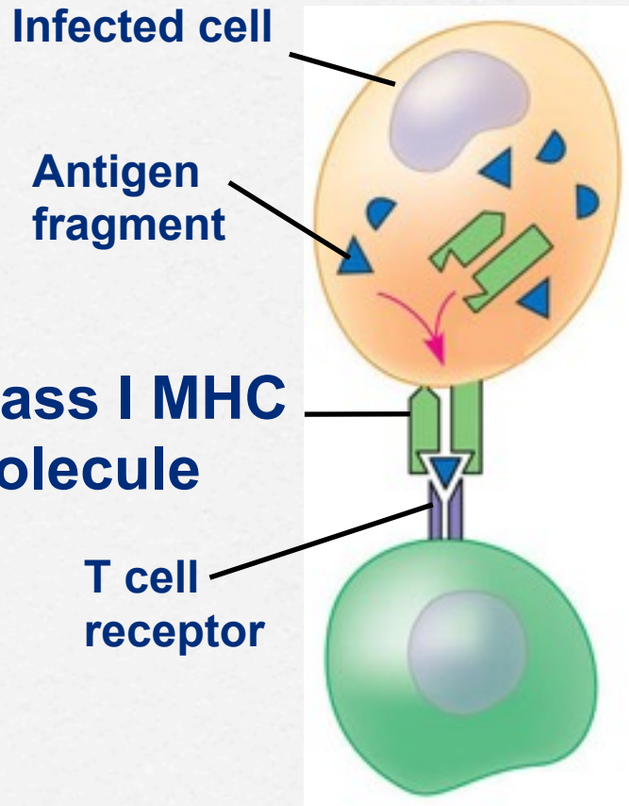


Animal Defenses against Pathogens

Antigen:

Presentation & Recognition

- Class I MHC molecules, found on almost all nucleated cells of the body.
- Display peptide antigens to cytotoxic T cells



1.

A fragment of foreign protein (antigen) inside the cell associates with an MHC molecule and is transported to the cell surface.

2.

The combination of MHC molecule and antigen is recognized by a T cell, alerting it to the infection.

Animal Defenses against Pathogens

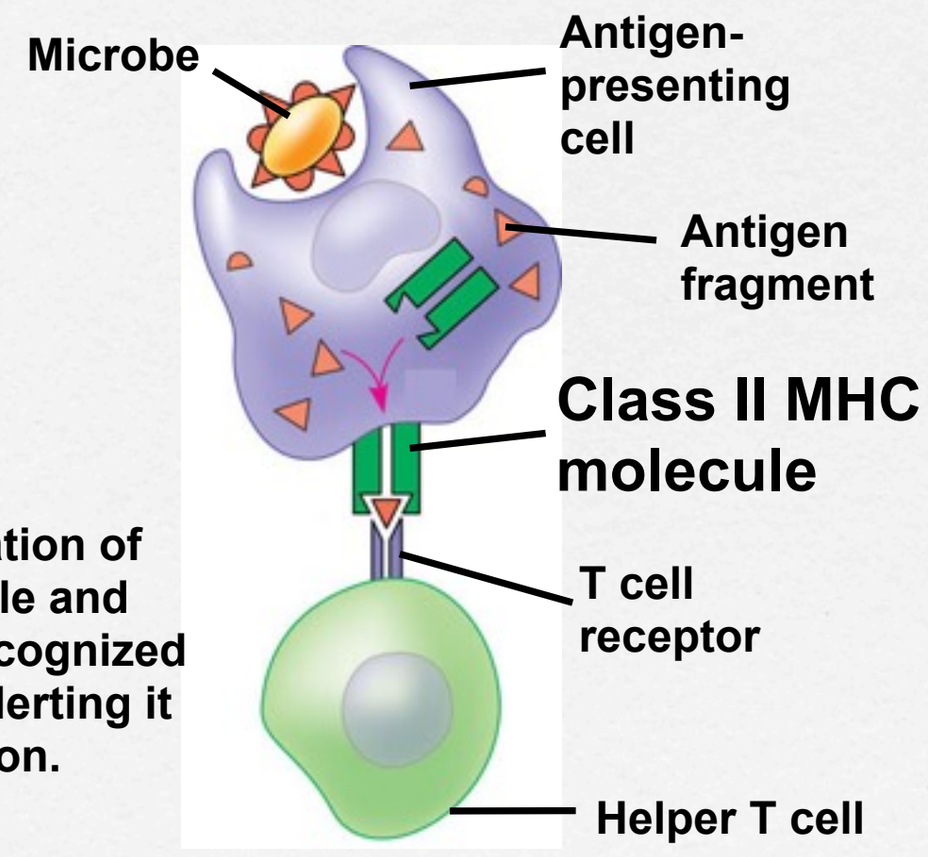
Antigen:

Presentation & Recognition

- Class II MHC molecules, found on dendritic cells, macrophages and B cells.
- Display peptide antigens to helper T cells

1. **A fragment of foreign protein (antigen) inside the cell associates with an MHC molecule and is transported to the cell surface.**

2. **The combination of MHC molecule and antigen is recognized by a T cell, alerting it to the infection.**



Review & Build

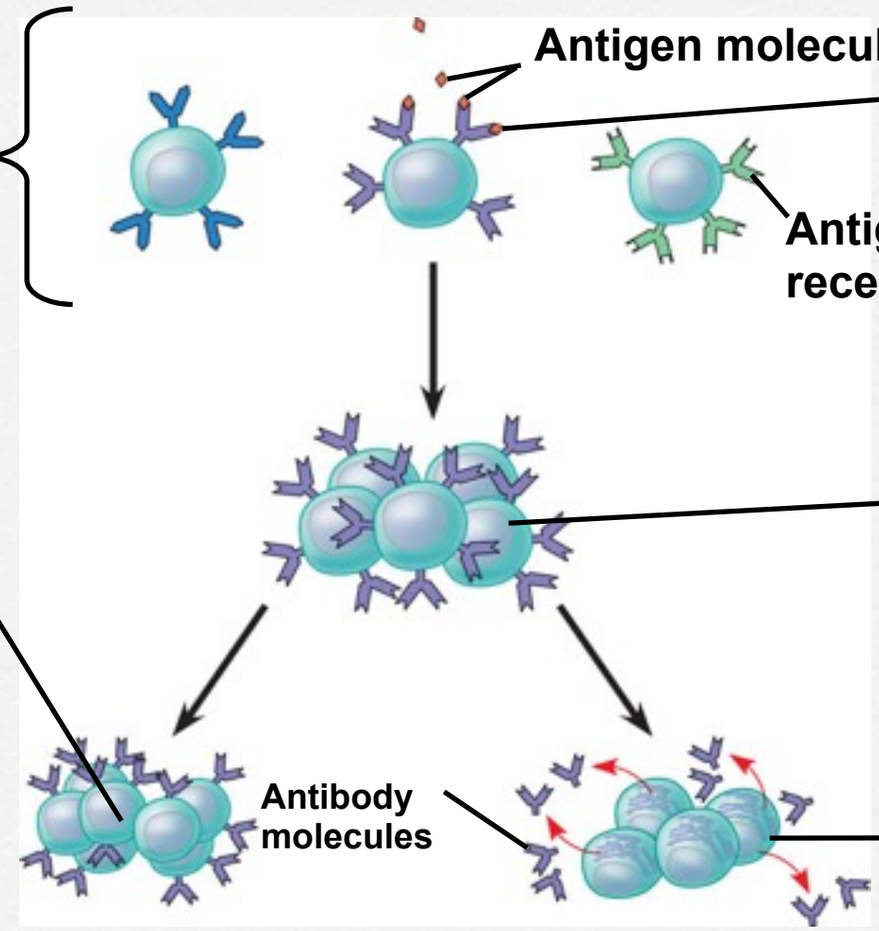
- ACQUIRED or ADAPTIVE IMMUNITY: 4 Characteristics
  - **1. Immense diversity- of lymphocytes & receptors (millions)**
    - achieved by shuffling genes around to create a thousands of different proteins later assembled to produce millions of different receptors
    - details discussed later in the year

Review & Build

- ACQUIRED or ADAPTIVE IMMUNITY: 4 Characteristics
  - **2. Self Tolerant- should not attack own cells**
    - the generation of B cell and T cell diversity is somewhat random, as a result some carry receptors for its own epitopes
    - as **B cells** mature in **B**one marrow these lymphocytes carrying self epitopes are killed via apoptosis (programmed cell death)
    - as **T cells** mature in **T**hymus these lymphocytes carrying self epitopes are killed via apoptosis (programmed cell death)

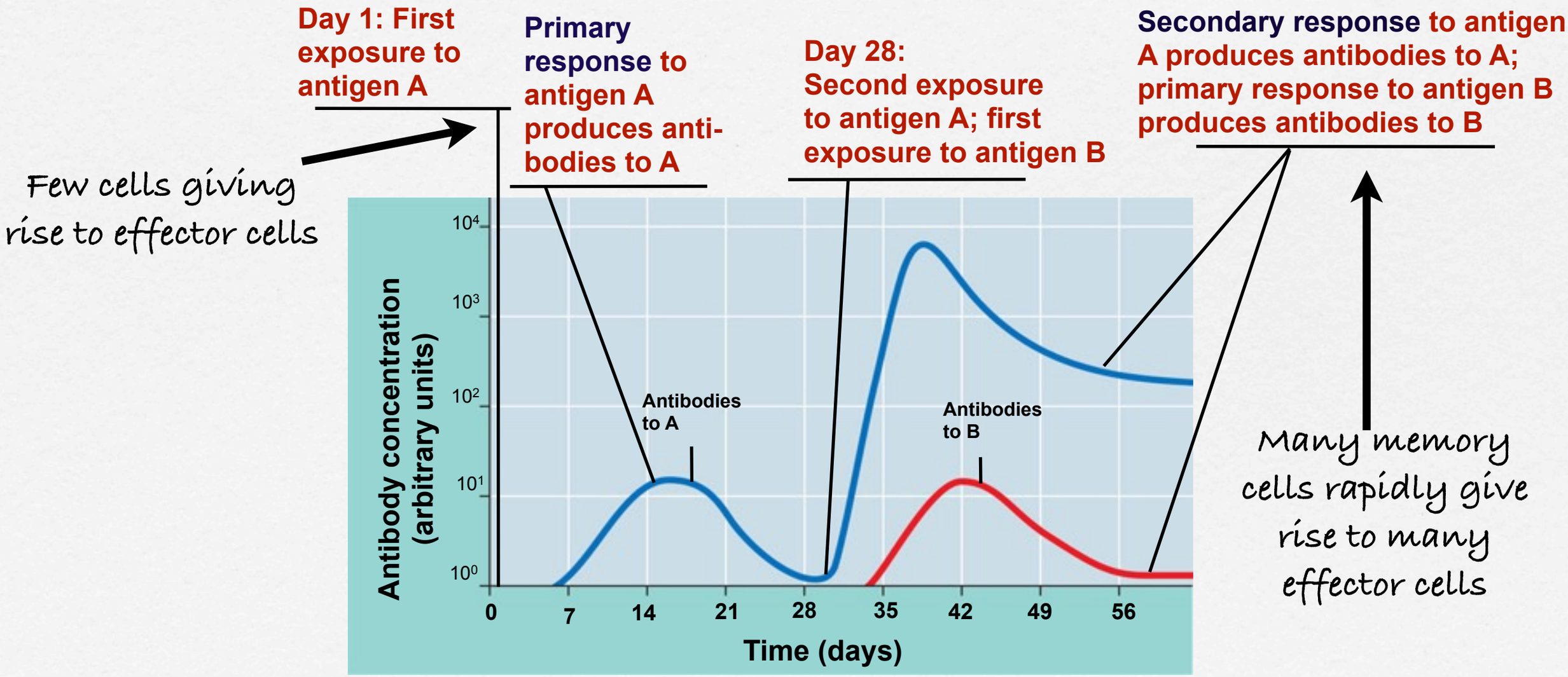
Review & Build

- ACQUIRED or ADAPTIVE IMMUNITY: 4 Characteristics
  - 3. Proliferation- activation of immune response creates many more T cells and B cells

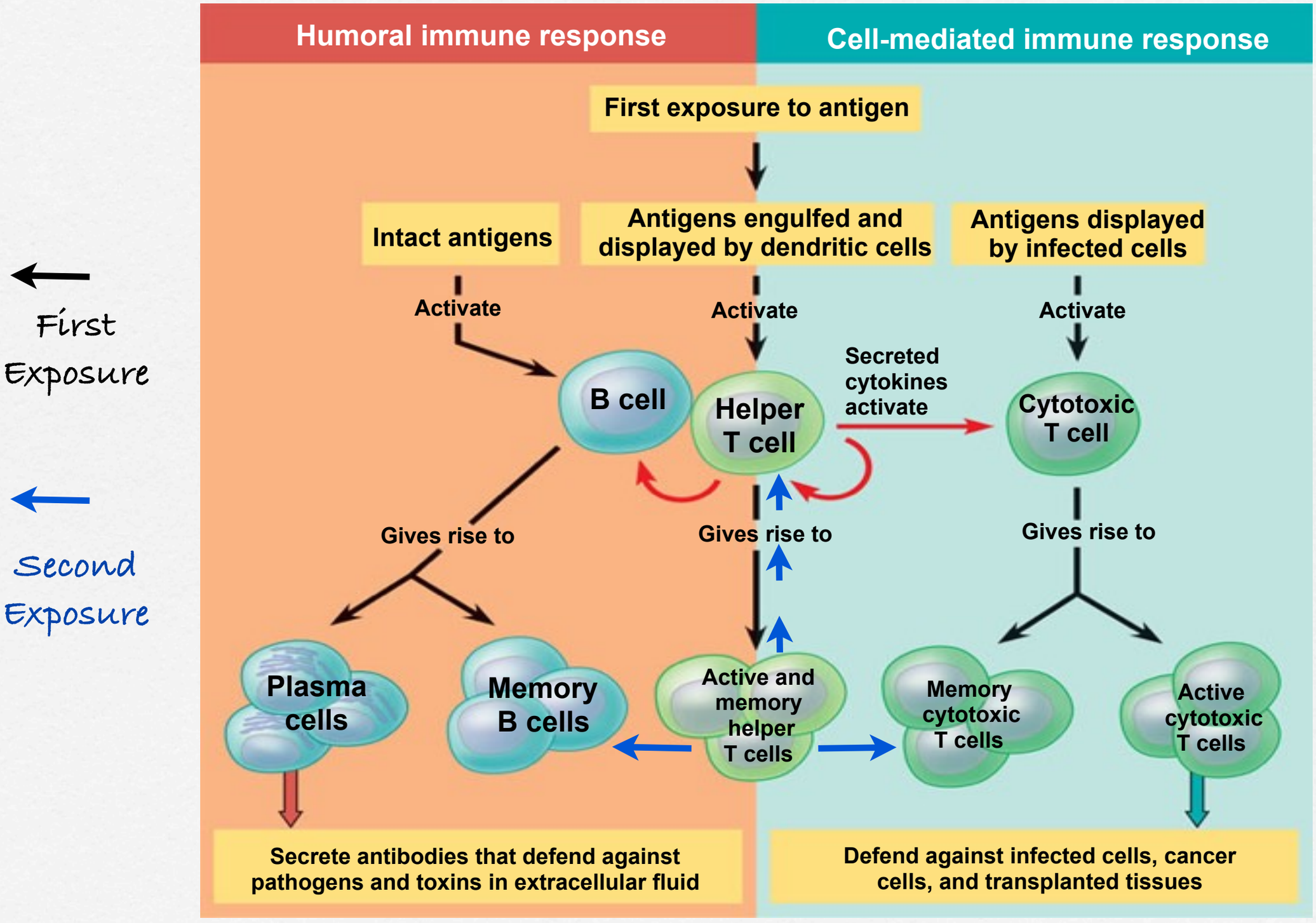


Review & Build

- ACQUIRED or ADAPTIVE IMMUNITY: 4 Characteristics
  - 4. Immunological Memory- stronger and more rapid response to a previously encountered antigen



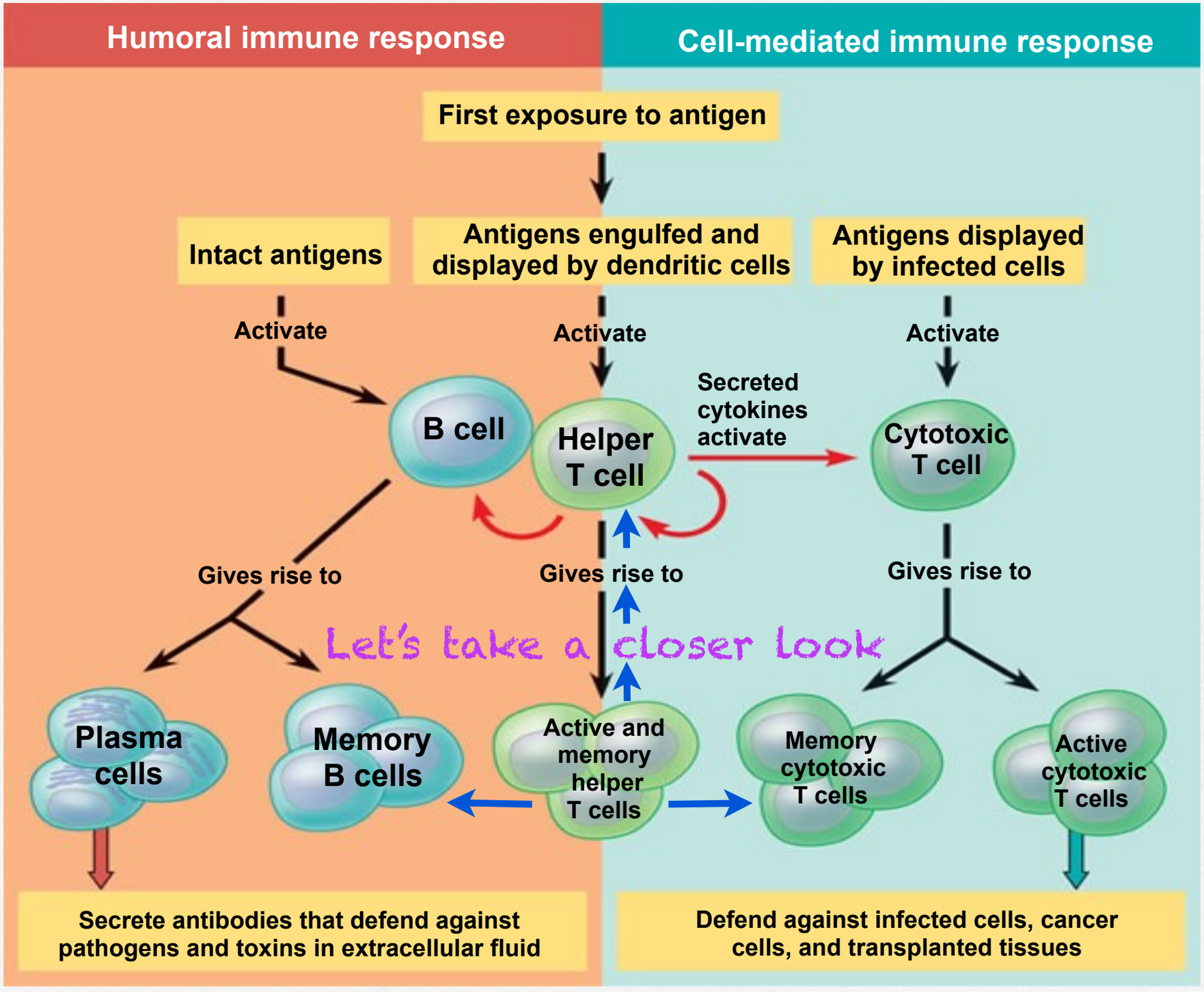
Overview Of Acquired Immunity



First Exposure

Second Exposure

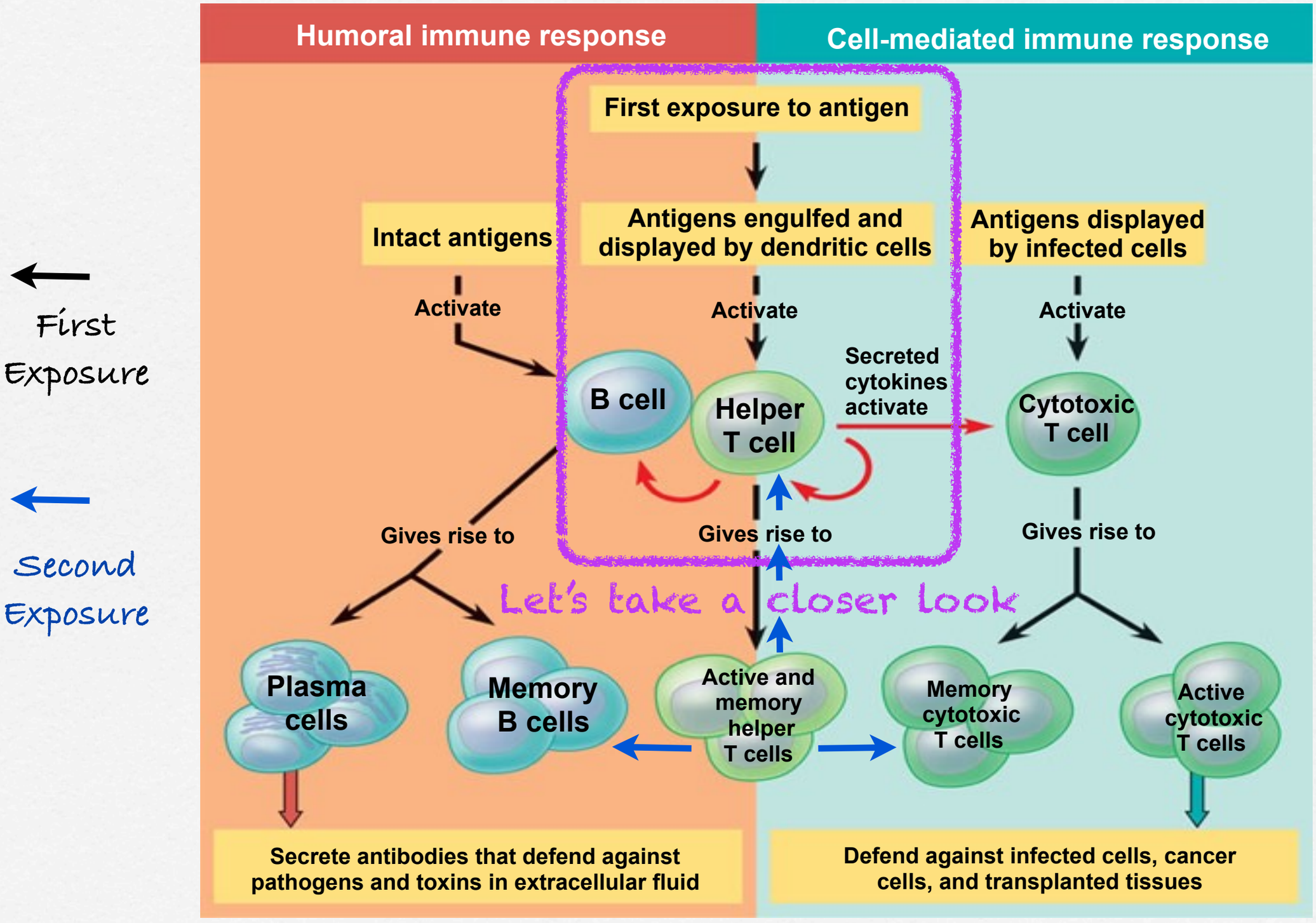
Overview Of Acquired Immunity



← First Exposure

← Second Exposure

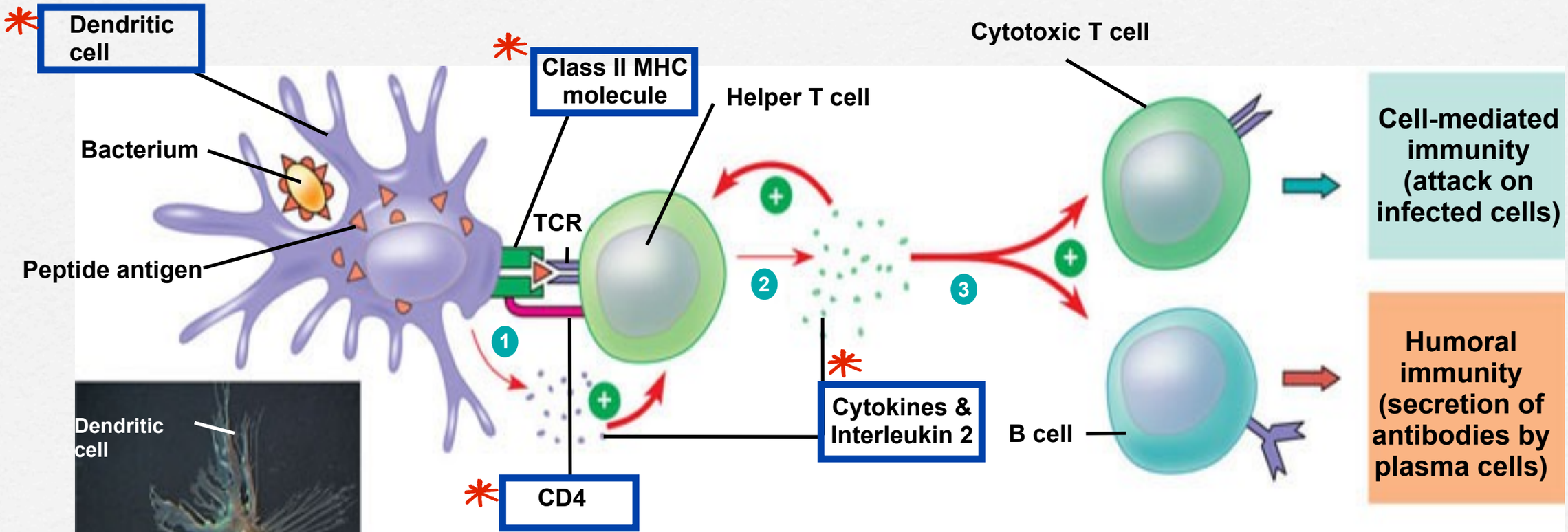
Overview Of Acquired Immunity

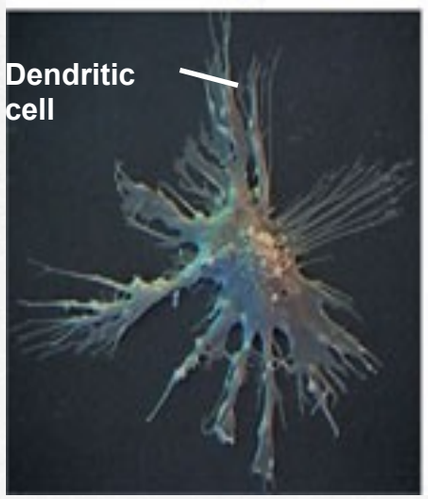


Central Role of Helper T Cells

If dendritic cell presents antigen it is likely a primary immune response

1. **After a dendritic cell engulfs and degrades a bacterium, it displays bacterial antigen fragments (peptides) complexed with a class II MHC molecule on the cell surface. A specific helper T cell binds to the displayed complex via its TCR with the aid of CD4. This interaction promotes secretion of cytokines by the dendritic cell.**

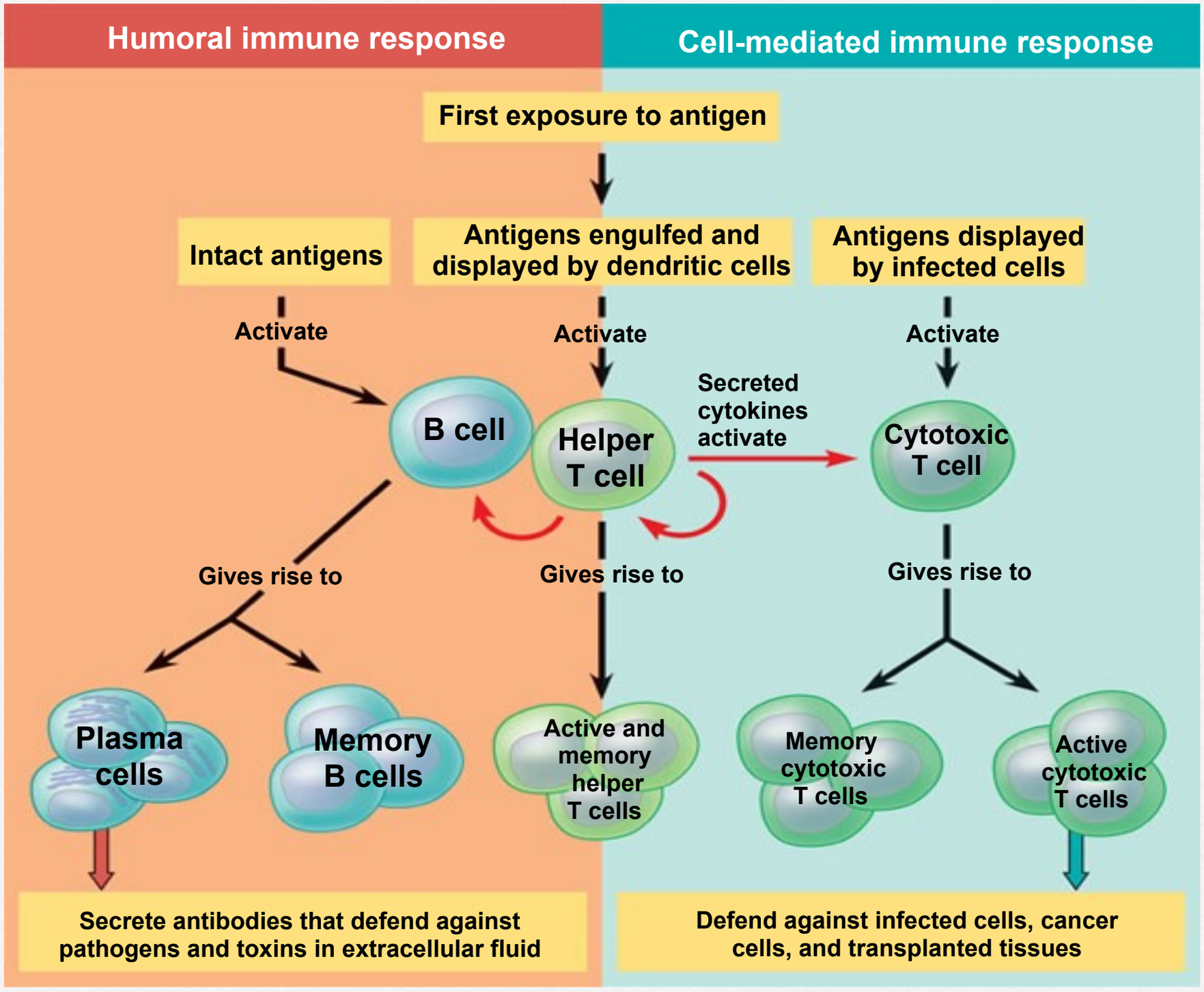




2. **Proliferation of the T cell, stimulated by cytokines from both the dendritic cell and the T cell itself, gives rise to a clone of activated helper T cells (not shown), all with receptors for the same MHC–antigen complex.**

3. **The cells in this clone secrete other cytokines that help activate B cells and cytotoxic T cells.**

Overview Of Acquired Immunity



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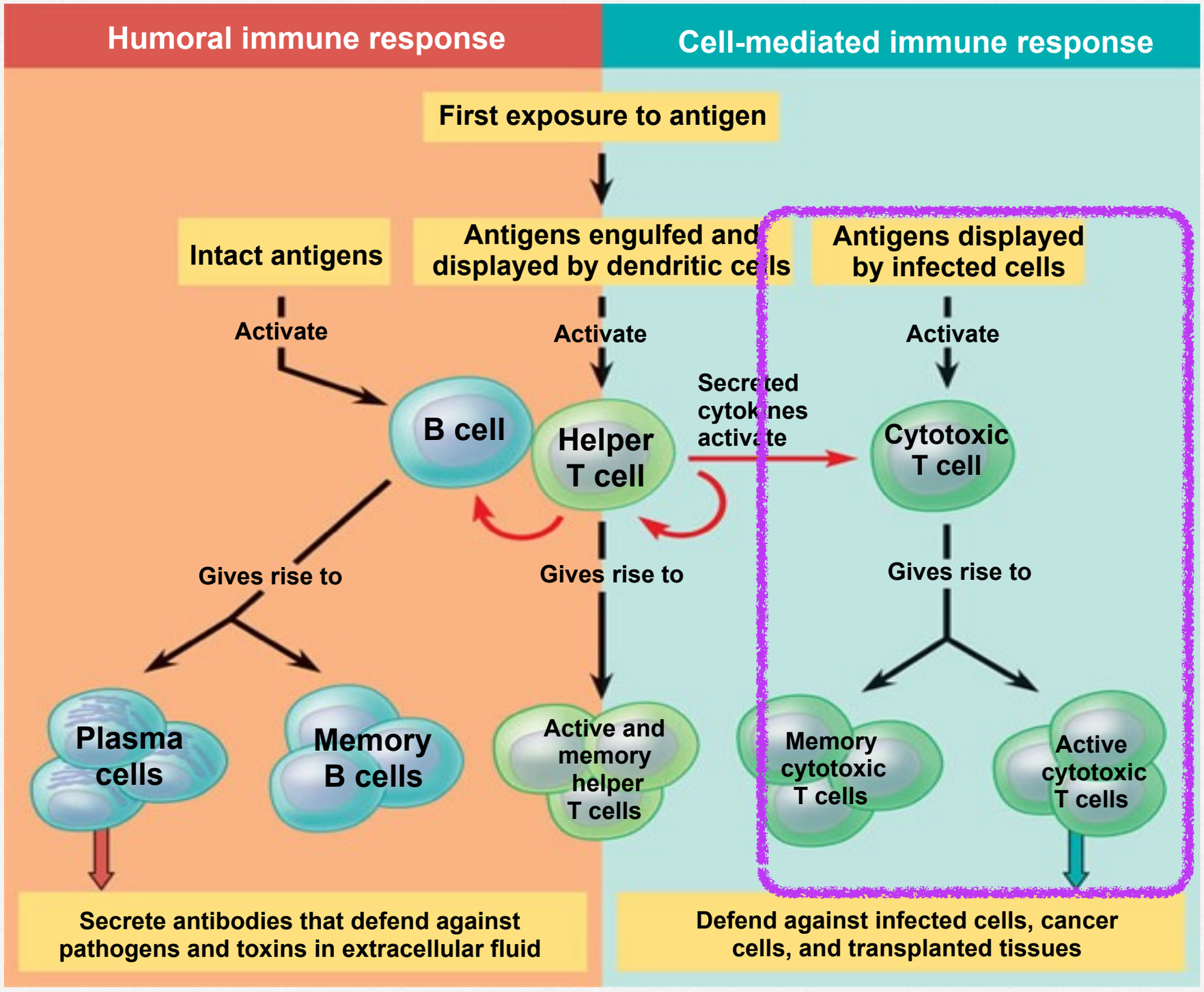

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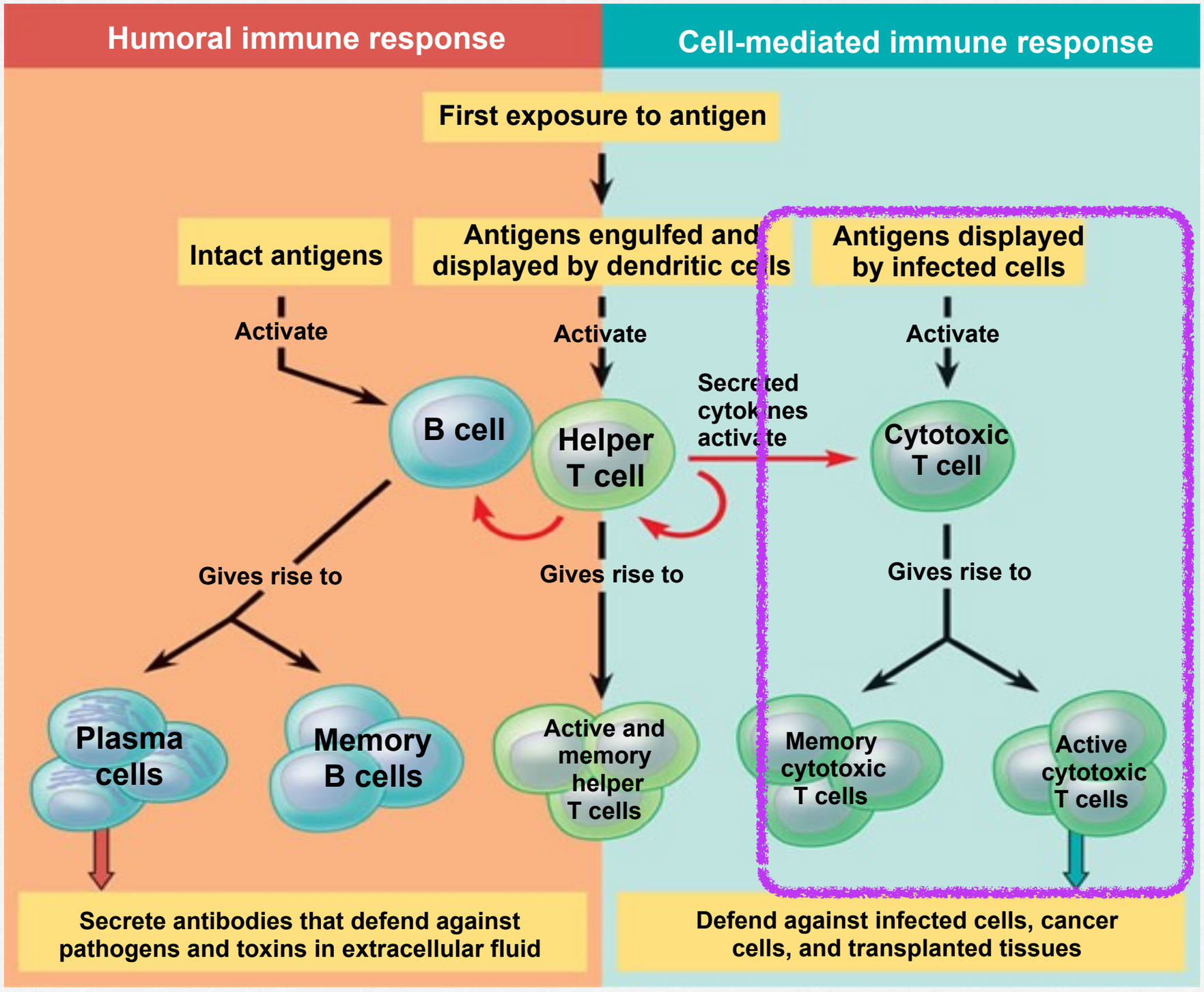


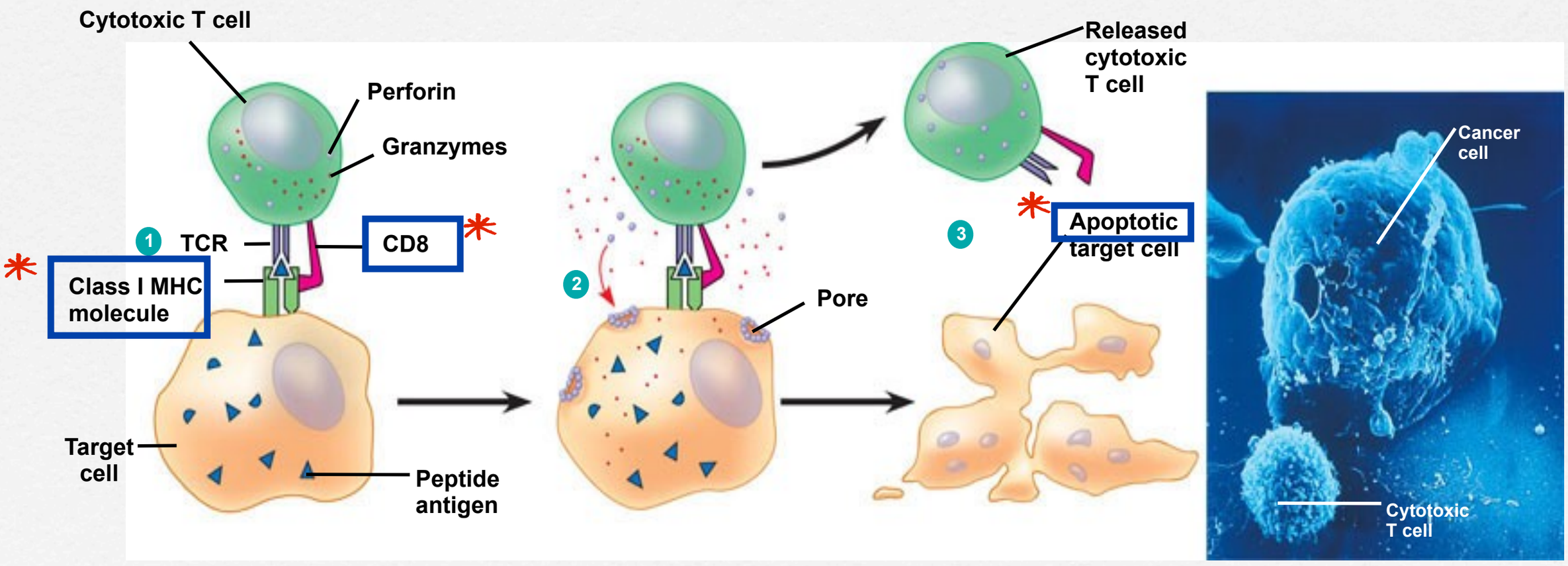
Let's take a closer look

Cytotoxic T Cells

1. A specific cytotoxic T cell binds to a class I MHC–antigen complex on a target cell via its TCR with the aid of CD8. This interaction, along with cytokines from helper T cells, leads to the activation of the cytotoxic cell.

2. The activated T cell releases perforin molecules, which form pores in the target cell membrane, and proteolytic enzymes (granzymes), which enter the target cell by endocytosis.

3. The granzymes initiate apoptosis within the target cells, leading to fragmentation of the nucleus, release of small apoptotic bodies, and eventual cell death. The released cytotoxic T cell can attack other target cells.



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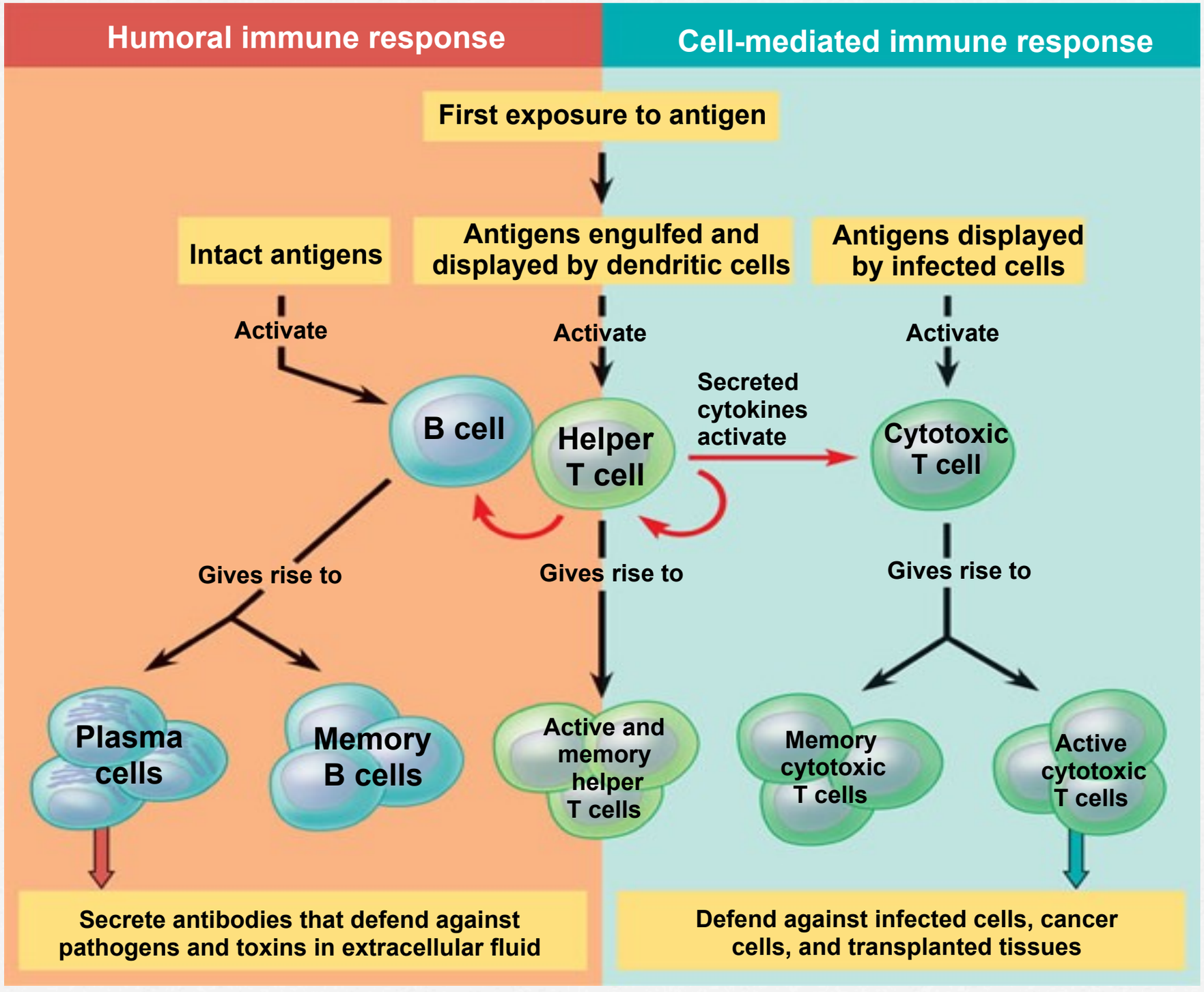

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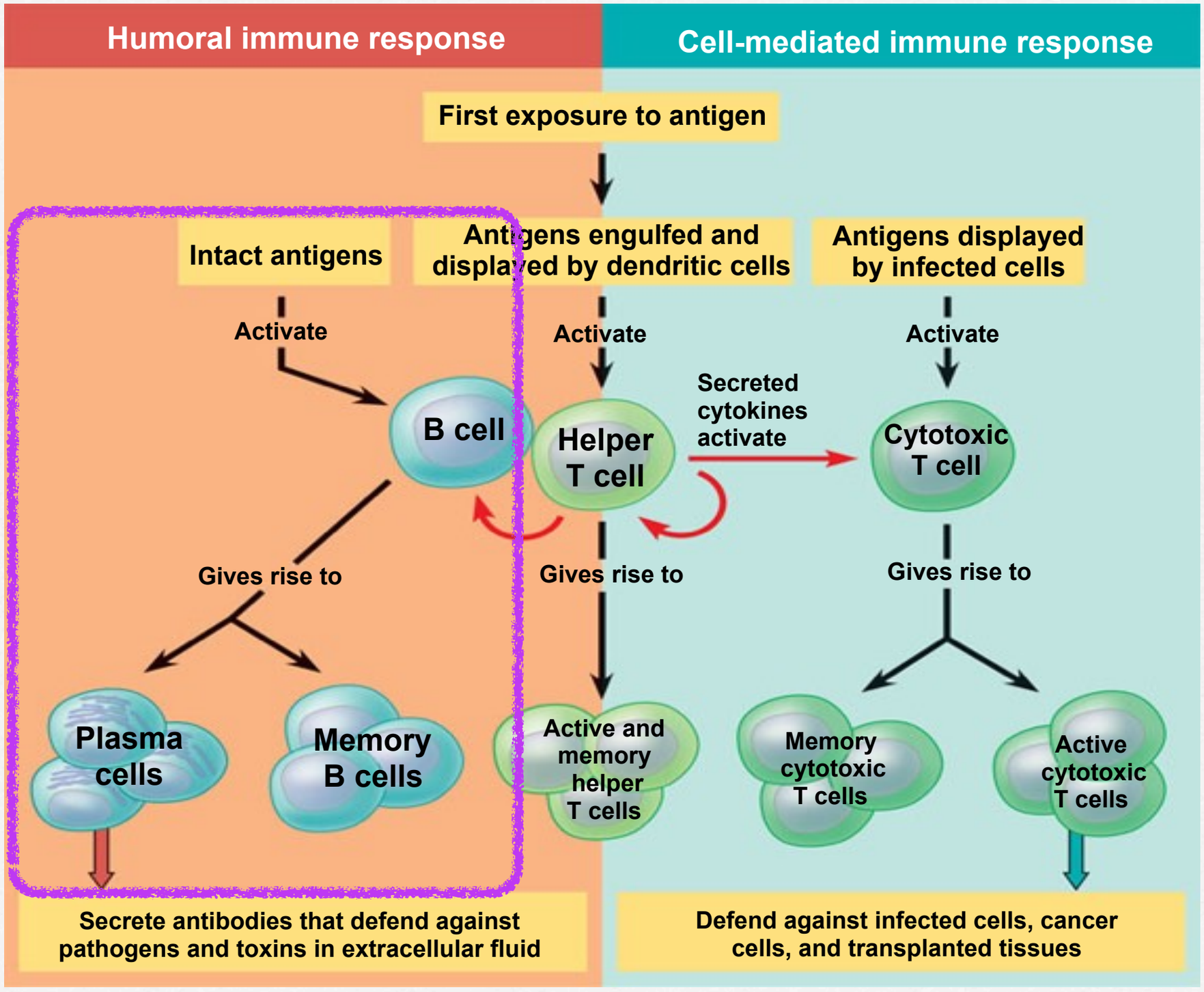

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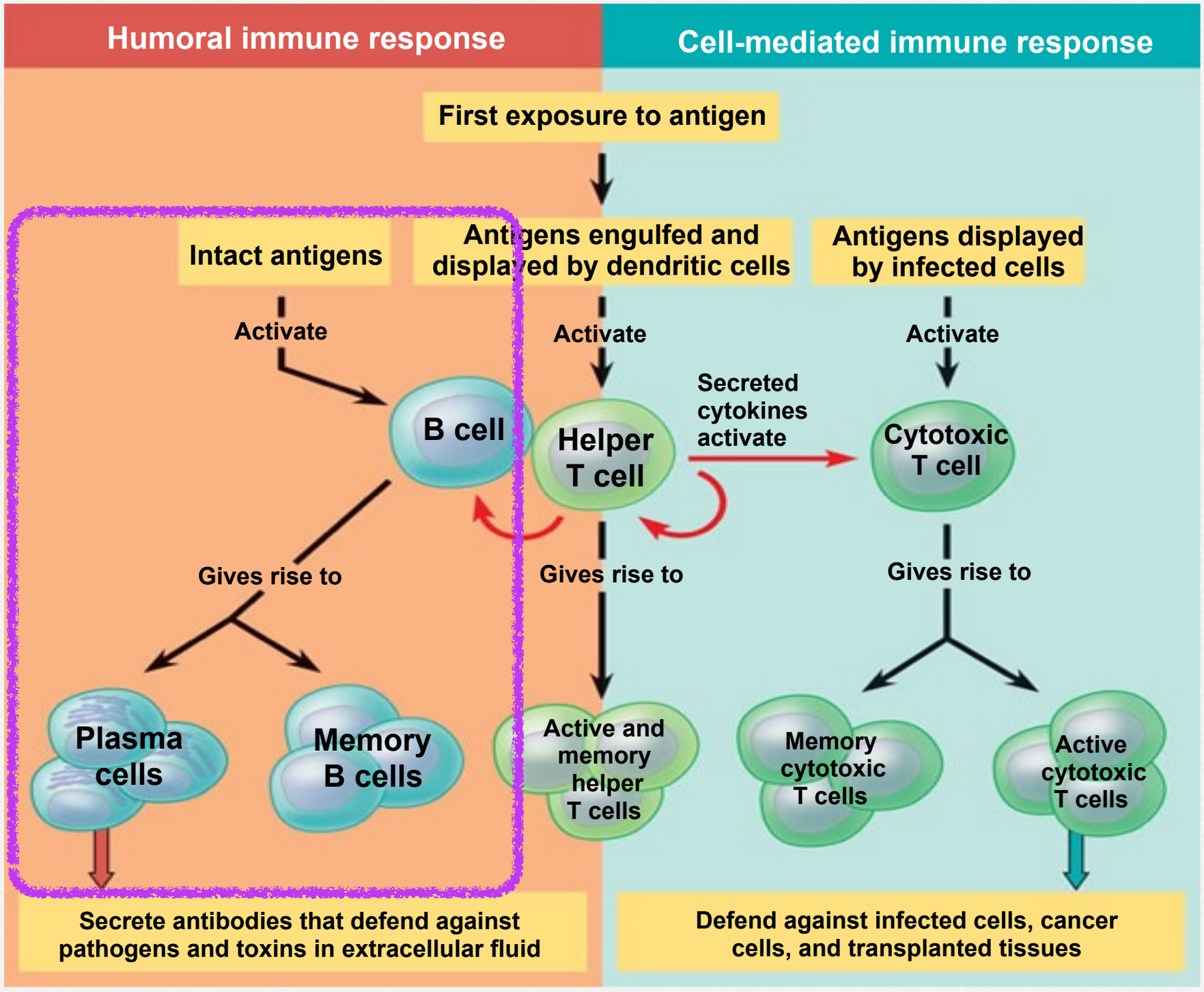
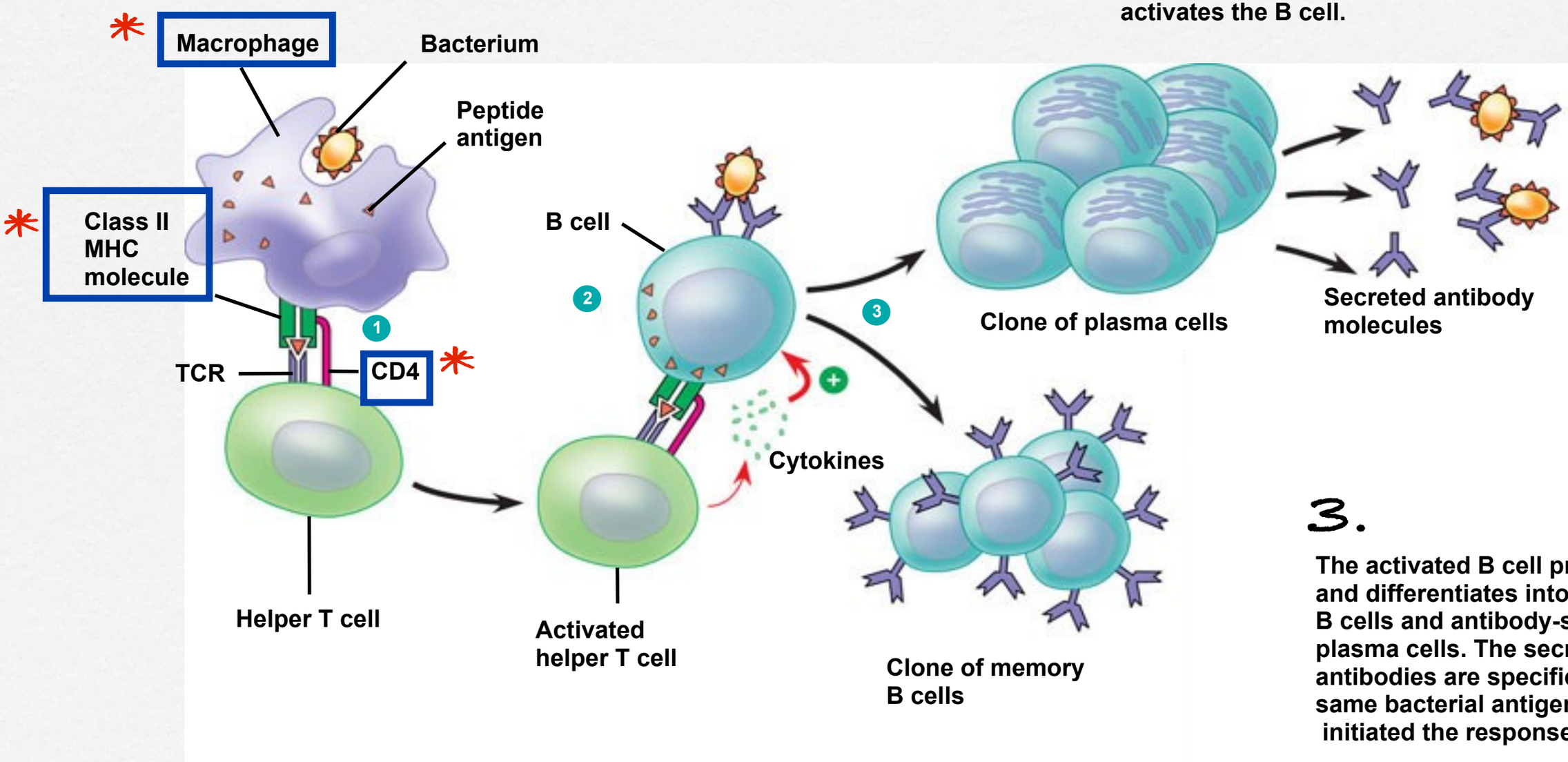


Humoral Immune Response

If macrophage presents antigen it is likely a secondary immune response

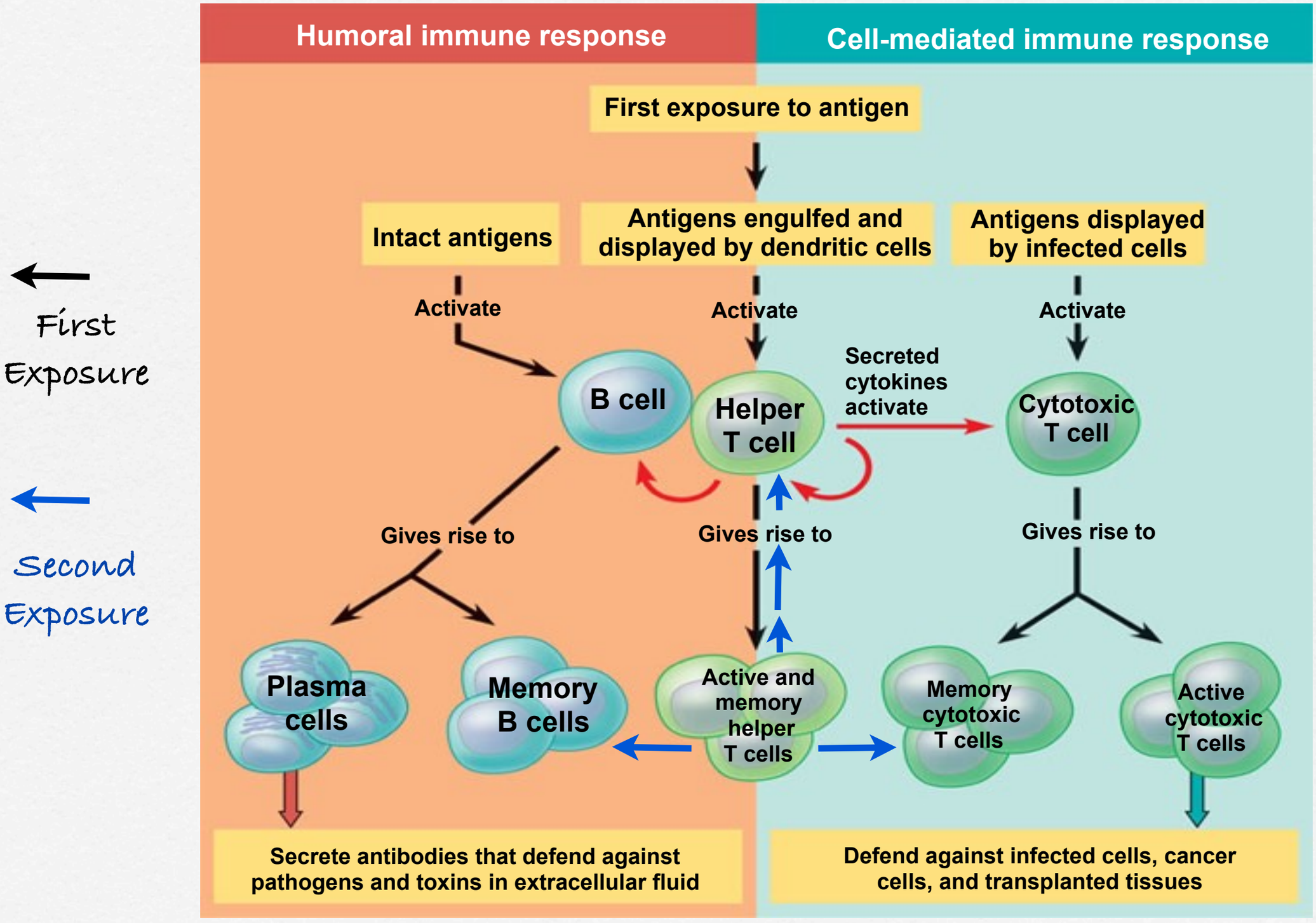
1. After a macrophage engulfs and degrades a bacterium, it displays a peptide antigen complexed with a class II MHC molecule. A helper T cell that recognizes the displayed complex is activated with the aid of cytokines secreted from the macrophage, forming a clone of activated helper T cells (not shown).

2. A B cell that has taken up and degraded the same bacterium displays class II MHC–peptide antigen complexes. An activated helper T cell bearing receptors specific for the displayed antigen binds to the B cell. This interaction, with the aid of cytokines from the T cell, activates the B cell.



3. The activated B cell proliferates and differentiates into memory B cells and antibody-secreting plasma cells. The secreted antibodies are specific for the same bacterial antigen that initiated the response.

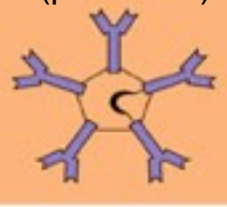
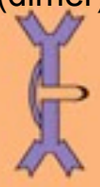
Overview Of Acquired Immunity



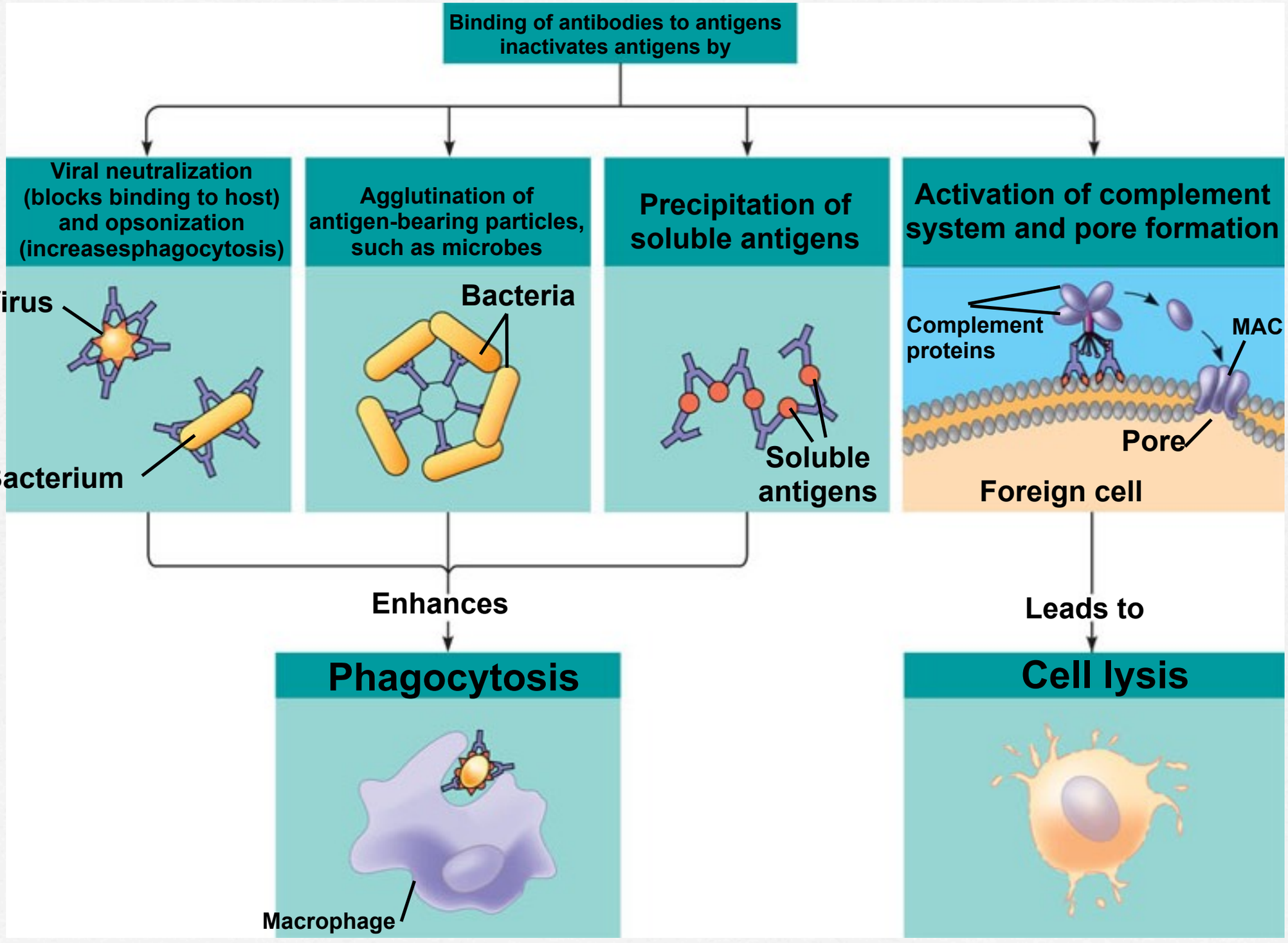
First Exposure

Second Exposure

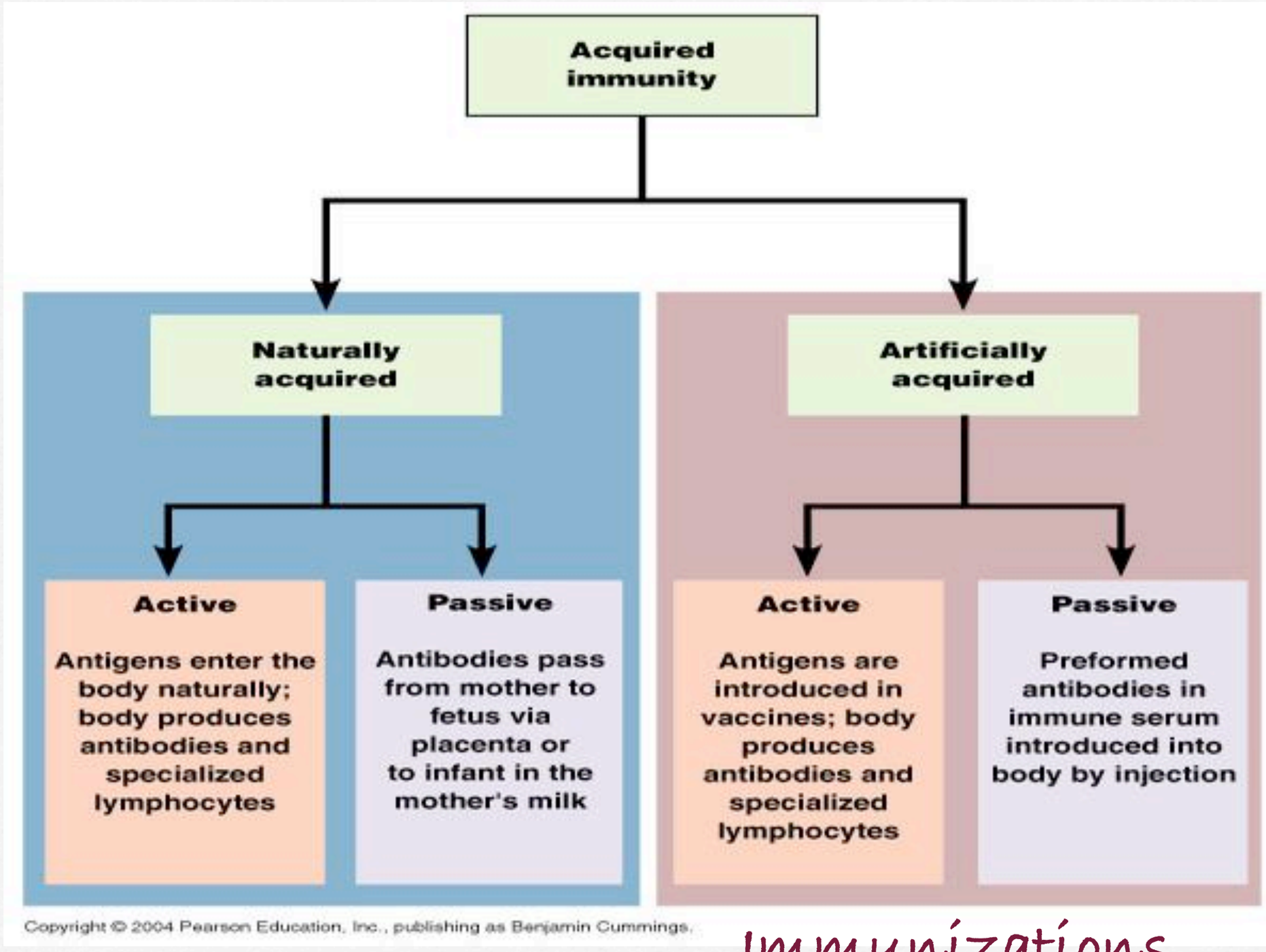
5 Classes of Immunoglobulins

IgM (pentamer) 	► First Ig class produced after initial exposure to antigen; then its concentration in the blood declines ► Promotes neutralization and agglutination of antigens; very effective in complement activation
IgG (monomer) 	► Most abundant Ig class in blood; also present in tissue fluids ► Only Ig class that crosses placenta, thus conferring passive immunity on fetus ► Promotes opsonization, neutralization, and agglutination of antigens; less effective in complement activation than IgM
IgA (dimer) 	► Present in secretions such as tears, saliva, mucus, and breast milk ► Provides localized defense of mucous membranes by agglutination and neutralization of antigens ► Presence in breast milk confers passive immunity on nursing infant
IgE (monomer) 	► Triggers release from mast cells and basophils of histamine and other chemicals that cause allergic reactions
IgD (monomer) 	► Present primarily on surface of naive B cells that have not been exposed to antigens ► Acts as antigen receptor in antigen-stimulated proliferation and differentiation of B cells (clonal selection)

Antibody Mechanisms of Action



Active & Passive Immunity



Immunizations

Active & Passive Immunity

- **Active: Natural or Artificial**
  - slower to acquire immunity but lasts much longer
  - involves patient's T cells or B cells thus memory develops

- **Passive: Natural or Artificial**
  - immediate immunity but lasts only for a few weeks/months
  - does not involve patient's T cells or B cells

Immunizations / Vaccinations

- **Active or Passive Immunity: "Artificially"**
  - 1796 Edward Jenner noticed milkmaids were immune to severe and dangerous smallpox symptoms
  - Edward Jenner injects people with cowpox virus (antigens)
    - (a weak but similar virus to smallpox)
  - cowpox antigen generates active immunity including memory against cowpox and smallpox
  - Today's vaccines might include weakened toxins, killed pathogens, pathogen pieces or weakened pathogens

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What can we deduce about the cowpox virus if it can serve as a smallpox vaccine?

Immunizations / Vaccinations

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What can we deduce about the cowpox virus if it can serve as a smallpox vaccine?

The surface of each virus must be very similar

Antibodies as Tools

- **Monoclonal Antibodies**
  - The power of antibody-antigen specificity has been harnessed in research, diagnosis and therapy.
  - Monoclonal antibodies- produced in culture for specific epitopes on an antigen
    - monoclonal antibodies in home pregnancy tests detect HCG a hormone that is released when embryo attaches to uterus
    - using mice to create human antibodies that can be injected into patients

Learning Objectives:

LO 2.29 The student can create representations and models to describe immune responses. [See SP 1.1, 1.2]

LO 2.30 The student can create representations or models to describe nonspecific immune defenses in plants and animals. [See SP 1.1, 1.2]

LO 2.43 The student is able to connect the concept of cell communication to the functioning of the immune system. [See SP 7.2]