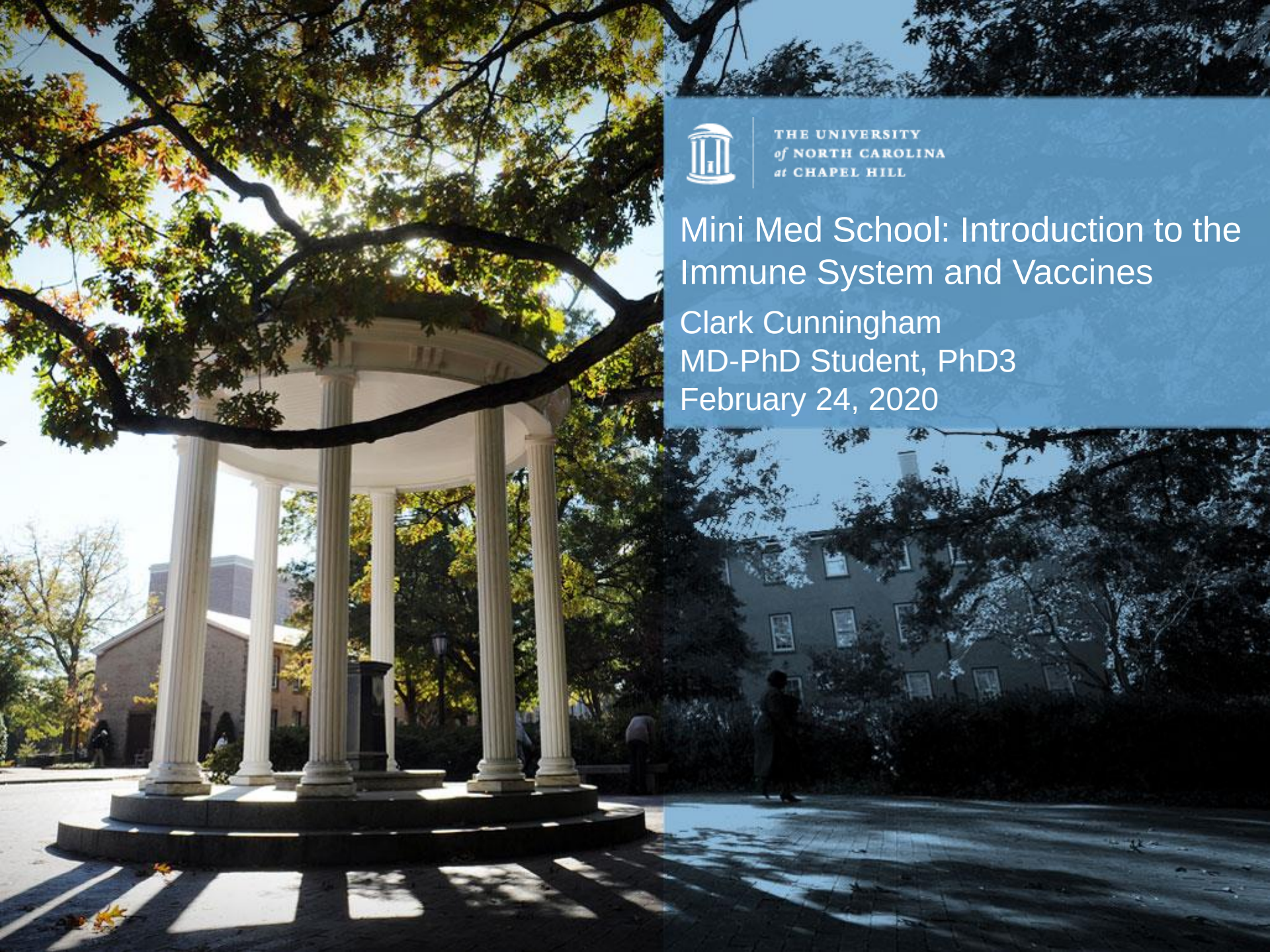


THE UNIVERSITY of NORTH CAROLINA at CHAPEL HILL

Mini Med School: Introduction to the Immune System and Vaccines

Clark Cunningham
MD-PhD Student, PhD3
February 24, 2020

Objectives

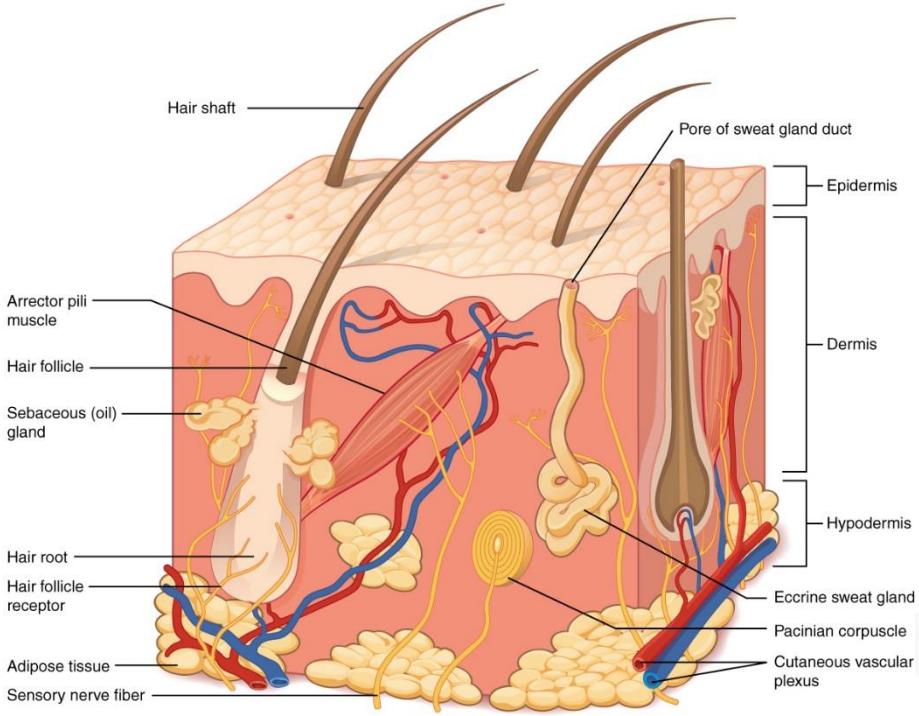
- Immunology 101
- Immune memory: generation and activation
- Avoid jargon! (key terms underlined)

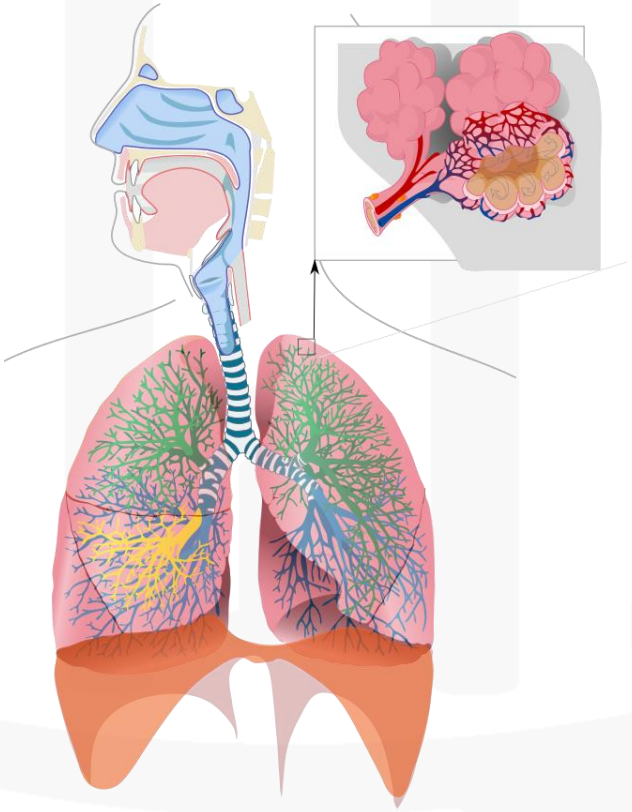
Immune System: Innate and Adaptive

- Innate immune system
  - » Non-specifically protects against pathogens
    - Pathogen: invasive organism
      - » E.g. Bacteria, viruses

Innate Immune System

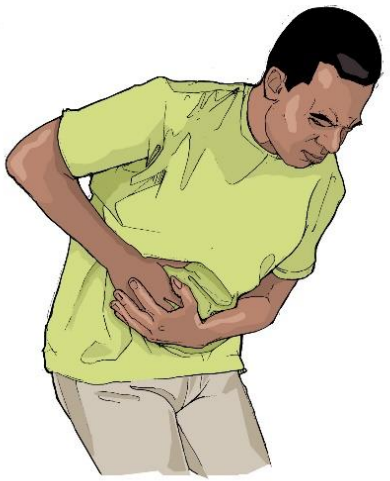
- Skin, GI tract, respiratory tract





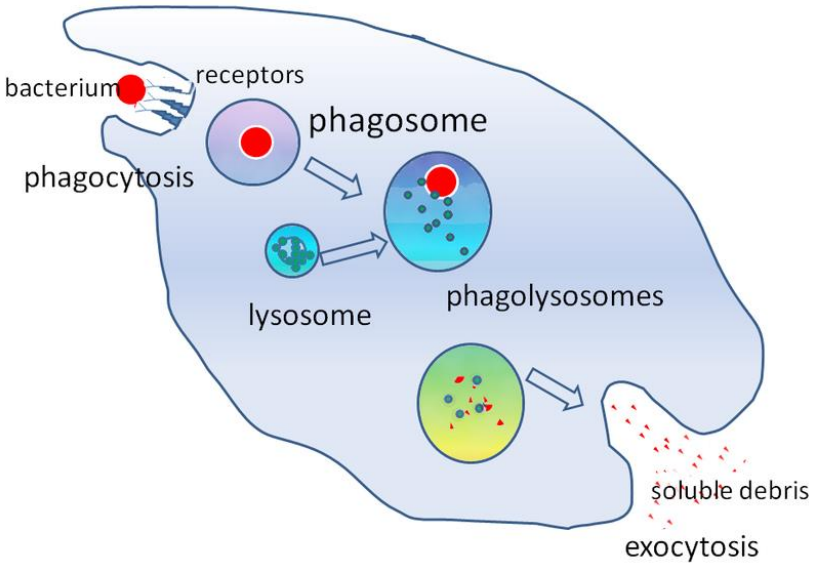
Innate Immune System

- Skin, GI tract, respiratory tract
- Inflammation
  - » Increases blood flow and recruits immune cells
  - » Also causes fever, pain, redness, and swelling



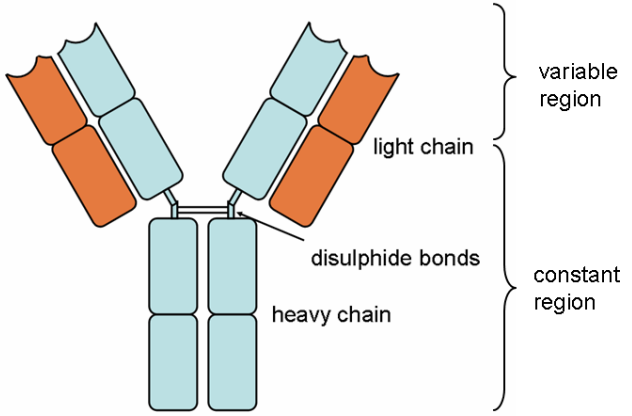
Innate Immune System

- Skin, GI tract, respiratory tract
- Inflammation
- Phagocytes:
  - » “Eating cells” that engulf and digest pathogens and infected host cells



Immune System: Innate and Adaptive

- Innate immune system
- Adaptive immune system
  - » Target specific pathogens and generate/activate immune memory



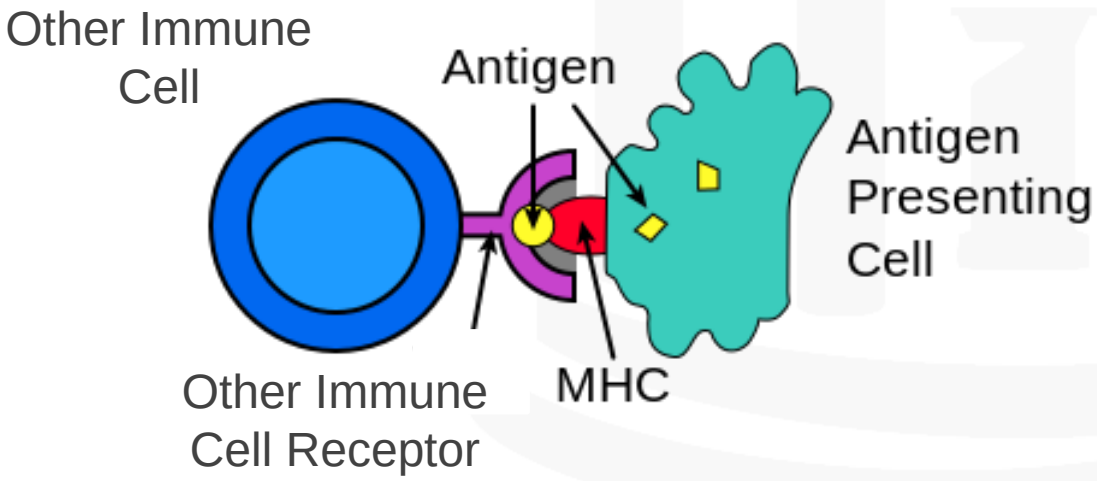
Antibody

Immune System: Innate and Adaptive

- Innate immune system
- Adaptive immune system
  - » Target specific pathogens and generate/activate immune memory
    - A key step in adaptive immunity is antigen presentation

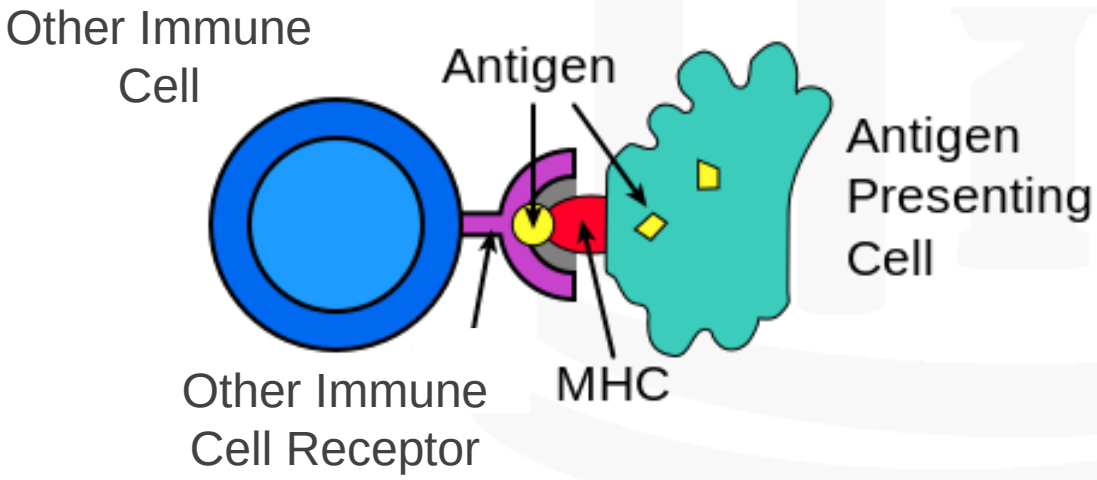
Antigen Presentation

- Antigen: Small molecule (usually protein) that is recognized by the immune system
  - E.g. Bacterial or viral proteins



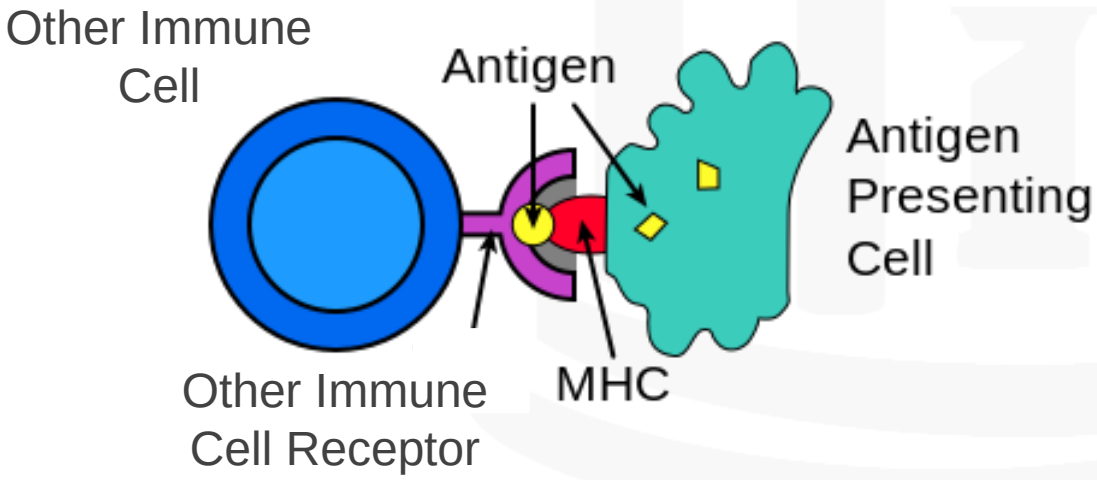
Antigen Presentation

- Antigen: Small molecule (usually protein) that is recognized by the immune system
- Cells digest proteins from inside and outside of the cell and display them on their surface
  - » Major Histocompatibility Complex (MHC): Receptor that displays antigens

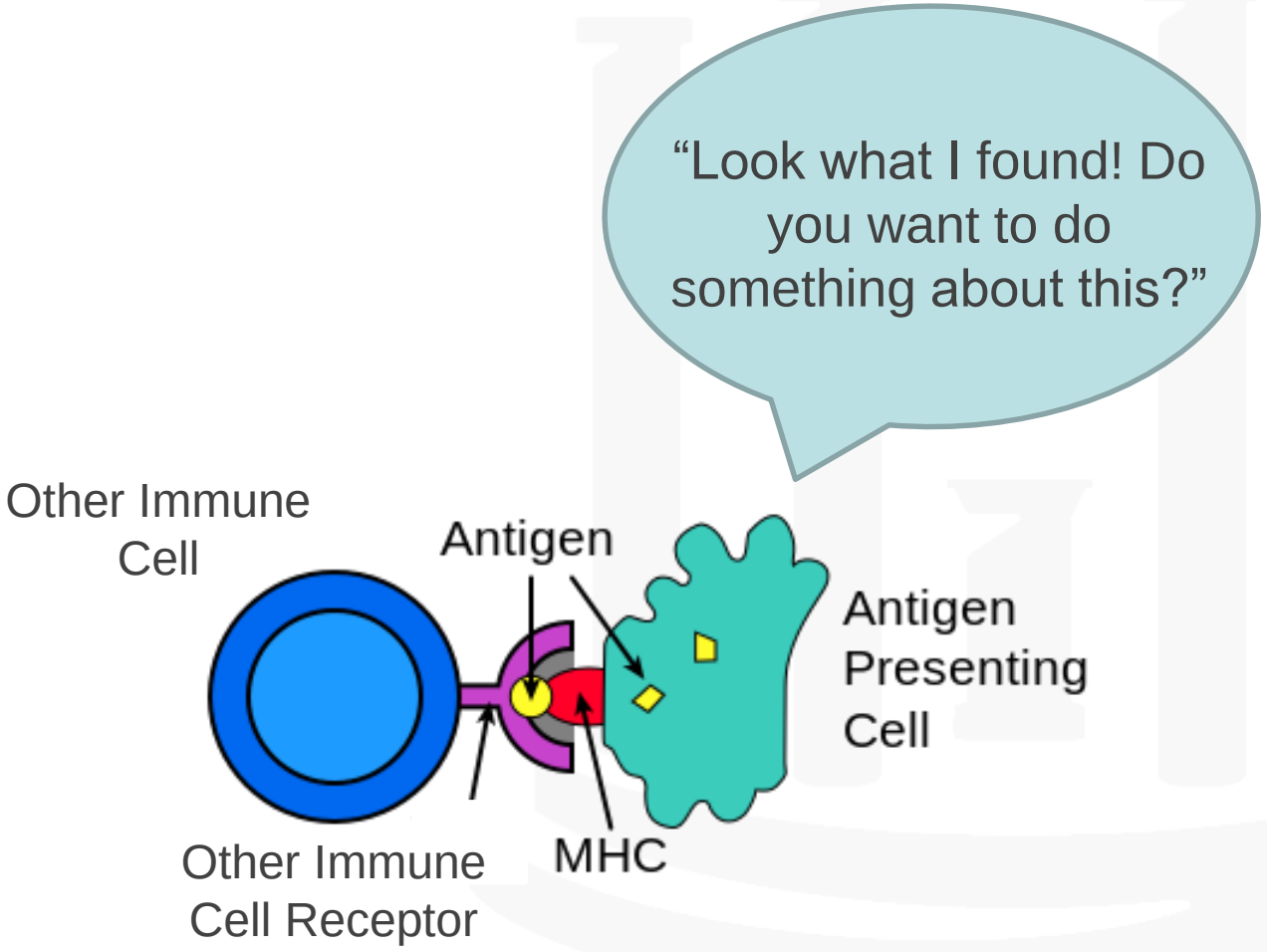


Antigen Presentation

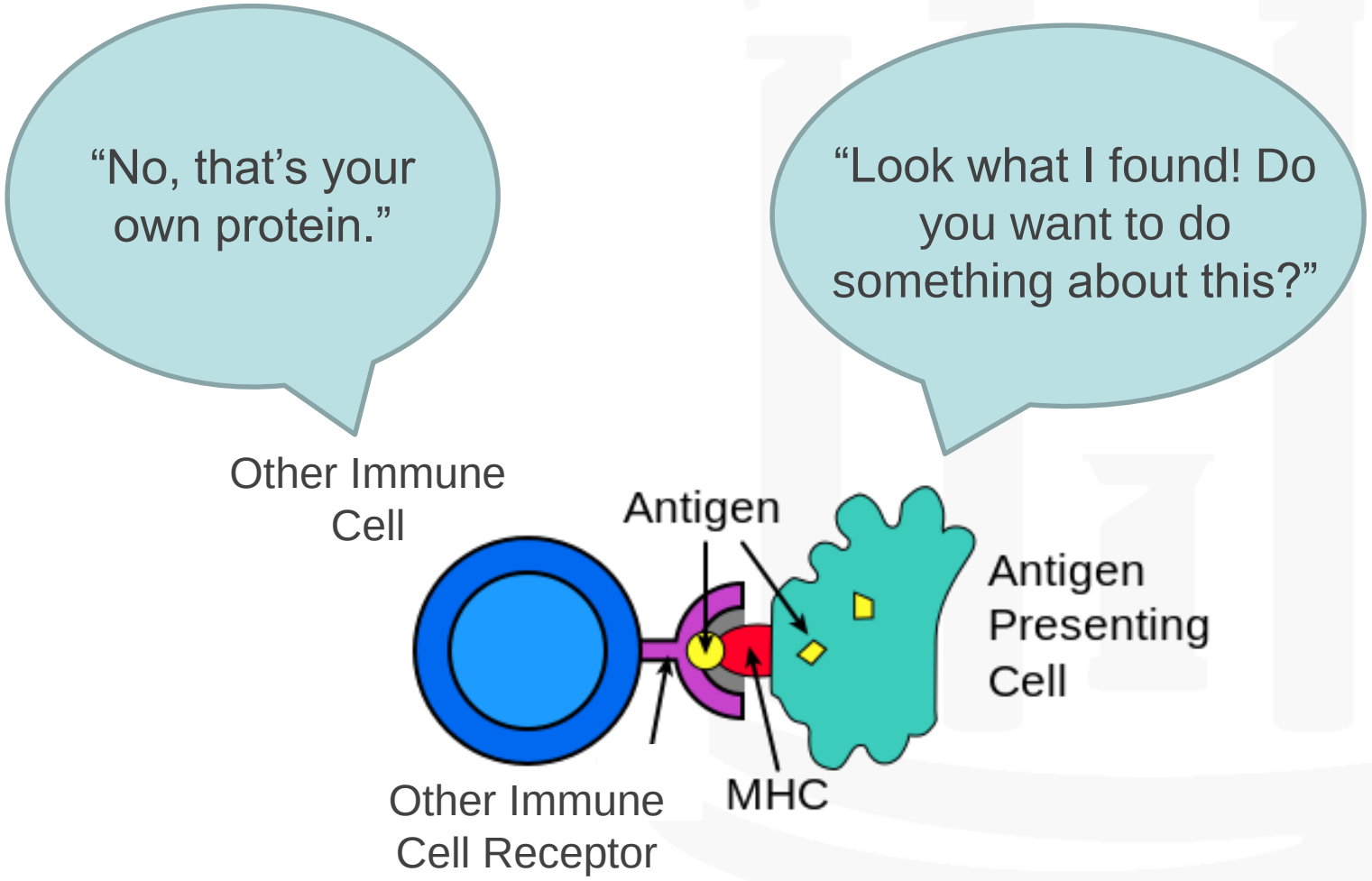
- Antigen: Small molecule (usually protein) that is recognized by the immune system
- Cells digest proteins from inside and outside of the cell and display them on their surface
- Immune cells recognize MHC-antigen complexes and either stimulate or repress an immune response



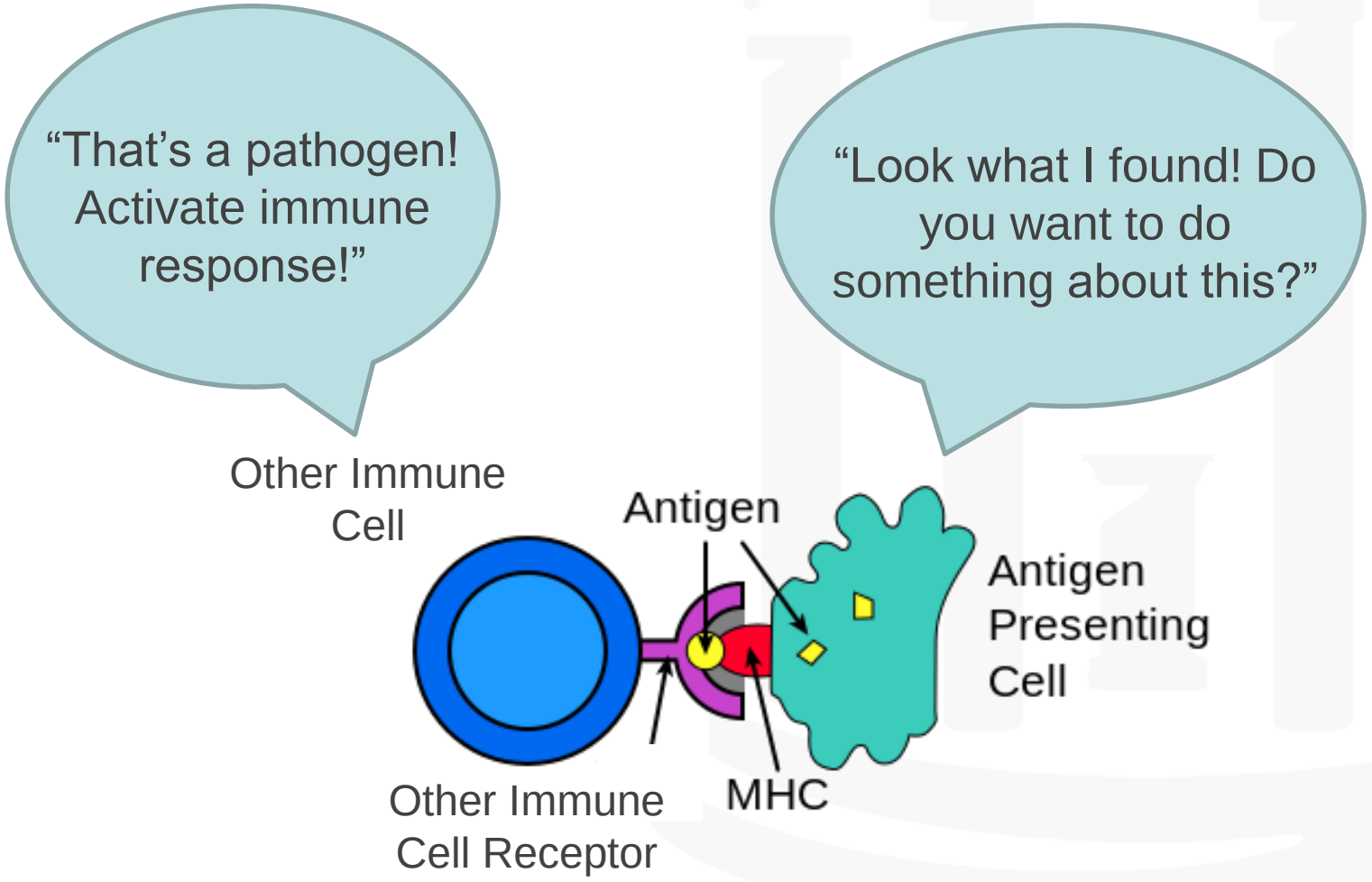
Antigen Presentation



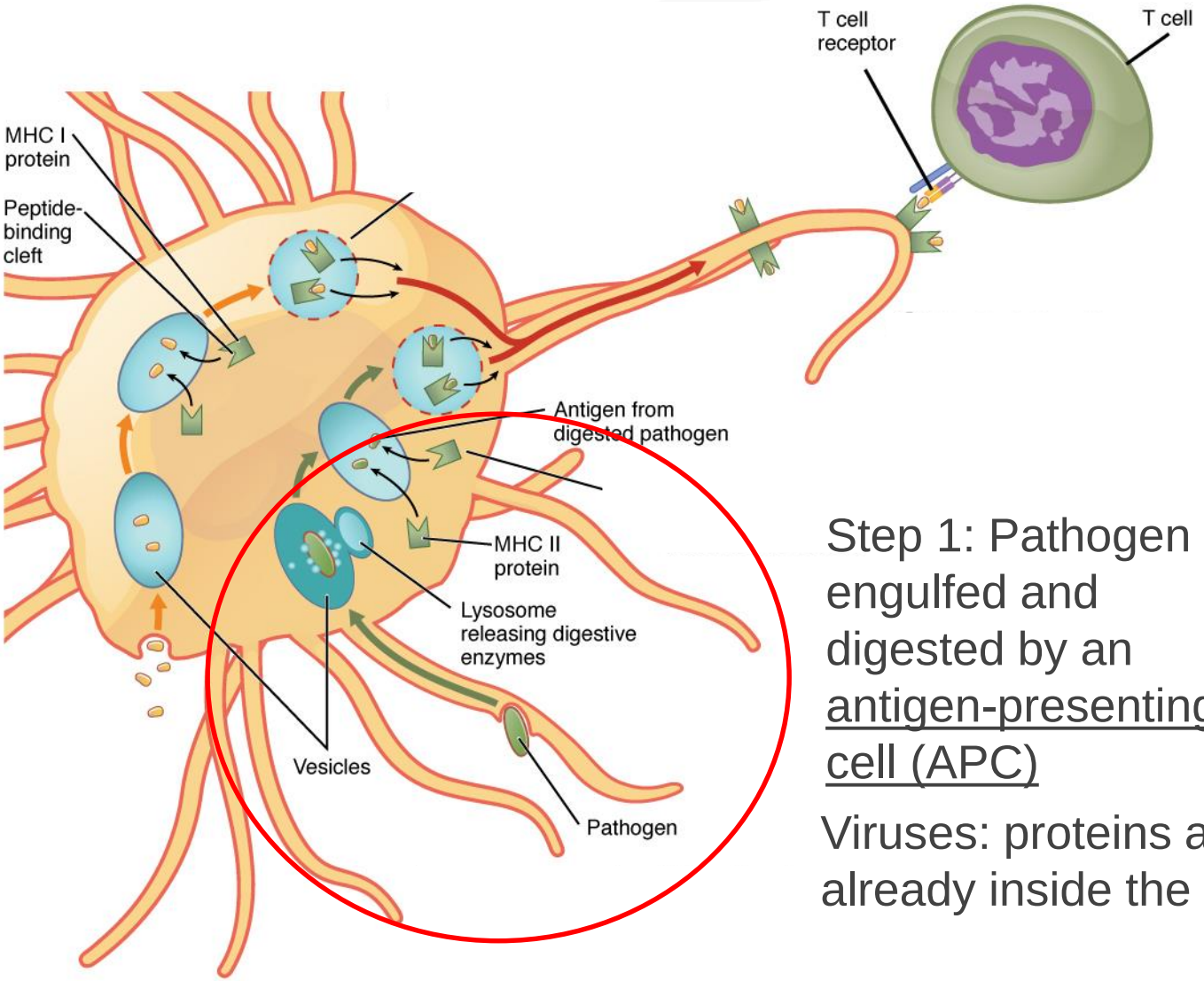
Antigen Presentation



Antigen Presentation



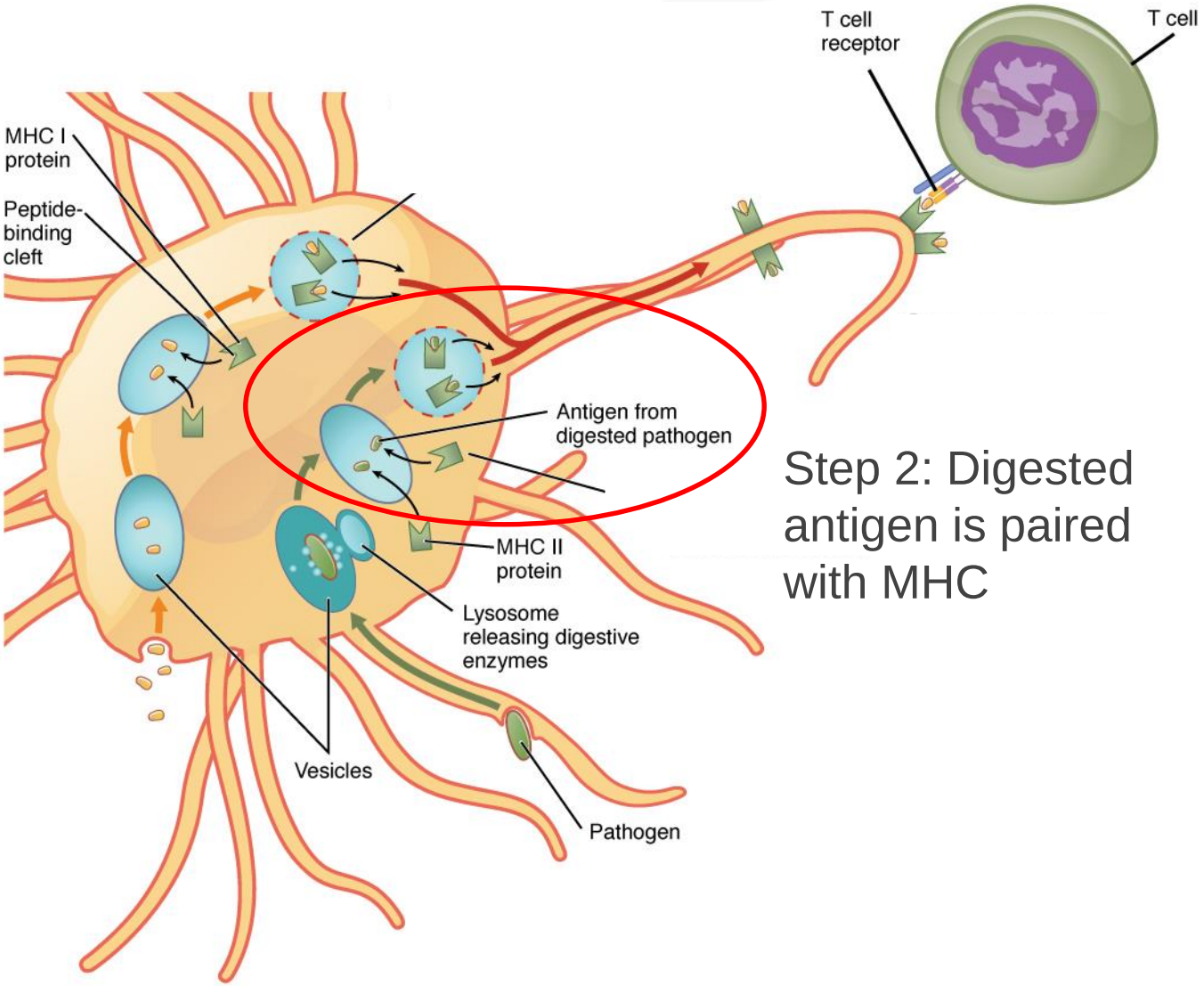
Antigen Presentation



Step 1: Pathogen is engulfed and digested by an antigen-presenting cell (APC)

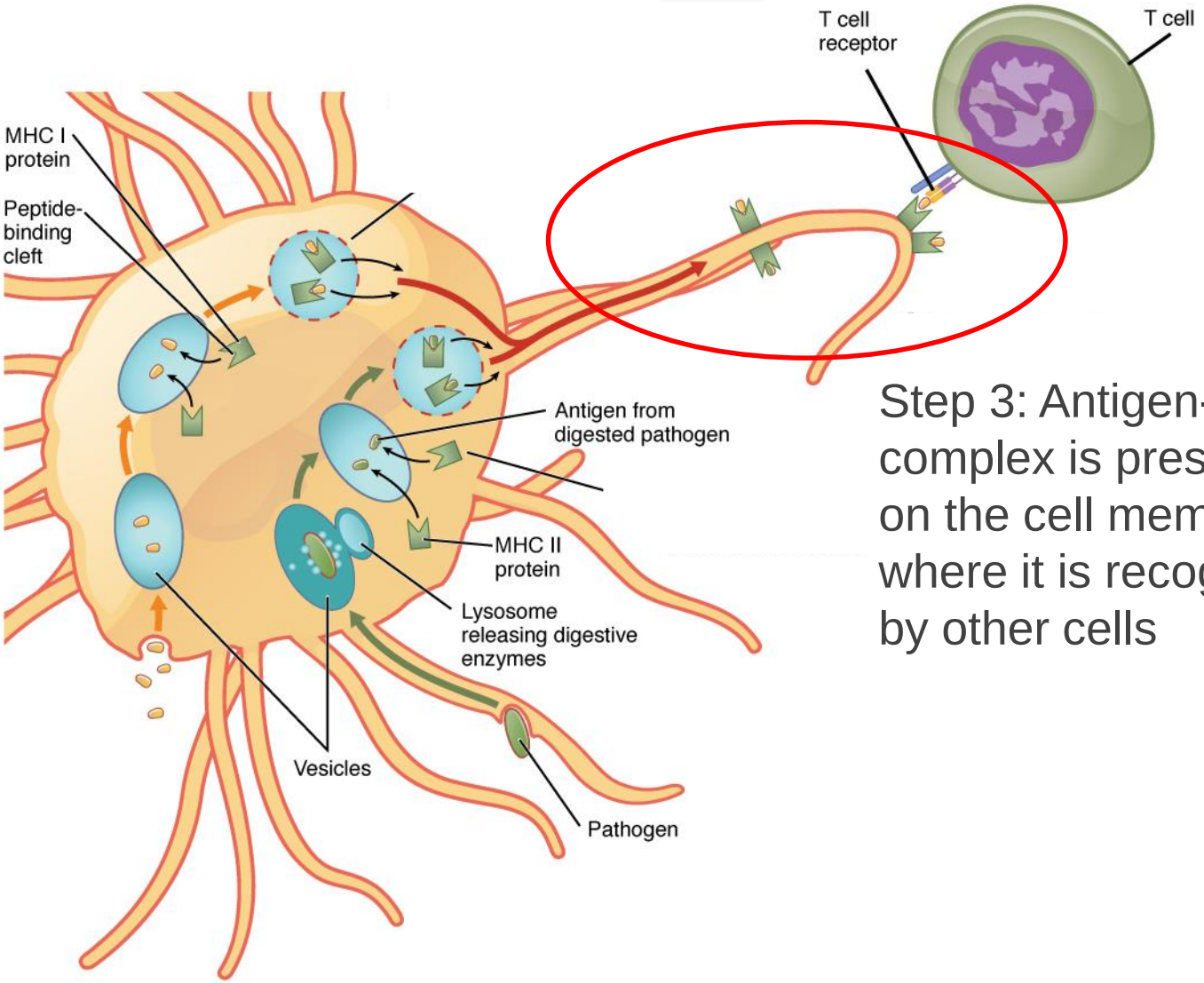
Viruses: proteins are already inside the cell

Antigen Presentation



Step 2: Digested antigen is paired with MHC

Antigen Presentation



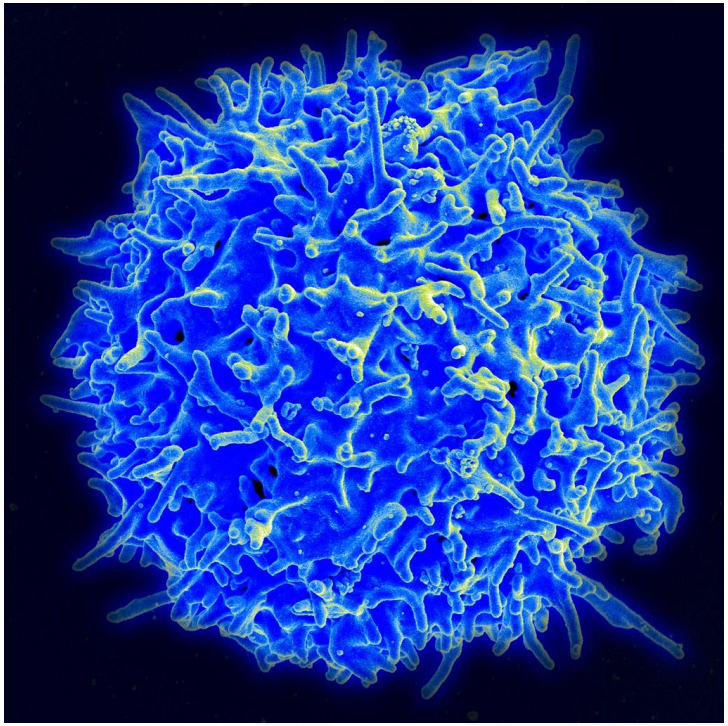
Step 3: Antigen-MHC complex is presented on the cell membrane, where it is recognized by other cells

Adaptive Immune System

- Teamwork
- Pathogen-specific memory
- Antigen presentation
- Two branches that work together
  - » Cell-mediated (T cells)
  - » Humoral (B cells)

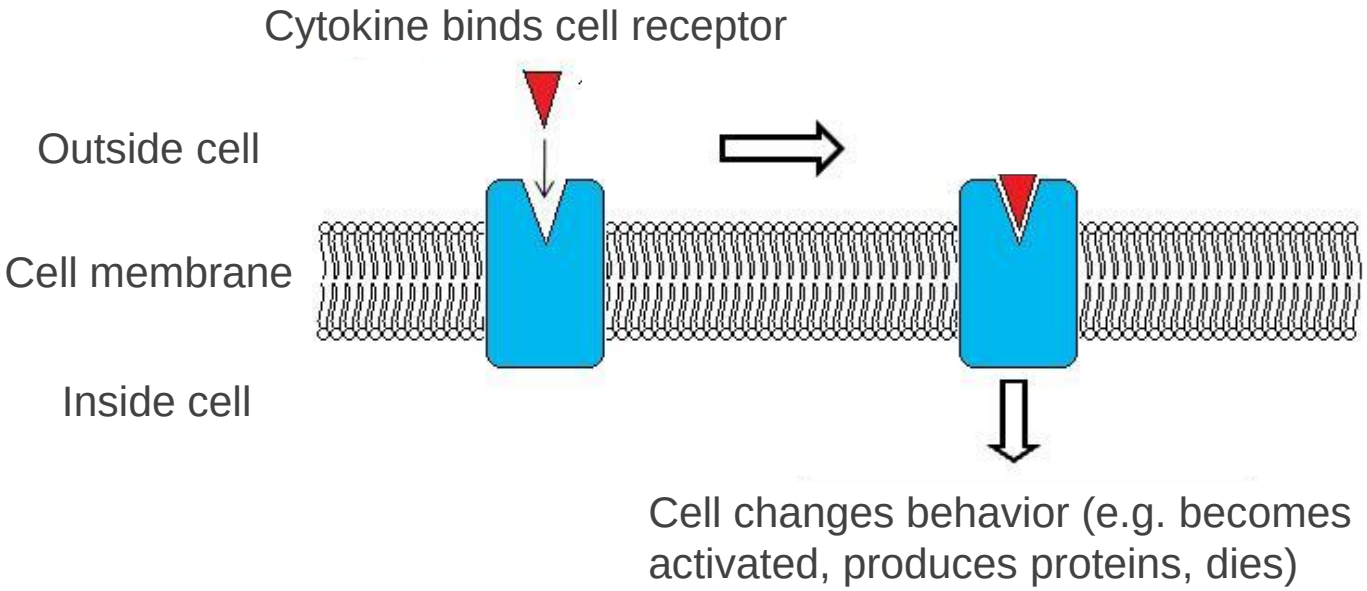
Cell-Mediated Immunity

- T cells either directly kill virally-infected cells or activate other classes of immune cells with cytokines



Cell-Mediated Immunity

- T cells either directly kill virally-infected cells or activate other classes of immune cells with cytokines
  - Cytokines: Small proteins involved in cell-cell communication, especially in the immune system

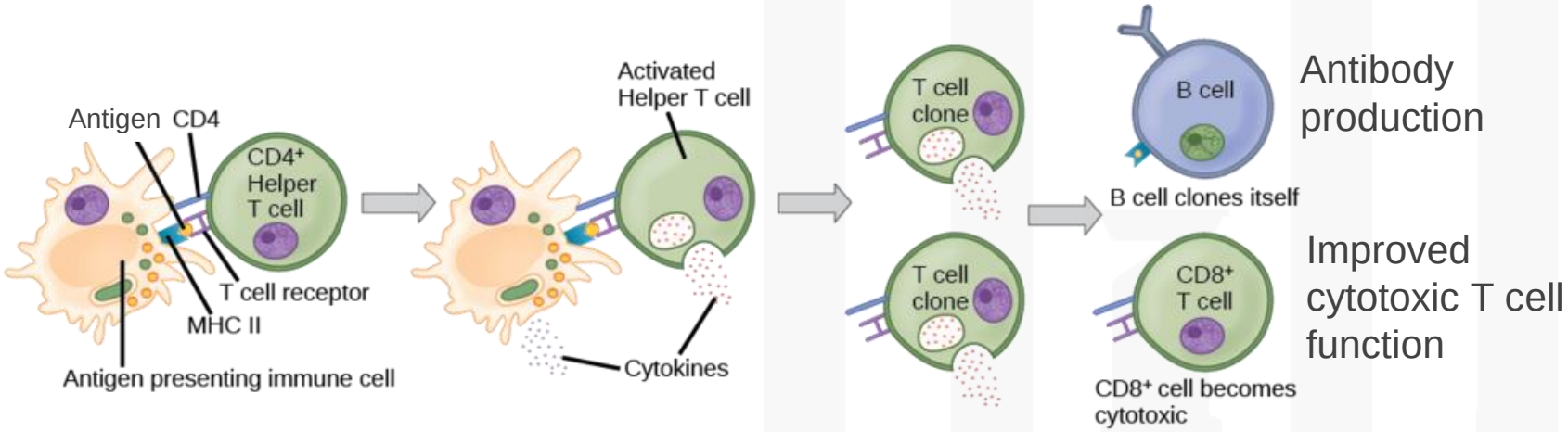


Cell-Mediated Immunity

- Cytotoxic “Killer” T cells
  - » Kill virally-infected cells by recognizing viral antigens presented by MHCI and releasing toxic enzymes

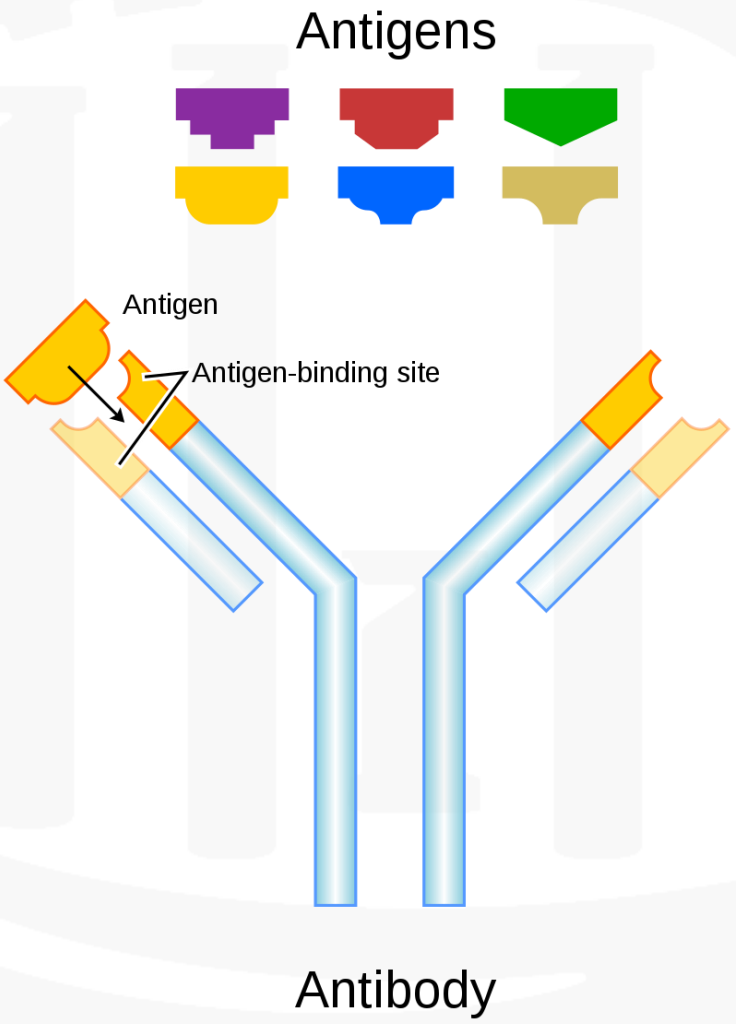
Cell-Mediated Immunity

- Cytotoxic “Killer” T cells
- “Helper” T cells
  - » Produce cytokines to activate cytotoxic T cells and B cells in response to MHCII signaling



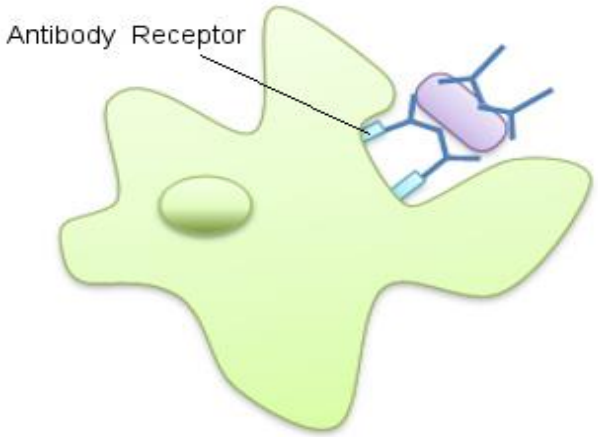
Humoral Immunity

- B cells produce antibodies to specific antigens present on pathogens
  - » Antibodies: proteins that bind antigens and target them for destruction



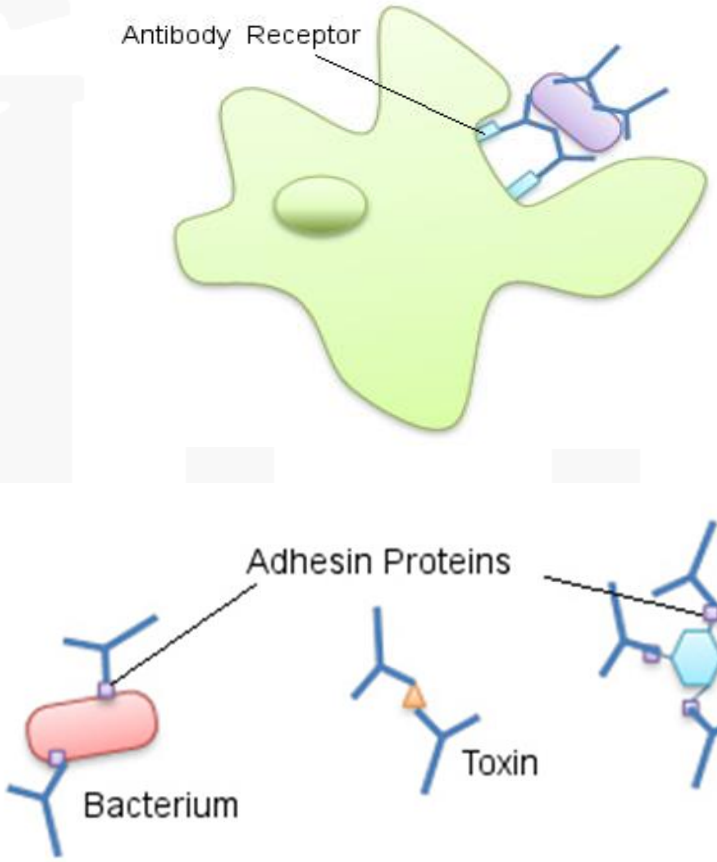
Antibody Function

- Stimulate phagocytes to engulf and destroy pathogens



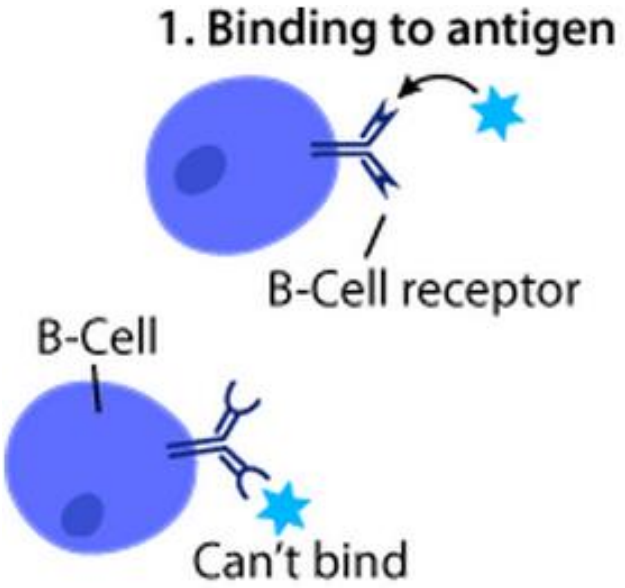
Antibody Function

- Stimulate phagocytes to engulf and destroy pathogens
- Neutralize pathogen proteins



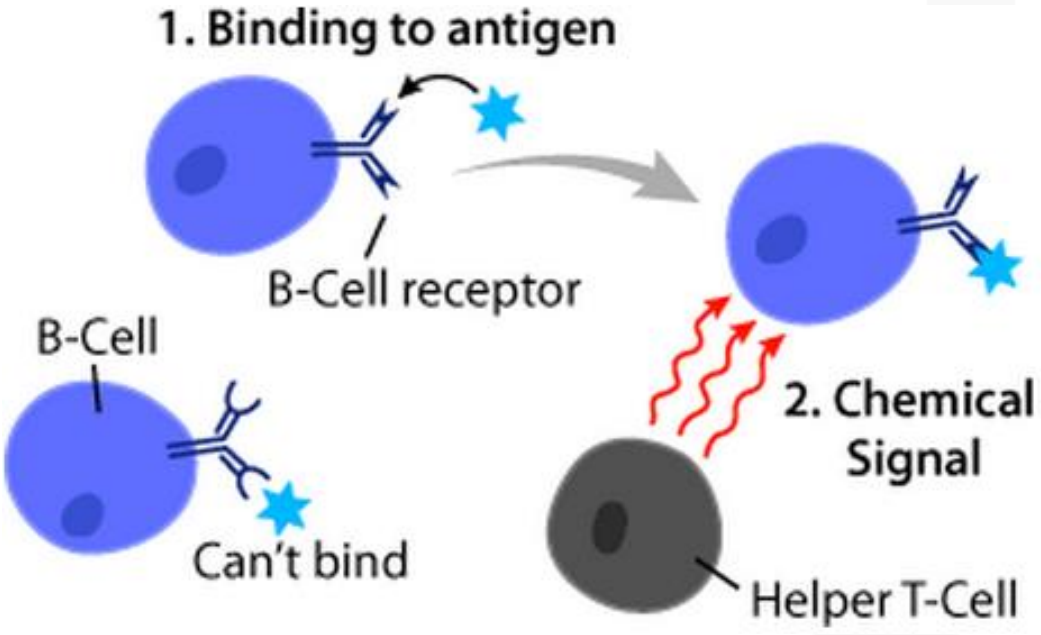
Antibody Generation

- B cell receptors recognize antigens
  - » Antigen binding activates B cells
    - Antigen: Small molecule from pathogen recognized by the immune system



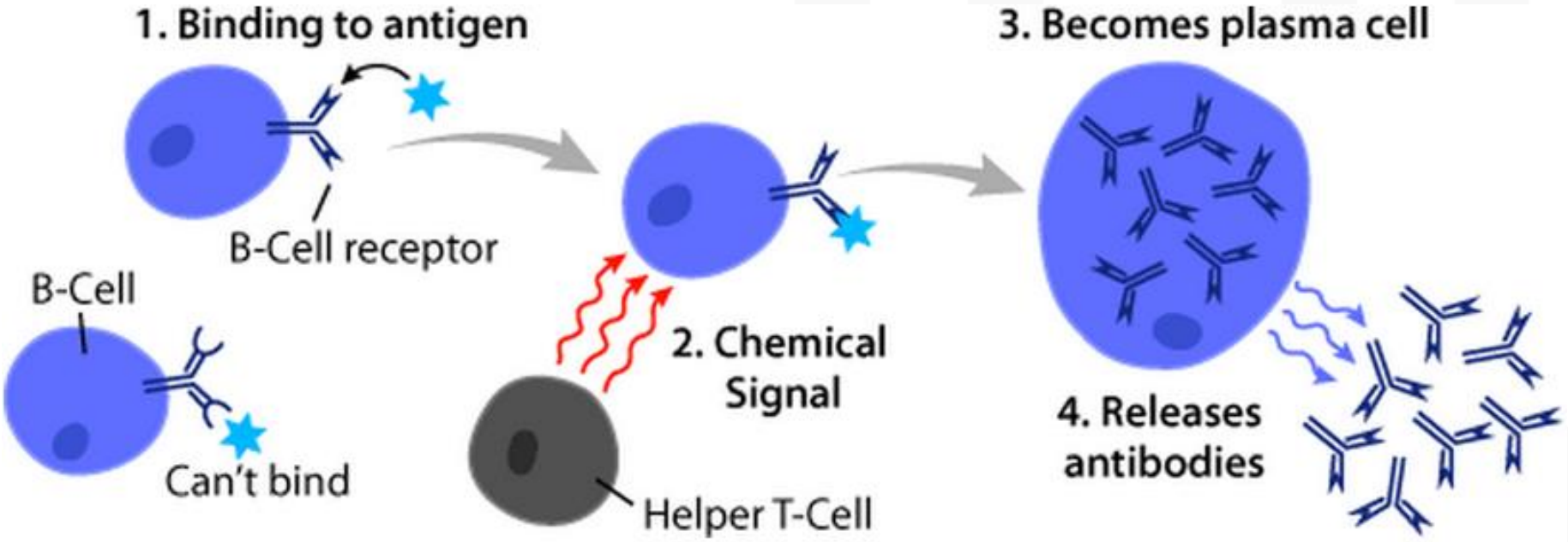
Antibody Generation

- Helper T cells stimulate B cells



Antibody Generation

- B cells become short-lived plasma cells, which produce large amounts of antibodies against the original antigen



Summary: Immunology 101

- The immune system is composed of both non-specific and specific defenses

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- Cells in the adaptive immune system communicate with each other about specific pathogens by antigen presentation

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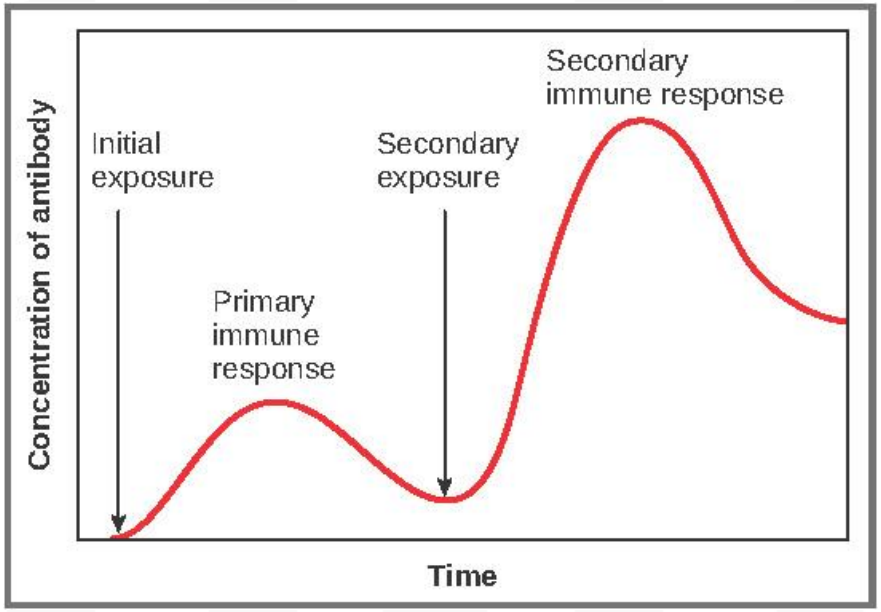
- The immune system is composed of both non-specific and specific defenses
- Cells in the adaptive immune system communicate with each other about specific pathogens by antigen presentation
- T and B cells work together to clear infected cells and produce antibodies against specific pathogens

Objectives

- Immunology 101
- Immune memory generation and activation

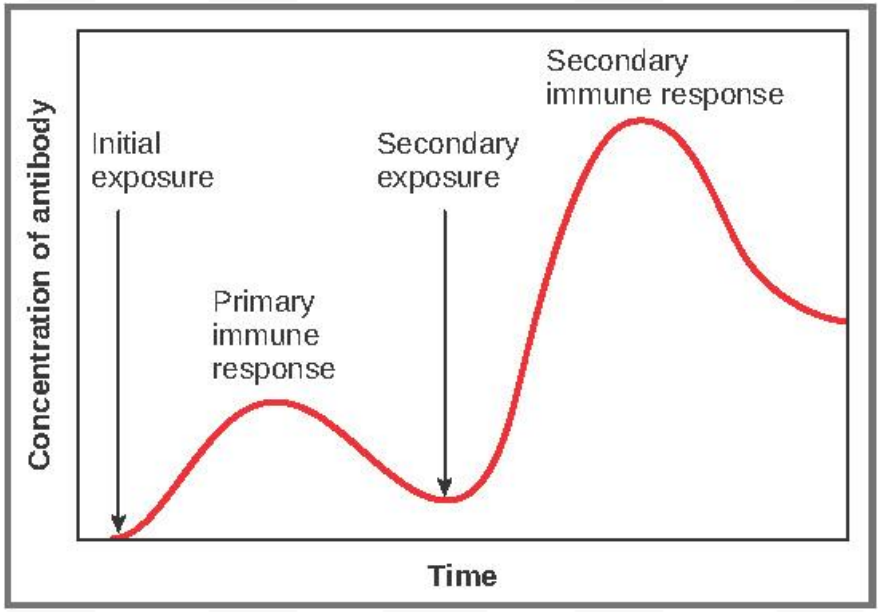
Immune Memory Generation and Activation

- Primary response: the immune system's first encounter with a pathogen, where memory is generated



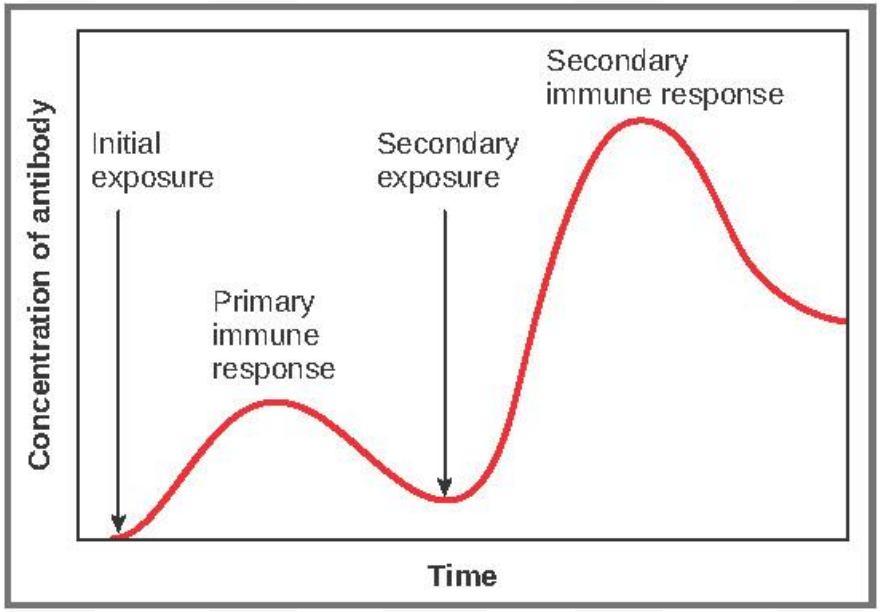
Immune Memory Generation and Activation

- Primary response: the immune system's first encounter with a pathogen, where memory is generated
  - » Vaccines cause a primary response in a controlled setting without clinical infection



Immune Memory Generation and Activation

- Primary response: the immune system's first encounter with a pathogen, where memory is generated
- Secondary response: subsequent encounters with a pathogen, where immune memory is activated to rapidly clear the pathogen
  - » Faster and stronger than a primary response



What is a Vaccine?

- A therapeutic that stimulates a primary immune response, generates immune memory against a pathogen, and prevents future infections

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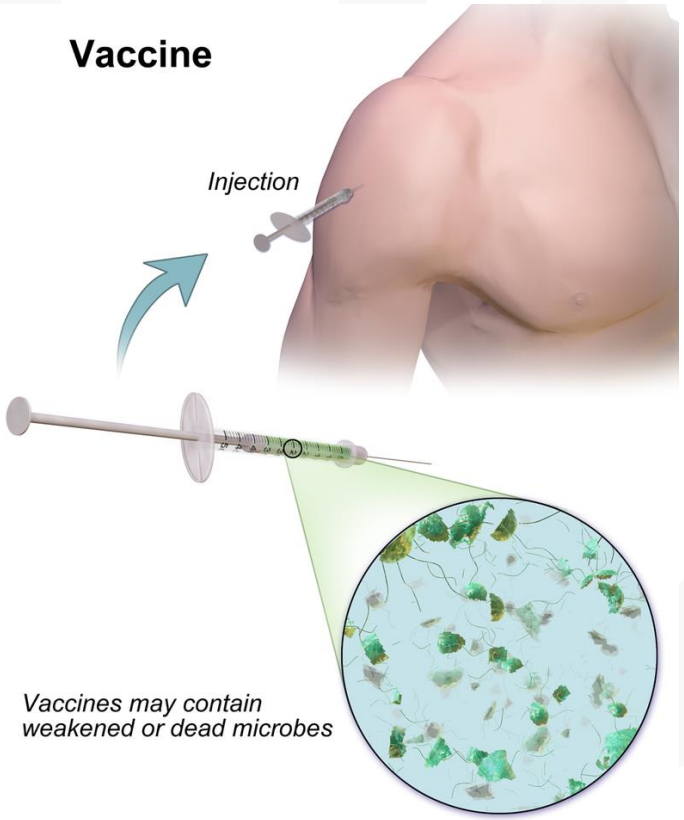
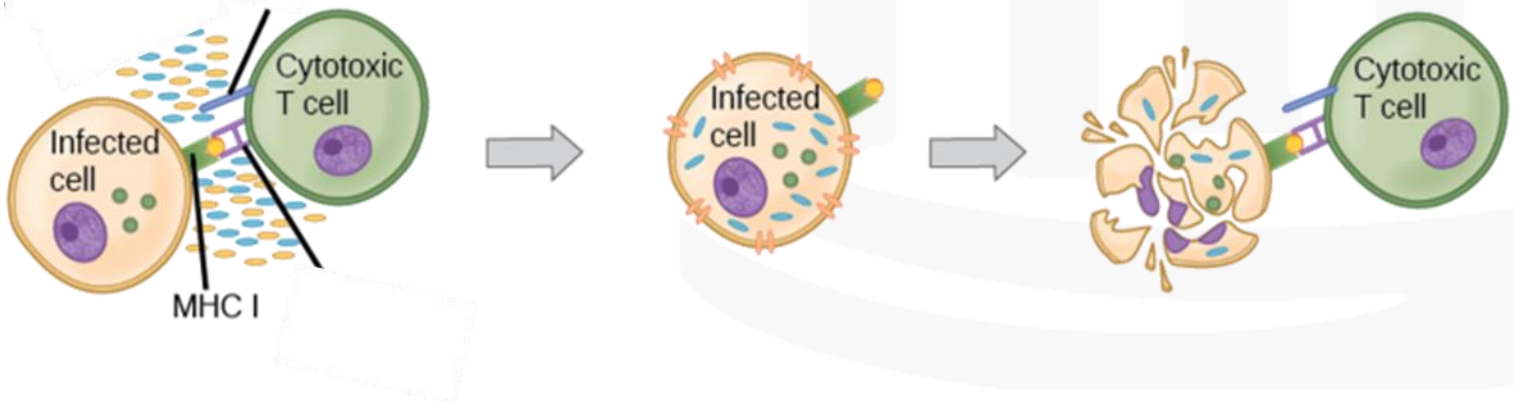
- Examples of vaccines
  - » Inactivated (dead pathogen)
    - E.g. injectable influenza vaccine



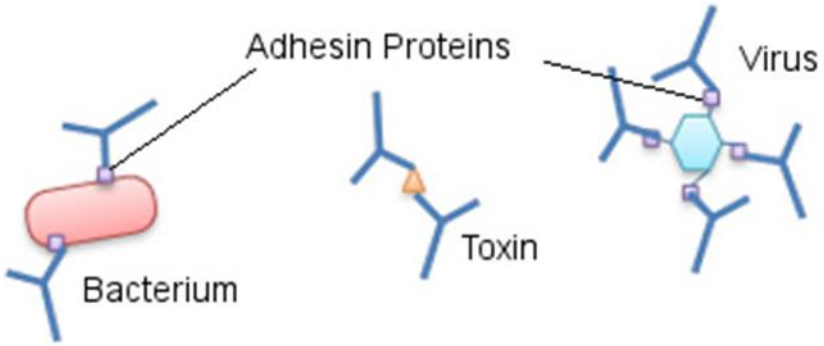
What is a Vaccine?

- A therapeutic that stimulates a primary immune response, generates immune memory against a pathogen, and prevents future infections
- Examples of vaccines
  - » Inactivated (dead pathogen)
  - » Live attenuated (weakened pathogen)
    - Stronger immune response (T and B cell)
    - Not suitable for immune-compromised patients
    - E.g. Measles, mumps, rubella (MMR) vaccine



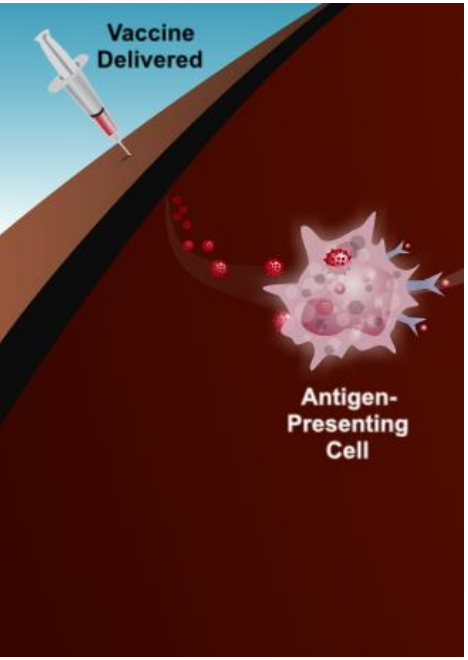
What is a Vaccine?

- A therapeutic that stimulates a primary immune response, generates immune memory against a pathogen, and prevents future infections
- Examples of vaccines
  - » Inactivated (dead pathogen)
  - » Live attenuated (weakened pathogen)
  - » Protein/Toxoid
    - Creates antibodies against pathogen proteins or toxins
    - E.g. Tetanus vaccine



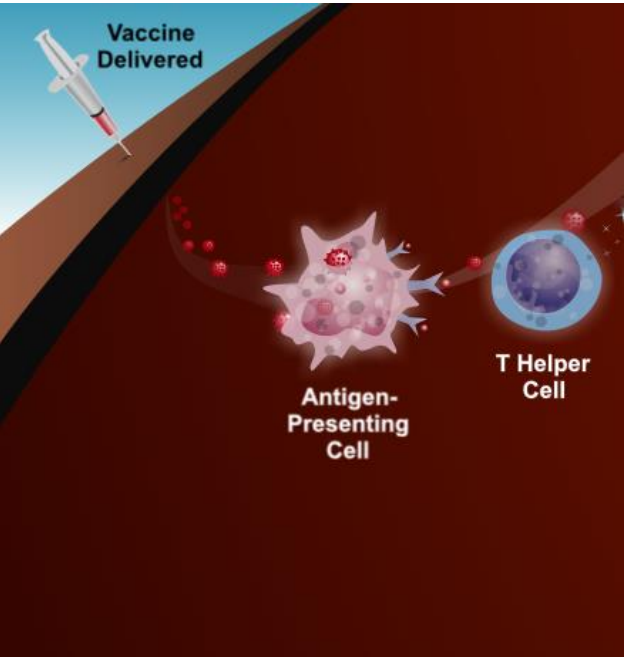
Primary Immune Response

- When a vaccine is administered, APCs encounter the antigens and present them on their membranes



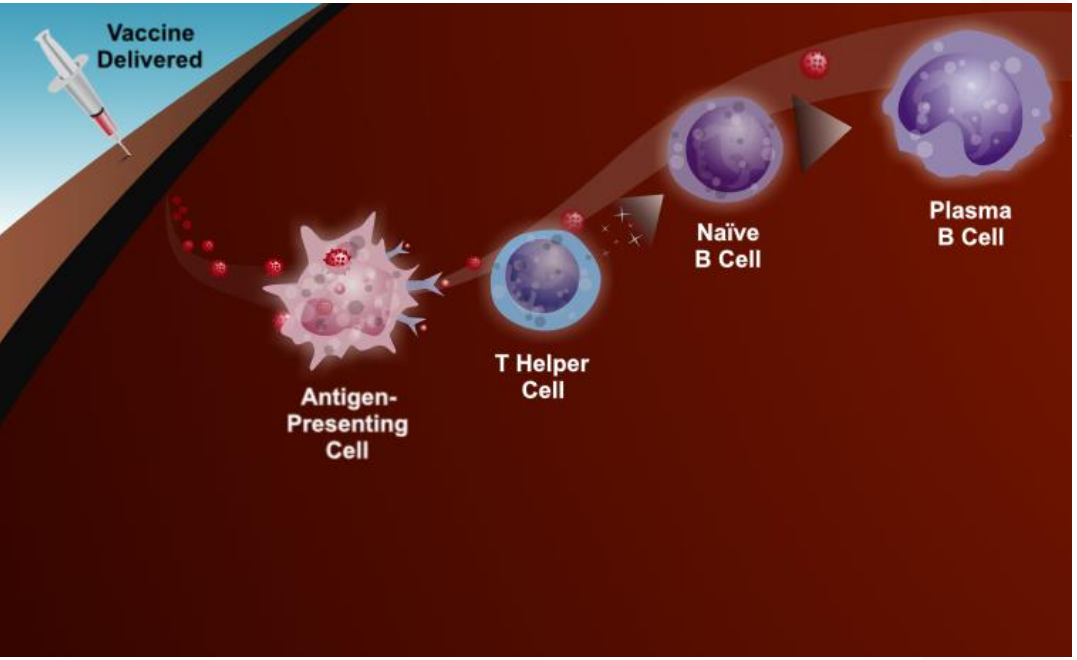
Primary Immune Response

- APCs present their antigens to helper T cells, which become activated



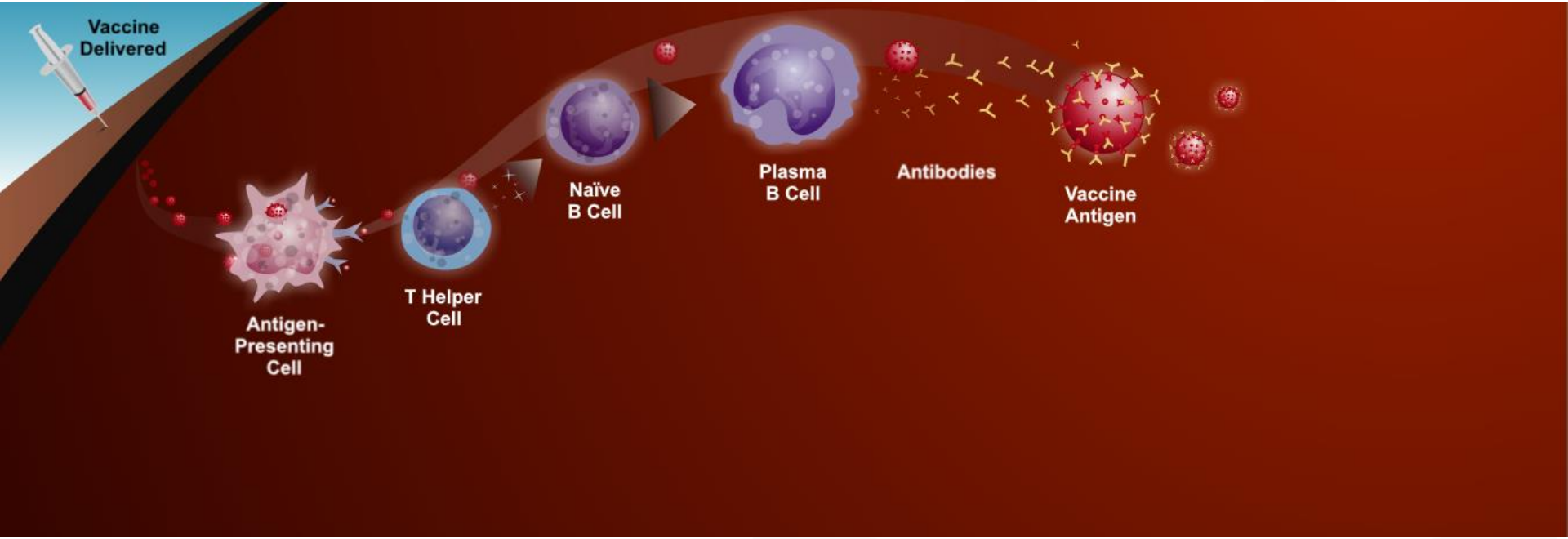
Primary Immune Response

- Helper T cells stimulate B cells that are specific to the vaccine antigens to mature into plasma cells



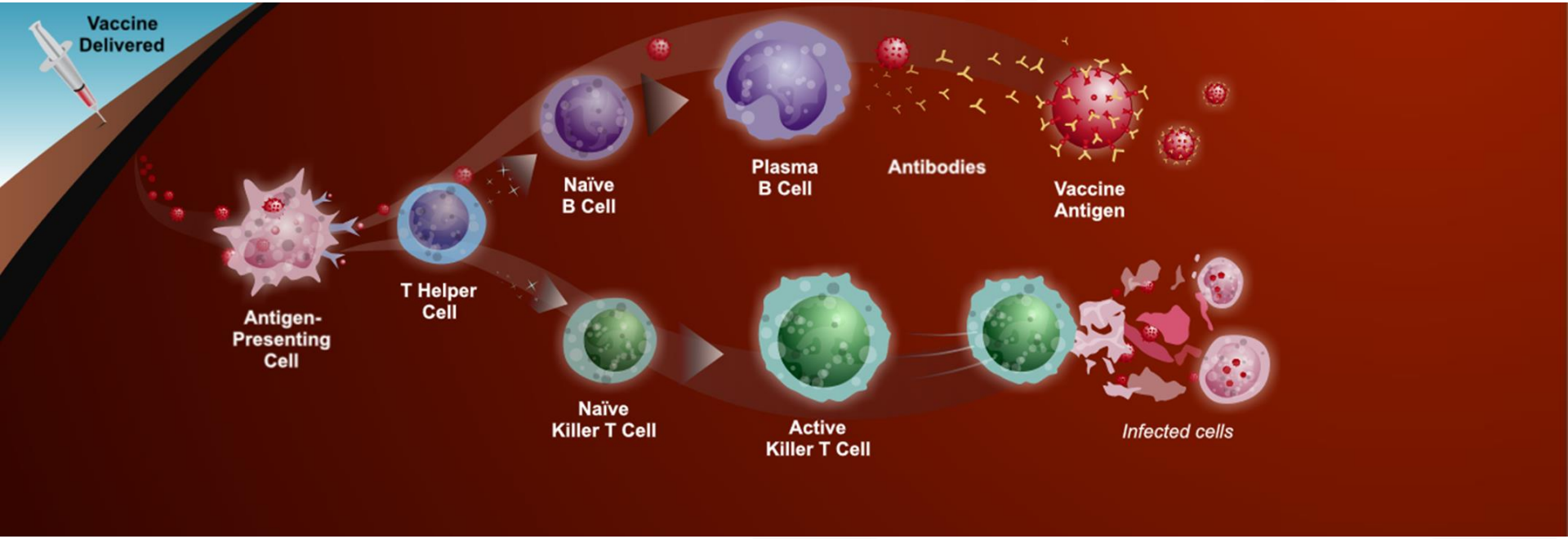
Primary Immune Response

- Plasma cells produce antibodies against the vaccine antigens, targeting them for destruction



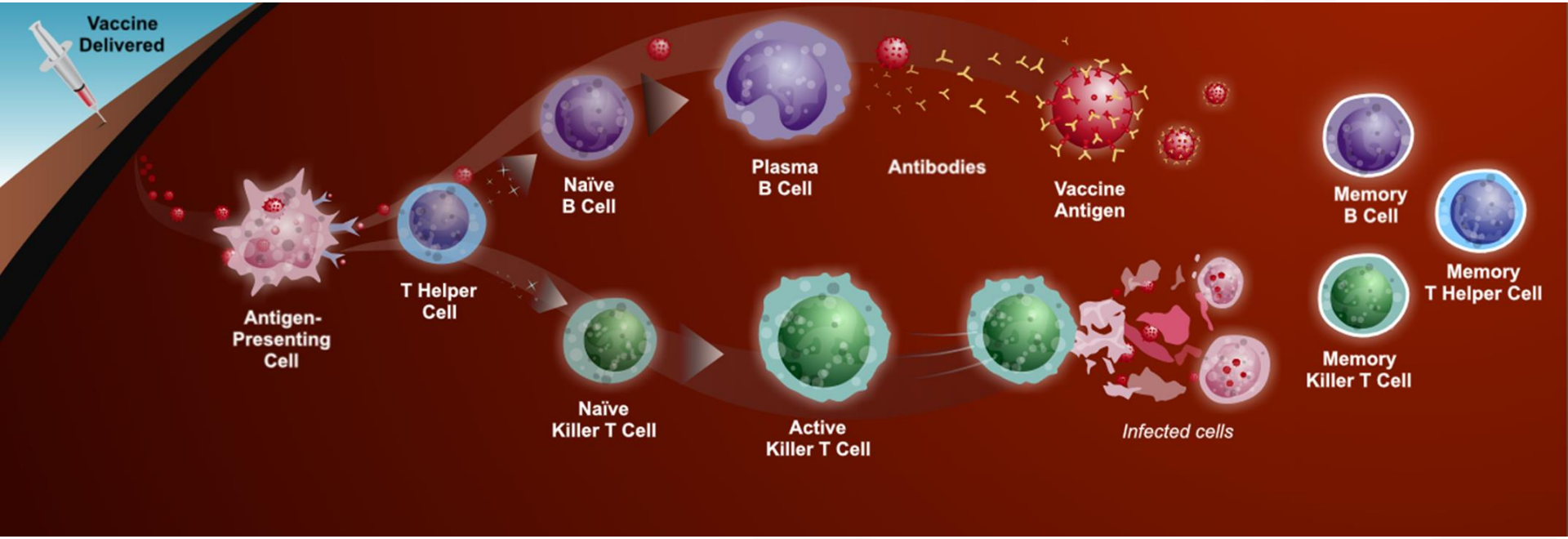
Primary Immune Response

- Live attenuated vaccines also stimulate a cytotoxic “killer” T cell response, offering stronger and more durable immunity



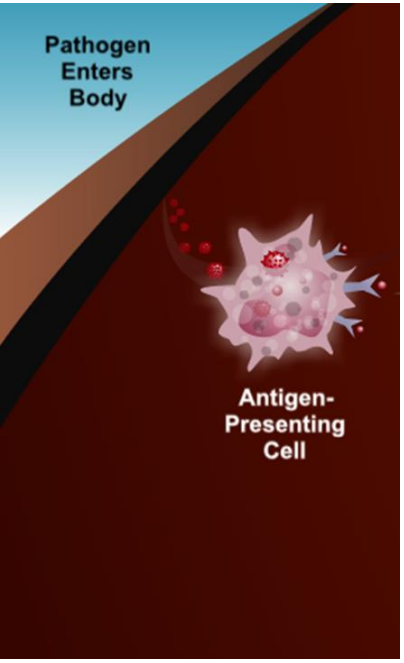
Primary Immune Response

- After a primary immune response, some T and B cells turn in to long-lasting memory cells that remain after the infection and can be rapidly activated by the same antigens



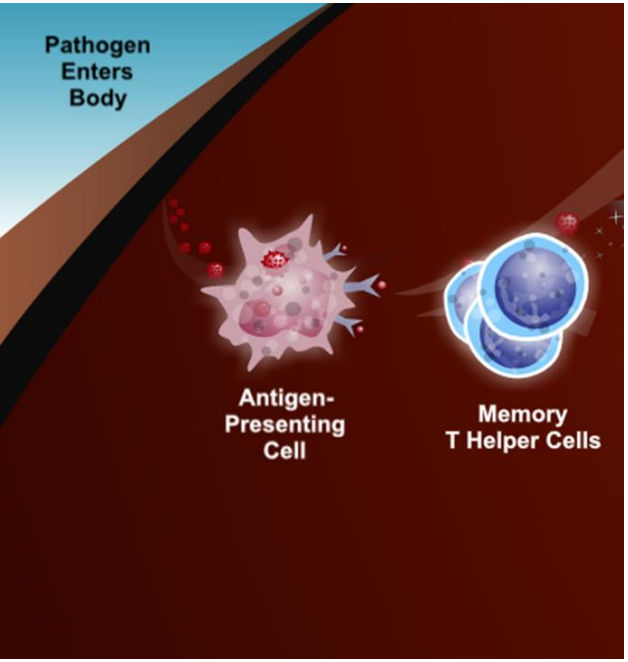
Secondary Immune Response

- APCs encounter and digest the pathogen and present its antigens on their membranes



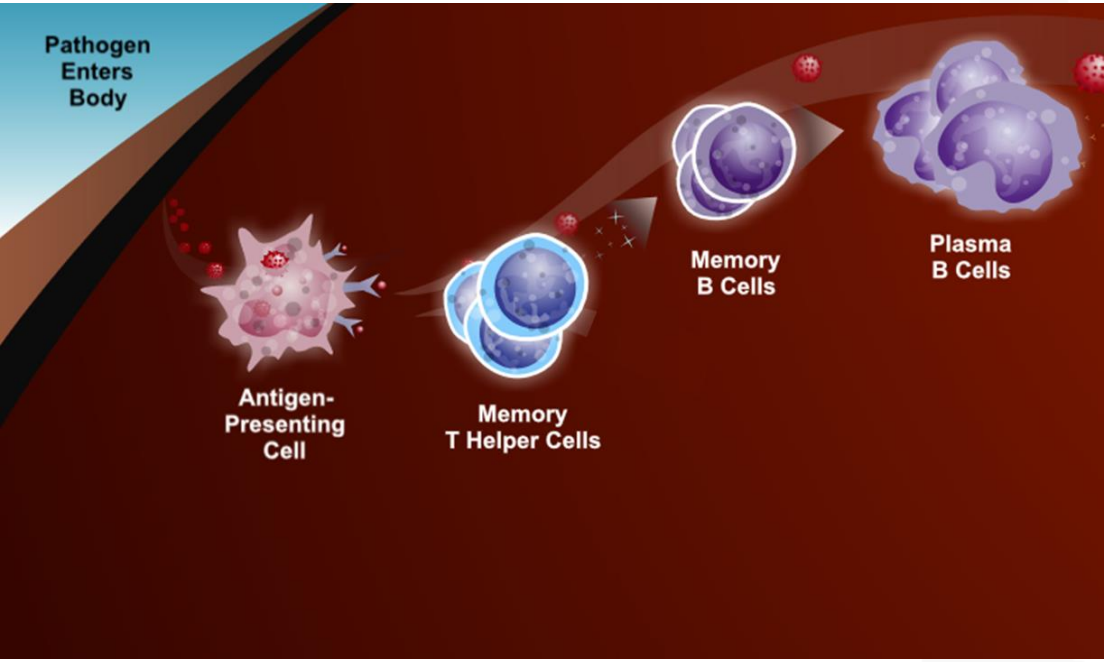
Secondary Immune Response

- APCs present antigens to memory T cells that have persisted from the primary response



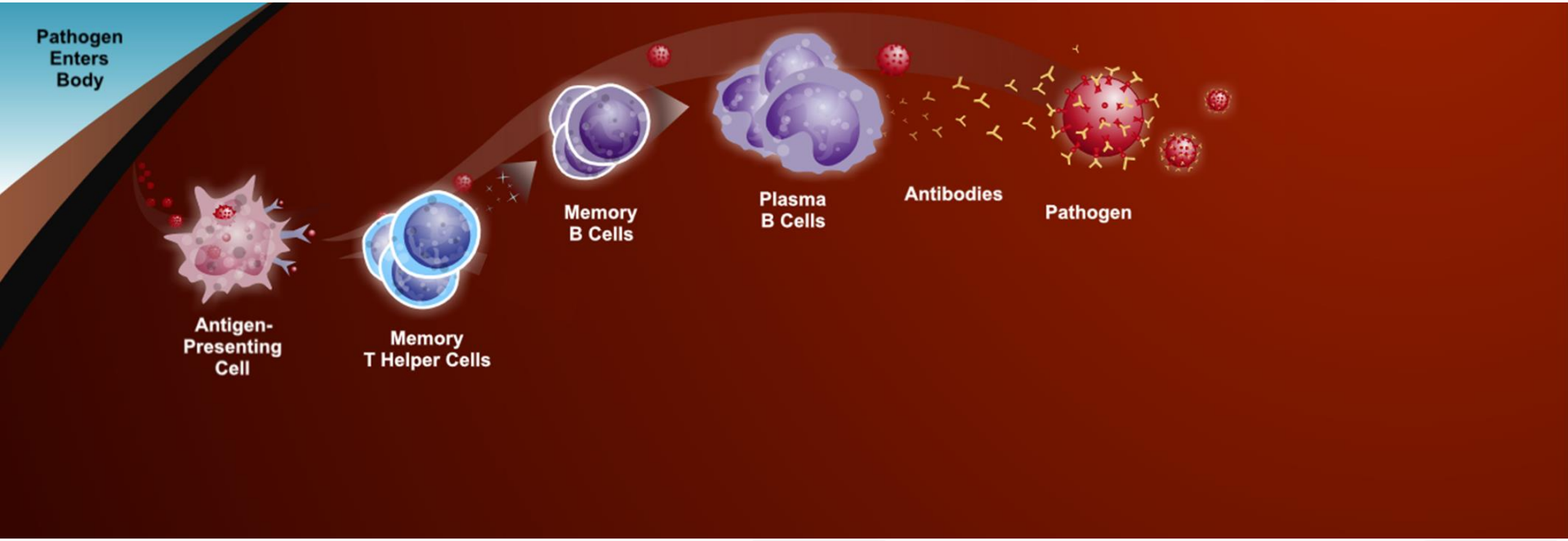
Secondary Immune Response

- Memory T cells activate memory B cells to mature into plasma cells



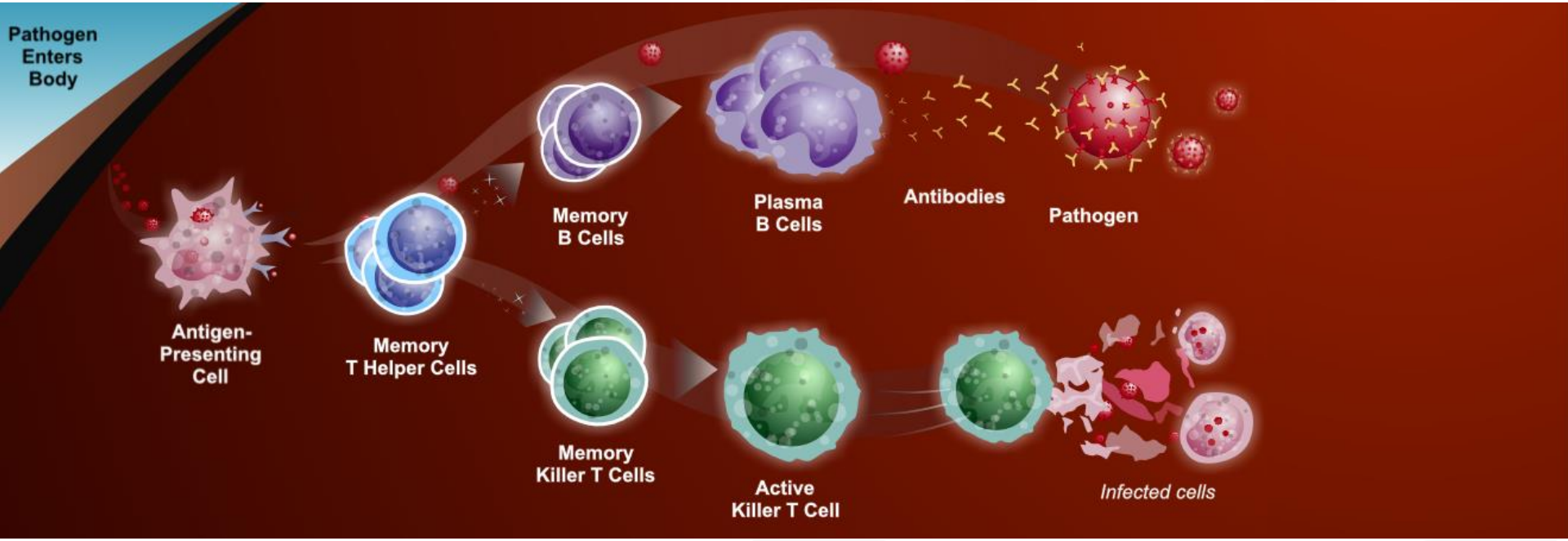
Secondary Immune Response

- Plasma cells rapidly generate high levels of antibodies specific for the pathogen, preventing widespread infection



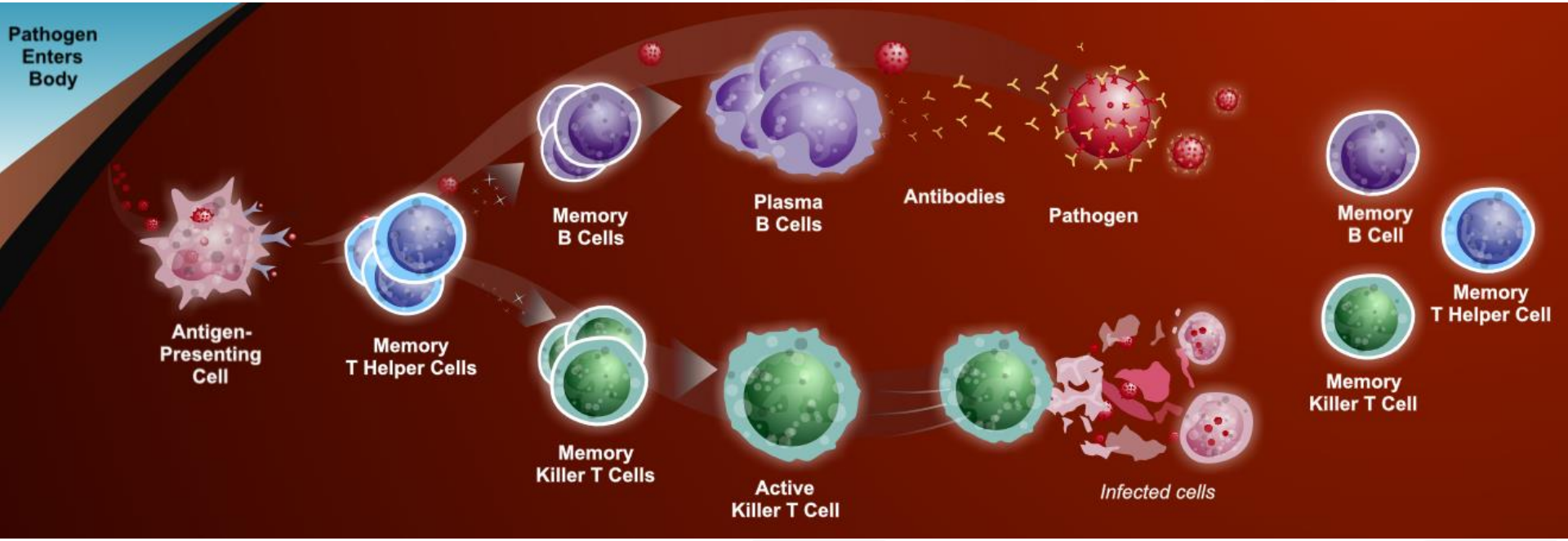
Secondary Immune Response

- Memory “killer” T cells can also be reactivated to clear virally-infected cells and prevent widespread infection



Secondary Immune Response

- Immune memory remains after a secondary response



Summary: Immune Memory

- Primary response: generation of immune memory

Summary: Immune Memory

- Primary response: generation of immune memory
- Secondary response: activation of immune memory

Summary: Immune Memory

- Primary response: generation of immune memory
- Secondary response: activation of immune memory
- Vaccines stimulate a primary response against a pathogen without causing clinical infection, allowing for a robust secondary response to prevent future infections

Acknowledgements

- All images used in this presentation are labeled for reuse unless otherwise cited
- How Vaccines Work, College of Physicians of Philadelphia, historyofvacines.org

Questions?