Unit 1: Lesson 3 – The Adaptive Immune System

- **Lesson questions:** What are the key features and processes of the adaptive immune system? How does the adaptive immune system differ from the innate immune system?
- **Lesson objectives:** Define glossary terms related to the adaptive immune system. Create a concept map of the adaptive immune system. Create analogies to illustrate features and processes of the adaptive immune system.
- **Overview:** In this lesson, students learn about the adaptive immune system, which provides an antigen specific response. Students explore glossary terms associated with the adaptive immune system. They define cells, molecules and processes of the adaptive immune system and then create a concept map that describes how the adaptive immune system works.
- **Length:** Three 45 minute sessions
- **Glossary terms:** antibody, antigen, B cells, cognate antigen, proliferation, protein, T cells
- **Standards:**
    - **Next Generation Science Standards**
        - HS-LS1-2 Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.
        - HS-LS1-2.2.1 Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system.
        - HS-LS1-2.4.1 Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales.
        - HS-LS1-2.LS1.A.1 Multicellular organisms have a hierarchical structural organization, in which any one system is made up of numerous parts and is itself a component of the next level.
        - HS-LS1-2.LS1.A.2 Feedback mechanisms maintain a living system's internal conditions within certain limits and mediate behaviors, allowing it to remain alive and functional even as

external conditions change within some range. Feedback mechanisms can encourage (through positive feedback) or discourage (negative feedback) what is going on inside the living system.

- Common Core State Standards
  - RST.11-12.4 Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context.
  - RST.11-12.7 Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem.
  - WHST.9-12.2 Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes.
  - WHST.9-12.9 Draw evidence from informational texts to support analysis, reflection, and research.
  - WHST.9-12.5 Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most significant for a specific purpose and audience.

- **Materials:**
  - student worksheet
  - computer with Internet access
  - graphics software (optional)

BACKGROUND FOR TEACHER

The adaptive immune system provides the body with a specific response to antigens. This targeted response contrasts with the generalized response of the innate immune system. (Lesson 2 covers the innate immune system.) When a pathogen invades the body, it is detected by antigen presenting cells (APCs), such as macrophages and dendritic cells. These APCs display pieces of the pathogen, known as antigens, on their cell surface as a means of alerting and engaging other immune system cells, such as T

cells. Some T cells attack or neutralize the pathogen directly, while others help to "train" B cells. Activated B cells produce antibodies, which either neutralize the pathogen by preventing it from entering cells or flagging it for destruction. Some B cells survive long after infection to serve as "memory" for the adaptive immune system. These memory-based responses are faster and more efficient at stopping future infections with the same pathogen. The adaptation of the immune system to new challenges is the basis of vaccination. (Unit 2 covers the relationship of between vaccination and the immune system.) In this lesson, students use a concept map to understand this complex system. Rather than trying to recall the many details, students should focus on understanding the basic principles of the adaptive immune system.

GLOSSARY

The following glossary terms are required vocabulary for this lesson. It is not necessary for students to recall all the details, but students should be able to articulate how these play a role in the adaptive immune system.

Antibody –Y-shaped proteins produced by B cells. Antibodies neutralize pathogens. Five different classes of antibodies occur which have distinct functions.

Antigen – Part of a pathogen that generates an immune system response

An antigen is typically a molecule on a pathogen's cell surface that is recognized by immune system cells. A cognate antigen is a molecule that is recognized by an immune cell in the manner of a lock and key.

Antigen presenting cells (APCs) – Cells that display antigens on their surface

APCs present antigens to activate adaptive immune responses to pathogens. The main antigen presenting cells are dendritic cells, macrophages, and B cells.

B Cells – Cells that produce (and secrete) antibodies

B cells are formed in the bone marrow. They are primarily known for production of antibodies; however, they also serve as antigen presenting cells and some are long-lived as memory B cells.

Dendritic Cells – Technically considered an innate immune cell, dendritic cells play a central role in the adaptive immune response as antigen presenting cells.

Neutralize – To render a pathogen inactive, so that it cannot cause infection.

A typical example is when an antibody binds to a protein on the surface of a pathogen, so that it cannot bind to and infect a cell.

Proliferation – The process of rapid multiplication

The proliferation of B cells following presentation of an antigen by T cells enables a rapid, specific response.

Protein – molecules composed of amino acids

Proteins each have a unique, genetically defined amino acid sequence that determines its shape and function. Proteins form the basis of cell signaling that mediates the adaptive immune response.

Receptor – signal molecule on cell surface

Receptors are typically a protein molecule. They are located on the surface of a cell to facilitate interaction with another cell or molecule, typically by binding in a specific manner, such as that of a lock and key.

T Cells – Lymphocytes that regulate immune responses or directly attack pathogens

T cells originate in the bone marrow but then migrate to the thymus where they mature. T cells can directly attack pathogens or stimulate and modulate other parts of the immune response, primarily through cytokines.

ENGAGE

1. Ask students to list three serious diseases they have heard about. For each, students should write one or two sentences to describe how they think these diseases can be prevented.
2. On your whiteboard, list and tally responses. Ultimately, count how many students mentioned vaccines or vaccination in their descriptions.
3. Explain to students that they will learn about the adaptive immune system, which is the basis for vaccination.

EXPLORE

1. Working in small groups, students discuss how they think vaccination works. If needed, prompt students by reminding them that vaccination is also called immunization.
2. Lead students to understand that the principle of vaccination is to "prime" the adaptive immune system.
3. Students read the Reading Passage, *Killer Cells, Memory Cells: A Brief Introduction to the Adaptive Immune System*.
4. Students watch the animation, *The Adaptive Immune System* (https://vimeo.com/227178817).
5. Students explore glossary terms related to the features and functioning of the adaptive immune system.
6. Students complete the vocabulary table in their worksheets.
7. Students watch the animation, *How do Antibodies Work?* (https://vimeo.com/227176366).
8. Students work in pairs or small groups to research online resources to learn about the adaptive immune system. The goal of the exploration is to develop a simple model that explains the adaptive immune system.

EXPLAIN

1. Working in groups, students create a graphic organizer such as a flowchart or concept map that models the adaptive immune system for Activity 1, *Function of the Adaptive Immune System.*
2. Groups discuss their models with other groups.
3. Hold a class discussion to address any questions or misconceptions. If needed, guide students with prompt questions:
    a. How representative is your model of the real immune system?
    b. Are some parts of the immune system more important than others?
    c. Why is an adaptive immune system needed if we have an innate immune system?
4. Working individually, students write a short passage to explain the difference between the innate and adaptive immune system.
5. Students work individually to complete Activity 2, *The Components of the Adaptive Immune System.*
6. Students drag and drop terms into fields in the interactive diagram of the adaptive immune system, correctly completing the diagram.
7. Students describe differences between the interactive diagram and their flowchart or concept map.

ELABORATE

1. Students choose a major component of the adaptive immune system to explore in more detail:
    a. Antibodies
    b. Antigen presenting cells
    c. B cells
    d. T cells
    e. Cytokines
2. Students write a short passage describing their selected component's role in the adaptive immune system.
3. Students characterize their component as part of a feedback system (negative or positive).

EVALUATE

1. Students work in pairs or small groups to create a multimedia resource (story, skit, webpage, video script, etc.). The resource uses a metaphor to explain the features and functioning of the adaptive immune system (Activity 3, *Illustrating the Adaptive Immune System*).
2. Students identify aspects of their metaphor that symbolize or relate to immune system components.
3. Working individually, students complete multiple-choice and short answer questions.

Rubric for Elaborate

Activity 2. The Components of the Adaptive Immune System

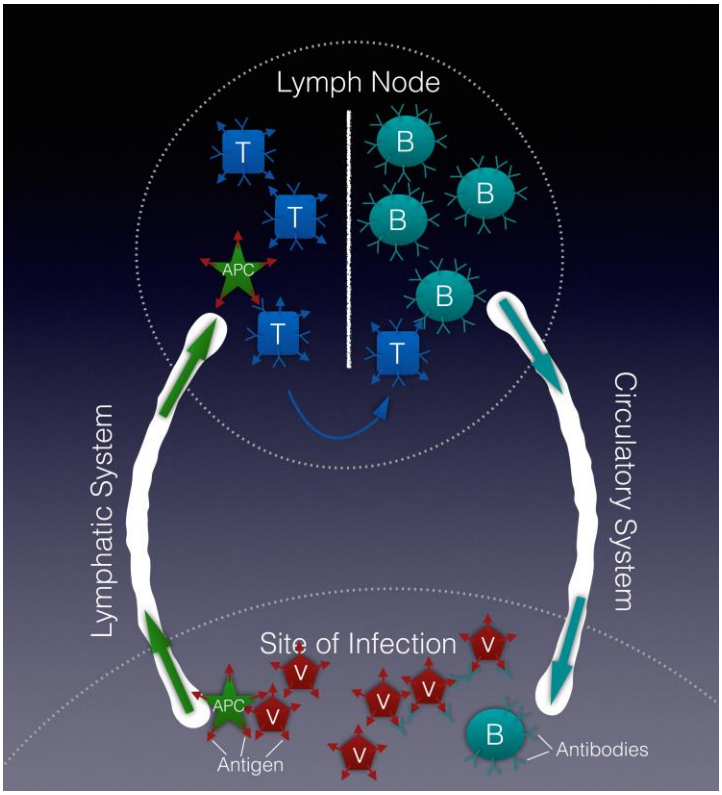
A. Completed table

Function	Component(s)
Fight infection	antibodies, T cells, cytokines
Communicate information about infection	antigen presenting cells, T cells, cytokines
Establish immunological memory	B cells, T cells
Create antibodies to fight infection	B cells

B. Completed table

Component	Function to fight infection
Antibodies	• Mark pathogens for destruction by phagocytes and complement proteins. • Neutralize pathogens so they cannot attach to cells.
T cells	• Release factors that can induce programmed death of a target cell. • Killer T cell: lyses cells that have antigens that are recognized by the T cell on their surface. • Helper T cells: release cytokines to stimulate other immune system components. • Memory T cells: remember antigen to protect against future infections
B cells	• Serve as antigen presenting cells • Produce antibodies specific to the antigen. • Become memory B cells to rapidly neutralize future infections by the same antigen.
Antigen presenting cells	• Capture and process antigen during infections, then display antigen to activate T and B cells.
Cytokines	• Chemicals that modulate immune responses

C. Correct diagram of the adaptive immune system



Rubric for Evaluate Questions

Multiple Choice

1. Where are B cells formed? Bone marrow (B)
2. Where do T cells mature? Thymus (A)
3. An antibody is a protein. (D)
4. What is proliferation? What is proliferation? (A)

Short Answer

1. Describe the different roles of the three types of APC's.
    - Dendritic cells are an important connection between the adaptive and innate immune system and the activated T cells.
    - Macrophages are important because they support the activity of dendritic cells and stay at the site of infection.
    - B cells that cluster in the spleen or lymph node can also activate other B cells, which helps to increase the response to a threat.

2. Which classes of cells involved in the *adaptive* immune response release cytokines?
    - T cells release cytokines.

3. Describe the function of cytokines in the immune system.
    - Answers will vary. The key concept is that cytokines are used by the immune system to communicate.

4. What parts of the adaptive immune system are involved in immunological memory?
    - T cells and B cells are involved in immunological memory.

5. Why is immunological memory beneficial?
    - Immunological memory provides the basis for responding more quickly to future encounters with the same antigen. Antibodies alone would not provide a lasting response since they are shortly eliminated from the blood.