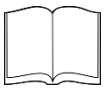
| | | |
|---|---|---|
| **SUBJECT CODE:** | Bio 1 | *Fundamentals of Biology 1* |
| **LEARNING GUIDE CODE:** | 4.0 | *Immunity* |
| **LESSON CODE:** | 4.3 | *Specific Defenses of the Human Body (Acquired/ Adaptive Immunity)* |
| **TIME FRAME:** | | *30 minutes (1 session)* |



## MATERIALS NEEDED

To complete this lesson, you need the following:

1. pen;
2. paper;
3. phone/tablet/laptop;
4. Moodle app;
5. Moodle (PSHS Knowledge Hub) account;
6. stable internet connection and;
7. Biology: A global Approach by Campbell et al. (2015).

## TARGET

After completing this lesson, you are expected to:

1. compare nonspecific and specific defenses;
2. Describe how various specific defenses work: humoral vs. cell-mediated immunity.

## HOOK

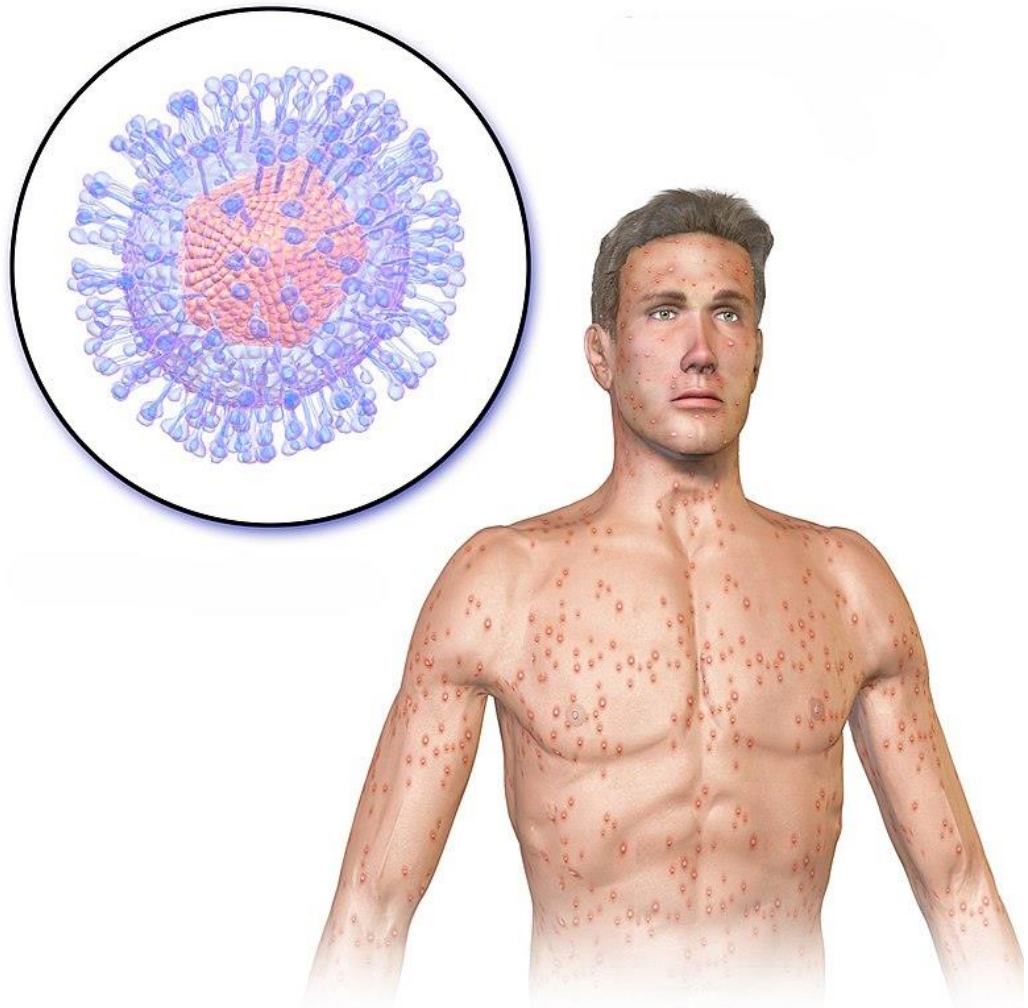


**FIGURE 1: A viral infection**

By BruceBlaus - https://commons.wikimedia.org/wiki/File:Chickenpox.png, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=56635082

Shown above is a picture of a widely-known contagious viral infection which infects mainly children and is characterized by itchy red blisters in the skin. Can you name this viral infection? What are the symptoms of this infection? How does your body fight off this infection? Is it true that you can only catch this viral infection once in your lifetime?

In this module, we will be answering those questions.

## IGNITE

In the previous lesson, we have learned that vertebrates have two types of immune defenses, the **innate defenses** which are non-specific and **acquired or adaptive defenses** which are specific to a class of pathogens. We have learned the different structural, chemical, ecological, and biological innate defenses which are present in a vertebrate's body. In this lesson, we will be exploring the specific or acquired/adaptive defenses of vertebrates - their characteristics and corresponding mechanisms for defense.

### ACQUIRED/ADAPTIVE IMMUNITY OF VERTEBRATES

The adaptive immunity of vertebrates rely on the pathogen-specific recognition ability of **lymphocytes** – white blood cells which are produced in the bone marrow. There are basically three types of lymphocytes: **B cell, T cell** and **natural killer cells.** The latter is part of innate immunity as discussed in the previous lesson. Lymphocytes are both produced in the **bone marrow.** T cells **migrate from bone marrow to the thymus until maturity** while B cells **remain and mature at the bone marrow.** The **antigen receptors** on the surface of B cell or T cell recognizes an **antigen** (any substance that elicits an immune response) by binding to it. Antigen are usually **small protruding parts of viruses and bacteria**. Antigen could also be in the **form of toxins which are released on bodily fluids**. The particular part of the antigen where the antigen receptors of the lymphocytes attach to is referred to as **epitope.** A single B cell or T cell has about **100,000 antigen receptors** on its surface. Look at the illustration of B cell and T cell below and notice the difference between their respective antigen receptors.

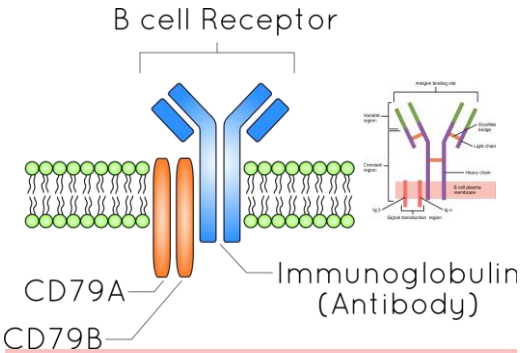



**FIGURE 2. Antigen receptor of a B cell**

By CNX OpenStax - http://cnx.org/contents/GFy_h8cu@10.53:rZudN6XP@2/Introduction, CC BY 4.0, https://commons.wikimedia.org/w/index.php?curid=49935883
By Clarkdn (talk) (Uploads) - Own work, CC0, https://commons.wikimedia.org/w/index.php?curid=32925894

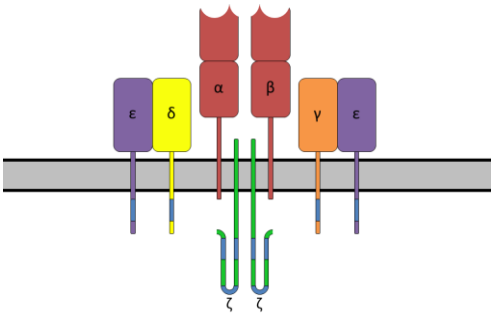



**FIGURE 3. Antigen receptor of a T cell**

By No machine-readable author provided. Anriar~commonswiki assumed (based on copyright claims). - No machine-readable source provided. Own work assumed (based on copyright claims)., CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=9520024

## ANTIGEN RECOGNITION: FIRST STEP OF ADAPTIVE IMMUNITY

For adaptive immunity to proceed, the B cell and T cell must first recognize a pathogen. How would recognition happen? **Recognition** happens when the antigen receptor of a B cell or T cell binds to an **antigen.** Antigen recognition by T cell and B cell is illustrated in Figures 4 and 5, respectively.

**Antigen Recognition by B Cells** – When the antigen receptor of a B cell binds to the epitope of an antigen, the B cell secretes a soluble form of the antigen receptor also known as **antibody** or **immunoglobulin**. Antibodies can recognize epitopes of antigens on a pathogen's surface or even freely floating antigens on body fluids such as blood and lymph.

**Antigen Recognition by T Cells** – Antigen receptors of T cells only bind to fragments of pathogens that are displayed or presented on the surface of an already infected cell. When a cell is infected, the antigen will bind to an MHC molecule inside the cell. MHC molecules will then display the antigen on the surface of the infected cell and wait until the antigen receptor of T cells bind to it. When a T cell successfully binds to the displayed antigen, then it could now identify the cell as infected and also the pathogen which caused the infection.

## FOUR CHARACTERISTICS OF ADAPTIVE IMMUNITY

Since you are already familiar with the two types of lymphocytes and the mechanism on how they recognize antigens, we can now explore the four main characteristics of adaptive immunity. These four characteristics and their implications to immunity are as follow.

1. There is a **rich diversity of lymphocytes and antigen receptors.**
    - This explains why we have immunity to a variety of pathogens especially those which our body has already encountered before.
2. **Self-tolerance or lack of reactivity** against an animal's own molecules and cells.
    - One major event which could be potentially fatal is when the lymphocyte's antigen receptor binds to an antigen found on the surface of **its own body cells.** How is this event prevented? When the lymphocytes are still immature in the bone marrow, the self-reactive lymphocytes (those whose antigen receptors are specific to the body's own molecules) are destroyed by **apoptosis** or programmed cell death. When these self-reactive lymphocytes are destroyed, what will remain are lymphocytes whose receptors are specific to foreign molecules only. The immune system of a human is then described as self-tolerant since it does not act against the body's own cells and molecules.
3. **Cell proliferation triggered by activation** greatly increases **the number of B cells and T cells.**

4. **Immunological memory – a stronger** and **more rapid response** to an antigen encountered before.

    - When a B cell or a T cell binds to an antigen, this B cell or T cell undergoes multiple cell division to produce T cells and B cells which are specific to the recognized antigen. Two types of T cells and B cells can be produced after this series of cell division. **Effector cells** are short-lived lymphocytes which **immediately act against the recognized pathogen**. **Memory cells,** on the other hand, are long-lived lymphocytes, which do not necessarily act against the present pathogen but are **reactive when the pathogen infects the body again for the second time in the future.** The effector cells produced by T cells and B cells are called **helper T cells** and **cytotoxic T cells,** and **plasma cells**, respectively. The memory cells produced by T cells and B cells are **memory T cells** and **memory B cells**, respectively.

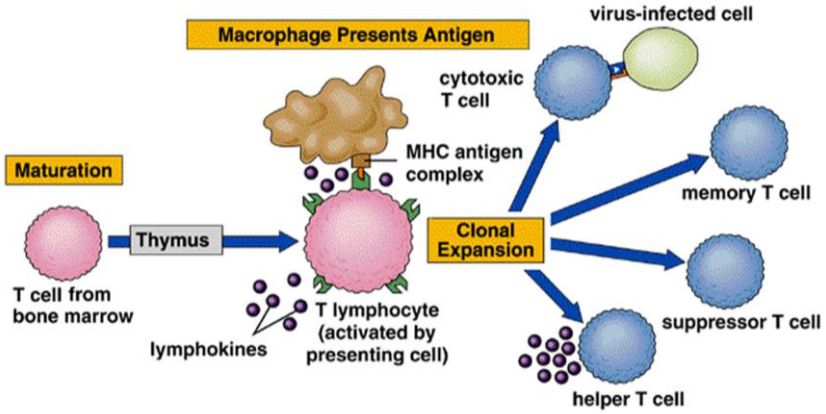



**FIGURE 4. Antigen recognition by T cell and activation**

From https://healthjade.com/what-is-thymus/, Reprinted with permission

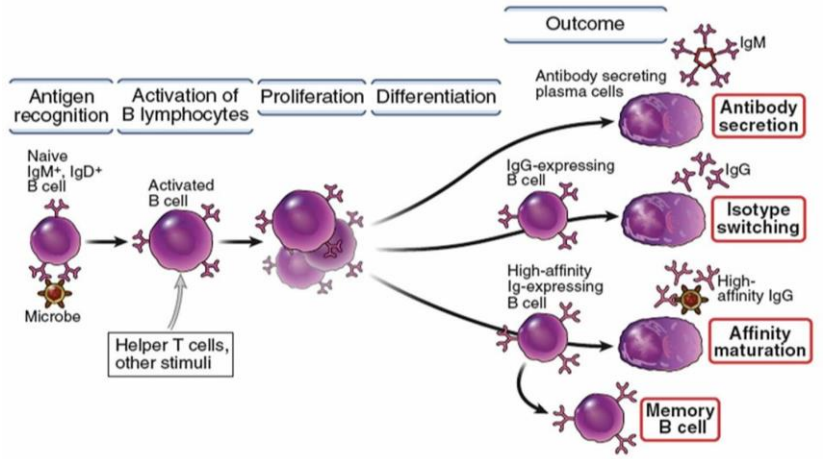



**FIGURE 5. Antigen recognition by B cell and activation**

From https://healthjade.com/what-is-thymus/, Reprinted with permission

- Why are memory cells evolutionarily important? If there are already lots of memory cells in the bloodstream, once a pathogen infects the body, the body can save time in cloning the T cells or B cells since clones are already present. To make it clearer, let us have an example. Let us say you are infected with chickenpox virus. During the first time that you are infected, your body will react by producing clones of B cells and T cells which are specific for chicken pox. This reaction is the **primary immune response** and is summarized in Figure 6. Once the chickenpox virus is eliminated from your body, your body will have **memory cells** specific for chicken pox which are all ready to defend yourself when chicken pox virus infects your body for the second time. When chicken pox virus infects your body for the second time, your body will have a stronger and more rapid response. This is what we call a **secondary immune response.** This is also the explanation for the fourth characteristic of adaptive immunity which is **immunological memory,** a **stronger** and **more rapid response** to an antigen encountered before.

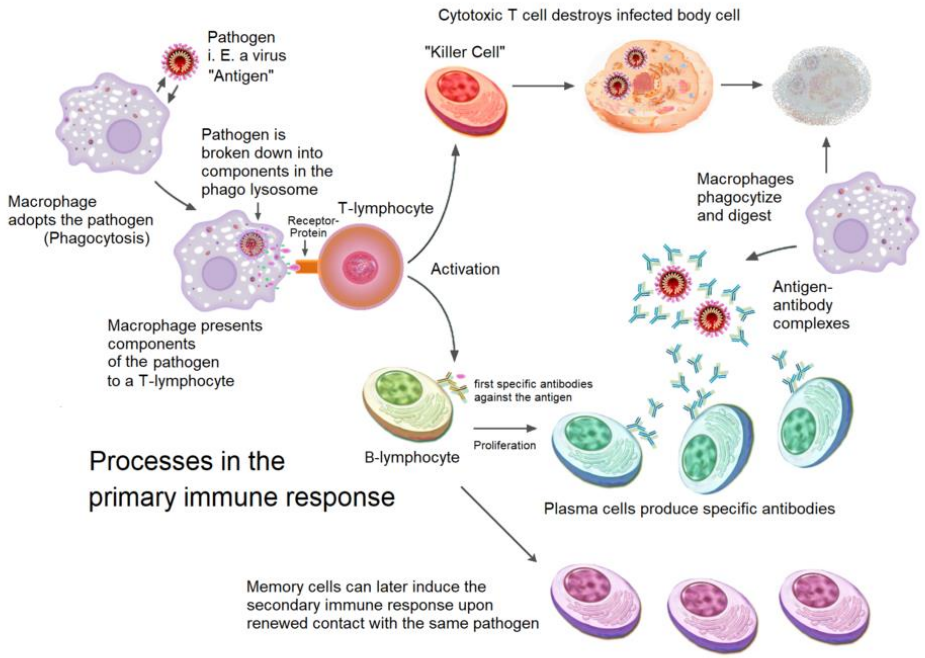



**FIGURE 6. Overview of the primary immune response**

By me=Sciencia58 an the makers of the single images Domdomegg, [1], Fæ, Petr94, Manu5 - Own Grafic using File:Macrophage.svg, File:201308 B cell.svg, File:Normal plasma blood cells.jpg, File:Aufbau einer Tierischen Zelle.jpg, File:3D medical animation coronavirus structure.jpg, source: Immune response, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=90421209

Now that you already understand the characteristics of adaptive or acquired immunity, it is now time to discuss the mechanisms on how this specific immunity kills, neutralizes or eliminates invading pathogens.

# TWO RESPONSES OF ADAPTIVE IMMUNITY

The lymphocytes act against antigens which are present in infected cells or antigens which are freely floating in the bodily fluid. An immune response against antigens found in infected cells is what we call as **cell-mediated immune response** and is carried out by **T cells.** An immune response against antigen which are freely floating in body fluids is what we refer to as a **humoral immune response** (humor means body fluid) and is carried out by **B cells.** The table below differentiates **cell-mediated immune response** from **humoral immune response.**

**Table 1. Differences between humoral response and cell-mediated response**

| PARAMETERS | TYPES OF ADAPTIVE IMMUNITY | |
|---|---|---|
| | HUMORAL RESPONSE | CELL-MEDIATED RESPONSE |
| **TYPE OF CELL** | B cell | T cell |
| **ORIGIN OF LYMPHOCYTES** | Bone marrow | Bone marrow |
| **SITE OF MATURATION OF LYMPHOCYTES** | Bone Marrow | Thymus |
| **CONVERTED TO** | **Plasma cells** (produce antibodies /immunoglobulins and marks them for killing)<br>**B memory cells** (remember the antigen for faster antibody production, persists for years). | **T Helper cells** (activate T killer cells and B cells)<br>**T Killer cells** (kill pathogens and cancer cells)<br>**T memory cells** (remember the antigen, activates T killer cells during second infection) |
| **PATHOGEN/ALLERGY RESPONSE** | Specific viruses, bacteria, parasites, acute hypersensitivity | Viruses, bacteria, parasites, organ transplant and delayed hypersensitivity |
| **BASIS OF VACCINATION** | Yes | No |
| **DEFINITION** | Antibodies defend against infection in body fluids | Cytotoxic cells defend against infection in body cells |

1. In a **humoral immune response** as shown in Figure 7**,** the antibodies produced by the activated **B cells** either neutralize or present the antigen for phagocytosis by neutrophils. Humoral immune response has two main mechanisms:

    a. **Neutralization** – antibodies bind to the protein on the surface of a pathogen thereby preventing the pathogen from infecting the body cells.
    b. **Opsonization** - instead of neutralizing pathogens, antibodies present the pathogen for phagocytosis by neutrophils.

2. In **cell-mediated immune response** as shown in Figure 8**,** the T Cells use toxic proteins to kill cells infected by viruses or other intracellular pathogens before pathogens mature inside the cell. The toxic proteins trigger apoptosis or cell death.

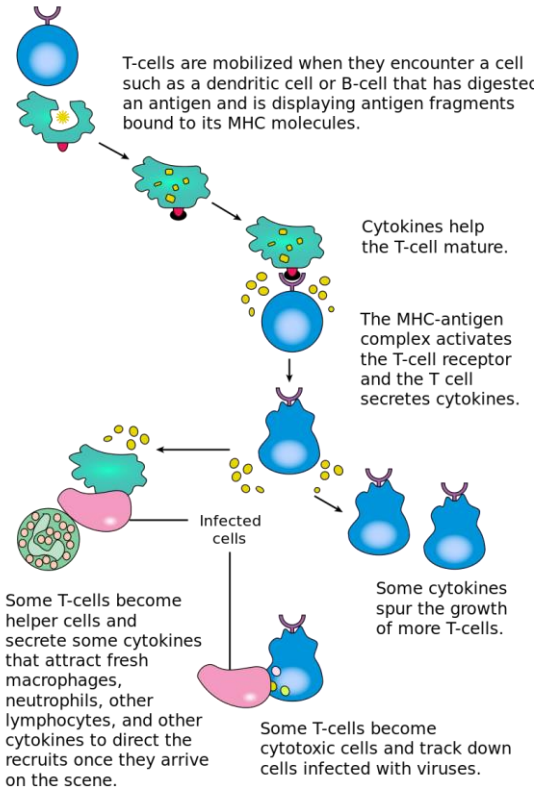



**FIGURE 7. Humoral Immune Response**

By Fred the Oyster - The Immune System (pdf), Public Domain, https://commons.wikimedia.org/w/index.php?curid=36367201

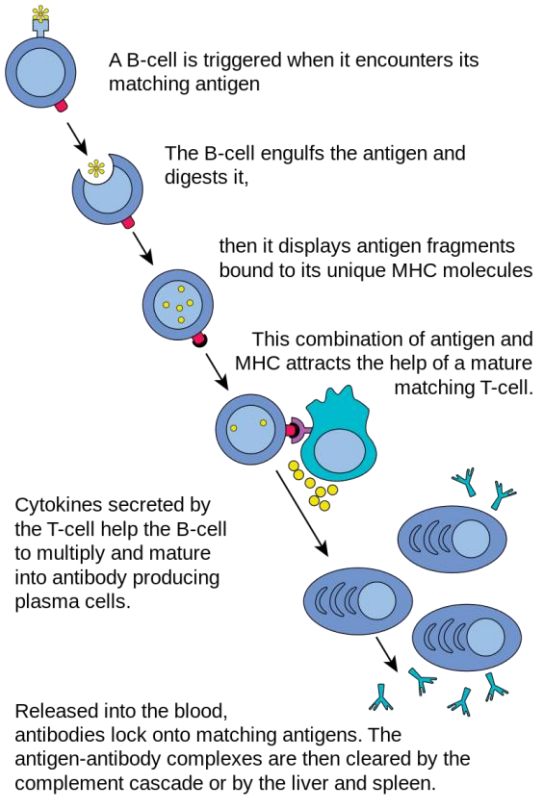



**FIGURE 8. Cell-mediated Immune Response**

By T_cell_activation.png: Template drawing and caption text from "The Immune System", any modifcations, made by myself are released into the public domain.derivative work: Rehua (talk) - This file was derived from: T cell activation.png:, Public Domain, https://commons.wikimedia.org/w/index.php?curid=18189140

You may also refer to your textbook (Campbell et al., 2015) for other illustrative examples and more detailed explanations.

## NAVIGATE

# CONCEPT MAP: A FINAL HURRAH

As we inch closer to the end of this module on Immunity, let us take a stop in order to summarize and organize what we have learned so far.

On a separate bond paper, make a **concept map** summarizing the different aspects of vertebrate immunity as discussed in our previous lessons and this one.

**THIS IS A GRADED FORMATIVE ASSESSMENT** and you will be assessed using the rubrics below.

### RUBRICS

**TOTAL NUMBER OF POINTS: 10 POINTS**

| | | | |
|---|---|---|---|
| **Submission/ Compliance** | **2** | **1** | **0** |
| | The student submitted the output on or before the deadline. | The student submitted the output beyond the given deadline. | The student did not submit any output. |
| **Application of Concepts Learned and Completeness of Output** | **3** | **2** | **1** |
| | **All** of the explanations are accurately anchored to the concepts presented in the lesson. | There is **at most one part** of the concept map which is inaccurate and not founded on the scientific principles learned. | There are **more than one part** of the concept map which is inaccurate and not founded on the scientific principles learned. |
| **Completeness of Concept Map** | **3** | **2** | **1** |
| | **All necessary** concepts are present in the concept map. | 2-3 key concepts are missing from the concept map. | There are at least 4 missing concepts from the concept map. |
| **Creativity/ Appropriateness of Concept Map Design** | **2** | **1** | **0.5** |
| | The design of the concept map is appropriate to the topic, creativity is evident on all parts of the concept map. | The design of the concept map is appropriate to the topic, creativity is evident on **most** parts of the concept map. | The design of the concept map is not appropriate to the topic, creativity is evident on **some** parts of the concept map. |

*Take a picture or scan the activity sheet provided and submit your output through your Knowledge Hub classroom on or before the deadline set by your teacher.*

## KNOT

In summary, the immune or defense system of vertebrates is classified as either innate defense or acquired immunity. Acquired immunity are specific defenses which protect the body from the invasion of specific pathogens. Acquired immunity relies on two types of lymphocytes, T cells and B cells. A T cell and B cell must first recognize a pathogen by binding to its antigen through the lymphocyte's antigen receptor. After recognition, the T cell and B cell will either neutralize, opsonize, or kill the invading pathogen. There are two types of acquired immune response. **Humoral immune response** acts against antigens found in the body fluids and is carried out by B cells. **Cell-mediated immune response**, on the other hand, acts against infected cells and is carried out by T cells. Adaptive immunity has four main characteristics which include the presence of diverse lymphocytes, self-tolerance, clonal ability after antigen recognition and immunological memory.

## REFERENCES

**Photographs/ Illustrations:**

Blueblaus, B. (2017, February 1). Chicken Pox (Varicella zoster) [Illustration]. https://commons.wikimedia.org/wiki/File:Chicken_Pox_(Varicella_Zoster).jpg

Clarkdn. (2012, May 18). Bcellreceptor.svg [Illustration]. Wikimedia Commons. https://commons.wikimedia.org/w/index.php?curid=32925894

Fred the Oyster. (2014, October 24). B cell activation.svg [Illustration]. Wikimedia Commons. https://commons.wikimedia.org/wiki/File:B_cell_activation.svg

Health Jade Team. (2017, December 14). What is thymus. Health Jade. https://healthjade.com/what-is-thymus/

Rehua. (2012, January 28). T cell activation.svg [Illustration]. Wikimedia Commons. https://commons.wikimedia.org/w/index.php?curid=18189140

Sciencia58. (2020, May 18). Primary immune response 1.png [Illustration]. Wikimedia Commons. https://commons.wikimedia.org/w/index.php?curid=90421209

TCRComplex.svg. (2010, February 20). [Illustration]. Wikimedia Commons. https://commons.wikimedia.org/w/index.php?curid=9520024

**Text Book:**

Reece, J., Urry, L. A., Cain, M. L., Wasserman, S. A., Minorsky, P. V., & Jackson, R. B. (2011). Campbell Biology 10th edition. San Francisco: Pearson Education Inc.

**Prepared by:**

**JOHN JOSHUA A. AZUCENA**
Special Science Teacher I
Philippine Science High School – CALABARZON Region Campus

**Reviewed by:**

**ELEAZAR B. GUIA**
Special Science Teacher V
Philippine Science High School – Central Visayas Campus

**MICHELLE B. DUCUSIN**
Special Science Teacher V/Team Lead (Biology)
Philippine Science High School – Ilocos Region Campus