Of Microorganisms and Men

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Inspired by: Disease? Let's B. Cereus by Grace Kim

Field(s) of Interest: Microbiology, Immunology, Medicine

Brief Overview (1-3 sentences):
Mentees will be introduced to how the human immune system works to fight off disease-causing pathogens through the lens of scientific modelling. We will teach modes of disease transmission in conjunction with innate immunity, discussing how pathogens enter the body and how our bodies work to prevent their entry. Mentees will also learn how our bodies react with adaptive immunity when pathogens enter the body, discussing how symptoms arise when sick.

Agenda:

- Introduction (5 min)
- Module 1: Somewhere in Germ-any (10-15 min)
- Module 2: Can I See Some ID? (10-15 min)
- Module 3: Pass the Emergen-C (15-20 min)
- Conclusion (5 min)

Main Teaching Goals/Key Terms:

- **Pathogen**
- **Virus**
  - **Genetic Material**
  - **Capsid**
- **Scientific Model**
- **Modes of Transmission**
  - **Airborne**
  - **Waterborne**
  - **Foodborne**
- **Immune System**
- **Innate Immunity**
- **Adaptive Immunity**
- **Cell**
- **Antigen**
- **Antibody**
- **White Blood Cell**
  - **Antigen-presenting cell**
  - **B-cell**
  - **Macrophage**
- **Symptoms**

Background for Mentors

Module 1

1. **Pathogen**
2. **Virus**
    a. **Genetic Material**
    b. **Capsid**
3. **Scientific Model**

A **pathogen** refers to any biological agent that causes disease in its host. Pathogens are typically microorganisms such as viruses, bacteria, and parasites. This lesson will focus on viruses.

A **virus** is a submicroscopic, non-living infectious agent. It acts as an obligate intracellular parasite, meaning that it must enter a host cell and hijack its machinery in order to replicate and proliferate. Most viruses can only survive for a few hours to a few days outside of a host.

All viruses contain two main components: genetic material and a capsid layer.

The **genetic material** of a virus consists of either DNA or RNA, which codes for the set of instructions the virus needs to infect host cells, replicate its genetic material, and produce new particles (genetic material + capsid). Host cells already contain the molecular machinery required to duplicate its own DNA or translate RNA. When a virus enters a host cell, it tricks this machinery into replicating its genetic material instead of the cell's. It uses the host's resources and energy for its survival.

The **capsid** is a rigid shell made of proteins that allows a virus to enter its host. It surrounds the genetic material, playing a critical role in infection by facilitating attachment and entry into host cells. It can have many different shapes and textures due to the diversity of its protein structure.

A **scientific model** is a simplified representation of a complex system, process, or phenomenon. Scientists utilize scientific models to explain, visualize, or make predictions in a logical, objective way about things that are too small or complicated to study directly. Examples include physical models such as the model virus in Module 1, conceptual models such as the water cycle diagram, and mathematical models such as equations.

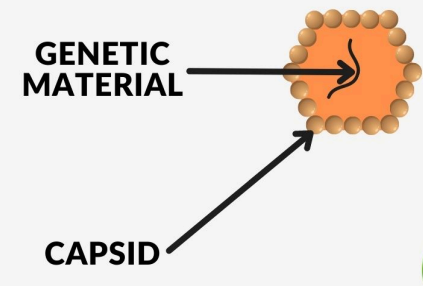
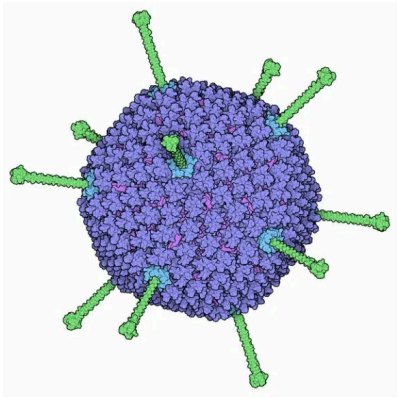


Figure 1: Basic structure of a virus

	 **Figure 2:** Adenovirus capsid layer

Module 2

4. **Modes of Transmission**
    a. **Airborne**
    b. **Waterborne**
    c. **Foodborne**
5. **Immune System**
6. **Innate Immunity**

There are several different ways that viruses can enter the body, and these are referred to as **modes of transmission.** Examples include

- **airborne** diseases (pathogens are carried through air in droplets by sneezing or coughing)
- **waterborne** diseases (pathogens are present in water and drank or bathed in)
- **foodborne** diseases (pathogens are present in contaminated or rotten food).

The human **immune system** is a complex network of cells, tissues, and organs with the function of fighting off foreign or harmful material in the body. It recognizes “self” versus “not self” in order to fight invaders while preventing damage to healthy tissue. There are two main branches of the immune system: innate and adaptive immunity.

Innate immunity is your body’s rapid, nonspecific first line of defense against pathogens. It acts quickly once it recognizes foreign or harmful material, providing a generalized response. Innate immunity’s primary function is preventing pathogens from entering the body. Features such as skin, mucus, and hair (particularly eyebrows, eyelashes, nose hair, and ear hair) provide physical barriers that trap pathogens before they can enter.

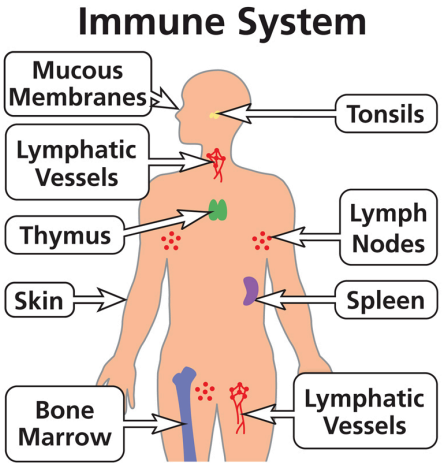


Figure 1: *Parts of the immune system*

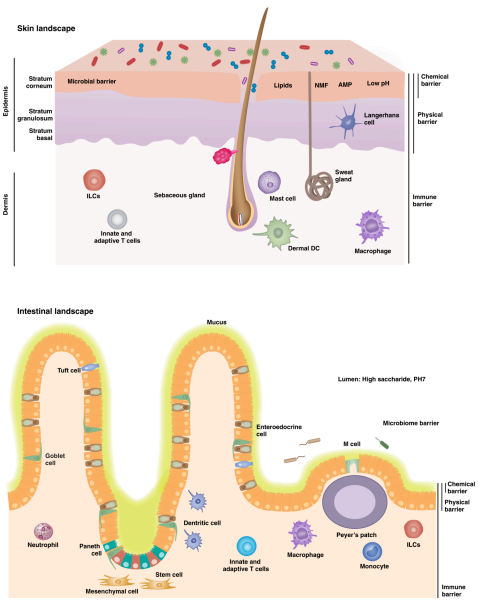


Figure 2: *How skin defends against pathogens*

Module 3

7. **Adaptive Immunity**
8. **Cell**
9. **Antigen**
10. **Antibody**
11. **White Blood Cell**
    i. **Antigen-presenting cell**
    ii. **B-cell**
    iii. **Macrophage**
12. **Symptoms**

Adaptive immunity kicks in when pathogens are detected inside of the body. The adaptive immune system is a highly specific and long-lasting defense mechanism in vertebrates that targets particular pathogens using specialized cells.

Cells are the tiny basic building blocks of all living things. They are individual living units with many different functions. The most important cells of the immune system are white blood cells.

White blood cells are a diverse class of immune cells that help fight pathogens by recognizing foreign material, neutralizing it, and clearing it from the body. White blood cells are produced by bone marrow and account for around 1% of total blood volume. These cells recognize antigens on pathogens and produce antibodies to fight them.

Antigens are substances, such as proteins, sugars, or lipids, found on the surface of pathogens that white blood cells detect, triggering an immune response. When white blood cells detect antigens, they produce matching **antibodies**, which can then bind to the surface antigens of pathogens. Antibodies work by preventing pathogens from entering healthy cells and/or marking them for destruction by other white blood cells.

There are also subcategories of white blood cells that these functions are divided between. **Antigen-presenting cells** recognize antigens and display them to B-cells. **B-cells** take the antigens and produce antibodies that match their shape, then aid in binding these antibodies to pathogens. After the pathogen is marked and killed by B-cell antibodies, **macrophages** then come in to engulf and degrade the pathogen. These cells can also remember pathogens and produce antibodies more efficiently upon subsequent infections.

When your immune system is working to fight off sickness, your body can show physical symptoms as a result. **Symptoms** are the physical or mental features that are regarded as being a condition of disease.

For example, some common symptoms of a viral cold are cough, runny nose, and fever. Cough and runny nose arise because your body produces excess mucus when sick in order to trap and flush out pathogens from the body. Fevers are a result of your body raising its set temperature to kill pathogens that cannot survive in higher heat.

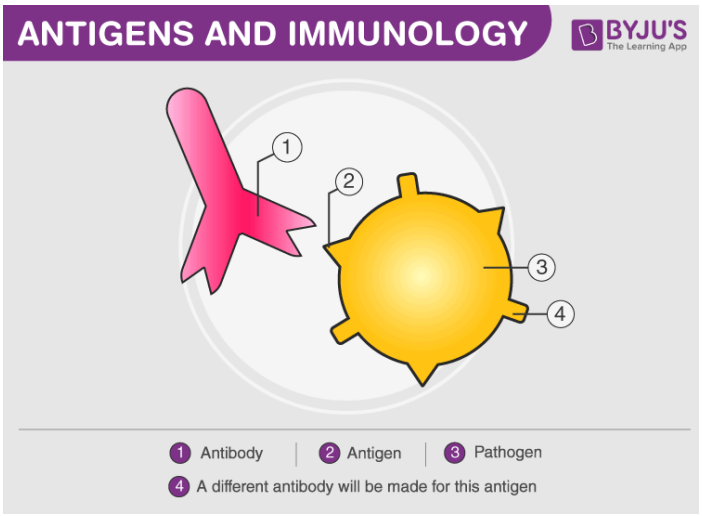


Figure 1: Antibody binding to antigens

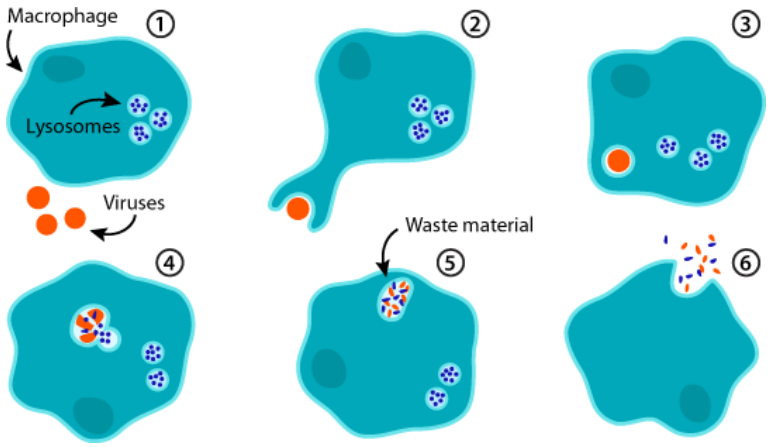


Figure 2: How macrophages consume viruses

Introduction

Pathogens and disease are a huge part of our everyday lives. Almost everyone has fallen ill with a cold or flu at some point in their lives, especially kids, as their immune systems are still developing. The goal for this lesson is to help mentees understand the mechanisms through which pathogens enter our bodies and make us sick, and how our immune system works to prevent and fight disease.

Concepts to Introduce ● Pathogens are the “germs” that make us sick when they enter our bodies. ● Pathogens can enter the body in several different ways. ● Your immune system is your body’s defense team against pathogens. ● Innate immunity works to prevent pathogens from entering the body, providing generalized defenses. ● Adaptive immunity provides specialized defenses, recognizing and killing specific pathogens.	**Questions to Pique Interest** ● Have you ever been sick? How did you feel? Hot? Cold? ● What did you do to feel better? Take medicine? Rest? ● Do you pick your boogers? ● Have you gotten your flu shot?
Scientists, Current and Past Events ● The COVID-19 pandemic was caused by a virus (coronavirus). Making the COVID-19 vaccine was the fastest successful vaccine production effort. ● The virus began in China and within a few months, spread all over the world ○ People were told to stay indoors and wear masks to prevent the spread of this disease	**Careers and Applications** ● Virologists are specialized biologists that study the structure and function of viruses. ● Immunology is a field of biology that helps develop immunotherapies against pathogens and other diseases. ● In medicine, understanding viruses is necessary in order to diagnose many types of disease and develop vaccines.

Module 1: Somewhere in Germ-any

Mentees will learn about pathogens, which are the “germs” that cause sickness. Mentees will learn how to use a scientific model to study the structure and function of viruses.

Teaching Goals	**Materials (per mentee)**

1. **Pathogen:** an infectious agent or microorganism that invades the body and causes disease
  a. **Virus:** pathogen that hijacks regular body functions in order to live and grow
  i. **Genetic Material**: instructions inside the virus that tell it how to grow and replicate itself using the body
  ii. **Capsid**: protective outer shell that allows the virus’s genetic material to enter the body unharmed
2. **Scientific Model:** a simplified or pretend version of something that is too big, small, or complicated to study directly
	● 1 plastic easter egg
	● 1 sticky note
	● Pencil
	● 8-12 gemstones

Different Methods for Teaching

1. **Ask the students if they have ever gotten sick**
   a. Real life examples: Cold, flu, COVID-19
2. **Viruses cannot live on their own.**
   a. They are like hitchhikers which invade the body and hijack its systems in order to live, grow, and replicate.
3. **Capsids:** They are like armor for the virus. They differ greatly between types of viruses. They can be rough, bumpy, smooth, spiky, and many other patterns.
   a. The plastic easter egg and gemstones together represent the capsid layer.
   b. Mentees can get creative with their gemstones!
   c. Another example you can use is saying your skull is the capsid for your brain, i.e. the skull protects the brain.
4. **Scientific Model:** This can be simplified by talking about examples (i.e. your egg virus, model planes/trains, legos)

Procedure

1. Pass out one easter egg, a sticky note, and gemstones to each mentee.
2. Have mentees brainstorm and write down creative "genetic instructions" to put inside their viruses.
    a. What kind of illness will their virus cause? What will the instructions make the virus' host do?
    b. Examples: "jump up and down uncontrollably" or "fall asleep whenever you hear applause"
3. Close instruction slips inside of plastic easter eggs.
4. Mentees will finish the texture of the capsid layer by decorating the outside of the easter egg with gemstones.

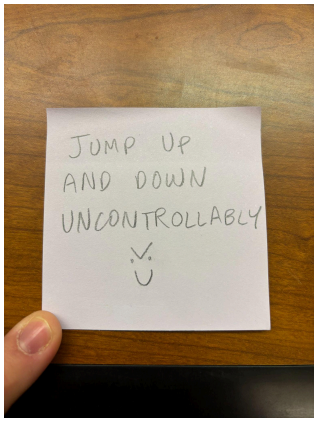


Figure 1: *Viral "genetic instructions" on paper slip*

Figure 2: Genetic instructions go inside "capsid"

Figure 3: *Complete virus model!*

Classroom Notes

Make sure students do not eat the gemstones!

Module 2: Can I See Some ID?

Mentees will learn about the different ways that pathogens can enter the body, such as through air, food, or water. Mentees will also study innate immunity, focusing on how the body prevents pathogens from entering by modelling the function of mucus in the nose.

Teaching Goals

1. **Modes of Transmission:** the different ways in which pathogens can enter your body
    a. **Airborne:** pathogens are carried by the air; breathed in
    b. **Waterborne:** pathogens are carried by water; drank or absorbed
    c. **Foodborne:** pathogens are present in food that is contaminated, rotten, or expired
2. **Immune System:** your body's "security team" of structures such as cells, tissues, and organs that works together to fight off pathogens and prevent disease
3. **Innate Immunity:** your body's first line of defense against pathogens that helps prevent pathogens from entering your body
    a. Skin
    b. Mucus
    c. Hair (eyebrows, eyelashes, nose hair, ear hair)

Materials (per group)

- Plastic ziploc bag of plastic sprinkles
- 1 balloon
- 1 cotton swab

Per class:

- Container of petroleum jelly

Different Methods for Teaching

5. **Modes of Transmission:**
    a. Why do we cover our mouths when sneezing/wear masks?
    b. Why does food have to be cooked to a specific temperature?
6. **Innate immunity:** your body's security guard/bouncer; it acts on pathogens quickly or prevents their entry in the first place
    a. Have mentees brainstorm external examples of innate immune defenses: skin, mucus, hair.
    b. Other internal examples could be saliva, tears, and stomach acid.
7. **Immune System:** This is like the police and viruses are the criminals living in your body. The police are trying to hunt the criminals down to make you healthy.
8. **Tie into scientific models:** The balloon nose demo is also a scientific model, representing airborne disease transmission and the function of our nasal mucus. (boogers!)

Procedure

5. Place the balloon into the bag with the fake sprinkles.
    a. The balloon represents your nose and the sprinkles represent pathogens.
6. Close the bag, leaving plenty of air inside.
7. Shake the bag vigorously. This works best if you cup your hands gently around the bag and shake.
    a. Many sprinkles will enter the balloon.
8. Mentors will then swab the entry rim of the balloon with a generous amount of petroleum jelly.
    a. The jelly represents our nasal mucus.
9. Close the bag, leaving plenty of air inside, and shake vigorously again.
    a. Fewer sprinkles will enter the balloon; many more will get stuck in the "mucus" on the rim.
10. With your group, analyze differences between presence/absence of jelly. How does our nasal mucus help prevent disease?

Figure 1: *Balloon in sprinkle bag with lots of air*

Figure 2: *Balloon after shaking w/o petroleum jelly*

Figure 3: *Generous amount of petroleum jelly in balloon rim*

	 **Figure 4:** *"Pathogens" get stuck in the "mucus"*

Classroom Notes

SPRINKLES ARE PLASTIC - DO NOT EAT!

Make sure the ziploc bags are fully closed before shaking!

Module 3: Pass the Emergen-C

When pathogens do enter the body despite innate immunity's best efforts, the body must fight them off internally using adaptive immunity. Mentees will learn how specialized cells fight off pathogens, a battle resulting in the symptoms we experience when we get sick.

Teaching Goals

13. **Adaptive Immunity:** your body's specialized response to specific pathogens
    a. **Cell:** tiny basic building blocks of all living things with many different responsibilities
    b. **Antigen:** material on the surface of pathogens that the body identifies as foreign/a harmful invader
    c. **Antibody:** produced by the body to bind to specific antigens in order to kill pathogens
    d. **White Blood Cell:** essential immune cells that help fight pathogens by recognizing antigens, producing antibodies, and clearing pathogens.
        i. **Antigen-presenting cell:** recognizes antigens and presents them to B-cells
        ii. **B-cell**: produces antibodies and binds them to antigens
        iii. **Macrophage**: clears dead pathogens from the body by engulfing and degrading them
14. **Symptoms:** clues that your body gives you letting you know that you're sick
    a. Examples: cough, runny nose, fever

Materials (per group)

- Bag of cut-out shapes
  - 3 circles (non-pathogens)
  - 1 triangle, 1 square, and 1 diamond (pathogens)
- Construction paper with shape templates
- Scissors
- Tape

Different Methods for Teaching

1. **Ask the mentees: what happens when you get sick?**
    a. **Symptoms**: the result of the fight between your immune system and pathogens
        i. Excess mucus production to trap and flush out pathogens → runny nose and cough
        ii. Your body heats up to kill pathogens inside → fever
2. **Your body produces antibodies to recognize antigens and destroy pathogens.**
    a. It's like a big battle happening inside of you, and the intensity of the fight produces the symptoms you experience like coughing and fever.
    b. On your virus model, the gemstones can represent antigens.
9. **For younger mentees,** you can refer to all of the adaptive immune cells simply as "white blood cells" and simplify their functions.

a. recognize antigens, produce antibodies, and clear out pathogens

Procedure

11. Divide your site into groups of 4 mentees, 3 if your site is smaller.
12. Each group of 4 mentees receives one plastic bag of “cells” (cut-out shapes), one pair of scissors, one sheet of “antibodies” (template shapes), and tape
    a. Cells are circles, pathogens are the squares, triangles, and diamonds
13. The first mentee represents the first team of white blood cells (antigen-presenting cells). This mentee will “recognize antigens” by sorting out the pathogens from the other cells, then passing the pathogens to the second mentee.
14. The second and third mentees together represent the second team of white blood cells (B-cells).
15. The second mentee will receive the pathogen shapes from the previous mentee. They will then “produce antibodies” by cutting out the shapes from the paper template and matching up their cutouts to the existing shapes.
16. The third mentee will be responsible for antibody binding to the antigens. They will tape the antibody shape onto the pathogen. Antibody shapes must match the antigens they are binding to. This binding kills the pathogen.
17. The fourth mentee will represent the final team of white blood cells (macrophages), responsible for clearing the dead pathogen out of the body cells. This mentee will take their group’s taped-together antibodies and pathogens to their designated mentor.
18. The group that clears all of their antigen shapes first wins!
    a. If time crunch, can race for how many antigens can we clear in x amount of time

Figure 1: *Bag of healthy cells and pathogens*

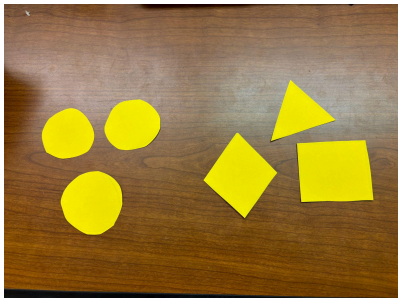


Figure 2: *Pathogens are sorted out from from the healthy cells*

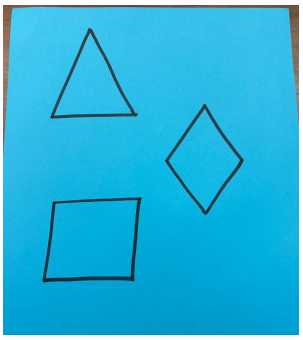


Figure 3: *Antibody shapes template*

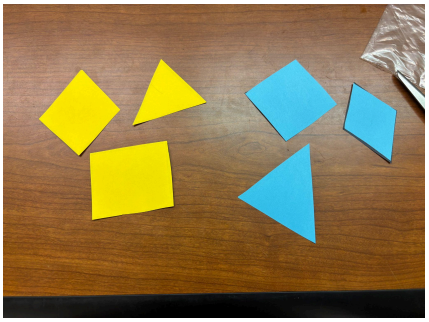
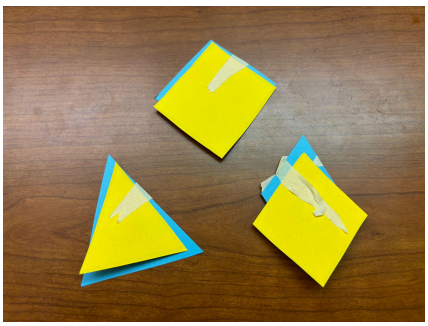


Figure 4: *Antibodies are cut out, matching antigens*

	 ***Figure 5:*** *Antibodies are bound to antigens; pathogens are dead*

Classroom Notes

For smaller sites, you can combine the “sorting” and “cutting” roles in the relay race. Mentors can join if needed to even out numbers!

Conclusion

You can wrap up this lesson by discussing disease mitigation strategies, such as washing our hands and covering our coughs. The next time mentees get sick, they should remember that their immune system is actively battling pathogens to the death! ⚔️

References

- Viruses: https://my.clevelandclinic.org/health/body/24861-virus
- Innate vs. adaptive immunity: https://www.ncbi.nlm.nih.gov/books/NBK279396/
- Scientific models: https://www.sciencelearn.org.nz/resources/575-scientific-modelling
- Balloon nose: https://enjoy-teaching.com/immune-system/

Summary Materials Table

Material	Amount per Site	Expected $$	Vendor (or online link)
hinged eggs	1 per mentee	37.99	Amazon
gemstones	8 per mentee	17.98	Amazon
pencil			MCL
sticky notes	20-30 per site		MCL
balloons	6	4.99	Amazon
fake nonpareils	20 grams	33.87	Amazon
ziploc bags	12		MCL
cotton swabs	6		MCL
petroleum jelly	1 container	10	MCL/Amazon
colored paper	60 sheets	17.19 for 500	Amazon
scissors	6		MCL
tape	1 roll		MCL