

Unit 1: Lesson 2 –The Innate Immune System

- **Lesson Questions:** What are the key features and processes of the innate immune system? How can the innate immune system be modeled?
- **Lesson Objectives:** Define glossary terms related to the innate immune system. Identify features of the innate immune system that respond to antigens. Analyze the castle and moat model as an analogy for the innate immune system.
- **Overview:** In this lesson, students learn about the body's first line of defense—the innate immune system. Students explore glossary terms associated with the innate immune system. They conduct an activity that models the barriers of the innate immune system, and analyze data from the activity. In an optional activity, students describe the symptoms, and the innate immune response given a specific scenario that introduces pathogens into the body.
- **Length:** Three 45 minute sessions
- **Glossary terms:** complement system, cytokines, edema, inflammatory response, macrophages, natural killer (NK) cells, neutrophils, pathogen-associated molecular patterns (PAMPs)
- **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.
 - **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.
 - HSS.IC.A Understand and evaluate random processes underlying statistical experiments.
 - HSS.IC.B Make inferences and justify conclusions from sample surveys, experiments, and observational studies.
 - HSS.ID.A Summarize, represent, and interpret data on a single count or measurement variable.
- **Materials:**
 - shoebox without lid
 - craft knife or scissors
 - 10 ping pong balls
 - 10 marbles
 - 10 1½" foam balls
 - masking tape
 - student worksheet
 - computer with internet access

BACKGROUND FOR TEACHER

The innate immune system is the body's first line of defense. The key concept for students is that the innate immune system is a generalized defense system, as opposed to the specific defenses provided by the adaptive immune system. (The adaptive immune system is covered in Lesson 3.) Innate immune system defenses include passive barriers, such as the skin and mucous membranes, as well as active cellular and biochemical responses. The castle and moat analogy is a good model for the innate immune system's barriers to pathogens. In this lesson, students conduct an activity that allows them to quantitatively analyze the castle and moat model. The goal is for students to understand how the castle and moat model is

analogous to the innate immune system. They should also be able to explain how the model differs from the real 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 innate immune system.

Complement system – Class of proteins in the blood plasma

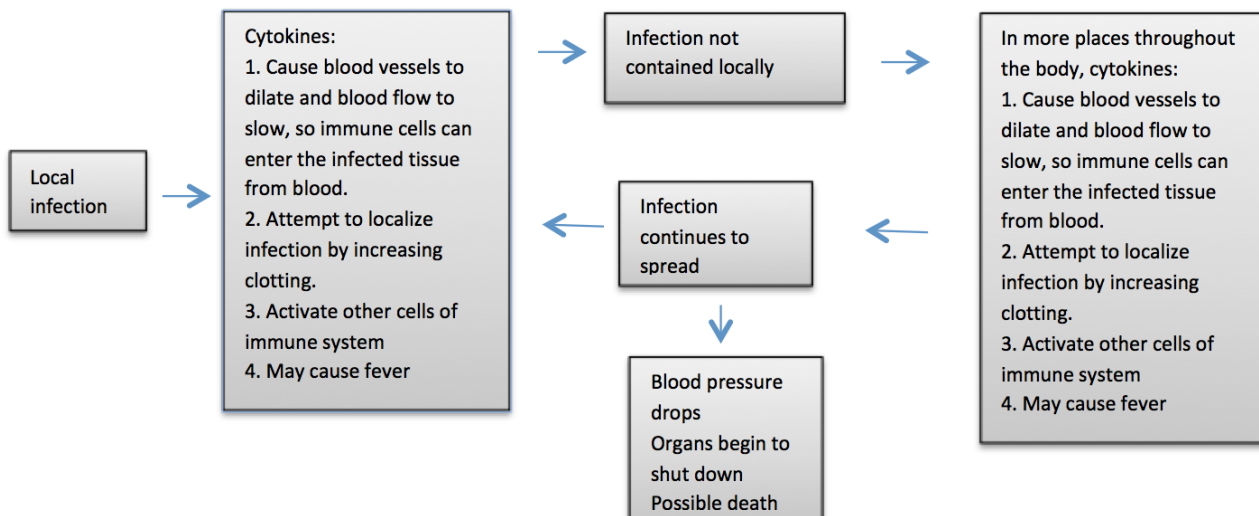
Complement system proteins identify potential pathogens. These proteins activate the inflammatory response to an infection. In some cases during bacterial infections, the proteins help kill bacteria by making holes in the bacterial membrane.

Cytokines – Small protein molecules

Cytokines play a role in all phases of the immune response. They mediate the innate immune response with several functions:

- Cause fever
- Activate other immune system cells
- Decrease ability of viruses to replicate
- Cause clotting to keep an infection localized

If the immune response gains too much momentum, such as can occur when an infection is not kept localized, too many cytokines can be released leading to septic shock.



Edema – Swelling of tissue

Edema is a feature of the inflammatory response.

Inflammatory response – Response initiated by macrophages

The inflammatory response is characterized by pain, redness, heat and swelling at the site of the infection. The inflammatory response has three purposes:

- Allows additional immune cells to come to the site of the infection
- Helps in local blood clotting to prevent further spread of the infection
- Helps promote the repair of damaged tissues

Macrophages – Cells found in tissues

Macrophages are particularly common in tissues just beneath epithelial cells. Macrophages are activated when a pathogen breaches a physical barrier such as the skin. These cells play a central role in the innate immune response because they ingest pathogens. They also release cytokines, which activate other parts of the immune response. Macrophages are long-lived. These cells also ingest debris, such as dead cells in tissues.

Natural killer (NK) cells – Cells that prevent infection from spreading

NK cells activate early during an infection, and play a key role in the innate immune response.

Neutrophils – Cells that circulate in the blood, then enter tissues when signaled by cytokines to combat an infection

Neutrophils ingest and kill pathogens. Unlike macrophages, neutrophils die. These sacrificial cells are a major component of pus.

Pathogen-associated molecular patterns (PAMPs) – Molecules characterized by repeat patterns that make them recognizable as foreign to the immune system.

PAMPs are antigenic molecules found in bacterial cell walls, flagella, bacterial DNA, and viral RNA. The innate immune system uses PAMPs to detect pathogens as foreign.

ENGAGE

1. Ask students to list in their notebooks fun games they have played that simulate defending castles or other similar scenarios. Students can also list stories or books they have read about castles.

2. Students work in pairs to brainstorm and then write a list of castle defenses and methods of attack.
3. Students write a brief passage on why castles are no longer used in modern warfare.

EXPLORE

1. Students explore online sources and the interactive glossary, completing the vocabulary table in their worksheets.
2. Students watch the animation, *The Innate Immune System* (<https://vimeo.com/198068546>).
3. Working in small groups or pairs, students conduct the “Castle of the Body” activity. Ensure students record their data accurately.
4. Students tally up the scores. Tally up the scores for the class as a whole.
4. Students calculate the percentages and averages of the data from the activity.
5. Students discuss the overall score, focusing on whether attack or defense was more successful.

EXPLAIN

1. Students complete the first three questions on their worksheets.
2. Students describe differences observed between the results for each trial.
3. Students hypothesize why they observed differences. Hypotheses should include factors such as differences between the size and weight of the balls, the stickiness of the masking tape and variation in how hard or far the balls rolled.
4. Students should be able to explain that this activity is a model for the immune system in that:
 - a. The sides of the cardboard box are like castle walls and represent the body's skin
 - b. The sticky tape around the box is like the castle moat and represents the body's mucous membranes.

ELABORATE

1. Working in small groups, students create a list of ways to get more of the balls or marbles into the box. These could include different-sized projectiles or launching the balls with a rubber band.
2. Students repeat the activity using different materials to represent various kinds of pathogens. Students calculate statistics (mean, range) from the data collected during the activity.

3. Students complete an interactive table showing how the innate immune system responds to immune system challenges.
4. If time allows, students conduct the optional activity to consider symptoms that indicate the innate immune system is functioning.

EVALUATE

1. Students work in pairs or small groups to create a multimedia resource that demonstrates understanding of the innate immune system. Encourage students to develop their own ideas. Example assignments include:
 - Make a 30 second television commercial.
 - Design an ad for a magazine.
 - Write a newspaper article.
 - Create a web page (blog, wiki, etc.)
 - Perform a skit
 - Create a slide presentation

TEACHER NOTES

- You may wish to divide the lesson so that Engage and Explore are completed in the first 45-minute session, completing the remainder of the lesson in the next two sessions.

Rubric for optional activity:

Scenario	Q1. Symptoms	Q2. Innate system contributing to symptom	Q3. Effect of innate immune responses
Splinter after skateboarding accident	Punctured skin, splinter breaches skin, introducing pathogens into body	Macrophages below the skin activated	<ul style="list-style-type: none"> • Macrophages eliminate pathogens and activate other parts of the immune response. • Blood vessels dilate. Blood flow slows so immune cells can leave the blood and enter tissue near wound. • Cytokines clot blood in tissue so pathogens cannot cause wider infection. • NK cells help fight infection. • Inflammatory response promotes repair of damaged tissue. • Pathogens identified due to PAMPs, therefore targeted by immune cells.
	Pain	Inflammatory response	
	Red		
	Warm to touch	<ul style="list-style-type: none"> • Dead neutrophils • Plasma containing complement 	
	Pus	Cytokines	
Bleeding when splinter removed			

Scenario	Q1. Symptoms	Q2. Innate system contributing to symptom	Q3. Effect of innate immune responses
Sick after eating out	Upset stomach or nausea	Movement of stomach or intestine trying to eliminate pathogen.	<ul style="list-style-type: none"> • Mucus in gastrointestinal tract traps pathogens. • Low pH stomach acid kills some bacteria. • Anti-bacterial peptides in digestive tract act as barrier to infection. • If pathogen crosses epithelial and mucosal barrier of digestive tract, macrophages, cytokines, and neutrophils activate.
	Vomiting	Induced by the innate response to eliminate pathogen	
	Diarrhea		
	Chills or fever		

Scenario	Q1. Symptoms	Q2. Innate system contributing to symptom	Q3. Effect of innate immune responses
Pimple before class pictures	Pus	<ul style="list-style-type: none"> • Dead neutrophils • Plasma 	<ul style="list-style-type: none"> • Blood vessels dilate. Blood flow slows so immune cells can leave the blood and enter tissue near pimple. • Cytokines clot blood in tissue so pathogens cannot cause wider infection. • NK cells help fight infection. • The inflammatory response will promote repair of damaged tissue. • Pathogens may be recognized by PAMPs so that immune cells are signaled to their presence.
	Red Sore	Inflammatory response	
	Raised skin		

Scenario	Q1. Symptoms	Q2. Innate system contributing to symptom	Q3. Effect of innate immune responses
Getting coughed on in class	Sore throat	Inflammatory response	<ul style="list-style-type: none"> • Macrophages eliminate pathogens and activate other parts of the immune response. • Blood vessels dilate. Blood flow slows so neutrophils and other immune cells can leave the blood and enter lung tissue. • NK cells help fight infection. • Inflammatory response promotes repair of damaged tissue. • Pathogens identified due to PAMPs, therefore targeted by immune cells. • Airways swell as a result of inflammation.
	Red throat		
	Cough	Cough	
	Runny nose	<ul style="list-style-type: none"> • Mucus • Cilia in respiratory tract move mucus up to throat • Pathogens killed in the digestive tract. 	
	Mucus production during cough		
Fever	Inflammatory response		