LESSONS FOR GRADES K–12

Educator Guide

MacGillivray Freeman's

SUPER HUMAN BODY 3D

WORLD OF MEDICAL MARVELS

Narrated By
Matthew McConaughey

PRESENTED BY Edwards Lifesciences GRIFFIN CATALYST

Hello, Educators!

TABLE OF CONTENTS

LESSONS for K–2

Bird Biomimicry .... page 8

Rhythm of the Heart .... page 15

AI Emotions .... page 27

LESSONS for 3–5

T-Cell Receptor Puzzle ..... page 41

Heart Stations .... page 52

Prosthetic Possibilities ... page 75

LESSONS for 6–8

Building Immunity .... page 88

Pump It Up .... page 94

Universal Design Challenge .... page 100

LESSONS for 9–12

Optimal Optics .... page 109

Clear It Out: Stent Design .... page 116

Accessible Engineering .... page 124

INTRODUCTION

The *Superhuman Body: World of Medical Marvels* Educator Guide was created by the Daniel G. and Carole L. Kamin Science Center (formerly Carnegie Science Center) in Pittsburgh, Pennsylvania, in partnership with MacGillivray Freeman Films.

This guide features lessons most appropriate for students in the following grade bands: K-2, 3-5, 6-8, and 9-12. The guide is most useful when used as a companion to the film but is also valuable as a resource on its own. Activities developed for this guide support the Next Generation Science Standards (NGSS). Educators are strongly encouraged to adapt activities included in this guide to support specific state or national standards and the needs of their students. This guide focuses on the amazing biology of the human body and how scientific discoveries and advances in engineering play a role in helping each of us live our best life.

All lesson plans and activities are designed for student inquiry, with communication and teamwork interwoven throughout. Lessons challenge students to learn through observation, engineering, testing and iterating ideas, and formulating conclusions based on data collection.

Throughout the guide, educators can find question prompts and additional information on items to read, watch, and do in their classroom to further students' learning.

The greatest machine and the greatest mystery on Earth is our human body. Pioneers, researchers, innovators, doctors, bioengineers, as well as countless others are working day in and day out to ensure that our greatest machines are operating at their best. Innovations in the medical world have worked to fight disease, immune disorders, and cancer and are making strides each day to allow everyone to live their best, most effective lives.

The *Superhuman Body* film, as well as the lessons in this guide, allow you to travel inside the most complex system we know to discover just how amazing the human body really is, what it's capable of, and to see how people are uncovering solutions to our most pressing medical challenges.

Superhuman Body: World of Medical Marvels is a MacGillivray Freeman film for IMAX® and giant screen theaters presented by Edwards Lifesciences and Griffin Catalyst. It is directed by Academy Award®- nominated filmmaker Greg MacGillivray and Shaun MacGillivray. The film has a run time of 40 minutes.

The *Superhuman Body* Educator Guide was made possible with generous support from:

Kenneth C. Griffin and Griffin Catalyst, Edwards Lifesciences, The Ambrose Monell Foundation, Richard King Mellon Foundation, Merkin Family Foundation, Burroughs Wellcome Fund, Eli Lilly and Company Foundation, The Citadel Foundation, IF/THEN, an initiative of Lyda Hill Philanthropies, Silicon Valley Bank, a Division of First Citizens Bank, MacGillivray Freeman Films Educational Foundation, The Murcko Family Foundation, Andy Palmer, McGuire Family Foundation, Robert Tepper, The Barry E. and Natalie T. Greene Family Foundation, Paul Schimmel, Mark and Becky Levin, Robert Paull, Biogen, Alfred W. Sandrock, Jr., Brian and Steph Spector, John Maraganore, Broad Institute of MIT and Harvard, Mass General Brigham, Michelle Detwiler, Adam Koppel and Brenda Haynes, The Milford Street Fund and Olin College of Engineering.

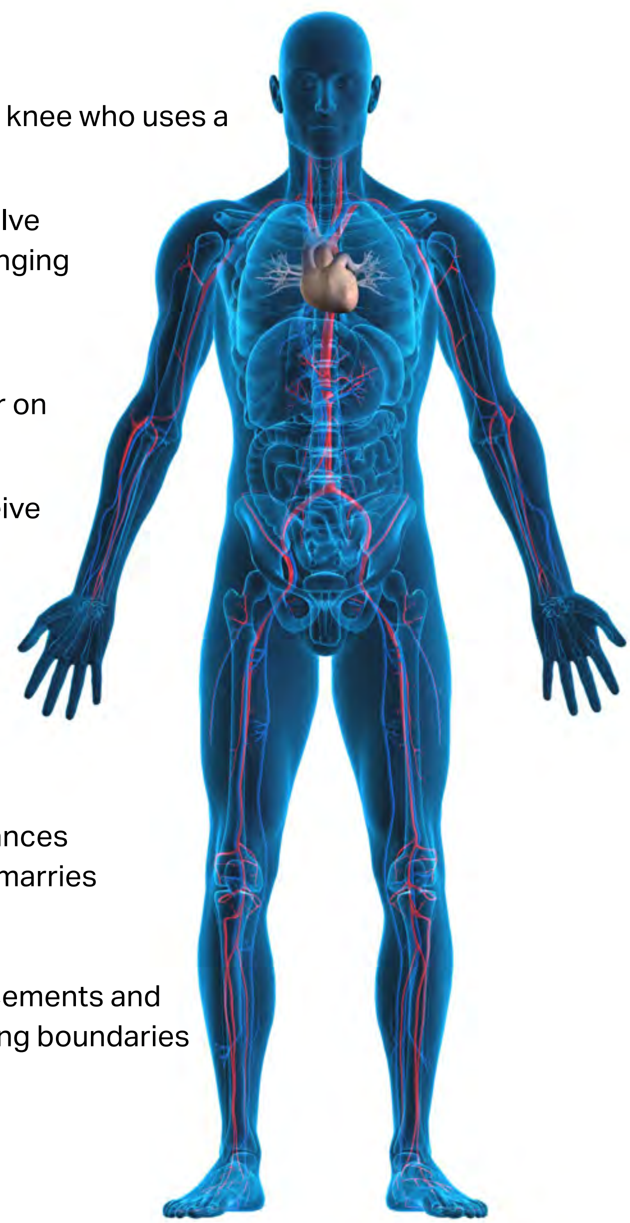
BACKGROUND INFORMATION

The human body is one amazing machine! It's a single structure, but made up of billions of small structures, separated into cells, tissues, organs, and systems. All of these systems work together in unison to perform the many complex functions of the body. In order for humans to survive, the body must maintain homeostasis. The ten major systems of our body (skeletal, muscular, nervous, endocrine, cardiovascular, lymphatic, respiratory, digestive, urinary, and reproductive) need to work together, in balance, for an individual to maintain life. There are times when our bodies' systems don't function correctly and provide us with medical challenges. Medical advancements are being made daily through research, design, and testing in hopes of transforming the way healthcare is provided.

In the film, *Superhuman Body: World of Medical Marvels*, viewers follow four stories of medical advancements that have impacted healthcare and provide solutions to some pressing medical challenges. In the film, audiences meet a variety of scientists and medical professionals who are working on future medical advancements and individuals who are benefiting from these medical breakthroughs.

Individuals include:

- **Ty Duckett**, a surfer with a unilateral amputation below the knee who uses a prosthetic device to continue doing what he loves.
- **James Garrett**, a retired nurse and transcatheter aortic valve replacement patient who volunteers and provides life-changing cataract surgery to individuals in Ghana.
- **Dr. Carl June**, a Leukemia specialist who pioneered an experimental treatment for Leukemia by putting a receptor on T-Cells to fight cancer cells.
- **Emily Whitehead**, the first pediatric cancer patient to receive CAR T-cell therapy treatment to fight childhood Leukemia.
- **Dr. Ayanna Howard**, a roboticist at The Ohio State University, whose team develops various kinds of medical robotics, including robots to coach children in developing fine motor skills.
- **Dr. Hugh Herr**, a professor at MIT and a double amputee who designs bionic limbs and is responsible for many advances in the emerging field of biomechatronics, technology that marries human physiology with electromechanics.



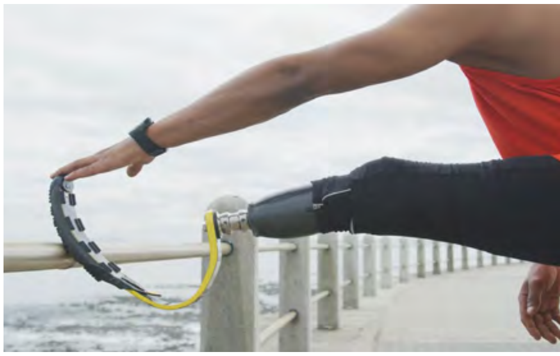
All of these stories highlight the hope found in medical advancements and how amazing individuals are working day in and day out, pushing boundaries to transform the healthcare system as we know it.

MEDICAL ROBOTICS

Medical Robotics is an evolving field of study, with many advancements being made. Previously, the thought of robots was just found in science-fiction literature, but as technology advances, robots, including medical robots, are becoming more and more common. Using robotics in the medical field has various benefits, including alleviating workloads for nurses and caregivers and enabling a high level of patient care. Robotics are used to monitor patients, complete minimally invasive procedures, and ensure more consistent processes, just to name a few.

As advancements are made, surgical-assistance robots are becoming more common and more precise. These types of robots assist surgeons who perform a number of different tasks. Some surgical robots can operate autonomously, or by themselves, while others need the surgeon to "drive" the robot to complete the task. Engineers, including biomedical engineers, are constantly iterating robot designs to create new innovative ways to solve the problems our bodies face.

PROSTHETICS



There are many reasons why an individual might require a prosthesis including, but not limited to, amputation, loss of a limb, or a birth defect. A prosthesis is an artificial body part designed to help individuals with limb differences improve mobility, manage daily activities, and provide the individual with a way to stay independent.

The earliest proof of prosthetics comes from a 3,000-year-old Egyptian mummy, who was found with a prosthetic toe made from wood and leather. Since then, there have been numerous advances in how prosthetics are made, fitted, and utilized. New-age prosthetics can be made from a clear silicone, and even painted to match existing skin tones, body hair, and can even include natural features like freckles. Tattoos and other artwork can be added to prosthetics for even greater expression. Orthotists and prosthetists can create these devices for individuals. They can measure, design, fit, and adjust these devices for the patients in need.

THE HEART AND TAVR

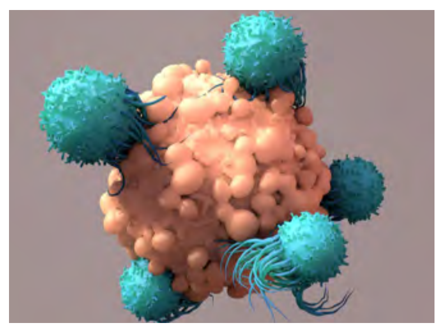
Made up of four chambers, a healthy human heart tirelessly pumps blood through a 60,000-mile-long network of blood vessels, bringing nutrients to all the vital tissues of the body. It circulates around 1.5 gallons of blood through the body about every minute, and moves about 1/3rd cup of fluid with each pump. It is one of nature's most incredible machines—elegant, efficient, and remarkably durable.

One common problem that occurs in the heart is aortic stenosis, which affects as many as 300,000 people each year in the U.S. alone. The aorta is the largest artery in the human body, and carries freshly oxygenated blood from your heart to your brain, organs, and muscles. Aortic stenosis simply means the aortic valve—a crescent-shaped structure that crucially controls the blood entering into the aorta and ensures blood does not flow backwards—has narrowed. This can thwart blood flow, causing fatigue, breathlessness, light-headedness, and other worsening symptoms.

In the past, replacing a heart valve was not so simple. Valve replacements could be only performed as majorly invasive open-heart surgery. But recently, a non-surgical procedure known as TAVR (Transcatheter Aortic Valve Replacement) has completely transformed the treatment of aortic stenosis, lending a chance for a longer life to many.

With TAVR, recovery from valve replacement can take place in a matter of days rather than arduous months, and dangerous complications are significantly reduced. In the minimally invasive procedure, a specially manufactured artificial valve is carefully threaded upwards through an artery all the way to the heart where it is implanted inside the natural valve that is not working properly. First performed on a human in 2002 in France, TAVR is now approved in more than 50 countries, and has changed thousands of lives.

T-CELL THERAPY



In recent decades, cancer treatment centered around surgery, chemotherapy, and radiation therapy but the emergence of targeted immunotherapy has gained prominence over recent years. Targeted immunotherapy uses the patient's immune system to shrink or eliminate tumors.

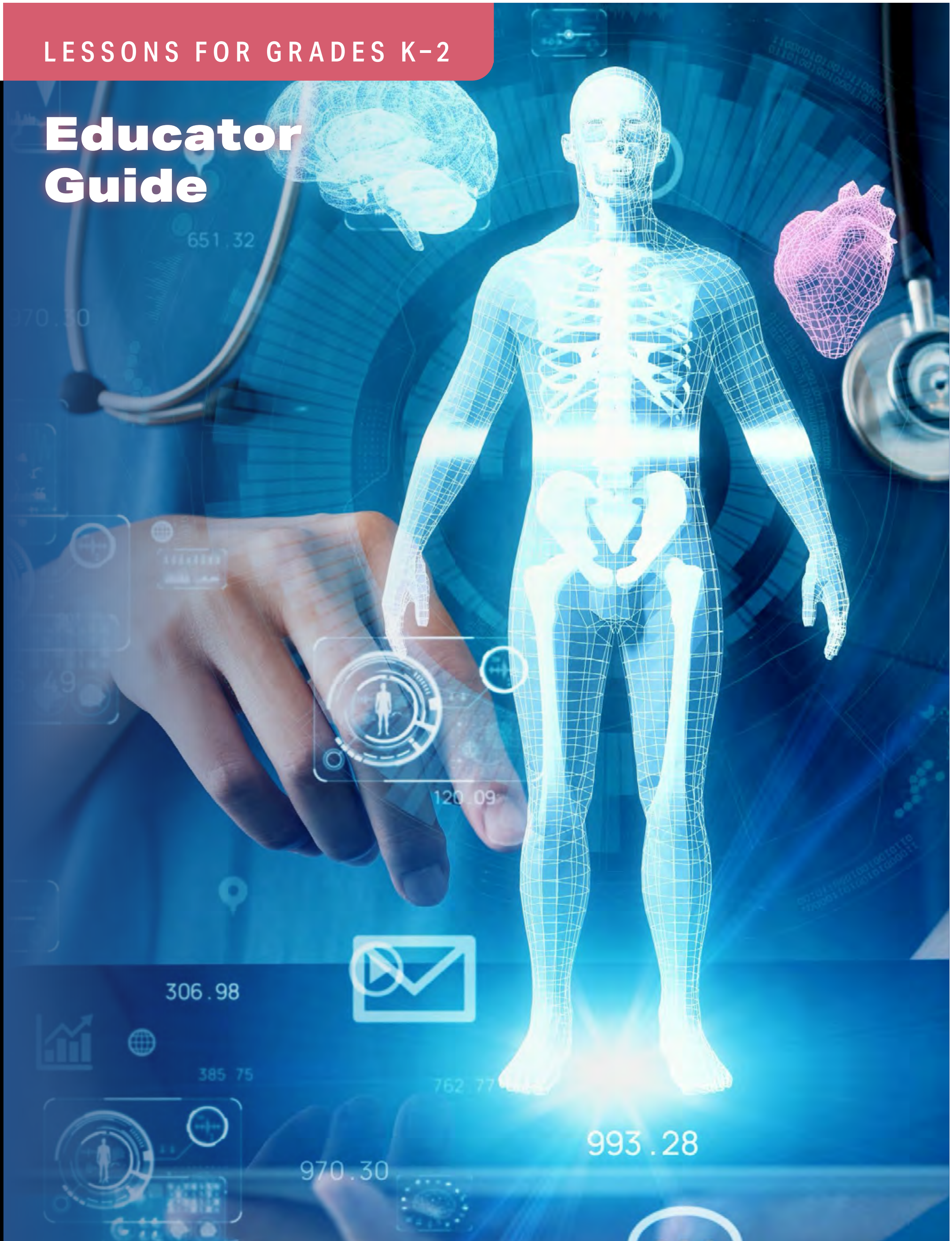
CAR T-cell therapy, a form of immunotherapy, has demonstrated the ability to eradicate advanced leukemias and lymphomas, achieving long-term cancer control. Since 2017, six CAR T-cell therapies have gained FDA approval.

At the core of CAR T-cell therapy are T-cells, essential components of the immune system responsible for orchestrating immune responses and killing infected cells. Current CAR T-cell therapies are personalized for each patient. Physicians collect T-cells from the patient, re-engineer them to express chimeric antigen receptors (CARs) and infuse them back into the patient.

The CARs are synthetic molecules that recognize specific proteins on cancer cells and guide the engineered T-cells to identify and eliminate the cells. Each CAR comprises external fragments of lab-made antibodies, which determine the overall function of the CAR T-cells, providing a versatile tool for cancer treatments.

LESSONS FOR GRADES K–2

Educator Guide



Bird Biomimicry

Total time to complete activity: 45 minutes

BIG IDEA

Students explore how humans use biomimicry to create technological solutions to problems.

IN THE FILM

In *Superhuman Body*, we see some of the many prosthetics engineers have designed for people with limb differences and we watch Paralympians competing. Track and Field Paralympians use a “blade” prosthetic, designed to mimic the legs of cheetahs.

NGSS STANDARDS

K-2-ETS1-1

Ask questions, make observations, and gather information about a situation people want to change to define a simple problem that can be solved through the development of a new or improved object or tool.

K-2-ETS1-2

Develop a simple sketch, drawing, or physical model to illustrate how the shape of an object helps it function as needed to solve a given problem.

K-2-ETS1-3

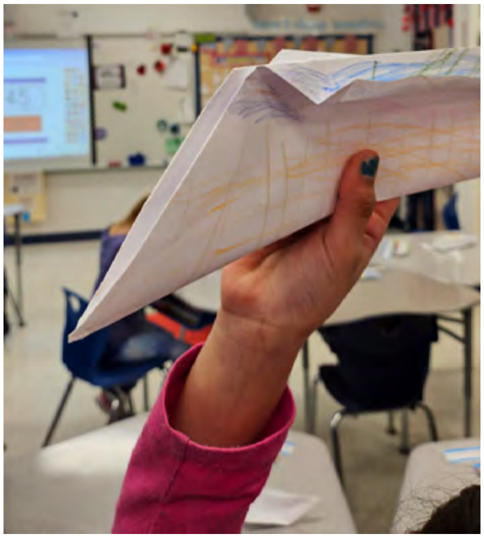
Analyze data from tests of two objects designed to solve the same problem to compare the strengths and weaknesses of how each performs.

1-LS1-1

Use materials to design a solution to a human problem by mimicking how plants and/or animals use their external parts to help them survive, grow, and meet their needs.

MATERIALS

- ☐ Paper
- ☐ Biomimicry Matching Game
- ☐ Scissors
- ☐ Painter's tape
- ☐ Laminator (optional) and laminating sheets



OBJECTIVES

1. Students will sort and compare photographs of technologies and the animals they were inspired by.
2. Students will plan, create, and test the efficiency of paper airplanes, using aspects of biomimicry to inform their designs.

LESSON PREPARATION

Before students arrive, make sure to review the lesson materials. Review background information. Gather materials and set up the classroom.

Material preparation:

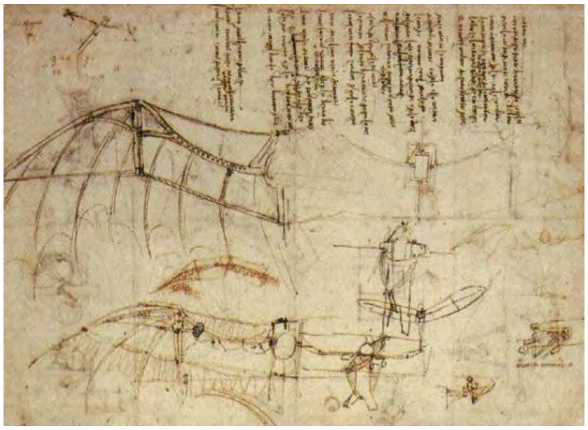
- Print, laminate (optional), and cut one set of the Biomimicry Matching Game for each group.
- Create paper airplane examples.
- Determine an area of the room for students to test their paper airplanes. Their goal will be to hit a piece of paper on the wall. Tape a piece of paper on the wall in the designated area. Place a piece of tape on the floor 4 ft. (level 1), 6 ft. (level 2), and 8 ft. (level 3) from the wall to mark where students should throw from.

BACKGROUND INFORMATION

Biomimicry: Solving design problems by mimicking solutions from nature.

The idea of **biomimicry** has existed long before we had a name for it. Thousands of years ago, historians believe Chinese inventors realized large leaves repelled and redirected water. This inspired them to create umbrellas.

In the 1480s, Leonardo Da Vinci used bird anatomy as inspiration for his flying machines. Engineers still use biomimicry today and we can find examples in common items, such as Velcro, inspired by burrs and wind turbines based on humpback whale fins.



Leonardo Da Vinci's sketches for flying machines

BACKGROUND INFORMATION (continued)

Peregrine Falcons are the fastest animals on earth. While they usually fly at speeds near 40 mph, these birds hit their record speeds of 150 mph or more while diving for the smaller birds they hunt as prey. A unique combination of traits makes this possible including stiff feathers and wings that bend back to create a more streamlined shape than other birds.

PROCEDURE

ANTICIPATORY SET

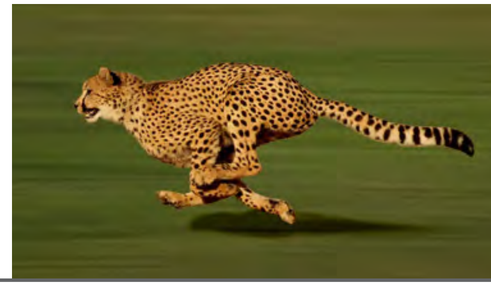
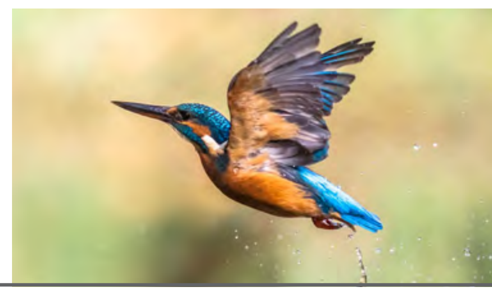
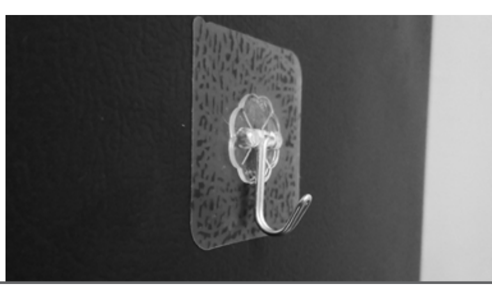
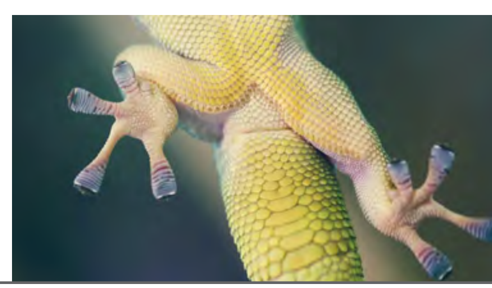
1. Explain to students that engineers often get ideas from nature when they're solving problems. This is called **biomimicry.**
2. Pass out one set of the Biomimicry Matching Game per group. Explain that this game includes technologies and the animals they were inspired by. Their group's job is to match the technologies to the animals. If they're not sure, that's okay! They should be making their best guesses.

DIFFERENTIATION TIPS:

For more advanced groups, consider having students play this as a memory matching game. In this version of the game, all cards should be face down. Then students will take turns flipping two cards. If they think those cards are a match, they will take them. Once all cards are gone, announce the correct matches to the group. Each correct pair is worth one point.

For groups that need more support with this activity, consider finding matches as a whole group under a document camera.

Biomimicry Matching Game

Blade prosthetic	Cheetah legs
	
Wind turbine	Humpback whale fin
	
Bullet train nose	Kingfisher beak
	
Velcro	Burr
	
Adhesive wall hooks	Gecko feet
	

ACTIVITY

1. Tell students that now they will get a chance to be engineers and use biomimicry.
2. Play [“Why peregrine falcons are the fastest animals on Earth”](). Ask if anyone knows the fastest animal in the world. It’s the Peregrine Falcon! Have students pay close attention to how the Peregrine Falcon changes its shape when it’s gliding slowly compared to when it’s diving quickly.
3. After playing the video, ask students what they noticed. What does a peregrine falcon do to move at speeds over 150 mph?
4. Have students extend their arms like they’re a Peregrine Falcon gliding slowly through the air. Encourage them to change their shape to look more like a Peregrine Falcon speeding through the air while it dives. Peregrine Falcons pull back their feet and pin their wings back when they do their fast dives so they can shoot quickly through the air. Students should tuck their limbs in so they’re a straight line to model this.
5. Now students work like engineers using biomimicry to create paper airplanes using their knowledge of Peregrine Falcons. Show students the target on the wall. Their goal is to be fast and precise, like a Peregrine Falcon. Show students the markers on the floor for levels 1, 2, and 3.
6. All students should attempt to solve the challenge from the level 1 starting point before attempting levels 2 and 3. Model throwing an example paper airplane at the target from the starting points. Ensure students understand that planes should only be tested in the testing area, not thrown in other parts of the room, for safety.

DIFFERENTIATION TIP:
If students are still developing the fine motor skills required to fold paper airplanes, consider making this a team activity. Ask who already knows how to make a paper airplane and pair them with students who are still learning. You can also simplify this activity by pre-folding basic paper airplanes and allowing students to alter them with scissors and additional folds.

7. Pass out paper and scissors. If students know how to make paper airplanes, they may start experimenting. If students have access to technology, consider allowing them to research paper airplane tutorials. If they would like to learn a basic paper airplane, walk them through the following steps.
    - Fold the paper in half hot dog style.
    - Open the paper and fold two corners to meet at the center line.
    - Again, fold these corners down so the edges meet the center line.
    - Fold the edges down.

Bird Biomimicry

ACTIVITY (continued)

8. Walk around as students work, asking them to describe how they are modeling their designs after the Peregrine Falcon. Are they designing a plane that's wide and allows the plane to glide slowly or compact that will move quickly and accurately?

   Monitor the testing area and use guiding questions to help students' problem solve if they're not successful. For example, "Is your plane having trouble with accuracy or distance? Why might it be curving to the right?"

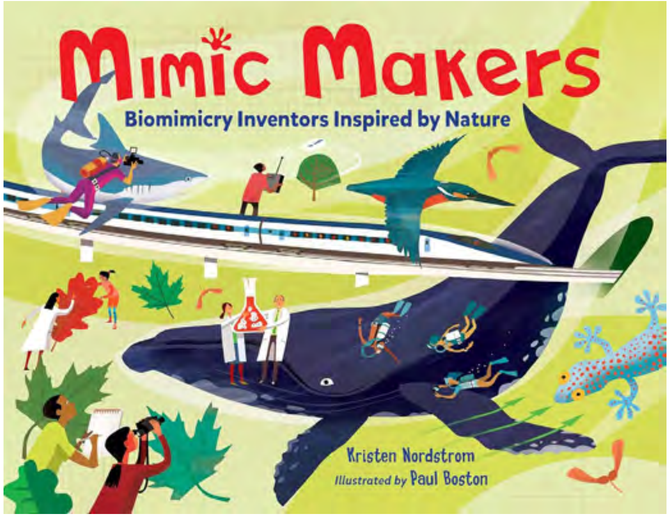
WRAP-UP

Review and Discussion Questions:

How did your knowledge of Peregrine Falcons help you in the challenge?

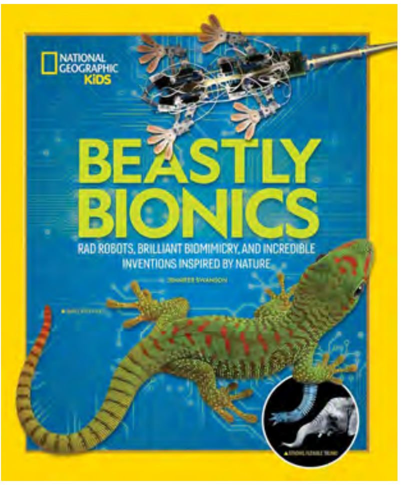
Have you seen any examples of biomimicry in the everyday items that you use?

ADDITIONAL LEARNING



READ

Learn more about real technology inspired by nature with ***Mimic Makers: Biomimicry Inventors Inspired By Nature*** by Kristen Nordstrom and ***Beastly Bionics: Rad Robots, Brilliant Biomimicry, and Incredible Inventions Inspired by Nature*** by Jennifer Swanson.



WATCH

Super Sema's town is being polluted by a villain's jet! See how she problem-solves to help her neighbor's using biomimicry in **"Mission Biomimicry"** by Super Sema.

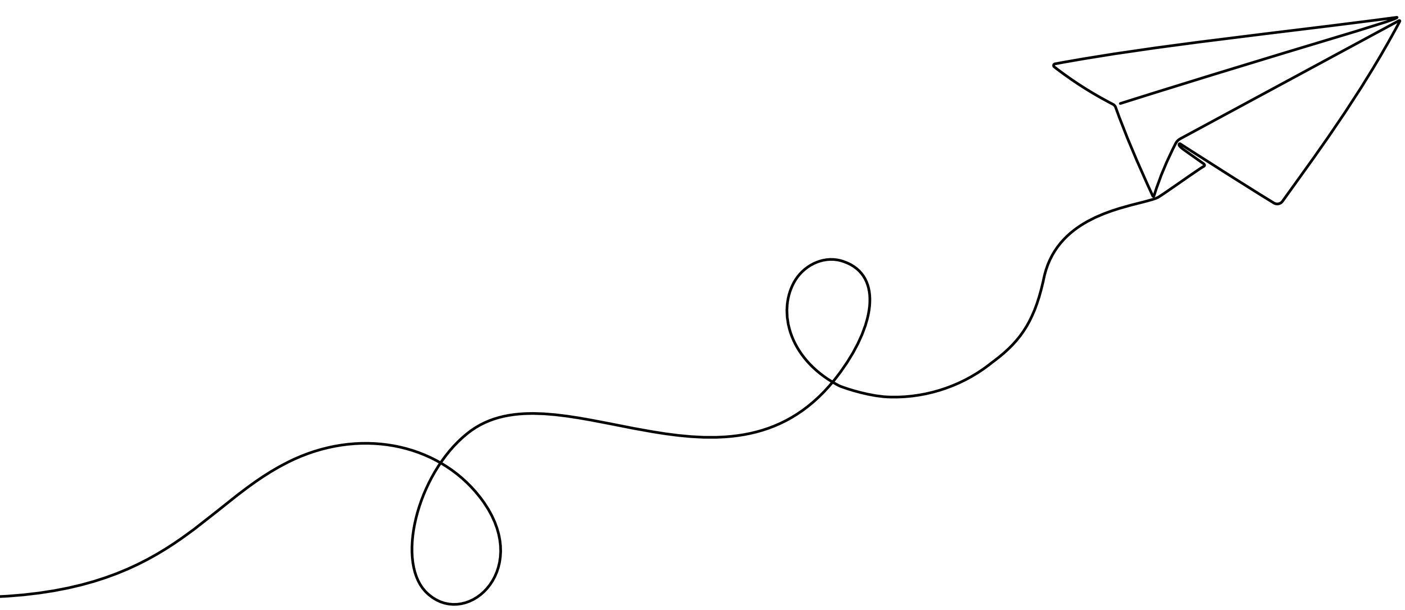
Sing about biomimicry and see more examples of biomimicry with **"The Biomimicry SONG | Science for Kids | Grades K-2"** by GenerationGenius.

Read along and learn more about Peregrine Falcons in **"Meet the Animals 15 | Peregrine Falcon | Wild Animals | Little Fox | Animated Stories for Kids".**

DO

Extend this activity by giving students a new goal to design a paper airplane that flies the farthest. Should this airplane look more like a Peregrine Falcon gliding or diving? Are there other animals they could use as inspiration?

Encourage students to keep an eye out for technology that could be inspired by biomimicry in their everyday life. If they notice something, they can sketch the item and animal they believe it's inspired by to share with the class.



Rhythm of the Heart

Total time to complete activity: 45 minutes

NGSS STANDARDS

K-LS1-1

Use observations to describe patterns of what plants and animals (including humans) need to survive.

1-LS1-2

Read texts and use media to determine patterns in behavior of parents and offspring that help offspring survive.

BIG IDEA

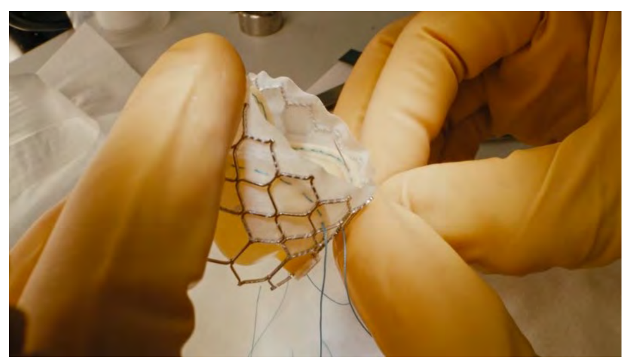
Students explore their heartbeats and the heart rates of different animals in this lesson that integrates music and science.

IN THE FILM

In *Superhuman Body,* James Garrett realized something was wrong when he started getting tired and needed to rest more often.

Eventually he learned that he had aortic stenosis, which meant enough blood wasn't getting pumped to the rest of his muscles and organs to keep his body working properly. Engineers designed a valve to help his heart pump blood efficiently again.

James Garrett visiting Edwards Lifesciences' lab



Sewing TAVR Heart Valve

OBJECTIVES

1. Students will compare fast and slow heart rates.
2. Students will predict the speed of a heart rate based on the size of an animal.
3. Students will explain what a heartbeat is.

MATERIALS

- ☐ Computer and speaker (or physical metronome)
- ☐ Rhythm of the Heart worksheet
- ☐ Animal Heart Rate Cards
- ☐ Writing utensils
- ☐ Crayons, colored pencils, or markers
- ☐ Laminator (optional) and laminating sheets

LESSON PREPARATION

Before students arrive, make sure to review the lesson materials. Review background information. Gather materials and set up the classroom.

Material preparation:

- Print and laminate Animal Heartbeats cards or prepare to show them on a screen.
- Pull up an online metronome, like [www.musicca.com/metronome.](www.musicca.com/metronome)
- Print one Rhythm of the Heart worksheet per student.

BACKGROUND INFORMATION

Pulse: The number of times your heart beats per minute, measured by feeling the expansion of an artery

Heart rate: The number of times your heart beats per minute

Heartbeat: One pump of your heart

Tempo: The speed of music, often measured in bpm with a metronome

BPM: Beats per minute

PROCEDURE

ANTICIPATORY SET

1. Ask students to place a hand on their chest. What do they feel? They should feel their heartbeat! This is their heart squeezing each time it pumps blood through their body.
2. Have students stand up and ensure they have enough space to reach their arms out without touching anyone. Then do 30 jumping jacks, counting aloud as a group.
3. Encourage students to put a hand on their chest again. What do they notice? Is their heart beating faster or slower?
4. Allow a few student volunteers to lead the group through a 60 second workout. After the mini-workout, students should discuss what they notice about their heart rates.

EDUCATOR TIP:
If any students are having trouble feeling their heartbeat at first, that's okay. After physical activity it will become more noticeable, so have them try again in step two.

DIFFERENTIATION TIP:
Students with mobility differences can raise their heart rate by moving any part of their bodies. For example, a student in a wheelchair could wave their arms to do a partial jumping jacks or raise and lower a book.

ACTIVITY

1. Explain to students, "Your heart is a muscle, pumping blood throughout your body all day, every day. Blood enters your heart on the right side, where it is pumped to the lungs. In the lungs, it drops off carbon dioxide for you to breathe out and picks up oxygen. The re-oxygenated blood enters the heart again, this time on the left side, where it is pumped back out through your body. This blood brings the oxygen, nutrients, and disease-fighting white blood cells to the rest of your body."

2. Share the song, "Thump, Thump, Thump My Heart" (page 19 of this guide) to the tune of "Row, Row, Row Your Boat" and encourage students to sing along.

   Thump, thump, thump my heart
   Beats in my chest.
   A muscle that pumps
   Blood to my body
   So I can play and rest.

EDUCATOR TIP:
The online metronome does not go fast enough for the squirrel or hamster. Set the metronome to be as fast as possible and have the group attempt to sing the song at that speed. Tell students that squirrel and hamster heartbeats are even faster than that!

3. Pull up the online metronome at www.musicca.com metronome. Set the metronome to 80 bpm. Clap along to the beat with the students. Explain that this is the average resting heart rate for an adult human. Each time they clap their hands they're representing a heart squeezing and pumping blood through the body. Sing the "Thump, Thump, Thump My Heart" song to this tempo.

4. Tell students that all animals have heartbeats, but the speed can be very different. Display the Animal Heart Rate cards, one at a time (pages 21–26 of this guide). Change the metronome to match each card and sing the song at that tempo with the group. After a few animals, ask students if they're noticing any patterns. Can they guess if an animal's heartbeat will be faster or slower? (Hint: Think about the size of the animals).

5. Pass out Rhythm of the Heart worksheets (page 20 of this guide). Tell students to choose one animal they learned about during the lesson that had a slow heartbeat. They will write that animal's name in the first box and draw it. Then they will repeat this with an animal that has a fast heartbeat in the second box.

WRAP-UP

Review and Discussion Questions:

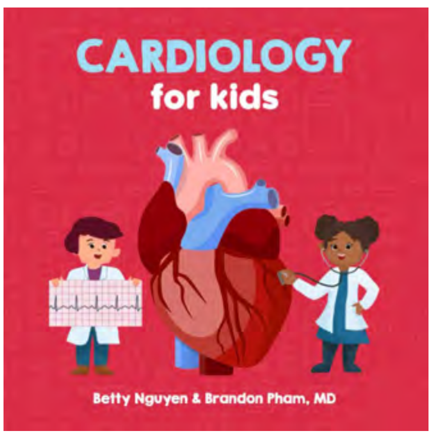
What is a heartbeat?

Do heart rates get faster or slower when we exercise? Why?

Do larger animals tend to have faster or slower heart rates? Why?

Since your heart is a muscle, how can you exercise it to make it healthier?

ADDITIONAL LEARNING



READ

Read about the heart and diseases that cardiologists, doctors who are heart experts, treat with ***Cardiology for Kids*** by Betty Nguyen & Brandom Pham, MD.

WATCH

Test students' knowledge of heart facts with the American Heart Association by watching **"Kids Heart Challenge Heart Facts."**

DO

Encourage students to guess the heart rate of their favorite animal, based on the animals' heart rates they learned about today. Do they think it will be fast or slow? Encourage them to look up the animal's heart rate with an adult at home and teach their adult the "Thump, Thump, Thump My Heart" song.

Thump, Thump, Thump My Heart

To the tune of Row, Row, Row Your Boat

Thump, thump, thump my heart

Beats in my chest.

A muscle that pumps

Blood to my body

So I can play and rest.

Rhythm of the Heart

Choose two animals to compare. Draw the animals.

A ________________________________ has a slow heartbeat.

A ________________________________ has a fast heartbeat.

Name ________________________________

Animal Heart Rate Card 1

Cat – 150 BPM

Animal Heart Rate Card 2

Hamster – 450 BPM

Animal Heart Rate Card 3

Elephant – 30 BPM

Animal Heart Rate Card 4

Tiger – 70 BPM

Animal Heart Rate Card 5

Squirrel – 300 BPM

Animal Heart Rate Card 6

Cow – 60 BPM

AI Emotions

Total time to complete activity: 45 minutes

BIG IDEA

In this social emotional learning lesson, students explore the concepts of emotions and artificial intelligence. All humans have emotions. There are patterns in how we express emotions but also differences. Artificial intelligence functions by learning patterns.

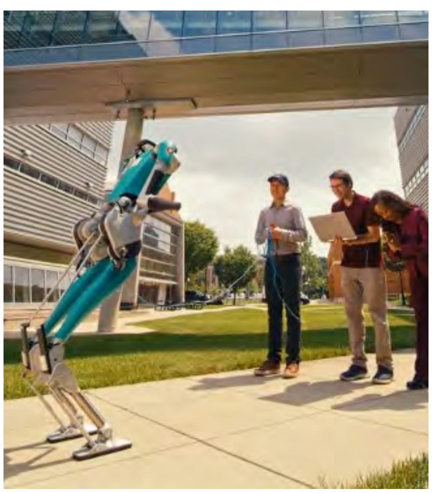
NGSS STANDARDS

K-2-ETS1-1
Ask questions, make observations, and gather information about a situation people want to change to define a simple problem that can be solved through the development of a new or improved object or tool.

K-2-ETS1-2
Develop a simple sketch, drawing, or physical model to illustrate how the shape of an object helps it function as needed to solve a given problem.

IN THE FILM

In *Superhuman Body*, we meet Dr. Ayanna Howard. She is a roboticist who engineers a wide variety of robots. One of these robots is the NAO robot. In the movie, children practice their motor skills by copying it. This robot is unique because it can also read and display emotions. In this lesson, students learn more about their own emotions and how robots with AI, like NAO, work.



OBJECTIVES

1. Students will identify emotions and how they're expressed.
2. Students will demonstrate how AI learns by sorting pictures of emotional expressions.

AI Emotions

MATERIALS

- ☐ Board or chart paper
- ☐ Smart board or projector
- ☐ AI Emotion Sorting Cards (1 set per group)
- ☐ Printer
- ☐ White paper
- ☐ Scissors
- ☐ Paper clips or rubber bands
- ☐ Laminator (optional) and laminating sheets

LESSON PREPARATION

Before students arrive, make sure to review the lesson materials. Review background information. Gather materials and set up the classroom.

Material preparation:

- On the board, or chart paper, write the heading, "Today, I am feeling…"
- Prepare the video, "NAO Robot speaking with a child" by Axentel Robotics to begin at 6:25.
- Prepare one set of AI Emotion Sorting Cards per group of 3-5 students.

  Print the AI Emotion Sorting Cards.

  Laminate the pages (optional).

  Cut on the lines.

  Shuffle the cards.

  Group with paperclips or rubber bands.

BACKGROUND INFORMATION

Artificial Intelligence: Programming machines to problem-solve, make decisions, or learn, similar to how humans think, by inputting large amounts of data.

Emotions: Mental states impacted by one's situation or physiology, often with their own physiological and behavioral reactions.

PROCEDURE
ANTICIPATORY SET

1. If possible, have students sit in a circle, so they can all see each other's faces. Use a talking piece to give each student a chance to share without being interrupted. Ask students to answer the question, "What emotion are you feeling today?"

2. Model answering the question yourself with the sentence starter, "Today, I am feeling…" and write your answer under the heading, then pass the talking piece to the next student in the circle.

3. As students share, add any new answers to the chart paper, or allow students to add their answers.

4. Once all students have shared how they're feeling, encourage students to look at the list of feelings they've created. Reread the list for the class. Ask students if they know any other emotions that could be added to the list. Write any additional suggestions.

ACTIVITY
EMOTION SIMON SAYS

1. Tell students we are going to play a quick game of Simon Says. During this game, learners can stand up if they keep their hands and feet to themselves. The teacher will be Simon and give directions to show an emotion from the list saying, "Simon says, act like you're ______."

   However, they need to listen carefully, because if you leave off the phrase "Simon says," learners should not show the emotion! If the group is familiar with this game, consider letting students take a turn as Simon.

2. Encourage students to think about how they displayed the emotions Simon said. How could they tell their classmates were showing the correct emotion? Possible answers may include:

   - Facial expressions like furrowed brows (worried or upset) or a smile (happy)
   - Body language like jumping (excited) or clenching fists (angry or frustrated)
   - Vocalizations like crying (sad) or growling (angry)

AI Emotions

ARTIFICIAL INTELLIGENCE

1. Tell students to pay close attention to this robot and notice what programmers taught it to do. Play "NAO Robot speaking with a child" by Axentel Robotics at from 6:25-7:00.

2. Ask students what they noticed. Share that this robot by Dr. Ayanna Howard was designed to show emotions and notice the emotions of the human it's interacting with. Do you have any ideas for how programmers could teach robots to interpret human emotions?

EDUCATOR TIP:
To scale back this activity, limit the cards to two or three emotions (e.g., happy and sad).

Make it more open-ended and challenging by removing the category titles and allowing students to determine their own categories.

3. Tell students that we're going to do an activity that is similar to how programmers teach robots. Put students in groups of 3-5. Pass out a set of AI Emotion Sorting Cards to each group. Read the emotion categories as a group: happy, sad, excited, and angry. Tap out the sounds and syllables of each word. Explain that students will look at the faces and separate them into groups based on what emotion they seem to be showing.

4. Give students time to work.

5. Once groups have finished sorting, discuss their results. Did all of the tables sort the same way? Were there any differing interpretations?

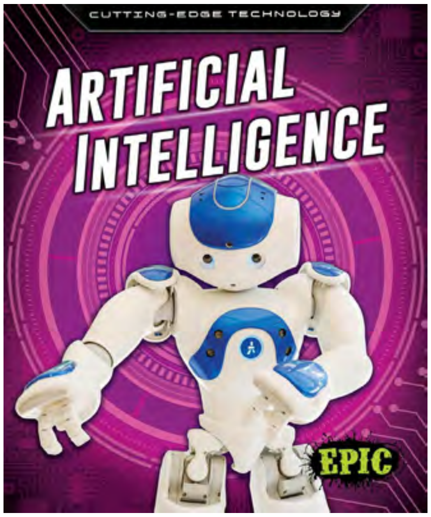
WRAP-UP

Review and Discussion Questions:
Explain that artificial intelligence works because programmers give data to robots. If a programmer was teaching a robot to tell a happy face from a sad face, they would give the robot lots of pictures of happy faces and tell it that those faces are happy. The robot would notice all of the similarities between happy faces and be able to tell that a new happy face belongs in that group and not with the sad faces.

Did any tables sort the pictures differently? Has anyone ever been happy, but not smiling? Or sad, but put on a happy face and pretended they felt okay?

There are similarities to how humans show emotions, but there are also differences and that's okay! Even though we can use artificial intelligence to train robots, because humans are unique, robots won't interpret emotions correctly all the time, just like we'll sometimes interpret our friends' emotions incorrectly. This is why it's important to use our words to share our emotions and check on our friends.

ADDITIONAL LEARNING



READ

Learn more about artificial intelligence by reading ***Artificial Intelligence*** by Betsy Rathburn.

Expand your social-emotional learning by reading ***The Boy with Big, Big Feelings*** by Britney Winn Lee.

WATCH

Explore artificial intelligence, and the many ways people use it, by watching **"What is ARTIFICIAL INTELLIGENCE?" - Argo's World | STEM for Kids (Science, Tech, Engineering, Math).**

DO

What do you do when you're experiencing a feeling you don't like, such as anger or frustration? Do you have strategies to help you feel better? Try taking a deep breath in and blowing out slowly, like you're trying to blow on birthday candles without putting them out. When you've pushed all of the air out of your lungs, try it again. Do this a few times. Do you feel different?

When you get home tonight, observe the body language of the other members of your household. If you can't tell what they're feeling, ask how they're doing. If any household members are feeling difficult emotions, like sadness or frustration, is there anything you can do to help them and cheer them up?

Explore more ways you and your friends, family, or classmates express emotions by playing a charades-style game! Adults, or all players, will write scenarios on slips of paper. For players who can't read, an adult can whisper a scenario into their ear. Players will take turns acting out the emotion they would feel in that scenario. (For example: "You score a touchdown in your football game.") Then the group will guess the emotion the actor is demonstrating. Once they get it right, the actor can explain the scenario and other players are offered the opportunity to share if they would have the same emotion or express it in a different way.

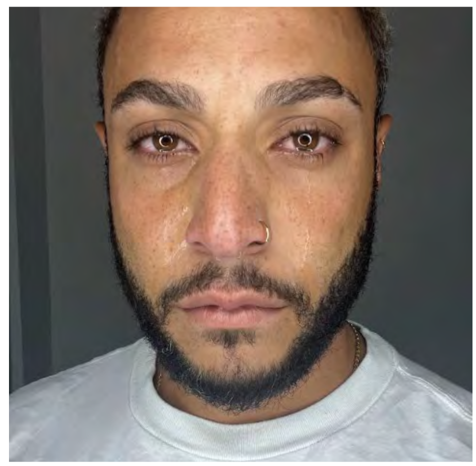
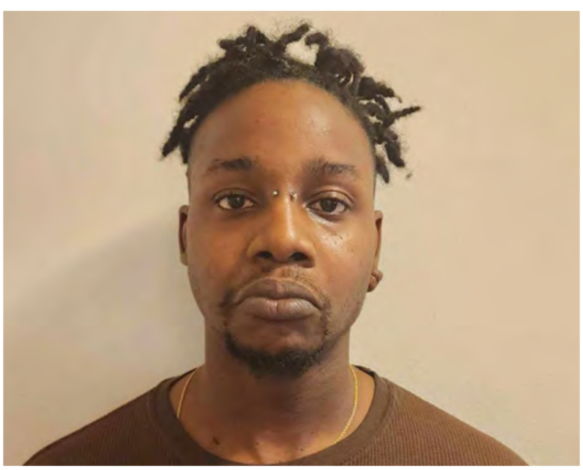
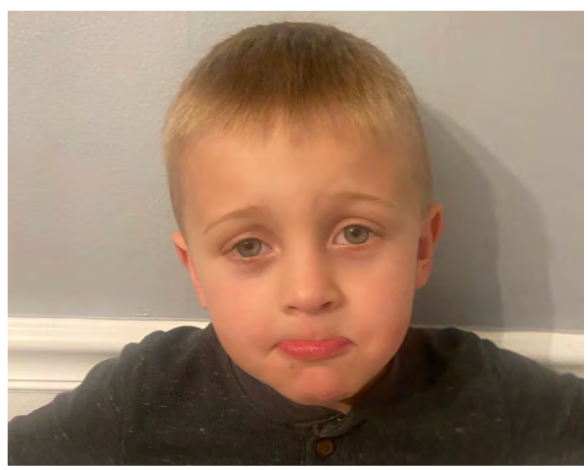
AI Emotions Sorting Cards

HAPPY	
	
	

AI Emotions Sorting Cards

AI Emotions Sorting Cards

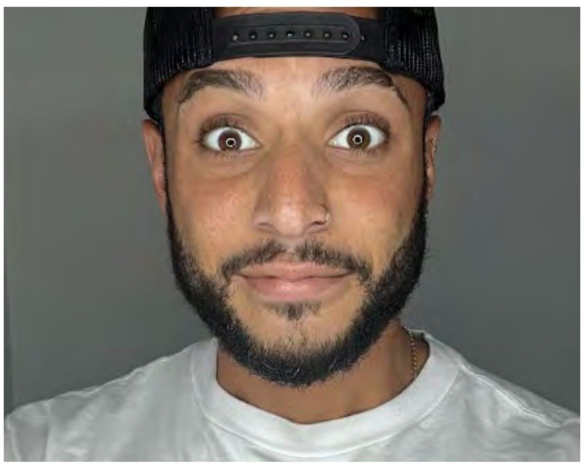
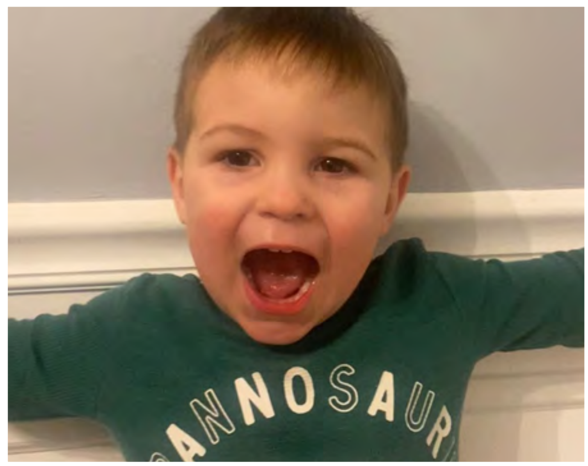
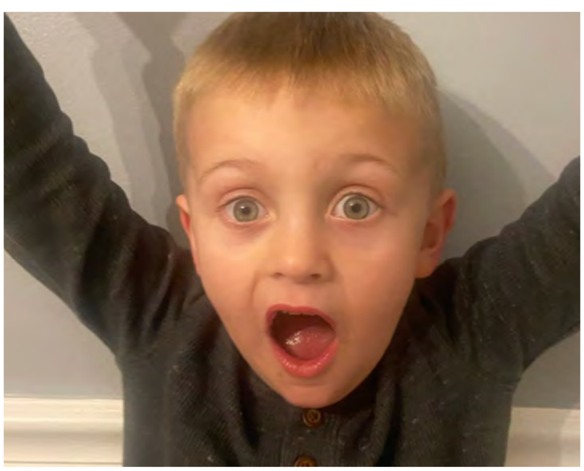
SAD	
	
	

AI Emotions Sorting Cards



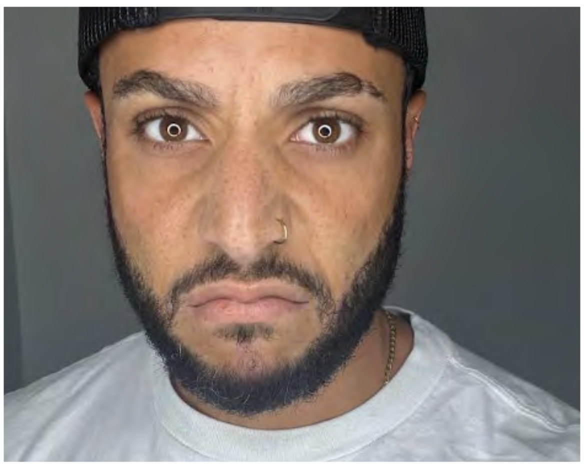
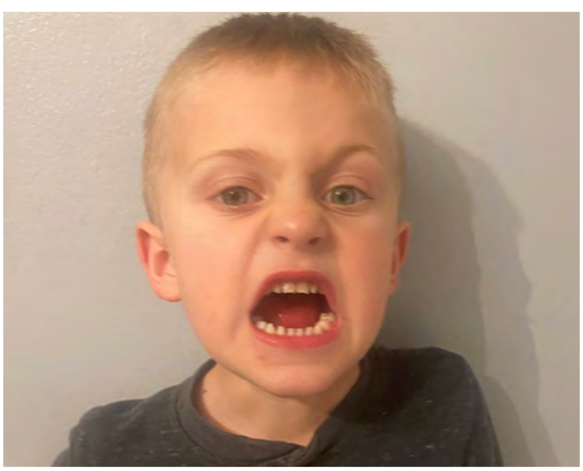
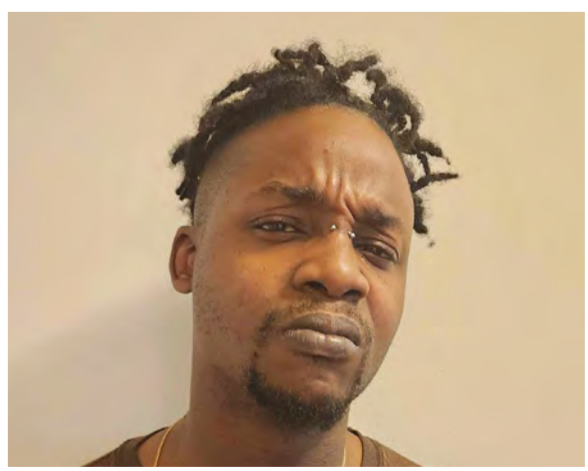



AI Emotions Sorting Cards

EXCITED	
	
	

AI Emotions Sorting Cards

AI Emotions Sorting Cards

ANGRY	
	
	

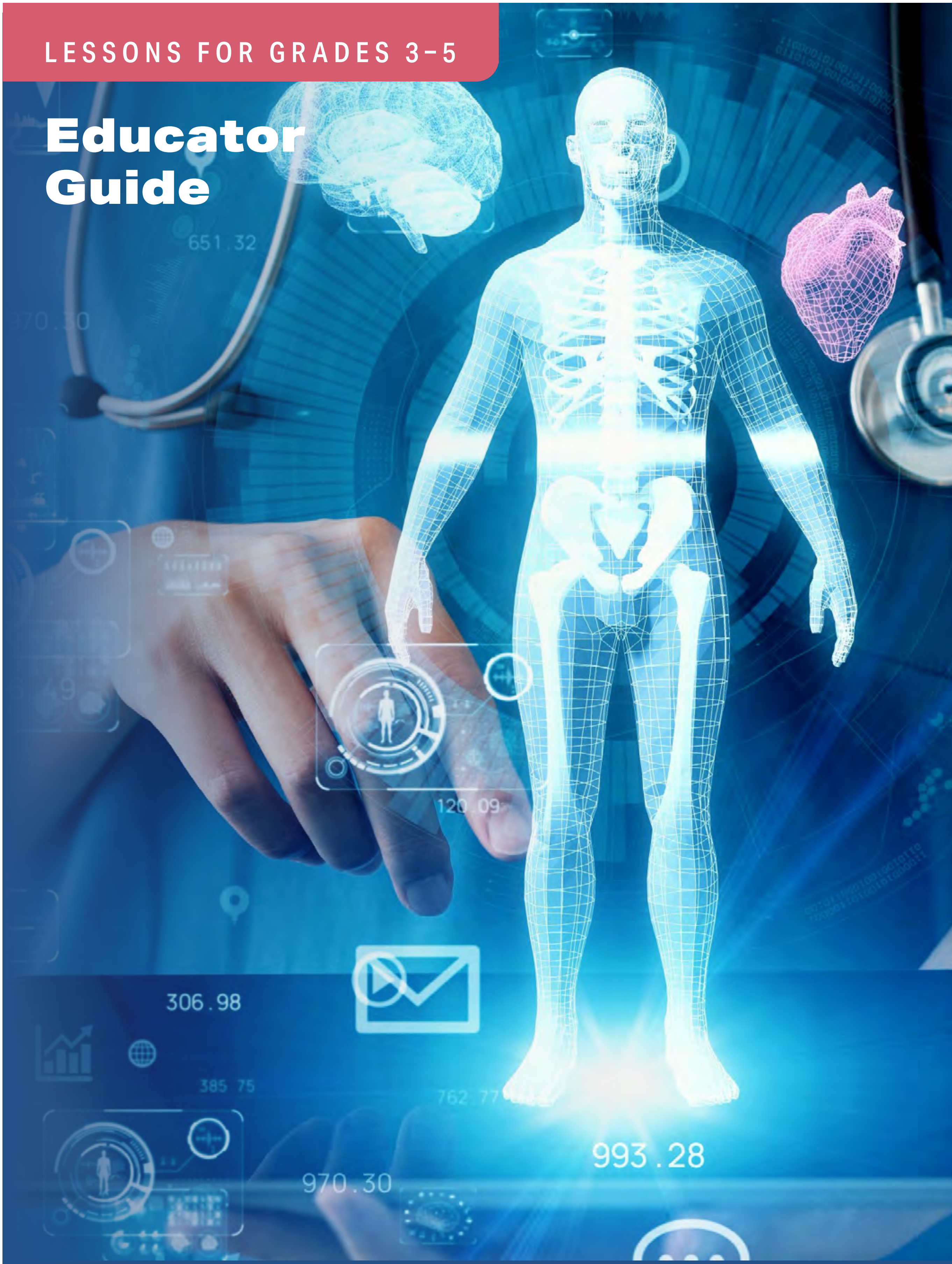
AI Emotions Sorting Cards






LESSONS FOR GRADES 3–5

Educator Guide



T-Cell Receptor Puzzle

Total time to complete activity: 45 minutes

BIG IDEA

Students will model how T-cells attach to an infection by creating a puzzle.

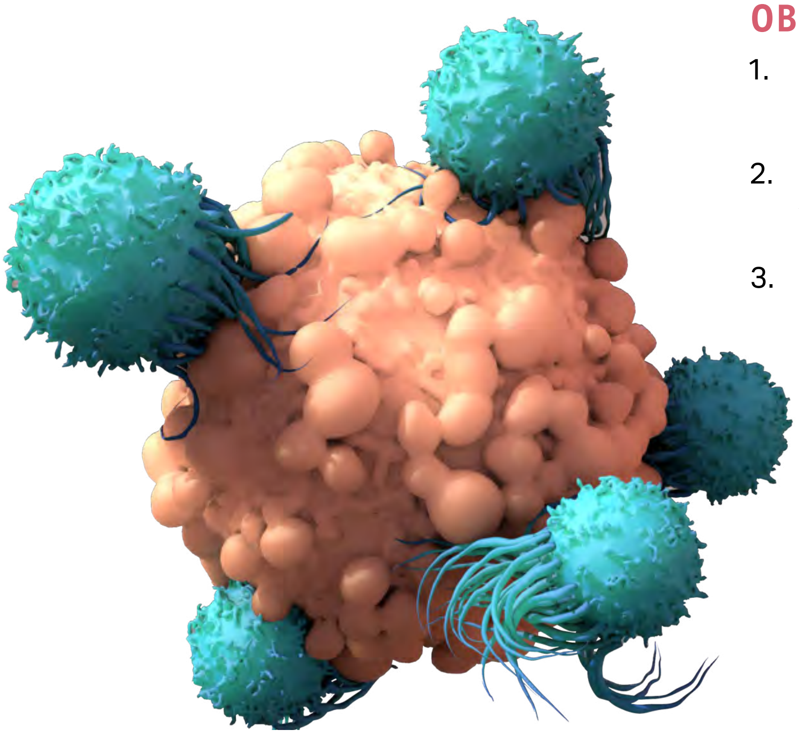
NGSS STANDARDS

4-LS1-A

Construct an argument that plants and animals have internal and external structures that function to support survival, growth, behavior, and reproduction.

IN THE FILM

In *Superhuman Body,* we learn how Dr. Carl June developed new cancer therapy that uses T-cells, a type of white blood cell that fights infection. T-cells work by learning what certain infectious cells look like and attaching to them. In this lesson, students explore how white blood cells, and more specifically T-cells, help them stay healthy.



OBJECTIVES

1. Students will identify strategies for staying healthy.
2. Students will demonstrate the function of white blood cells by participating in a game.
3. Students will model how T-cells attach to an infection by creating a puzzle.

T-Cell Receptor Puzzle

MATERIALS

- ☐ Board or chart paper
- ☐ Smart board or projector
- ☐ T-Cell Puzzle template
- ☐ Cardstock
- ☐ Plastic bags
- ☐ Markers
- ☐ Scissors
- ☐ T-Cell Photo
- ☐ Germ Invader Cards
- ☐ Hole punch
- ☐ String

LESSON PREPARATION

Before students arrive, make sure to review the lesson materials. Review background information. Gather materials and set up the classroom.

Determine a location to play Germ Invaders. Students will need an open area to run across for this game. A field or gym is ideal.

Material preparation:

- On the board, or chart paper, write the heading, "We stay healthy by…"
- Print and cut Germ Invader cards double-sided. Ensure one side shows a white blood cell and the opposite shows a germ. Punch two holes in the top of each card. Thread the string through and tie as a necklace.
- Print one T-Cell Puzzle template on cardstock for each learner.
- Color and cut an example T-Cell Puzzle.

BACKGROUND INFORMATION

Immune System: The system of organs, cells, proteins, and chemicals that defend the body from infection.

White Blood Cells: A type of blood cell that fights disease and infection.

T-Cells: A type of white blood cell that recognizes specific invading cells and destroys them.

Germ: A common way to refer to bacteria, viruses, protozoa, or fungi that can make people sick.

PROCEDURE
ANTICIPATORY SET

1. Tell students that today we're going to talk about how we stay healthy. Invite students to turn to a partner and discuss ways they keep themselves and the people around them healthy.
2. After students have shared their ideas, pull the group back together and invite learners to share what they discussed. Possible answers:

- Getting enough sleep
- Washing our hands
- Sneezing into our elbows
- Sanitizing frequently-touched surfaces (desks, doorknobs, etc.)
- Exercising regularly
- Eating nutrient-dense foods
- Staying home when we're sick
- Washing our hands after blowing our noses
- Throwing away expired food
- Drinking clean water
- Going to the doctor and getting recommended vaccines

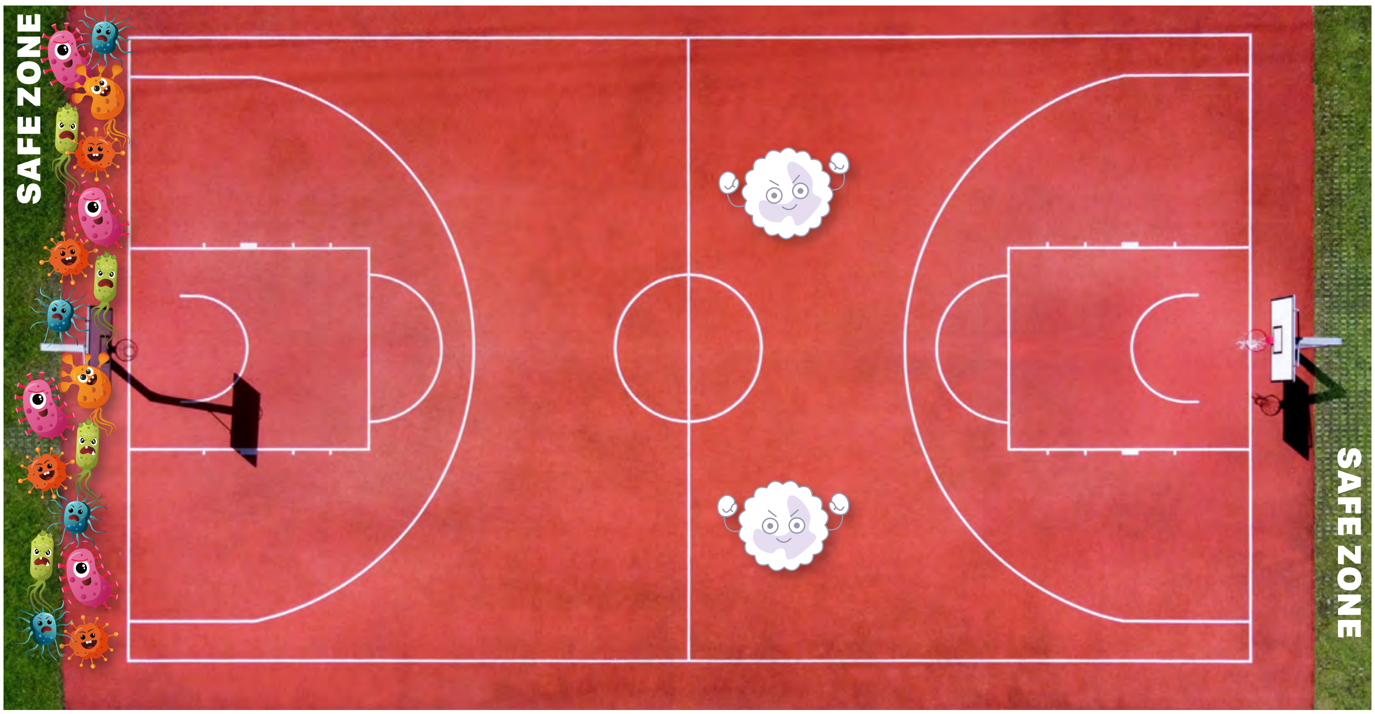
3. As students share, add any new answers to the list, or allow students to add their answers.
4. Explain that now we're going to learn why these actions help keep us healthy by exploring what is happening inside our bodies when we get sick.

EDUCATOR NOTE:
There are many common misconceptions about how people get sick. For example, one common myth is that being in the rain will make you sick. Although rain can't give you an illness, putting your body under stress from being cold and wet for a prolonged period of time could make it more difficult for your body to fight off infection. If you come across any ideas you're unsure of, use this as a teaching moment to model searching for quality sources to verify if something is true.

ACTIVITY
GERM INVADERS GAME

Ask if anyone has played the game Sharks and Minnows. Explain that in the classic Sharks and Minnows game, the minnows' goal is to get across the area without being "eaten" (tagged). The sharks' goal is "eat" (tag) the minnows and stop them from reaching the other side.

This is similar to how our **immune systems** function. Germs are bacteria, viruses, protozoa, and fungi that get in our bodies and make us sick. Sharks are like white blood cells. **White blood cells'** job is to attack invading cells and destroy them before they make us sick. The **germs** are trying to evade the white blood cells. When your body realizes you're sick, it starts producing more white blood cells to destroy the germs.



1. Ensure the group is in a safe place to run. All players will receive a Germ Invaders necklace. Designate lines marking "safe zones" on either end of the space. Explain the rules:

- White blood cells must start behind the middle line.
- Germs must start in the safe zone on one designated end.
- When the teacher announces "Germs, attack!" germs must leave the safe zone and white blood cells may move anywhere between the safe zones.

  Player goals:
  - Germs: Evade white blood cells and reach the opposite safe zone without being tagged.
  - White blood cells: Gently tag the germs to neutralize them before they reach the safe zone.

NOTE:
In your body, germs do not turn into white blood cells. They are destroyed. However, white blood cells multiply rapidly when you're sick so that they can overtake the infection.

GERM INVADERS GAME (continued)

If a germ is tagged, they have been destroyed and must sit down in place until the rest of the germs reach the safe zone. When the next round begins, they may flip their necklace and rejoin the game as a white blood cell.

2. Identify who will begin as the white blood cells. There should be a ratio of about 1 white blood cell to 9 germs. Show them their starting point in between the safe zones and ask them to wear their necklace so that it shows the white blood cell. Remind them they will be trying to gently tag as many germs as they can. Have the rest of the students start in one safe zone.

Explain that they are the germs. Make sure they know where the safe zone is that they're running to and to sit down if they're tagged.

3. Begin the game by stating a way germs could get inside a human body and releasing the germs with the phrase, "Germs, attack!" Examples:

- You skin your knee on the playground and don't wash out the dirt.
- You drink water from a puddle.
- Your sister sneezes on you.
- You eat a chip off the floor.
- You touch a germy doorknob then rub your eyes.
- You drink expired milk.
- You put your mouth on the drinking fountain.

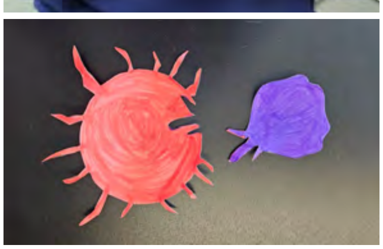
4. Once the germs who evaded white blood cells have reached the other safe zone, ensure the tagged germs rejoin as white blood cells, flipping their necklaces. Remind them that in the body, germs don't become white blood cells. They are just destroyed; however, your body does make more and more white blood cells once it realizes you're sick. Explain that now the germs will try to make it back to the safe zone where they started and evade these extra white blood cells. Continue the game with another example of how germs can get in the body and the release phrase, "Germs, attack!"

5. Once all of the germs have been eliminated, congratulate the immune system for doing its job.

6. If time allows, restart the game, giving the last remaining germs a turn to start as the white blood cells.

T-CELL PUZZLE

1. Think about the game we just played. If you eat a snack without washing your hands, and germs get inside your body, what will happen? We now know that white blood cells will attack the germs.
2. Explain to students that if these first white blood cells can't destroy the invaders, your body will focus on making a specific type of white blood cell called T-cells. T-cells are specialized to neutralize specific types of infections.
3. For example, if you've ever had chicken pox, your body created T-cells that recognize and destroy chicken pox germs. Most people only get chicken pox once because if chicken pox germs get in their body again, those T-cells remember what it is, and kill it quickly. In fact, most of us have probably never had chicken pox because scientists made a vaccine that teaches your body to make chicken-pox T-cells without you ever getting sick.
4. T-cells attach to their specific infection like a puzzle piece. They're great at neutralizing the germ they were made for, but they won't be effective against other types of germs.
5. Tell students that we're going to make T-cell puzzles. Then we'll mix up the pieces and see if we can match the germs to their T-cell. Show your T-cell puzzle example. Explain how you colored the germ and T-cell, and then cut them so they can attach like puzzle pieces. Point out that the cut separating the germ and T-cell is unique so other puzzle pieces won't fit.



6. Pass out the T-cell templates and markers. Give students time to color.
7. Once students begin to finish coloring, pass out the scissors and allow students to cut out the shapes and create the puzzle. The infection and T-cell shapes can be customized by cutting off the microvilli (the T-Cell's fingerlike protrusions) or adding more.
8. Collect all germ puzzle pieces and shuffle them. Allow students to keep their T-cell pieces. Explain that they are going to receive a different students' germ. Their job as a T-cell is to track down their corresponding germ and receive the matching puzzle piece. Once they've done this, and the T-cell that matches with their germ has found and taken their puzzle piece, they can sit down. The goal is to be the first sitting down!

WRAP-UP

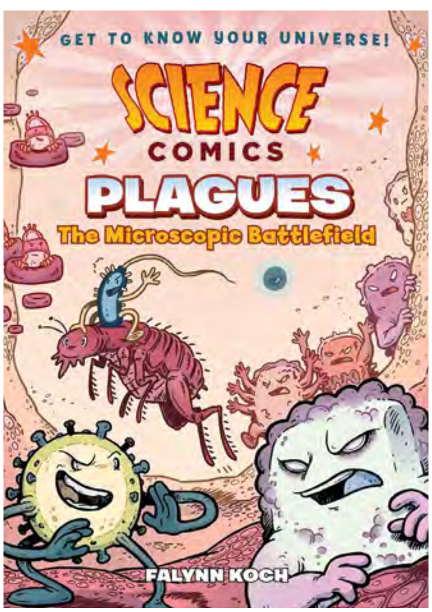
Review and Discussion Questions:

Have students look at the "I Stay Healthy By…" list again. *Knowing what we've learned about the immune system, why might these actions keep us healthy?*

Possible answers:

1. These actions keep bacteria and viruses from getting into our bodies:
   - Washing our hands
   - Sneezing into our elbows
   - Sanitizing frequently touched surfaces (desks, doorknobs, etc.)
   - Staying home when we're sick
   - Washing our hands after blowing our noses
   - Throwing away expired food
   - Drinking clean water
2. These actions give our white blood cells the energy they need to reproduce and destroy invaders:
   - Getting enough sleep
   - Eating nutrient-dense foods
   - Exercising regularly
3. Going to the doctor and getting recommended vaccines allow our bodies to create T-cells without getting sick.

ADDITIONAL LEARNING



READ

Explore the immune system and some of the worst diseases in history with the graphic novel ***Science Comics Plagues: The Microscopic Battlefield*** by Falynn Koch.

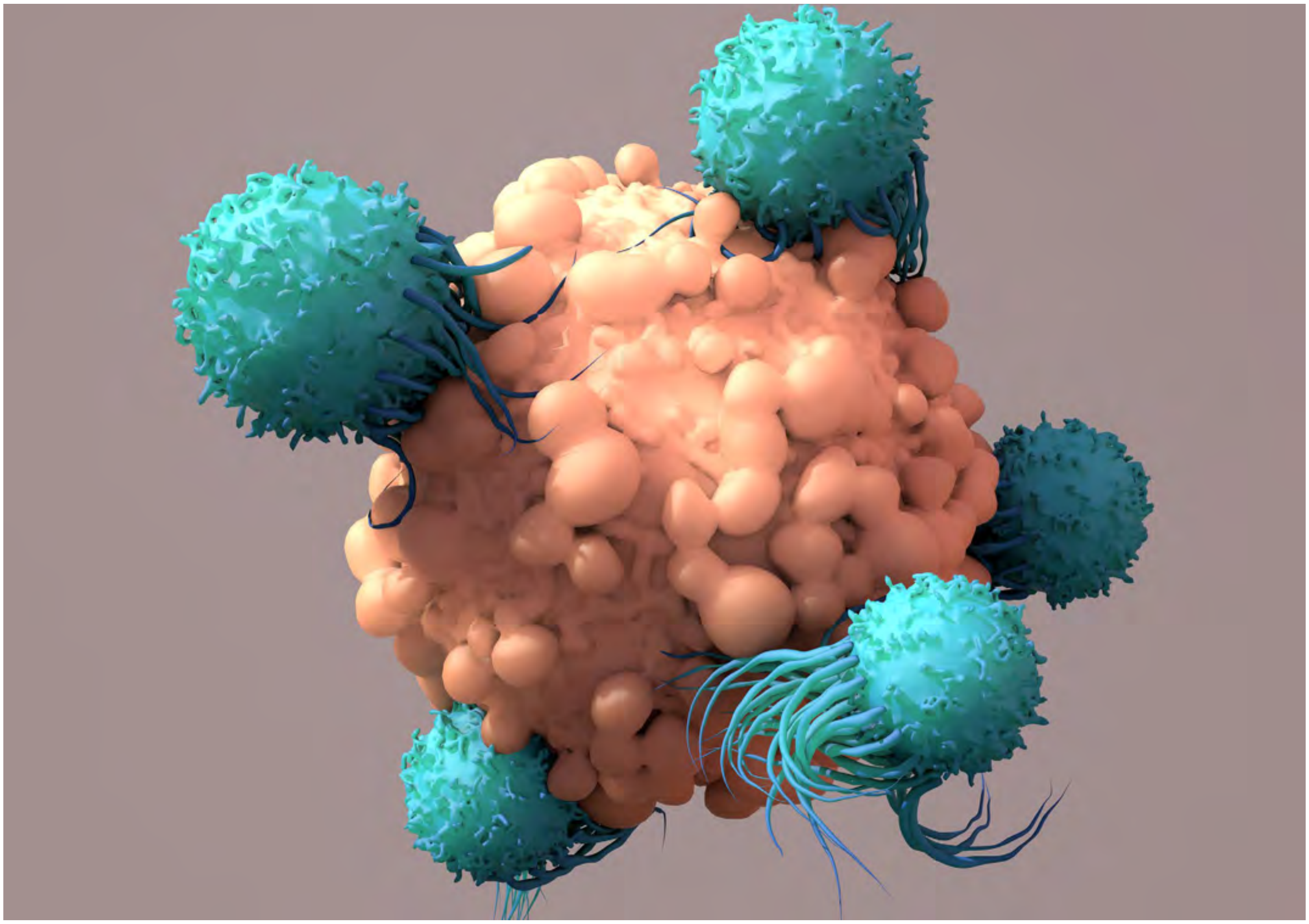
WATCH

Learn more about your immune system with the video, **"How Your Immune System Works" by Neumours KidsHealth.**

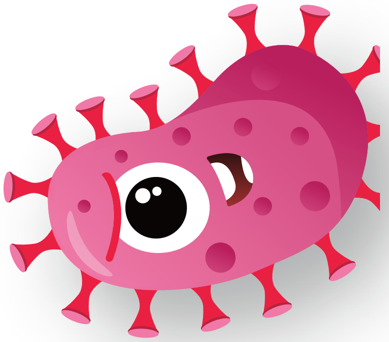
DO

What can you do to help your immune system? Are there habits you should start or stop? Make a list of actions you can take to keep yourself healthy.

Printable image to share with students: T-cell attaching to an infection

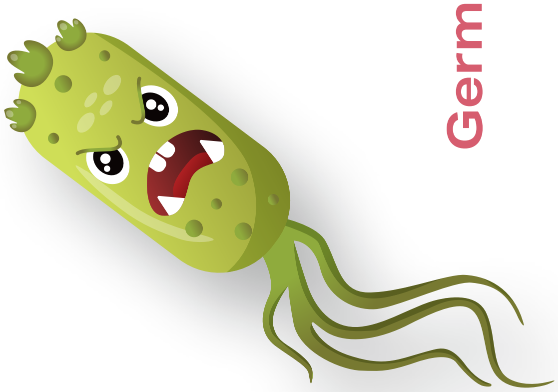


Germ Invader Game Cards



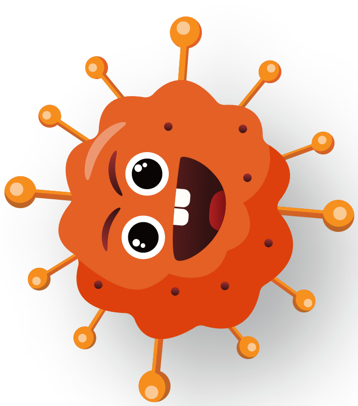
Germ

White Blood Cell



Germ

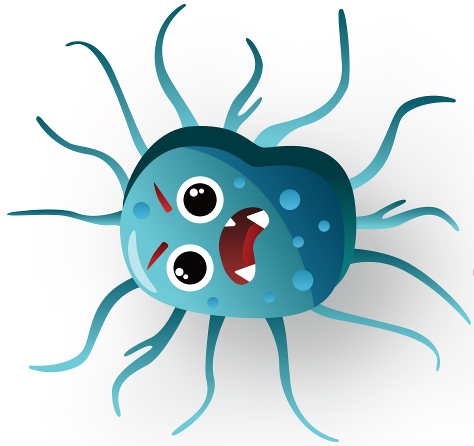
White Blood Cell



Germ

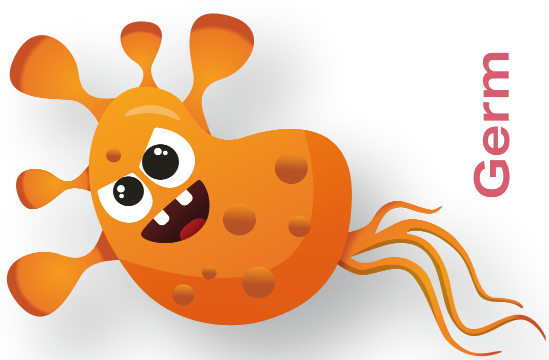
White Blood Cell

Germ Invader Game Cards



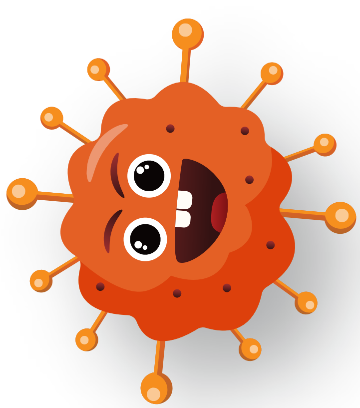
Germ

White Blood Cell



Germ

White Blood Cell



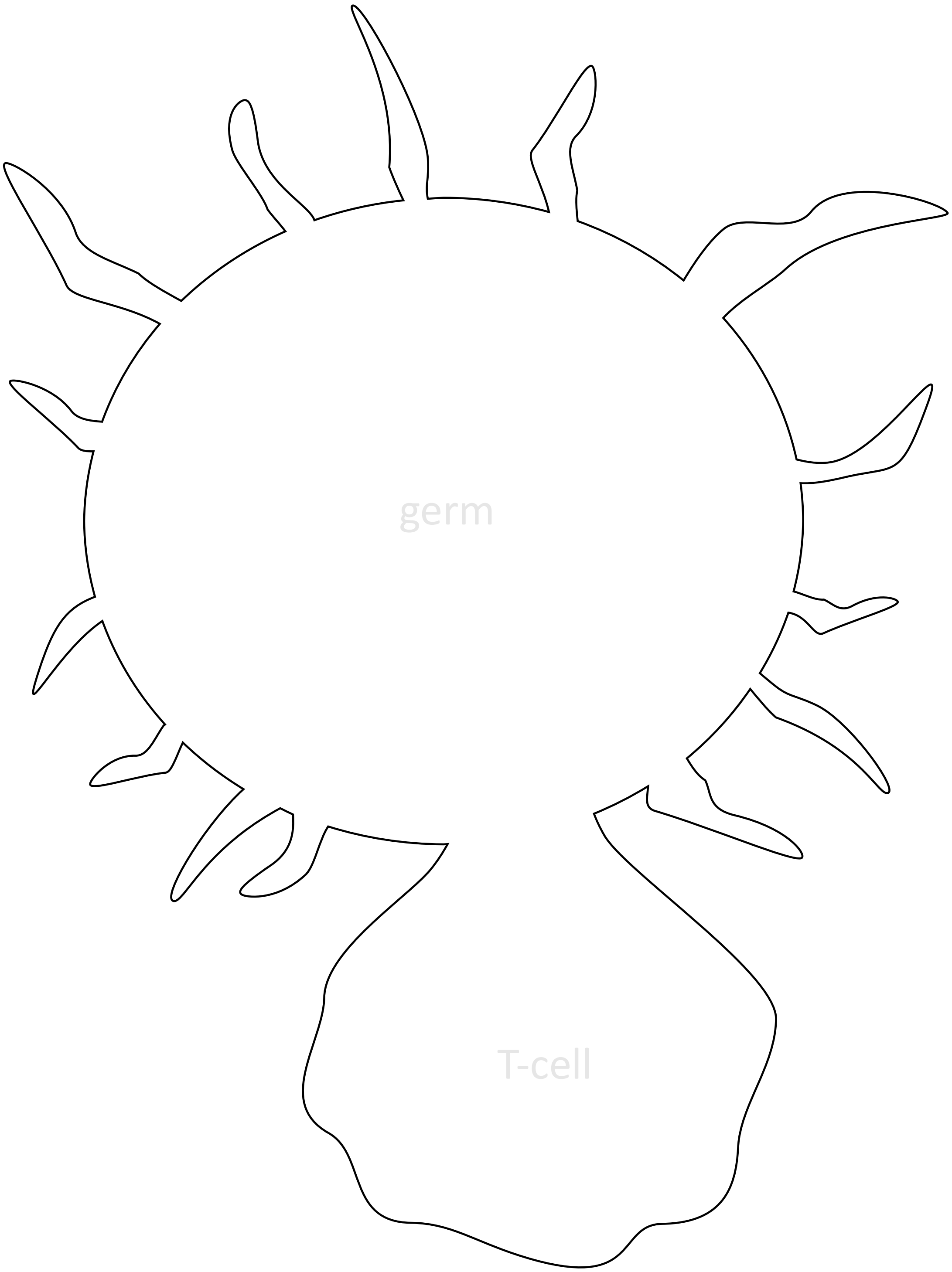
Germ

White Blood Cell

T-Cell Receptor Puzzle

T-cells are specialized white blood cells that recognize and attack specific infections. T-cells can only attach to the specific infection they were designed to fight.

DIRECTIONS: Color your T-cell and infection. Then cut them out. Create a unique cut between your T-cell and infection so they fit together like puzzle pieces.



Heart Stations

Total time to complete activity: 45 minutes

BIG IDEA

In this interdisciplinary experience, students rotate through stations to learn about the human heart while strengthening English Language Arts, math, and physical education skills.

NGSS STANDARDS

4-LS1-1

Construct an argument that plants and animals have internal and external structures that function to support survival, growth, behavior, and reproduction.

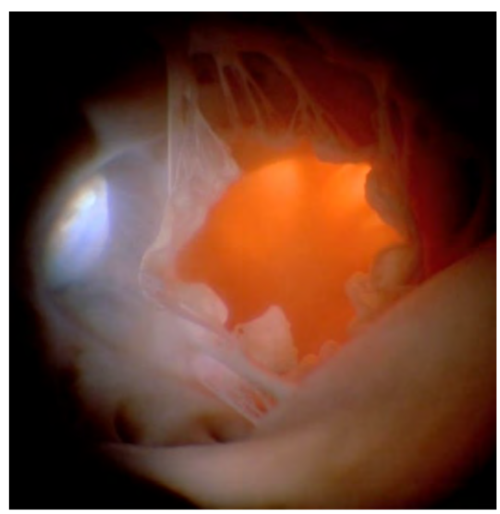
IN THE FILM

In *Superhuman Body,* we learn how important heart function is for the human body when James Garrett wasn't able to keep up with his normal, active lifestyle. Doctors diagnosed him with aortic stenosis, which means that not enough blood was getting pumped to the rest of his muscles and organs. Surgeons installed a human-engineered valve called the SAPIEN 3 to help his heart pump blood efficiently again.

James Garrett visiting Edwards Lifesciences' lab

OBJECTIVES

1. Station 1: Students will calculate their pulse.
2. Station 2: Students will demonstrate how much blood the heart pumps in one minute.
3. Station 3: Students will plan a nonfiction 5-sentence paragraph with a topic sentence, content, and conclusion.
4. Station 4: Students will practice heart-healthy exercises.



Open heart valve

MATERIALS

NOTE: If this lesson can be facilitated outside, or in an area with easy cleanup, exchange red pom poms for water in station 2 to make the activity more similar to the heart and extra engaging!

Station 1

- ☐ Play-Doh Pulse station sign
- ☐ Play-Doh Pulse worksheet
- ☐ Play-Doh
- ☐ Straws
- ☐ Timer
- ☐ Calculators (optional)

Station 2

- ☐ Blood Pumping Challenge station sign
- ☐ Two 1-gallon buckets
- ☐ Red pom poms
- ☐ 1/3 C. measuring cup
- ☐ Timer
- ☐ Larger bin to place buckets in to contain spilled pom poms (optional)

Station 3

- ☐ All about…the heart! station sign
- ☐ Paragraph planning graphic organizer printable (1 per student)
- ☐ Final draft printable (1 per student)
- ☐ Pencils
- ☐ Colored pencils (optional)
- ☐ Grade level appropriate books on the heart and human body. See suggestions to the right.

Station 3 (continued)

The Science of the Heart and Circulatory System by Richard and Louise Spilsbury

The Heart: All about Our Circulatory System and More! by Seymour Simon

Q&A About the Human Body by Nancy Dickmann

Utterly Amazing Human Body by Robert Winston

Peeking Under Your Skin by Karen Latchana Kenney

The Magic School Bus: Inside the Human Body by Joanna Cole and Bruce Degen

Human Body DK Find Out by DK

Wow in the World: The How and Wow of the Human Body by Mindy Thomas and Guy Raz

The Body Book: Blood, Bones, Guts, and More by DK and Bipasha Choudhury

Station 4

- ☐ Heart Workout station sign
- ☐ 1 die
- ☐ Bingo cards (6)
- ☐ Laminator (optional) and laminating sheets
- ☐ Coins or chips to use as Bingo markers

EDUCATOR TIP: Often, libraries have a request form. Try requesting books on the heart for your grade level and see what gems they curate for you!

DIFFERENTIATION TIP: Provide audio books or read aloud videos for students who cannot read independently.

Heart Stations

LESSON PREPARATION

Before students arrive, make sure to review the lesson materials. Review background information. Gather materials and set up the classroom.

General Preparation:

- Print table signs and prepare them to be displayed.
- Determine the number of students per group and the number of supplies needed accordingly.

Station 1: Play-Doh Pulse

- Set out station directions table sign, enough Play-Doh for each student in the group to have a one-inch ball, and one straw for each group member.

Station 2: Blood Pumping Challenge

- Fill a one-gallon bucket with red pom poms.
- Set out the station directions table sign, an empty one-gallon bucket, the one-gallon bucket with red pom poms, a stopwatch, and a 1/3 cup measuring cup.

  Optional: Place buckets in a larger bin to contain spilled pom poms.

Station 3: All About…the Heart!

- Set out the station directions table sign, assorted books on the human heart, any technology students are permitted to use for research, paragraph planning graphic organizer, final draft papers, pencils, and colored pencils (optional).

Station 4: Heart Workout

- Print and laminate Bingo cards.
- Set out the station directions table sign, Bingo cards, a die, and a choice of Bingo markers.

BACKGROUND INFORMATION

Heartbeat: One squeeze-and-release of the heart as it pumps blood throughout the body.

Pulse: Regular movement of blood through arteries, typically measured by feeling arteries close to the skin, including the neck and wrist.

Cardiovascular exercise: Movement that increases breathing and raises a person's heartbeat, also called aerobic exercise or cardio. Common examples include running, swimming, and biking.

Oxygenated blood: Blood with a high volume of oxygen found in arteries.

Deoxygenated blood: Blood with a high volume of carbon dioxide found in veins.

PROCEDURE

- Explain to students that they will be rotating through four stations. Students will have 10 minutes at each station. Briefly explain the directions for each table and point out the table signs where they can reference the directions.
- Split students into groups and begin the first 10-minute timer. After the timer goes off, ask students to clean up their stations and rotate to the next station. Then begin another 10-minute timer. Repeat two more times.

ACTIVITY

STATION 1: PLAY-DOH PULSE

Your heart's job is to pump **oxygenated blood** through your body and **deoxygenated blood,** or blood that needs oxygen, to your lungs. The heart circulates, or moves the blood, by squeezing at regular intervals. You can feel your **heartbeat** by resting your hand on your chest. You can also feel the speed at which your heart is pumping by feeling an artery, which transports the blood to your body.

The rate at which blood pumps through your arteries is called your **pulse.** Two of the easiest places to feel an artery are on your wrist and on the side of your neck, under your jaw.

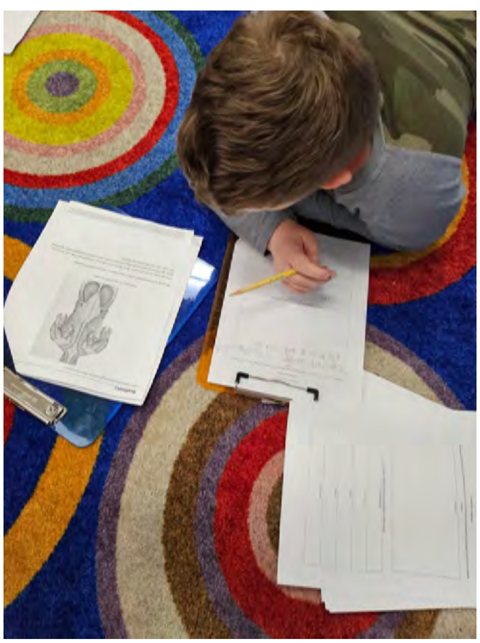
1. Roll Play-Doh into a ball.
2. Stick a straw into the Play-Doh.
3. Rest your hand on the table with your palm facing the ceiling.
4. Place the Play-Doh on your wrist with the straw pointing at the ceiling.
5. Set a 30 second timer and count the number of times the straw moves.
6. Multiply this number by two. This is your pulse!
7. Close your eyes and take 10 slow breaths. Now check your pulse again. Did it change?
8. Run in place for 30 seconds. What is your pulse now?
9. Can you estimate how many times your heart beats in one hour? (Hint: Multiply your pulse by the number of minutes in an hour.)
10. How many times does your heart beat in one day?
11. How many times does your heart beat in one year?

DIFFERENTIATION TIP:
Consider providing calculators for students as needed.

STATION 2: BLOOD PUMPING CHALLENGE

With a single pump, the heart moves about 1/3 cup of blood. For the average adult this will add up to about 1.3 gallons of blood in a single minute. Can your hands keep up?

1. Determine a timekeeper and the first player.
2. When the timekeeper says "Go!" the player will scoop as many pom poms as they can from bucket 1 into bucket 2. If pom poms fall outside of the bin, you may pick them up with your hands and put them back in bucket 1.
3. After one minute has passed, the timekeeper will say "Stop!" and the player will stop scooping. Was the player able to "pump" as well as the heart?
4. Reset the game by putting all of the pom poms in one bucket and restarting the stopwatch. Rotate timekeeper and player responsibilities.
5. Repeat until everyone in the group has had a chance in each role.



STATION 3: ALL ABOUT…THE HEART!

Science writers research science topics and write facts so others can easily understand them. Practice being a science writer by researching and writing an organized, 5-sentence paragraph on the human heart!

1. Do research on the human heart using books and any teacher approved technology. Record your results in the graphic organizer.
2. Use your research to plan a paragraph on the heart.
3. *Optional:* If you have time, write your final draft!

ACTIVITY (continued)

EDUCATOR TIP:
If mobility makes any of these exercises difficult, work with the student to determine alternate exercises. You don't need to use your legs to do cardio. Lifting items or moving your arms can also get your heart rate up!

STATION 4: HEART WORKOUT

Your heart is a muscle. Just like doing push-ups builds stronger arm muscles, doing exercises that get your heart rate up, called **cardiovascular exercise** or cardio, makes your heart stronger. Play Heart Workout Bingo to practice heart healthy activities and give your heart a workout!

1. Choose a Bingo card.
2. Take turns rolling the die and announcing the number to your group.
3. All players will do the exercise that matches the number and mark the corresponding number on your Bingo sheet.
4. Continue taking turns rolling the die, doing the corresponding exercise, and marking your card until a player has four numbers marked in a row. Call out Bingo!
5. If time allows, erase your card, and restart the game.
6. Before moving to the next station, erase your cards to reset for the next group.

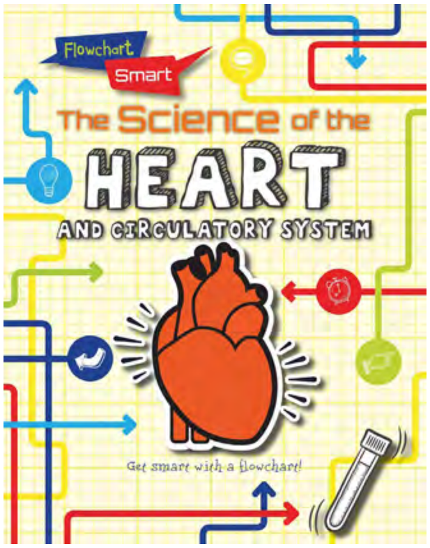
WRAP-UP

Review and Discussion Questions:

Invite students to share what they learned about the heart.

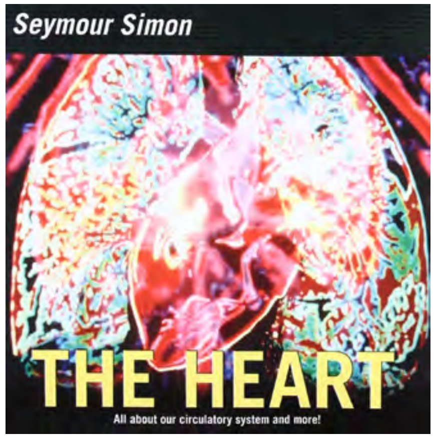
How can they keep their heart healthy?

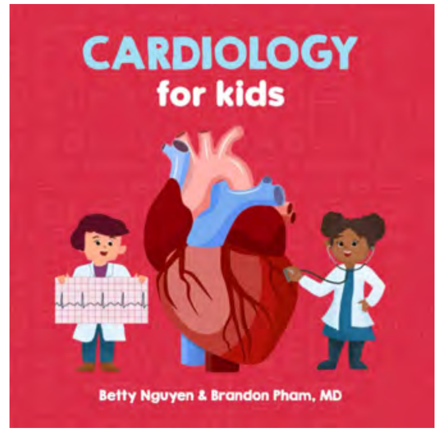
ADDITIONAL LEARNING



READ

Read more about the heart in ***The Science of the Heart and Circulatory System*** by Richard and Louise Spilsbury, ***The Heart: All about Our Circulatory System and More!*** by Seymour Simon, and ***Cardiology for Kids*** by Betty Nguyen and Brandon Pham, MD.





WATCH

Learn more about the heart in **"The Human Body: The Heart | Educational Videos For Kids"** by Happy Learning English.

DO

Allow time for students to do peer revisions on their writing. Not only will they get feedback, but they will get a chance to learn more heart facts.

Play-Doh Pulse

Station 1

Your heart's job is to pump oxygenated blood through your body and deoxygenated blood, or blood that needs oxygen, to your lungs. The heart circulates, or moves the blood, by squeezing at regular intervals. You can feel your heartbeat by resting your hand on your chest.

You can also feel the speed at which your heart is pumping by feeling an artery, which transports the blood to your body. Two of the easiest places to feel an artery are on your wrist and on the side of your neck, under your jaw.

DIRECTIONS

1. Roll Play-Doh into a ball.
2. Stick a straw into the Play-Doh.
3. Rest your hand on the table with your palm facing the ceiling.
4. Place the Play-Doh on your wrist with the straw pointing at the ceiling.
5. Set a 30 second timer and count the number of times the straw moves.

6. Multiply this number by two. This is your pulse!
7. Close your eyes and take 10 slow breaths. Now check your pulse again. Did it change?
8. Run in place for 30 seconds. What is your pulse now?
9. Can you estimate how many times your heart beats in one hour? (Hint: Multiple your pulse by the number of minutes in an hour.)
10. How many times does your heart beat in one day?
11. How many times does your heart beat in one year?

Play-Doh Pulse

TIP: Make counting easier by resting the Play-Doh on your non-dominant wrist and making tallies with your dominant hand as you count.

1. Set a 30 second timer and count the number of times the straw moves.

2. Multiply this number by two. This is your pulse! ____ x 2=____ **bpm (beats per minute)**

3. Close your eyes and take 10 slow breaths. Now check your pulse again. Did it change? ____ bpm

4. Run in place for 30 seconds. What is your pulse now? ____ bpm

5. Can you estimate how many times your heart beats in one hour? (Hint: Multiple your pulse by the number of minutes in an hour.) ____x 60=____ bpm

6. Challenge questions:
   - How many times does your heart beat in one day? ____ bpm
   - How many times does your heart beat in one year? ____ bpm

Play-Doh Pulse

TIP: Make counting easier by resting the Play-Doh on your non-dominant wrist and making tallies with your dominant hand as you count.

1. Set a 30 second timer and count the number of times the straw moves.

2. Multiply this number by two. This is your pulse! ____ x 2=____ **bpm (beats per minute)**

3. Close your eyes and take 10 slow breaths. Now check your pulse again. Did it change? ____ bpm

4. Run in place for 30 seconds. What is your pulse now? ____ bpm

5. Can you estimate how many times your heart beats in one hour? (Hint: Multiple your pulse by the number of minutes in an hour.) ____x 60=____ bpm

6. Challenge questions:
   - How many times does your heart beat in one day? ____ bpm
   - How many times does your heart beat in one year? ____ bpm

Blood Pumping Challenge
Station 2

With a single pump, the heart moves about 1/3 cup of blood. For the average adult this will add up to about 1.3 gallons of blood in a single minute. Can your hands keep up?

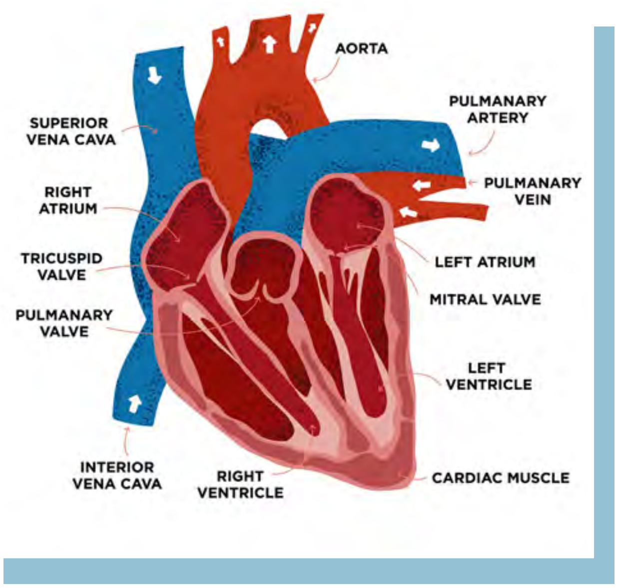
DIRECTIONS

1. Determine a timekeeper and the first player.
2. Place all of the red pom poms into bucket 1.
3. When the timekeeper says "Go!" the player will scoop as many pom poms as they can from bucket 1 into bucket 2.
4. After one minute has passed, the timekeeper will say "Stop!" and the player will stop scooping. Was the player able to "pump" as well as the heart?

NOTE: If you spill pom poms outside of the bin, that's okay! Pick up the pom poms with your hands and put them back in bucket 1.

5. Reset the game by putting all of the pom poms in one bucket and restarting the stopwatch. Rotate timekeeper and player responsibilities.
6. Repeat until everyone in the group has had a chance in each role.

All about...the heart!
Station 3



Science writers research science topics and write facts so others can easily understand them. Practice being a science writer by researching and writing an organized, 5-sentence paragraph on the human heart!

DIRECTIONS

1. Do research on the human heart using books and any teacher approved technology. Record your results in the graphic organizer.
2. Using your research, plan a paragraph on the heart.
3. *Optional:* If you have time, write your final draft.

All about...the heart!

Nonfiction Writing

Do research on the human heart using books and any teacher approved technology. Record your results below.

Use your research to plan a paragraph on the heart.

TOPIC SENTENCE
FACT 1
FACT 2
FACT 3
CONCLUSION

All about...the heart!

All about…the heart!

All about...the heart!

Heart Workout
Station 4

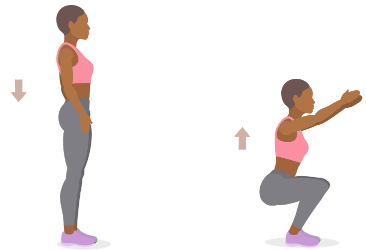
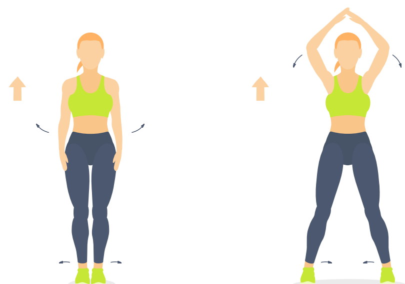
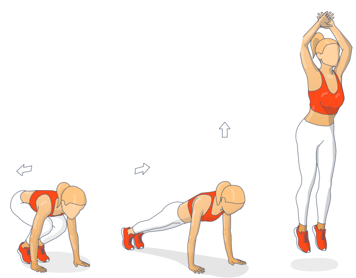
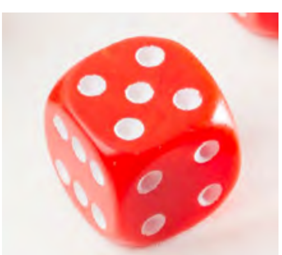
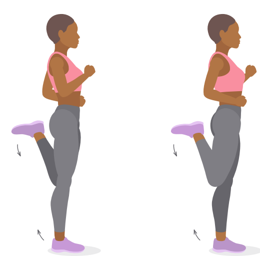
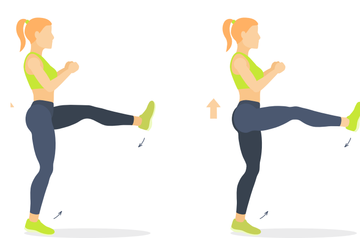
Your heart is a muscle.

Just like doing push-ups builds stronger arm muscles, doing exercises that get your heart rate up, called cardiovascular exercise or cardio, makes your heart stronger. Play Heart Workout Bingo to practice heart healthy activities and give your heart a workout!

DIRECTIONS

1. Choose a Bingo card.
2. Take turns rolling the die and announcing the number to your group.
3. All players will do the exercise that matches the number on the die.
4. If a number rolled appears on your Bingo card, choose one to mark.
5. Continue taking turns rolling the die, doing the corresponding exercise, and marking your card until a player has four numbers marked in a row. Bingo!
6. If time allows, erase your card and restart the game.
7. Before moving to the next station, erase your cards to reset for the next group.

Heart Workout

		**10 high knees**
		**10 air squats**
		**10 jumpking jacks**
		**10 burpees**
		**10 butt kicks**
		**10 switch kicks**

Heart Health Bingo 1

Your heart is a muscle. Just like doing push-ups builds stronger arm muscles, doing exercises that get your heart rate up, called cardiovascular exercise or cardio, makes your heart stronger!

1	5	2	2
4	2	6	1
3	6	5	3
4	2	6	5

Heart Health Bingo 2

Your heart is a muscle. Just like doing push-ups builds stronger arm muscles, doing exercises that get your heart rate up, called cardiovascular exercise or cardio, makes your heart stronger!

2	6	4	3
2	1	4	5
6	2	3	6
5	2	2	3

Heart Health Bingo 3

Your heart is a muscle. Just like doing push-ups builds stronger arm muscles, doing exercises that get your heart rate up, called cardiovascular exercise or cardio, makes your heart stronger!

6	6	2	1
1	1	4	2
3	6	1	3
4	5	2	5

Heart Health Bingo 4

Your heart is a muscle. Just like doing push-ups builds stronger arm muscles, doing exercises that get your heart rate up, called cardiovascular exercise or cardio, makes your heart stronger!

5	3	2	1
6	4	4	2
3	3	2	6
5	4	2	5

Heart Health Bingo 5

Your heart is a muscle. Just like doing push-ups builds stronger arm muscles, doing exercises that get your heart rate up, called cardiovascular exercise or cardio, makes your heart stronger!

4	2	1	5
6	1	6	5
6	1	4	6
3	2	5	3

Heart Health Bingo 6

Your heart is a muscle. Just like doing push-ups builds stronger arm muscles, doing exercises that get your heart rate up, called cardiovascular exercise or cardio, makes your heart stronger!

3	2	4	3
6	5	2	3
2	1	1	5
4	3	5	4

Prosthetic Possibilities

Total time to complete activity: 45+ minutes

BIG IDEA

Students explore how engineers design technology to meet specific needs and use the **Engineering Design Process** to meet an accessibility need.

NGSS STANDARDS

3-5-ETS1-1
Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.

3-5-ETS1-2
Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.

IN THE FILM

In *Superhuman Body*, we see many examples of technologies that have been designed to enable people to accomplish tasks. Ty Duckett has unilateral lower limb loss and uses a prosthetic designed specifically for surfing.

OBJECTIVES

1. Students will follow the **Engineering Design Process** to create a piece of technology that allows an individual with a limb difference to complete an assigned task.
2. Students will collaborate with a group.

Prosthetic Possibilities

MATERIALS

- ☐ Markers
- ☐ Miscellaneous building supplies
- ☐ Pencils
- ☐ Plain paper
- ☐ Laminator (optional) and laminating sheets
- ☐ Tape measurers – 1 per group
- ☐ Task cards – 1 per group
- ☐ Soccer ball (optional if task card is selected)

BUILDING SUPPLY IDEAS

- ☐ Balloons
- ☐ Cardboard or construction paper
- ☐ Felt
- ☐ Foam
- ☐ Paper towel tubes
- ☐ Pool noodles
- ☐ Popsicle sticks
- ☐ Rubber bands
- ☐ Straws
- ☐ String
- ☐ Tape
- ☐ Yard sticks

LESSON PREPARATION

Before students arrive, make sure to review the lesson materials. Review background information. Gather materials and set up the classroom.

Prepare task cards:

Look through the task cards and choose options that are appropriate for your space and your students' experience level with design challenges. Each group may have a different task, or multiple groups might be tasked to solve the same challenge in different ways. If multiple groups receive the same task, this will allow students to compare solutions during the reflection. Print and cut the cards. If you're using the cards for multiple classes, consider laminating them.

Prepare materials:

Gather a variety of miscellaneous building supplies. See list of possibilities to the left.

Optional: Make an assistive technology example with the available materials

BACKGROUND INFORMATION

Prepare yourself to answer students' questions on limb differences by exploring these resources:

"Limb difference – what is it" by Limbs 4 Kids

"Limb Difference" by Illinois University

"Born Different: Teaching Kids How To Talk to Someone Who Looks Different" by Hannah Fox

BACKGROUND INFORMATION (continued)

Assistive Technology: Tools that allow people with differences to accomplish tasks.

Bilateral limb loss: An amputation affecting both sides of the body.

Unilateral limb loss: An amputation affecting one side of the body.

Iterate: In the context of engineering, to go through multiple cycles of the engineering process, revising designs and retesting.

Engineering Design Process: A series of steps to guide problem solving and creation including: ask, research, imagine, plan, create, test, and improve.

Universal Design: Designing products or environments to be used by as many people as possible, including those with differences.

VOCABULARY TIP:
Write the vocabulary words on the board and guide students to use background knowledge to determine the meanings. Put emphasis on the morphology of **bilateral** and **unilateral.** "Uni" comes from the Latin word "unus" and means one. Other words with this prefix include unicycle (one wheel) and unicorn (one horn). The Latin prefix "bi" means two and can be found in words like bicycle (two wheels) and bilingual (two languages).

EDUCATOR TIP:
Children aren't born knowing how to respond to differences, so it's important to model talking about limb differences respectfully. Give students the correct language to use and model how to do research if there are questions you can't answer.

PROCEDURE

ANTICIPATORY SET

1. Explain the rules of *This or That.* Designate an area of the room for "yes" and an area for "no." For example, the question might be, "Do you like pineapple on pizza?" If the student says, "Yes, I like pineapple on pizza," they go to one side of the room. If they say, "No, I don't like pineapple on pizza," they go to the opposite side of the room. This game will provide an opportunity for the students and facilitator(s) to discover commonalities, including their prior experience with assistive technologies.
2. Begin with some silly prompts to get to know the group. Suggestions:

   Can you spin a basketball on your finger?

   Do you like to dance?

   Have you tried sardines?

4. Then add in prompts to activate students' prior knowledge of **assistive technologies.**

   Have you ever worn glasses or contacts?

   Have you ever used a step stool or ladder to reach something?

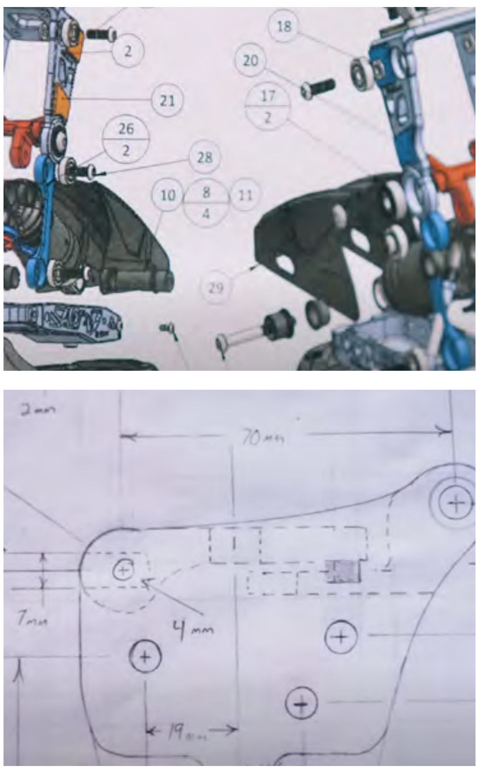
   Have you ever used voice to text?

   Have you, or a family member, ever needed crutches or a wheelchair?

   Would you be able to hang something on the classroom ceiling without help or standing on something?

   Have you ever had a phone, tablet, or computer read aloud to you?

5. Show "How This Action Sports Star Built His Own Prosthetic Leg" featuring Mike Schultz.



Mike Schultz' concept designs for a new prosthetic leg.

DISCUSSION QUESTIONS

Have you, your family, or friends used technology to accomplish tasks (e.g., crutches, glasses, step stool)?

How did Mike create technology to solve a problem?

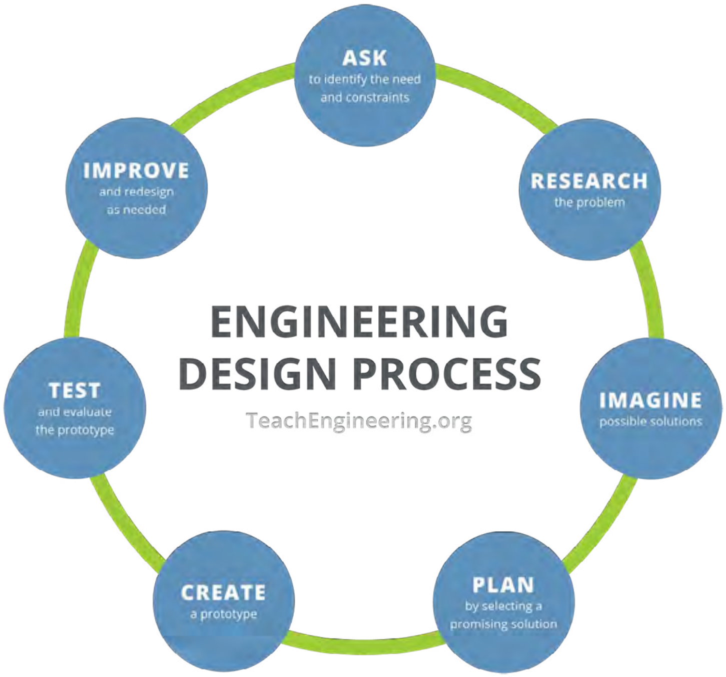
How have engineers designed technology to help people with limb differences accomplish tasks?

EDUCATOR TIP:
If time allows, this lesson can be extended to a multi-day project by focusing more time on each step of the engineering design process and allowing for more iteration.

ACTIVITY

1. ORGANIZE:

Put students into groups of 3-5. Explain that today, students will get a chance to be engineers and design technology to meet a specific need. Each group will receive a task card describing the patient and the task they are attempting to accomplish. The group will follow the Engineering Design Process to solve this problem by designing, building, testing, and iterating.



Source: TeachEngineering.org

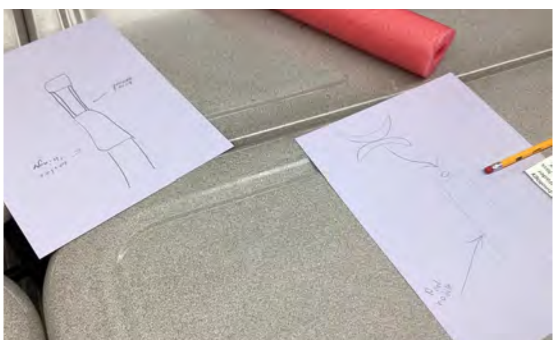
2. ASK:

Pass out task cards (pages 82–84). The first step of the **Engineering Design Process,** "ask," is for ensuring you fully understand the problem you're trying to solve. Encourage groups to look at their tasks and ask questions as needed.

Discuss vocabulary that appears on their cards including **assistive technology, bilateral limb loss,** and **unilateral limb loss.**

3. RESEARCH:

The "research" phase includes getting more information on the problem. This could include other solutions that have been attempted in the past. Consider showing students images from the Student Work Examples document (pages 85–86) as inspiration, or showing a teacher made example.



Sketches of possible devices to build

EDUCATOR TIP:

Real engineers have material constraints. Don't be afraid to limit the number of materials students can use! This information should be provided during the "ask" stage, if possible, to allow them to plan accordingly.

4. IMAGINE:

Pass out one piece of paper and a pencil to each student. Give them three minutes of silent work time to brainstorm designs. Then encourage individuals to share their ideas with their groups and continue brainstorming. While students discuss with their groups, walk around the room and ask guiding questions as needed. For example:

What pressure or motion is needed to accomplish this task?

Could someone use another limb or body part (e.g., foot or shoulder) instead of hand?

5. PLAN:

When groups settle on an idea, give them a fresh sheet of paper for their final sketch.

6. CREATE:

Students use available materials to build a prototype.

7. TEST:

Once students have built a prototype, they will test it out. Encourage students to think about what is working well and what they can improve.

Prosthetic Possibilities

ACTIVITY (continued)

8. IMPROVE:

Students will use any remaining time to redesign, based on the weaknesses of their initial prototype.

Continue going through the cycle. Engineers **iterate** to design the most effective solution. This means they go through the **Engineering Design Process** more than once, redesigning and testing until they find a solution they're happy with.

EDUCATOR TIP:
One of the most important takeaways from using the **Engineering Design Process** is that failing and restarting the process is expected.

No design will be perfect the first time. If students did not solve the challenge in the allotted time, be sure to stress this idea and focus discussion on what they learned and what they would try if they had time for more iterations.

WRAP-UP

Review and Discussion Questions:

What would your next step be if you had more time?

What are you most proud of?

What surprised you about this challenge?

Universal Design is the philosophy of designing products and environments to be used by as many people as possible, including those with differences.

How could the room be changed to make your technology unnecessary?

"When engineers design buildings and transportation so that everyone naturally fits in, then the idea of disability disappears."

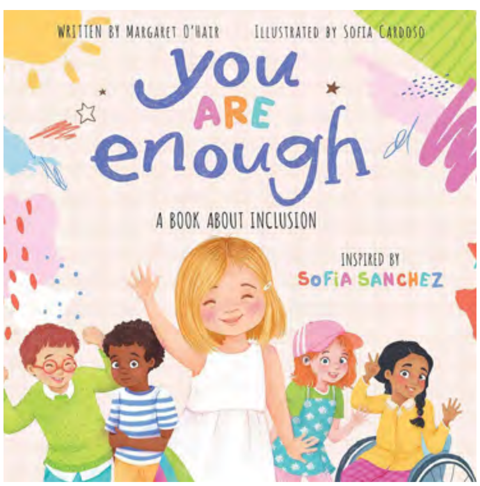
— Superhuman Body: World of Medical Marvels

ADDITIONAL LEARNING

READ

Engineering can be tricky. When we don't solve the problem on our first try it's easy to get frustrated! Be inspired to design and iterate with ***The Most Magnificent Thing*** by Ashley Spires.

Celebrate differences with the book ***You are Enough: A Book About Inclusion*** by Margaret O'Hair.



WATCH

Dig deeper into the Engineering Design Process by watching **"The Engineering Process: Crash Course Kids #12.2".**

DO

Write a paragraph on challenges you faced during this challenge and how you overcame them.

Brainstorm other problems you can solve using the **Engineering Design Process.**

Choose a specific type of assistive technology to research and present to the class.

SOURCES CITED

Fox, H. (2020, April 20). Born different: Teaching kids how to talk to someone who looks different. Kansas City Mom Collective. https://kansascitymomcollective.com/born-different-teaching-kids-how-to-talk-to-someone-who-looks-different/

Limbs 4 Life. (n.d.). Limb difference – what is it. Limbs 4 Kids. https://www.limbs4kids.org.au/about-limb-difference/limb-difference-what-is-it#:~:text=There%20are%20many%20different%20causes,cause%20for%20a%20congenital%20difference.

University of Illinois at Urbana-Champaign. (n.d.). Libguides: Limb Difference. Home - Limb Difference - LibGuides at University of Illinois at Urbana-Champaign. https://guides.library.illinois.edu/limbdifference

Design assistive technology for a third grader with bilateral upper limb loss to open an upper cabinet.

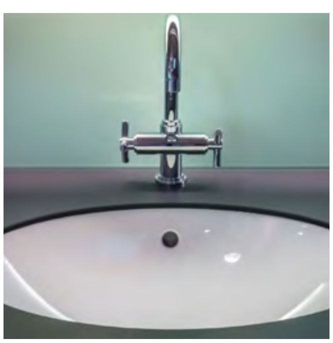
LEVEL 1

Design assistive technology for a fourth grader with bilateral upper limb loss to turn on the light.

LEVEL 1

Design assistive technology for a third grader with bilateral upper limb loss to open a lower cabinet.

LEVEL 1



Design assistive technology for a fifth grader with bilateral upper limb loss to turn on the sink.

LEVEL 1

Design assistive technology for a fourth grader with a unilateral amputation at their right knee to kick a soccer ball with their right leg.

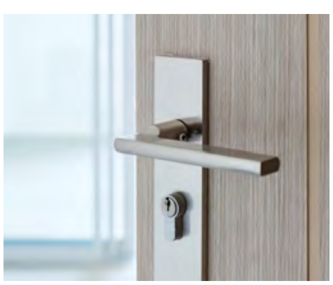
LEVEL 1

Design assistive technology for a third grader with a unilateral amputation at their left shoulder to pass out papers to classmates.

LEVEL 1

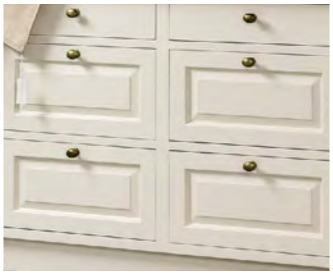
Design assistive technology for a fifth grader with bilateral upper limb loss to erase the chalkboard.

LEVEL 1



Design assistive technology for a third grader with bilateral upper limb loss to open the door.

LEVEL 1



Design assistive technology for a third grader with bilateral upper limb loss to open cabinets. Ensure your technology works with all cabinets in the room.

LEVEL 2

Design assistive technology for a fourth grader with a unilateral amputation at their right knee to kick a soccer ball with their right or left leg.

LEVEL 2

Design assistive technology for a fifth grader with bilateral upper limb loss to turn the sink on and off.

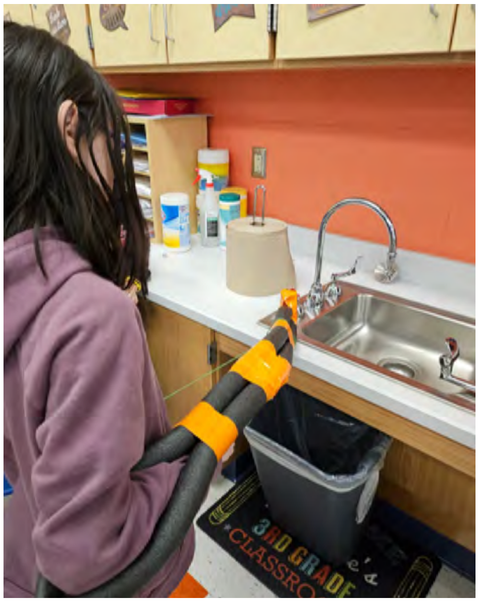
LEVEL 2

Design assistive technology for a fifth grader with bilateral upper limb loss to write on and erase the board.

LEVEL 2

Prosthetic Possibilities — Student work examples

OPTIONAL: Print or display these images as inspiration for student designs

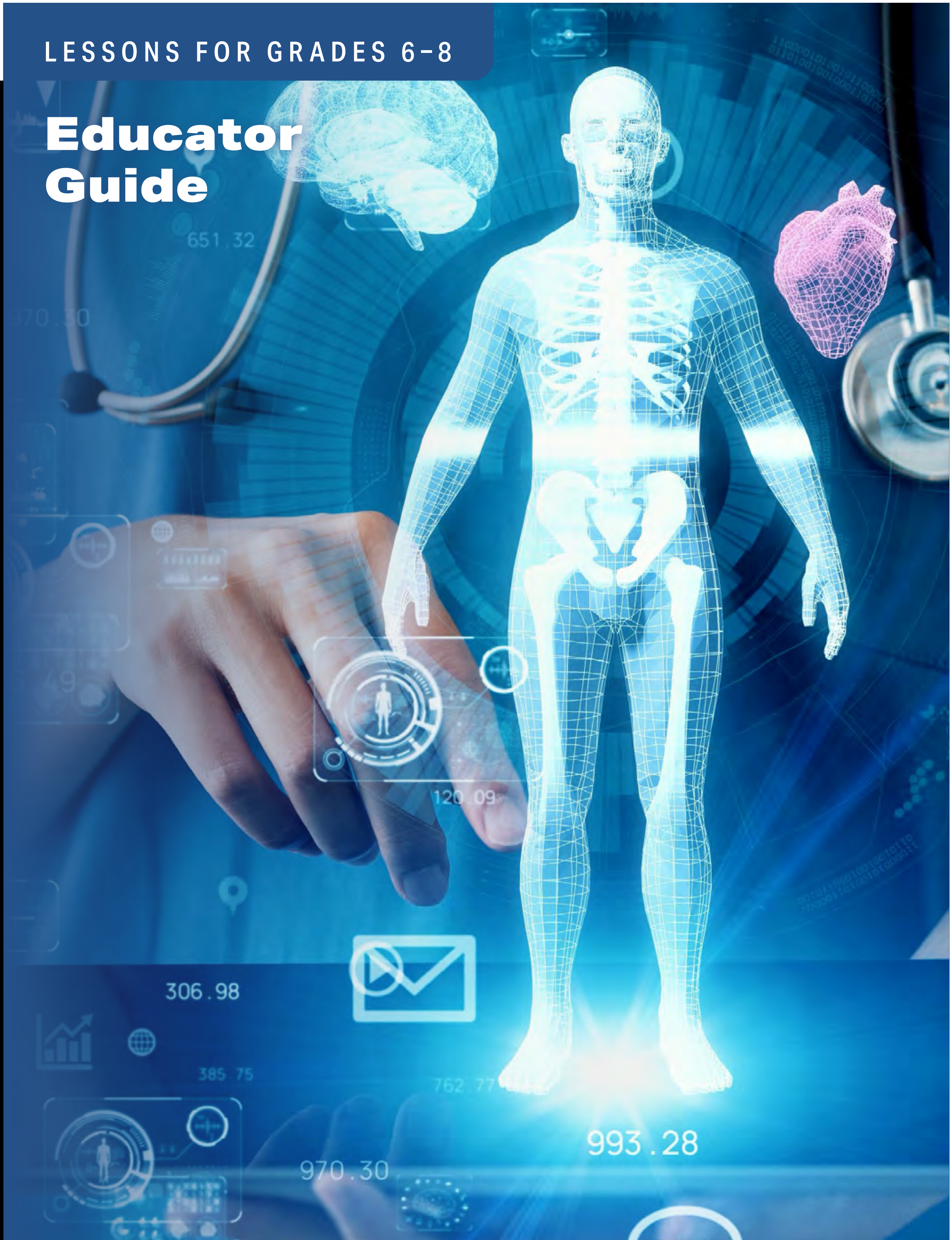


Prosthetic Possibilities — Student work examples

OPTIONAL: **Print or display these images as inspiration for student designs**

LESSONS FOR GRADES 6–8

Educator Guide



Building Immunity

Total time to complete activity: 45 minutes

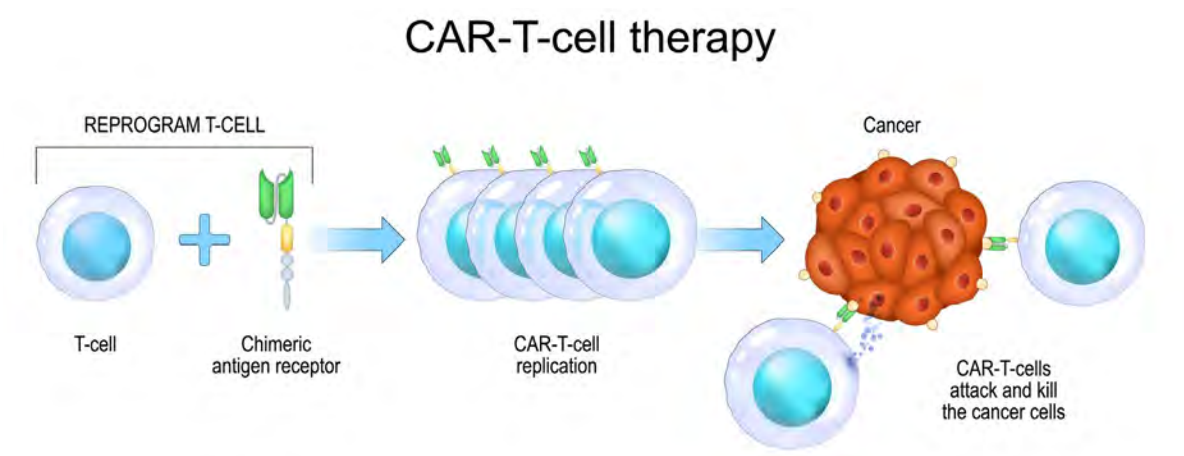
NGSS STANDARDS

MS-LS1-3

Use argument supported by evidence for how the body is a system of interacting subsystems composed of groups of cells.

BIG IDEA

Students will explore how the body responds to infected cells, invading bacteria, and cancerous cells. They will take on the roles of different immune system cells and use communication, teamwork, and engineering design principles to come up with a solution.



IN THE FILM

In *Superhuman Body,* doctors use genetic modifications to give killer T-cells new chemical receptors called chimeric antigen receptors (CAR) to attack cancerous cells. These modified killer T-cells are called CAR T-cells. While this is a major advancement, the body already trains itself to fight a myriad of threats by identifying receptors on the exterior of cells and then forming new receptors that can fight off new threats.

OBJECTIVES

1. Students will act as B-cells and T-cells to identify an antigen and create an antibody from Legos.
2. Students will communicate and work together in groups.

MATERIALS

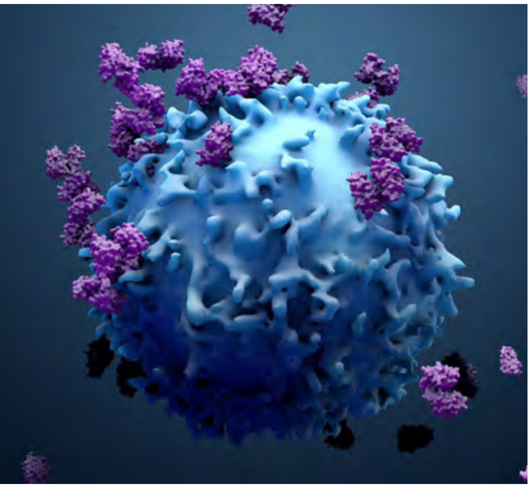
- ☐ Lego bricks or similar toy building materials. Teacher will need a supply, as well as each student group.
- ☐ Containers for student Legos
- ☐ Divider screen
- ☐ Sketch paper
- ☐ Pencils
- ☐ Clock, timer, or stopwatch

LESSON PREPARATION

Before students arrive, make sure to review the lesson materials. Review background information. Gather materials and set up the classroom.

Material preparation:

- Before the lesson, build the model antigen out of Legos, or whatever building materials that you have. The antigen should stand less than a foot tall and have multiple points where the students can build an antibody that can attach to the antigen.
- Once the antigen has been built, put it behind a privacy screen, or in another room to keep the students from seeing the antigen model.
- Separate antibody building supplies (student Legos) into containers and set them to the side.



Lymphocytes attack a cancerous cell

BACKGROUND INFORMATION

Lymphocytes: A type of white blood cell involved in the immune system. They play a crucial role in recognizing and responding to foreign substances in the body, such as pathogens or abnormal cells. There are two main types of lymphocytes: B-cells, which produce antibodies, and T-cells, which play various roles in immune responses.

Proteins: Large organic molecules that regulate many functions in the body.

Antigen: A molecule or molecular structure that is recognized by the immune system as foreign or non-self. Antigens can be found on the surface of pathogens, cancer cells, and foreign substances. The presence of antigens triggers an immune response.

Antibody: Proteins produced by B-cells in response to the presence of antigens. Antibodies bind specifically to antigens killing the harmful cell.

Cytotoxin: A substance, often a protein or chemical, that has toxic effects on cells. Cytotoxic T-cells are a type of T-cell that can release cytotoxins to induce the death of infected or abnormal cells.

BACKGROUND INFORMATION (continued)

Innate Immune System: The first line of defense against pathogens. It provides immediate, non-specific responses to infections or injuries.

Adaptive Immune System: Also known as the acquired or specific immune system, responds to specific pathogens and develops memory to provide long-lasting protection. It involves the activation of B-cells and T-cells, leading to the production of antibodies and the elimination of specific pathogens.

Vaccines can contain dead or weakened viruses that allow the body to build antibodies safely.

Cells in our bodies have strands of **proteins** on their exterior called antigens. An **antigen** is a signaling marker that informs your immune system whether a cell is harmful or harmless to the body. These markers are present on virus-infected cells, bacteria, tumors, and normal human cells.

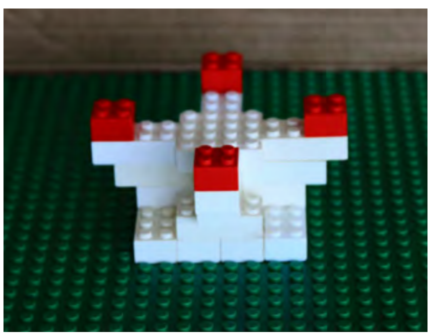
The immune system, made up of various cells, has two main systems: the innate system, which provides general defense, and the adaptive system, which responds specifically to threats. The **innate immune system** includes cells like neutrophils and macrophages that quickly respond to invading threats like bacteria, fungi, and allergens. The **adaptive immune system** involves specialized cells like lymphocytes. These **lymphocytes** are often called B-cells and T-cells. When B-cells encounter a cell with unfamiliar antigens they produce **antibodies** to aid in the immune response. Antibodies can kill harmful cells outright when they attach to an antigen. In other cases, T-cells search for antigens that they recognize and attach themselves to the harmful cell. They then attack it with **cytotoxins,** a compound that instructs cells to act differently, or even shut down and die. These lymphocytes are crucial in viral infections and even destroying cancer cells.

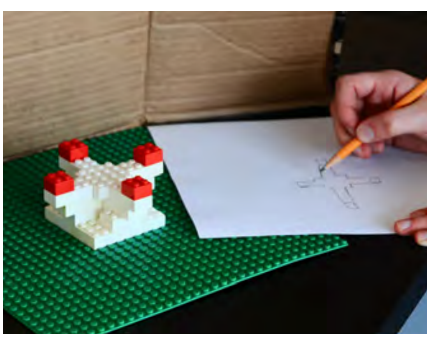
One member of each team will observe the antigen that is hidden behind the divider screen. Once observed, the team member will return to their team. The observer can use words and draw diagrams to communicate to their team how to construct an antibody using Lego bricks to flawlessly attach to the proteins on the infected cell.

PROCEDURE
ANTICIPATORY SET

Provide an overview of the following information:

1. Think of the immune system as our body's defense team, with different players working together to keep us healthy. There are two main squads: the innate team, which provides general protection, and the adaptive team, which tackles specific threats.
2. Today, you are all going to be a part of the adaptive team and take on the role of the B-cells and T-cells. These cells have specific missions. B-cells look for strands of proteins that stick out from organic cells called antigens. If they recognize an antigen as harmful, they produce antibodies. These antibodies match up to the antigen and kill the harmful cell. Activated T-cells directly attack harmful cells by recognizing their antigens and attaching to them. The T-cell then releases cytotoxins that will shut down the harmful cell.
3. One member of each team will observe the antigen that is hidden behind the divider screen. Once observed, the team member will return to their team. The observer can use words and draw diagrams to communicate to their team how to construct an antibody using Lego bricks to flawlessly attach to the proteins on the infected cell.





ACTIVITY

ANTIBODY CONSTRUCTION:

1. Divide students into groups of 4-5 students.
2. Have students select which group member will be the observer. This student will take on the role of the B-cell. This group member will be the only group member who can observe the antigen.
3. Tell the remaining group members that their goal is to listen carefully to the observer and follow their instructions. Their task is to build an antibody that will attach to the antigen flawlessly and destroy the harmful cell. The observer may instruct the other B-cells but may not touch the building materials. There may be multiple ways to make the antibody, and at the end of a set time, the group members will need to test their designs.
4. Once they have selected a team member to observe the antigen, give the observer a pencil and sketching paper.
5. Allow the observer to check out the model antigen. Start the timer.

6. Encourage the observers to make multiple trips to the antigen and to use the paper and pencil to communicate their design.
7. If the students are having difficulty communicating, encourage the students to take a breath and identify the core part that is giving them difficulty.
8. Circulate among the teams, providing guidance, answering questions, and ensuring safety protocols are followed.

TESTING AND PRESENTATION:

9. Once time is up, reveal the antigen model to the whole class.
10. Have each team pick a member, not the observer, to bring the antibody up to the front and then attach it to the antigen model.
11. How well does the antibody fit with the antigen?
12. Does the antibody connect with every part of the antigen?
13. If the antibody does not fit, what changes would need to be made to the design?

WRAP-UP

Review and Discussion Questions:

What were the challenges of making a model of something without all the information?

What part was the most difficult? What would have improved the experience?

Observers, what could you have done to better communicate what you saw?

What tools might have helped you?

Encourage students to consider how this activity relates to real-life scenarios in the human body.

What problems arise if our immune system cannot develop new antibodies?

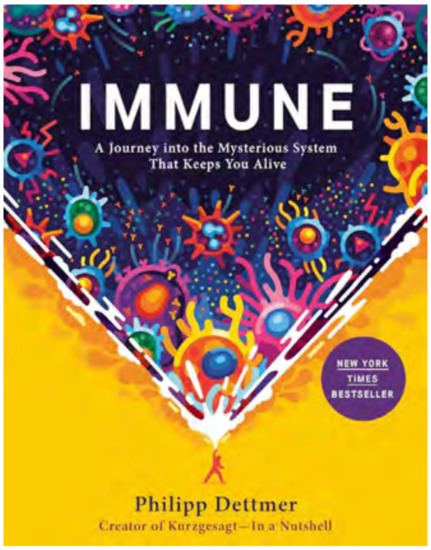
What conditions can you think of that can inhibit the immune system?

Help the students think about the story from *Superhuman Body* in which the doctors designed the CAR T-cells to attack cancer cells. A component of this work was providing the T-cells with the genetic data that would allow them to connect to receptors on the exterior of the cancerous cells. Our body's ability to adapt in this way allows doctors to engineer new solutions for problems that have been lethal for centuries, from cancer treatments to new vaccines.

EXTENSION ACTIVITY

If time and preparation allow, have the groups go again with a different antigen model. Ensure that they choose a new observer. Allow them to try new strategies for communication. Compare this to our immune system that adapts overtime to recognize and respond to threats better over time.

ADDITIONAL LEARNING



READ

Immune: A Journey into the Mysterious System That Keeps You Alive by Philipp Dettmer uses wit, wisdom, and well-designed images to take readers on a funny but extremely informative ride through their own immune system.

WATCH

"How does your immune system work?" by Emma Bryce provides an overview on how our immune system works including a breakdown of the kind of immune cells that travel through the body.

DO

Adapt to Mutations

Run the activity again. This time, halfway through the building phase, add an extra piece to the antigen that represents a mutation. This can represent how different viruses or cancers can mutate. Inform the teams that the antigen has changed, then have the observers return to record the new branch of proteins.

Pump It Up

Total time to complete activity: 45 minutes

BIG IDEA

Using a simple model of the heart that they create, students experiment with the function of the heart chambers and valves to circulate blood.

NGSS STANDARDS

MS-LS1-3

Use argument supported by evidence for how the body is a system of interacting subsystems composed of groups of cells.

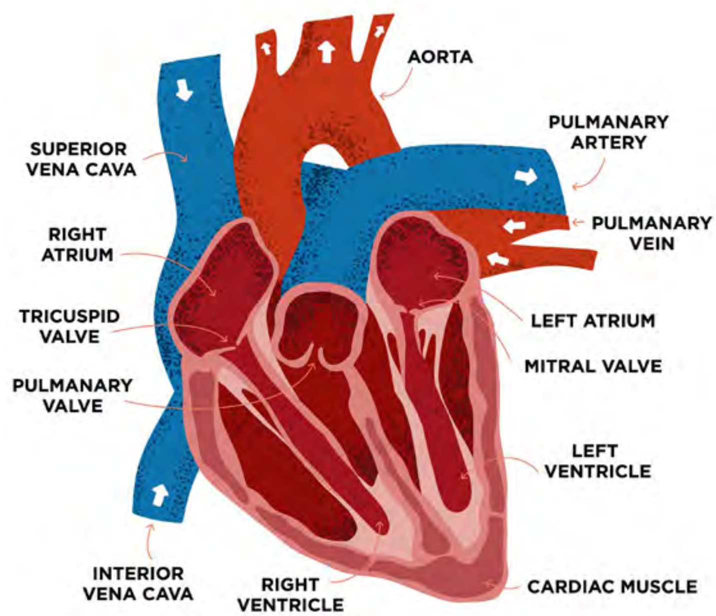
IN THE FILM

In *Superhuman Body,* doctors utilize pig heart valves to repair proper valve function in human hearts. This procedure shows us the precise mechanics necessary for maintaining a muscle that must work properly 24/7 to keep a person alive. This activity will further explain the function of these valves as well as the timing required to operate the heart.

Open heart valve

OBJECTIVES

1. Students will construct a model of heart valves using simple materials.
2. Students will demonstrate the function of the heart chambers and valves to circulate blood.
3. Students will use their constructed model to simulate blood flow through the chambers by working collaboratively, some students pump the chambers while other students control the opening and closing of valves.



MATERIALS

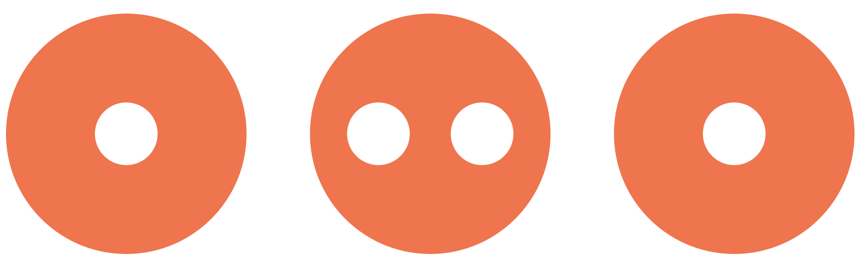
- ☐ Soda bottles with caps and labels removed (3-per group)
- ☐ Bendy straws (4-per group)
- ☐ 3 cups of water per group
- ☐ Food coloring (red for effect)
- ☐ Pitcher of water
- ☐ Funnel
- ☐ Duct or Painters' Tape
- ☐ Modeling clay
- ☐ Stopwatch (optional)
- ☐ Drill with 3/32 or 7/64 drill bit

EDUCATOR TIP:
It is suggested that teachers follow the steps in the lesson below and make a heart model of your own prior to conducting this lesson. Be sure to test the tolerances of your materials, especially the seals around the straws on the bottle caps. If the clay does not create a strong seal, you may need to wrap tape or hot glue around the cap. Experiment beforehand to find the best seal for your bottles.

LESSON PREPARATION

Before students arrive, make sure to review the lesson materials. Review background information. Gather materials and set up the classroom.

General Preparation:
Drill holes or use a sharp object to bore holes into the center of the soda caps. Drill one hole into the center of two of the caps for each set of bottles, and drill two holes into one of the caps for each set of bottles. If using a drill, the average straw is just over 3mm in diameter and so a 3/32 or 7/64 drill bit should work best. The bottle caps for each group should resemble the image below.



Lay out the straws and soda bottles. If needed, fill the bottles with water ahead of time and set them aside from where the students will be working.

BACKGROUND INFORMATION

Heart: A muscular organ that pumps blood throughout the body, ensuring the delivery of oxygen and nutrients to cells and removing waste products.

Circulatory System: This system includes the heart, blood vessels, and blood. It is responsible for transporting nutrients, oxygen, and hormones to cells, as well as removing waste products.

Heart Chambers: The heart has four chambers – two atria (upper chambers) and two ventricles (lower chambers). Blood moves from the atria to the ventricles and then is pumped out to the lungs or the rest of the body.

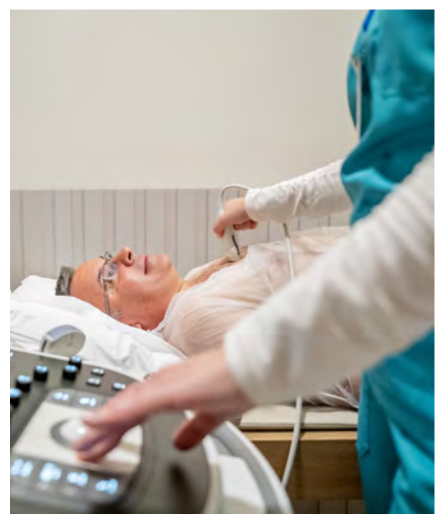
Valves: The valves in the heart prevent blood from flowing backward. The atrioventricular valves (between atria and ventricles) and semilunar valves (between ventricles and arteries) ensure one-way blood flow.

The efficiency of our **heart** can be measured in two ways:

- Heart rate — how many times your heart beats in a minute.
- Stroke volume — how much blood your heart pumps with each beat. Stroke volume can be measured in liters per minute.

Physicians can use an ultrasound to produce an echocardiogram to image the **valve** and **heart chambers.** These ultrasounds can measure the frequency of each beat to determine heartbeat, and wave height to determine the volume of an individual stroke. Heart rate and stroke volume are influenced by different factors and change depending on stress, diet, and health of the rest of the **cardiovascular system.** Physicians multiply the heart rate by the stroke volume to determine the cardiac output, or how much blood the heart pumps over a period of time.

In humans, cardiac output is usually 5-6 liters per minute at rest and can go up to more than 35 liters per minute in elite athletes during exercise.



Patient receives an ultrasound of his heart.

The heart rate is controlled by signals from a tiny group of fibers near the right atrium of the heart called the sinoatrial node. The sinoatrial node produces electrical impulses to automatically speed up or slow down the heart rate. Stroke volume, on the other hand, depends on factors like preload (how much blood is in the heart before it contracts), contractility (how forcefully the heart contracts), and afterload (the resistance the heart faces when pumping blood into the blood vessels). In this specific activity, students will be focusing on heart rate, but they can also observe stroke volume.

PROCEDURE
ANTICIPATORY SET

1. You probably know that the heart pumps blood throughout the body. Without this pumping our body doesn't have the ability to move oxygen to the rest of the body. Without oxygen the body cannot break down glucose to make fuel for our muscles and other bodily processes. We can feel this pumping by finding our pulse. To find our pulse:
    - Place your index and middle finger on your neck to the side of your windpipe.
    - To check your pulse at your wrist, place two fingers between the bone and the tendon over your radial artery — which is located on the thumb side of your wrist.
    - When you feel your pulse, count the number of beats in 15 seconds.
    - You can multiply this number by 4 to find your beats per minute.
    - It may be challenging to find your pulse. Be patient and try the different locations if one isn't working.
2. Once most students have found their pulse, you can have them do some exercise to increase their heart rate. Jumping jacks and running in place work well if you have the space. Once the students have done about 30 seconds of cardio, have them take their pulse again.
3. What is the difference? The heart rate should be higher. During aerobic exercise your body may increase your normal cardiac output because your muscles need more oxygen. Your heart typically beats faster during exercise so more blood can circulate. Your heart can also increase its volume by pumping more forcefully or increasing the amount of blood that fills the left ventricle before it pumps.

ACTIVITY

Have students build a simple model of the heart.

1. Place the three bottles in a line. Fill two soda bottles with colored water about 80% full. Leave the third soda bottle empty. Replace the caps on the bottles. Tell students that while the heart has four chambers, two atriums and two ventricles we will be working with half of the heart, one atrium and one ventricle. In the case of oxygenated blood, the blood enters the left atrium first, then goes into the left ventricle, and then goes from there into the body. In this model, the first bottle represents the atrium, the second bottle represents the ventricle, and the third bottle represents the rest of the body. Deoxygenated blood flows from the body into the heart's right atrium, then to the right ventricle, and then into the lungs.

2. Carefully slide the straws through the bottle caps. Place modeling clay around the straw base (where the straw meets the bottle cap) to make an airtight seal. If the clay does not create a strong seal, you may need to wrap tape, or hot glue around the cap. Experiment before had to find the best seal for your bottles.

3. To make the model work, pinch the straw between the first and middle bottle. Squeeze the middle bottle and watch your "blood" squirt out into the open, third bottle.

4. Keeping the middle bottle "squeezed" move your fingers and pinch the straw between the ventricle and body. Now release the middle bottle and watch your blood move from the atrium into the ventricle.

5. Invite the students to consider what happens when the body is working under stress or performing exercise. Challenge the student groups to move the liquid from one end of the system of pumps to another as fast as possible. Have the students coordinate the proper rhythm of opening and closing valves, and pumping fluid from atrium to ventricle and into the body.

6. Encourage the students to figure out a rhythm to coordinate the valves and pumps. There are strategies that will help them keep time, such as singing songs, counting, or developing a chant that will help them find a rhythm to pump the simulated blood.

WRAP-UP

Review and Discussion Questions:

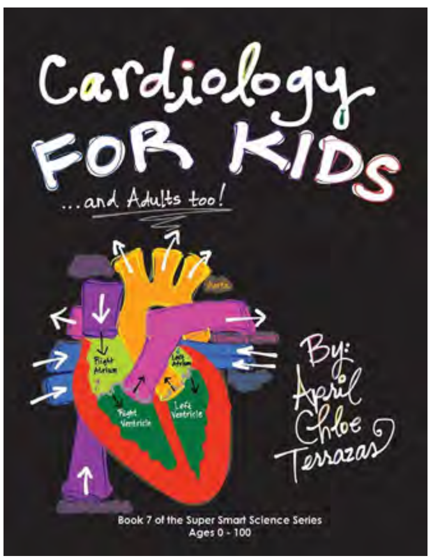
What did you observe about how the heart pumps blood?

What forces do you think are at play in the ways the heart works?

What are some things we can do to keep our hearts healthy?

The heart is an incredible muscle that never takes a break. Without this system of hydraulics working in our bodies nearly every system in our body would fall apart. It is important to make sure that we keep our hearts healthy and our arteries clean.

ADDITIONAL LEARNING



READ

Cardiology for Kids ...and Adults Too! by April Chloe Terrazas contains a color-coded breakdown of how each part of the heart works and its relationship to the body. This book also includes quizzes and review sections at the end of each chapter to extend the learning.

WATCH

"How the heart actually pumps blood" by Edmond Hui is an animated video that provides an accessible history of cardiovascular studies, as well as diagrams that illuminate how blood moves through the heart and body.

DO

Consider hosting a tournament to see which group can pump the heart the fastest. The objective should be to empty the atrium bottle so that all of the water heads out to the ventricle and the bottle representing the body is at capacity. Use a stopwatch to time their heats.

Universal Design Challenge

Total time to complete activity: 45+ minutes

BIG IDEA

Using the seven Universal Design Principles, students will define an accessibility problem in their community and then design a solution.

IN THE FILM

Our world is built and designed for a certain kind of human— one with two arms and two legs who stands a median height and weighs a median weight. However, there are people, like Ty Duckett from *Superhuman Body*, who have different physical characteristics that engineers and architects must take into consideration when designing items, buildings, and other spaces.

OBJECTIVES

Students will design an accessibility device that allows a user with a limb difference to complete a task using the seven Universal Design Principles.

NGSS STANDARDS

MS-ETS1-1

Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

MATERIALS

- ☐ Paper, pens, pencils (1 per group)
- ☐ Universal Design Principles handout (1 per group)
- ☐ Pickle, jam, or other food jars that require two hands to open (1 per group)

LESSON PREPARATION

Before students arrive, make sure to review the lesson materials. Review background information. Gather materials, print out worksheets, and set up the classroom.

BACKGROUND INFORMATION

Vocabulary is very important for this lesson. Use terms that the disabled community prefers and avoid words that have a negative history or connotation. Here is a good resource for language to use and avoid.

SAY THIS ...	NOT THAT ...
Accessible	Handicapped
Disability	Differently-abled, special needs
People without a disability, able-bodied	Normal, healthy

Disability: A condition of the body or mind that makes it more difficult for a person to do certain activities and interact with the world around them.

NOTE: the "problem" that makes activities and/or interactions more difficult is not with the person with the condition or often the condition itself. The difficulty is that the world around the person is not designed to accommodate them.

Limb difference: The partial or complete absence or malformation of arms and/or legs.

Prototype: A first, or preliminary model of something, especially a machine, from which other forms are developed or copied.

Assistive devices: External devices that are designed, made, or adapted to assist a person to perform a particular task.

Universal Design: The design of buildings, products, or environments to make them accessible to people, regardless of age, disability, or other factors.

EDUCATOR TIP:
If you have a student with disabilities in your class, do not use them as an example or put them on the spot by asking them to share their experience.

The following seven principles were developed by
THE CENTER FOR UNIVERSAL DESIGN AT NORTH CAROLINA STATE UNIVERSITY

1. **Equitable use** — Can be used by different people with different needs
2. **Flexibility in use** — Accommodates a wide range of individual preferences and abilities
3. **Simple and intuitive** — Use is easy to understand, regardless of the user's experience, knowledge, language skills, or current concentration level
4. **Perceptible information** — Communicates necessary information effectively, regardless of ambient conditions or the user's sensory abilities
5. **Tolerance for error** — Minimizes hazards and adverse consequences of accidental or unintended actions
6. **Low physical effort** — Can be used efficiently, comfortably, and with a minimum of fatigue
7. **Size and space for approach and use** — Appropriate size and space are allotted regardless of user's physical characteristics

PROCEDURE
ANTICIPATORY SET

1. Separate students into groups.
2. Introduce students to their client, Ollie. Ollie is an entrepreneur and a chef with a limb difference — she only has the use of her right hand. This doesn't affect her culinary creativity, but she does have difficulty opening jars of ingredients like pickles, jam, etc. and she saw a business opportunity!

   Ollie has published a call for proposals from engineering firms for an assistive device that will allow her to open these jars with one hand. She will partner with the firm with the best design to market and sell the product.

ANTICIPATORY SET (continued)

3. Introduce students to their challenge: Each group of students is an engineering firm who wants Ollie's business! Their goal is to develop a prototype design for Ollie that will allow her, and people like her, to complete a task that might be more difficult because of their limb difference.

   - Pass out jars, and challenge students to open them with one hand. Students are not allowed to use their mouths!

   - Discussion questions:

     Why is this task hard?

     Who was the jar designed for?

     Whose responsibility is it to make sure Ollie can complete this task?

4. Pass out the **Universal Design Principles** handout (page 106).

   - At the top of the handout, students should identify the product or design that is causing the issue for Ollie. In the pickle jar example, this would be the jar itself.

   - Have students grade the product or design using the Universal Design Principles on their handout. They should feel free to give partial credit but should be able to defend their grades in discussion.

ACTIVITY

1. Challenge students to design a device to allow Ollie to complete the task. There are two ways to go about this:

   - Students can re-design the product that they graded. In the pickle jar example, they would design a pickle jar that can be opened with one hand (or no hands!)

   - Students can design an **assistive device** that would allow Ollie to complete the task. In the pickle jar example, they would design a clamp that will open the jar for Ollie.

2. As students are working on their designs, challenge them to fulfill as many of the Universal Design Principles as possible. Here are some questions you may ask for each:

   Can someone with only the use of their right arm use this? What about someone whose hands shake?

   Can both a right-handed and left-handed person use this?

   Do I need instructions to use this, or can I figure it out easily?

Can I use it if I don't speak or read English instructions?

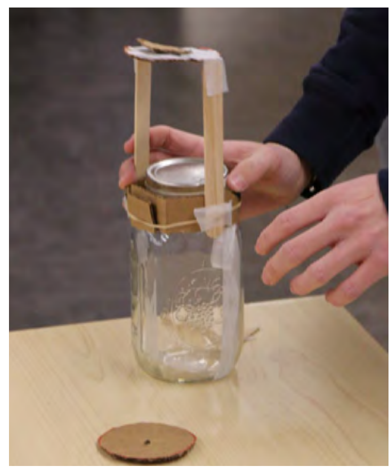
Can a blind, visually-impaired, Deaf, or hearing impaired person use this?

Will this item break if it is dropped? If I use it upside down or backwards, will it break or cause a hazard?

How much strength does this require to operate?

Can a very large or a very small person use this? Is it too big to keep handy? Is it too small and possibly get lost?

DIFFERENTIATION TIP:
You can also have students brainstorm their own tasks that Ollie might require an assistive device to complete or give every group a different task. Some ideas for tasks include hammering a nail, opening a stick of string cheese, or opening and closing a drawstring bag.



WRAP-UP

Review and Discussion Questions:

Have students share their re-designed products or assistive devices with the rest of the class.

Are any designs similar?

Discuss what aspects of this challenge were difficult. *Was it challenging to keep all of these principles front of mind when designing your assistive devices?*

EXTENSION ACTIVITY

If you have extra time, or want to make the project last multiple days, assign students to create an advertisement poster, commercial, or social media post trying to sell their re-designed product or assistive device.

If you have a thoughtful group, have other students grade their peers' designs using the Universal Design handout. Then, have groups iterate their designs to make them more accessible.

If you have plenty of extra time and materials, have students build a **prototype** of their design. Have students respond to some or all of the following writing prompts:

What does it mean to be inclusive or to accommodate?

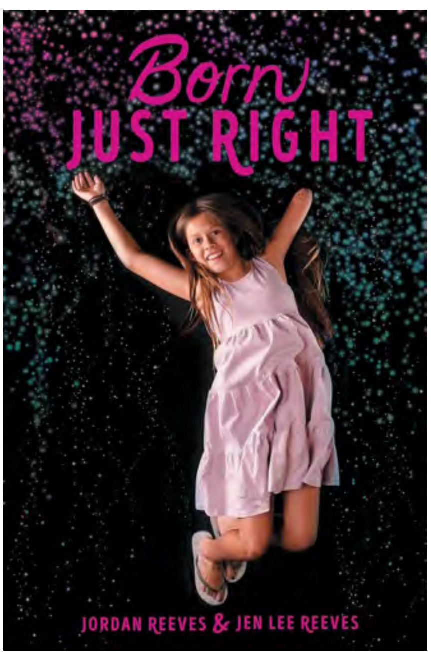
What does my school do to accommodate students with disabilities? What can my school do better?

What does my community do to accommodate community members with disabilities? What can my community do better?

What do I do to accommodate people with disabilities in my life? What can I do better?

Can you always tell when someone has a disability? Why or why not?

ADDITIONAL LEARNING



READ

Learn more about the lives of teens with limb differences by reading the memoir ***Born Just Right,*** by Jordan and Jen Lee Reeves.

WATCH

Explore different ways of thinking of disability by watching **"Social Model of Disability"** by Shape Arts.

DO

Encourage your students to research disabled activism in their community. Is there enough accessible public transit? Are there ADA-compliant ramps and parking in public spaces? Is there a petition they can sign? A service project they can work on?

Universal Design Principles Worksheet

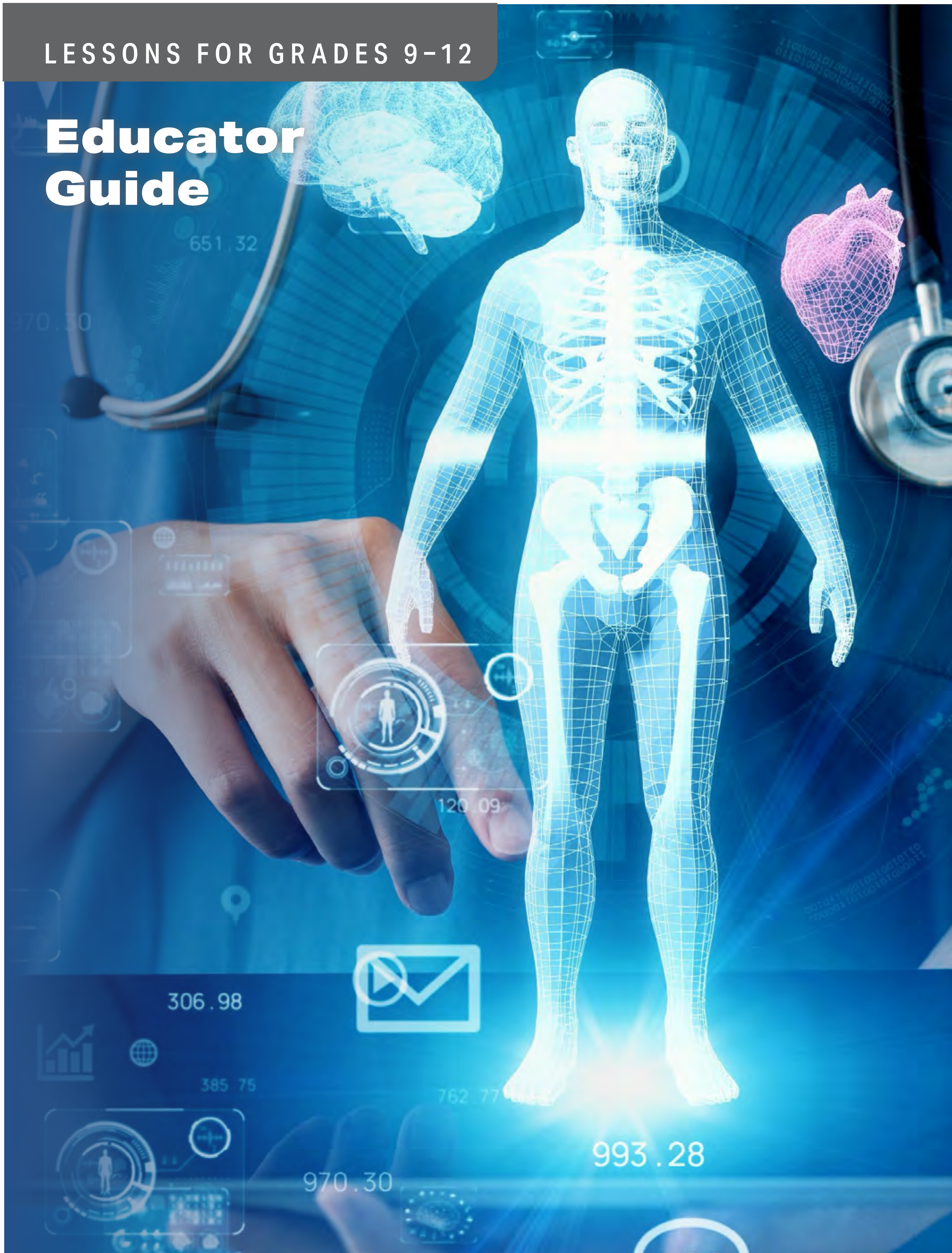
	GRADE
1) Equitable use • Useful, marketable, and safe for everyone— Identical, when possible, equivalent when not • Avoids segregating or stigmatizing any users	____ / 5
2) Flexibility in use • Accommodates a wide range of preferences and abilities • Can be used by right-handed and left-handed people • Accurate and precise • Adapts to a user's pace	____ / 5
3) Simple and intuitive use • Easy to understand • Intuitive and consistent with user expectations • Accommodates a wide range of literacy and language skills	____ / 5
4) Perceptible information • Essential information presented legibly and obviously in different ways (pictures, written, etc.) • Compatible with assistive technology	____ / 5
5) Tolerance for error • Minimizes and warns users of hazards and errors	____ / 5
6) Low physical effort • Minimizes repetitive actions and sustained physical effort	____ / 5
7) Size and space for approach and use • Approach, reach, manipulation, and use is comfortable, regardless of posture, body or hand size, or mobility	____ / 5
TOTAL	____ / 35

Universal Design Challenge — Student work examples

OPTIONAL: Print or display these images as inspiration for student designs

LESSONS FOR GRADES 9–12

Educator Guide



Optimal Optics

Total time to complete activity: 45 minutes

BIG IDEA

Participants will make pinhole cameras to investigate how the focal length of a lens affects the image created. Additionally, the students will use their experience to investigate the brain's role in vision.

IN THE FILM

In *Superhuman Body*, we learn about efforts to perform cataract surgery in underserved countries. A cataract is a clouding of the lens of the eye. In order to correct a person's blurry vision, the patient needs the surgical removal of a lens and the replacement of a new one.

This lesson will give students experiences with some aspects of lenses as well as how our brains work to provide our sense of sight.

OBJECTIVES

1. Students will construct and then measure the focal length of a camera obscura.
2. Students will compare similarities between their devices and the human eye.

NGSS STANDARDS

HS-PS4-5

Communicate technical information about how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy.

James Garrett aiding cataract patients in Ghana

Optimal Optics

MATERIALS

- ☐ At least 3 small plastic or paper cups in different sizes for each group; 3 oz., 12 oz., and 18 oz. are good options
- ☐ A large sheet of wax paper per group.
- ☐ Small flashlights or a lamp
- ☐ 1 Thumbtack or small pin per group
- ☐ Tape measure
- ☐ Rulers with millimeter markings

LESSON PREPARATION

Before students arrive, make sure to review the lesson materials. Review background information. Gather materials and set up the classroom.

General Preparation:

- Determine the best place to set up a lamp in the room.
- Ensure that you can create a dark or dim space to experiment with the camera obscura.
- Create a camera obscura as an example.

BACKGROUND INFORMATION

Aperture: A variable opening that allows light to pass through a lens.

Lens: A transparent substance that concentrates or disperses light.

Cataract: A clouding that occurs on the surface of the lens of the eye. This condition usually occurs with age as proteins in the eye clump together on the lens but can occur earlier on in some cases. Sun exposure, smoking and constant exposure to eye irritants can accelerate the formation of cataracts.

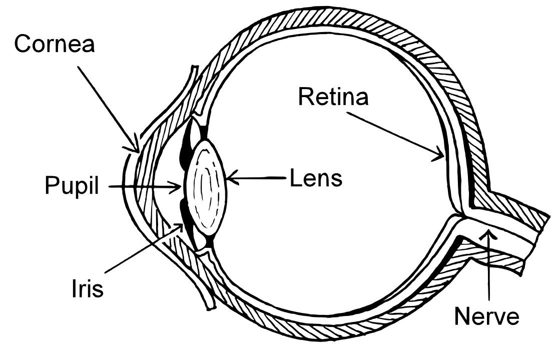
Pupil: Opening in the iris through which light passes into the eye. The pupil adjusts in diameter to control the amount of light that enters the eye.

Retina: The light sensitive tissue on the back of the eye, it sends sensations into the optic nerve.

Focal length: The distance from a lens to its focal plane. In the case of the eye, the focal length is the distance from the lens to the retina. This number can be used to contextualize near or far sightedness. Nearsighted people have eyes with a longer focal length and Farsighted individuals tend to have shorter focal lengths in the eye.

F-number: The ratio of a focal length to the diameter of the aperture of a lens. In the eye, this is the distance from the pupil to the retina.

BACKGROUND INFORMATION

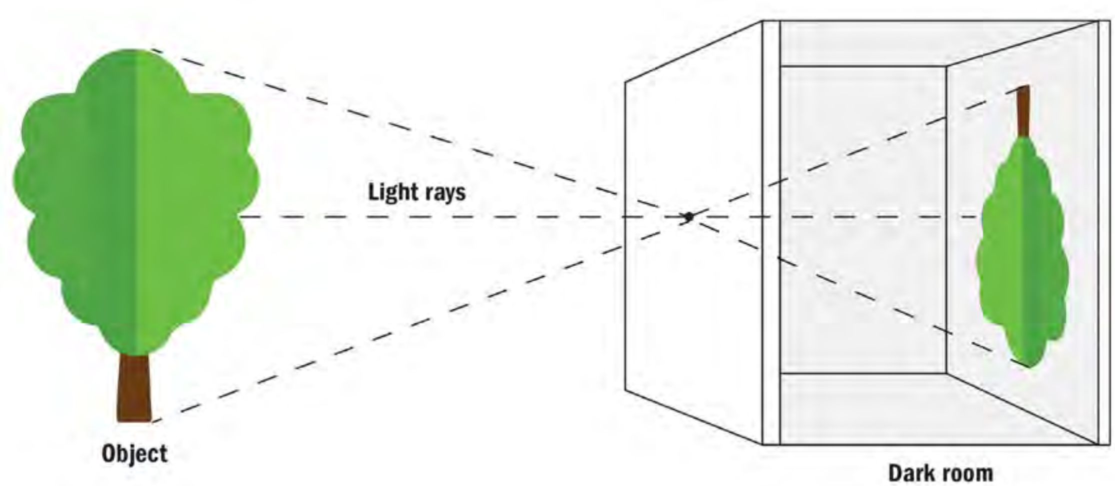


A camera obscura is a dark chamber with a small hole on one side, and a flat screen on the other. Light comes in through the hole from a light source and makes an upside-down picture on the opposite side. The idea has been around since 400 BC when a Chinese philosopher named Mo-tzu first wrote of the phenomenon. In the 11th century the Muslim scientist and writer, Alhazen, made improvements and provided the first details on how this mechanism works.

Our eyes are a bit like a pinhole camera. The **pupil** is similar to the pinhole and the retina is the screen at the back of the chamber. While we know that light moves in waves, we can also think of light traveling in straight lines for the purposes of the diagramming how light moves. The light that travels through our eyes arrives at the **retina** in the same way that it hits the screen on the back of a camera obscura, upside down. Our brain then flips the image once the information travels through the optic nerve to the brain.

Like a camera, the lens of our eyes can be damaged, and this affects our vision by changing the way light enters our eyes. **Cataracts** can cause cloudy vision because proteins and other compounds settle on the lens, and imperfections in the curvature of the lens cause astigmatism. The mechanics of how light travels, and how a lens affects the way light travels applies to both the eye and a camera.

Our eyes are different from a camera obscura in several important ways. First, and most obvious, we have two eyes that work together. Additionally, our eyes have variable **aperture** lenses because of the ways our **pupils** dilate and contract. Lastly, our eyes can shift focus on objects at different distances by changing the shape of the lens using small muscles in the eye. Whereas the camera obscura students make will need to be manually moved forward and backwards to focus on the light source properly. This lesson focuses on our eyes as a single pinhole camera to illustrate the ways that light interacts with a lens as well as the **retina.**



Source: www.camera-obscura.co.uk

PROCEDURE

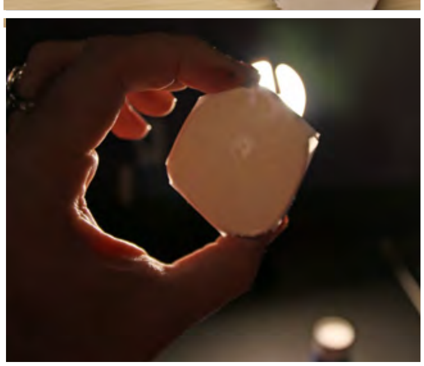
ANTICIPATORY SET

1. Explain that our eyes are one of the many complex parts of our bodies that are easy to take for granted. Most people tend to navigate the world using their vision and that vision is the result of these extremely complex organs. Ask the students:

   Can anyone name the parts of the eye and explain each part's specific function?

   Can anyone describe what glasses do for the eye? How do glasses work?

2 Discuss the class's relationship with eyes and then explain that they are going to make camera designs that can mimic a few aspects of how the eye works. If you wish, you may also share **this brief video** with the students to provide more clarification for what a camera obscura is and how it works.



ACTIVITY

1. Distribute cups, wax paper, and tape to each group. You may distribute the thumbtacks or small pins as well, or you may pre-poke holes in the cups before the students arrive.

2. If students are poking the holes in the cups, instruct them to create a small hole in the bottom of the cup as close to the center as possible.

3. Once the students have made the pinholes in the bottom of the cup instruct them to cut out pieces of wax paper larger than the mouth of their cups.

4. Next students should tape the wax paper over the mouth of the cup. The wax paper must be pulled flat over the cup to get the best image.

5. Once the students have finished constructing their camera obscura, turn off the lights and turn on your lamp. Instruct students to aim the hole at the lamp and look for an image of the bulb or lamp projected onto the wax paper. If they are successful, they will see an image of the light source projected onto the wax paper. This may look like a lightbulb or the outline of a lampshade if the lamp has one. They will not need to put their eyes to the paper but will need to keep their heads in line with the camera obscura.

6. Encourage the students to find alignment with where the image of the lamp appears projected on the wax paper. If the students are having trouble, tell the students to move their cups around and move forward and backwards. Once they have an alignment, they should see the light inverted on the wax paper. If the inversion is not clear encourage the students to place a finger or hand in front of the cup and the light source

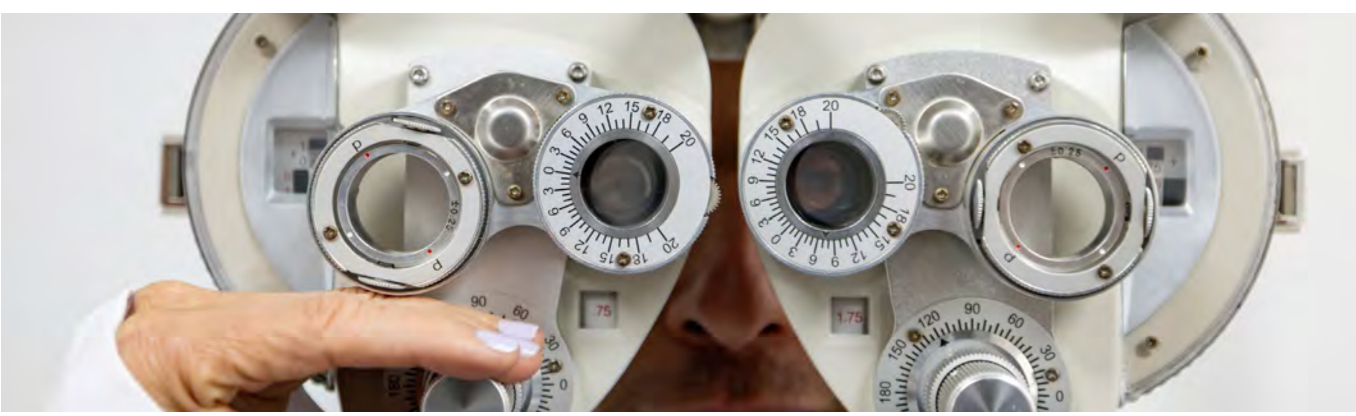
7. Pose the following questions:
   What do you notice about the image of the light source?
   What happens as you move the cup forward and backward?
   What happens when you put a finger in front of the cup between the cup and the light?
   Do all cups show the image clearly at the same distance away?
   Discuss the concept of inversion and how it relates to the lens in the eye.

8. Once the students have made their observations, explain the following: The focal length of our camera obscura will impact the distance from the light source at which the image is sharpest. In our devices, the pin hole is our lens, and the wax paper is our viewing plane.

   The calculation of the camera obscura's f-number involves dividing the distance from the pinhole to the viewing plane by the diameter of the pinhole. We need to determine the focal length of each camera. Thankfully this is simple with pinholes. We need to divide the distance to the viewing plane by the diameter of the pinhole.

9. Distribute rulers and instruct the students to find the f-number of each camera. Measuring the diameter of the pinhole may be very challenging so provide rulers that measure down to the millimeter at least. A standard 19-gauge thumbtack should leave a hole just over 1mm. Instruct students to use standard units.

10. The human eye is a lens, though it is a very different device than our pinholes. For one, the eyes function binocularly, that is both eyes work together to focus on one object and create our sense of depth perception. The diameter of the pupil can change to accommodate lighting conditions. However, we can still do a quick calculation to determine the eye's f-number. The focal length of the human eye is about 17-24mm, so we'll choose 17mm for the low end. The pupil can dilate or open to about 8mm. So, we can easily determine the f-number of a 17mm human eye.



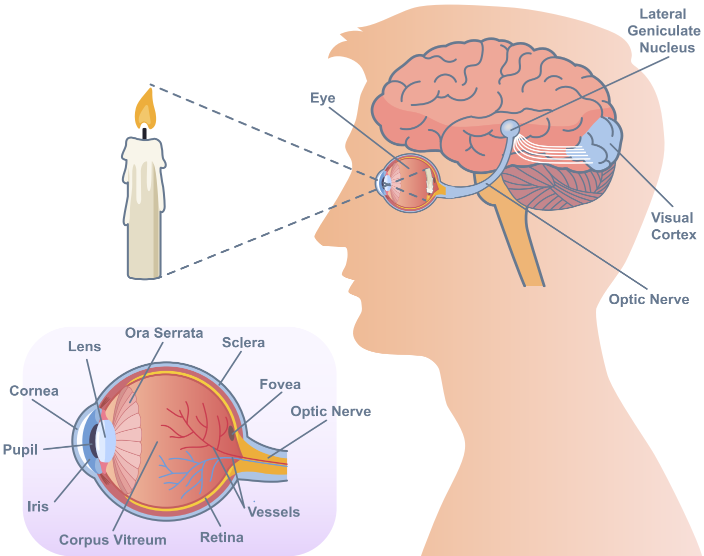
Opthalmologists use specialized instruments to test for irregularities in the shape of the eye and the condition of the lens

ACTIVITY (continued)

11. But what about the inverted image? Light travels in a straight line from the source as well as an object we can see. This means that when you see a person light is bouncing off of them. Due to inversion, light bouncing off their shoes enters the eye in such a way that the light touches the upper portion of the retina. Light from the head, hits the bottom portion of the retina. This applies to our pinhole cameras as well, resulting in a flipped image. Naturally, we don't see the world as appearing upside down, so what is happening?

    Our brain flips the image accordingly. So, while our eyes are giving the brain an upside-down view of the world, our brain flips the image to help us make sense of our surroundings.

    What other work is our brain doing for our vision? For one, our brains edit out our nose from our vision. It something that we don't notice until someone points it out. Our brain also hides the blind spot caused by the optic nerve. Learn more about this blind spot and the role our brains play in the extension activities.



WRAP-UP

The eye is a complex mechanism but there are components that we can simplify to better understand it. Numerous vision conditions are caused specifically by changes to the physical condition of the eye. While the film focused on cataracts, which occurs from hazing on the lens, some conditions will cause the eye to extend and contract reducing or increasing the focal length, causing nearsightedness or farsightedness.

EXTENSION ACTIVITY

The physiological blind spot is the place in our field of view that corresponds to the lack of light-detecting photoreceptor cells on the retina where the optic nerve passes through the optic disc. Due to the fact that there are no cells to detect light on the optic disc, the corresponding part of the field of vision is invisible. We don't notice that we have small holes in our vision, because our brain fixes it all for us behind the scenes.

Processes in the brain fill in the blind spot based on surrounding detail and information from the other eye, so we don't notice it, unless we go looking for it. Check out **this video** on why we have blind spots, then follow the directions on the next page to find yours.

Find Your Blind Spot

To find your right eye's blind spot:

- Close your left eye.
- Hold your left thumb out in front of you, with your arm straight.
- Look at your left thumb with your right eye.
- With your left eye still closed, hold up your right thumb.
- Place your right thumb next to your left thumb.
- Keep looking at your left thumb.
- Slowly move your right thumb to the right while looking at your left thumb.
- When your right thumb disappears, you found your right eye's blind spot.

To find your left eye's blind spot:

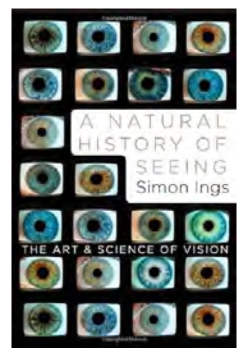
- Close your right eye.
- Hold your right thumb out in front of you, with your arm straight.
- Look at your right thumb with your left eye.
- With your right eye still closed, hold up your left thumb.
- Place your left thumb next to your right thumb.
- Keep looking at your right thumb and slowly move your left thumb to the left.
- When it disappears, you found your left eye's blind spot.

To find out how big your blind spot is, move your thumb around, up, and down, and to the left and right.

ADDITIONAL LEARNING

READ

A Natural History of Seeing: The Art & Science of Vision by Simon Ings examines the evolutionary history of the eye as both an instrument of physics as well as the histories of the people who have studied it. In addition to the various stories, the work contains numerous diagrams and full color images.



WATCH

NOTE: *Viewer discretion is advised for the following video.* This video may not be appropriate for all classrooms. **"Cow's Eye Dissection"** from the Exploratorium. In this video an instructor demonstrates the parts of the eye by dissecting a cow's eye.

TED-Ed **"How do glasses help us see?"** by Andrew Bastawrous and Clare Gilbert This video uses animation to walk the viewer through the ways that physicians use optics to improve our vision with glasses as our eyes age and wear down over time.

DO

If your students enjoyed learning about how the brain reverses upside down images, and compensates for the blind spot, then they may enjoy optical illusions. **This website contains over 150 optical illusions that work in the browser.**

Clear It Out: Stent Design

Total time to complete activity: 45 minutes

BIG IDEA

Students will apply design and engineering principles to the design of a prototype. The prototype will be for stents, whose objective is to clear plaque from clogged arteries.

NGSS STANDARDS

MS-ETS1-1

Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

IN THE FILM

In *Superhuman Body*, doctors need access to patients' hearts for multiple reasons. One reason is to combat heart disease. Stents are expandable devices that have numerous uses but mostly allow doctors to widen blood vessels to increase blood flow.

OBJECTIVES

1. Students will apply design and engineering principles to craft a prototype stent for clearing plaque from clogged arteries.
2. Students will test their designed prototypes and assess how well they perform.

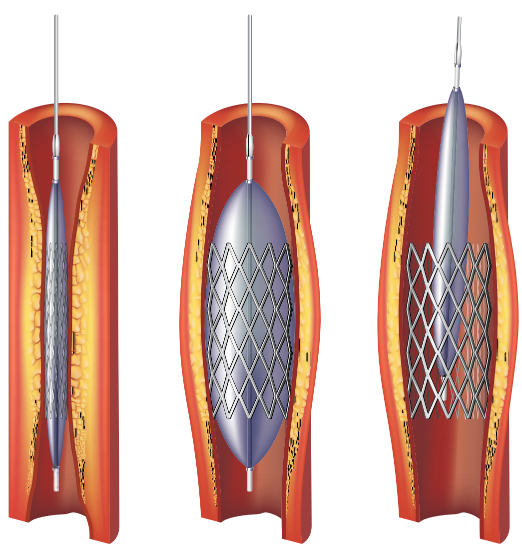


Illustration of a stent used to open a blocked artery

MATERIALS

- ☐ Straws
- ☐ Long balloons
- ☐ Wax paper
- ☐ Pipe cleaners
- ☐ Thin wire
- ☐ Rubber bands
- ☐ Duct or Painters' Tape
- ☐ Play-Doh or modeling clay
- ☐ Scissors
- ☐ Rulers or measuring tape

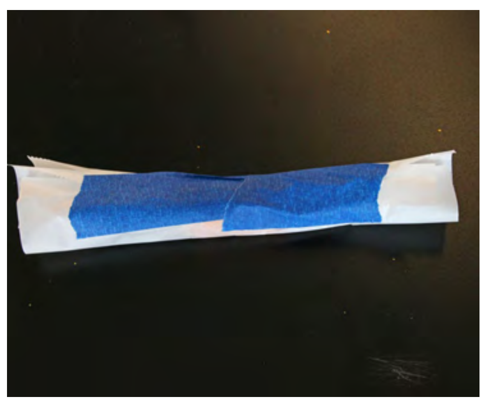
LESSON PREPARATION

Before students arrive, make sure to review the lesson materials. Review background information. Gather materials and set up the classroom.

Material Preparation:
Make enough model blocked arteries to provide one per team. If time allows, allow the groups to make their own blocked arteries to test.

- There are multiple ways you can go about making a model of a blocked artery, but we suggest starting with a flat, square sheet of wax paper. This material will form the artery wall.
- Take Play-Doh or modeling clay (about the size of a fist and spread it out on top of the wax paper or plastic sheet. The Play-Doh or modeling clay will represent plaque blocking the artery.
- Next take the wax paper or plastic sheet and roll it up with the blockage inside. This should look like a tube. Be sure to leave some space in the center for any "blood" to flow.
- If using wax paper use a strip of duct or painters' tape to secure the walls of the artery and keep the tube from unrolling. Rubber bands will work well you have access to plastic sheets. If there isn't something to hold the arteries together the tube may unroll as the students begin to insert their designs.






Clear It Out: Stent Design

BACKGROUND INFORMATION

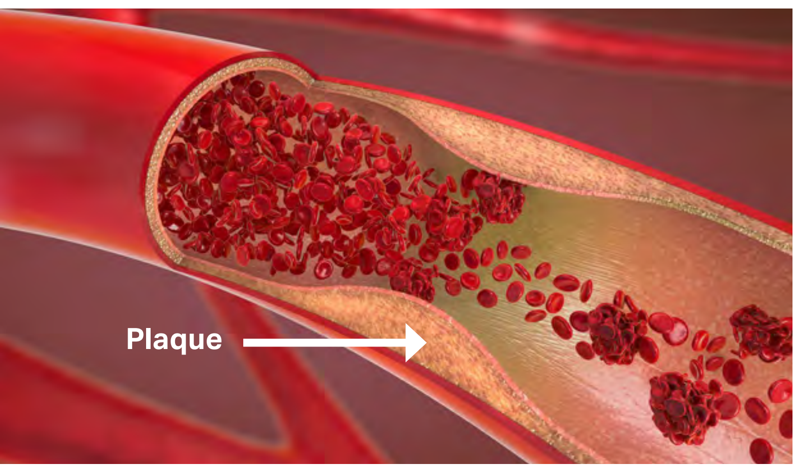
Stent: A tiny tube, often made of metal or plastic mesh, placed in an artery, blood vessel, or duct to prevent closure and ensure blood flow.

Plaque: Deposits of fatty substances that can be made of cholesterol, calcium, and other waste products produced by the body's cells.

Carotid Arteries: Arteries located on both sides of the neck. Plaque buildup in these arteries can impede blood flow to the brain, and stents are used to keep them open.

Prototype: An early model of a device or creation meant to test out its effectiveness. Typically, the prototype goes through multiple iterations.

Catheter: A hollow, flexible tube for insertion into a body cavity to allow the transmission of medicine or technology directly into a specific body part.



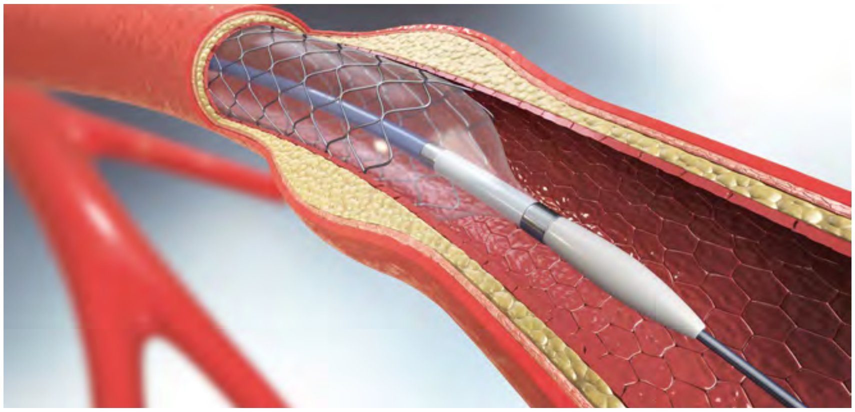
In a well-functioning circulatory system, blood vessels are clean and have a smooth configuration, like unobstructed pipes. Over the course of a lifetime, there are instances where the interior walls of blood vessels accumulate deposits of fatty substances and mineral substances collectively called **plaque.** Whether this plaque solidifies in place or hardens and becomes dislodged, it poses serious health risks.

This obstructive material hinders the normal flow of blood, impeding the delivery of adequate nutrients and oxygen to various parts of the body while also increasing blood pressure. Additionally, if plaque material traverses the blood vessels, it may eventually encounter smaller vessels, completely obstructing blood flow causing heart attacks and strokes.

Prevention is the best way to deal with these medical complications, with practices such as healthy eating and exercise. However, when blockages are identified, prompt treatment is necessary to prevent serious complications. Collaborations between engineers and medical professionals have yielded diverse strategies to alleviate obstructions in plaque-coated blood vessels. The focus of this lesson is on the treatment and prevention of heart attacks and strokes through the process of restoring blood flow to the heart when blocked by plaque or a blood clot. Biomedical, mechanical, chemical, and electrical engineers, among others, collaborate with medical doctors to refine treatments for these critical conditions.

BACKGROUND INFORMATION (continued)

One product of this collaboration are **stents.** Stents play a pivotal role in addressing various arterial issues. The procedure involves a minor incision in a blood vessel, usually in the groin, through which a slender, flexible tube known called a **catheter** is threaded to the specific location requiring stent placement. In cases involving the heart, the **coronary arteries** may accumulate plaque.



The **stent** is a small self-expanding metal mesh-like tube positioned within the artery. A tiny balloon is inflated to position the stent to prevent re-closure. Once inflated, the balloon and catheter are removed. Some stents are coated with medication, further mitigating the risk of artery re-closure.

PROCEDURE

ANTICIPATORY SET

1. Ask the students to consider what happens when a pipe gets clogged in their house or school?
2. Draw comparisons to our veins and arteries. What do the students know about how our arteries can get clogged? They may know that fatty foods can lead to these blockages, but it can also arise from other blockages such as poorly digested calcium or scar tissue. When our blood vessels get clogged with plaque, what can happen? Ask about what kind of complications might arise from trying to clear these clogs. Many of the complications result in heart attacks or strokes. Even before things can get to that point plaque blockages can cause high blood pressure and low oxygen levels to certain parts of the body.
3. Introduce the concept of a heart stent. Remind the students about the scene in *Superhuman Body: World of Medical Marvels*, where the doctors used a device to inject medication directly into the heart. Cardiovascular surgeons can use tiny devices similar to a plumber's snake to deliver medication, or even clear out these blockages.
4. Ask the students to think of what a device would look like to clear out clogged veins and arteries, and how it might work.

Clear It Out: Stent Design

ACTIVITY

1. Divide students into small groups (3-4 students each).

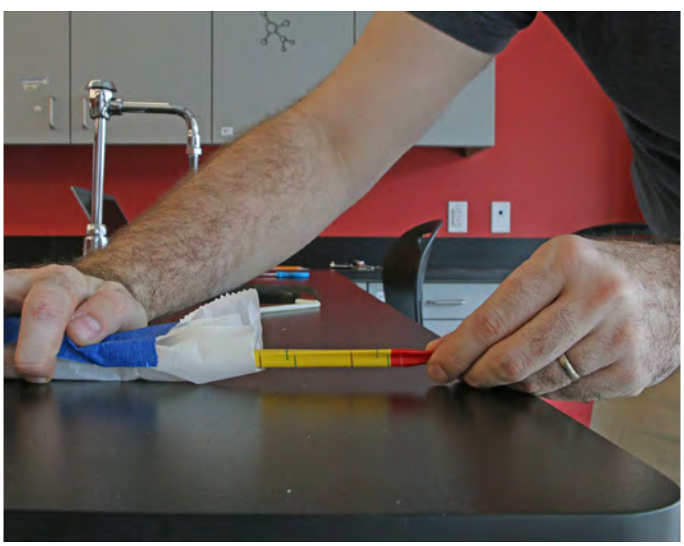
2. Explain that students will be playing the role of biomedical engineers tasked with creating prototype heart stents using provided classroom materials. The goal of the stent is to clear blockages in the model arteries. As the engineers in charge of developing a solution, the students must come up with a creative solution to clear the plaque from the arteries. You can share **this video** with students to provide them with an example of heart stents.

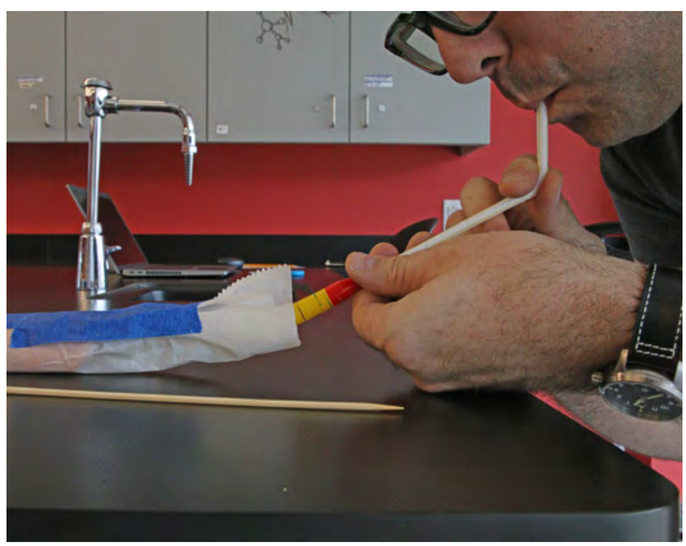
3. Introduce the available materials: straws, pipe cleaners, tape, Play-Doh, scissors, rulers or measuring tapes, and balloons. Emphasize that students should use these materials to design and create their stents. Remind them that they are making a **prototype**, an early model meant to test the concept, not something meant to fully function. The important thing is to learn from the efficacy of the design, not for the model to be perfect.

4 Encourage students to brainstorm and sketch their stent designs. Discuss possible design solutions, like how to move through the plaque, or how to clear it out entirely.

5. Allow time for students to build their prototype stents. They can cut, fold, and assemble straws and pipe cleaners to form their designs. Ensure the students consider the shape and structure of the stent in relation to the model artery.

6. Set up the testing phase by creating a model artery with a blockage using Play-Doh or modeling clay inside a tube. Each group will insert their device into the model artery to clear the blockage without causing damage. Emphasize safety and efficacy during testing.





Clear It Out: Stent Design Worksheet

Brainstorm stent ideas! Draw your designs below.

Name

WRAP-UP

Stents are tiny mesh coils made of metal or plastic that can be placed into a blocked artery. The coil is placed around a thin guide wire and guided into the blocked area. Doctors will then inflate a tiny balloon that will expand and push the plaque to the side and allow blood to flow more freely.

Engage the class in a discussion about the successes and challenges faced during the testing phase. Encourage students to share what worked well and what could be improved in their designs. Some questions for consideration include:

What differed from your original design and the final version?

Did the enhanced prototypes work better than the original prototype? Why?

What would you do differently in future iterations?

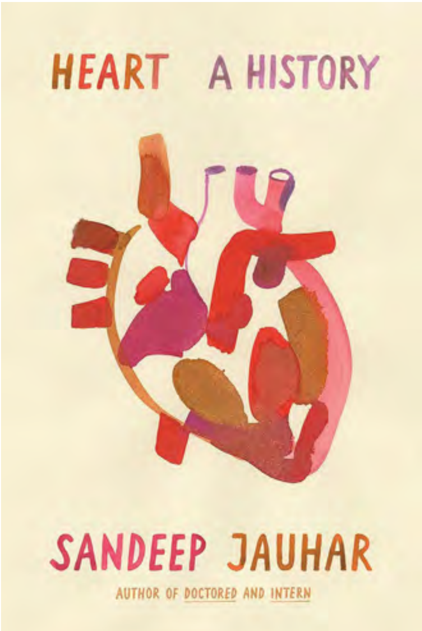
Do you think your prototype would function well in the human body?

Reflect on the significance of the students' designs and the importance of testing in engineering. Discuss how the designs could be modified or enhanced to better clear blockages without causing harm.

EXTENSION ACTIVITY

Iteration: If time allows, encourage the students to iterate the designs. First prototypes rarely make it into production. Can the students build a more effective stent? Encourage them to rethink their designs. If the students have had a chance to iterate on their own designs already, encourage them to swap designs and improve each other's.

ADDITIONAL LEARNING



READ

Heart: A History by Sandeep Jauhar explores the history of cardiovascular medicine, while also writing stories about his own family's history of heart problems.

WATCH

"Oxygen's surprisingly complex journey through your body" by Enda Butler
This animated video goes in-depth on how many of the body's systems work together to move oxygen around the body, from the creation of blood and how it travels through our arteries.

DO

Test blood flow using water! Students can use a thick plastic or hose material to simulate the artery. Use a dowl or unsharpened pencil to push Play-Doh or clay into the tube. Try out your prototype by pouring water through the hose and time the delay caused by the blockage. You can time this flow again once the blockage has been cleared by stents to quantify the improvement.

Accessible Engineering

Total time to complete activity: 45+ minutes

BIG IDEA

Using the seven Universal Design Principles, students will define an accessibility problem using the social and medical models of disability and then design a solution.

IN THE FILM

Our world is built and designed for a certain kind of human— one with two arms and two legs who stands a median height and weighs a median weight. However, there are people, like Ty Duckett from *Superhuman Body*, who have different physical characteristics that engineers and architects must take into consideration when designing items, buildings, and other spaces.

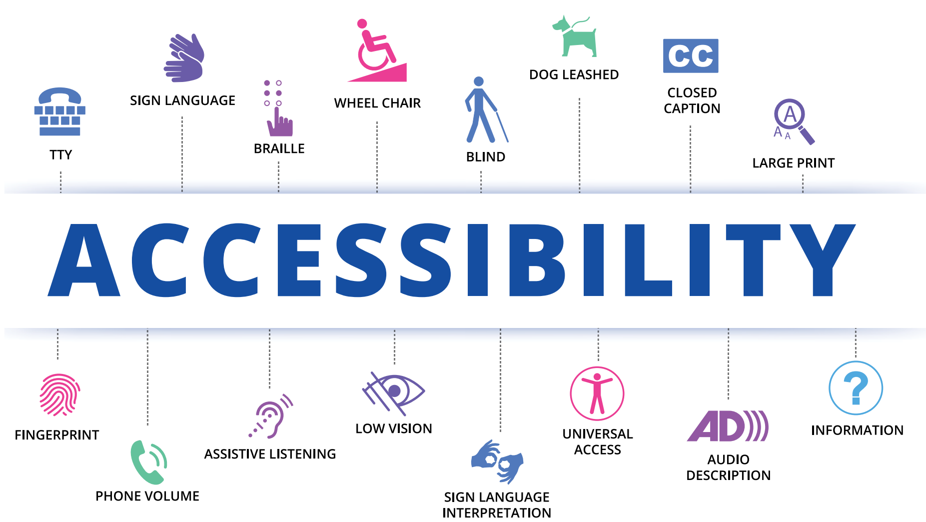
OBJECTIVES

1. Students will design and compare solutions to accessibility problems that use the medical model and the social model of disability.

NGSS STANDARDS

HS-ETS-1-3

Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.



MATERIALS

- ☐ Paper, pens, pencils (1 per group)
- ☐ Universal Design Principles handout (1 per group)
- ☐ Drawstring bags (1 per group)

LESSON PREPARATION

Before students arrive, make sure to review the lesson materials. Review background information. Gather materials, print out worksheets, and set up the classroom.

BACKGROUND INFORMATION

Vocabulary is very important for this lesson Use terms that the disabled community prefers and avoid words that have a negative history or connotation. Here is a good resource for language to use and avoid.

This resource shares age-appropriate disability education.

SAY THIS ...

- Accessible
- Disability
- People without a disability, able-bodied

NOT THAT ...

- Handicapped
- Differently-abled, special needs
- Normal, healthy

Disability: A condition of the body or mind that makes it more difficult for a person to do certain activities and interact with the world around them.

NOTE: The "problem" that makes activities and/or interactions more difficult is not with the person with the condition or often the condition itself. The difficulty is that the world around the person is not designed to accommodate them.

Limb difference: The partial or complete absence or malformation of arms and/or legs.

Prototype: A first, or preliminary model of something, especially a machine, from which other forms are developed or copied.

Assistive devices: External devices that are designed, made, or adapted to assist a person to perform a particular task.

Universal Design: The design of buildings, products, or environments to make them accessible to people, regardless of age, disability, or other factors.

EDUCATOR TIP:
If you have a student with disabilities in your class, do not use them as an example or put them on the spot by asking them to share their experience.

The following seven principles were developed by
THE CENTER FOR UNIVERSAL DESIGN AT NORTH CAROLINA STATE UNIVERSITY

1. **Equitable use** — Can be used by different people with different needs
2. **Flexibility in use** — Accommodates a wide range of individual preferences and abilities
3. **Simple and intuitive** — Use is easy to understand, regardless of the user's experience, knowledge, language skills, or current concentration level
4. **Perceptible information** — Communicates necessary information effectively, regardless of ambient conditions or the user's sensory abilities
5. **Tolerance for error** — Minimizes hazards and adverse consequences of accidental or unintended actions
6. **Low physical effort** — Can be used efficiently, comfortably, and with a minimum of fatigue
7. **Size and space for approach and use** — Appropriate size and space are allotted regardless of user's physical characteristics

PROCEDURE
ANTICIPATORY SET

1. Separate students into groups, if needed.
2. Introduce students to their client, Charlie. Charlie is a soccer coach and an entrepreneur with a limb difference— she doesn't have use of her right arm. This doesn't affect her athletic skills, but it is difficult for her to get gear into and out of the drawstring bags everyone else on her team uses. Charlie saw a business opportunity here and has published a call for proposals from engineering firms to address this problem. She plans to partner with the firm who develops the best design to market and sell the product!
3. Introduce students to their challenge: Each group is an engineering firm who wants Charlie's business! Their goal is to develop a prototype design for Charlie that will allow Charlie, and people like Charlie, to access their gear easily.

4. Pass out drawstring bags, and challenge students to open them with one hand. Students are not allowed to use their mouths! Discussion questions:

   Why is this task hard?

   Who was the drawstring bag designed for?

   Whose responsibility is it to make sure Charlie can open the bag?

5. Pass out the Universal Design Principles handout. At the top, students should identify the product or design that is causing the issue for Charlie, which is the bag itself.

ACTIVITY

1. Separate the class in half.
   - The first half of the students will re-design the drawstring bags such that they can be opened with one hand.
   - The second half of the students will design an assistive device that would allow Charlie to open the existing bag.

2. As students are working on their designs, challenge them to fulfill as many of the Universal Design Principles as possible. Here are some questions you may ask for each:

   Can someone with only the use of their right arm use this? What about someone whose hands shake?

   Can both a right-handed and left-handed person use this?

   Do I need instructions to use this, or can I figure it out easily? Can I use it if I don't speak or read English instructions?

   Can a blind, visually-impaired, Deaf, or hearing-impaired person use this?

   Will this item break if it is dropped? If I use it upside down or backwards, will it break or cause a hazard?

   How much strength does this require to operate?

   Can a very large or a very small person use this? Is it too big to keep handy? Is it too small and possibly get lost?

STUDENT NOTE:
An existing zipper backpack isn't very accessible, either! The user must balance it on something and twist around to get the whole thing to open.

Prototype idea

ACTIVITY (continued)

3. Have groups share their re-designed products or assistive devices with the rest of the class.

   Optional discussion:

   Which device is more likely to break first?

   Which would be cheaper or easier to produce?

   What challenges did students face in designing their products?

WRAP-UP

Medical vs. Social model of disability
Facilitate a discussion about these two different methods of addressing individuals' disabilities.

- Can students identify the "problem" with disability? Is the issue the person with the disability themself, thus requiring assistive devices? Or is the issue with a society or culture that doesn't design spaces or products to accommodate them?
- The assistive device groups worked with the medical model of disability, where it's Charlie's responsibility to make sure she can use the bag. The re-design groups worked with the social model of disability, where it's the designer's responsibility to make sure anyone can use the bag.

- What do students think about these two models? Is one always better than the other?
- An example of a medical vs. social disability model is building a stair-climbing wheelchair instead of utilizing ramps and elevators. Can students think of other examples of two different solutions to solve the same problem?
- An example students might be familiar with is TikTok's captioning system. Is the responsibility for making sure Deaf and hearing impaired users can understand the video on the content creator or is the responsibility on the disabled viewer? In this example, does that make this a medical or a social solution?

EXTENSION ACTIVITY

If you have extra time, or want to make the project last multiple days, assign students to create an advertisement poster, commercial, or social media post trying to sell their re-designed product or assistive device. If you have a thoughtful group and extra time, have other students grade their peers' designs on a new Universal Design handout. Then, have groups iterate their designs to make them more accessible.

If you have plenty of extra time and materials, have students build a **prototype** of their design. Have students respond to the some or all of the following writing prompts:

What does it mean to be inclusive or to accommodate?

What does my school do to accommodate students with disabilities? What can it do better?

What does my community do to accommodate community members with disabilities?

What can it do better?

What do I do to accommodate people with disabilities in my life? What can I do better?

Can you always tell when someone has a disability? Why or why not?

ADDITIONAL LEARNING

READ

Explore the lives and experiences of teens with disabilities by reading ***Unbroken: 13 Stories Starring Disabled Teens***, an anthology edited by Marieke Nijkamp.

Learn more about the history of disabled activism with the graphic novel ***The Disability Experience: Working Toward Belonging***, written by Hannalora Leavitt and illustrated by Belle Wuthrich.

ADDITIONAL LEARNING (continued)

WATCH

Hear from disabled activists about how they view the different models of disability in the video, **"What is the social model of disability?"** by Scope video.

DO

Encourage your students to research ways they can get involved in the disabled community. One suggestion is having students download and participate in the Be My Eyes app, which allows sighted volunteers to video chat with blind and low-vision users, providing a little assistance to solve everyday tasks.

NOTE: Please ensure that students obtain the proper parental permissions prior to using this app.

SOURCES CITED

Association of University Centers on Disabilities. (n.d.). Respectful disability language: Here's what's up! National Youth Leadership Network and Kids As Self Advocates. https://www.aucd.org/docs/add/sa_summits/Language%20Doc.pdf

NC State University. (n.d.). The Principles of Universal Design. Center for Universal Design. https://design.ncsu.edu/research/center-for-universal-design/

Parisi, K. (2020, July 28). How to teach children about disability, at every age. TODAY. https://www.today.com/parents/how-teach-children-about-disability-every-age-t187942

Accessible Engineering — Sketch Sheet

Sketch out your group's idea for a prototype to assist Charlie in opening the drawstring bag. Remember, a prototype is a preliminary model of something.

Name

Universal Design Principles Worksheet

	GRADE
1) Equitable use • Useful, marketable, and safe for everyone— Identical, when possible, equivalent when not • Avoids segregating or stigmatizing any users	____ / 5
2) Flexibility in use • Accommodates a wide range of preferences and abilities • Can be used by right-handed and left-handed people • Accurate and precise • Adapts to a user's pace	____ / 5
3) Simple and intuitive use • Easy to understand • Intuitive and consistent with user expectations • Accommodates a wide range of literacy and language skills	____ / 5
4) Perceptible information • Essential information presented legibly and obviously in different ways (pictures, written, etc.) • Compatible with assistive technology	____ / 5
5) Tolerance for error • Minimizes and warns users of hazards and errors	____ / 5
6) Low physical effort • Minimizes repetitive actions and sustained physical effort	____ / 5
7) Size and space for approach and use • Approach, reach, manipulation, and use is comfortable, regardless of posture, body or hand size, or mobility	____ / 5
TOTAL	____ / 35

SOURCES CITED

Advances in eye care. American Academy of Ophthalmology. (2021, May 28).
https://www.aao.org/eyenet/article/advances-in-eye-care

Car T cells: Engineering immune cells to treat cancer. National Cancer Institute. (n.d.).
https://www.cancer.gov/about-cancer/treatment/research/car-t-cells

Encyclopedia.com. (2024, February 1)." science and its times: Understanding the social significance of scientific discovery. encyclopedia.com. 8 Jan. 2024. Encyclopedia.com.
https://www.encyclopedia.com/science/encyclopedias-almanacs-transcripts-and-maps/advancements-optics-700-1449

How your heart works: Information on how your heart functions, including the structure of your heart, cardiovascular system, blood pressure and what can go wrong
https://www.nhsinform.scot/illnesses-and-conditions/heart-and-blood-vessels/about-the-heart/how-the-heart-works/#:~:text=The%20right%20side%20of%20the,the%20rest%20of%20your%20body

Evolution of Transcatheter Aortic Valve Replacement
https://www.ahajournals.org/doi/10.1161/CIRCRESAHA.114.302292

Transcatheter Aortic Valve Replacement
https://www.ncbi.nlm.nih.gov/books/NBK431075/#:~:text=In%202002%2C%20Dr.,patients%20at%20high%20surgical%20risk.

Prosthetic Technology. Arm Dynamics. (n.d.).
https://www.armdynamics.com/research-and-technology/prosthetic-technology

Slamdot, Inc. (2017, January 11). History of prosthetics. Premier Prosthetic.
https://www.premierprosthetic.com/02/history-of-prosthetics/#:~:text=The%20earliest%20proof%20of%20prosthetics,Ages%20saw%20only%20limited%20progress

MACGILLIVRAY FREEMAN FILMS

WRITERS AND CONTRIBUTORS

LESSON PLAN DEVELOPERS

Luci Finucan, Kamin Science Center
Shannon Gaussa, Kamin Science Center
Stu McNiell, Kamin Science Center

PROJECT MANAGEMENT

Lori Rick, MacGillivray Freeman Films

Kathy Almon and Janna Emmel,
MacGillivray Freeman Films
Educational Foundation

Tina Seidelson, Kamin Science Center

GRAPHIC DESIGN

Bethany McCall, Kamin Science Center
Megan McKenzie, Kamin Science Center

Superhuman Body: World of Medical Marvels Educator Guide was developed by the Daniel G. and Carole L. Kamin Science Center (formerly Carnegie Science Center)

MacGillivray Freeman
FILMS