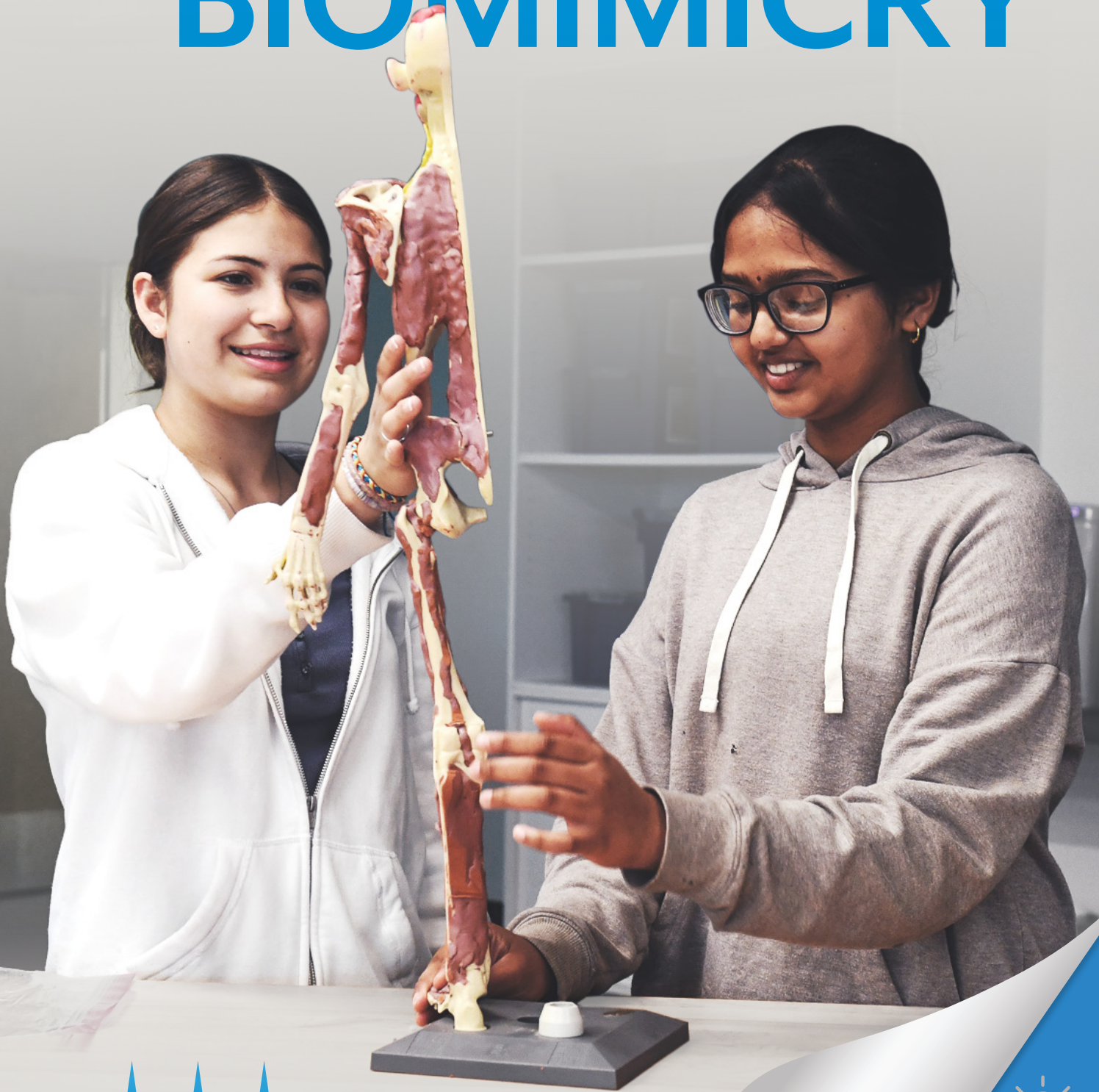


# BODY SYSTEMS AND **BIOMIMICRY**



TGR FOUNDATION



MIDDLE  
SCHOOL  
AND HIGH  
SCHOOL

## LESSON OVERVIEW

In this lesson, students will build a mechanical arm that mimics a human forelimb. They will observe the forelimb structure of other animals to see homologies and think about how their model could be adapted to mimic these other forelimbs. Students will learn about the field of "biomimicry" and see examples of how nature is being used as an inspiration and template for problem-solving technology.

Next, students will complete a squid dissection to see anatomical adaptations of squid and compare and contrast the body systems of a squid to that of mammals, such as marinedwelling mammals and to us, humans.

Finally, students will choose one anatomical feature of a squid and create a product that mimics that feature of the squid. Students will sketch a prototype of their product and create a short sales pitch that would explain how they are incorporating biomimicry in the product and how it could help humans solve a problem.

## THIS LESSON FOCUSES ON

ENGINEERING DESIGN CYCLE	21ST CENTURY SKILLS
<ul style="list-style-type: none"> <li>○ Defining the Problem</li> <li>○ Designing Solutions</li> <li>○ Creating or Prototyping</li> <li>○ Refine or Improve</li> <li>○ Communicating Results</li> </ul>	<ul style="list-style-type: none"> <li>○ Collaboration</li> <li>○ Communication</li> <li>○ Critical Thinking</li> <li>○ Creativity</li> </ul>

## OBJECTIVES

Students will be able to:

- Compare and contrast body structures and functions in humans and other animals by examining appendages.
- Dissect a squid to examine adaptations and identify their anatomical similarities and differences with the human body.
- Design a theoretical product that uses biomimicry of the squid structure and function to solve a problem.

## MATERIALS

For Mechanical Arm Model (per group):

- |   |  |  |
|---|--|--|
| <ul style="list-style-type: none"> <li>• 1 Pencil</li> <li>• 10 Craft sticks</li> <li>• 15 Rubber bands</li> <li>• 1 Wire hanger</li> <li>• 10 Paper clips</li> <li>• 6ft Fishing line</li> <li>• 6ft String</li> <li>• 1 Roll of masking tape</li> </ul> | <ul style="list-style-type: none"> <li>• 1 Cardboard</li> <li>• 4 Brass brads</li> <li>• 8 Clothespins</li> <li>• 6 Small binder clips</li> <li>• 1 Big binder clip</li> <li>• 1 Ball</li> <li>• Organs and Organ Systems student capture sheet</li> </ul> | <ul style="list-style-type: none"> <li>• Mechanical Arm student capture sheet</li> <li>• Teacher Resource: Homologies of the Forelimb</li> <li>• Engineering Design Process flow chart</li> <li>• Computer or mobile device with internet access for virtual dissection</li> </ul> |
|---|--|--|

**For Mechanical Arm Model (per group):**

- Supplies for students to create a sketch of their product

## HAVE YOU EVER WONDERED...

**How your body compares to bodies of other types of organisms?**

Our bodies are made up of many smaller parts that work together to solve problems and keep us alive. These smaller parts can be divided into cells, tissues, organs and organ systems. For example, the respiratory system in humans is made up of organs such as your mouth, nose, trachea and lungs, and allows you to bring oxygen into your body and remove carbon dioxide. What about animals that don't have lungs? How do they perform this important function? The organs and organ systems in different types of animals often function in similar ways even if they seem very different. In this lesson, you will see how the structures and functions of bodies in animals have striking similarities, as well as unique adaptations.

**If nature may have solutions to help solve our problems?**

In an emerging field called biomimicry, scientists and engineers work together to study the amazing abilities and anatomy of living things to come up with products that can help make human lives better. Everything from planes, trains and submarines to adhesives and architecture can take inspiration and be improved from the things that nature already has figured out.

## MAKE CONNECTIONS!

This section captures how this activity connects to different parts of our lives and frames the reason for learning.

### HOW DOES THIS CONNECT TO STUDENTS?

It is important that students have an understanding of their anatomy and how the parts of their body work together for their overall health and well-being. From a system to a cellular level, knowledge of how their body works and what can damage it may help students make healthier life choices that can result in their overall better health.

### HOW DOES THIS CONNECT TO CAREERS?

**Kinesiologists** study the science of human movement in home, work, sport and recreational environments. With an education in kinesiology, individuals can work as a coach, athletic trainer, fitness instructor or physical therapist, among other options. Kinesiologists will train their patients to use exercises, stretches or therapy to manage pain, prevent injury, increase mobility and facilitate wellness. They also guide development of prosthetics and artificial limbs.

**Orthotists and Prosthetists** design and make medical supportive devices for artificial limbs, braces and other medical devices. They measure or take impressions of a patient's body to fit patients for their devices and teach them how to use them.

**Nuclear Medicine Technologists** prepare radioactive drugs and administer them to patients for imaging or therapeutic purposes. Technologists target tissues and organs to mimic cellular activity for treatment.

**Nutritionists** are experts in the use of food and nutrition to promote health and manage disease. They advise people on what to eat in order to lead a healthy lifestyle or achieve a specific health-related goal.

**Animal Health Specialists** participate in animal health investigations seeking to identify the source and spread of infection and preparing and filing reports of the investigation for professional review. They may assist in tissue and other biological sample collection, coordination and submission, perform animal management tasks to include, but not limited to animal control, or present program materials to a broad range of audiences including livestock laborers and owners and animal industry workforce.

### HOW DOES THIS CONNECT TO OUR WORLD?

An understanding of how the human body works is important for the future of global healthcare. Students that have studied human anatomy and physiology may decide to pursue a career in the healthcare or medical field. An awareness of how the body systems work together and what happens when they are not working properly is important to prevent global epidemics from occurring as it encourages people to seek treatment for ailments before it spreads in communities and cities.

## BLUEPRINT FOR DISCOVERY

### DAY 1:

#### Whole Group (35 min):

1. Explain to students that today they will be comparing their own body structures and functions with that of an animal that may seem very different than a human—a squid. Although they may not think they have anything in common with a squid, they might just be surprised.
2. First, have them look at the human body and how it is made up of many parts that make a whole. Ask students if they can name the main organ systems in the human body. Share the FAST FACTS with students by displaying them on the overhead or writing them on the front board.

#### FAST FACTS

Characteristics of an animal include: mobile, eukaryote (multicellular), nervous system and ingest and digest.

#### Main organ systems

- |  |   |
|--|---|
| <p><b>a. Respiratory system</b>—takes in oxygen and releases carbon dioxide</p> <p><b>b. Circulatory system</b>—carries blood and nutrients from the heart to the rest of the body</p> | <p><b>c. Digestive system</b>—breaks down food and absorbs nutrients</p> <p><b>d. Excretory system</b>—gets rid of waste that cells produce</p> |
|--|---|

3. Hand out the Organs and Organ Systems student capture sheet and ask students to see if they can name the organs on the sheet and which of the organ systems on the board that they belong to. They can discuss their answers with the students sitting near them.
4. Go over the answers to Organs and Organ Systems student capture sheet.
5. Tell students to keep this sheet with them as they work through a virtual squid dissection. They will compare these organs and systems to those of the squid. Begin the squid dissection using: <https://tgreduexplore.org/interactives/following-natures-lead>. During the exploration, students will discover that squid structures are specialized to serve similar functions to human systems.
6. Inform students that they will be applying what they learned about structure and function to create a mechanical arm to complete a challenge.

### DAY 2: MECHANICAL ARM

#### Whole Group (15 min):

1. Engage students by asking them to move their arm and pick something up near them. Can they explain how their arm works? Allow a few students to give their best explanations. Now ask students, does their same description work to push in a chair? How about throw a ball? Clarify with students that our arm is designed to accomplish many tasks and is designed to be very flexible.
2. Introduce to students that they will be competing in a timed challenge against other groups. Teams will design a mechanical arm to accomplish a series of tasks. A member from each team will use their engineered mechanical arm to grab a ball from a starting table, walk 10 feet to another table, drop the ball into a cup, grab another ball on the table, bring the ball back to the starting table and drop the ball into another cup. Each team will get three trials and the best time out of three will be recorded.
3. Have students go to the following link (if they have a device) where they can explore the anatomy of a virtual arm: <https://www.healthline.com/human-bodymaps/arm>. (Teachers may project the webpage on the overhead screen. Adobe Flash Player will need to be enabled for viewing.) Have students look at the different layers of the human arm—paying close attention to the muscles and the bones.

4. Explain that they will now have the task of designing and creating a simple mechanical arm using supplies they will be given. Divide the class into teams of three or four and hand out the Mechanical Arm Challenge student capture sheet to each student.

Note to Teacher: In this activity, students will be creating a solution for a mechanical prosthetic arm using supplied materials. It is helpful to point out arms have ligaments, tendons and bones to help them function. There are some constraints: the mechanical arm must be at least 12 inches in length, must be able to pick up a ball and transport it and the mechanical arm should be arm/hand-like in its form and function.

5. Tell students they should draw out a quick sketch using the Mechanical Arm Challenge student capture sheet of what they intend to construct and the materials they will utilize.
6. Explain to students they will need to collaborate and employ trial and error as they are key components of the Engineering Design Process. Also, remind students to be creative and have fun.
7. Show students the Engineering Design Process flow chart and explain to them the steps and what they should look like.

Note to Teacher: It is important to remind students that there is no right or correct way to design the arm. Other groups will surely come up with a design that is different from theirs, the main concern is the design and the function of the mechanical arm.

### **Small Group (30–35 min):**

1. Give students time to plan and construct their mechanical arm models with their group.

### **Whole Group (15–20 min):**

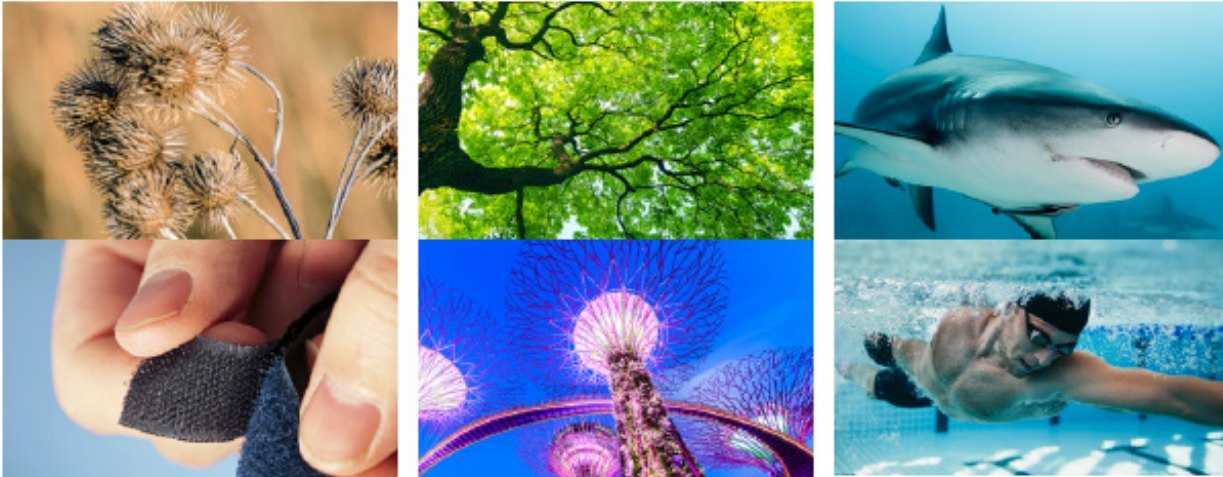
1. When the building time is over or when all groups have completed their models, allow each group to come and test their model for the challenge. If time allows, direct students to redesign their mechanical arms to successfully complete the task or to be even more efficient if their first design was successful.
2. After all groups have tested their model, ask students if it was helpful to study the anatomy of the human arm before creating their mechanical one. What applications does an understanding of the human body have in the field of mechanicals and prosthetics?
3. Show students the Teacher Resource: Homologies of the Forelimb on the overhead screen or white board. Ask students to brainstorm with their group about ways that they would alter their mechanical arm if it were for one of the other species shown in the image? What differences do they notice? What are the similarities?
4. Ask groups to share how they would modify their mechanical arm design if it were to model a different species.

## **DAY 3: STRUCTURE AND FUNCTION**

### **Whole Group (10 min):**

1. Explain to students that today they will take on the role of an engineer working in the field of biomimicry. With their group, they will create a theoretical product that mimics a structure in the organism of their choice to demonstrate a specific function.
2. Ask students to take out the Organs and Organ Systems student capture sheet, completed previously, and report the unique features and adaptations they saw or learned about as they examined the squid's anatomy in the dissection. Create a list on the front board, overhead projector or white board of students' observations.
3. Engage students by asking if they have ever heard of the term "biomimicry." If so, ask them to define "biomimicry" and how it relates to problem solving. Students may use examples from the exploration.

4. Show students images below and ask them if can identify how the images connect to each other.



5. Ask students to get into their small groups. Explain that for their next task, they should collaborate and choose one feature of the squid or a species of their choice that they think can help solve a human problem or become a useful product in the field of biomimicry.

### Small Group (30–40 min):

1. Have students create a theoretical product (if money and materials were not a limitation) based on an organism's anatomy that would be an example of biomimicry. It could be focused on the squid or a species of their choosing.

○ Examples from the squid may include camouflage suits that mimic the squid chromatophores, submersible vehicles that mimic the squid's body shape, a defense system that mimics the squid's ink sac, etc.

○ Encourage students with devices or internet access to try to come up with a novel biomimicry product, not one that already exists—OR to improve/modify a product that exists.

Share the FAST FACTS (below) with students to review some of the interesting body functions of a squid.

#### FAST FACTS

- |   |  |
|---|--|
| a. Squid belong to the phylum Mollusca.                   | d. Some species of squid are bioluminescent and have the ability to generate light like a firefly.                                     |
| b. Squid have gills just like fish.                       |  |
| c. Many species of squid have a lifespan of about 1 year. | e. Like the octopus and cuttlefish, squid have an ink sac that creates a dark cloud that acts like a smokescreen to confuse predators. |

2. When the group has decided on their product, have them create a detailed sketch of the what the product would look like and create a sales pitch (3 minutes or less) that they would use to sell their product idea to a company to manufacture (such as seen on the show Shark Tank).

Have students create a short slideshow (using PowerPoint, Google Slides, Prezi) that will accompany their sales pitch. Their slideshow should explain how the anatomy of their chosen organism has influenced their design and how their product will help solve a human problem.

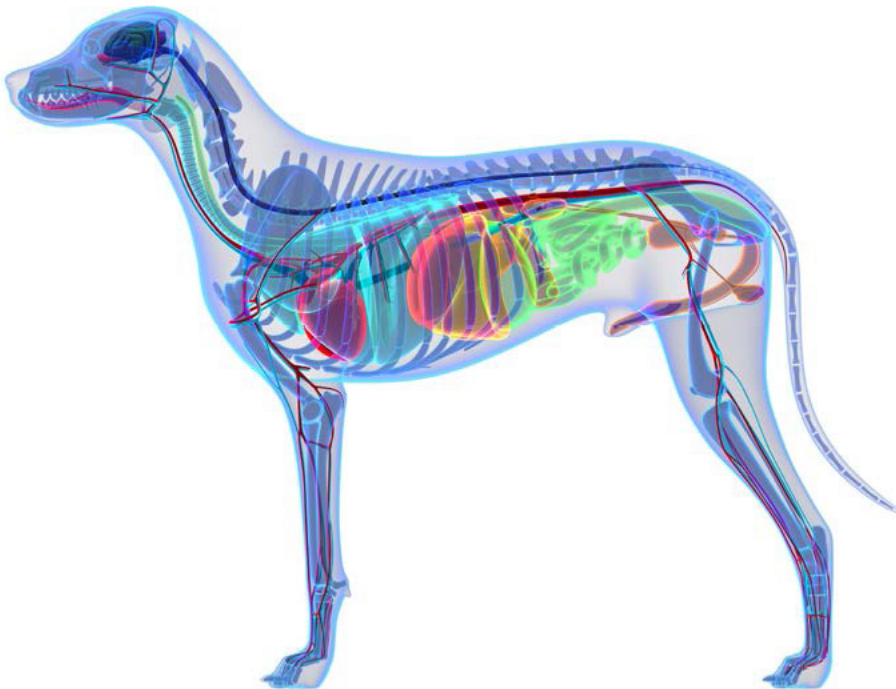
\*If time allows, students could also make a (non-working) prototype three-dimensional model of their product to accompany their sales pitch.

## Whole Group (10–15 min):

- Have student groups present their sales pitch and sketch of their product to the class. Students can vote on which products they would want to buy, or teacher could choose the most innovative or creative product presented.

## TAKE ACTION!

- Locate an image of an animal body system of your choice with the main internal organs. Categorize the organs into the correct systems based on your knowledge. For example, lungs, trachea and nose could be categorized under the respiratory system. Below is an example picture one could use for this activity. Once a new animal body system has been identified and labeled, compare the organs and organ systems to either a squid or human.





## NATIONAL STANDARDS

### Next Generation Science Standards

#### MIDDLE SCHOOL

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concept
<p><b>Systems and System Models</b></p> <p>Systems may interact with other systems; they may have sub-systems and be a part of larger complex systems.</p>	<p><b>LS1.A: Structure and Function</b></p> <p>In multicellular organisms, the body is a system of multiple interacting subsystems. These subsystems are groups of cells that work together to form tissues and organs that are specialized for particular body functions.</p>	<p><b>Constructing Explanations and Designing Solutions</b></p> <p>Construct a scientific explanation based on valid and reliable evidence obtained from sources (including the students' own experiments) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.</p>








#### HIGH SCHOOL

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concept
<p><b>Constructing Explanations and Designing Solutions</b></p> <p>Construct an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.</p>	<p><b>LS1.A: Structure and Function</b></p> <p>Multicellular organisms have a hierarchical structural organization, in which any one system is made up of numerous parts and is itself a component of the next level.</p>	<p><b>Structure and Function</b></p> <p>Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem.</p>

## ORGANS AND ORGAN SYSTEMS STUDENT CAPTURE SHEET

Part I: Name each organ and match the organ system they belong to using columns 1 and 2.

Part II: Navigate through the Following Nature's Lead exploration to identify the external and internal features of a squid using columns 3 and 4.

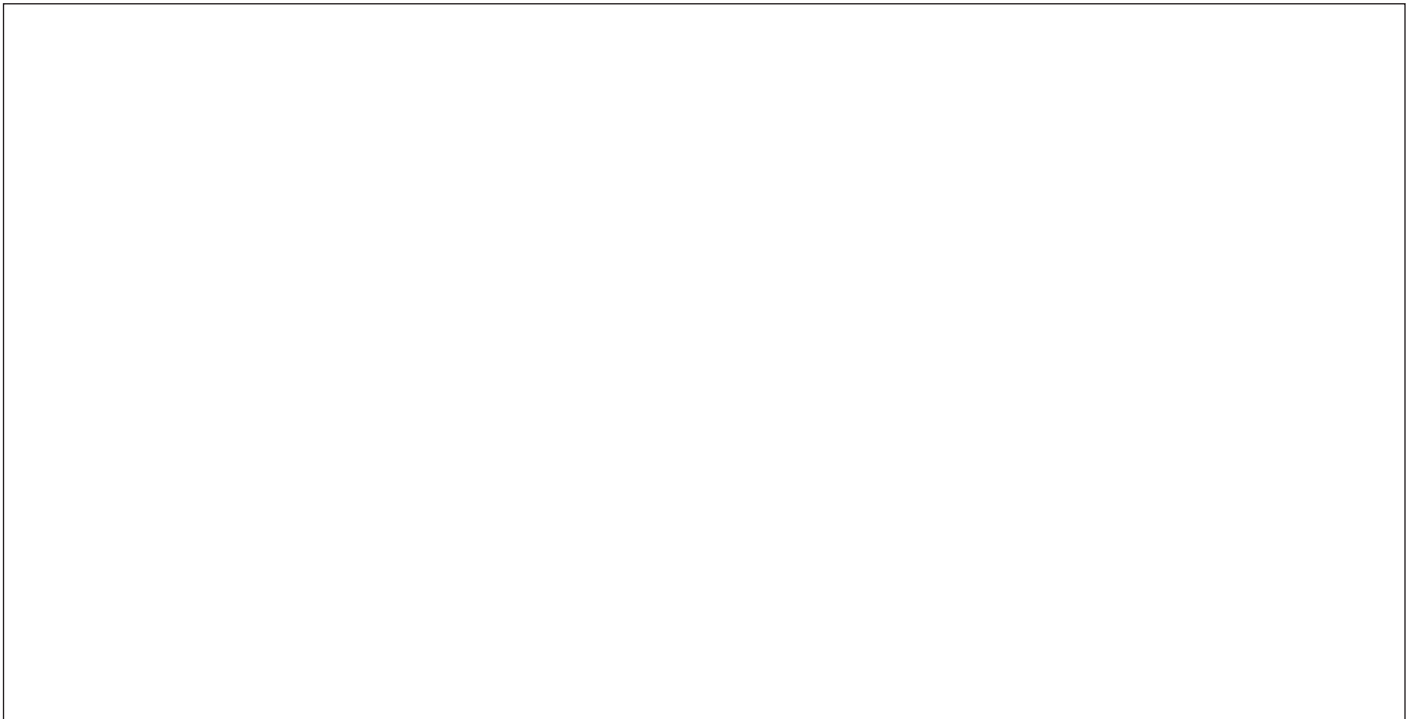
HUMAN		SQUID	
Organs	Organ Systems	External Features	Internal Features
			
			
			
			
			
			
			

## MECHANICAL ARM CHALLENGE STUDENT CAPTURE SHEET

### How to Build Your Mechanical Arm:

Work in groups of 3 or 4. Your mechanical arm must be at least 12 inches in length, must be able to pick up a ball and transport it and the mechanical arm should be arm/hand-like in its form and function. Work as a team, be creative and have fun.

Draw a sketch of your mechanical arm:



### Challenge Rules:

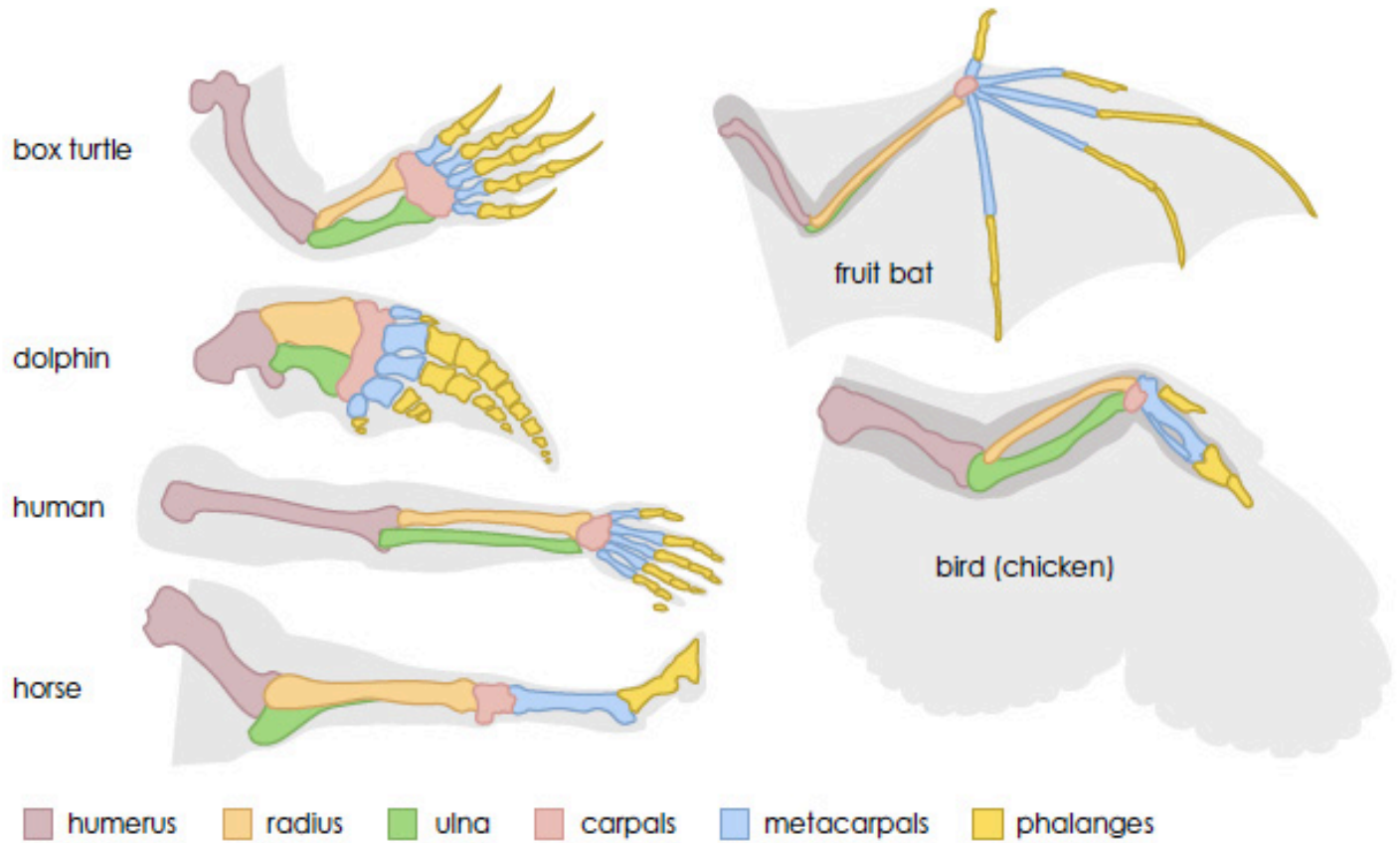
A member from each team will use their engineered mechanical arm to grab a ball from a starting table, walk 10 feet to another table, drop the ball into a cup, grab another ball on the table, bring the ball back to the starting table and drop the ball into another cup. Each team will get three trials and the best time out of three will be recorded.

Follow up Questions:

1. Did you use all the materials provided? Why or why not?
  2. Which item was the most important in your design? Why?
  3. What were the biggest challenges your team faced in designing or constructing your mechanical arm?
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## TEACHER RESOURCE: HOMOLOGIES OF THE FORELIMB

Homologies of the forelimb in six vertebrates



## ENGINEERING DESIGN PROCESS

