# Teacher Guide
# Looking at Joint Structure and Function

**Biomechanics Day 2017**
3 Sessions

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| **Learning Objective** | Students will explore the functions and abilities of joints by building a mechanical leg that has a ball and socket joint *and* a hinge joint. |

**Suggested Timeline Aligned with Engineering Design Process**

| Inspiration/Demonstration/Plan | Build/Test/Redesign | Reflect |
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| Day 1<br>60 mins | Day 2<br>60 mins | Day 3<br>30 min |

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| **Vocabulary** | Biomechanics | Force | Ball and Socket Joint | Hinge Joint | Translation |
| | Rotation | Adduction/Abduction | Flexion/Extension | | |

| ***Preparing for the Lesson*** | | |
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| **Action** | | **Suggested Materials** |
| *Preparing to teach the Design Challenge* | **1.** Reference the design challenge 'Make a Hip Joint' on Curiosity Machine: [curiositymachine.org/challenges/44/](curiositymachine.org/challenges/44/) Watch both videos, there is one on the main screen and one if you click on 'view challenge' and then 'guide'.<br><br>**2.** Plan and build your *own* prototype. This will be a good example to show students and will help you answer their questions. It is very important for educators to have experienced the building process prior to leading students through the design challenge.<br><br>**3.** Gather materials that students will need to complete the design challenge. Students should be able to pick what they want to build with and have various options. This design challenge is intended to be open ended and have multiple solutions to the prompt.<br><br>**4.** Print out the Design Portfolio (add link) for students. | Design Challenge Materials:<br>• Assorted cups of different sizes<br>• Assorted balls of different sizes<br>• Popsicle sticks<br>• Dowels or skewers<br>• Masking tape<br>• Rubber bands<br>• Cardboard<br>• Scissors<br>• Straws<br>• String<br>• Brass fasteners<br>• Toilet paper or paper towel tubes<br>• Rulers |

| **Day 1** | |
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| **Inspiration/Demonstration/Plan**<br>60 minutes | |
| **First demonstration:** Ask students to stand in place and move their arms and legs. Ask them to march in place, raise their hands and bend their elbows. Have them focus on how their joints move as they do this. Joints are what allows your limbs to bend. Have them move in other ways that you think demonstrate how their joints move. | • Access to curiositymachine.org and internet<br>• Access to a projector with speakers to |

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Once the students have completed their study of how their own bodies move, work together to create a list of joints. Include: knee, elbow, wrist, ankle, hip and shoulder. Have students complete pages 1 and 2 of the student guide.<br><br>
Questions to Ask : How are these joints similar? How are they different? Answers can include, size and location of joint, direction of the movement and size of the movement created, etc.<br><br>
*S*how Running, Jumping, and Hitting: The Science of Sports: http://tinyurl.com/biomechanics2017. This video introduces biomechanics and will inspire the students on what to build.
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show video: http://tinyurl.com/biomechanics2017
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Second Demonstration: Introduce design challenge and key concepts.<br><br>
Say "For this activity you will be a biomechanical engineer and will study how joints function.  You will use what you find out to build your own mechanical leg that includes a hip joint and a knee joint." To prepare, have students study how their hip joints move and compare and contrast them to how their knee joints move. Ask students to stand up and do the following or you can demonstrate these motions for them:
<ul>
<li>First experiment: With your legs straight, feet pointed forward, swing your right leg forward and backward off the ground while keeping it straight. Ask students if they notice the movement is occurring in their hip socket. Now, ask students to swing their leg again, but this time kick it by bending their knee back and extending it when they bring their leg forwards. Compare and contrast these different motions. How does the leg move differently when it's straight versus when you are kicking it?
<ul><li>This movement in the hip and the knee is called flexion and extension.</li></ul></li>
<li>Second experiment: With your legs straight and feet pointed forward, move your right leg off the ground and out to the side, towards your right hand. Continue this motion several times. Ask the students where the movement is taking place. Now, can you keep your hip still and do this motion by moving only your knee? Ask students why they think this isn't possible.
<ul><li>This movement in the hip is called adduction and abduction.</li></ul></li>
<li>Third experiment: With legs straight and feet pointed forward, rotate one foot to the right and left while keeping your ankle stiff. Ask the students if they notice the movement is taking place in the hip. Ask students to try to rotate their feet without moving the hip or ankle and by using their knee. They will quickly see that this is not possible.
<ul><li>This movement in the hip is called lateral rotation and medial rotation.</li></ul></li>
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Demonstration Materials:
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<li>Assortment of balls (various sizes): Tennis, wiffle, ping pong, etc.</li>
<li>Plunger</li>
<li>Jump ropes or string</li>
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National Biomechanics Day


Introduce the types of joints:

- Hip→ Ball and socket joint: A type of joint that rotates on or in a spherical object. This type of joint creates multi directional movements. That is why you are able to move your hip in more directions than your knee.
- Knee→ Hinge joint: A type of joint that moves by opening and closing. Your knee joint can't rotate or bend all the way around.

Ask the question: How do these joints stay together and how are they able to move? The answer: muscles, tendons and ligaments!

**Additional Demonstration (Optional):** Have an assortment of playground balls on a table. These balls will act as the ball in the ball and socket joint. Next, introduce the socket, a plunger (*a cheap toilet plunger is best that has a simple rubber semi sphere*), salad bowl or box may also work. Note: The socket will need to have a stick attached so if using a bowl or box you can tape a short stick to one side. A plunger is ideal since it already has an attached stick but not necessary if you can attach something different.

Ask the students which ball they think will  work the best. Ask one student to select a ball that fits nicely into the socket. Have a different student hold the ball on the table. Have another student rotate the socket on the ball. Notice how many directions of rotation you are able to achieve and how fluid the movement is. If it isn't smooth, try another ball.

Next, position the socket upright on a selected ball with the attached stick pointed vertically. Ask two students to tie two ropes onto the socket handle in opposite directions and one student to hold the ball. Now ask the students to coordinate and pull the handle in multiple directions without it falling over. How hard is it to control?

Introduce a third rope and see how many directions of movement they are able to achieve without having the handle fall over. Encourage the students to move the position of the ropes to see if that influences the motion. The goal is to have students fluidly rotate the socket three hundred and sixty degrees around the ball.

Take away: The ropes are acting as muscles attached to the bones. The position of the muscles is important for how the joint will move. For a joint like the hip joint that is able to move multi directionally, many muscles need to be working together in order to achieve positive range of motion.

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| **Plan: Review  the Design Challenge:** In this design challenge, we will make our own mechanical leg that has a ball and socket joint and a hinge joint. To test if | • Plan pages |

your leg is working, it will have to touch three different cups in different places. To reach the cups, you need to design a ball and socket joint that can **rotate**, **extend** and **flex**, and **abduct** and **adduct**.

Start out by making a functioning hip joint,then add a hinge joint to represent the knee.

It is recommended to show the students examples of mechanical legs that you built and discuss how they could improve your design. Remember your design doesn't have to be perfect, encourage the students to work together to find solutions to the prompt. Emphasize that there are many ways to solve the design challenge.

DIsplay or list materials that the students will have access to when they build.
**Prototype example:**

Place students into groups and have them draw plans of what they want to build, page 3 of the student guide. Ask them to label materials that they will use and to draw it from more than one perspective to indicate how the joint will move. These drawings will be used for building the mechanical leg in the the lab, so the more detailed they are the better. Encourage students to think about the following:

- How can you show movement on your drawing? Include directional arrows.
- The hip can move in multi directions, remember the terms: rotation, flexion, extension, adduction and abduction. How are you going to build a hip joint that can do all of these movements?
- The ball has to fit inside the socket and rotate without falling out, how are you going to secure your joint without limiting movement?

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<tr><td>Prep the students for the lab visit and share any lab specific rules. The lab is a working environment so best practices and rules need to be mentioned.</td><td></td></tr>
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<table>
<tr><th colspan="2">Session 2 - At the Lab</th></tr>
<tr><td colspan="2">Build<br>45 minutes</td></tr>
<tr><td>Action</td><td>Materials</td></tr>
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Ask the lab managers to give a brief tour and introduction to the lab. Also ask the lab managers to tell the students where they can store their belongings, how to keep the space clean, and who to contact if they need to leave the space before the end of the session.<br><br>
Reintroduce the concepts from session 1. If you did not do the first or second demonstration you can do that now.<br><br>
Make sure that the following concepts are reintroduced:<br>
• Similarities and differences between our hip and knee joints..<br>
• The hip joint is a ball and socket joint that can move multi directionally.<br>
• The knee joint is a hinge joint and has a more limited range of motion.<br>
    ○ Ask students if they can remember what motions these two joints can make. Ask for vocabulary words.<br>
• Joints are able to move because of muscles that push and pull the structures in various directions.<br><br>
Design Challenge Prompt: In this design challenge, we will make our own mechanical leg that has a ball and socket joint and a hinge joint. You need to design a ball and socket joint that can rotate, extend and flex, and abduct and adduct in order to touch three cups positioned in direction locations.<br><br>
Building Steps<br>
1. Display the design challenge materials in a central location. Students should be able to pick what they want and explore various options.<br>
2. Distribute worksheets that students started in the previous class. Students should consult their plans. Encourage students to continue to plan what they want to build before getting materials.<br>
3. Students should work in groups to build their mechanical legs. One mechanical leg per 2-4 students..<br>
4. Students should focus on the hip socket first, they will have to build a joint that moves fluidly but doesn't fall out of the socket.<br>
5. Let students explore different balls and different sockets, finding which ones work better than others.
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Design Challenge Materials:<br>
• Assorted cups of different sizes<br>
• Assorted balls of different sizes<br>
• Popsicle sticks<br>
• Dowels or skewers<br>
• Masking tape<br>
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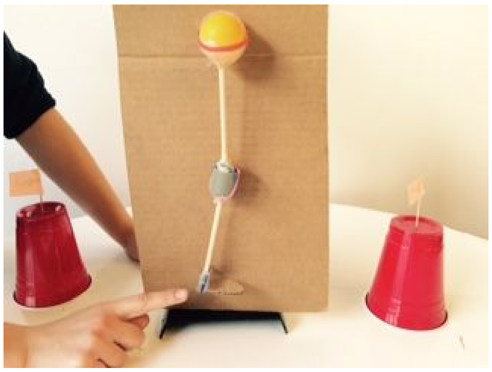
## Testing

*20 minutes*

### Action

For testing: Students go to the designated testing station to test how their mechanical leg works. They can set their leg on a piece of cardboard to help make it stand on its own. See image below:



Testing Criteria

- Test 1: Can your leg flex and extend to touch the cups in front and behind the leg?
- Test 2: Can the leg abduct and adduct to touch the cup away from the leg?
- Test 3: Can the leg rotate from the hip without falling out of the socket?

Students should build the hip joint first, test the functionality and then add the knee joint after successfully passing the three tests.

After most of the students have tested their designs. As a group, identify the areas that can be improved. Some examples could be:

- Securing the ball in the socket better so it doesn't fall out when it rotates.
- Using a larger/smaller socket or different ball for it to move fluidly.
- Using different materials for the hinge joint so it doesn't over extend or flex.

Working together, groups can create a list of redesign options to improve their design.

### Materials

Testing Station

- Table
- 3 cups positioned in different locations

| **Redesign**<br>*25 minutes* |
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| Students take their model back to their work stations, review the suggested improvements and prioritize them. If possible, give each group a copy of their original plan to record the adjustments they make. If not, students can use a different color pen to indicate their changes. Encourage students to alter their prototypes and retest. |

**Session 3**

**Reflection**
*30 minutes*

**Group Reflection**
Ask students to complete these reflection questions together in their groups:
1. How did you create your mechanical legs to complete the task?
2. What materials did you use in your design?
3. What motions did you have the most problem creating?
4. What types of joints did we learn about? What types of movements do they do?

**Whole Group Reflection**
Do these activities with the whole class.
1. Have students share their mechanical leg plans and prototypes and talk about what didn't work the first time, how they knew it didn't work, and what they did to improve.

2. Like the mechanical legs the students built, muscles have an internal structure that supports the body. As a group, brainstorm some internal structures that help humans and animals to survive. Examples could be skeletal system, respiratory system, digestive system, etc. For further discussion ask "Do robots need any of these structures in order to function? Why or why not?"

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| *Tips* | 1. If a student gets stuck when they are planning or start building, have them look at the material table and see if there's anything there that gives them ideas.<br>2. Have students make sure that the ball fits snuggly in the socket but can also move around easily. The ball should also be secured in the socket so it doesn't fall out. Students can secure it with a rubber band or string that keeps it in place but doesn't limit the movement.<br>3. If students get stuck, pause the build time for a brief sharing of work in progress so students can compare strategies and redesign.<br>4. Encourage students to be persistent and creative. This isn't easy and there isn't just one right way so if they are having trouble, that's okay! We can all learn from failure instead of letting it limit our capabilities. |
| How to make it simpler | 1. Have student build only a functional hip joint and omit the knee joint.<br>2. Decrease the amount of testing scenarios. For example, have students create a hip joint that only needs to flex and extend instead of creating a multi directional hip joint.<br>3. Simplify the materials students can use. For example, instead of giving students a lot of options to make their ball and socket joints,, give them one ball and one cup that will fit together well. This allows them to spend more time focusing on other parts of the design challenge, such as finding a way to secure the ball to the socket and making it move. |

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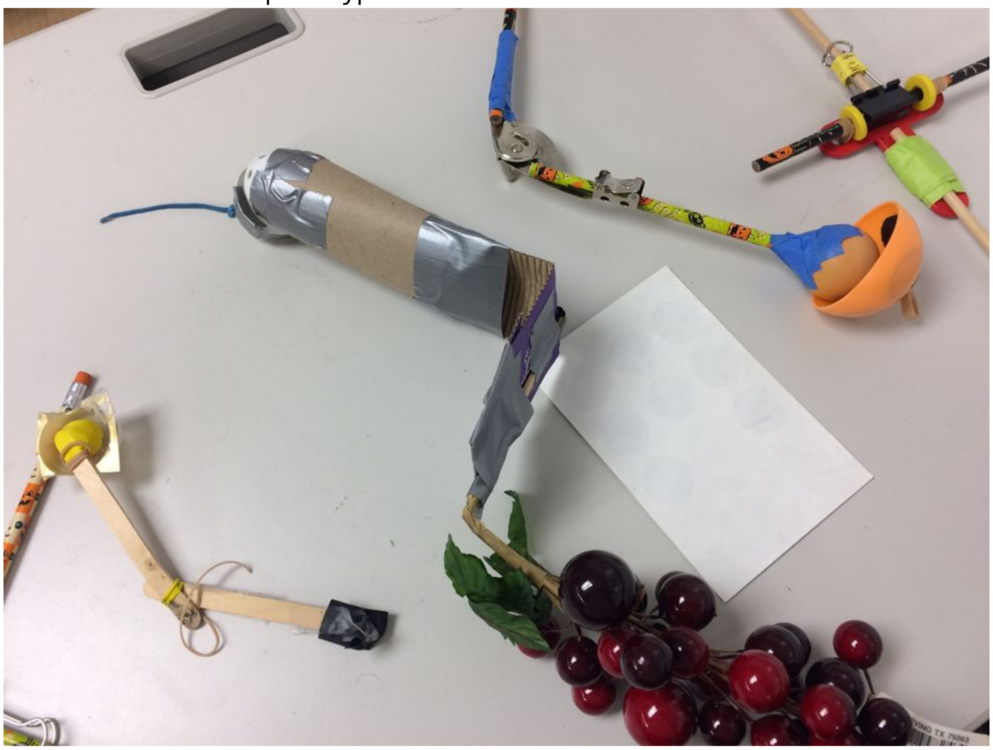
| How to make it more challenging | 1. If students have created a functioning hip and knee joint, they can create an ankle joint which acts similarly to a hip joint and moves in multiple directions.<br>2. Students can create a mechanical leg that operates from a distance. For example, they can add string to the leg at the jointed sections and pull in a certain directions to move the leg. |

Here are some other prototypes:





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