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# iBIO STEM Kits: Robot Walkers

## iBIO STEM Kits welcomes you to a SCIENTIFIC JOURNEY!

This kit contains the materials you will need to investigate **biomimetics, robotics and gravity**. The purpose of this kit is to challenge you to explore how we can use gravity (a possible source of green energy) to move a simple walking robot and how we can DEFY gravity to build an arch. We also challenge you to explore these two engineering problems as a scientist would. What does this mean?

Scientific exploration is different than just playing around because it asks you to think about HOW you investigate. This means you need to do your investigation by observing what happens when you change a variable you have carefully chosen. This helps you to understand WHY something happens. Scientific exploration also means that you record WHAT you see or measure and that you record WHY you think it happens. The STEM Kit Journal that you are holding will help to guide your investigation and give you a place to record your observations, measurements and conclusions.

Follow the QR code at the top of the page for additional resources on this activity. This type of investigation is associated with some very exciting careers! We hope that you will explore these resources while you are doing your investigation!

## Let's Get Started!

**FIRST**, you will need to prepare your workspace. This can be a very wet and messy investigation, so make sure that you are using a space that will not be easily damaged. A kitchen table will work nicely. To make your clean up easier, you should protect your surface by laying out some used newspaper or opening up a paper grocery bag.

**SECOND**, you want to unpack your materials. Use the list below to identify which materials are used in each part and organize them in your workspace. There are some additional materials that you will need to supply from your home.

**Kit Materials for Part A:**
- Legs template (cardstock)
- Foam with adhesive backing
- Wooden skewer
- 2 Mini craft sticks (2-½ inches long)
- Wooden or plastic beads
- Sharpened pencil
- Duct tape

**Other items needed:**
- An incline ramp (use your box)
- Scissors
- Safety glasses

**Kit Materials for Part B:**
- Legs template (cardstock)
- Foam with adhesive backing
- Wooden skewer
- 2 Mini craft sticks (2-½ inches long)
- Wooden or plastic beads
- Sharpened pencil
- Duct tape

**Other items needed:**
- An incline ramp (use your box)
- Scissors
- Safety glasses

**Kit Materials for Part C:**
- 2 Cardstock "brick" templates
- Tape
- Glue stick
- Sandpaper

**Other items needed:**
- Scissors
- Safety glasses

**LAST**, you need to be prepared for experimenting safely. Always be careful when working with scissors or sharp instruments to prevent injury. Wear safety glasses if you have them.

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# Passive Dynamic Walking Robot-Engineering

**Adapted from Bots!** Robotics Engineering with Hands-On Makerspace Activities **by Kathy Ceceri**

## Part A: Build - How can robots be powered by gravity?

**Here's what you will need to make ONE robot:**

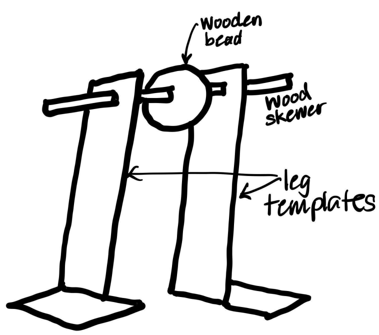
- Legs template (cardstock)
- Foam with adhesive backing
- Wooden skewer
- 2 Mini craft sticks (2-½ inches long)
- Wooden or plastic beads about ½ inch across with holes big enough to fit on the skewer
- Duct tape
- Scissors
- Sharpened pencil
- An incline ramp to use to test your walker (you can use your box for this!)

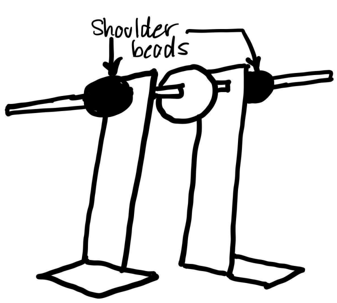
**What is a robot?**

A robot is defined as a machine that looks and acts like a human being. In real life, robots can take on many different forms. Some robotic models don't even need a motor. They are called passive-dynamic walkers and they can use gravity. When they are set on an inclined surface, this type of walker will begin a walking action that gravity will power the rest of the way. It creates a natural-looking walking action and it saves energy!

Researchers have become interested in these simple, behavior based robots because they are cheaper and easier to build and can be used as models to help scientists to build more complicated robots.

We are going to build a small-scale passive dynamic walker.




**Procedure for making a BASIC robot:**

1. Make two "L" shaped legs using the template from cardstock. Important: As you build the legs, make sure they match so that your walker stands evenly on its feet!
2. Use the pencil to poke a hole through the tops of the legs, near the center. Insert the skewer through the holes. Make sure the legs can swing back and forth freely. If not, make the holes bigger.
3. Remove one leg, slide a bead onto the middle of the skewer, then replace the leg on the other side of the bead. With the toes pointing toward you, fold one foot out to the left, and the other foot to the right.
4. To make the "shoulder," slide two beads onto the skewer on the outside of the legs to hold them in place. They should be almost touching the legs. Leave just enough room for the legs to swing back and forth freely. If the beads don't stay in place, wrap a little piece of duct tape around the skewer to keep them from sliding around.
5. Use a glue stick to attach a mini-craft stick on top of each foot, right next to the leg. The craft stick should stick out a bit more in the front, like a ski. It adds weight to help the left swing.

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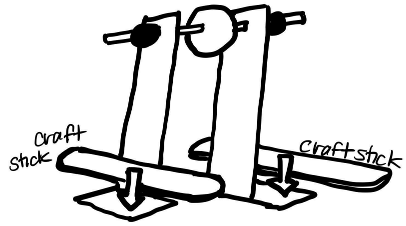


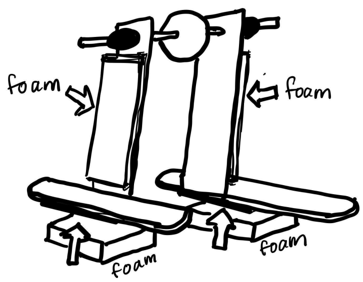


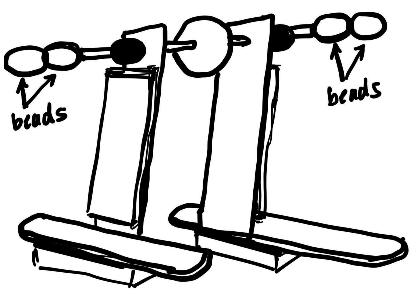


6. Cut out two pieces of craft foam that are the same size as the bottom of each foot. Then stick each foam piece to the bottom of one of the feet for traction.
7. The cardstock used to make our leg templates may not be enough to support the weight of the beads. Cut two pieces of craft foam that you can stick to the sides of the leg templates. This will help to keep the legs from buckling and folding.
8. For the “hands” of your robot, stick a bead on the end of each skewer. The weight at the ends helps the robot to tip back and forth as it walks. If the beads don’t stay in place, use a small piece of tape to hold them in place. You will need to tinker with the placement of all of the beads on the skewer so that they are well balanced and allow the robot to walk.

**Troubleshooting Tips:**
Check to make sure that the following are true:

- The legs can swing back and forth freely.
- The beads are not sliding on the skewer.
- The feet have traction to grip the test ramp.
- The body is balanced in the middle of the rod.

**Test The Basic Walker:**
Make a slanted test ramp. To test the walker, set it at the top of the ramp and gently tap one end of the skewer. The walker should tip from side to side as it makes its way downhill. If your walker is not working, you will need to tinker with the placement of all of the beads on the skewer so that they are well balanced and allow the robot to walk. You may need to do this many times until your robot is able to walk well.

Once it seems to be working consistently, you should measure the effectiveness of your robot by measuring TWO factors.

1. Measure the time it takes to go down the incline. Start your timer at the top of the incline. Stop your timer when your robot reaches the bottom of the incline. Record this time measurement (in seconds) in your data table.
2. Measure how straight the walking path is. Either draw a line on your incline plane or place a piece of tape on the incline plane to mark a straight path. Start your robot at the top of the incline on the line you have created. When the robot reaches the bottom of the incline, measure the distance from the center line to the closest edge of the robot. Record this measurement (in centimeters) in the data table shown on page 4:

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| Basic Robot Walker | Time for walker to move from top of incline to bottom (in seconds) | Distance from the center line to the robot (in centimeters) |
|---|---|---|
| Trial 1 | | |
| Trial 2 | | |
| Trial 3 | | |
| Average | | |

## Part B: Re-design - How can I redesign a passive dynamic walker to be faster and walk straighter?

**Here's what you will need to re-engineer your robot:**

- Legs template
- Cardstock
- Foam with adhesive backing
- Wooden skewer
- 2 Mini craft sticks (2-½ inches long)
- Wooden or plastic beads about ½ inch across with holes big enough to fit on the skewer
- Duct tape
- Scissors
- Sharpened pencil
- An incline ramp to use to test your walker
- You can use additional materials from home to make improvements to your robot.

A passive-dynamic walker is studied to understand how to make an efficient machine with the simplest mechanics possible. It walks down a shallow slope while rocking sideways to lift the foot on the other side so it can swing forward. It is the ability for it to swing and lift the foot on each side that determines how quickly and directly the robot can move down the incline.
Now that you have a basic passive-dynamic walking robot, you need to build a second walker that is able to move faster and more in a straighter line.

**Redesign, build and test a new walker.**

- You can try different sized legs or different leg shapes.
- You can make the legs or shoulders/arms out of other materials that you have on hand.
- You can try four legs instead of two.
- You could give your walker knees.
- You could attach swinging arms to add energy to each step.

Decide what changes you think will make a difference and then plan out your design!

**RE-DESIGN the Walker:**

1. Use what you have learned to design a passive dynamic walker that will win a race with the basic walker you built.
2. Make a new design plan in your journal with a sketch of your design.
3. Use the materials to build your new and improved walker! Test it out and tinker with your design so that it will walk.

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| RE-DESIGN PLAN for a Passive-Dynamic Walker | |
|---|---|
| Ask: What is the problem you need to solve? | Plan: What will your design look like? Draw a labeled diagram and write down your materials with the amounts you need: |
| Imagine: What are your ideas for solving the problem?<br>1.<br>2.<br>3. | |

**Test Your Design:**
Make a slanted test ramp. To test the walker, set it at the top of the ramp and gently tap one end of the skewer. The walker should tip from side to side as it makes its way downhill. If your walker is not working, you will need to tinker with the placement of all of the beads on the skewer so that they are well balanced and allow the robot to walk. You may need to do this many times until your robot is able to walk well. Once it seems to be working consistently, you should measure the effectiveness of your robot by measuring two factors.

1. Measure the time it takes to go down the incline. Start your timer at the top of the incline. Stop your timer when your robot reaches the bottom of the incline. Record this time measurement (in seconds) in your data table.
2. Measure how straight the walking path is. Either draw a line on your incline plane or place a piece of tape on the incline plane to mark a straight path. Start your robot at the top of the incline on the line you have created. When the robot reaches the bottom of the incline, measure the distance from the center line to the closest edge of the robot. Record this measurement (in centimeters) in the data table.

| Redesigned Robot Walker | Time for walker to move from top of incline to bottom (in seconds) | Distance from the center line to the robot (in centimeters) |
|---|---|---|
| Trial 1 | | |
| Trial 2 | | |
| Trial 3 | | |
| Average | | |

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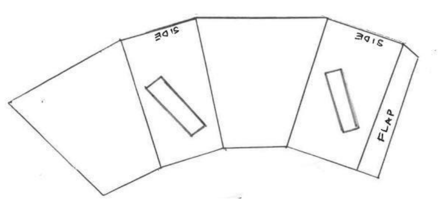
## Part C: Building Bonus - How can precisely engineered shapes defy gravity?

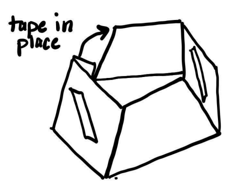
**Materials**: 2 Cardstock “brick” templates, Scissors, Tape or Glue Stick, sandpaper.

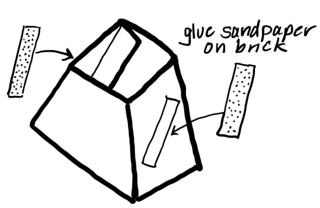
Our passive-dynamic walker USES gravity to generate movement. But some structures can actually defy gravity. Our last challenge is to make a free-standing “Brick” archway. Bricks are heavy and gravity should pull the bricks straight to the ground. However, this does not happen when the bricks are organized in an arch. There are two reasons why the bricks do not fall. Compression force and friction.

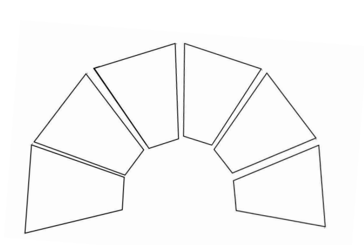
Compression force is what happens when the bricks in the arch push against each other. Instead of pushing straight down, the force of the mass of an **arch** is carried outward along the curve**.** The force travels to the supports at each end called the abutments. The abutments carry the load and keep the ends of the bridge from spreading out.

While not all arches are built from bricks, all arches need to be made of materials that create friction. Friction is the resistance between the bricks that keep them from sliding apart. The bricks don’t fall down because the bricks do not slide apart and this keeps the arch in place. Long lasting arches must have the perfect balance of friction and compression force.



**<u>Procedure for making an archway brick:</u>**

1. Cut out each of the brick templates.
2. Fold one template at a time.
3. Fold the template on the solid lines so that the lines are visible on the outside of the brick. It is very important that the folds are very sharp so that the shape is as “perfect” as possible.
4. The final fold should be the flap which will need to be tucked inside the brick.
5. Secure the brick structure with tape. Be very careful to keep the brick as symmetrical as possible.
6. Continue by folding the other five templates, making sure that each brick is as close in shape as possible.
7. Take the sandpaper and cut it into small strips
8. Use your glue stick to glue a small strip of sandpaper on each of the sides of the bricks. The sides are labeled so that you will not be confused!
9. Allow the glue to set.
10. Once your bricks are completed, create your arch. If you have made your bricks precisely, your arch should stand!

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**Extension:** Try making a new brick shape to make your arch! Remember it needs to have a balance of compression force and friction! Try the one below!