

ADVANTAGES OF LEVERS ACTIVITY GUIDE

How are biological levers advantageous in different ways?



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FOR EDUCATOR

APPLICATIONS IN:

- LIFE SCIENCES – Structure and Function/Adaptations
- PHYSICAL SCIENCES – Levers/Simple Machines
- MATHEMATICS – Ratios/Graphing

NGSS* ALIGNMENT:

	Elementary School	Middle School	High School
PS2.A Force and Motion	X	X	X
PS2.B Types of Interactions	X		
PS3.B Conservation of Energy and Energy Transfer			X
PS3.C Relationship between Energy and Forces	X	X	
LS1.A Structure and Function	X		
LS4.C Adaptation	X	X	X

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NATURE'S ULTIMATE MACHINES

LEVER EXPERIMENTS – Introduction for Educators

OVERVIEW

The lever is a simple machine often seen in nature, the jaw being a prime example. Levers are particularly known for their force advantage: taking a small force and translating it into a larger force. There are adaptations in animals that take advantage of this, such as the hyena's jaw. However, levers can also offer a speed advantage that can be seen in animals that are adapted to eat "zippy" prey, such as fish.

LEARNING GOALS

- Students will explore the basic types of levers
- They will be able to describe the trade-off between a force advantage and speed advantage.
- Students can apply their knowledge to create arguments about whether animals are adapted for speed or force advantages.

HOW TO USE

The materials are segmented specifically for you to use according your needs. You can have students simply explore ideas or follow a more quantitative approach. You can do everything either as a **demo** or **experiment**. We have provided pre-made "**concept overview**," "**record sheets**," "**questions to think about**" to use and hand out if you wish.

TIPS

In General:

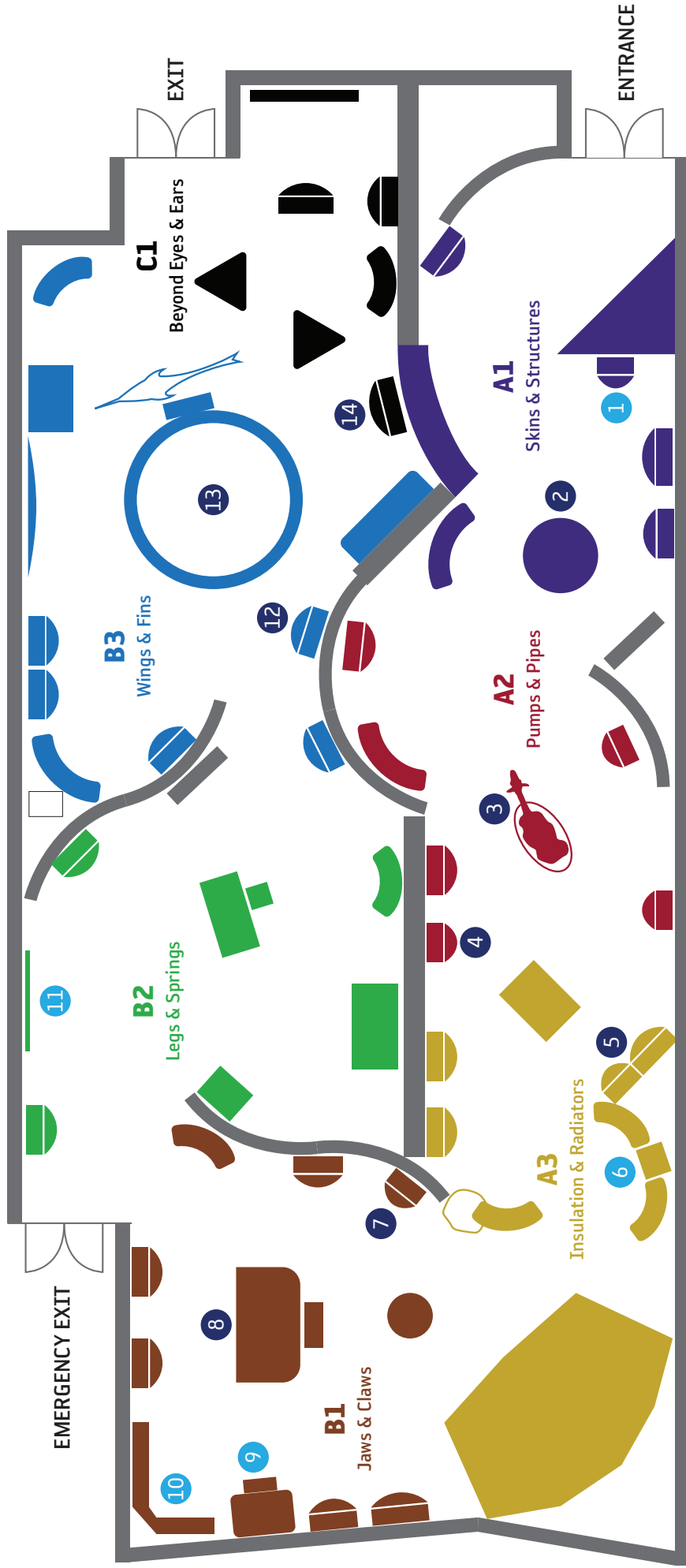
- It may be helpful to introduce basic levers to your students and then ask them to think of examples of levers in everyday life (e.g. crowbars, wheelbarrows, teeter totters, etc).
- Make sure your students have an understanding of independent vs. dependent variables.

Speed Advantage Activity:

- The students are asked to measure the linear height difference as an effort force is applied. This is technically not correct as the ruler rotates along an arc. The difference is negligible, but you may wish to discuss this with students.



EXHIBITION MAP



Activity Connections

Interactives

- 1 Domes Array Case
- 2 Materials
- 3 Giraffe Heart
- 4 Spider Legs
- 5 Insulation
- 6 Bergman's Rule
- 7 Leverage
- 8 Fish Jaws
- 9 Hard Biters Case
- 10 Fast Biters Case
- 11 Gaits Array Video
- 12 Reynold's Number
- 13 Flapping Wings
- 14 Eye Diversity

CONCEPT OVERVIEW – Basic Physics of Levers

Levers consist of a rigid bar, a **fulcrum** (pivot point), the **load** (what you want to move) and the **effort** force you need to exert to lift the load. They work by translating the effort force into the force that moves the load. This can give you a **mechanical advantage**, which can be found by using the principle of work

$$Work = Force \times Distance.$$

The *effort force times the distance to the fulcrum* needs to be the same for the *resulting force on the load times the distance of the fulcrum*. The mechanical advantage is the ratio of the effort force to the load force (or the load distance over the effort distance).

Mathematical Expression, Explaining Force Advantage:

Definition of Work:

$$Work = Force(F) \times Distance (L)$$

Work In Equals Work Out:

$$F_{effort} \times L_{effort} = F_{load} \times L_{load}$$

Definition of Mechanical Advantage:

$$\frac{F_{effort}}{F_{load}} = \frac{L_{load}}{L_{effort}} = \text{Mechanical Advantage (MA)}$$



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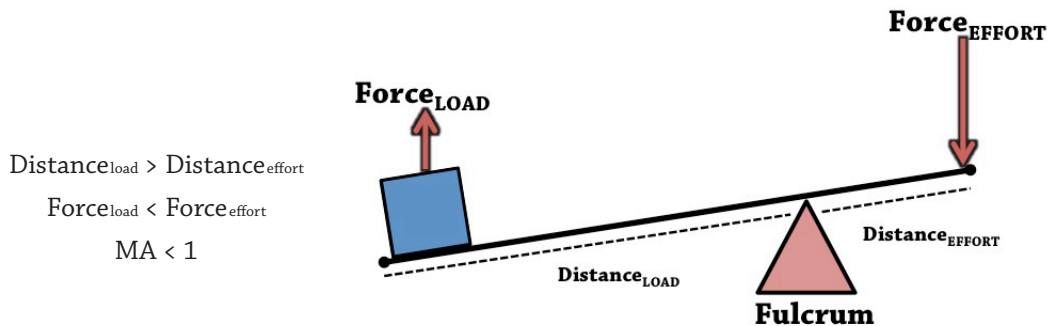
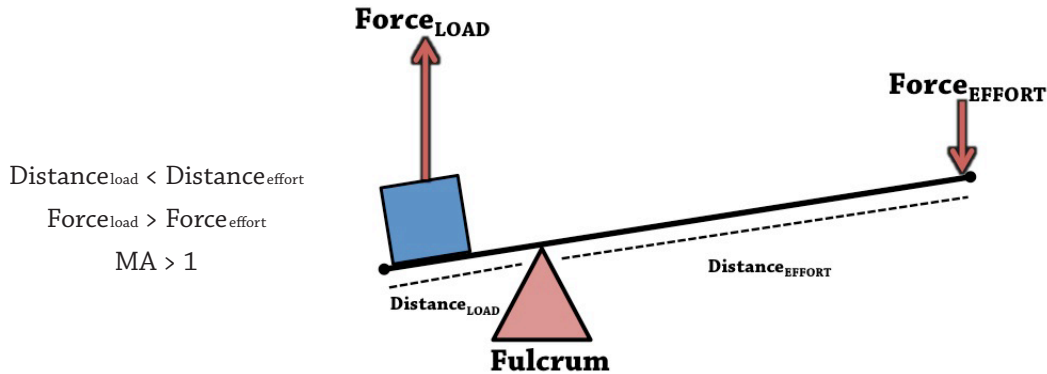
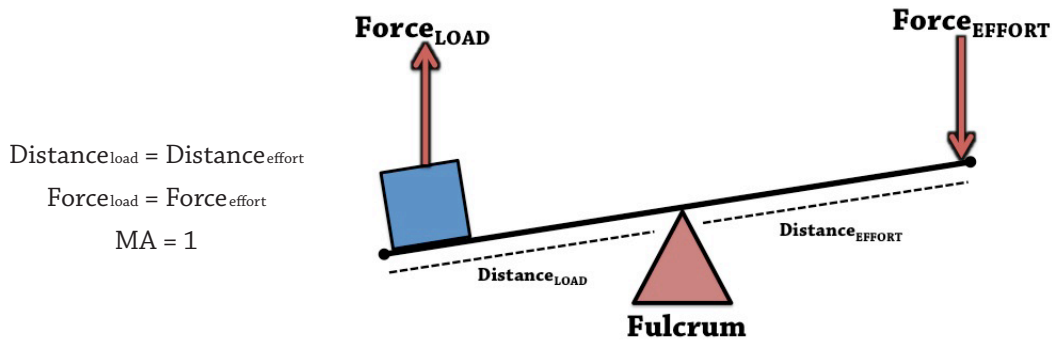
CONCEPT OVERVIEW –

Basic Physics of Levers, *cont'd*

If the distances are equal, then the force “in” is equal to the force “out”. But if the force is small over a larger distance, that translates to a large lifting force over a small distance when the fulcrum is close to the load. Similarly, a fulcrum closer to the effort force, means a small force over a small

distance results in a smaller force over a larger distance. This is not a great lever for gaining force advantage, but it is seen in nature quite often because it can give a different advantage – speed.

FOR STUDENT OR EDUCATOR



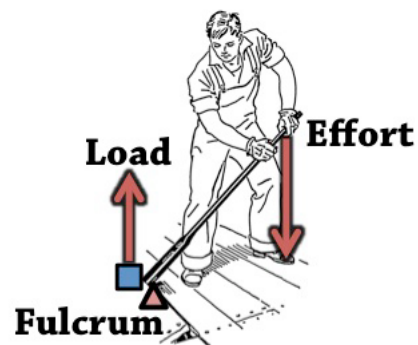
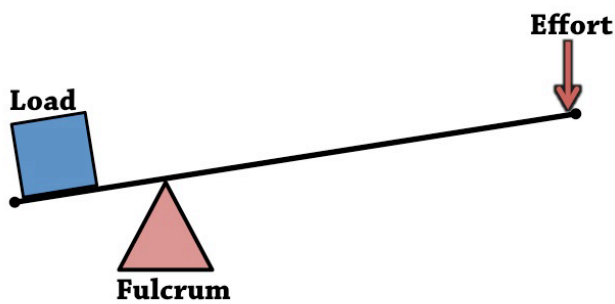
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CONCEPT OVERVIEW – Lever Classes

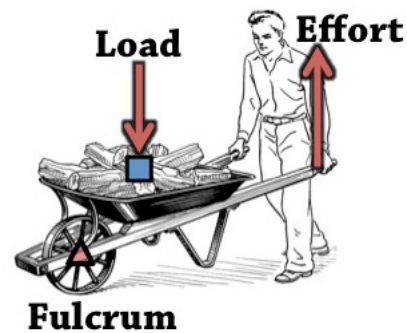
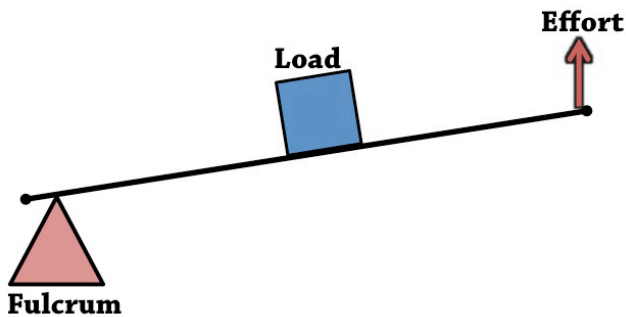
The basic lever involves the **load** and **effort** on either side of a **fulcrum**, like a teeter-totter; however, that is only one class of lever, one that is commonly seen in tools humans have made. However, there are other orientations or classes

of levers. A wheelbarrow is a good example of a class 2 lever, and our jaws and arms are both examples of class 3 levers.

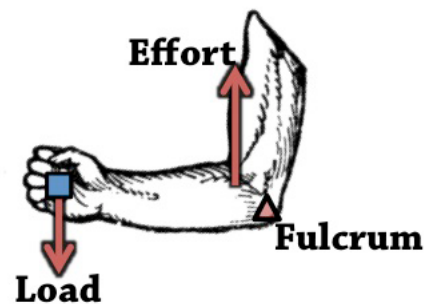
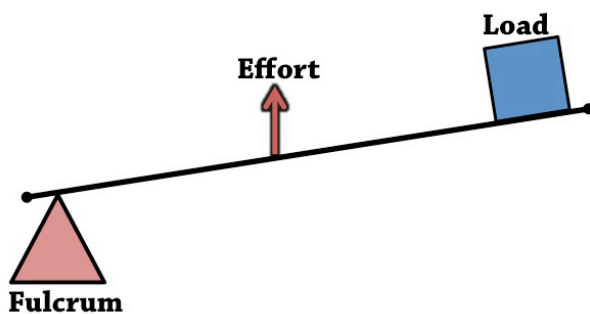
Class 1



Class 2



Class 3

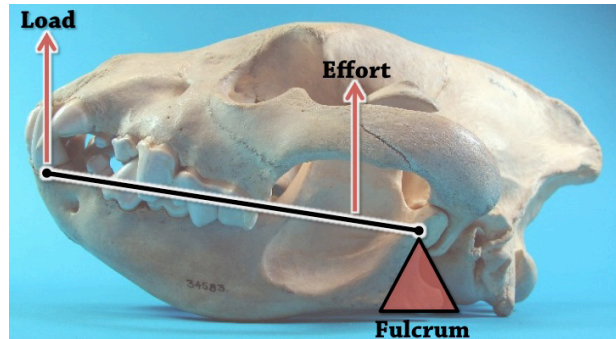


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OVERVIEW – Jaws as Levers

An excellent example of levers in nature is our jaw. Its shape is just a little bit different than a simple plank and pivot point, but the system still behaves the same.

The jaw is an “L” shape with the effort force provided by a muscle that pulls on the vertical portion of the jaw and it rotates. The rotational point acts as a fulcrum. This results in a force at the front teeth. The total force is partially determined by the muscle strength attached to the jaw, but that initial force is still translated.



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Mathematical Expression, Explaining Force Advantage:

Definition of Work:

$$Work = Force(F) \times Distance (L)$$

Work In Equals Work Out:

$$F_{effort} \times L_{effort} = F_{load} \times L_{load}$$

Definition of Mechanical Advantage:

$$F_{effort} = L_{load} = Mechanical\ Advantage\ (MA)$$

Solve for The Load Force in terms of Mechanical Advantage:

$$F_{load} = \frac{F_{effort}}{MA}$$



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CONCEPT OVERVIEW – Speed and Force Trade-Offs

In nature there is a wide variety of jaw shapes. Some are rather short, meaning the effort and load lengths are comparable and the force provided by a jaw muscle (effort) is equal to or more at the end of the jaw, resulting in a hard bite. Some jaws are long and slender, meaning the distance to the load is much longer than the distance to the effort provided by the muscle making the force advantage more or less non-existent. There is however a speed advantage.

This speed advantage comes from solid body rotation. When a rigid body rotates, everything moves together. The point farther from the fulcrum (rotation point) has a larger turning radius, meaning it has a larger circumference in which it has to turn. Since the whole jaw rotates together, the farther point needs to move along a longer arc in the same amount of time to keep up, meaning it rotates faster. The speed at which a muscle contracts in order to close the jaw then gets translated to a faster speed at the end of a longer jaw. The distance at which the lever moves in the same amount of time is proportional to the distances between the fulcrum. The velocity is just those distances over the same amount of time.

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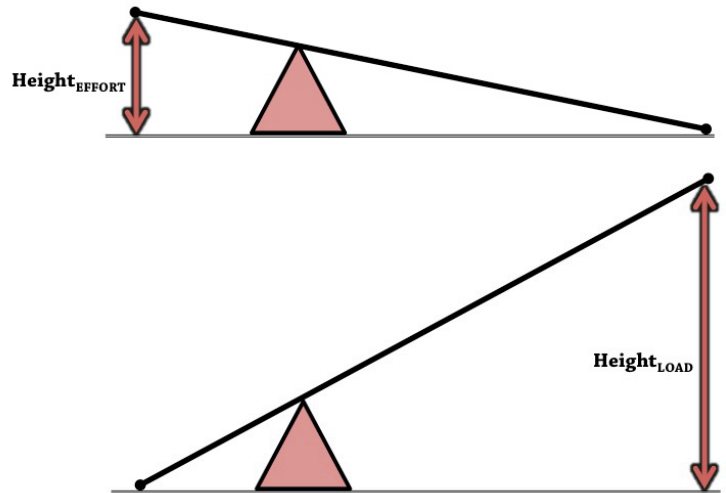
Close to fulcrum



Far from fulcrum

$$v_{\text{effort}} = \frac{H_{\text{effort}}}{t}, v_{\text{load}} = \frac{H_{\text{load}}}{t}$$

$$\frac{v_{\text{load}}}{v_{\text{effort}}} = \frac{H_{\text{load}}}{H_{\text{effort}}} = \frac{L_{\text{load}}}{L_{\text{effort}}} = MA$$



**Note that we are assuming the height is a linear distance. The lever technically rotates in an arc, but at small angles we can approximate that motion as a straight line.*



NATURE'S ULTIMATE MACHINES

EXPLORING LEVERS

Have you ever wondered how different animals can bite so hard? It's all because they have strong muscles attached to jaws that act like levers. Levers are amazingly simple machines that can help you lift heavy objects with little force. Levers use the principle of work to take advantage of force and distance trade-offs:

$$\text{Work} = \text{Force} \times \text{Distance}$$

A lever works by putting in a little force over a large distance to equal a larger force over a small distance.

How do levers help lift object?

MATERIALS:

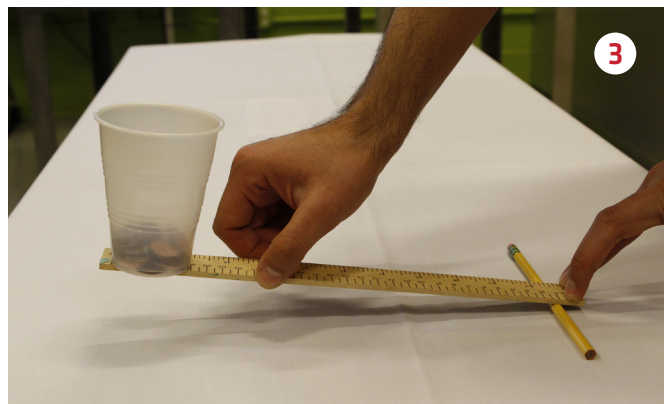
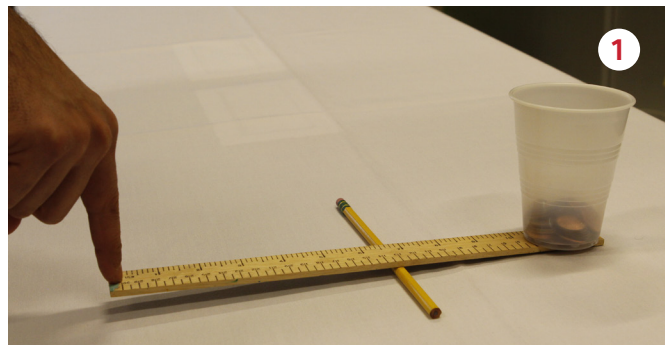
- A Ruler
- A pencil
- Weight of some kind (books or a cup full of pennies)



FOR STUDENT

WHAT TO DO:

- 1) Set up your lever as shown in picture 1. Then try to lift the book by pushing with one finger at the effort point. Keep adding books until you can't lift them with just one finger. Record the distance between the load and fulcrum and the effort and fulcrum. Move the pen (fulcrum) around to see where it's easier or harder to lift the book, recording the distances again.
- 2) Set up your lever as shown in picture 2. Then try to lift the book by using one finger at the effort point and repeating the rest of step 1.
- 3) Set up your lever as shown in picture 3. Then try to lift the book by using one finger at the effort point and repeating the rest of step 1.



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CALCULATING FORCE ADVANTAGE

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Have you ever wondered how different animals can bite so hard? It's all because they have strong muscles attached to jaws that act like levers. This activity will quantitatively define the advantage of levers. Though there are different classes of levers, this activity is done with the first class lever to simplify the process. Challenge yourself and try it out with other classes.

PREDICT:

How many pennies will it take to lift 10 pennies if the fulcrum is 5 centimeters from the load? 10 centimeters? 20 centimeters?

MATERIALS:

- A Ruler
- A pencil
- Cups
- A scale
- Pennies (or other small, relatively heavy objects such as glass beads)
- Tape



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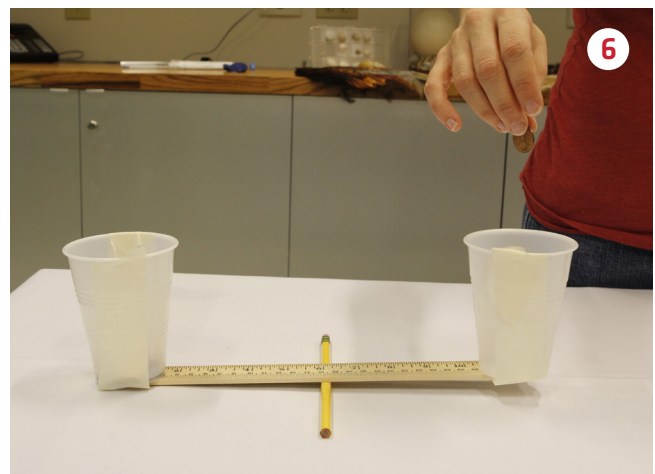
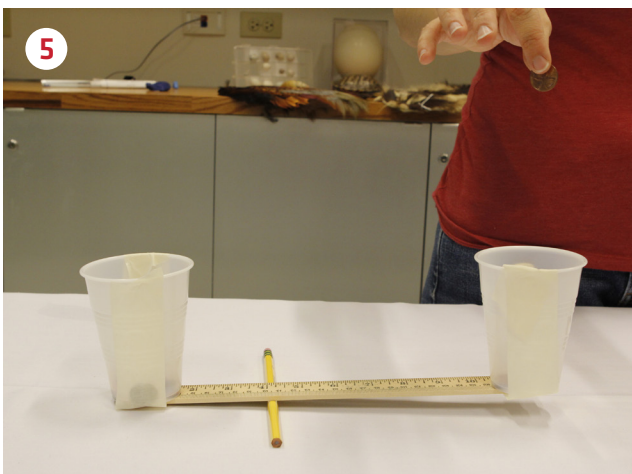
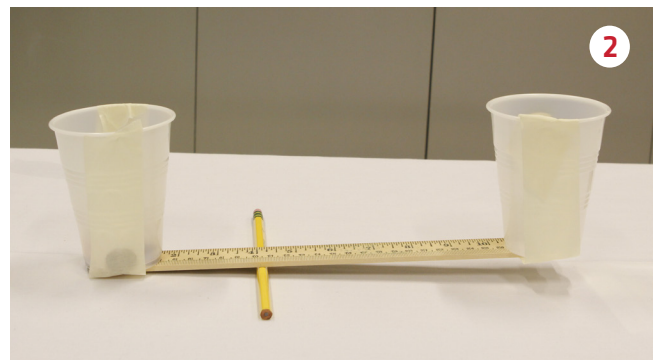
NATURE'S ULTIMATE MACHINES

CALCULATING FORCE ADVANTAGE

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WHAT TO DO:

- 1) Measure the mass of a single penny and record this information.
- 2) Set up a first class lever using a pen for the fulcrum and ruler. Place the pen (fulcrum) 2 times closer to the load than the effort and tape it to the ruler. Then tape a cup to either end of the ruler. Place about 15 pennies in the cup on the load end.
- 3) Calculate the force of the pennies on the load end exerting downwards as a result of gravity.
 $\text{Force} = \text{mass}_{\text{book}} \times 9.8 \text{ m/s}^2$
- 4) Make a prediction for how many pennies it will take in the effort cup to lift the load cup.
- 5) Start putting pennies into the effort end one at a time until the load lifts up. Record the number of pennies and calculate the mass of the pennies. The force of the effort is then the mass of the pennies $\times 9.8 \text{ m/s}^2$. Record this information.
- 6) Repeat all steps with different fulcrum points (equal distance between load and effort and 2 times closer to the effort). Record all the information information.
- 7) Graph your results of mechanical advantage vs. effort distance.



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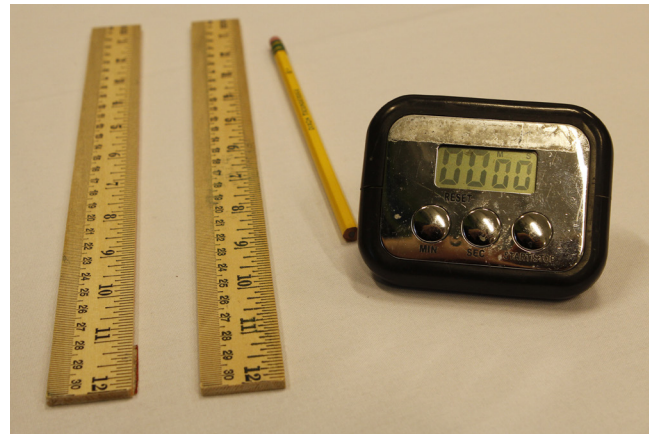
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EXPLORING SPEED ADVANTAGE

Some animals effortlessly catch fish in their mouths. If you've ever tried to catch a fish with your bare hands, you know this is not an easy task. Explore how animals can use levers for a speed advantage! This activity will involve calculating the speed advantage of a lever. Levers are most commonly considered in terms of the force advantage they can offer; however, they can also offer a speed advantage!

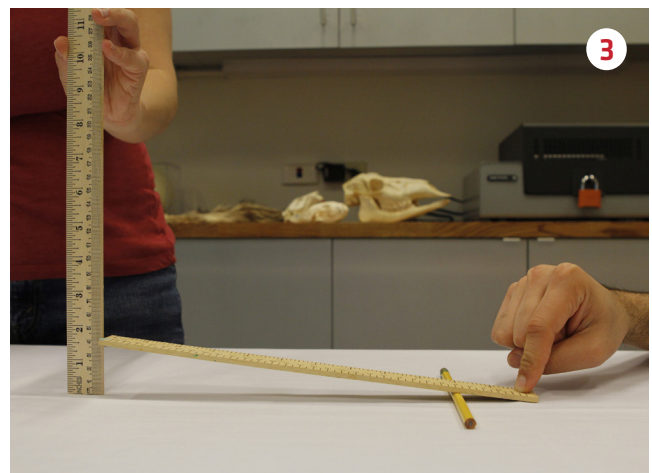
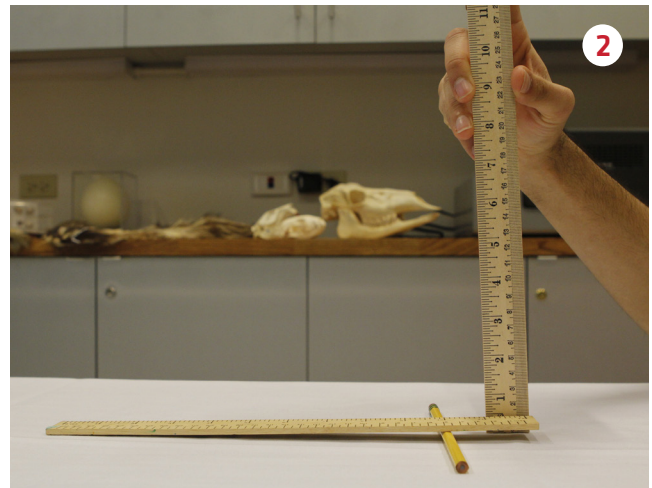
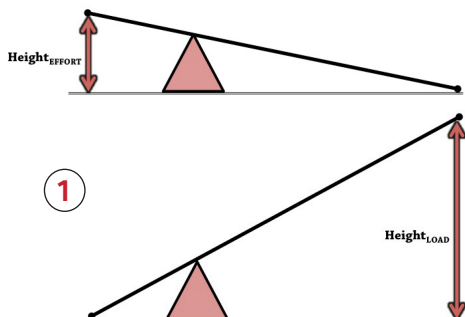
MATERIALS:

- 2 Rulers
- a Pencil
- Stopwatch (optional)
- Math!



WHAT TO DO:

- 1) Set up a first class lever by placing a pen underneath the ruler. Place it anywhere you want to begin and note the distance of the pen (fulcrum) from the point where you will push on the ruler and the distance from the other end. Record this information.
- 2) Measure the height of the end you will be pushing on and record that information.
- 3) Push that end of the lever. Then measure and record the height of the other end. As you push you can time how long it takes. If you do not have a stopwatch or it is too fast, assume it took 1-second.
- 4) Use the information recorded to calculate the speed of the end you pushed and the speed of the other end of the ruler: $\text{Speed} = \text{height}/\text{time}$.
- 5) Repeat steps 1-4 with the fulcrum at different points under the ruler.
- 6) Create a plot that shows the speed vs. effort distance to the fulcrum.



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RECORD SHEET – Exploring Levers

CLASS 1 LEVER

Effort Distance	Load Distance	Ratio of Effort Distance to Load Distance	Rank the trial by least (1) to most (3) difficult

CLASS 2 LEVER

Effort Distance	Load Distance	Ratio of Effort Distance to Load Distance	Rank the trial by least (1) to most (3) difficult

CLASS 3 LEVER

Effort Distance	Load Distance	Ratio of Effort Distance to Load Distance	Rank the trial by least (1) to most (3) difficult

Explain the relationship between the ratio of effort distance and load distance to the fulcrum:

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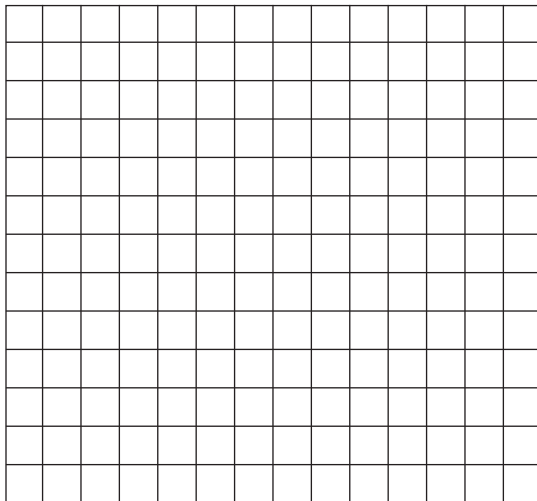


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RECORD SHEET – Force Advantage

FOR STUDENT

Effort Distance	Load Distance	Ratio of Effort to Load Distance	Prediction: Number of Pennies	Actual: Number of Pennies	Effort Force to lift Load



**Be sure to label axes*

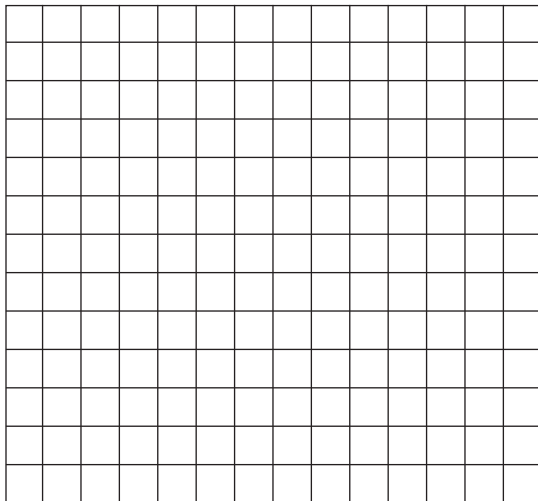


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RECORD SHEET – Force Speed Advantage

Effort Distance	Load Distance	Effort Height	Load Height	Effort Speed	Load Speed	Ratio

FOR STUDENT



**Be sure to label axes*



NATURE'S ULTIMATE MACHINES

CHALLENGE

Below are pictures of different animal skulls. Guess whether or not they are hard or fast biters. Do you think they can be both? Look up the diet for each of the animals and write an explanation or argument for why they need to be hard or fast biters in order to eat their usual meals.



Ganges River Dolphin (*Platanista gangetica*)



Wood Stork (*Mycteria americana*)



Spotted Hyena (*Crocuta crocuta*)



Human (*Homo Sapiens*)



Gharial (*Gavialis gangeticus*)



Hyacinth Macaw (*Anodorhynchus hyacinthinus*)

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OTHER RESOURCES

Other Lever Activities

Science Buddies - Lifting With a Lever:

http://www.sciencebuddies.org/science-fair-projects/Classroom_Activity_Teacher_Levers.shtml

Public Broadcasting Station - Lever Lift Activity:

http://www.pbs.org/wgbh/nova/education/activities/27po_sle2phar.html

Bite Force Videos

Science Channel - Mammals vs. Dinos – T-Rex Bite Force:

<http://www.youtube.com/watch?v=mrXI18hO5vE>

National Geographic - Piranha Bite Force:

<http://www.youtube.com/watch?v=WIWdFDLBzbY>

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