Scientific Connections through Inquiry

Edition 1

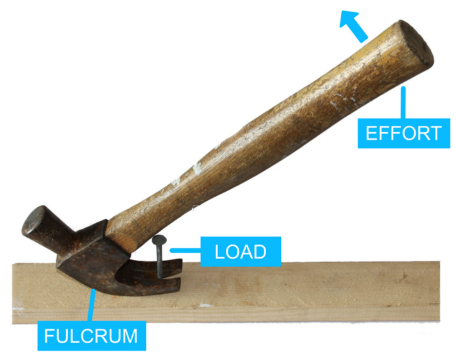
LEVEL 4

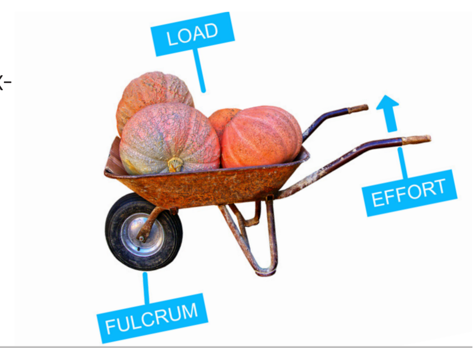
Everyday Levers

Everyday Levers

Ask: Do we use levers, or at least the principle of leverage, in everyday life? (Think Time) Challenge your student to find levers in your home. If your student is stumped, help them find items such as a bottle opener, fingernail clippers, scissors, and a nutcracker. Likewise, suggest actions such as using a screwdriver to pry the top off of a paint can, or pulling a nail with a claw hammer.

You will find various tools with variations on the theme of levers. Variations that may cause questions and require assistance include:





- Many common tools consist of two levers hinged at the fulcrum. Such tools include scissors, pliers, and wire cutters.
- The lever may have an angle or bend such that effort applied may be at a right angle to the load. Pulling a nail with a claw hammer is an example. Likewise, note that the fulcrum, the butt of the hammer on the surface, in this case, may move in the course of pulling.
- The fulcrum may be at the end of the lever rather than between the load and the effort. In such a case, the short arm is simply the lesser distance from the fulcrum to the load. Examples include wheelbarrows and common nutcrackers.
- We usually think of levers as a means of applying a greater force at a given point. However, they may be used in the opposite way to amplify distance. Consider a fishing pole, for example. It can be thought of as a lever with the fulcrum near the base of the fishing rod. A small motion of the hand near the base results in a large movement at the tip of the rod. Since a large load is not applied at the tip (the lure is very light), it is not a problem that the force at the tip is smaller than the force applied by your hand.

Have your student analyze and diagram the tools they find in terms of a lever on Student Book page "Household Levers."

Forces & Distances

By asking your student to analyze various tools in this manner, they will gain an experiential familiarity with levers. Follow up by asking if they can discern a basic principle in describing how levers work, i.e., a basic principle regarding leverage. (Think Time)

If necessary, ask them to particularly look at how far the *load* moves in contrast to how far the *effort* moves in the course of the action. They will observe that a *load* on the *short arm* is moved a shorter distance than the *effort* applied to the *long arm*. In such cases, the *load* can be much greater than the *effort* applied.

Conversely, in cases such as casting with a fishing pole, the *load* on the long arm—the lure dangling from the end of the pole—moves further than the hand on the grip, which is the *effort*, but the hand's force on the grip (effort) will be greater than the *load*, the force on the lure.

In summary, when using a lever a *high force* applied a *small distance* from the fulcrum can balance a *low force* applied a *long distance* from the fulcrum.

Machines I Wrap-Up

At the end of this unit, students should be able to:

- Use models to demonstrate the principle of a lever, and identify the fulcrum, long arm, short arm, load, and effort.

- Analyze common hand tools such as scissors, fingernail clippers, and bottle openers in terms of levers and leverage. In each tool, identify the fulcrum, long arm, short arm, load, and effort. In the course of such analyses, show how levers may differ in the position of the fulcrum and the relative lengths of the arms.

- Use a model or actual hand tool to demonstrate how a lever works in terms of load, effort, and the distance each is from the fulcrum.

- Plan and carry out investigations to compare the force times distance at the load and effort ends of a lever. Use the data collected to show that force times distance at the two ends is equal.

- Explain what work is and identify whether different activities involve doing work.

- Describe the relationship between work and energy.

- Speak to the question, "Does a lever produce energy?" Argue from evidence (actual data) that it does not.

- Describe what mechanical advantage means, and what it tells us about a lever (or other tools).

Topics for Further Investigation:

- Archimedes levers
- How the body's muscles, bones, and joints illustrate examples of levers
- Big machines which use levers
- How levers can be used to throw things, e.g., a catapult
- Levers in sports

Capillaries

Transportation in the Body

We have seen that the body's need for food, oxygen, water, and to rid itself of wastes is a reflection of the needs of cells that make up every part of every organ of the body. The central question becomes: How is the body constructed and how does it function such that eating, drinking, breathing, and excreting serve the needs of the cells that comprise its body? More specifically: How do the nutrients from food eaten get from the stomach and intestines to the brain cells? How does the oxygen we inhale get from our lungs to the muscle cells in our arms and legs? How is the waste from each individual cell collected for removal? And so on.

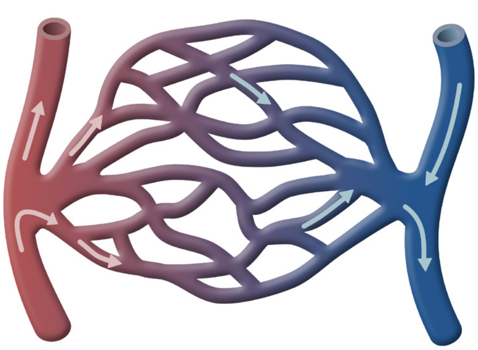
As your student ponders such questions have them observe that all of these functions involve transportation from one location to another. Have them create a list of the different locations involved on Student Book page "Transportation System." For example, food molecules must go from the intestines to all cells of the body. Carbon dioxide waste from energy metabolism must go from all the cells to the lungs.

The Circulatory System

As your student finishes their list, focus their attention on the extreme importance of the body's "transportation system" and ask them if they can figure out what it is. (Think Time) It is the CIRCULATORY SYSTEM. If it fails even for a matter of minutes cells perish and before long the whole body will die.

Ask your student what they already know (or think they know) about the circulatory system. This will both help to focus their attention and reveal misconceptions that will need special attention.

Rather than the usual practice of starting with the heart, students will gain a better grasp of the concept by keeping their focus on the cells and their needs. From where and how do cells fulfill their needs? Show your student a diagram of the capillary network on Student Book page "Capillary Network Diagram." Emphasize that this diagram is a grossly enlarged picture; the actual size of the capillaries (tiny tubes or blood vessels) is microscopic. The capillaries themselves are made of cells—pancake-shaped cells wrapped around to make a tube that is just large enough to permit the passage of blood cells in a single file. Such capillary networks permeate every tissue, organ, and part of the body. Therefore, while most diagrams show empty space between the capillaries, this space is actually occupied by cells of the surrounding tissue.



Use Student Book page “Capillary Network Diagram” in your discussion.

On the diagram, have your student pencil in cells within the “empty” spaces between capillaries. How large should he cells be? Make them in proportion to the capillaries. That is, there should be no more than three or four cells between adjacent capillaries. What kind of cells? They might be any kind! Emphasize again that such capillary networks permeate every tissue of the body. Most cells of the body have a capillary right beside them; no cell of the body is more than two or three cells removed from a capillary. This is why even quite minor cuts or scratches bleed to some extent. It is essentially impossible to disrupt a tissue without also breaking some capillaries, which results in some bleeding. But, cut capillaries soon seal themselves and bleeding stops. (Cuts of more major arteries or veins, of course, are another matter.) Capillaries re-form along with the healing of the tissue.

Exploring Loops

Surface Runoff & Groundwater

With your student, model the Surface Runoff Loop and Groundwater Loop as follows:

- Fill a wide-mouth jar about two-thirds full with pea-sized gravel or marbles. Add a layer of an inch or so of cotton batting or folded cotton washcloth on top of the gravel and a few layers of paper towels on top of that. A straw extending partway down into the gravel/marbles may be built into the arrangement to represent a well.
- The bottom of the jar represents a solid layer through which water will not penetrate, an impermeable layer of bedrock or clay. The gravel/marbles represent rock/earth material with cracks and spaces. The paper towels and cotton below represent the soil surface and dirt.
- Sprinkle water on the surface to represent precipitation. Your student will observe that the initial amount soaks into the towels and cotton and is held there. This represents soil water, or more technically, capillary water, since it is held from percolating further by capillary action.
- As more water is sprinkled on or sprinkled faster, some of it runs off the surface. That's surface runoff. In our model, it probably runs to and down the inside of the jar. Emphasize that in real life, surface runoff goes into streams and thence into rivers, lakes, and eventually the ocean. The surface runoff water is also frequently referred to as stormwater since it is most conspicuous during storms.
- Finally, as the cotton "soil" is fully saturated, additional water sprinkled on the surface begins percolating down through the gravel/pebbles and collects at the bottom of the jar, filling any spaces. This represents groundwater, its upper surface being the water table. Emphasize the distinction between soil water and groundwater. Soil water is held tightly in the soil; in the absence of more water being added at the top, it does not move further by gravity. Groundwater, on the other hand, is free to move by gravity insofar as the permeability of rock/soil allows it to do so.

SCIENCE NOTE

Capillary action is the movement of a liquid in narrow spaces without the assistance of—or even in opposition to—outside forces, due to the strength of the adhesion of the liquid to the walls of the space. Capillary action is what causes water to move up a dry paper towel if its end is dipped in water.

Pose the question: What fraction of the water takes each of these pathways? (Think Time) On reflection and discussion, your student should recognize that there is no single answer; it depends on multiple factors. Among the factors that should come to light are the intensity and duration of the rainfall; the nature of the surface, i.e., to what degree it allows water to enter; the nature of the soil, e.g., how much water it is capable of soaking up and holding. Have your student discuss and derive how each of these factors will affect the direction that water takes.

Transpiration

Transpiration can be easily demonstrated by placing a plastic bag over a well-watered plant and tying it securely around the "trunk." For larger plants, you can tie the bag around a leaf or branch. Droplets of water will soon be seen condensing on the inside of the bag. These droplets are made of water that evaporated from the leaves.

Heat & Density

Heat Causes Expansion

Stress again to your student that heat itself does not rise. However, heat causes fluid to expand, which results in it having a lower density than it did before the heat was added. This causes the heated fluid to rise through and "float" on top of the surrounding cooler fluid.

Your student will be familiar with some examples of this effect. A hot-air balloon rises because heating expands the air inside of it and, therefore, lowers its density to the point that the balloon plus its passengers weigh less than the equal volume of air they displace.

Similarly, your student will be familiar with smoke rising from a fire, but will be likely to explain this by the simple conclusion: smoke rises. Guide their reasoning: Are particles of smoke actually lighter/less dense than particles of air? If this were the case the upper atmosphere would be full of smoke. What is another explanation? (Think Time) The fire heats the air, lowers its density, and hence, creates an updraft that carries the particles of smoke with it.

To demonstrate that smoke particles are being carried by air rather than rising by themselves, carry out this impressive demonstration:

ACTIVITY NOTE

This demonstration works best with no wind or draft.

Place a clear-sided glass in the freezer until it is cold. Remove the glass and put it on its side near the edge of a table or other elevated, fire-safe surface.

Cut a sheet of white paper into quarters and loosely roll one quarter into a tube. Place the middle of the tube into tongs or between the tines of a fork.

Use a match or lighter to set half of your paper tube on fire. Be sure it catches aflame for at least a handful of seconds. You can reapply the flame, if needed. After it has burned a few seconds, you can gently blow it out or snuff the flame.

Observe that the smoke rises. You can tip the tube downward so smoke "pours" out the unburnt end and observe that it still rises. Then, using your tongs or fork, move the unburnt end of the tube into the cold glass, so smoke "pours" into the glass. Watch what happens. Smoke flows in a stream from the glass across the table, off the edge, and down toward the floor.

Ask your student to explain the result. Their reasoning should be that the cold glass cools the nearby air, making it denser than the surrounding air. The more-dense air sinks through the surrounding air and acts like water flowing downhill, carrying smoke particles with it.

Have your student complete Student Book page "Heat Blackout Poetry" to review this important concept.