Science of Athletic Shoes

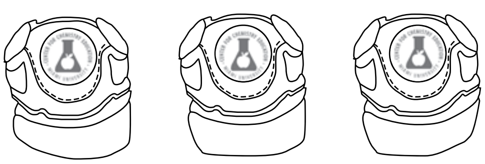
Human feet take quite a pounding. A typical athlete can generate up to 700 pounds of pressure on a foot in a single stride or bound. Many athletic shoes are designed to minimize the stress that sports put on the feet. In this activity, you'll examine foot types and the types of wear patterns that occur on shoes.

Stuff You'll Use: ▸spray bottle and water ▸paper grocery bags ▸permanent marker ▸paper towels ▸pair of worn sneakers or athletic shoes ▸(optional) ruler

flat foot medium arch high arch

Sample data table

Person	Foot Length (L)	Foot Width at Narrowest (W)	L/W
Alex			
Sandy			
Joshua			
Kaitlyn			
Jordan			



overpronation neutral supination

Rear view of right shoes

What to Do:

Activity works best if done with a large group of individuals.

1. Take off a shoe and sock and spray the bottom of your foot with water.
2. Make a wet print of your foot by standing on a paper grocery bag for about 10 seconds, making sure the weight on your foot is equally distributed.
3. Use the permanent marker to trace your wet foot print.
4. Compare your wet print to the ones at left. *Which type matches your foot the best?*
5. (optional for advanced students) For each wet print, measure the length and divide it by the width at the narrowest part. Record results in a data table. *What do you think a high number indicates? What do you think a low number indicates?* Plot the results on a histogram. *What range of numbers was most common in the group? What was the high number? What was the lowest number? Why did you need to measure the length of the foot when collecting your data?*
6. Look at the soles on your pair of athletic shoes. Notice any areas of heavy wear. Place a shoe on a level surface and examine it from behind. Does it tilt to the inside or the outside?
7. Based on the figure at left, does the wear on your right shoe indicate that your gait is neutral, overpronated, or supinated?

How It Works:

The arch in your foot is an energy storing mechanism. The arch flattens when you step down, storing energy like a spring. This energy is released when you step up. The width of the band connecting the forefoot with the heel (narrowest part of the wet print) determines your arch type. If the band is narrow you have a high arch, and if it is wide you have a flat foot.

In optional step 5, you divided the foot length by the width at the narrowest part of the print. This normalizes the data to account for different foot sizes. A higher number indicates a higher arch.

The type of arch you have can affect your style of walking, contributing to how the heels of your shoes wear down. Heavy wear along the inside of your shoes indicates that you overpronate, or roll you your foot inward, as you walk. Wear on the outside of the heel indicates that you supinate, or roll your foot to the outside, as you walk. People with flat feet commonly (but not always) overpronate, while those with high arches are more likely to supinate.

Athletes should buy shoes that work best for their arch and gait to avoid injury. Straight shoes with firm midsoles are ideal for flat or overpronate feet. Feet that supinate or have high, firm arches feel most comfortable with curved shoes that allow plenty of flexibility.

Activity adapted from Athletic Shoes: Studies in Compounding Polymers; *Carolina® Active Science™ Series: Burlington, NC, 1999.*

Let's Break a Sweat

You've probably noticed how athletes, such as gymnasts and weight-lifters, chalk their hands before engaging in their sport. The chalk improves an athlete's grip by absorbing sweat. In this activity, you'll use a moisture-absorbing cellophane fish to detect sweating in the palms of the hands. You'll compare the fish's behavior in various settings to confirm that moisture is the key factor for the toy fish's movement. You'll also design an experiment to determine whether an increase in physical activity increases sweat production in the palms of the hands.

Stuff You'll Use:

- Fortune Teller Fish
- paper towel
- water

What to Do:

1. Remove the Fortune Teller Fish from its plastic wrapper and save the wrapper for step 2. Lay the fish in the palm of your hand. *What do you observe? What factors might cause the observed behavior?*
2. Lay the plastic wrapper on your hand and put the fish on the wrapper. *What happens?* Based on your observations in steps 1 and 2, develop a hypothesis on what caused the fish to behave as it did.
3. Slightly dampen a folded paper towel with water and squeeze out as much excess water as possible. Place the cellophane fish on the moist paper towel and observe the behavior of the fish. Compare and contrast the fish's behavior in steps 1, 2, and 3. *Which variable had the greatest effect on the fish's motion?*

   Avoid overly wetting the fish when you put it on the damp paper towel and do not put the fish directly into water, as these actions could render the fish useless.

4. Design an experiment that uses the cellophane fish to determine if physical activity affects the amount of sweat in the palms of your hands or the rate of its evaporation from the palms. Make sure to specify the type of physical activity and its duration. *Did your physical activity affect the amount of sweat on the palm of your hand?*

How It Works:

The Fortune Teller Fish curls and twists primarily because it absorbs water from the sweat glands in your hand and subsequently loses this water through evaporation. The fish is made of cellophane that is hygroscopic. ("Hygro" means "wetness" and "scopic" means "to view or find.") As water is absorbed, it moves through small pores in the cellophane and evaporates due to the heat from your hand. The lightness of the cellophane makes the fish very susceptible to air currents, which adds to the "dancing" effect. This type of movement is not observed when the fish is on the plastic wrapper, because the bag forms a barrier that prevents the cellophane from absorbing water from your palm. When placed on a moist paper towel, the fish behaves like it does when placed on the palm, indicating that moisture is an important factor in the fish's behavior.

Most people experience an increase in palm sweating with an increase in physical activity, although results will vary depending on the individual, the intensity of the physical activity, and the humidity of the air. If body temperature increases during physical activity, the rate of sweat evaporation will also increase.

The chalk that athletes put on their hands is magnesium carbonate ($MgCO_3$). It is water-insoluble and hygroscopic, just like the cellophane fish. This hygroscopic property allows the chalk to absorb moisture (particularly perspiration) from the athlete's hands.

More Fun?

Terrific Science Press offers the following books that include activities about this hygroscopic toy:

- *Teaching Chemistry with TOYS*
- *What's That Smell? The Science Behind Adolescent Odors*

Bubble Blowup

Lung capacity is the amount of air your lungs can hold. Good lung capacity is helpful in competitive sports. In this activity, you can have fun blowing bubbles while getting an idea of what your lung capacity is.

Stuff You'll Use:

- pipet
- plastic tray at least 25 cm x 25 cm (10 inches x 10 inches) in area
- distilled water
- bubble solution
- metric ruler

What to Do:

1. Pour a small puddle of bubble solution in the center of the tray and add 3 mL (¼ tablespoon) distilled water. Use your hands to smear the solution all over the tray. (The whole tray should be wet.)
2. Pour another puddle of bubble solution in a corner of the tray. Dip your straw into the liquid and blow some bubbles, holding your straw 1–2 cm above the tray.
3. Dip the straw again, and while holding it near the center of the tray, take a big breath and blow the biggest bubble dome you can without taking another breath. Pop the bubble and measure the diameter (longest distance across a circle) of the ring of soap left behind (in cm). Half of the diameter is called the radius of the circle. Write the radius in your data table.
4. The volume of a sphere is:

$$V = (4/3) \times (\pi) \times (r^3), \text{ where r is the radius}$$

5. Calculate the volume and divide it by half (because the bubble domes are half-spheres). This is your lung capacity in cubic centimeters, cm^3. (Cubic centimeters are equivalent to milliliters.)
6. Do steps 3–5 two more times and calculate the average. Record your results in the data table.
7. Compare your results with the rest of the class. *Who has the largest lung capacity (blew the biggest bubble)?*

FYI...

It may take you a couple of tries to get the blowing technique down. Experiment with the height of the straw above the tray until you are comfortable blowing large bubbles.

If the bubble hits the edge of the tray it is likely to burst. Make sure you use a tray big enough to hold at least a 10-inch diameter bubble.

Sample data table

Trial	Radius (cm)	Lung Capacity (mL)
1		
2		
3		
	Average	

How It Works:

If you could completely empty your lungs, the amount of air in the bubble dome would equal your total lung capacity, which is 6 L (6,000 mL) for the average adult. In reality, it is impossible for you to empty all the air from your lungs. No matter how completely you exhale, some air will always remain in your lungs. What this activity measures is called vital lung capacity, which is about 4.6 L on average. Also, you may have found it hard to blow a bubble big enough to hold all the air you were capable of blowing without the bubble bursting first. A bubble dome holding 4.6 L of air would be about 26 cm (10 inches) in diameter.

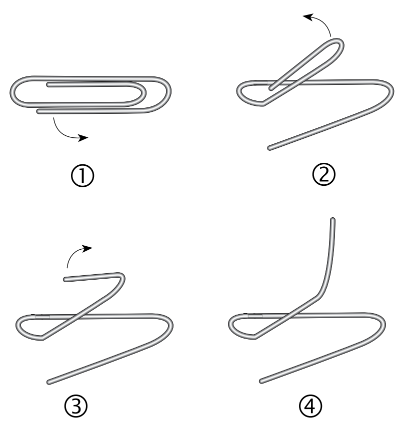
People can increase their lung capacity through training, so you may find higher lung capacities among classmates who participate in competitive sports. Also, larger people usually have greater lung capacities than smaller people.

Calories in Snack Foods

Athletes need a lot of energy to compete in sporting events. This energy comes from the foods they eat. Foods high in fat are also high in energy. The measure of energy in food is the calorie. Many snack foods are particularly high in calories because of high fat content. In this activity, students discover how much energy is present in cheese snacks.

Stuff You'll Use: ▸Cheez-It® crackers or cheese ball snacks ▸square piece of aluminum foil (10 cm x 10 cm) ▸paper clip ▸balance ▸100-mL graduated cylinder ▸water ▸empty soft-drink can ▸ring stand ▸three-pronged clamp with 6.3-cm (2½-inch) grip size ▸alcohol or metal cooking thermometer ▸matches or lighter

What to Do:



1. Fold the edges of the foil square up to make a small tray.
2. Make a small stand out of the paper clip as follows. (See figure at left.)
   a. Lay the clip on the table. Make the base of the stand by bending the outermost end out, horizontally to the table.
   b. Bend the inner loop up to about 45°.
   c. Bend the innermost (short) end up, vertically, so that the end is pointing straight up.
3. Use a graduated cylinder to measure 100 mL tap water. Pour the water into the soft-drink can.
4. Fasten the can into the three-pronged clamp on the ring stand.
5. Place the thermometer in the open can top and measure and record the initial temperature of the water.
6. Determine and record the mass of the cheese snack.
7. Impale the cheese snack on the straight vertical end of the paper-clip stand and put the cheese snack with its stand onto the aluminum tray.
8. Place the tray containing the cheese snack assembly on the base of the ring stand underneath the can and lower the clamp so that the bottom of the can is about 4–5 cm above the cheese snack. Arrange the setup so that the cheese snack is centered directly under the suspended can.
9. Ignite the cheese snack and allow it to burn.
10. When the cheese snack is finished burning, gently stir the water with the thermometer and record the maximum temperature reached.
11. Using the formula below, calculate the number of calories absorbed by the water in the can:

    100 mL water × 1.0 g/mL × rise in temperature (°C) × 1.0 calorie/g degree = number of calories
12. Divide this number by 1,000 to obtain the amount of nutritional Calories in the cheese snack.

Important...
Light the snack as quickly as possible and extinguish the match properly. Do not touch the cheese snack or tray during burning.

How It Works:

In this experiment, the fat and other food components of the cheese snack burn when the snack is ignited. The products of this process are carbon, carbon dioxide (CO_2), water, and heat. Most of the heat energy will be transmitted to the can of water, and thus will raise the temperature of water. However, measuring the temperature change of the water gives only a rough estimate of how much energy the cheese snack contained because some of the heat is lost to the air and the metal can.

In this activity, it's important to understand the difference between scientific calories and nutritional (food) Calories (with a capital "C"). In this activity, you measured scientific calories. A scientific calorie is the amount of heat needed to raise the temperature of 1 gram of water 1 Celsius degree. This unit is so tiny that to avoid using very large numbers in describing the energy content of food, nutritionists use the kilocalorie (1,000 calories) as their unit of Calories. This is why you divided the results by 1,000 in step 12 to get results in food Calories. So when you gobble that snack containing 100 Calories, you're really consuming 100,000 scientific calories.

More Fun?

Learn more about the properties of fats. Terrific Science Press offers the following books that include activities involving the science of fats and the foods we eat:

- *Fat Chance: The Chemistry of Lipids*
- *Science Fare: Chemistry at the Table*

Effects of Chlorine on Germs

Test Substances...

Use the following test substances:

- chlorine bleach
- table salt (NaCl)
- antibacterial hand sanitizer
- liquid soap
- baking soda

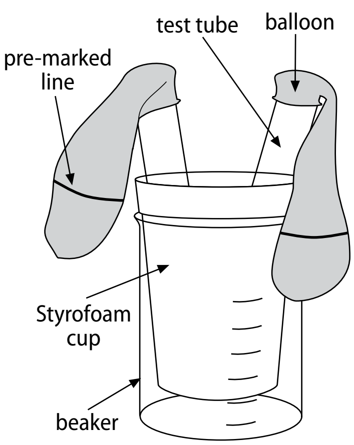
To be safe for swimmers, swimming pools must be disinfected. Chlorine is a typical disinfectant used in pools. In this activity, you'll observe the effects of chlorine on yeast growth, which simulates the bacterial activity that can occur in pools.

Stuff You'll Use:

▸large Styrofoam® cup ▸warm water ▸250- to 400-mL beaker ▸150-mm test tubes with stoppers ▸wax pencil or labels and permanent marker ▸1.25-mL (1/4-teaspoon) and 15-mL (1-tablespoon) measuring spoons ▸sugar ▸rapid-rise active dry yeast ▸test substances (See box at left.) ▸9-inch-diameter round balloons ▸measuring tape or string and ruler

What to Do:

⚠ *This activity works best if done in groups. Each group should have its own setup and test substance. At minimum, test substances should include chlorine bleach and table salt (NaCl). If people with latex allergies are present, use latex-free balloons or do not do this activity.*



1. Prepare a water bath by filling the Styrofoam cup halfway with warm water. Place the cup into the empty beaker to prevent the cup from tipping.
2. Inflate two balloons about halfway. Use a marker or wax pencil to draw a line around each balloon at its widest point. Deflate, reinflate, and deflate the balloons several times to stretch the latex.
3. Label one test tube "control" and the other one with the name of your test substance. Add 15 mL (1 tablespoon) warm water, 1.25 mL (¼ teaspoon) sugar, and 1.25 mL (¼ teaspoon) yeast to each test tube. Stopper the test tubes and shake for about 20 seconds to mix the contents. Remove the stoppers and place the test tubes in the water bath.
4. Add 2.5 mL (½ teaspoon) of the test substance to the appropriate test tube, replace the stopper, and shake for about 20 seconds. Remove the stopper and place the test tube back into the water bath.
5. Add a small puff of air to each balloon (just enough to get the wrinkles out). Secure a balloon over the opening of each test tube. Use a measuring tape or a piece of string and ruler to measure the circumference of each balloon at the premarked line. *Compare the relative size and quantity of bubbles in the test tubes.* Return the test tubes to the water bath.

⚠ *Yeast can vary in activity due to age and other factors. You may want to proportionally increase the amount of yeast and sugar in step 3 if bubbling in the control sample seems minimal.*

6. Observe the test tubes and balloons, noting the bubbling action. After 30 minutes, measure the circumference of each balloon. Fill out the appropriate information in the data table.
7. Share your results with other groups. Discuss your observations, noting any differences between groups who used different test substances.

Did your test substance affect the growth of yeast? Which test substances had the most significant effect on the growth of the yeast?

Sample data table

Test Substance	Balloon Circumference (cm) After 30 Minutes
control	
chlorine bleach	
table salt	
hand sanitizer	
liquid soap	
baking soda	

How It Works:

Active dry yeast is a very small fungus in the dormant stage. In this activity, yeast simulates the bacteria and algae that can grow in swimming pools.

Yeast cells produce carbon dioxide (CO_2) gas when they metabolize sugar. The test tube containing the chlorine bleach should show less CO_2 production than the control, because the chlorine has killed some of the yeast.

When chlorine is added to water in a swimming pool, a reaction occurs splitting it into hypochlorous acid (HOCl) and hypochlorite ions (OCl^-). Both components are strong oxidizing agents that kill microbes by attacking the cell walls and destroying key enzymes in the cells needed for metabolism.

More Fun?

Learn more about the science behind disinfectants. Terrific Science Press offers the following books that include activities involving chlorine, water purification, germs, and personal hygiene:

- *Lather Up! Hand Washing Activity Handbook*
- *Wet Your Whistle! Drinking Water Activity Handbook*
- *What's that Smell: The Science Behind Adolescent Odors*

The Bounce of Playgrounds and Gym Floors

How does the surface of a gym, tennis court, or playground affect the bounceability of a ball? This activity allows you to investigate how balls bounce on different surface materials.

Stuff You'll Use:

▸various sports balls, including ping-pong balls, tennis balls, baseballs, and golf balls ▸different surfaces to bounce the balls on (such as carpet, grass, floor tile, ceiling tile, wood, cardboard, cork, foam pad, Styrofoam®) ▸meterstick ▸graph paper

What to Do:

1. Choose one ball from a variety for sports balls to be your test ball.
2. Look at and feel each of the different surfaces but don't bounce the ball on them yet. *On what surfaces do you think the ball will bounce best? Why?*
3. As a group, design an experiment to determine how different surfaces affect how high your ball bounces. Write your experimental design and create a data table to record your observations.
4. Conduct your experiment. Record the results in your data table and make a graph of your results using graph paper. *How do different surface affect how high the ball bounces? How do the results compare with your predictions? Why did the ball bounce better on some surfaces than others?*
5. Compare your results with those of others who used different balls.

How It Works:

What determines how high balls bounce on different surfaces? During the bounce, both the shape of the ball and the shape of the surface are deformed. The height of the bounce is determined by how much energy of compression is returned as the shape of both the ball and the surface go back to normal. Each ball type and surface type interact differently, producing a unique result.

Even so, some surfaces produce fairly consistent results with all types of balls. For example, all of the balls bounce on the foam pad because the foam deforms rather than the ball, acting much like a trampoline. In contrast, if the surface stays deformed as the Styrofoam surface may, then the energy that went into causing the deformation does not return to the ball. Rubber is an elastomer, which is characterized by its elasticity and flexibility. Elastomeric materials stretch and have the ability to recover with limited distortion.

When looking at which playground flooring to install, many factors have to be considered, including safety, accessibility, cost, and maintenance. In recent years, playground safety been an increasing concern. Playgrounds with climbing equipment often have wood mulch surfaces to break children's falls. Rubber mulch from recycled tires is also becoming popular for environmental reasons and because of its added capacity to break falls.

More Fun?

Learn more about the physics and chemistry of bouncing balls. Terrific Science Press offers the following books that include activities involving bounceability and elasticity:

- *Chain Gang: The Chemistry of Polymers*
- *Exploring Energy with TOYS*
- *Teaching Physics with TOYS EASYGuide Edition*

national chemistry week

Chemical Heat Packs

Many types of sports-related pain come from strained muscles. Heat application eases pain by dilating the blood vessels surrounding the painful area. Increased blood flow provides additional oxygen and nutrients to help heal the damaged muscle tissue. In this activity, you'll measure the amount of heat produced from a commercial reusable heat pack.

Stuff You'll Use:

▸reusable heat pack ▸480-mL (16-ounce) or larger Styrofoam® cup ▸thermometer ▸graduated cylinder ▸water

What to Do:

1. Create a calorimeter setup to determine the temperature change (ΔT) and the amount of heat produced by the heat pack: Place the heat pack in the large Styrofoam cup. Measure and record the volume of room-temperature water needed to totally cover the heat pack. Record the temperature of the water.
2. Remove the heat pack from the cup, activate it, and submerge it in the water. Record the temperature every few minutes until it stops rising.
3. Calculate the ΔT using the starting and ending temperatures. Calculate the heat released (q) in the crystallization process using the equation below where m is the mass of the water used and C_P is the specific heat (for water, C_P is 4.18 J/g•K).

$$q = m \times \Delta T \times C_P$$

4. *How much heat will be needed to reactivate the heat pack?*

How It Works:

The heat pack contains a supersaturated solution of the salt sodium acetate in water. A supersaturated solution is one in which there is more solute (sodium acetate) dissolved in the solvent (water) than would normally be possible at a given temperature. This is accomplished by heating the solution to a higher temperature and allowing it to slowly cool.

A supersaturated solution is inherently unstable but remains as a solution until something initiates crystallization. In the heat pack, the flexing of the metal disk creates a shock wave that is sufficient to initiate crystallization. Once this occurs, the supersaturated solution immediately crystallizes to form the more stable solid. Heat is given off as the solution crystallizes.

More Fun?

Terrific Science Press offers the following book that includes activities involving the chemistry of heat, phase changes, and heating solutions:

▸▸ *Teaching Chemistry with TOYS*

If the Shoe Fits—Athletic Shoe Activity for Multiple Grades

For many kids, summer activities involve athletics. Most of your students probably watched the Olympics on TV and/or were active themselves in sports. At every grade level, sports make a great springboard into science. Through sports, students who might not otherwise be interested can see how science and technology play a large role in their daily lives.

The design of athletic shoes is one example in which chemistry and biomechanics are employed to help minimize strain to the lower body and enhance athletic performance. A shoe should not only provide support and protection to the foot and ankle, but must also provide maximum traction and flexibility and, above all, be lightweight. In track and field sports, for example, a few ounces of extra weight can reduce a runner's speed enough to lose a race. To this end, Nike recently introduced an ultralight shoe that uses thin, liquid-crystal polymers that act like suspension bridge cables to resist shoe stretching and maintain stiffness without adding weight. For cushioning and support, many shoes employ lightweight gel cavities or air pockets.

All modern athletic shoes have at least four components: the **upper,** the **insole** or insert, the **outsole,** and the **midsole.** The upper holds the shoe together and protects the foot. The insole lies directly beneath the foot and provides cushioning and arch support. Insoles are removable in many shoes, and extra insoles called inserts can be added for comfort or moisture control. The outsole is the part of the shoe in contact with the ground; it's usually made of rubber or a synthetic polymer and has treads or cleats for traction. The midsole is the hidden layer between the outsole and the insole, mainly designed for shock absorption. Other specialized athletic shoe terms include wedge, heel counter, and toe box.

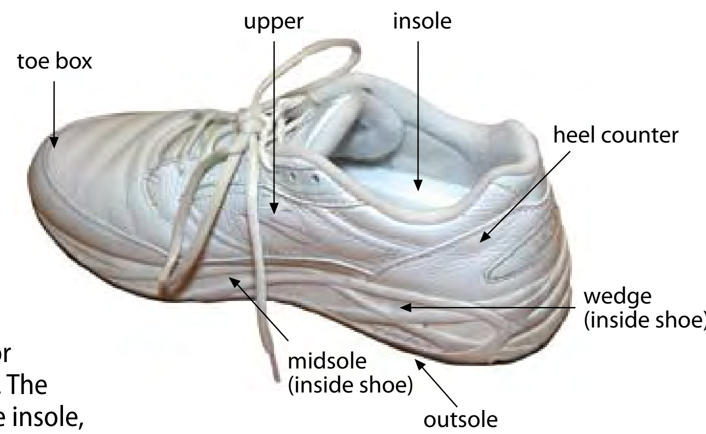


Figure 1

In this activity, students explore shoes to gain an appreciation for the technology involved in shoe construction and to practice gathering and analyzing scientific data. The activity is divided into three parts based on grade level. Part A has two parts: one for younger students and another for older students. Depending on the student level of abilities, you may want to incorporate elements of various parts into a single classroom activity.

Materials

- metric rulers
- computer with Internet access (for Part C)
- old, worn athletic shoes and other shoe types

☞ *You should have at least one other type of shoe (dress shoes, sandals) for comparison. One shoe per four students should be adequate. You may wish to have students bring an old pair of shoes from home, so they can be free to disassemble the shoe to examine the insole and other interior parts of the shoe. If you have access to a band saw, you may wish to saw the shoes in half lengthwise.*

Procedure

Part A: Comparing, Sorting, and Graphing Activity

Introduce the activity by asking students what scientists do. One thing that scientists do is sort and classify objects and phenomena by similar characteristics. Sorting and classifying help scientists simplify the natural world. Explain that scientists also observe, measure, predict, do experiments, and make conclusions based on their findings.

For grades K–3:

Tell students that they are going to sort a group of objects in the class. (The youngest students may need an example of what sorting is.) Have students remove their shoes and sort the shoes based on common characteristics. Characteristics might include shoe type, color, size or shape, and degree of wear. Let students try several different ways, but make sure they can explain the method used to sort the shoes. Ask them how many of the shoes are athletic shoes. Have them compare the characteristics of athletic shoes with other types of shoes.

For grades 4–6:

Have students explore the shoes as scientists might, asking questions and gathering, graphing, and analyzing data as appropriate. For example, students might measure shoe length and work to answer questions such as the following: What is the average (mean) shoe length for the classroom? What is the most common (mode) shoe size? Are boys' and girls' shoe sizes different? How? Are all girls' size 4 shoes the same length? If they're different, how might these differences be explained? For another activity that deals with athletic shoes, see the "Science of Athletic Shoes" at *www.terrificscience.org/ncw.*

Part B: Dissected Shoes (grades 7 and up)

Have students examine an athletic shoe to find the various parts of the shoe labeled in Figure 1. Then have students measure thicknesses of the insole, midsole, and outsole at various points along the length of the shoe (toe, arch, and heel). Have students create and fill out a data table that contains these measurements. The table can also include descriptions of tread design and the color and textures of various parts of the shoe.

Have students answer the following questions:

- Can you tell which of the shoes have traveled the furthest (have the most miles on them)? Explain. Describe at least three features that support your answer.
- Do the insoles of the older shoes look different than the insoles of the newer shoes? Explain.
- Does the thickness of the insole change depending on its location in the shoe? How?
- Do you see visible wear patterns? Discuss.
- Are air pockets present? What purpose do air pockets serve?

Part C: Brand Comparison and Shoe Design (advanced project)

Have students compare different brands of athletic shoes and use the Internet to explore each manufacturer's claims. Have them research the ideal features of an athletic shoe for a given sport. Let students select a sport and then design a shoe they think would be ideal for that sport. Have them draw and label the shoe. Students should show and describe at least three features that apply to the chosen sport.

Activity adapted from Athletic Shoes: Studies in Compounding Polymers; *Carolina® Active Science™ Series: Burlington, NC, 1999.*

Playing with the METS

Ever wonder how many calories you burn while playing your favorite sport? Health scientists have devised a method that allows you to estimate how much energy it takes to do a wide variety of activities. In this activity, you'll learn how to use Metabolic Equivalents, or METs.

What to Do:

1. Choose an activity in the table below and multiply the number of METs by 3.5.
2. Multiply the number in step 1 by your weight in kg (1 kg = 2.2 lbs).
3. Divide the number you get in step 2 by 200.
4. Enter the activity and the number of minutes you do the activity per day into a data table. Multiply that number by the number you obtained in step 3. This will give you the total number of calories burned for the activity. Enter that number into the data table.
5. Complete the data table to figure out how many calories you burn from your daily activities.

Sample data table

Sport/ Activity	Minutes per Day	Calories Burned
	Total	

How It Works:

The Metabolic Equivalent (MET) is the ratio of your work metabolic rate to your resting metabolic rate. One MET is 1 kilocalorie/kg/hour. It is roughly the equivalent of the energy you use while sitting quietly. One MET also equals 3.5 milliliters of oxygen (O_2) per kg of body weight per minute. This is the oxygen rate your body requires at rest.

METs are only an approximation of your body's energy use. The exact amount of energy you expend in an activity depends on many variables, such as your age, gender, amount of body fat, and environmental conditions (for example, climate).

MET Activity Table

Sport/Activity	Metabolic Equivalents (METs)	Sport/Activity	Metabolic Equivalents (METs)
sleeping	0.9	baseball	5.0
watching television	1.0	skateboarding	5.0
eating	1.5	social dancing	5.0
talking on phone	1.5	track (general)	6.0
sitting in a classroom	1.8	wrestling	6.0
driving a car	2.0	basketball	7.0
showering	2.0	jogging/swimming laps	7.0
light housework	2.5	tennis	7.0
weight lifting	3.0	bicycle riding	8.0
walking	3.5	football/soccer	8.0
gymnastics (general)	4.0	hockey (field and ice)	8.0
volleyball	4.0	running fast	10.0
golf	4.5	roller blading	12.0

FYI...

Olympic gold metalist Michael Phelps consumes 12,000 calories a day to fuel his rigorous swimming regimen. For breakfast alone Phelps eats three fried egg sandwiches with mayo, a five-egg omelet, a bowl of grits, three pieces of French toast with powdered sugar, and three chocolate chip pancakes.

Phelps, at 6 ft 4 in, weighs 200 pounds. Can you calculate how many hours a day he needs to swim to burn off 12,000 calories?

Polyurethane Foam

Polyurethane is a synthetic polymer found in many types of athletic clothing and sports equipment. As an impact-resistant foam, it is used to line the inside of athletic helmets and to make the outer sole of many types of footwear, including athletic shoes. Polyurethane also makes up the inflatable bladder of professional footballs and the strings and grips of pro tennis rackets. In this activity, you'll investigate the properties of polyurethane foam.

FYI...
Two teaspoons of each liquid will usually form enough foam to expand 1–2 inches above the top of the cup.

Stuff You'll Use:

▸polyurethane foam system (Polyurethane foam systems are available in craft and hobby stores. One brand name is Mountains in Minutes. The system comes in two parts; be sure to purchase parts A and B.) ▸clear plastic cup (9- to 10-oz) ▸plastic spoon ▸paper towels ▸newspapers or extra paper towels ▸(optional) food coloring ▸(optional) balance capable of measuring 0.1 g ▸(optional) paring knife

What to Do:

⚠ *Perform this activity only in a well ventilated area. Avoid breathing the vapors produced. Wear gloves and goggles to prevent contact with skin and eyes.*

1. Pour about 2 teaspoons of Part A of the foam system into a cup. Add a few drops of food coloring if you wish.
2. Add about 2 teaspoons of Part B to the cup and stir until the mixture is a uniform color throughout. Wipe spoon with a paper towel.
3. Place the cup on the newspaper or paper towel. (If you wish, you can place the paper towel and cup on a balance and record the initial and final weight.) Observe the cup for about 5 minutes. *What happens to the foam?* Feel the outside of the cup. *Do you notice a change in temperature? What type of reaction is taking place in the cup?*
4. Tap the foam with the spoon. *What property of the material changed during the reaction? What has happened to the volume of the material in the cup? Has the weight changed?*

⚠ *Since the foam may contain unreacted isocyanate, do not handle it until it has ample time to cure (approximately 24 hours).*

5. *What do you think the foam would look like if you cut it open?* (If desired, cut the foam open with a paring knife.)
6. *What properties of this polymer make it useful for sports?*

How It Works:

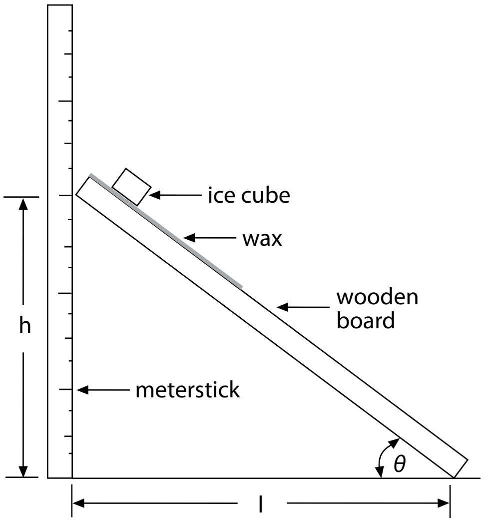
The foam is produced by a polymerization reaction between a polyether polyol (Part A) and a diisocyanate (Part B). The reaction is exothermic. Part A also contains a catalyst. During the reaction, water reacts with some of the diisocyanate to produce carbon dioxide gas, which forms bubbles and causes the foam to expand, much like baking bread. The weight before and after should be nearly the same, but the volume increases about 30 times, producing a corresponding decrease in density.

More Fun?

Learn how to make a variety of polymers, such as Gluep and slime. Terrific Science Press offers the following books that include activities about polymers:

- *Polymers All Around You, 2nd Edition*
- *Teaching Chemistry with TOYS*
- *Classroom Science from A to Z*
- *Science Night Family Fun from A to Z*
- *Exploring Matter with TOYS: Using and Understanding the Senses*

Effects of Wax on Sliding



Position of wooden board as ice cube begins to slide.

Why do skiers put wax on their skis? In this activity, you'll explore how wax reduces friction between ice and wood.

Stuff You'll Use:

- ice cubes
- unfinished wooden planks or boards (Make sure both sides of the board are equally smooth.)
- block of paraffin canning wax (Crayons will also work.)
- meterstick
- (optional) a variety of waxes, such as ski wax, surfboard wax, and floor wax

What to Do:

1. Apply wax to one side of the board by rubbing the block of paraffin or the crayon over the surface until the coating is thick and even. It's not necessary to coat the entire length of the board, just the end where you will be placing the ice cube. (See figure at left.)
2. Place an ice cube on one end of the non-waxed side of the board. *How high do you think the board can be lifted before the ice cube slides?* Holding the meterstick vertically next to the end of the board, slowly lift the end of the board until the ice cube begins to slide. Do at least three trials. Record the average height (h). *How do your results compare to your prediction? Do you notice much variation in the heights between trials? What factors could cause any observed variation?* Hint: Allow the ice cube to sit for several minutes on the board before lifting the end of the board. *How high can you lift the board?* Place the board down flat and gently pick up the ice cube. *What do you notice when you pull the ice cube off the wood?*
3. Repeat step 2 using the waxed side of the board. Compare the results.
4. (Optional) Repeat step 3 with boards that have been coated with other types of wax. *Which wax allows the ice to slide the best?*
5. (Optional) Determine the coefficient of static friction (μ_s) for each of the experimental conditions you tried: for example, ice on plain wood, ice on paraffin wax, ice on ski wax, and so forth. (See box at left.) Record the data in a table. *Look at your results. What is the relationship between the ease of sliding and the coefficient of static friction?*

FYI...

In the figure above, the coefficient of static friction (μ_s) is the force of friction at the area of contact divided by the force of gravity normal to the board. It's expressed mathematically as:

$$\mu_s = \tan\theta = h/l$$

Sample data table

Test Surface	Height (h)	Length (l)	μ_s
plain wood			
paraffin wax			
ski wax			
surfboard wax			
floor wax			

How It Works:

Friction is the force that resists motion between two materials in contact with each other. Friction can occur between two solid materials (such as a book on a table), two fluid materials (air moving over water), or a solid and a fluid (for example, water moving through a pipe). Friction depends on many factors, including the forces pressing the surfaces together, the types of surfaces rubbing together, temperature, the relative speed of the two surfaces, and the presence of lubricants.

Skis and snowboards are able to glide smoothly over snow because a thin film of water (melted snow) between the bottom of the skis and the surface of the snow acts as a lubricant to reduce friction. The friction between skis and snow (or wood and ice, in this activity) is more complicated than the dry friction between other solids. If too little water is present between the snow and the skis, then dry friction will slow the skier down. On the other hand, too much water from the melted snow creates "wet drag," which can also slow down the skier. The purpose of putting wax on skis is to help achieve a fine balance between friction and drag so that the glide is optimal. Different ski waxes are available for different snow conditions.

Physicists and engineers are still uncertain exactly how friction works. One model attributes friction to the tendency of materials in close contact with each other to stick together because of attractions between the atoms and molecules that make up the two surfaces.

You were probably able to lift the plain-sided board fairly high before the ice cube started to slide. After the ice cube had melted slightly, you may have noticed a small attraction between the ice and the wood when you pulled the ice cube off the board. Attractions also occur between the ice and water and the water and wax, but much less so than on the plain wood surface. Consequently, the ice cube on the waxed side of the board consistently slid down the board at a much lower angle (height) that it did on the non-waxed side of the board.

More Fun?

Learn more about the properties of waxes and fats. Terrific Science Press offers the following book that includes activities involving the science of lipids:

- ***Fat Chance: The Chemistry of Lipids***

Electrolyte Content of Sports Drinks

FYI...

Granular water-storing polymer products (such as Soil Moist™, Water-Gel Crystals, Sta-Moist™, Aquadiamonds®, or Watersorb®) are usually available where potting soil is sold.

Sports drinks contain large amounts of electrolytes (ions), such as sodium (Na^+) and potassium (K^+), in order to replenish the electrolytes that the body loses through sweat during exercise. This activity provides you with an indirect way to measure the amounts of electrolytes in a water beverage.

Stuff You'll Use:

▸water-storing polymer product with crystals measuring about 2–4 mm in diameter ▸Gatorade®, Propel®, or similar sports drink ▸bottled mineral water ▸distilled water ▸tap water ▸9-ounce (270-mL) or larger clear plastic cups (one for each sample) ▸1-cup (250-mL) liquid measuring cup with metric markings ▸strainer ▸permanent marker

What to Do:

1. Label a cup for each sample to be tested. Record the names of the liquids you will test in a data table. Record the ingredient list for each sample, if applicable.
2. Place 10 polymer crystals that are about 2–4 mm wide into each of the labeled cups. Make sure the sizes of the crystals are evenly distributed in the cups. (In other words, don't have one cup with only the largest crystals and another with only the smallest.)
3. Add 150 mL of the appropriate liquid to each of the labeled cups. Allow the cups to sit several hours or overnight.
4. Hold the strainer over the measuring cup and pour the contents from one sample cup into the strainer. Once the liquid has drained into the measuring cup, return the crystals to their original (now empty) cup. Record in milliliters the volume of liquid you collected in the measuring cup. Rinse the liquid down the drain.
5. Calculate the volume of liquid that the crystals absorbed by subtracting the volume of liquid you collected from 150 mL (the volume of the liquid added).
6. Repeat steps 4 and 5 for each sample.
7. Look at the data that you collected. *What (if any) trends do you observe with regard to the amount of liquid absorbed by the crystals and the ingredients/water sources listed for the samples?*

Sample data table

Liquid	Ingredients	H_2O Volume Absorbed
tap water		
distilled water		
sports drink		
mineral water		

Important...

When you are done with the crystals, throw them in the trash. *Do not* dump the crystals down the drain because they can clog plumbing.

How It Works:

The water-absorbent crystals in this activity are made from sodium polyacrylamide, a polymer that absorbs many times its own weight in water. The polymer has this property because it contains ions that attract the polar water molecules. When a sports drink comes into contact with the sodium polyacrylamide, the ions in the drink and the ions in the polymer are in competition for the water molecules. The more ions in the liquid, the less water molecules that can be absorbed by the polymer. Thus, the polymer swells less in liquids with high concentrations of ions. You should find that distilled water is absorbed the most and sports drinks and mineral water the least. How much tap water the crystals absorb depends on the concentration of ions in your local tap water.

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More Fun?

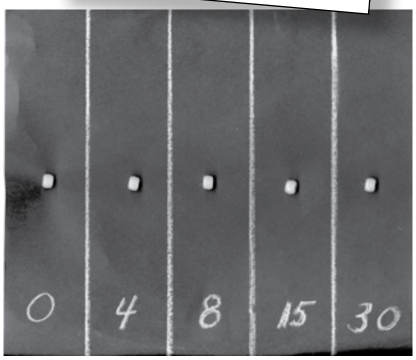
Terrific Science Press offers the following books that include activities involving the science of water-absorbing polymers:

- *Camp and Club Science Sourcebook: Activities and Planning Guide for Science Outside School*
- *Polymers All Around You, 2nd Edition*
- *Wet Your Whistle: Drinking Water Activity Handbook*

Sunscreens and SPF Ratings

Overexposure to sunlight is a risk common to many sports. UV-containing sunlight can damage our skin, causing painful sunburn and an increased risk for skin cancer. Sunscreens contain chemical agents that safely absorb the UV radiation and convert the energy into heat through a chemical reaction. In this activity, you'll test the effectiveness of several sunscreen products.

Important...
Sunscreens protect people with all skin shades from UV exposure.



Sample data table

SPF of Product	UV Bead Shade	
	Start	After UV Exposure
0 (control)		
Time and Weather:		

Stuff You'll Use:

▸3–5 UV detection beads (all the same color) ▸black construction paper ▸scissors ▸gallon-sized plastic bag ▸glue ▸cotton swabs ▸2–4 sun protection products having a wide range of SPF ratings (include at least one with an SPF rating of 8 or below)

What to Do:

1. Place the UV detection beads in direct sunlight and observe what happens. Then, remove the beads from the sunlight. What happens?
2. Working indoors, cut black paper to fit inside a gallon-sized plastic bag. Evenly space UV detection beads on the black paper, one bead for each sun protection product you will test and one bead for the control. Glue the beads to the paper, making sure not to get glue on the tops of the beads. Let dry.
3. Label the paper next to each bead with the SPF rating of the sun protection product you are going to test. The control bead will get no sun protection product (0 SPF). Slide the black paper into the gallon-sized plastic bag.
4. Using a clean cotton swab for each sun protection product, spread a small amount of the appropriate product on the bag over each bead in a circle about 1½ inches (about 4 cm) in diameter. Apply the same amount of product evenly over each bead.
5. Create a data table like the example at left. Record the SPF of each product, the starting shade of each bead, and the time of day and weather conditions.
6. Cover the bag and bead setup with a thick cloth or another material that does not allow sunlight to penetrate. Take the setup outside in direct sunlight. Remove the cloth but not the plastic bag. Observe and record the shade of each bead (such as white, nearly white, light, medium, and dark.) If you can't see through the plastic, take the setup indoors, open the bag, and immediately observe the beads. What is the trend between the shade changes of the beads and the SPF ratings?

How It Works:

UV detection beads turn from pale, off-white to color when exposed to UV from direct sunlight. The SPF ratings of the products correlate with how quickly and how deeply the beads change shade. Beads covered with no sun protection product or low SPF product quickly change to a deep shade, while those covered with a maximum protection (SPF 30 or higher) product remain white or nearly white. Beads covered with intermediate levels of SPF show a change somewhere in between. You should see the general trend from low SPF (deeper bead shade) to high SPF (lighter bead shade).

More Fun?

Terrific Science Press offers the following books that include more activities related to staying safe in the sun:

- *Camp and Club Science Sourcebook: Activities and Planning Guide for Science Outside School*
- *More Than Skin Deep! Skin Health Activity Handbook*

Surface Tension and High Diving

Surface tension makes water act as though it has an invisible skin. Anyone who's done a belly flop into a pool has had painful experience with this "skin." Olympic high divers need to enter the water with a knife-like precision, exposing the smallest cross-sectional area of their bodies to the water surface to lessen the blow caused by the water's surface tension. In this activity, you'll observe water's surface tension up close.

Important...

If you have trouble getting the horizontal needle to float, try one of these ideas:

- Rub it on your forehead, being careful not to stick yourself, then try to float it.
- Float a piece of tissue paper on the surface of the water. Gently place the needle on the paper. Using the point of a sharpened pencil, push the paper under the water. The needle should remain on the surface.

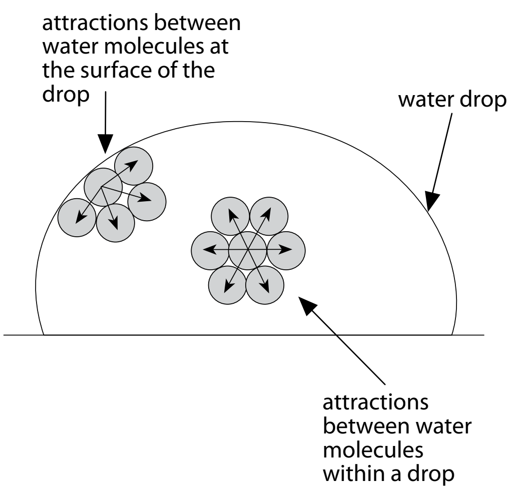
Stuff You'll Use:

▸clear plastic cups ▸needle ▸magnifying lens ▸waxed paper ▸water ▸dishwashing liquid ▸eyedropper ▸(optional) tissue paper ▸(optional) sharp pencil

What to Do:

1. Fill a cup (free from any soap residue) with water.
2. Drop a needle, point-first, into the water and observe.
3. Carefully lower a needle horizontally into the water and observe.
4. Using a magnifying lens, examine the surface of the water that is in contact with the needle. *Do you see a depression in the water?*
5. While the needle is floating, use an eyedropper to add several drops of dishwashing liquid. *What happens? Why?*

How It Works:



The high surface tension of water allows it to support objects that are more dense than water, such as a needle. The surface tension results from the very strong attraction water molecules have for each other. The tendency for particles of a liquid to be attracted to each other is called cohesion. The figure at left provides a graphical illustration of the cohesive forces in a water sample. Water molecules in the middle of the drop of water are attracted equally in all directions. Those water molecules on the surface, however, are only attracted to water molecules within the drop. This creates a force across the surface that causes a drop of water to form a bead.

Surface tension can be reduced by introducing a surfactant (a surface-acting agent) such as detergent, which interferes with the attractive forces between the water molecules. When the dishwashing liquid is added to the water, the horizontal needle sinks because the detergent has lowered the surface tension of the water.

More Fun?

Learn more about the topics addressed in this activity. Terrific Science Press offers the following books that include activities involving the science of water and surfactants:

- ▸▸ *Teaching Chemistry with TOYS*
- ▸▸ *Dirt Alert: The Chemistry of Cleaning*

Temperature Effects on Ball Bounceability

Ball bounceability is an important element of many sports. Tennis and ping-pong balls must meet certain bounce criteria to be used for regulation play. Golfers want balls with sufficient elasticity to be driven long distances, and a tightly wound baseball jumps off the bat faster and travels farther than a loosely wound, "dead" ball. In this activity, you'll investigate how ball bounceability varies with temperature.

FYI...

If you wish to do the experiment in a single session, you can gather two of each kind of sports ball and place one of each in the freezer the day before you'll do the activity.

Stuff You'll Use:

▸various sports balls, such as ping-pong balls, tennis balls, baseballs, and golf balls ▸access to a freezer ▸uniform hard surface such as table top or linoleum or wood floor ▸meterstick ▸graph paper

What to Do:

1. Look at and feel each of the sports balls but don't bounce them yet. *What variables do you think might affect how high a ball will bounce? Which ball do you think will be the best bouncer? Which ball the worst? Why?*
2. As a group, design an experiment to determine which ball is the best bouncer.
3. Test each ball for bounceability. Measure only the first bounce upon dropping and include at least three trials per ball.
4. Create a table to record your data. Record the results in your data table and make a graph of your results.
5. Place the balls in the freezer for 24 hours.
6. Repeat steps 3–4 with the balls from the freezer.
7. *How did the colder temperature affect each ball's ability to bounce?*
8. *Why do you think the cold had the effect it did on each ball? In particular, how do you think the air inside the hollow balls is affected by the decrease in temperature? Relate this to the bouncing behavior you observed.*

How It Works:

In general, cold balls bounce less than warm ones. For balls with solid interiors, temperature affects the elasticity of the material inside. For example, cold rubber is less flexible than warm rubber. This lack of flexibility causes more of the bounce energy to go into making the molecules vibrate and less into elastic potential energy.

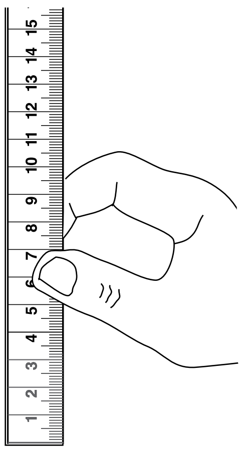
In the air-filled balls, the lower temperature causes the air pressure in the ball to decrease, resulting in a less bouncy ball. (Think of a partially deflated basketball.) The direct relationship of changing gas pressure with temperature is called Charles' Law.

More Fun?

Learn more about the physics and chemistry of bouncing balls. Terrific Science Press offers the following books that include activities involving bounceability and elasticity:

- *Chain Gang: The Chemistry of Polymers*
- *Teaching Physics with TOYS EASYGuide Edition*

Test Your Reaction Time



Reaction time is critical in many sports. In baseball, for example, a batter has only a fraction of a second to respond to a pitched ball. Soccer goalies must have excellent reaction time to block a potential score. In this simple activity, you'll determine your own reaction time and compare it to that of others.

Stuff You'll Use:

- centimeter-scale ruler
- calculator
- graph paper

What to Do:

1. Have a partner hold out his or her thumb and index finger. Hold the ruler so that the 0-cm mark is level between the tops of your partner's fingers.
2. Have your partner catch the ruler with the thumb and index finger when you release it. (Do not let your partner know when you will release the ruler.)
3. Record the position of the fingers on the ruler when your partner catches it. (See figure.)
4. Repeat steps 1–3 for at least three trials. Calculate the average.
5. Calculate the reaction time using the following formula: $t = \sqrt{2d/g}$ where t is the reaction time in seconds, d is the distance the ruler fell in cm (position of fingers), and g is the acceleration due to gravity (980 cm/sec^2).
6. Collect data for each student in the class and plot a histogram of the reaction times. *What is the mean reaction time? What is the fastest reaction time? The slowest? Do you see any relationship between those who play a lot of sports and their reaction times? How about those who play a lot of video games?*

How It Works:

Reaction time is the time that passes between the moment an observable change in the environment (called a stimulus) occurs and the response to that change. In this activity, the falling ruler represents the change in the environment and your partner catching the ruler is the response.

Reaction time is related to how fast your nervous system is able to gather, process, and respond to information in the environment. Signals from the eye pass down the optic nerve into the visual cortex of the brain where they are processed, and a response signal goes from your brain, down your spinal column, and into nerve cells telling your muscles to contract. All of this takes a measurable amount of time. Reaction time can vary with age, gender, degree of physical fitness, and other variables. For this activity, the mean reaction time for young adults is about 0.19 seconds.

More Fun?

Learn more about calculating and graphing. Terrific Science Press offers the following books that include activities on using scientific data:

- *Exploring Energy with TOYS*
- *Investigating Solids, Liquids, and Gases with TOYS*
- *Teaching Chemistry with TOYS*
- *Teaching Physics with TOYS EASYGuide Edition*

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