Forces at the Nanoscale: Activity 1

Gecko Feet

Splitting Hairs

We're Jennifer and Nooshin, rock climbers extraordinaire! We notice that we aren't the only ones who like to climb. The local lizards in Berkeley, California, are pretty good, too!

Our question:

Which lizards are the best climbers?

At the **Lawrence Hall of Science**, we compared the climbing ability of different lizards and discovered the best climbers were geckos. We wanted to know what was so special about geckos so we paid a visit to the **University of California Berkeley**. We learned that nanoscale hairs on geckos' feet are the secret to their amazing climbing abilities. Engineers are even mimicking these nanohairs to make a special gecko tape that could stick almost anywhere without leaving behind any goo!

Nano Matters

Gravity, a force we experience on a daily basis, depends on the mass of an object. When things get really small, at the nanoscale, the mass of an object (such as a molecule) becomes negligible and other forces dominate. In the case of a gecko, the small hairs (setae) on their feet have nanosized "split-ends" (spatulae). The millions of hairs on each foot make intimate contact with the surface of a wall or glass. The atoms of each are so close that a normally very weak force (van der Waals) becomes very strong. (There really is power in numbers!) At the nanoscale, this force becomes dominant over gravity, which is fighting to pull the lizard toward the Earth.

Icebreaker

Try this wacky water fun.

10 minutes

DragonflyTV Skill: Predicting

Guide your kids as they

1) Fill the full-sized teacup with water. Predict what will happen if you turn the cup upside down. Why? What force causes that effect?
2) Now fill the miniature cup with water and predict what will happen when you flip it upside down. Does the water pour out?
3) Try this with cups sized between the two teacups. At what size does the water no longer stay in?

You'll need:

- regular teacup
- tiny teacup (from a dollhouse)
- objects in between (e.g., thimble, cap from toothpaste, cap from a soda bottle)
- pan of water

Jones, M. Gail, Falvo, R. Michael, Taylor, R. Amy, and Broadwell, P. Bethany. "Shrinking Cups: Changes in the Behavior of Materials at the Nanoscale." In Nanoscale Science: Activities for Grades 6-12. pp. 89-94. Arlington, VA: NSTA Press.

For other Icebreaker activities on this topic, visit: pbskids.org/dragonflytv/superdoit/get_charged_up.html, pbskids.org/dragonflytv/superdoit/dancing_cereal.html and pbskids.org/dragonflytv/superdoit/charged_comb_water.html.

Are you a nano-bit curious?

It's easy to pour water from the regular-sized cup, but not from the miniature cup. That's because size can affect the way materials like water behave. When you tip the regular cup, the force of gravity pulls the water out of the cup. When you tip the miniature cup, gravity isn't strong enough to overcome the natural tendency of water molecules to stick together. The force holding the water molecules together is called surface tension. At the nanoscale, different physical forces and material properties dominate. If you were nanosized, you'd hardly notice gravity. Instead, you would be more concerned with the chemistry of your neighbors: will you be attracted to or repel away from other molecules?

Investigation

Try some simple shoe science.

3 Hours

Guide your kids as they

1) Look at the bottom of the shoes you are wearing and compare them to the shoes of others in your group. Why are some shoe soles flat while others have ridges? For what type of terrain are the shoes intended? How much contact do they make with the surface? Does this depend on the surface you walk on? How?
2) Gather a sampling of shoes with different soles, from very bumpy to very flat, to test how much how much contact they actually make with the ground. Place the crushed sidewalk chalk in the shoebox. Dip each shoe inside the box to cover the bottom with chalk. Be sure to cover the entire sole of the shoe.
3) Make an impression of the sole on the graph paper by placing your hand inside the shoe and pressing firmly against the graph paper. (You may need to slightly rock the shoe back and forth.)
4) Before removing the shoe, use a pencil to trace the shape of the shoe onto the graph paper.
5) It's counting time! Set counting rules from the beginning. For example: if half or more of the square is covered in chalk, then it is counted. If less than half is covered, it is ignored.
6) First, count the total number of squares enclosed by the shoe's outline. This is the total area.
7) Next, count the number of squares that have colored chalk on them. This is the contact area.
8) Determine the ratio by dividing the contact area by the total area. Which shoe had the highest contact ratio? What would happen if you did this experiment on muddy ground instead of a hard surface? Which shoe do you predict would have the most contact in that case? Why?

Adapted by permission from McREL, December, 2008 from Investigating Static Forces in Nature: The Mystery of the Gecko http://www.mcrel.org/nanoleap/ supported by the National Science Foundation, Division of Elementary, Secondary and Informal Education award # ESI-0426401.

You'll need:

- shoes with different soles that you don't mind getting a little dirty (e.g., a sneaker and flat dress shoe)
- crushed sidewalk chalk (not white)
- shoebox
- graph paper and pencils

DFTV Science Helper

Try this demonstration to help relate the activity to a gecko's foot. Take an old egg carton and flip it upside down. This represents an object that geckos would climb on (like a wall). Any object, when viewed at the nanoscale, will be very bumpy like the egg carton. Now, wrap a piece of bubble wrap around your hand and try touching the egg carton. How much contact does it make? Compare this to a soft bristle hair brush. Does the brush make more or less contact with the egg carton's surface? (The brush represents a gecko's foot which is covered in tiny hairs that can make maximum contact with the nanoterrain.)

Are you a nano-bit curious?

In this activity, you brought a macroscale object, your shoe, in contact with a flat surface (the graph paper). Imagine if we could repeat the experiment using soft, muddy ground. The ratios would change dramatically because the shoes with ridges have a large amount of surface area. At the nanoscale, the entire world is bumpy. Even smooth objects like glass have bumps and ridges when viewed with a powerful microscope. For an animal, like the gecko, to stick and make maximum contact, its feet have evolved specific nanoscale features. An average gecko has about 6.5 million setae (or tiny hairs) on its feet. Each setae branches out (like split ends on a hair) into approximately 100–1000 spatulae, which are about 200 nanometers wide. It is the contact of these near billion spatulae with the surface that creates enough interactions (van der Waals) to keep the gecko on the wall. Think of the bristles of your toothbrush making contact with the ridges of your teeth. See the **Image Gallery** on page 67 for up-close images of a gecko foot.

DFTV Kids Synthesize

Data and Analysis

Type of shoe	Total area	Contact area	% Contact (contact area/ total area x 100%)
sneaker	100	60	60%
dress shoe	50	40	80%

Keep Exploring!

Think about why people use cleats to play sports. Do cleats make a lot or very little contact with the surface? Does it matter which surface they are on? Would they make more contact on pavement or a soggy grass field? Why?