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 See also companion lesson Post #17

STEM: Science – Earth and Space Sciences

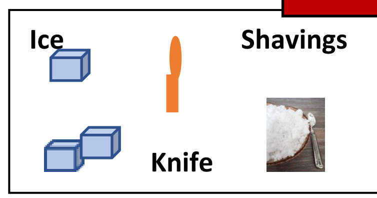
There's a lot in the news these days about the impact on our climate of melting glaciers. There is a great deal to know and even more still to learn about glaciers. This post introduces you to some basic concepts of glaciers. This information can be adapted for a wide range of learners. See Lift the Level for suggestions.

One Way Scientists Study Glaciers – Geophysics of Glaciers

Young children will need supervision.

Glaciers are huge sheets of ice that form on land. Lots of kinds of scientists study them. We are going to look at some *physical properties of glaciers*, which is what **geophysicists** do.

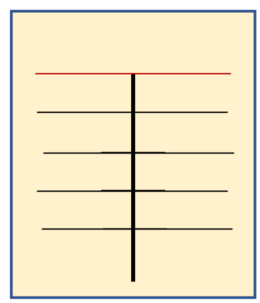
Investigation 1 You will need ground or shave ice or you can make your own using few ice cubes or a block of ice, a knife or potato peeler, and two towels or paper towels.
Put the ice on one towel. Hold it with the other towel. Working quickly, scrape it *away* from you with the knife or potato peeler. Make a pile of shavings from the ice. Scoop up the shavings in the towel and squeeze them between your two palms. *Note: ice can burn your skin. Don't handle it with your bare hands.* What do you notice?



Picture 1

Prep Work – Getting ready for the other Investigations
For the rest of the Investigations you will need Glacier Goo. The recipe is on page 6. You will also need:

- ✓ a plastic gallon bag
- ✓ a piece of cardboard cut to fit in the bag
- ✓ a ruler
- ✓ a marker in a dark color
- ✓ a damp scrap of cloth that nobody needs or an alcohol pad
- ✓ a book to prop up the cardboard
- ✓ a sheet of aluminum foil 36 inches long (heavy duty works best)
- ✓ a toothpick or small stick
- ✓ a stopwatch (optional)



Picture 2

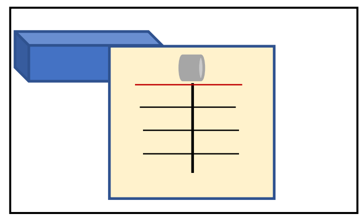
Use the ruler and marker to mark the cardboard on both sides as shown in Picture 2. The red line is about 10 cm from the top of the sheet, the thin black lines are about 5 cm apart. (The actual measurements are not important as long as they are evenly spaced and, as illustrated, they don't have to be exactly the same length. Slip the cardboard into the gallon plastic bag and zip or fasten shut.

Scientists make smart guesses, called ***predictions,*** about what will happen when they investigate. Get in the habit of making *predictions* and writing them down along with what you actually observe. Nobody makes predictions accurately all of the time. Be bold – write in ink or marker anyway!

Investigation 2 Scientists have to figure out how things behave before they can understand how to help or change them – or even if they *should* do so. So, in your role as a ***geophysicist*** studying glaciers, you need to be able to answer this question: ***Are glaciers always moving?***
Lay the plastic-covered cardboard on a flat surface. Form the Glacier Goo into a ball and place it in the center. Draw a ring around the ball with the marker. Watch the Goo glacier. What happens?

Predict what the ball will do – write or sketch:	**Observe and write or sketch what happens:**	**Wonder what would happen if you did it again, or if you changed something:**

Investigation 3 ***How does a glacier move downhill?*** Wipe off the ring from Investigation 2 with the damp cloth or alcohol pad. Prop up the cardboard on a book with the red line at the top. Form the Goo into a ball. Place it above the red line. Release it and count how long it takes to reach the first black line, then the second, and so on. It doesn't matter how fast or slow you count but you have to count at the same **rate** (speed) all the time. You can use a stopwatch if you have one. Also note the shape of your "glacier" as it moves.



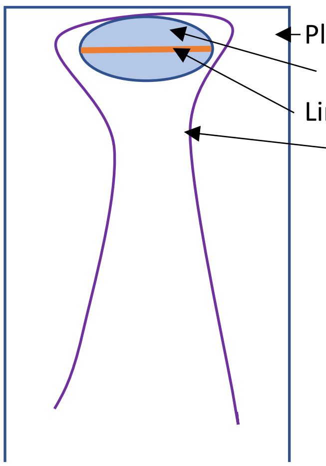
Picture 3

Predict what the ball will do – write or sketch:	**Observe and write the times:** **Line 1** **Line 2** **Line 3**	**Wonder why and think about what you already know:**

Investigation 4 ***Do different parts of a glacier move at different rates as it flows?*** Prop up the cardboard as in Investigation 3. Place the Goo ball above the red line. Stick a toothpick into the middle of the ball so it makes a right angle with the cardboard. Let go of the Goo. What happens to the toothpick?
Scientists try to figure out *why* something happens. They *wonder* and use what they learn in science to figure things out.

Predict: ___Stays the same ___Points toward the red line ___Points toward the bottom of the cardboard	**Observe and write or sketch what happens:**	**Wonder why it happened:**

Investigation 5 ***What happens to a glacier when it has to go through a narrow space, such as through a channel or fiord, or between two mountains?*** Take a sheet of aluminum foil and roll it from one long side to the other then scrunch to form a long tube. Form the foil into a fjord or channel that looks like Picture 4. Place it on the plastic-covered cardboard. Raise the end with the closed channel by resting it on a book. Put the blob of Glacier Goo in it and draw a line straight across the Goo with a marker as shown. **Predict:** Will the edges flow faster making the line into a frown or will the center flow faster making the line into a smile ?



Picture 4

Predict – frown or smile?	**Observe and write or draw**	**Wonder why**

What's the Science?

Investigation 1: Snow falls on land and, where it is below freezing all of the time, it doesn't melt. More snow falls, the weight presses on the snow below and **compacts** it into ice. Over many years the ice becomes thicker and heavier. Tremendous weight is distributed within the glacier and presses on the land below, assisted by gravity, a **force** acting on the glacier as well as on the land mass on which it sits. A **force** is a push or pull between two things.

Investigation 2: Gravity (gravitational force) pulls the ball downward. **Friction** is a force that resists the motion of surfaces. The friction between the bottom of the Goo ball and the plastic causes the ball to flatten because that surface moves slower than the rest of the Goo mass.

Investigation 3: You are measuring the **rate of flow** of the glacier. Yes, a solid can "flow". Was the rate *constant* – the same time to move from one line to the next – or *variable* – different times between different lines? This is somewhat simplified because the real rate of a glacier's movement will be influenced by changes in mass (such as snowfall or picking up boulders as it moves) and elevation, melting, Earth contours, and even minute changes in Earth's rotation. Some glaciers do move faster than others. In general, sea level is lower than land level. So, knowing the rate of flow helps scientists predict the changes in sea level resulting from **calving**, glaciers breaking off where land no longer supports them. (See **Lift the Level** below.)

Investigation 4: As in Investigation 2, **basal friction**, the friction between the base of the glacier (Goo) and the land (plastic), allows the non-basal surface to move somewhat faster so the toothpick is pulled down faster at its top than its base. Even allowing for the effect of heat from Earth, the phenomenon remains the same.

Investigation 5: Again, friction plays a role in the outcome. **Kinetic friction** between the glacier and the sides of the "channel" cause a **drag force** at the edges of the glacier which results in the center of the glacier flowing faster than the edges. So, the straight line becomes a "smile."

Lift the Level You can make this lesson deeper and/or suitable for older students by any of the following, including designing experiments and the inclusion of applicable mathematical principles and formulae. See **Solutions** below.

1. Fill a glass ¾ full with water. Mark the water level with a marker or tape. (As condensation forms on the glass, it may cause the marker to run or the tape to loosen.) Now add 3-5 ice cubes. Did the water level change? Watch as the ice melts. Does the water level change? Explain. Post #17 in this virtual series explains further.
2. An **ice shelf** forms when the advancing edge of a glacier leaves the landmass and extends over the ocean. While attached to the glacier, the ice shelf is **cantilevered,** supported only on the land side by the glacier's mass. Eventually, partially though contact with the warmer ocean water, it will break off, or **calve,** and fall into the water. The shelves in a refrigerator are typically cantilevered. Check your refrigerator to see how they are supported. Then research two more examples of cantilevering. Resources in STEM Online may help you.
3. What happens when a glacier encounters an obstacle? Tape a small box such as a toothpick or matchbox to the plastic about 10 cm (2 black lines) below the red line on the cardboard. Place the Goo ball on the red line and release. Predict and observe what happens, particularly what shape the glacier takes. *Note: If you plan to do #4, leave the box taped down.*
4. Keep the box from #3 taped in place. Place the Goo ball just above and touching the box. Predict and observe. Why do you think this happens? *Note: If you plan to do #5, do not pick up the Goo.*
5. After you finish #4, leave the Goo in place. Remove the box and tape. Predict and observe what happens to the shape of the Goo glacier. How do you explain this?
6. When glaciers are featured in the news, they are often said to be "retreating." You have demonstrated in several of the investigations in this lesson that glaciers are constantly moving forward/outward, even when there is little change in altitude. How do you explain this apparent contradiction?
7. There is a greater rise in temperature at the North and South Poles than anywhere else on Earth. This is called **polar amplification.** It occurs because the poles are covered in ice which can be white (new snow/ice) to bluish (old ice) in color. Light bounces off these colors much more than it does off darker, open water. The reflectivity **(albedo)** of ice and snow is between 50% and 90% while it is only about 6% for open water. As glaciers melt, there is less ice/snow and more open ocean water. Why does this polar amplification imply that Earth is warming?

STEM Online

These are suggestions only and no endorsement is implied. Although they have been screened for appropriateness before posting, adults should vet the websites children use, as they may change over time.

Glaciers The Center for Remote Sensing of Ice Sheets (CReSIS) is based at The University of Kansas (yes, pretty far from a glacier now although there were some there in the last Ice Age, the Pleistocene Epoch, https://geokansas.ku.edu/glaciated-region). Their website has a wealth of videos, data, and K-12 lesson plans about glaciers, including a series of short activities that could be used as warm-ups or extensions to lessons: https://cresis.ku.edu/; one of the most studied glaciers in the world is Thwaites Glacier in Western Antarctica: https://thwaitesglacier.org/

Reproducible copy of a Glacier Goo recipe https://cresis.ku.edu/sites/default/files/Education/K-12/IceIceBaby/2.2-glaciergoo-recipe.pdf

Force https://sciencing.com/ten-different-types-forces-7459343.html

Friction https://en.wikipedia.org/wiki/Friction

Cantilever https://en.wikipedia.org/wiki/Cantilever; https://en.wikipedia.org/wiki/Walkway_over_the_Hudson

Polar amplification https://www.peakoil.net/environment/what-is-polar-amplification-how-related-to-climate-change; https://weatherworksinc.com/news/radiational-cooling

NJ Student Learning Standards

Science: Physical Science K-PS2-1, K-PS2-2; 3-PS2-1, 3-PS2-2; 5-PS2-1; MS-PS2-1, MS-PS2-4

Earth Science K-ESS2-1; 2-ESS2-1, 2-ESS2-2, 2-ESS2-3; 3-ESS201, 3-ESS2-2; 4-ESS2-1; 5-ESS2-1; MS-ESS2-2; HS-ESS2-2

Solutions

Lift the Level

1. Ice added to the water causes the water level to rise. Ice melting in water has a negligible effect on the water level. As water molecules freeze, they expand. So, a volume of ice is slightly greater than the volume of water when it melts. See Virtual Learning Post #17 for more on this subject.
2. A variety of answers are possible. See https://en.wikipedia.org/wiki/Cantilever for examples.

3. Due again to friction, the obstacle slows the rate of flow of the portion of the glacier that comes in contact with it. This results in the glacier taking on a "game controller" shape. 
4. The taped-down box represents an ice shelf – the part of a glacier that is cantilevered, supported on land but carrying a load along its length, off the landmass and projecting over the ocean. It impedes the flow of the glacier due to the counterforce (back pressure) of its mass.
5. Removing the box simulates calving, breaking off, of an ice shelf. The glacier moves more rapidly due to the removal of the counterforce of the ice shelf.
6. Melting of glacial ice accounts for the illusion that the glacier is moving backwards.
7. Water absorbs light/energy/solar radiation at a much greater rate than ice and snow. As the proportion of ice to water changes in favor of water, there is more warming. This is also part of the phenomenon of calving (see Lift the Level #2 and #5)

Glacier Goo **Should be made with adult supervision.**

Derived from https://cresis.ku.edu/sites/default/files/Education/K-12/IceIceBaby/2.2-glaciergoo-recipe.pdf

Note: Borax is a mined compound used as a cleaning agent and insecticide and is an ingredient in commercial "slime," some toothpastes and cosmetics. It should not be swallowed and may irritate sensitive skin. To avoid contact with skin, wrap it in plastic before handling.

(C = standard cup or 8 ounces; t = teaspoon)	1 C. white glue (e.g., Elmer's)
Safety goggles	Disposable 8oz cup
Disposable stirring stick	About ½ C. warm water (this is additional water)
Disposable cup such as 20oz Solo	2 t. borax powder (e.g., 20 Mule Team Borax)
¾ C. warm water	1 qt plastic zip bag

Part 1 – In the large cup, add ¾ C warm water to 1 C glue. Stir until well mixed.

Part 2 – In the small cup, add 2 t. borax and enough of the ½ C warm water to dissolve the borax. This takes awhile. Wash your hands. Pour Part 2 mixture into Part 1 in the bigger cup. Stir until a blob forms. This happens quickly! Turn out on a countertop or board that can get wet. Knead the mix for 2-3 minutes. Most, if not all, of the water should be incorporated.

Store the Goo in the zip bag. If you keep it clean, it will keep for a few months in your refrigerator. *Always wash your hands after working with Glacier Goo.*