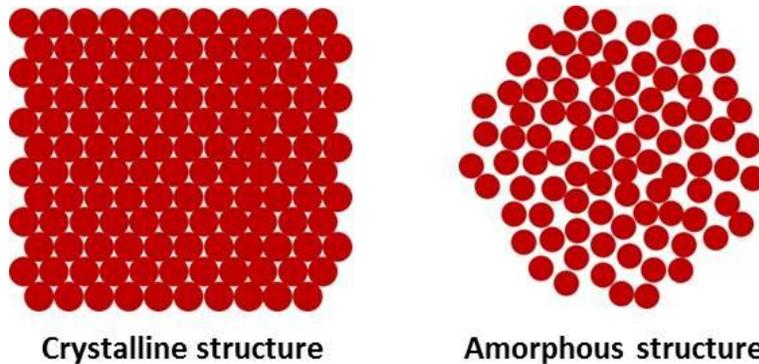


## TEACHER INSTRUCTIONS

### Candy Fiber Pull

**Objective:** To demonstrate the unique properties of glass by examining the solid-liquid and liquid-solid transitions of a glass-like system.

**Background Information:** Glass is an amorphous solid that is typically brittle and optically transparent. An amorphous solid is any material that has no long-range order of atoms. Crystalline materials (such as a metal) have an orderly arrangement of atoms, while amorphous materials do not (Figure 1). Glass is a unique material because its viscosity slowly decreases as heat is applied until it flows in a similar fashion to water. The temperature at which it transitions from solid to liquid is often referred to as the glass-liquid transition temperature. As the glass is cooled, the viscosity slowly increases. This property allows gaffers (people who “blow” glass) or machines to work with and shape the glass into products such as vases or bottles. If the glass is cooled too quickly, stresses will form in the glass causing it to crack. The glass-liquid reaction is typically reversible, meaning the solid can move to a liquid state and then back to a solid state. The glass-liquid transition of a solid to a liquid state typically occurs due to heating, and the reverse reaction of a liquid to a solid state typically occurs due to cooling or compression.



*Figure 1. Crystalline vs. amorphous atomic structures*

The term “glass” includes many different materials, some with which you are familiar. Soda-lime glass – composed primarily of silica (sand) – is used in the production of windows and drinking glasses. Sugar glass – composed of a brittle transparent form of sugar – is used in movies, photographs, and plays to simulate soda-lime glass. It breaks very easily and is less likely to cause injuries, but still has the look and breaking patterns of soda lime glass. Cotton candy and lollipops are two glasses that are made from cane sugar. Cotton candy is made by

heating sugar until it reaches a molten state (liquid form) and squeezing it through small holes into a larger bowl that is spinning. The thin sugar fibers solidify almost immediately in the room temperature air and begin to collect on the outer edges of the bowl. When you eat the cotton candy, the heat from your tongue causes the fibers to dissolve into a liquid form again. Other candies, such as lollipops and Jolly Ranchers, follow a similar process. Insulation used to keep your house warm in the winter is fiberglass, which is made in a similar fashion to cotton candy. See the introductory PowerPoint presentation on the flash drive in the kit for additional examples of how glass and the glass-transition temperature are used in real-world applications.

**Demo Description:** During this demo, Jolly Ranchers<sup>®</sup> will be melted in a beaker using a hot plate. Once the Jolly Ranchers<sup>®</sup> have reached a molten state, candy fibers can be pulled from the beaker. When a fiber is pulled, it is almost instantly cooled because of the small diameter of the fiber and how cool the air is in relation to the molten Jolly Ranchers<sup>®</sup>. This simulates the production of glass-like fibers.

**Keywords:**

- amorphous – non-crystalline materials that lack a long-range atomic order.
- glass – an amorphous, brittle solid which exhibits a glass-liquid transition when heated.
- liquid – fundamental state of matter characterized as having a definite volume, but no shape.
- solid – fundamental state of matter characterized by structural rigidity.
- glass-liquid transition – reversible reaction in amorphous materials from a hard, brittle state to a semi-liquid, molten state.
- viscosity – an internal property of a fluid that offers resistance to flow.
- fiberglass – a material fabricated from extremely fine fibers of glass and is used in a variety of applications ranging from household insulation to a reinforcing agent in ladders and automotive body panels.

**Materials List:**

*Items provided in the kit:*

- 1 beaker
- beaker tongs

*Items to be provided by the teacher/school:*

- hotplate (can also use a microwave if no hotplate is available)
- Jolly Ranchers<sup>®</sup>
- wooden skewers or popsicle sticks (something to pull fibers with)

**Safety Precautions:** The hot plate and the beaker will get very hot. Caution should be used when handling the beaker during the demo. Allow the beaker and hot plate to cool before cleaning and returning to the kit. It may be helpful to clean some of the Jolly Ranchers<sup>®</sup> while it is still warm and fluid, but be sure that the beaker is not hot to the touch. If the Jolly Ranchers<sup>®</sup> cool and harden, they can always be removed with soap and warm water. Allow the Jolly Ranchers<sup>®</sup> to melt away in the warm water rather than trying to scrub it.

**Instructions:**

1. Be sure that the beaker is clean and dry.
2. Place four to six Jolly Ranchers<sup>®</sup> into the beaker.
3. Place the beaker on the hotplate and set the hotplate to a medium temperature setting.
4. Stir the Jolly Ranchers<sup>®</sup> while heating for approximately 10 to 15 minutes. The Jolly Ranchers<sup>®</sup> should begin to melt into a more fluid form.

**Note:** The Jolly Ranchers<sup>®</sup> can burn! Pay close attention while melting the Jolly Ranchers<sup>®</sup> and be sure to stir them throughout the heating process. If they start to burn, reduce the heat (or remove the beaker from the heat) and continue to stir. If you have a microwave available in your classroom, it is easier to heat the Jolly Ranchers<sup>®</sup> in this fashion. You may have a shorter time period to pull the fibers before the Jolly Ranchers<sup>®</sup> harden again, but you are less likely to burn them.

5. Once the Jolly Ranchers<sup>®</sup> are in liquid form, use the wooden skewer/popsicle stick to pull one fiber from the beaker by dipping the skewer into the molten Jolly Ranchers<sup>®</sup> and removing it slowly.
6. Allow students to take turns pulling fibers.
7. Pick four or five students and have each one of them pull a fiber and quickly move away. Have the other students take rough measurements of how long the fiber gets before it breaks. See who can get the longest fiber.
8. Have students compare the flexibility and texture of a short, fat pulled fiber, a long skinny pulled fiber, and a solid Jolly Rancher<sup>®</sup>.

**Demo Delivery Hints:**

1. Turning the fiber pulling into a game to see who can get the longest fiber makes this demo fun. Most of the time, it helps to remove the beaker from the hotplate and tilt it so that the fiber doesn't contact the side of the beaker while the student is moving away. Do not touch the beaker with your bare hands; always use the beaker tongs or hot pads/gloves.
2. The Jolly Ranchers<sup>®</sup> do take a little time to heat up and turn to a liquid form. This portion of the demo can be started early, and the Jolly Ranchers<sup>®</sup> can continue to heat while you are explaining the background information and what is going to be done during the demo. Just make sure to stir the Jolly Ranchers<sup>®</sup> as they are heating.

3. If you have other beakers readily available in your classroom, it is recommended that you use the beaker included in the kit for *this lesson only* and designate it as a “*food-only*” *beaker*. This will allow students to eat the fibers without having to worry about contamination from the beaker. Be sure to clearly label the beaker as “food-only” and thoroughly wash and dry the beaker each time before using it for this lesson.

**Troubleshooting:** It may take some time for the hot plate to heat up. Make sure to test the hot plate prior to the demo to ensure that the heating elements and temperature settings are working correctly (you can do this by placing some water in the beaker and checking to see that it boils after 10 to 15 minutes of heating on the hot plate). Alternatively, you can melt the Jolly Ranchers® in a microwave if one is available.

**Cleanup/Replacement Parts:** This demo can get very messy. The easiest way to clean the beaker is to run hot water over it until all of the sugar is dissolved. Fibers that end up sticking to the desk or floor can also be dissolved by scrubbing with a paper towel moistened with hot water or using a mop with hot water. The used wooden skewers/popsicle sticks should be replaced after every demo. A damp paper towel should also be used to clean the hotplate once it has cooled. Make sure that the beaker and hot plate are clean and dry before returning them to the kit.

## TEACHER DISCUSSION QUESTIONS

### Candy Fiber Pull

#### Discussion Question to Ask Before the Demo

Ask students what they know about the formation of glass, glass fibers, or glass-like fibers (such as cotton candy).

*Discussion:* Students most likely will not know much about how glass and glass fibers are made. Describe the process outlined in the Background Information section of the Teacher Instructions.

#### Discussion Questions to Ask During the Demo

1. Before pulling a fiber for the first time, ask students what they think will happen when you remove some of the Jolly Ranchers<sup>®</sup> from the heat and “pull” a fiber.

*Discussion:* Emphasize the fact that the diameter of the fiber is very small compared to the amount of molten Jolly Ranchers<sup>®</sup> in the beaker. This facilitates an instant cooling of the Jolly Ranchers<sup>®</sup> fiber as it is removed from the heat and exposed to room temperature air, which causes it to take on a glass-like fiber quality.

2. Have students guess at how long of a fiber they think they can pull.

*Discussion:* If this demo is done correctly, students should be able to pull a fiber that runs a good distance across the room. Most of them will not guess a number this high for the length. The key is to have them move very quickly away from the beaker so that the fiber continues to be pulled, otherwise it will start to sag. Once the fiber makes contact with any other surface (a desk, the floor, etc.), it will not be able to be pulled much longer.

3. Once several fibers have been pulled, ask students to compare the texture and flexibility of the fiber to the solid Jolly Rancher<sup>®</sup>. Are there any changes in the properties of the fibers as a function of length (i.e., do shorter fibers feel or look different than longer fibers)?

*Discussion:* The fibers should be fairly flexible when they first start to cool, but may start to harden after being at room temperature for a while. In general, the thinner and longer the fiber, the greater the flexibility. The fibers may also have a different texture and color (transparency) compared to the original Jolly Rancher<sup>®</sup>.

4. Hold a short competition to see who can pull the longest fiber.

*Discussion:* This is best done in groups of two to three students. First, have each student (or each group) make a guess at the longest fiber they think will be pulled. Record the

guesses on the Student Question Handout. Have one student from each group pull the fiber, while the other students help measure the length of the fiber as it is being pulled. Use a meter stick, or have students walk alongside the fiber being pulled and count the number of steps taken along the length of the fiber. If you have enough space in your classroom, you can have each group take their fiber in a different direction (although this will make for some additional clean-up; a mop and warm water are suggested to help clean the floor if a lot of fibers end up on the floor). This allows all of the fibers to be pulled so that each student can evaluate the fibers of other groups to determine which is the longest. Give the student/group with the closest guess to the longest fiber pulled a reward, such as extra Jolly Ranchers<sup>®</sup> to take home.

### **Discussion Question to Ask After the Demo**

Allow the students to eat the fibers that haven't been in contact with the floor. Ask them what is happening to the fibers as they are eaten.

*Discussion:* Emphasize that the heat from your tongue as well as the pressure of you sucking on the candy will cause the fiber to go from a solid form back to the liquid form. This is the reverse reaction of what happened when they pulled the molten Jolly Ranchers<sup>®</sup> from the beaker.



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