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| **OBJECTIVE 1:** Students can explain the effects of time on crystal development. | **ASSESSMENT:** Questioning throughout; end review |
| **OBJECTIVE 2:** Students are able to find or create examples of symmetry. | **ASSESSMENT:** Symmetry examples; creation of Symmetrical snowflake |
| **OBJECTIVE 3:** Students can explain the necessity of a seed crystal in the crystallization process. | **ASSESSMENT:** Questioning throughout; end review |

## Academic Standards:

**12.E.2b** Describe and explain short-term and long-term interactions of the Earth's components (e.g., earthquakes, types of erosion).

**NGSS PS1.A (Grade 8)** Solids may be formed from molecules or may be extended structures with repeating subunits (e.g., crystals, metals).

**Lesson Materials:**

- M.C. Escher Lizard puzzle or other puzzle made of like shapes
- 3 pipe cleaners (Per Student)
- 9 tablespoons of Borax (Per Student)
- 1 popsicle stick (Per Student)
- 6 inches of kite string (Per Student)
- 2 packs of "Hot Hands"
- 1 seed crystal from "Hot Hands"
- 1 aluminum pie pan
- 1 hot plate

**Per Group:**

- 1 stereo microscope
- 2 gem viewers
- 1 crystal sample (sugar, salt, Gypsum Selenite, Quartz)
- 2 sheets of plain paper
- 1 box of colored pencils
- 1 SEM (scanning electron microscope) image of salt & sugar
- 1 picture of hail and snowflake

**Important Vocabulary & Background Information:**

- **Crystal:** a solid with a specific geometric pattern for either organic or inorganic materials.
- **Nucleation:** process of crystal growth. One by one like solute molecules bind together. Collectively, once the molecules reach a "critical size" the crystal will fall out of solution.
  - **Unassisted nucleation:** occurs naturally in nature.
  - **Assisted nucleation:** occurs if there is a solid surface or seed crystal.

- **Seed Crystal:** small piece of a single crystal from a large of the same material. A larger crystal can be grown from a seed crystal if the seed crystal is dipped into a supersaturated solution – this is known as recrystallization.
    - Recrystallization eliminates the need for random molecular collision or interaction to occur because it provides a pre-formed basis; therefore, reducing the amount of time needed for a crystal to form.
- **Symmetrical:** Made up of exactly similar parts facing each other or around an axis.

## Procedure and Planning:

**Prep Work:**

- Before students come to class, be sure to reset the "Hot Hands" to their original liquid state. Keep a few small solid crystals, each about the size of a seed. These will act as your "seed crystal."
- To reset the hot hands: keep the used contents of a "Hot Hands" in beaker and stir – keep it as a liquid. Cool in a refrigerator or cold water bath before using, but be careful not to agitate the liquid, as it will revert to its solid state.

**Introduction:**

1. Pass out 1 crystal sample, 1 stereoscope, and 2 gem viewers per group. Ask students to record their observations on a new piece of paper.
2. Ask students to compile a new list of words or drawings about everything they know about **crystals**.
3. Students should then compare their observation sheets to what they think they know about crystals and see what they notice is the same and what is different.
4. Conduct a class discussion on their findings. This discussion to lead to the conclusion that the four items are related by the fact that they are all crystals. Other conclusions about crystals:
    - Crystal literally means "physical structure". Crystal defines an object as a solid with a definite geometric pattern.
        - When I say "geometric pattern" what does that mean to you? Have students give examples or draw on the board examples of geometric patterns.
        - To emphasize this point bring molecular models and SEM images of both salt and sand. This could help students see that the pattern exists even at the molecular level.
    - Crystals can be organic or inorganic.
        - Organic- at some point came from a living being. Example: sugar
        - Inorganic – came from a nonliving material. Example: Quartz
    - Liquids cannot be crystals.

**Body of Lesson:**

5. Ask students how they think crystals form.
    - Nucleation: like molecules come together and form a solid.
6. The next section of the lesson addresses the two different ways that crystals can form:
    - At this point don't explain the difference between "fast-growing" and "slow-growing" crystals. Allow students to create their own definitions based on what they observe from the game.
7. Play the "lizards puzzle game" in groups of 2-4 (M.C. Escher foam lizards puzzle or another tessellation puzzle that is made up of the same repeating shape). Note: one lizard puzzle piece is a seed crystal.
    - In round one, have students place only one lizard on the floor in front of the group. Then give students 15 seconds to put the puzzle together. They have to use all pieces,

even if it means throwing the ones that couldn't be put together on the ground at the end. **(seed crystal is the original lizard leading to assisted nucleation-fast growing)**
    - In round 2, again have students place one lizard on the floor. Give students 45 seconds to build. **(seed crystal is the original lizard leading to assisted nucleation-slow growing)**
    - In round 3, students are not allowed to have one lizard on the floor. Give students 1 and a half minutes. Again, they have to use all of the puzzle pieces. **(unassisted nucleation)**
8. Ask students "What was different between the first time we put the puzzle together and the second?" Leading to the idea that the first time the puzzle wasn't as organized or nice looking whereas the second time it was.
9. Explain that this is just like crystals - given time they form slowly and are highly organized. Without much time they look far less organized.
    - During this time, it should also be discussed as to what role each lizard takes (the base component shape). Students can then identify the base shape of their crystal sample.
10. Demonstrate the importance of a seed crystal by performing the "Hot Ice Sculpture Demo".
    - Place the aluminum pie pan upside down.
    - Place a used "Hot Hands" crystal in the center of the pie pan.
    - Carefully pour the liquid "Hot Hands" (sodium acetate) over the crystal. Watch a solid form before your eyes in a matter of seconds.
        - **NOTES:**
            - Be very careful with the liquid "Hot Hands", if it even touches an extremely small crystal of sodium acetate, all of the liquid will immediately turn to a solid as well.
            - Good video: http://www.youtube.com/watch?v=i-xw2zlp_lw
11. Tell the students that you are now going to quiz them on what they've learned by making them apply it to two common winter crystals.
    - Hail vs. Snowflake
    - Show a picture of hail and of a snowflake.
    - Ask about their differences.
        - Hail is not organized – fast growing.
        - Snow is very organized – slow growing. In fact we would say that a snowflake is **symmetrical**.
            - As the snow falls toward the earth, gravity pulls on it at all ends (unlike most crystals, which experience gravity pulling on them in one direction). This makes it so that it is not only organized, but the same all around! In a discussion, lead to the fact that every snowflake is unique and that this depends on the seed crystal, which is usually dirt. It also depends on the level of humidity and the temperature.

**Closure:**

12. Ask students a few review questions before moving onto the final activity.
13. The final activity will be to create your own symmetrical snowflake out of pipe cleaners. Participants can then take these home with the borax or sugar kits in order to create crystal snowflakes, or if using this in a classroom (where you will see the participants the next day), you can have participants complete the instructions for this activity in class. It will need to sit overnight to be inspected again the next day.


## Write (or draw) everything you know about crystals.

## Observation of Samples: do they all have something in common?

| **Salt** | **Sugar** |
|---|---|
| **Quartz** | **Gypsum (selenite)** |

## Data from Lizards Game

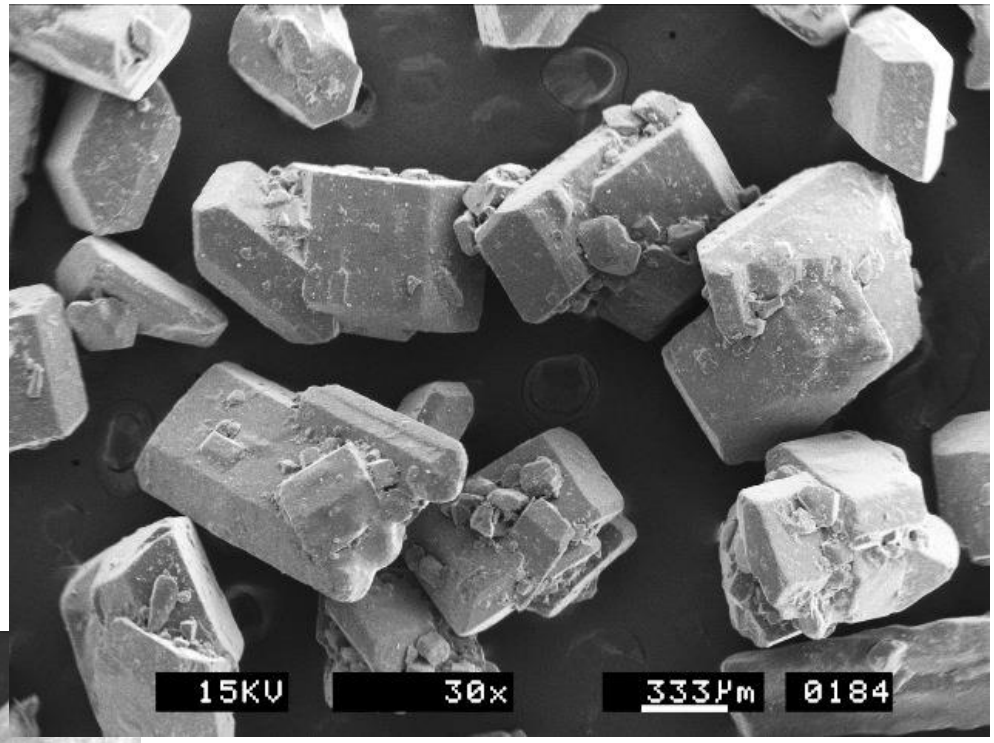
| | Round 1 | Round 2 | Round 3 |
|---|---|---|---|
| **Observations** | | | |
| **Type of Growth** | | | |

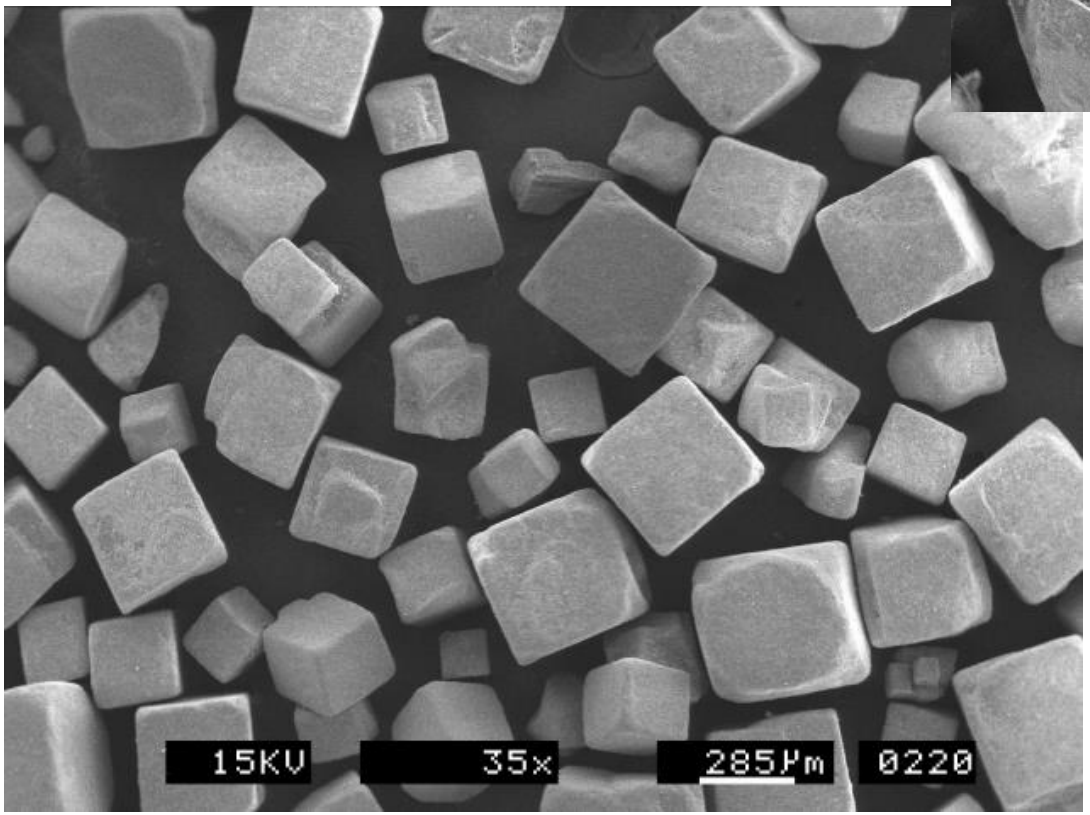
## Observations from "Hot Ice" and Crystals in Nature

Make Your Own Snowflake!

1. Tie your snowflake to a string. Then tie the string to a pencil or some other type of stick. This will hold the snowflake in a container in a later step without letting it touch the bottom or sides.
2. Find a jar or glass container large enough to hold your snowflake. Fill it up with enough water so that the water level is just above where your snowflake will sit.
3. Place the water in a pot. With a parent's help, boil the water.
4. As the water is boiling, add either borax or sugar. If you're adding borax, you want to add 3 tbsp for each cup of water; if you're adding sugar, keep adding and stirring in the sugar until it won't dissolve anymore (it will sit at the bottom of the pot).
5. After your solution has cooled, pour it into your jar. Gently drop in the snowflake so that the pencil rests on the jar's lid and so that the snowflake is dangling in the jar. Be sure that the snowflake is completely under the solution. Let sit for 12 hours and *DO NOT TOUCH OR BUMP!!*

Did you know that salt and sugar look like this?!




Sugar

Salt