Brittle vs. Ductile Rocks

Big Hunk™ as an analog for rock behavior

http://www.iris.edu/hq/inclass/lesson/70

Version 2; Last Revision October 2017

IRIS
www.iris.edu/educate

Incorporated Research Institutions for Seismology
Thanks to Dr. Robert Butler, University of Portland, for developing and piloting this demonstration.

OVERVIEW

A Big Hunk™ candy bar, made almost entirely from nougat, is a useful model for exploring how temperature affects a rock's response to stress. With their teacher, students compare and contrast the candy bar's response to stress with other materials explored previously such as rubber bands and Marble Tongs (see "Prior Knowledge", next page). They see how different materials respond to similar stress. Building on this, students also explore how temperature can affect the deformation of the same material undergoing the same stress. The discussion at the conclusion of the demonstrations ties the concepts of deformation to faulting (earthquakes) and folding of rocks.

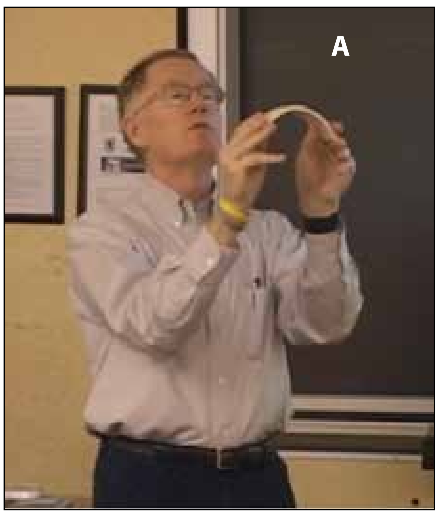


Figure 1—A) Dr. Robert Butler demonstrating ductile deformation of a warm Big Hunk™ candy (www.iris.edu/hq/inclass/video/65). B) Photo of the candy bar and wrapper.

Beginner

15 min

Demo

Whole Class

Materials

OBJECTIVES

By the end of the lesson, students will be able to:

- describe common examples of materials that exhibit brittle, ductile and elastic deformation.
- correctly identify images of faults and folds.
- describe at least one way that the conditions of formation may have differed for faulted rock vs. folded rock.

TABLE OF CONTENTS

MATERIALS

- Brown paper bag – Should be large enough to hold the items below
- Rubber band – Larger is better, so the demo grabs more attention
- Container with ice or a small cooler
- 2 Big Hunk™ candy bars per class – These can be obtained online if they are not available locally. This particular candy bar is ideal for this demonstration because it is comprised of only nuts and nougat… no chocolate to melt
- Safety Goggles – These are for the teacher
- Optional – A flex-cam, connected to your in class projection system is useful to make this demonstration more visible to the entire class

PRIOR KNOWLEDGE

- Video of Dr. Robert Butler demonstrating the Big Hunk™ model: www.iris.edu/hq/inclass/video/65
- A good activity, mentioned in the Overview to complement this is the Marble Tongs lesson called "Seeing is Believing—Rocks Are Elastic": www.iris.edu/hq/inclass/lesson/28
- Another good demo from easily obtained slat of wood is "*Elastic Rebound Demonstration Using a Yardstick"* which addresses a material's elastic and brittle response to different stress: www.iris.edu/hq/inclass/video/64 http://www.iris.edu/hq/inclass/video/64
- Animation of "*Layers of the Earth*", includes discussion of Big Hunk™ model as an analogy for the upper mantle:
  www.iris.edu/hq/inclass/animation/199

TEACHER PREPARATION

1) Place one Big Hunk™ candy bar/class in the freezer.
2) Prior to the class or demo, move the Big Hunk™ to the container or small cooler with ice.
   TIP = Every demonstration is an opportunity for teachers to convey their enthusiasm and curiosity for science to their students. This is in addition to the intended scientific content. Thus, showmanship is an important part of successful science demonstrations.
3) Place a second Big Hunk™ candy bar/class inside your shirt or in some other spot where it can warm up and be dramatically revealed (modestly, of course).

VOCABULARY

Brittle deformation: Irreversible strain when rocks break in pieces in response to stress. Any material that breaks into pieces exhibits brittle behavior.

Ductile deformation: when rocks flow or bend in response to stress (ex. clay). This strain is also irreversible.

Elastic deformation: When stress is removed the material will return to its original position or shape. Reversible strain.

Fault: a break in the rock that forms a crack, crevice, or deep fissure..

Fold: occurs when one or a stack of originally flat and planar surfaces, such as sedimentary strata, are bent or curved as a result of permanent deformation.

Fracture: the separation, under stress, of an object or material into two or more pieces.

Strain: changes in size, shape, or volume of an object due to stress.

Stress: is the amount of force applied per unit area of an object.

SAFETY

Safety glasses should be worn during the lab to protect the instructor's eyes from the stretched rubber band.

Big Hunk™ candy bars contain peanuts. Prior to conducting the demo identify students' allergies, so that they are not accidentally exposed to allergens. If anyone is allergic, work with the student, the student's parents, and/or the school nurse to make accommodations as needed.

ACTIVITY FLOW

This activity is structured using the "**OPERA**" system (Appendix B) and additionally offers leveled questions that will move your students from evaluating their knowledge to synthesizing new information.

1) Open/Prior Knowledge

a) Begin by putting on your safety goggles.

b) Next, place the brown paper bag on your demo table and dramatically reach into it and remove the rubber band.

c) Begin to stretch the rubber band a bit and then dramatically begin to pull the rubber band in opposite directions. Stop pulling when you begin to feel the elastic limit and ask the students the following questions…

?? Ask the students, "*What type of deformation has occurred?*" "How do you know?"

ANSWER: Elastic deformation. If you were to remove the stress the rubber band would return to its unstretched length.

?? Ask students, "*What might happen if you kept pulling*?

ANSWER: The rubber band would reach its elastic limit and then deform brittlely or break

d) Next reach into the paper bag and pull out the container with ice that has a wrapped Big Hunk™ candy bar that has been in the freezer.

e) Carefully open the candy bar wrapper and hold it up for all to see. (TIP: You might want to unwrap then rewrap the candy bar before placing it in the freezer. This makes it a lot easier to unwrap the frozen bar without breaking it.)

g) Apply stress to the ends of the candy bar by trying to bend it. It will break easily.

?? Ask "I*s the candy bar is more like the rubber band or the tongs*? (See Prior Knowledge)

ANSWER: The frozen candy bar is much more like the tongs than the rubber band as it reaches its elastic limit very quickly when frozen. Develop the analogy that the frozen candy bar is like relatively cold rock. Like the tongs, it has a relatively short elastic limit and once past deforms brittlely by fracturing.

2) Explore/Explain

a) Next, produce the second candy bar that you have been warming. A very dramatic way to do this is to have had it against your body (under a sweater etc) before class and then suddenly remove it (modestly).

b) Carefully open the candy bar wrapper and hold it up for all to see.

Ask students how this candy bar differs from the previous one?

ANSWER: The candy bar is identical to the previous one except that it has been warmed from being against your body.

?? **Ask** students, "*Can you predict what will happen if you were to apply stress to it?*"
ANSWER: Accept all answers but encourage students to use terms like stress, strain, elastic and brittle deformation in their responses.

c) Apply bending stress to the ends of the candy bar. This time it will bend easily by ductile (plastic) deformation. Once cooled or the stress is removed, the result is irreversible deformation.

?? **Ask** the students, "Can you describe how this behavior is similar or different from the behavior of the cold candy bar, the marble tongs, and the rubber band?
ANSWER: Student responses will vary but lead students to develop the idea that this type of deformation is irreversible. This means that when the stress is removed the deformation remains.

d) Show students these two road-cut images side-by-side. Figure 2 is offset by a normal fault. Figure 3 shows a fold in the rock layers. Folds form when rocks bend or undergo ductile deformation over a prolonged period of stress.

?? **Ask** students, "*Which of the two rock layers (Figures. 2 and 3)) appear to have undergone ductile deformation and which has undergone brittle deformation?*"
"*What is your evidence?*"
ANSWER: The image on the left shows that the layers on either side of the large crack moved relative to one another. This suggests that the rock was not relatively warm when the stress was applied to it and as a result it fractured. Conversely the image on the right shows "folding" and no offset of the layers. This suggests that these rocks were not cold when the stress was applied and as a result they experienced ductile deformation.

?? **Ask** which of these two would be most likely to have caused an earthquake?
ANSWER: The image on the left is a fault or a fracture along which the blocks of rock on either side have moved relative to one another. This fracturing of the rock produces an earthquake, or the sudden release of energy that has accumulated elastically in the rock over a long period of time.

Figure 2 (Above): Faulted rock.

Figure 3: (Righ) Folded rock layers.

Photographs courtesy of the US Geological Survey.

3) Reflect

?? Ask students to think of a common object that also exhibits ductile deformation.
ANSWER: Accept all correct answers but a common example is a piece of wire (e.g. electrical wire, metal coat hanger etc).

4) Apply

Show the cross section of Earth's interior (Figure 4). Earthquakes generally occur within the top 300km of Earth; in the lithosphere.

?? Ask "*Why don't earthquakes occur below this point*?"
ANSWER: Below this depth the confining pressure and temperature becomes so great that they inhibit nearly all fractures from forming. The exception is where cold subducting slabs stay brittle to depths up to 500 km as evidenced by seismic imaging and earthquakes.

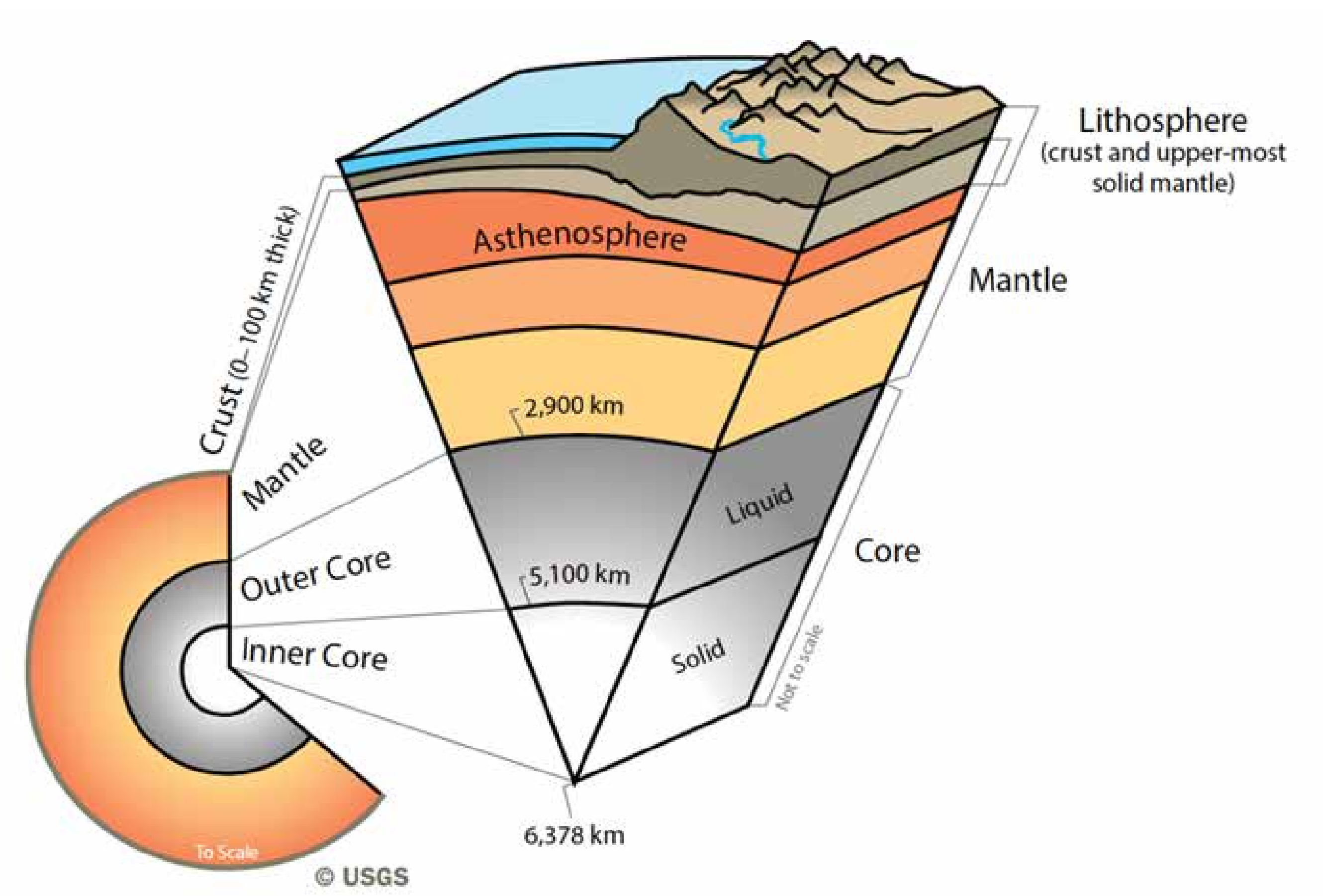


Figure 4: Cross section of the earth showing the approximate thickness of the layers. (Courtesy of U.S. Geological Survey.)

APPENDIX A

Teacher Background

The rocks that make up Earth's outer shell are continually subjected to stresses. Stress is the amount of force applied across the area of an object. There are three types of stress affecting rocks. Rocks can be squeezed by compressional stress, stretched by tensional stress, or sheared by shear stress (Figure 5). In response to the ongoing stress, rocks are said to strain or change in their size, shape or volume. As the stress increases rocks respond by passing through three successive stages of deformation.

As illustrated in Figure 6, rocks respond to stress in three ways (strain). Initially rocks respond elastically. Elastic deformation is reversible. This means that when the stress is removed the material will return to its original position. A common example of elastic deformation is the change in shape a rubber band experiences when you pull on it. Once this stress is removed, the rubber band returns to its original shape.

As rocks pass their elastic limits they experience ductile deformation. Ductile deformation is irreversible. This means that when the stress is removed the deformation remains. A common example of this is applying stress to a copper wire. As stress is applied the wire's shape is changed as it bends.

Finally, a rock experiences Fracture or irreversible strain were the material is separated into two or more pieces. A common example is a piece of uncooked spaghetti. When enough stress is applied, the strain becomes so great that the spaghetti breaks into two or more pieces.

The way rocks respond to stress depends primarily on the temperature and confining pressures of the rock when the stress is applied. For example, rocks near the surface experience relatively low temperatures and pressures. Under these conditions, fracturing is much more likely. Meanwhile, rocks deeper in Earth experience much higher temperatures and pressures (Figure 7) that inhibit the formation of fractures and allow ductile deformation. Other factors such as the strain rate and the composition of the rocks may also influence whether rocks fracture or experience ductile deformation.

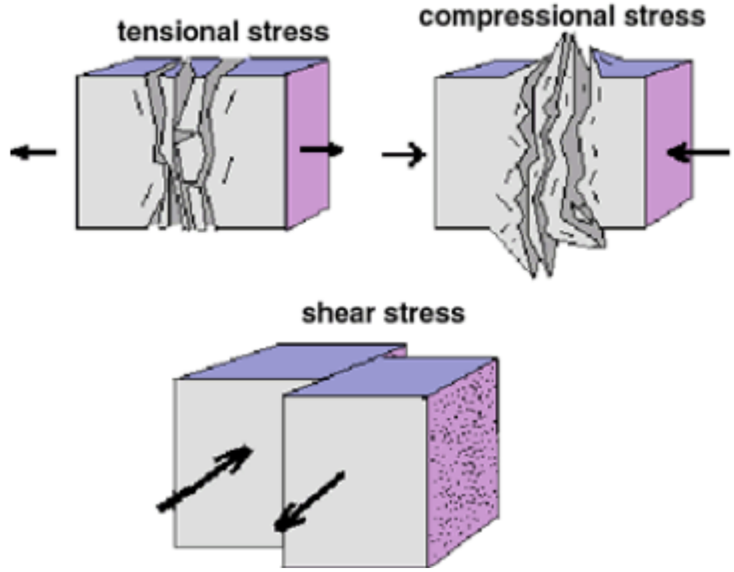


Figure 5. Rocks are subjected to three types of stress. (Image courtesy of Michael Kimberly, North Carolina State Univ.)

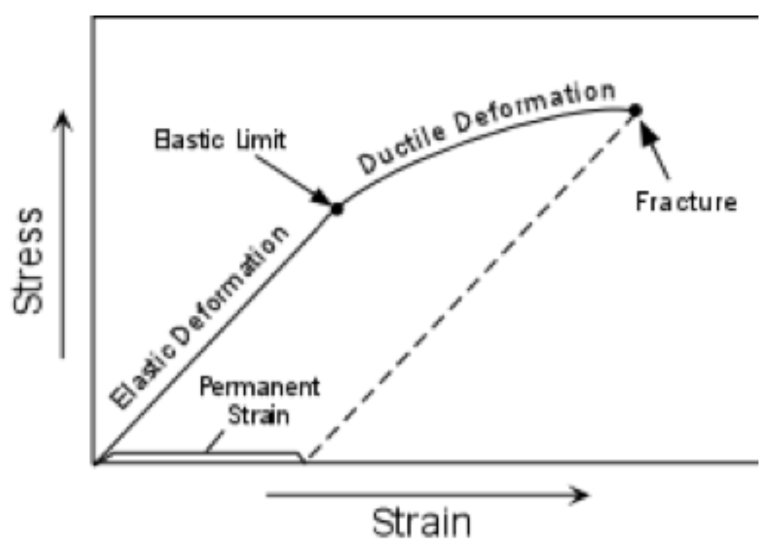
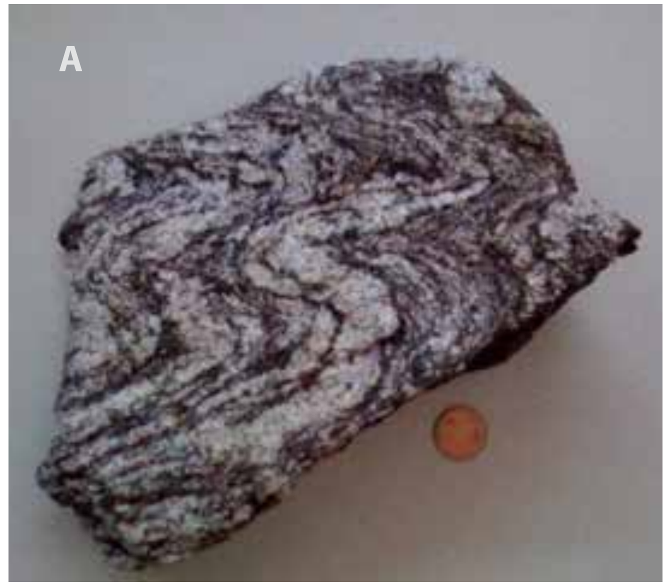


Figure 6. Rock passes through 3 successive stages of deformation as it is subjected to increasing stress.

Evidence that deformation has occurred in the past can be found in places where rock layers are exposed at the surface. For example, Figure 8A shows folded rock layers in a hand specimen. Folds form when rocks bend or undergo ductile deformation over a prolonged period. Figure 8B shows a faulted block of rock. A fault is a fracture along which the blocks of rock on either side have moved relative to one another parallel to the fracture. This fracturing of the rock produces an earthquake, or the sudden release of energy that has accumulated elastically in the rock over a long period of time.



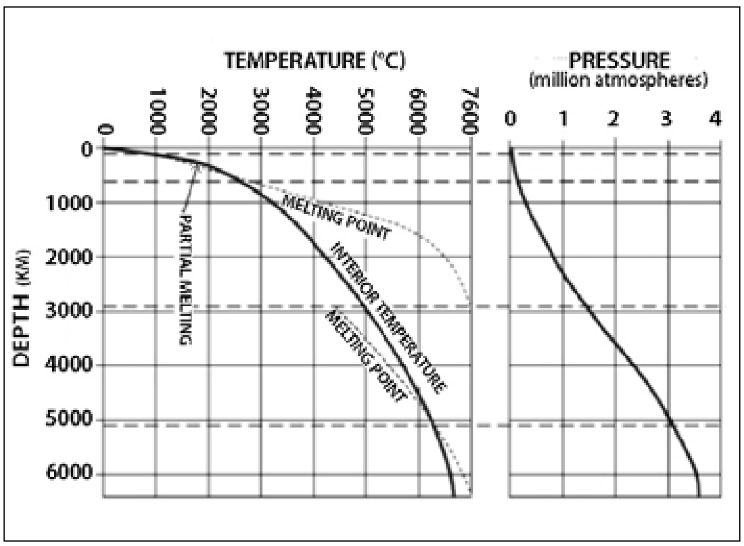


Figure 7: Inferred temperature and pressure of Earth's interior.

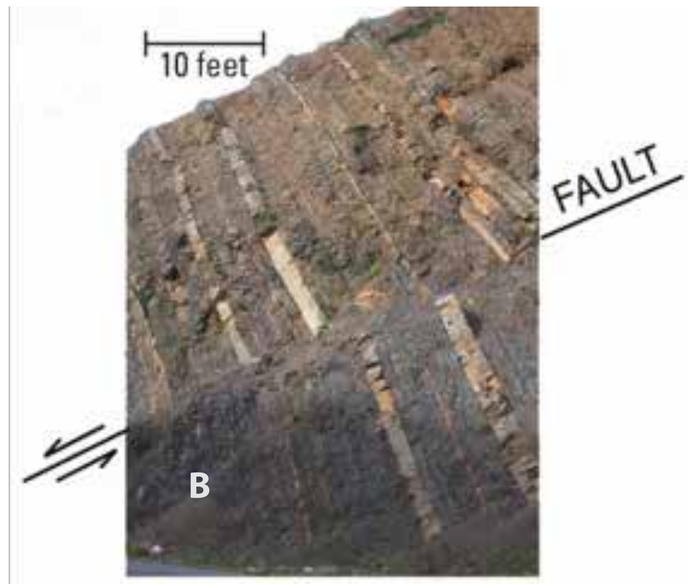


Figure 8: (A) Folding and (B) faulting in rocks provides evidence of past deformation.

APPENDIX B

OPERA Learning Cycle

A learning cycle is a model of instruction based on scientific inquiry or learning from experience. Learning cycles have been shown to be effective at enhancing learning because by providing students with opportunities to develop their own understanding of a scientific concept, explore and deepen that understanding, and then apply the concept to new situations. A number of different learning cycles have been developed. However, all are closely related to one another conceptually, and differ primarily in how many steps the cycle is broken into. The “flavor” of learning cycle that you choose is primarily up to what works best for you, just pick one or two and use it as the basic formula for all your instruction.

This lesson is designed around a learning cycle that can be remembered as O-P-E-R-A. OPERA is convenient when designing lesson-level instruction because one can generally incorporate all the major components into the single experience. Each phase of the OPERA cycle is briefly outlined below.

	Instructional Stage
<u>**O**</u>pen	**Open** the lesson with something that captures students’ attention. This is an invitation for learning and leaves students wanting to know more.
<u>**P**</u>rior Knowledge	Assess students’ **Prior Knowledge** and employ strategies that make this prior knowledge explicit to both the instructor and the learner.
<u>**E**</u>xplore	Plan and implement a minds-on experience for students to **Explore** the content.
<u>**R**</u>eflect	**Reflect** on the concepts the students have been exploring. Students verbalize their conceptual understanding or demonstrate new skills and behaviors. Teachers introduce formal terms, definitions, and explanations for concepts, processes, skills, or behaviors.
<u>**A**</u>pply	Practice concepts, skills and behaviors by **Applying** the knowledge gained in a novel situation to extend students’ conceptual understanding.

APPENDIX G— NGSS SCIENCE STANDARDS & 3 DIMENSIONAL LEARNING

Touch the url links to get more information

Earth's Systems

MS-ESS2-2 Construct an explanation based on evidence for how geoscience processes have changed Earth's surface at varying time and spatial scales. http://ngss.nsta.org/DisplayStandard.aspx?view=pe&id=224

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Analyzing and Interpreting Data Analyzing data in 6–8 builds on K–5 experiences and progresses to extending quantitative analysis to investigations, distinguishing between correlation and causation, and basic statistical techniques of data and error analysis.	**ESS2.A:: Earth Materials and Systems** The planet's systems interact over scales that range from microscopic to global in size, and they operate over fractions of a second to billions of years. These interactions have shaped Earth's history and will determine its future.	**Patterns** Patterns in rates of change and other numerical relationships can provide information about natural systems.

Matter and Its Interactions

MS-PS1-4 Develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed. http://ngss.nsta.org/DisplayStandard.aspx?view=pe&id=137

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Models Modeling in 6–8 builds on K–5 experiences and progresses to developing, using, and revising models to describe, test, and predict more abstract phenomena and design systems.	**PS1.A: Structure and Properties of Matter** The changes of state that occur with variations in temperature or pressure can be described and predicted using these models of matter.	**Cause and Effect** Cause and effect relationships may be usedto predict phenomena in natural or designed systems.