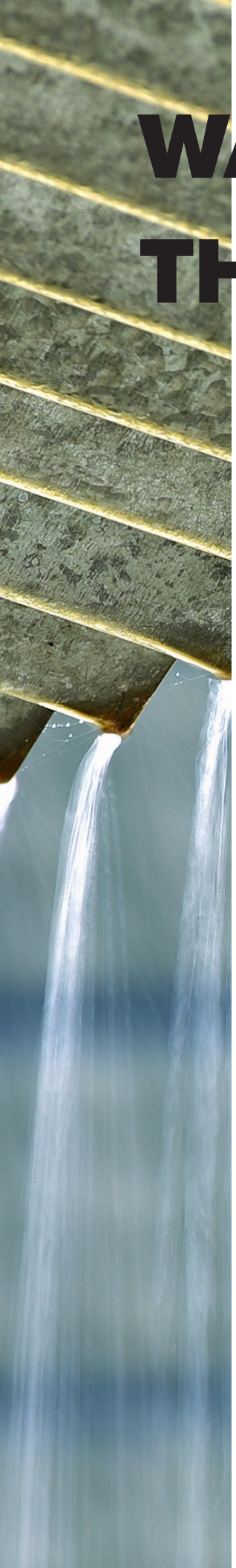

WATERPROOF THE ROOF

Grades 3–5, 6–8

30–45 minutes

DESIGN CHALLENGE

Design and construct a roof that will protect a cardboard house from getting wet.

MATERIALS

Supplies and Equipment:

- ☐ Spray bottle (1 per facilitator who will be testing designs)
- ☐ Scissors (several to share)
- ☐ Markers (enough to share)
- ☐ Large, shallow plastic storage container or other basin (optional)
- ☐ Water

Consumables:

- ☐ Assorted roofing materials:
  - 1 roll paper towels
  - Leaves (enough to fill a shopping bag)
  - Fabric scraps (enough to fill a shoebox)
  - 100 aluminum foil squares, 3" x 3"
  - 100–500 straws
  - 100–500 craft sticks
  - Other materials of your choosing
- ☐ Several rolls of tape
- ☐ Cardboard (two 4" x 4" and two 4" x 6" pieces per person)
- ☐ 1 Sunday newspaper

GETTING READY

Cut several 4" x 6" rectangles and 4" x 4" squares from the cardboard. Construct several “houses” by taping cardboard pieces together to form walls. (Or participants may construct and decorate the houses, depending on how much time you have.) You may choose to test roofs in a large, shallow plastic storage bin or outside to keep the activity area dry.

MacGillivray Freeman's DREAM BIG

INTRODUCTION

Imagine you are in your cozy home on a dreary, rainy day. You might be watching a movie or eating a meal with your family when, all of a sudden, you hear *DRIP... DRIP... DRIP...* Oh no! Your roof is leaking!

Modern roofing materials are engineered to last 20–30 years. Like most things that are engineered well, you probably don't think about your roof until something goes wrong. Roofs today are mostly maintenance-free compared to old thatched roofs of the past.

INSTRUCTIONS

Ask participants to consider the different shapes and materials used in the roofs they see in your community. Discuss how roof shapes need to change to suit different climates. For example, a flat roof is not a good choice for an area that receives a great deal of snow, because the weight of the snow can collapse such a roof.

Introduce the design challenge. Explain to participants that they need to develop a roofing system for a house that can prevent water from entering.

Give the participants at least 20 minutes to build their roofs. Some participants may choose to use one material to make their roof, while others will use a variety of materials. When participants are satisfied with their roof, they may submit it to a facilitator for testing.

Test the roofs.

- Place the newly roofed house on a sheet of newspaper. Then spray the roof with water. Lift up the house and examine the newspaper for moisture.
- Identify leaks in the roof and redesign. Test again. Repeat.

Evaluate the success of each roof.

- Did the roof prevent water from getting into the house?
- If water got in, how much?

Participants may design gable roofs or flat roofs. Credit: Abigail T. Watrous, ITL Program, College of Engineering, University of Colorado Boulder.

ACTIVITY VARIATIONS

- Instead of creating cardboard houses, construct a roof for a plastic bin. Pour a measured amount of water on the roof. Then collect and measure any water that leaked into the bin.
- Make the roof-building into a competition. The winner is the person/team that builds the most effective roof out of the fewest materials.
- Assign a cost to building supplies and give participants a budget. Participants must work within their budget to complete the activity.
- Have the participants use the same materials for the roof, but vary the design and roof pitch. Compare the efficacy of each based on how much water gets inside the structure and how much is shed by the roof.

TROUBLESHOOTING

If participants are struggling with choosing a roofing material, give them a hint, but only a small hint. You want them to use their own prior knowledge to decide on the best roofing materials and to discover the properties of those materials for themselves. For example, ask participants, "What materials might repel water or help it to run off the roof instead of being absorbed by the roof?"

Workers building a roof. Sheets of plywood are covered by asphalt shingles, overlapping tiles, or other waterproof materials. Credit: Federal Emergency Management Agency.

RELEVANT TERMINOLOGY

Absorption: Soaking up a particular substance, either a liquid or gas. It's what a towel does to the water on your body when you dry off.

Capillary action: The ability of a liquid to flow in narrow spaces without the help of gravity. This ability is due to attractive forces between molecules. It's why blood can flow through the narrowest veins and capillaries in our body.

Climate: The average weather in a given area over the course of several years. For example, a desert has a dry climate, and a tropical rainforest has a hot, wet climate.

Material science: The discovery or creation of new materials, usually solids.

GUIDANCE FOR YOUNGER CHILDREN

QUESTIONS TO ASK AFTER THE ACTIVITY

- How did you go about choosing your roofing material(s)? What characteristics of the available materials did you decide were most important?
- Did you use one roofing material or a variety of materials? Why?
- What roof shapes did you consider when building your roof?
- After building and testing your first roof, did you find any areas of weakness in your design? If so, how did you go about improving these areas?
- What roof shape worked the best? What materials worked the best?
- How is your roof different from the roof on your house or roofs you've seen in your community?

ENGINEERING CONNECTIONS

Engineers who design roofs and the materials for them must consider weather conditions for buildings in a particular climate. For example, in a place where it rains a lot, an architectural engineer would want to design a steep sloping roof so that water rolls off of it rather than sitting on top of it. That is why most roofs are sloped in cold and wet climates. In designing a roof for a rainy place, an architectural engineer would also want to make sure that there are no openings in the roof where water could get into the building.

A materials engineer, on the other hand, is more interested in *what the roof is made from* so that the materials used allow for water to easily run off the roof rather than be absorbed by it. To do this, a materials engineer would need a deep understanding of roofing materials that easily repel water, like rubber. That is why most roofs, especially those designed for cold, wet climates, include multiple layers of materials that work together to repel water and eliminate absorption.

SCIENCE CONNECTIONS

Have you ever dipped one end of a paper towel into a cup of water? Have you noticed that if you leave it there for a few minutes, eventually the entire paper towel is soaking wet? This is because of something called *capillary action,* also known as *wicking*, where water or other liquids can travel through small tubes or spaces no matter what direction it is, even up against the force of gravity! Although this sounds really cool, it can cause a lot of problems for buildings and houses, because it makes it easier for water to get into buildings. For example, water can wick from wet soil through a building's concrete foundation and into the basement. Water can also wick through the smallest hole in a roof and drip into the attic. This makes protecting a building from the effects of water much more difficult than most people imagine, and it presents an ongoing challenge to engineers who design buildings.

GUIDANCE FOR OLDER YOUTH AND ADULTS

QUESTIONS TO ASK AFTER THE ACTIVITY

- If you found you needed to make changes while building your roof, describe why your team decided to make those revisions.
- Do you think that engineers often change their original plans during the construction process? What do you think this might do to their construction budget?
- If you could have selected some building materials that were not made available to you, what would you have selected and why?
- What was the best part of your design? Describe one part of your design that you think worked the best.
- If you had a chance to do this project again, what would your team have done differently?
- If your roof design were used on a real building, do you think it would require frequent maintenance? Why or why not?

ENGINEERING CONNECTIONS

When designing roofs based on environmental conditions, structural, architectural, and materials engineers consider a number of key factors. These include roof pitch, ventilation, shading, heat storage, and reflective outer surfaces. In wetter climates, roofs are usually designed with a heavy pitch or slope to allow heavy rains to run off, as well as large overhangs to protect the walls and openings from radiation and precipitation. Engineers must also consider the ventilation in a given roof design, which is why roofs in warm, humid climates are usually double ventilated, with an insulated inner layer and a reflective outer layer.

Engineers also need to consider the materials used to build a roof based on the needs of a particular climate. Therefore, a roof in a warm, humid climate should be made from lightweight, reflective materials to keep it from getting too hot. Materials like these will reduce heat absorption, which will ultimately help keep the temperature inside the house, and especially on the top floor, cooler or similar to the outside temperature.

SCIENCE CONNECTIONS

Roofs designed for wetter climates not only need to be structurally sound to stand up to heavy rainfall or snowfall, but also must be made with suitable materials. Roofs found on most homes in wetter climates are made with asphalt shingles. This is because asphalt shingles are relatively inexpensive, and also because they are impermeable, meaning completely resistant, to capillary action. This means that water cannot seep through the roofing material.

MacGillivray Freeman's DREAM BIG

MacGillivray Freeman's
DREAM BIG
ENGINEERING OUR WORLD
dreambigfilm.com

ACKNOWLEDGMENTS

Activity courtesy of IEEE TryEngineering.org.

http://tryengineering.org/sites/default/files/lessons/roof.pdf

Supplemental content adapted for *Dream Big* Activities by the Carnegie Science Center.

CARNEGIE SCIENCE CENTER
One of the four Carnegie Museums of Pittsburgh

Find more great activities at DiscoverE.org

DISCOVER E
LET'S MAKE A DIFFERENCE

MacGillivray Freeman

ASCE
AMERICAN SOCIETY OF CIVIL ENGINEERS

BECHTEL