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MAKER LAB
OUTDOORS

25 SUPER COOL PROJECTS

Build · Invent · Create · Discover

JACK CHALLONER

MAKER LAB OUTDOORS

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SMITHSONIAN

Established in 1846, the Smithsonian—the world's largest museum and research complex—includes 19 museums and galleries and the National Zoological Park. The total number of artifacts, works of art, and specimens in the Smithsonian's collection is estimated at 154 million. The Smithsonian is a renowned research center, dedicated to public education, national service, and scholarship in the arts, sciences, and history.

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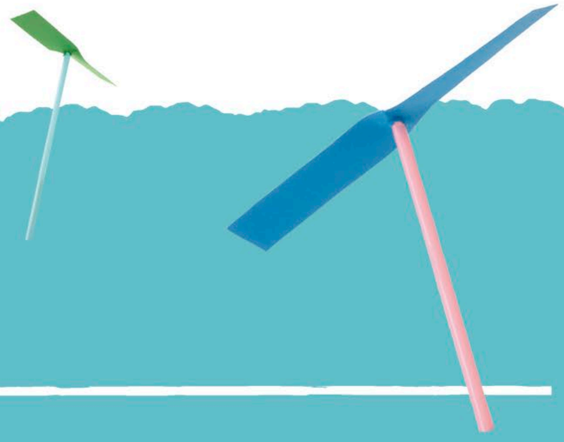

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FOREWORD

When I was a kid, I was very curious about how things worked and what things are made of. I asked myself questions like, "Why does sugar disappear when you put it in water?" "What is the air made of?" And, "Why is glass transparent?" I asked my parents and teachers those kinds of questions, too.

Luckily for me, there was an old book in my family home that was filled with simple science experiments anyone could try. I remember doing some of the activities in the kitchen and others outside in the yard. Doing those activities and then reading the explanations that went along with them really helped answer some of my questions—and it made me even more curious.

I'm hoping that this book will answer some questions you might have—and make you more curious, too. It's packed with lots of fun science activities and uses things you should be able to find at home or easily get hold of. They're perfectly suited to experimenting outside, in the fresh air. Most of the activities in the book need to be done in a yard or a park, or are connected with things that you encounter outside, like weather or plants. The activities in this book are easy to do, the steps are clearly laid out, and the explanations of what's going on in each activity are easy to understand. But creativity is really important in science, too. So don't be afraid to make your own versions of the activities, making them bigger or


using different materials, for example. And if you find yourself asking new questions as a result of doing the activities—questions that are not answered in the book—take your curiosity online or to the library, to see if you can find the answers.

While you are being curious and creative, it's extremely important for you to be safe. Make sure an adult is on hand when you are doing these activities. Also, watch out for any specific safety warnings that accompany each activity. Lastly, most of these activities use things you'll find around the home, such as old plastic bottles, cardboard boxes, and paper. Make sure you are allowed to use them, and then once you're finished, try to recycle them if you can. With all of that in mind, welcome to *Maker Lab: Outdoors*! We've had a lot of fun coming up with the projects, trying them out, photographing them, and writing about them. We hope you enjoy this book as much as the team here at DK enjoyed making it.

JACK CHALLONER

NATURE WATCH

Studying living things is a fascinating part of scientific study. In this chapter, you'll be growing plants without any soil and making your own recycled plant pots. You'll find out about animals, too, by making your own butterfly feeder, a home for earthworms, and even a periscope that will help you study other animals without them noticing you. You'll also be investigating fungi, by growing mycelium on cardboard.

Birds and animals often hide if they spot a human. Your periscope will allow you to get closer without them knowing you are there.

PERISCOPE

Have you ever tried to watch birds or other wildlife without being seen? It's hard to do! If you can see something, it can probably see you—and most animals will stay away if they know you are there. That's why a periscope is helpful. It lets you see around corners and peek over obstacles, which means you can hide in long grass, or even behind a fallen tree, to watch animals without disturbing them.

BOUNCING LIGHT

There are two mirrors inside this periscope—one at the top and one at the bottom. Each one changes the direction of the light coming from the birds and other things you are looking at. That's how you can see around corners, and therefore see things without being seen. Your periscope is perfect for using in the great outdoors, but take care not to point it directly at the Sun.


Light enters the periscope through the opening here.
Your periscope is camouflaged—decorated in colors that allow it to blend into the surroundings.

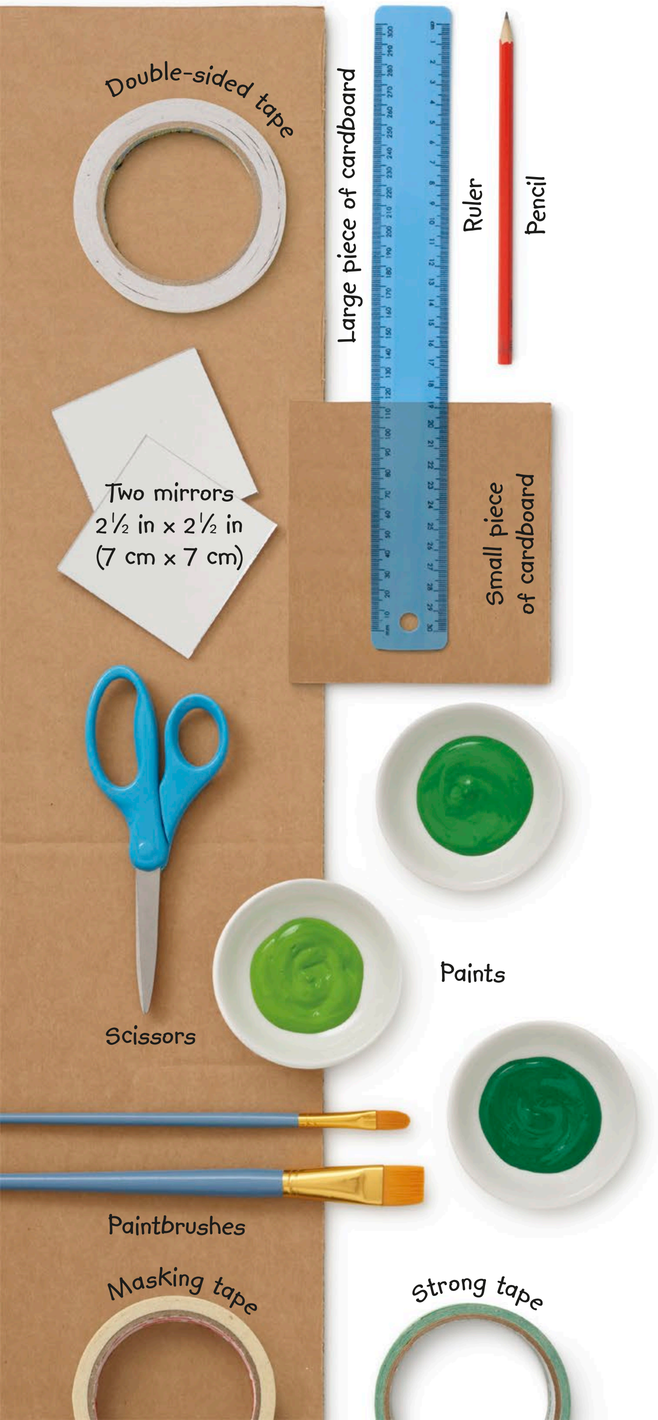
HOW TO BUILD A PERISCOPE

This project involves a lot of measuring and cutting, but if you take your time and are careful, you'll have a sturdy periscope you can use outdoors again and again. The paints are optional, but they'll help you stay camouflaged while you're out on location spying on birds or other animals.

Time
1 hour, plus drying time

Difficulty
Hard

WHAT YOU NEED



This narrow rectangle is ¾ in (2 cm) high.

1 Using the ruler, copy the design above, making each rectangle 20 in (50 cm) long. The narrow rectangle at the bottom will be a flap you'll use to stick the tube together.

These marks divide your periscope into three separate sections.

2 Make four guide marks, two on the top edge and two on the bottom edge of the shape you have drawn. They should be 4 in (10 cm) in from each end.

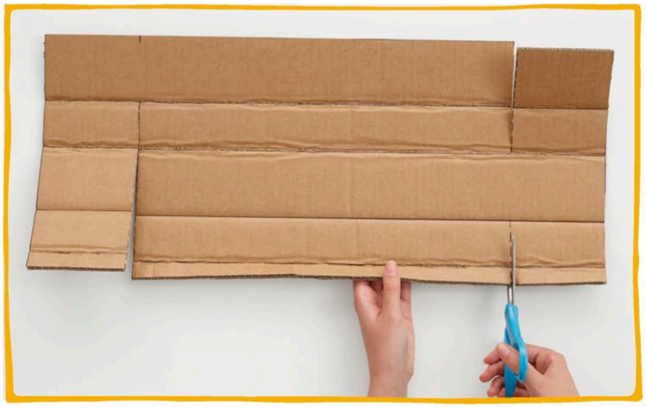
3 Draw dotted lines, as shown, connecting the marks you drew as guides, and using your ruler to make the lines straight. It's important to draw the dotted lines in the right place—an adult can help you.

This dotted line should cover the two top rectangles only.

This dotted line covers only four of the five rectangles.

This dotted line should stretch across the two bottom rectangles.

This folding bit might be tricky—ask an adult if you need help.



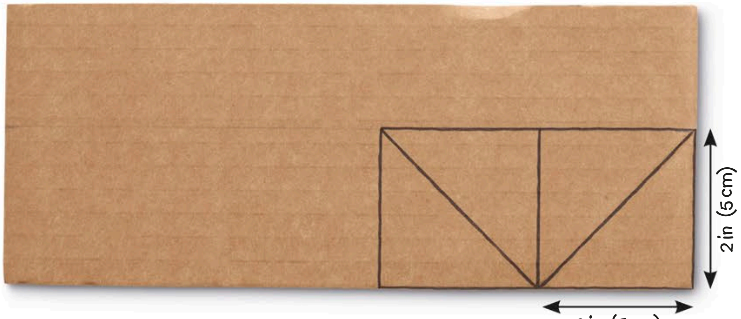
4 Using the blade of your scissors and a ruler, carefully score along each of the horizontal lines. Fold inward along each score.

5 Cut along the dotted lines you drew. Make sure you don't cut all the way across the cardboard.

Unpeel the tape to reveal another sticky side.

6 Stick double-sided tape along the tabs at the bottom of each of the three sections. Peel off the tape's protective strip.

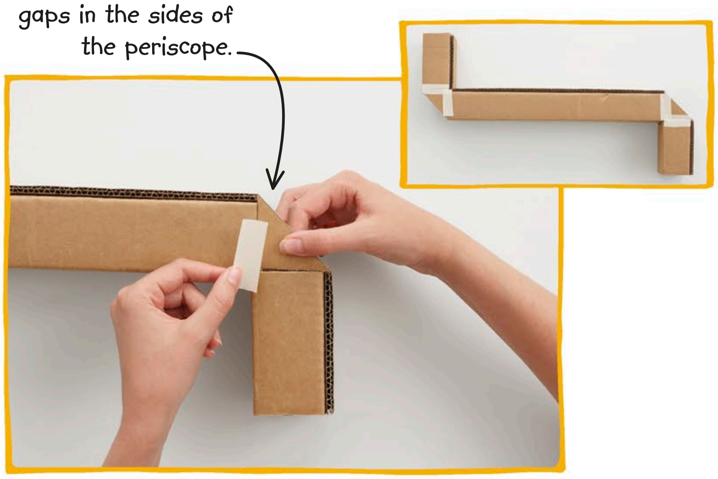
7 Now roll the tube together, and seal it by pressing down on the tab with double-sided tape.



8 On the small piece of cardboard, draw four right-angled triangles, with two sides measuring 2 in (5 cm) each.

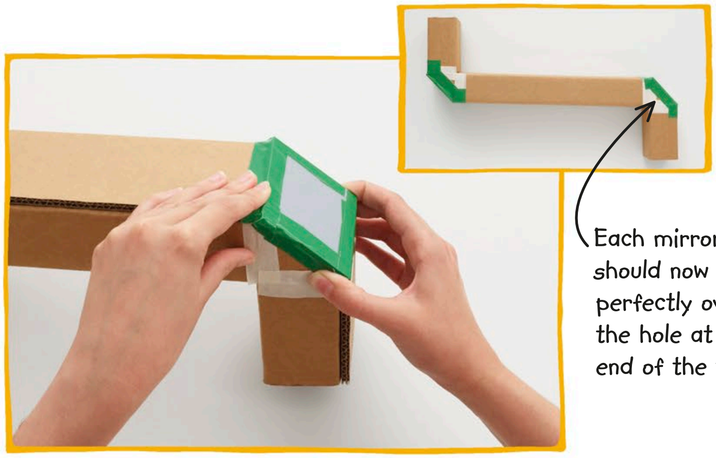
9 Carefully cut out your four right-angled triangles. These triangles will help support the two mirrors inside your periscope.

Make sure that the tape covers any gaps in the sides of the periscope.



10 With masking tape, stick the four triangles into the four openings at each end of the periscope to create a square-shaped opening.

11 At one opening, place the mirror with the reflective side pointing inward. Repeat for the other end. The mirrors need to be at a 45° angle for the periscope to work.



Each mirror should now fit perfectly over the hole at each end of the tube.

12 Use strong tape to attach the mirror to the tube. Do the same at the other end of the periscope.

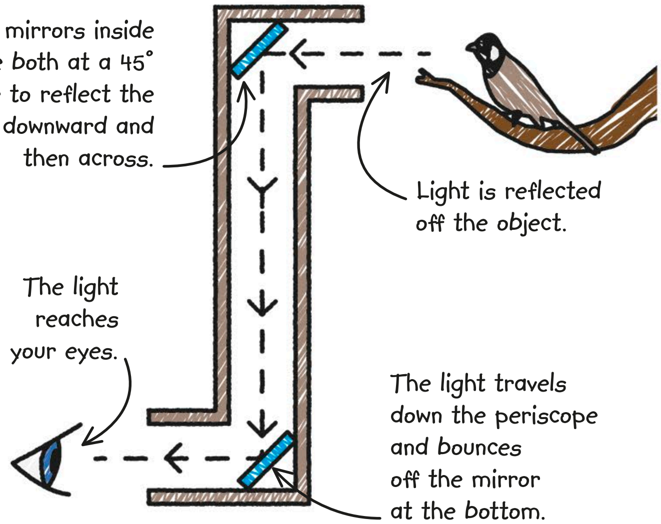
13 Paint the periscope different shades of green and let it dry.

14 You can improve the camouflage effect by cutting out some long, thin strips from any leftover cardboard, and painting them green to look like grass.

15 Stick small pieces of double-sided tape to the bottom of each blade of grass. Peel off the protective strip and attach the grass to your periscope.

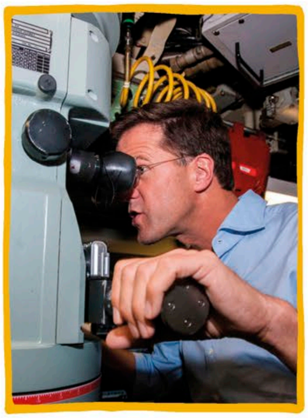
HOW IT WORKS

When you see an object, it's because light coming from that object enters your eyes. Some objects, such as a computer screen, produce the light themselves, but most objects simply reflect light that has come from somewhere else, such as the sun. Either way, the light coming from an object always travels in a straight line, so normally, you have to look straight at something to see it. But by arranging the mirrors inside the periscope in just the right way, you can guide the light that is coming from an object in a particular direction, so you can see an object without looking straight at it.



REAL-WORLD SCIENCE
UNDERWATER VISION

For a long time, periscopes were used on submarines so that the sailors could see what was going on above the water's surface while they were submerged. These periscopes were more sophisticated than yours—they had lenses inside to provide magnification. Modern submarines have external cameras instead, which send pictures to screens inside the vessel.



Hang this beautiful butterfly feeder somewhere high, such as from the branch of a tree.

Orange juice is inside the cup.

SUGARY TREATS

Try to find out what species of butterfly lives in your part of the world. You could look in a book or search online to help you identify the butterflies that visit your feeder. Scientists think there are about 15,000 species of butterfly altogether, living on every continent except Antarctica (the land around the South Pole).

BUTTERFLY FEEDER

Like bees, butterflies are very important for plants. They pollinate flowers, enabling a plant to produce fruit and seeds. You can attract butterflies to your yard or balcony, or your favorite spot in a local park, with this easy-to-make butterfly feeder.

HOW TO MAKE A

BUTTERFLY FEEDER

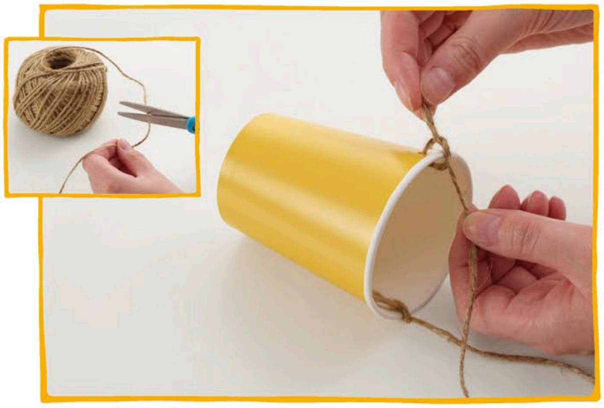
To attract butterflies, your butterfly feeder needs to be bright and colorful, like a flower. Inside, you'll place a small piece of a flat kitchen sponge, soaked in sugary orange juice. Butterflies love the taste of the juice, so hang your feeder on a tree on a warm summer's day, and then watch and wait.

Time
20 minutes

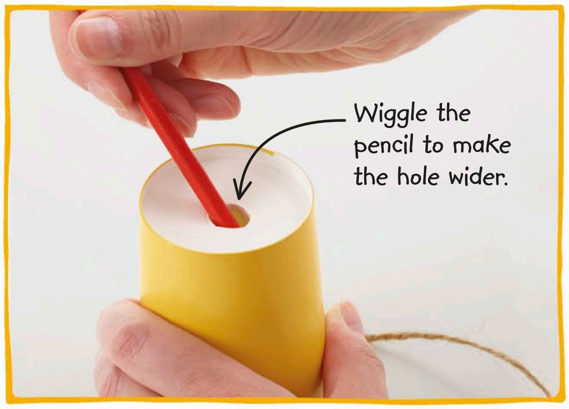
Difficulty
Medium

WHAT YOU NEED

1 Make two holes in opposite sides of the paper cup with the sharp end of the pencil. Use a lump of adhesive putty to protect the table.



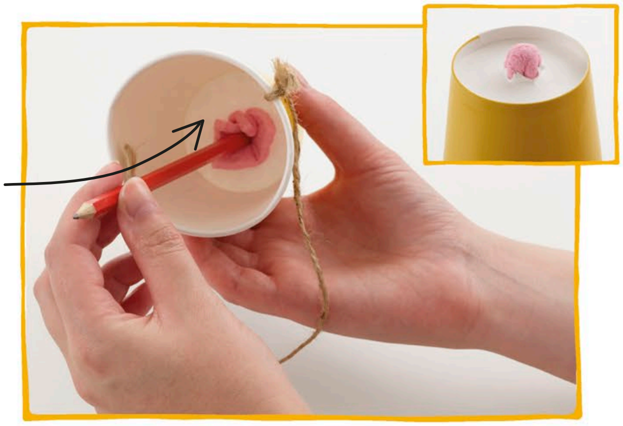
2 Cut a length of string about 12–15 in (30–40 cm) long and push the ends through the holes in the cup. Tie the ends, so that the string makes a handle.



3 Use the sharp end of the pencil to make a hole about ½ in (1 cm) in diameter, this time in the middle of the base of the cup.

4 Cut out a square with sides of about ¾ in (2 cm) from the flat kitchen sponge.

The sponge should poke a little way out of the bottom of the cup.



5 Using the blunt end of the pencil this time, push the square of sponge into the hole in the bottom of the cup.

Cut out a flower in any design you like.

6 Draw a flower onto the plastic bag and cut it out. Make your flower bigger than the cup's base, and cut a hole in the middle that is slightly bigger than the sponge poking through.

7 Stick small pieces of double-sided tape to the base of the cup, and peel off the protective strips.

Press firmly to make sure your flower is securely attached.

8 Press the flower down onto the base of the cup. Your butterfly feeder now just needs one crucial ingredient: orange juice.

The orange juice will soak into the sponge and slowly drip from it.

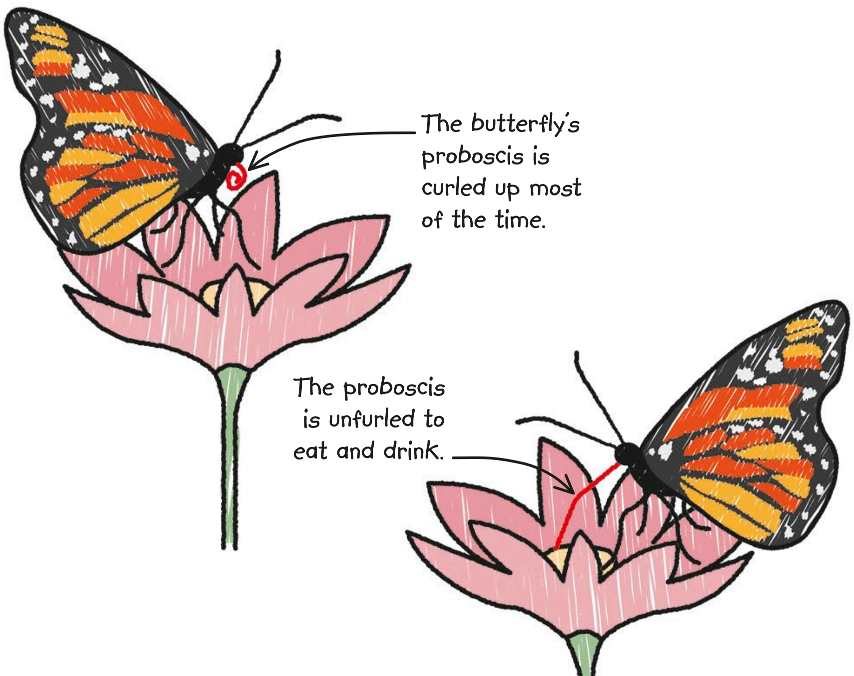
9 Outside, or over a sink, pour a little orange juice into the cup. Hang the feeder from a branch and watch hungry visitors flutter to it.

TAKE IT FURTHER

Different species of butterfly may be attracted to different types of flowers. Experiment with different colored plastic bags, cutting them into any design you want, to see if certain butterflies are attracted to particular combinations. Try using different fruit juices, too—some varieties may be more popular with butterflies than others. Make notes of the visitors to your feeder to help you spot any patterns.

HOW IT WORKS

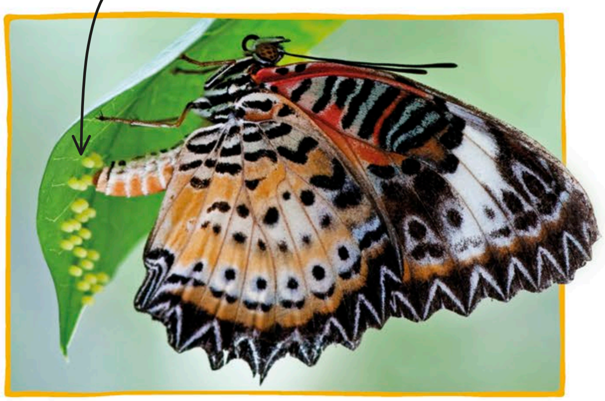
The plastic flower shape is mostly for decoration, though it may help butterflies notice the feeder. What they are after is the sweet orange juice dripping from the sponge at the center of the flower. A butterfly's taste organs are on its feet. That way, it can tell if it has landed on a flower that is safe to eat. When the butterfly is satisfied it has landed on something tasty, it extends its "proboscis," a long, curled feeding tube that protrudes (sticks out) from the front of its head.



REAL-WORLD SCIENCE
BUTTERFLY OFFSPRING

A butterfly tastes plants not just for itself, but also for its offspring: caterpillars. If the plant tastes good, the butterfly may lay its eggs there. Caterpillars hatch from the eggs and immediately begin chomping on the plant. A caterpillar spends its first few weeks eating and grows to many times its original size. Eventually it attaches itself to the plant and becomes a chrysalis. Several weeks later, the chrysalis becomes a butterfly.

These eggs have been laid on this leaf so the caterpillars can begin eating it when they hatch.




Your worms will burrow through layers of sand and soil.
It's important to keep the sand and soil moist because worms need water, just like you do.

WORMERY

Despite having no bones, no legs, and no eyes, amazing earthworms work very hard. They churn up the soil, allowing air and water in, and they eat plant waste and enrich the soil with their droppings—they are the perfect team of recyclers. In this activity, you'll be making your very own wormery—a habitat for your worms to live in while you study them. Be sure to check it every day—you'll be surprised how quickly your worms get to work.

Since earthworms prefer darkness, your wormery needs a cover that will keep out the light.

WORMING AROUND

Earthworms drag organic matter from the surface underground, and turn over the soil. They push themselves into the soil by creating wave movements in the muscles along the length of their bodies.

HOW TO MAKE A WORMERY

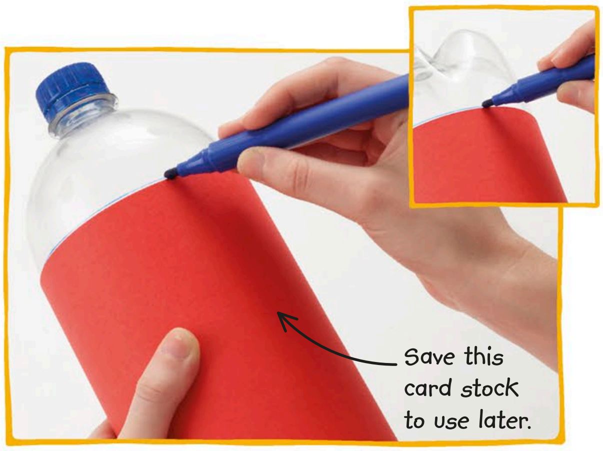
You will need worms for this activity. If you have a yard, you might be lucky and find some there. They often come to the surface after it rains. If not, you can get them from pet shops, garden centers, or even on the Internet. Be gentle with them—they are living creatures. Worms are sensitive to light, so make sure you keep them out of the light as much as you can. When you've finished handling the soil and the worms, remember to wash your hands.

Time
30 minutes, plus drying time for the paint

Difficulty
Medium

WHAT YOU NEED

1 Start by decorating your plant pot. We've used green and yellow paint, but you can use any colors and designs you like.



2 Wrap a piece of card stock around the bottle and, using the felt-tip pen, draw one line around the bottle near the top and another near the bottom.

Ask an adult to help you with cutting.

You can recycle the top and bottom pieces of the bottle.

3 With scissors, carefully cut along the lines you drew. You should now have a plastic cylinder that is open at both ends.

4 Use the tape to cover up any rough edges of the cut ends of the plastic cylinder. Carefully wrap the tape all the way around and fold it over.

5 Stand your plastic cylinder in the decorated plant pot. Add some soil into the bottom of the pot and around the outside of the cylinder to secure it in place. Be careful to wash your hands after handling soil, grass, and leaves in this activity.

Fill the cylinder to within 1 in (2½ cm) of the top.

6 Pour alternating layers of soil and sand into the cylinder. The soil layers should be thicker than the sand layers. Worms need water, so if the soil is very dry, make it damp by spraying on some water. The worms' home is almost ready.

7 Your worms will need some organic (living) matter to eat. Put some grass and leaves on top of your column of soil and sand.

8 Worms thrive in dark conditions. To encourage them to venture to the edges of the wormery, so you can see what they do, you need to make a cover. Wrap a large piece of dark-colored card stock around the cylinder. Tape it securely in place.

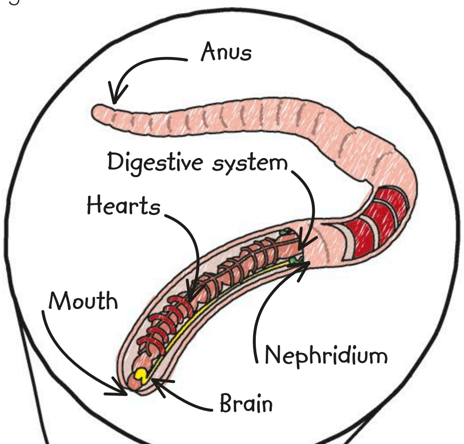
9 Now it's time to add the worms. Handle them carefully, with wet hands. Gently place about four or five worms on top of the grass, then slide the cover over the top. Wash your hands, then leave the wormery in a cool, dark place and check it each day. After a few days, return your worms to the great outdoors by pouring the wormery out into a garden.

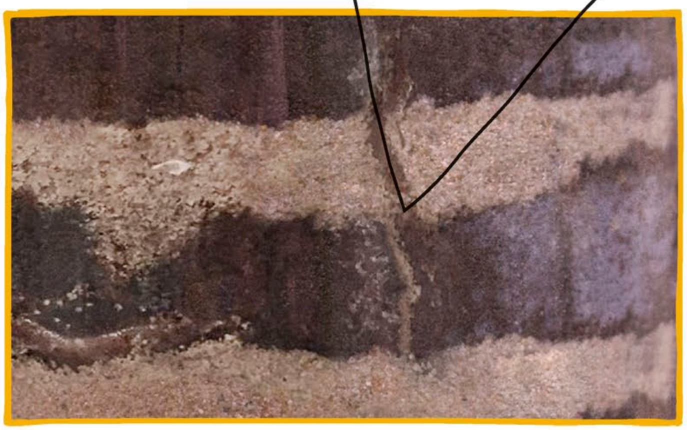
TAKE IT FURTHER

You could make a larger wormery, in which earthworms can recycle kitchen waste, using a large plastic box. Keep it outside in a cool, dark place, and allow air in by making holes in the box or by leaving the top of the box open. Add vegetable peelings and egg shells, but no meat or fatty foods like cheese. You'll need to wait a while, but after a few weeks or months, the kitchen waste will be digested by the worms and the box will be filled with rich, fertile compost that you can use in a potted plant or garden.

HOW IT WORKS

It doesn't take long for the worms to get to work, churning the soil layers as they burrow. In just a few days, the soil will be made richer by the solid waste that emerges from a worm's anus after it has eaten the soil. To help it slide through the soil, the surface of an earthworm's skin secretes (releases) a slimy liquid called mucus. Worms get rid of waste products (the equivalent of peeing) through several pairs of tiny holes called nephridia that lie along their bodies.





REAL-WORLD SCIENCE
COMPOST

Many gardeners put earthworms to good use in their compost bins. Once the plant waste (vegetable peelings, dead leaves, or grass cuttings) is added, the worms drag it under the surface to eat. The worms then shred and partially digest the waste, mixing it with the soil. By adding worms to a compost bin, gardeners can increase the rate at which their plant waste becomes rich compost.

EROSION BOTTLES

Soil is more than a place for plants to grow: it holds the nutrients and water that plants need. We depend on soil, too, because we need the plants that grow in it. Not only do plants produce the oxygen we breathe and the food we eat—we also use them to make shelter, clothes, and medicines. This experiment shows how unprotected soil can be washed away by rain, causing damage to the environment, and it also reveals how the plants dependent on soil to survive can help protect it.

CLOUDY OR CLEAR?

In this experiment, water running through bare soil erodes (takes away) some of the soil—that's why the cup on the left is cloudy. A layer of mulch (fallen leaves or other dead plant material) in the middle bottle protects the soil, and the water that runs off is less cloudy. But soil with plant roots anchoring it in place is the best protected, and the water running out of that soil is almost clear.


Soil is made of tiny pieces of broken rock, plus the remains of long-dead plants and animals.
The grass roots hold onto the soil.
The water is clear because very little soil has been washed away.

HOW TO MAKE

EROSION BOTTLES

This dramatic experiment is easy to do, but you will need to have some patience. Start setting it up at least a week in advance, to give the grass time to grow in one of the bottles. When you actually run the experiment, it's best to do it outside if you can.

Time
30 minutes, plus growing time

Difficulty
Medium

WHAT YOU NEED

1 Draw a large rectangle on one bottle with the felt-tip pen. You need to make the hole big enough to put soil and then water into the bottle.

2 Cut along your lines and remove the rectangle shape you drew from the bottle. An adult can help you. Recycle the piece of plastic that you remove.

3 Repeat the previous steps for the other two bottles, so you have three bottles that are just the same. Put two of the bottles aside for now.

4 Put a layer of soil about 1 in (2.5 cm) deep into one of the bottles. The level of the soil should be just below the lid of the bottle.

5 Sprinkle the grass seeds onto the soil, then wash your hands.

Don't add so much water that the soil becomes waterlogged.

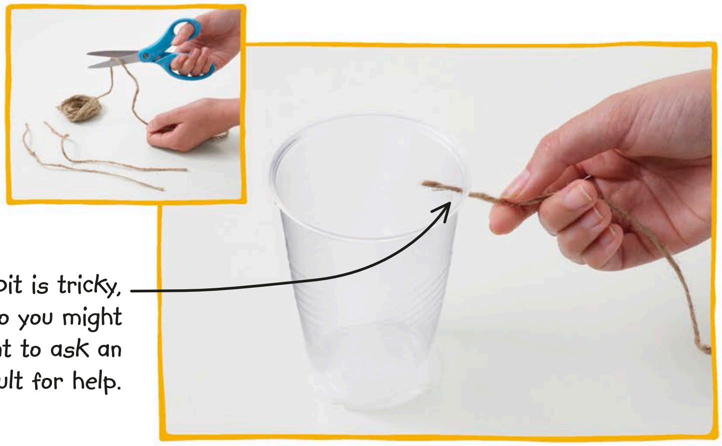
6 Using your watering can, pour water over the grass seeds. Use enough to make the soil damp.

7 Leave the bottle in a place where it will get lots of sunlight, and where it won't get too cold. Add a little water each day to stop the soil from drying out. After a week or so, your grass should have grown.

8 Once the grass has grown, you can prepare your other two bottles. Add about the same amount of soil to them as you put in the first bottle.

Mulch can include fallen leaves, straw, dried grass, and twigs.

9 Leave one of the bottles with soil only. In the other bottle, place a layer of mulch on top of the layer of soil. Now wash your hands.



10 Now you need to make three mini buckets. Near the top of each plastic cup, make two small holes opposite each other using the sharp end of the pencil. Put some adhesive putty underneath, before making the hole, to protect the table.

11 Cut three lengths of string, each about 8 in (20 cm) long. Thread one end of a piece of string through one of the holes in the cup and tie a knot in it so it will not come back through. Do the same in the hole on the other side, to make a handle.

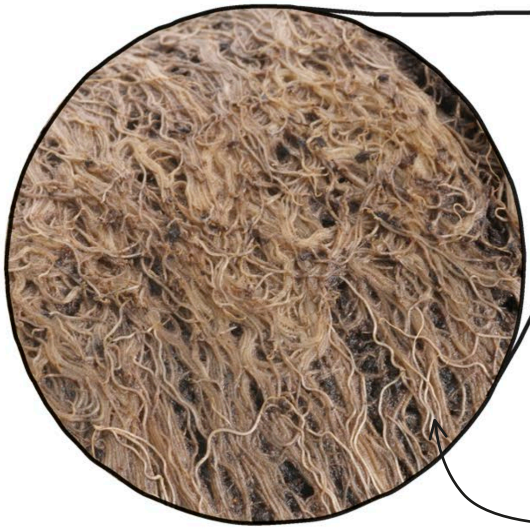
12 Make string handles for your other two cups. You should check that they are strong enough to hold the cups when they are full of water.

13 Hang your buckets from the neck of your bottles. You are now ready to perform the experiment. It might get messy, so be sure to do this part outside. Remove your bottle lids, then slowly pour water over each of the three bottles. The water will start to trickle through the soil into the buckets.

HOW IT WORKS

Roots are crucial to a plant's survival. The roots grow down into the soil and absorb water into tubes that extend right up into the stem and leaves of the plant, above ground. Each grass plant has roots of many different sizes—from tiny fibrous roots up to bigger ones almost as big as the stem. The fibrous roots push out in all directions in the soil, not just downward. The result is a complicated web of roots that holds the soil firmly in place. That's why the water runs out almost completely clear from the bottle with the grass growing in it.

When you have finished the experiment, lift the soil out of the grassy bottle by pulling on the grass. You'll see that the roots keep the soil in place.



You will be able to see hundreds of tiny roots twisting their way through the soil. It is these roots that prevent the soil from being eroded.

Squeeze the grassy soil—you'll be surprised how much water is still in it.

REAL-WORLD SCIENCE
SOIL EROSION

If it is left unprotected, soil can be swept away during heavy rains, taking the nutrients that plants need to grow with it. As this image taken from space shows, soil runs off into rivers and can be harmful to fish and other wildlife living there. Planting grass and trees along riverbanks can prevent soil erosion because they hold onto the soil, keeping rivers cleaner. Farmers can protect the soil they need for their crops and animals with a layer of mulch (dead leaves) or the roots of plants.

FINDING WATER

These bean seedlings have grown in damp cotton balls without any soil. As the plants grow, their roots reach downward to find water. To become strong and healthy, the plants will need extra nutrients, but they can start to grow with access to only light and water.

SOIL-FREE PLANTER

How would you grow plants if you were on a long space mission, and your ship had no room for a garden? You'd use a technique called hydroponics, in which plants grow without any soil. Here, you can try it for yourself.

HOW TO MAKE A

SOIL-FREE PLANTER

This planter is easy to make, and it can be constructed mostly from simple household items. The bean seeds you plant will take a few days to germinate (begin sprouting roots and a shoot), and a week or two to grow into small plants.

Time
30 minutes, plus growing time

Difficulty
Medium

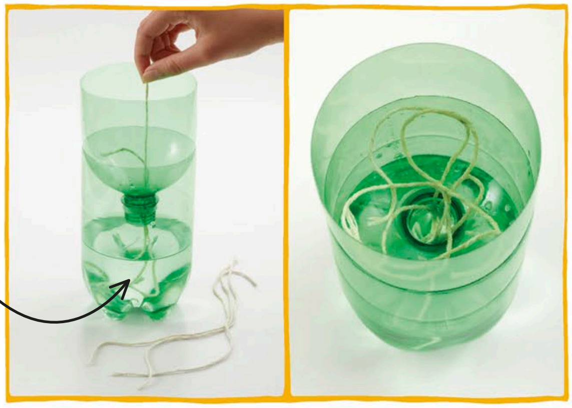
WHAT YOU NEED

1 Cut five pieces of string, about as long as the bottle. Four will soak up water to feed the plants and one will tie the wood skewers together to make a tripod to support the growing plants.

2 Use the scissors carefully to cut a 2 in (5 cm) section from the middle of the bottle. Keep the top and bottom, and recycle the middle section.

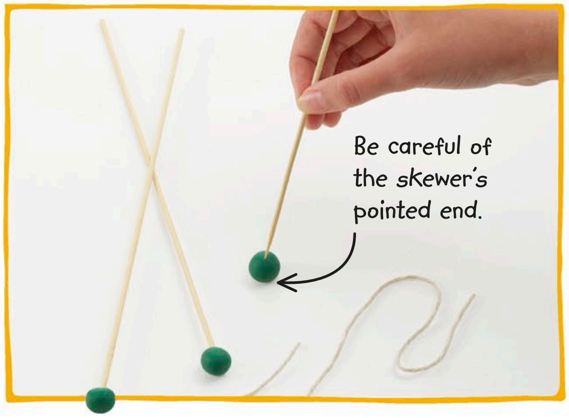
3 Place the top section upside down in the base section. This provides a platform for the seeds, and it stops the water from evaporating.

4 Pour water into the planter so it fills the bottom almost up to the bottle's neck. The water should be about 4 in (10 cm) deep.



5 Feed four of the pieces of string down through the opening of the bottle, but leave a few inches of each string in the top section.

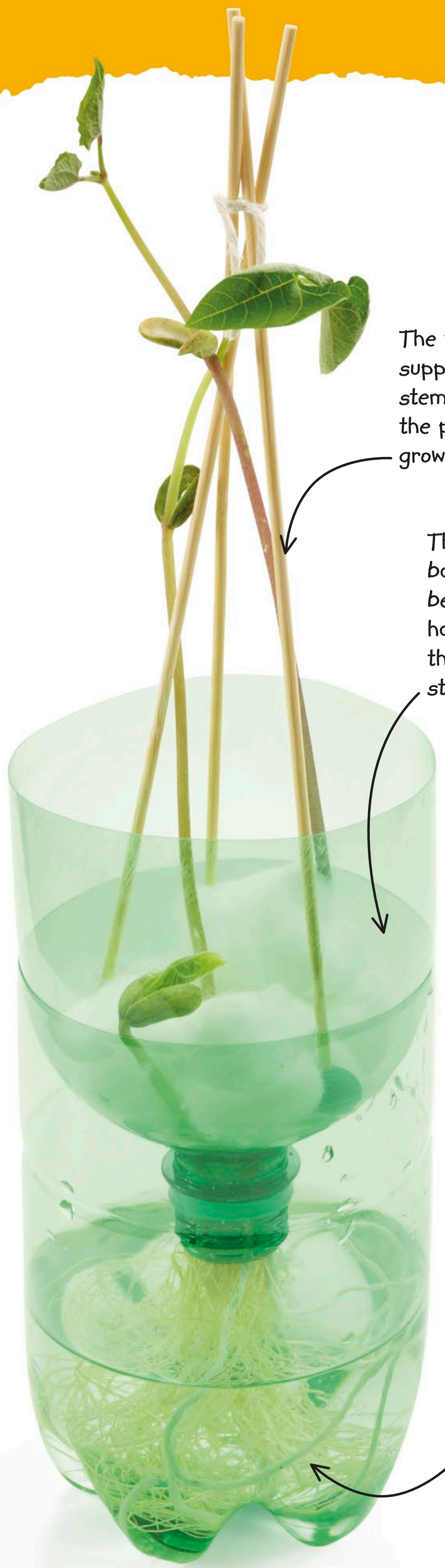
6 Put several cotton balls into the top of the planter, then drop a few bean seeds onto the cotton balls.



7 To make a tripod that will support the stems of the plants as they grow, put a blob of modeling clay on the pointed end of each wood skewer.

8 Stand the three skewers on end and bring the tops together so they cross. Use the final piece of string to tie them together, to make a tripod.

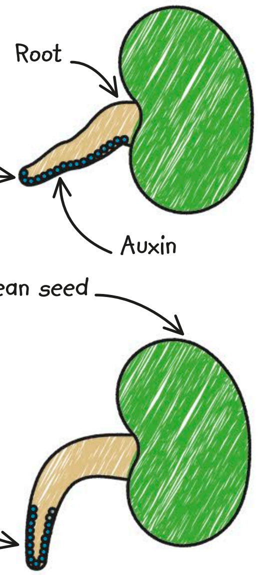
9 Place the tripod on top of the cotton balls, and put the planter in a bright place.



10 The seeds should germinate after a few days. After a few weeks, transfer your plants to a pot with soil, or ask an adult to add fertilizer to the water, so the plants can flourish.

HOW IT WORKS

Water from the bottom of the planter soaks up through the strings and wets the cotton balls. The seeds grow roots and a shoot when they absorb water. Water, air, and light are all a plant needs to start growing—that's why this plant can grow without any soil. A special chemical in the roots, called auxin, helps direct them downward so that they grow toward the water. Auxin makes a root grow more slowly on one side, causing it to bend in the direction of the force of gravity.



REAL-WORLD SCIENCE
AQUAPONICS

Some plants are grown in hydroponic tanks. There, they are fed water containing the nutrients, normally found in soil, that they need to grow quickly and healthily. Aquaponics, a type of hydroponics, feeds plants with nutrients from the waste products of fish kept in tanks. The fish provide food for the plants, and the plants filter the water for the fish.

SEEDLING POTS

Gardeners use seedling pots to grow and protect young seeds. These homemade seedling pots are made with a torn paper mush, which is shaped around a plastic plant pot. Once the paper has dried out, plant a pea seed in the pot and watch it grow!

PAPER POTS

These paper plant pots are perfect for planting outside in the ground because they will decompose (break down) in the soil without causing any harm.

HOW TO MAKE

SEEDLING POTS

In this activity, you make old paper into a wet mush called pulp, shape it into pots, and then let it dry. Here, construction paper is used, but you could use any type of paper, including old newspapers. The paper pots keep their shape once they dry out, and break down harmlessly when they are planted in the ground.

Time
30 minutes,
plus 24 hours drying

Difficulty
Medium

WHAT YOU NEED

1 Tear the two pieces of construction paper into strips about ½ in (1 cm) wide, and then rip these strips into small squares and put them in the bowl.

2 Add enough water to the bowl to soak the paper squares. Don't add too much—just enough to make the paper very wet.

3 Pick up a clump of soggy paper and squeeze and scrunch it with your hands. Do this repeatedly until the paper feels like a mushy pulp.

You could try adding more or less flour to your pulp to see how it affects your pots.

4 Add the flour to your pulp and mix it in. Squeeze and stir the flour and pulp with your hands until they are fully mixed together.

Paper is made from cellulose, a strong, fibrous material found inside plants.

5 Take a clump of pulp and gently squeeze it to drain the excess water. Press it onto the side and the bottom of the plastic plant pot. Once you have covered the pot completely, stand it upside down, somewhere warm and dry for at least 24 hours, so it dries out.

Be careful not to crack the pot.

6 When your paper pot is completely dry, you need to remove the plastic plant pot. Carefully loosen the paper around the top of the pot, then pinch the sides of the plastic pot together. Gently wiggle the plastic pot free from the paper pot.

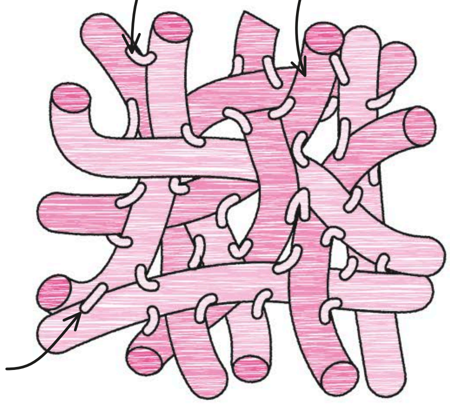
This step is tricky, so ask an adult to help you.

7 Fill your pot with soil and plant the seeds about ½ in (1 cm) deep. Wash your hands after handling soil. Place the pot on a tray, in case any water seeps through, and leave it on a window sill.

8 Water the soil. Check your seeds regularly, adding more water if the soil is dry. When the plants have grown to about 6 in (15 cm) tall, dig a hole and place the pot in the soil outside where it can continue to grow.

HOW IT WORKS

A piece of paper is formed of millions of microscopic fibers, which are made of a material called cellulose. These cellulose fibers are tiny tubes that form the outer part (the cell wall) of plant cells. The cellulose fibers are linked together by tiny fibers called fibrils, but when you add water to the paper to make a pulp, the fibrils detach from the cellulose fibers. As the pulp dries, the fibrils rejoin, attaching the cellulose fibers together again. When you bury your paper pot in the soil, tiny living things (microorganisms) break down the cellulose fibers into smaller particles, and the paper gradually becomes part of the soil.



REAL-WORLD SCIENCE
PAPER RECYCLING

Paper is one of the easiest materials to recycle because the cellulose fibers it is made from can be mashed into a pulp and reformed into paper again and again. Recycling collections are taken to recycling plants, like the one in this picture, where the paper is separated into types, such as cardboard or newspaper, then cleaned and pulped.

MYCELIUM

This mass of white fibers is called mycelium, and it is the main body of a fungus. Mycelium grows from reproductive cells called spores, which are released by another part of the fungus—its mushrooms. In this experiment, you will make mycelium in controlled conditions.

DO NOT eat the mushrooms or mycelium at any stage of this activity!

Oxygen, which the fungus needs to survive, enters the jar through a tissue paper top.

You will be able to see mycelium growing through the side of your glass jar.

FEEDING TIME

Fungi don't make their own food, like plants do. They need to feed on something to gain energy and materials in order to grow. The mushroom spores that make the mycelium in this activity feed on corrugated cardboard.

HOW TO GROW
MYCELIUM

To grow a jar full of mycelium, make sure that your hands, the jar, and the cardboard are clean. If bacteria get into the jar, they may grow and compete with the mycelium. When you have finished this activity, ask an adult to throw away the jar's contents and recycle the glass.


Time
90 minutes


Difficulty
Medium


Warning
Don't do this activity if you are allergic to mushrooms.

WHAT YOU NEED


Pitcher of water


Microwave-safe lunch box


Scissors


Rubber band


Oyster mushrooms


Pencil


Clean glass jar


Corrugated cardboard


Tissue paper

You will also need a microwave oven

1 Draw six circles on the cardboard with the pencil. Trace around the bottom of the glass jar to make sure the circles are the right size.

2 Using the scissors, carefully cut out the circles. They will provide the surface on which the mycelium will grow.

Make sure the water completely covers the cardboard.

3 Place the cardboard circles in the microwave-safe lunch box and cover them with water.

Heating the water kills any bacteria that might affect how the mycelium will grow.

4 Put the uncovered lunch box in a microwave and heat it on full power for two minutes. Let it cool down for an hour with the door closed.

5 Before you remove the lunch box from the microwave, wash your hands thoroughly with soap, rinse them, and dry them on a clean towel.

6 Lift the cardboard circles out of the water and squeeze them in your hand. This will get rid of some of the water they contain, but they should still be damp. Put them all on a clean plate.

You can get oyster mushrooms from any big supermarket.

7 Place one cardboard circle into the bottom of the clean glass jar. Snip small pieces of oyster mushroom over the jar, making sure the pieces all land on the cardboard.

Ideally, the mushroom pieces will be near the middle of each circle, but their placement doesn't need to be exact.

8 Once you have a few pieces of mushroom on the first cardboard circle, add another damp circle on top and repeat.

9 Add the damp cardboard circles one by one, dropping a few small pieces of mushroom onto each layer. Wash your hands after touching the mushrooms.

The tissue paper allows air to come in, which contains the oxygen the fungus needs to survive.

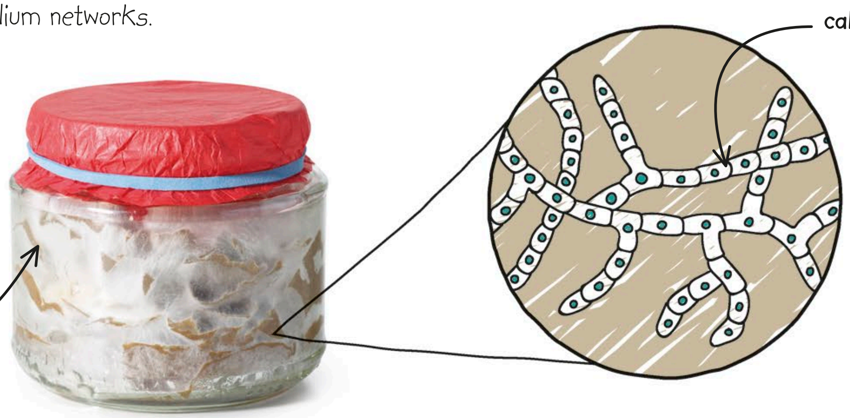
10 Don't put the lid on the jar. Instead, place a piece of tissue paper over the opening and secure it with the rubber band.

11 Place the jar in a cool, dark place, such as a cupboard. Check the jar every couple of days. You'll be amazed at how fast it fills up with mycelium!

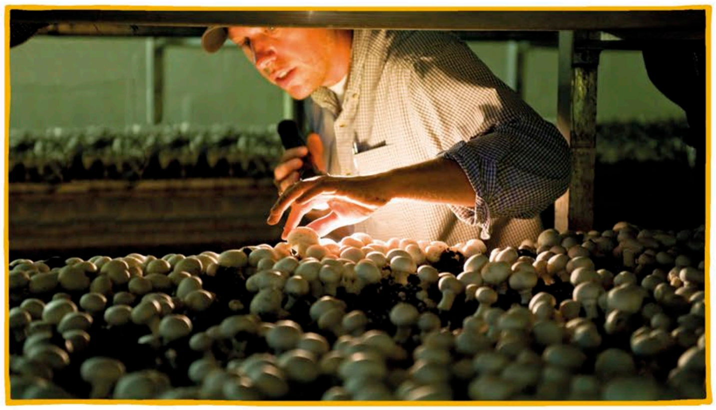
HOW IT WORKS

A mushroom you see above ground is just a tiny part of a fungus. Hidden underground, beneath the mushroom, is a vast network of tiny threads that together make up mycelium. Fungi usually live in soil, rotting wood, or dead animals—anything that contains decaying organic matter. To reproduce, strands of the mycelium emerge from the soil, bunching into a knot, and grow into a mushroom. This mushroom then releases millions of spores, which scatter to make new mycelium networks.

If you have access to a microscope, you could use it to see if you can see the structure of the mycelium.



Mycelium is made of tiny threads, one cell thick, called hyphae.



REAL-WORLD SCIENCE
MUSHROOMS

Some mushrooms contain nutrients that are good for us to eat, but many contain poisons so don't eat any wild mushrooms unless an adult confirms that they are safe. Most mushrooms that are safe to eat are grown on mushroom farms, where farmers make sure that the humidity levels and temperature are kept as consistent as possible. Mushrooms grow best when they are kept in cool, dark, moist, and humid environments.


2

WORLD OF WEATHER

The science of weather is called meteorology, and scientists who study it are called meteorologists. In this chapter, you'll be building four different meteorological instruments: a thermometer (to measure temperature), an anemometer (to measure wind speed), a barometer (to measure atmospheric pressure), and a rain gauge (to measure rainfall). You'll also investigate freeze-thaw action, and learn about how water and ice can cause erosion.

BRILLIANT BAROMETER

It may be hard to believe, but the air around you is pressing on you from every direction! This powerful push is called atmospheric pressure, and it's measured using a device called a barometer. Weather forecasters use barometers to help predict how the weather will change over the next few days, as the atmospheric pressure changes.

ATMOSPHERIC PRESSURE

Around Earth, there is a layer of gas more than 60 miles (100 km) thick—the atmosphere. The amount of that air above you causes atmospheric pressure. This pressure changes all the time as air warms or cools, picks up water that evaporates, or loses water when it rains.

HOW TO MAKE A

BRILLIANT BAROMETER

This barometer is easy to make—you just stretch a piece of rubber cut from a balloon over the opening of a glass jar. As atmospheric pressure increases, it pushes the balloon down against the air trapped inside, and as the pressure goes down, the rubber relaxes. Tape a straw to the rubber and watch it rise and fall as the pressure changes.

Time
20 minutes

Difficulty
Medium

WHAT YOU NEED

1 Cut the neck off the balloon and throw it away immediately. This will make it possible to stretch the piece of rubber over the jar's opening. There's no need to blow up the balloon.

Make sure you have a smooth surface.

2 Stretch the rubber over the top of the jar, trapping the air inside. Pull the rubber tight, to get rid of any creases.

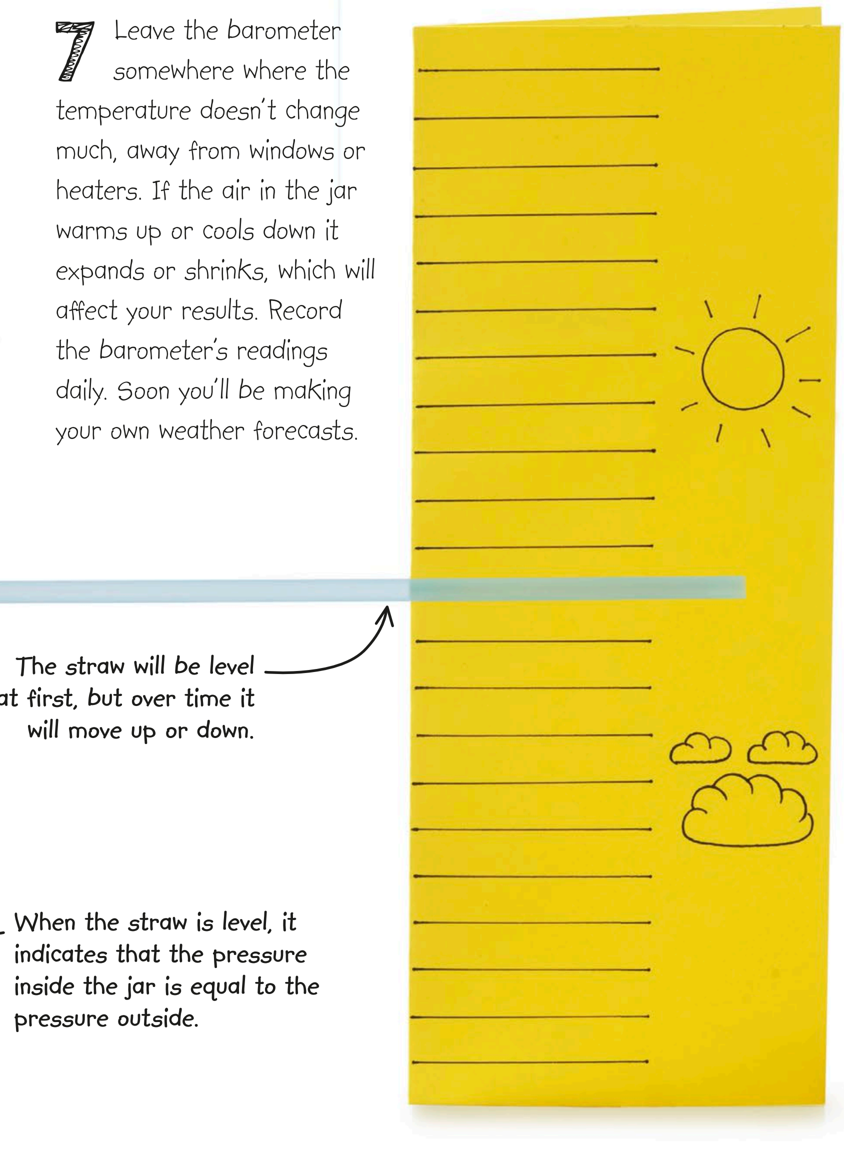
3 Secure the rubber in place with a rubber band. No air should be able to escape from the jar.

4 Cut a short piece of tape and stick it to the end of the straw. Now place the end of the straw across the middle of the rubber and attach it firmly.

5 To make the scale, neatly fold the piece of colored card stock in half lengthwise.

6 Using a ruler, draw lines ½ in (1 cm) apart across one side of the folded card stock.

7 Leave the barometer somewhere where the temperature doesn't change much, away from windows or heaters. If the air in the jar warms up or cools down it expands or shrinks, which will affect your results. Record the barometer's readings daily. Soon you'll be making your own weather forecasts.

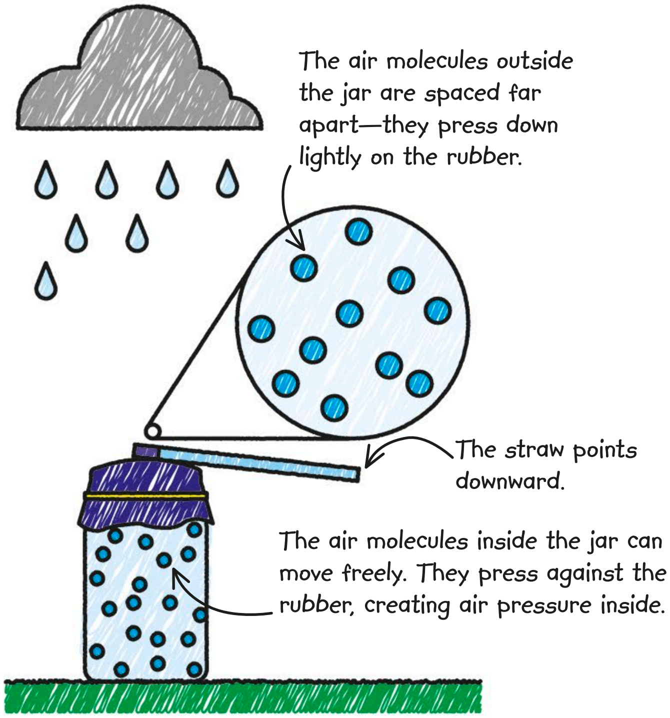


HOW IT WORKS

If you press down on the rubber, you compress (squash) the air inside the jar. The air pushes back, so when you let go the rubber returns to its original position. The same happens when atmospheric pressure changes. When atmospheric pressure increases—when the weather is fine—the outside air pushes down on the rubber. Atmospheric pressure falls when rainy, unsettled weather approaches.

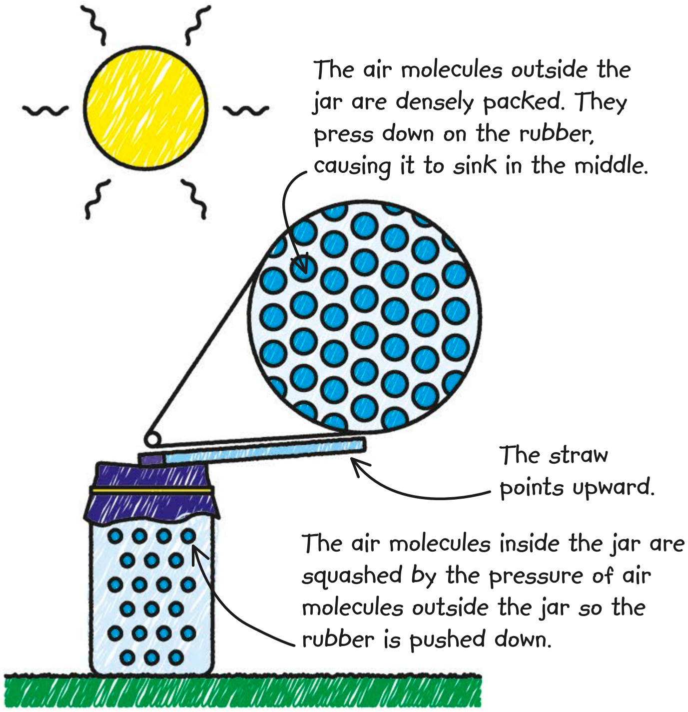
LOW PRESSURE: RAINY WEATHER

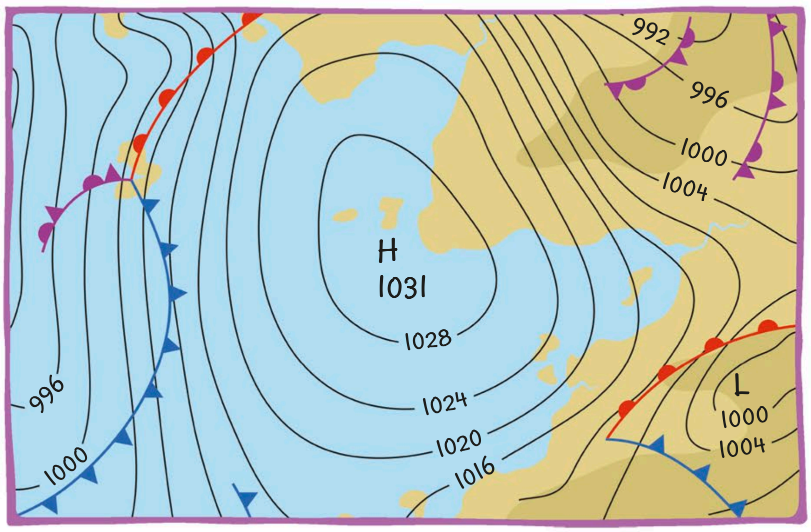
When the atmospheric pressure is low, the weather is cloudy and rainy.



HIGH PRESSURE: SUNNY WEATHER

High pressure means dry weather and clear, sunny skies.





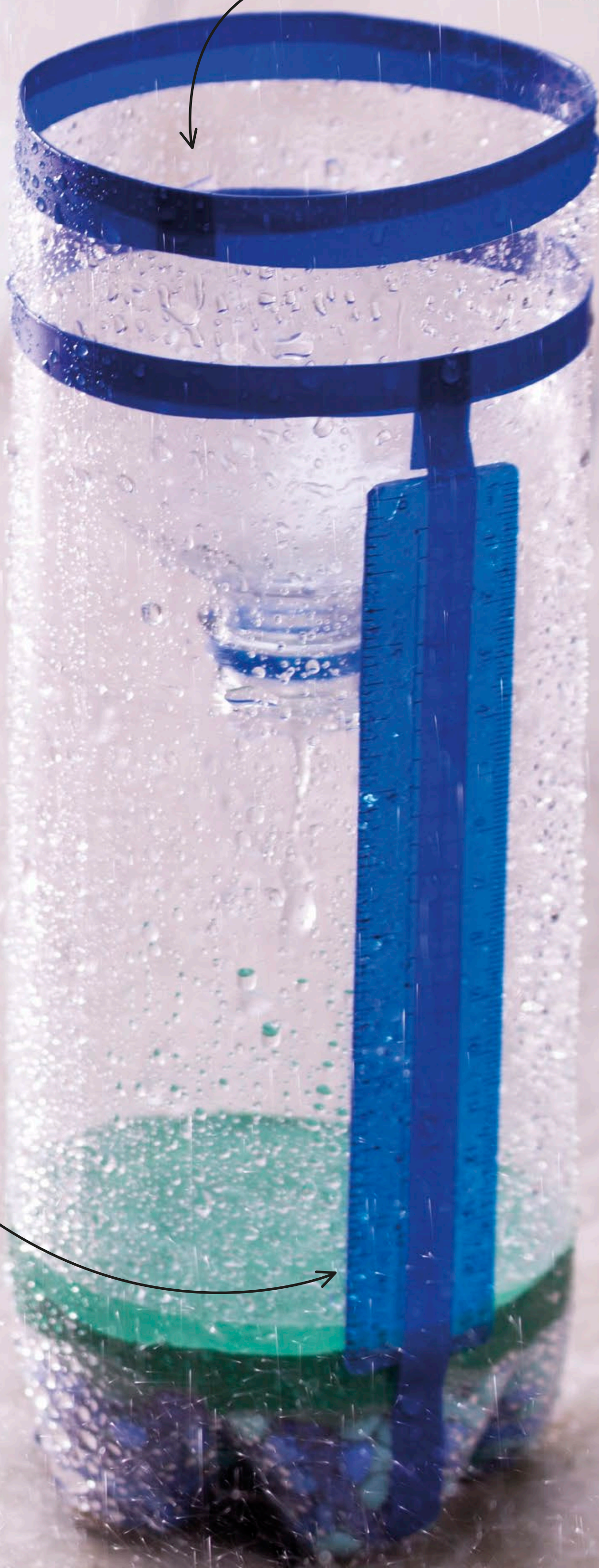
REAL-WORLD SCIENCE

ISOBARS

You might have noticed that the maps used by weather forecasters on television are covered in numbers and squiggly lines. These lines are called isobars and they join together locations with equal atmospheric pressure. The higher the number on the bar, the higher the pressure. In areas of low pressure, storms start to form.

RAIN GAUGE

Meteorologists, or weather forecasters, measure and compare rainfall over time to find patterns in the weather. With the help of weekly, monthly, and yearly records, they can predict when there might be heavy rain, or if a drought is on the way—vital information for farmers and gardeners. To measure rainfall, meteorologists use a device called a rain gauge.



RAINY DAY

Do you live in a place where it rains often? Or is it very dry where you live? Does it rain more in the winter months or during the summer? Keep weekly, monthly, or even yearly, records of rainfall with your rain gauge, and find out!

HOW TO MAKE A

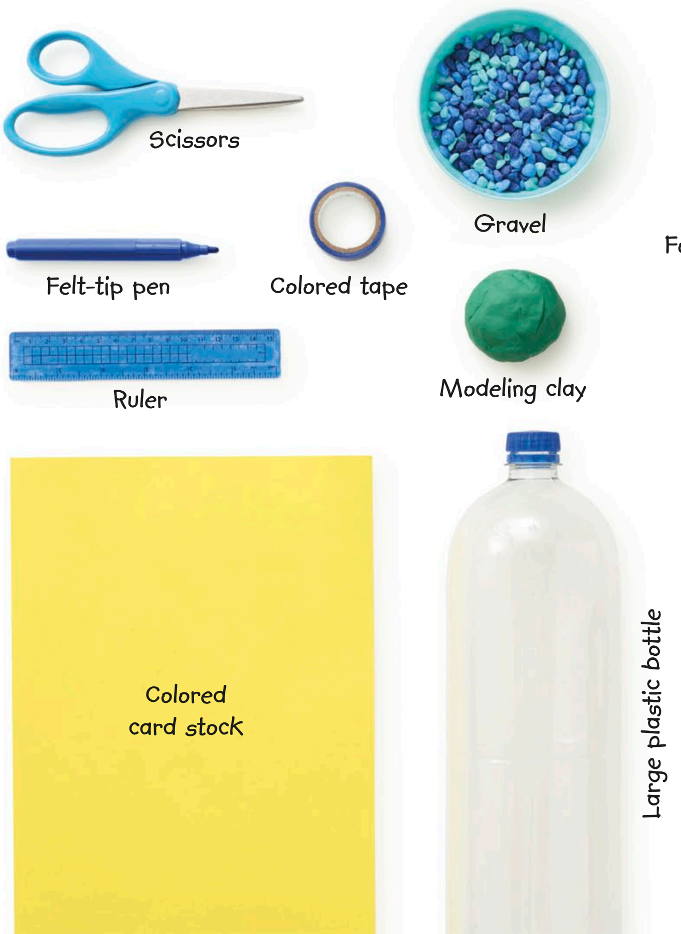
RAIN GAUGE

To make this simple rain gauge, you need to cut off the top of a bottle and make a flat surface at the bottom, inside the bottle, by adding gravel and modeling clay. There's a ruler stuck with tape to the side of the rain gauge that will allow you to measure and record how much rain falls in your local area.

Time
30 minutes

Difficulty
Medium

WHAT YOU NEED



1 Wrap the card stock around the bottle, to help you draw straight. Draw a straight line around the bottle, about 4 in (10 cm) down from the top.

2 Carefully cut along the line to separate the bottle into two parts. Be careful of any sharp edges and ask an adult to help you if you're finding it tricky.

3 Wrap tape neatly around the cut edges of the two parts, leaving enough to fold over. This will cover up any uneven cutting.

If your bottle has an uneven bottom, the layer of gravel will help to flatten it.

4 Pour gravel into the bottom part of the bottle, to weigh down your rain gauge so it won't fall over.

5 Press and mold the modeling clay into a thick, flat disk with the same diameter as the bottle. Make it as flat and smooth as you can.

6 Push the modeling clay disk down onto the surface of the gravel and press it against the sides of the bottle, to make a watertight seal.

7 Attach the ruler to the outside of the bottle with tape. Make sure the zero at the end of the ruler lines up with the top of the modeling clay disk.

The funnel covers the container, preventing the collected rainwater from evaporating (turning into vapor).

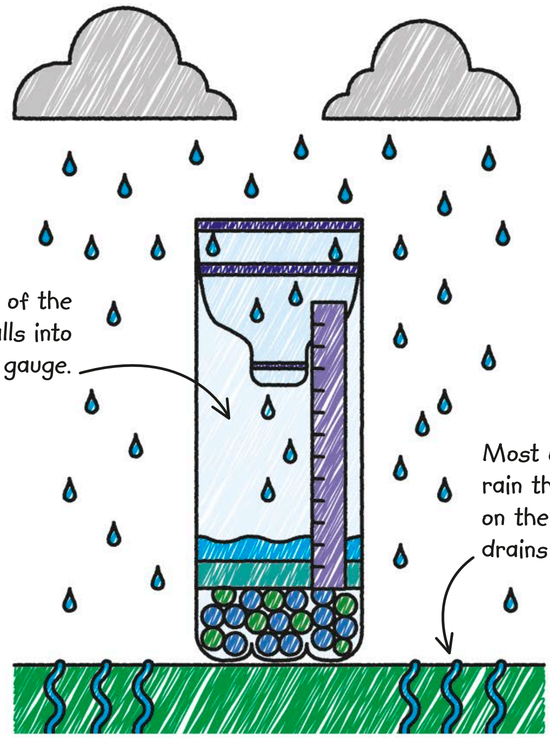
8 Put the funnel upside down in the bottom part. Place your rain gauge outside, away from buildings or trees. After the next shower, go outside to check the water level and make a note of how much rain has fallen.

TAKE IT FURTHER

Why not keep a journal of the rainfall over a year? If you empty out the rainwater from your gauge every week at the same time of day, you will have a set of weekly totals for the year. You could make a bar graph of your weekly totals to figure out which months are the wettest—or you could compare your results with the average rainfall for other parts of the world, which you can find online.

HOW IT WORKS

When rain falls, it normally runs away down drains or it soaks into the soil. If rain couldn't run away like this, it would collect on the ground, and the more rain that fell, the deeper the water would be. That's the principle behind a rain gauge: you are collecting rainwater that falls on a particular area—in this case, the circular opening at the top of your gauge—to see how deep the water becomes. If you made a rain gauge with an opening twice the size, it would collect twice as much water, but the depth of water collected would still be the same because the area of the bottom part of the rain gauge would be doubled too. If you had a rain gauge the size of a football field, it would collect hundreds or even thousands of gallons of water in a single rain shower, but the water would still be just a fraction of an inch deep.



REAL-WORLD SCIENCE
WEATHER WATCHERS

Rain gauges are a very important piece of equipment for meteorologists and other scientists. They use the information they gather not only to keep track of how the weather in different places is changing over time, but also to predict what the weather is going to be like in the future. This can warn people about possible floods and droughts, and it also helps us understand climate change. However, it's not just scientists that benefit from rain gauges. Farmers often use them to keep track of how much rain their crops are getting.

THERMOMETER

A thermometer measures temperature (how hot or how cold something is). There are lots of different types, but one of the most common is the liquid thermometer, a tube in which a liquid rises and falls as the temperature changes. These steps show you how to make a simple liquid thermometer that works inside and outside.

HOT OR COLD?

Place your thermometer in different parts of your home or in outside spaces that are warm or cool, and watch as the water level in the straw goes up and down. You'll need to be patient: it will take a little time before the level of the water changes.

HOW TO BUILD A
THERMOMETER

It's easy to make your own thermometer, using colored water as the liquid and a plastic straw as the tube. Once you've made your thermometer and tested to see that it's working well, you can create a temperature scale, in a process called "calibration."

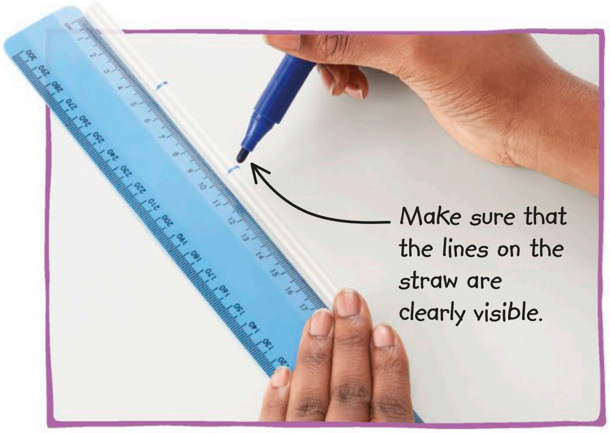
Time
30 minutes

Difficulty
Medium

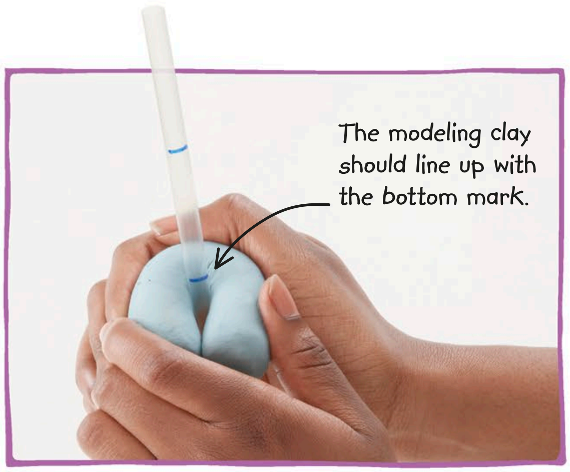
Warning
An adult is vital since this experiment uses hot water.

WHAT YOU NEED

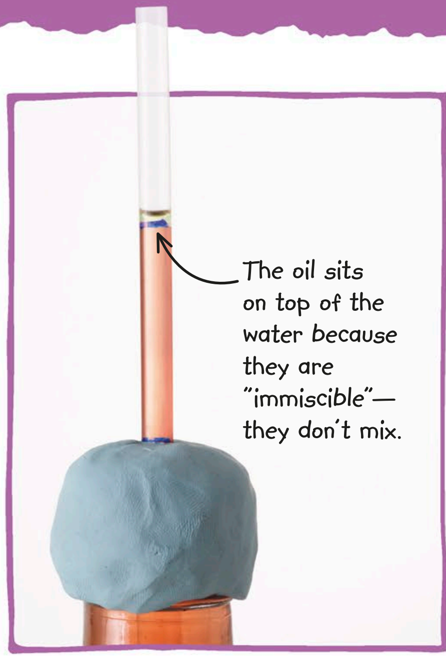
1 Fill the bottle with water almost to the top and add a few drops of food coloring.



2 Mark your straw with two lines, one 2 in (5 cm) from the end and one 4 in (10 cm) from the same end.



3 Roll the modeling clay into a sausage shape and wrap it around the straw, so that the top of it is level with the bottom line.



4 Maneuver the bottom half of the straw into the bottle (it shouldn't touch the base), and seal the opening with the modeling clay so it's airtight.

5 Mix more water and food coloring, and use the pipette to add a few more drops of colored water into the straw.

6 Add just a drop of oil to stop the water from evaporating (turning into vapor).

7 Your thermometer is complete and ready to use. To test that it's working, carefully place it in a bowl of hot water. The water level in the straw should rise.

8 Next put cold water into the bowl and see what happens.

TAKE IT FURTHER

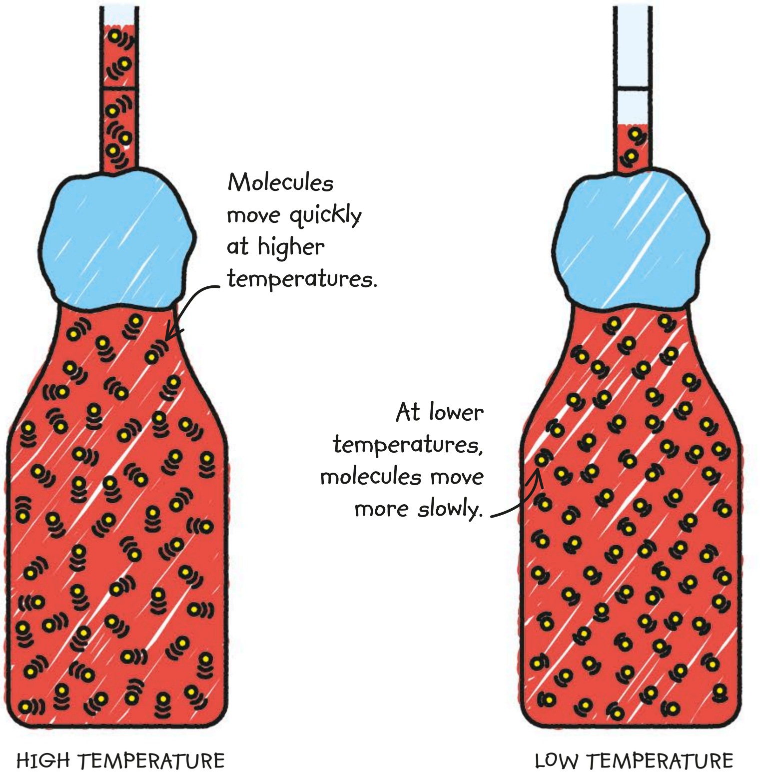
The thermometer you've made only shows whether the temperature is high or low, but creating a scale by referring to a store-bought thermometer will give you more accurate temperature readings. This process is called "calibration." Start with hot water in the bowl and let it cool. Every so often, mark the water level on your scale and the temperature shown on the bought thermometer. To add lower temperature readings to your scale, put cold water into the bowl to bring down the temperature.

HOT WATER IN BOWL

COLD WATER IN BOWL

HOW IT WORKS

Water is made of tiny particles called molecules. The molecules are constantly moving around. The higher the temperature, the more vigorously they jiggle, causing the water to expand (take up more space). The only space into which the water can expand is in the straw—that's why the water level rises when your thermometer is put in hot water. As the temperature falls, the molecules move more slowly and take up less space, causing the water level to drop.



REAL-WORLD SCIENCE
BODY TEMPERATURE

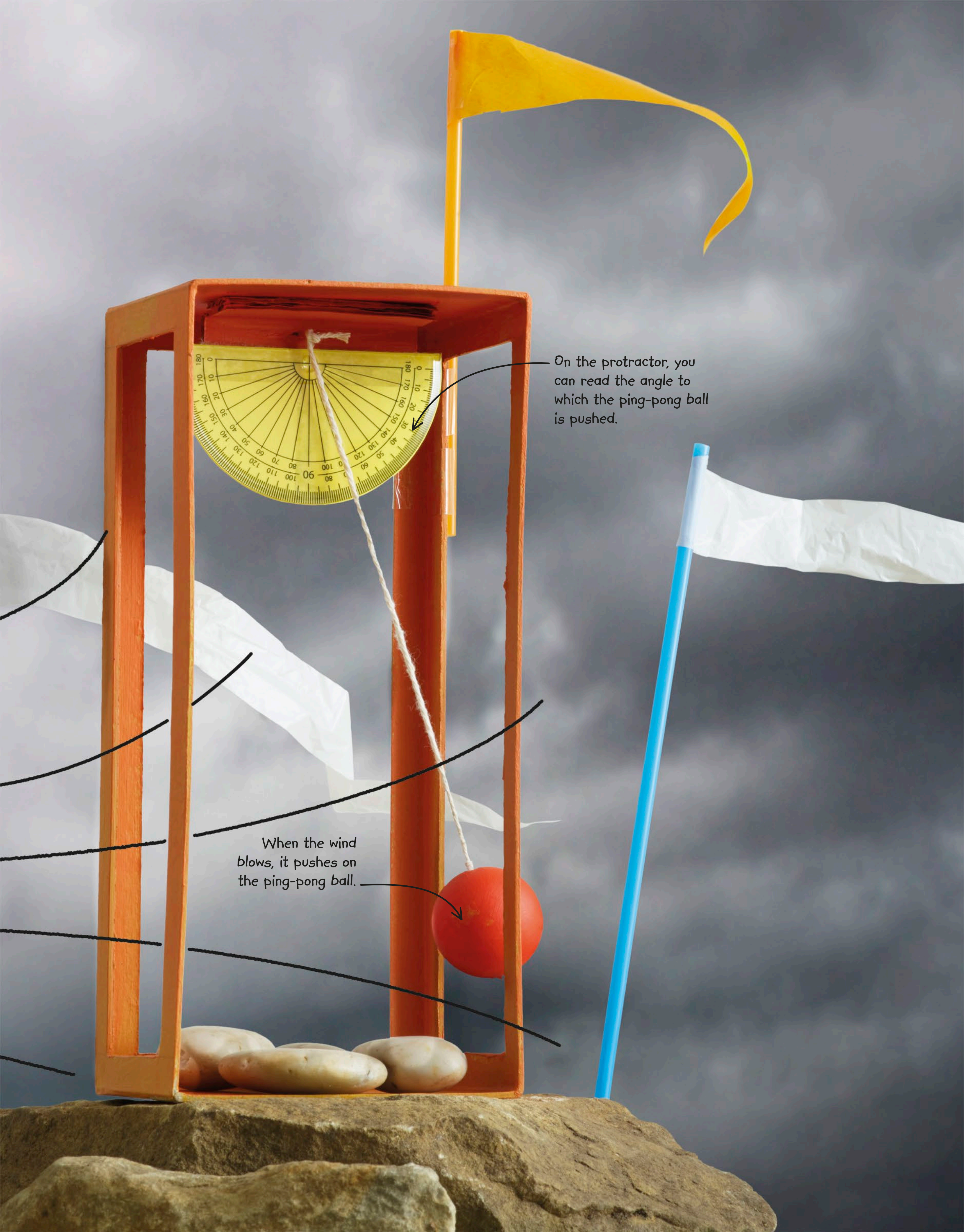
A liquid thermometer can be used to measure the temperature of a room or check your body's temperature to see if you have an infection. Infections are caused by germs, such as bacteria and viruses, that reproduce (breed) inside you. When you have an infection, your brain increases your body's temperature to try to slow down the rate at which the germs can reproduce.

ANEMOMETER

The wind can be anything from a gentle breeze to a very strong gale, but it is really just air in motion. Weather forecasters, or "meteorologists", use a device called an anemometer to measure the wind speed—the speed at which air is moving. You can measure the speed of the wind, too, by making your own anemometer using a ping-pong ball and a shoe box.

MOVING AIR

The wind speed often increases when the weather is about to change from clear to unsettled, wet weather. Why not use your anemometer to keep a record of the wind speed over several days and see how the weather changes?


On the protractor, you can read the angle to which the ping-pong ball is pushed.
When the wind blows, it pushes on the ping-pong ball.

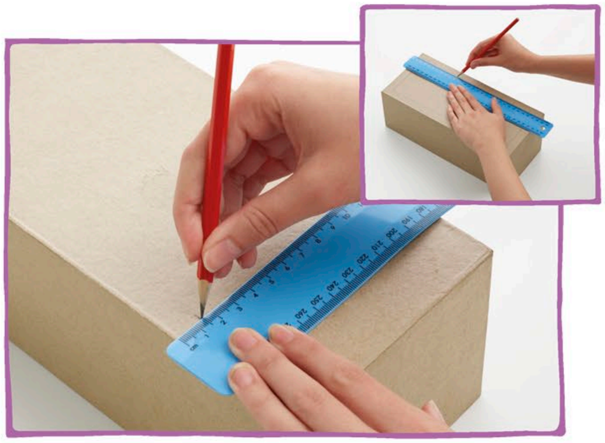
HOW TO BUILD AN
ANEMOMETER

This is a very complicated project, so take your time and follow the instructions carefully. In this anemometer design, a ping-pong ball is suspended on a string inside a cardboard frame made from a shoe box. You'll need to place it in a spot where the wind will push against the ball. The stronger the wind, the farther the ping-pong ball will move.

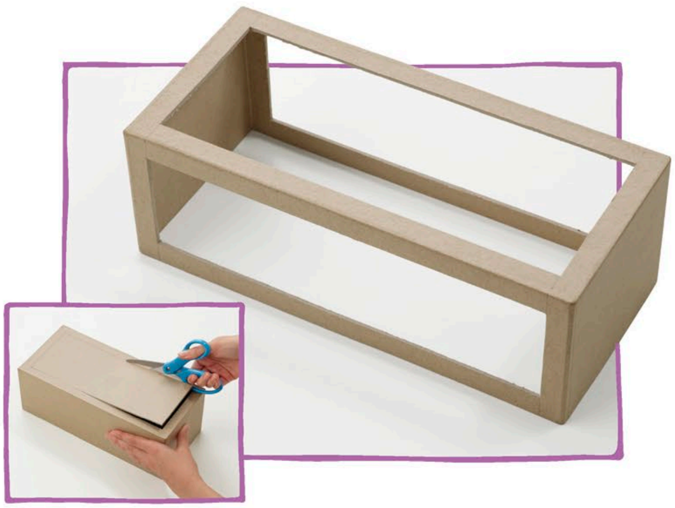
Time
1 hour plus drying time

Difficulty
Hard

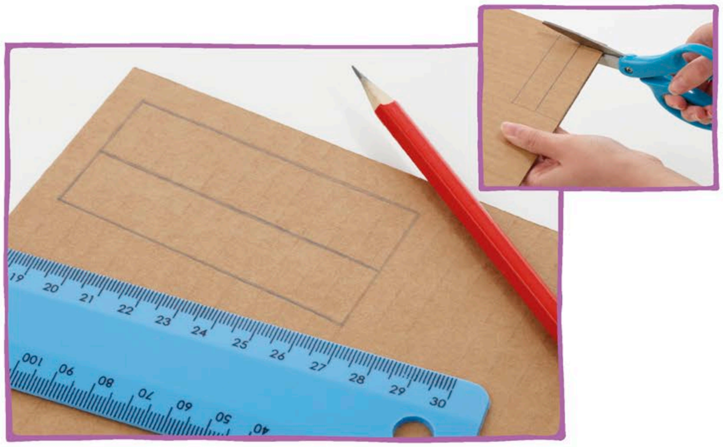
WHAT YOU NEED



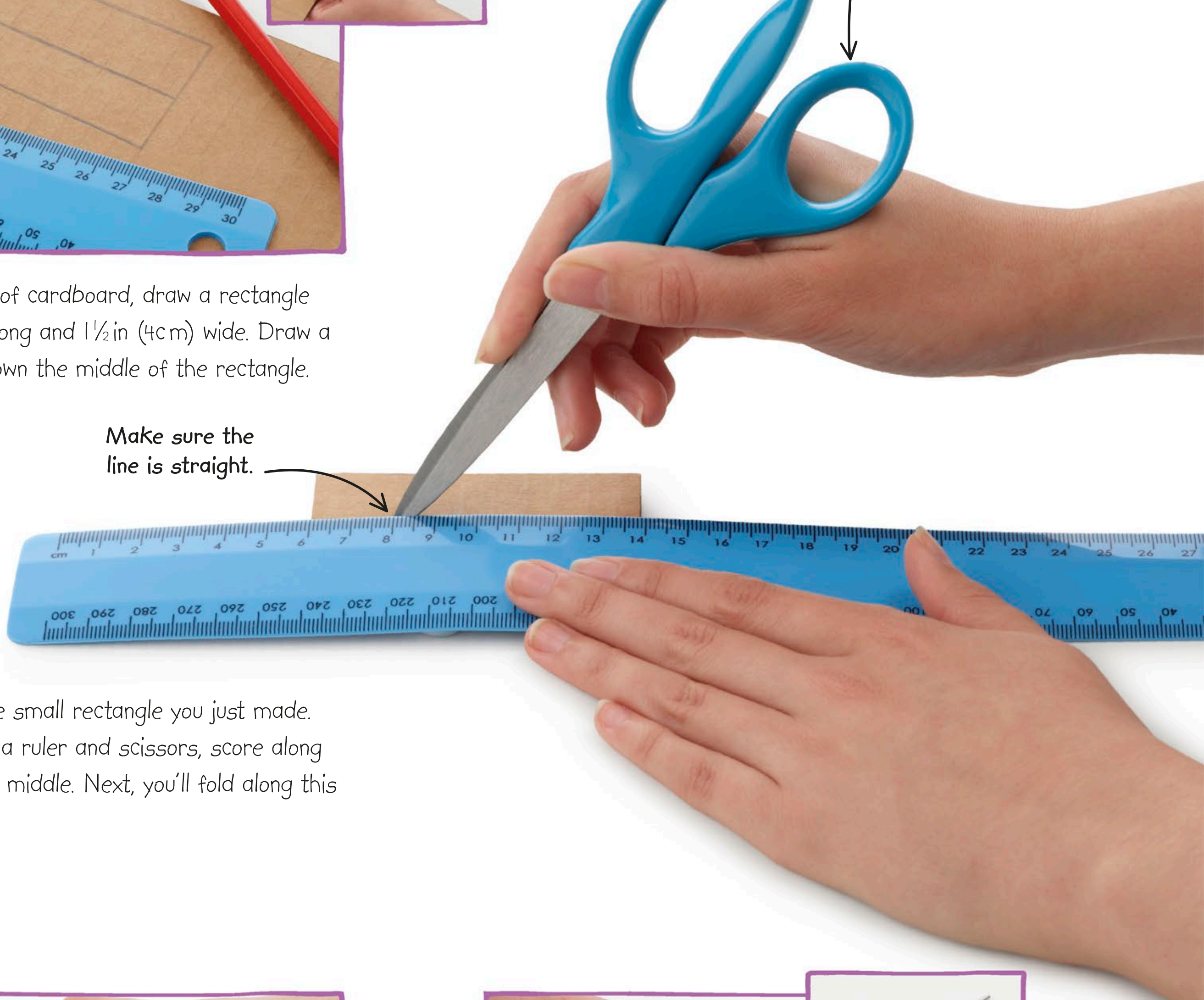
1 Make a mark $\frac{3}{4}$ in ($1\frac{1}{2}$ cm) in from each edge of the three long faces of the shoe box. Use these marks to draw a rectangle on each face.



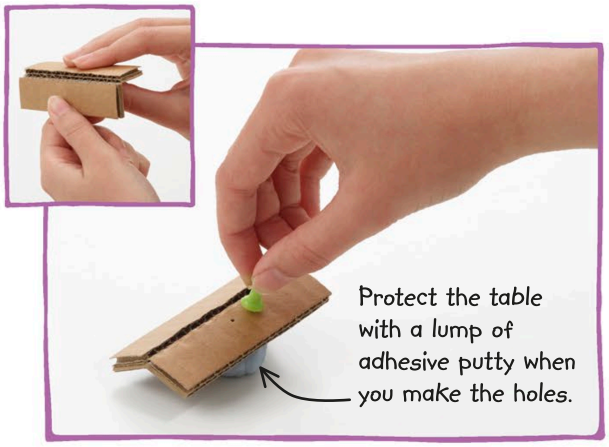
2 Carefully cut out the rectangle you have drawn on each of the three sides, to create an open frame.



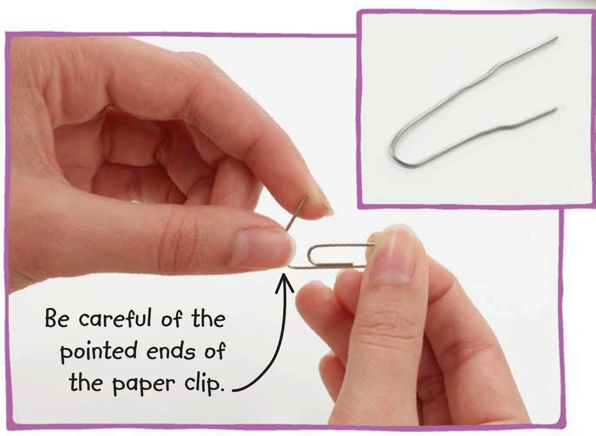
3 On a piece of cardboard, draw a rectangle 3 in (8 cm) long and 1½ in (4 cm) wide. Draw a line lengthwise down the middle of the rectangle.



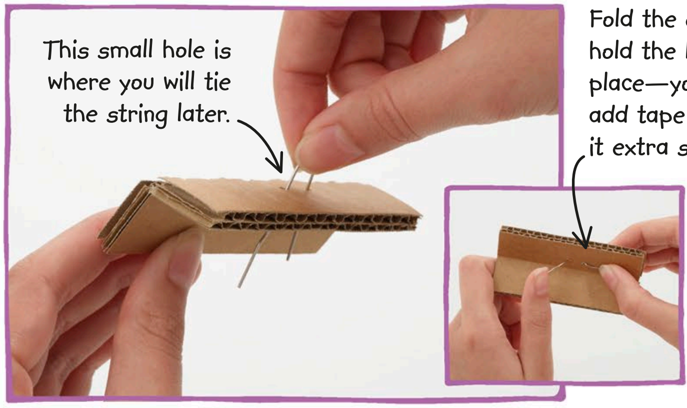
4 Cut out the small rectangle you just made. Then, with a ruler and scissors, score along the line down the middle. Next, you'll fold along this scored line.



5 Using the pushpin, make two holes on one side of your cardboard rectangle. The holes should be 1¼ in (3.5 cm) from each end of the rectangle and about ½ in (1 cm) apart.

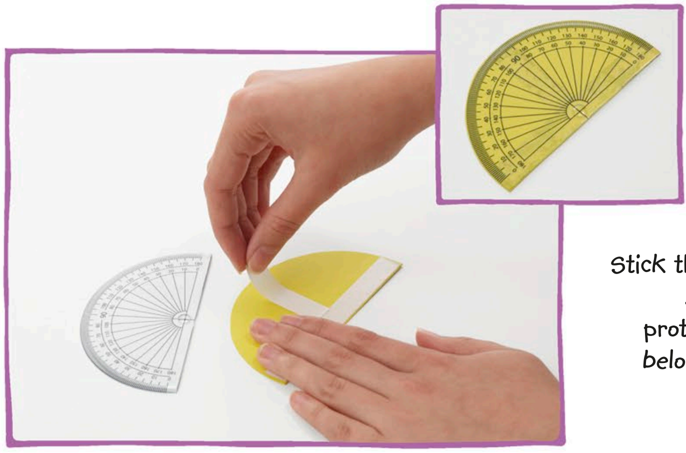


6 Unfold the paper clip to make a "U" shape. This step is tricky, so you might want to ask an adult to help you.

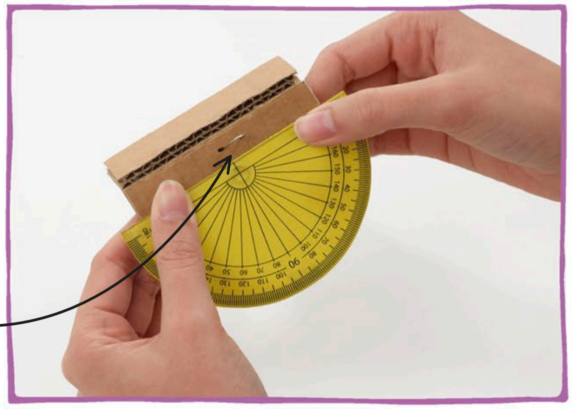


7 Push the paper-clip ends through the holes you made and leave a small gap above to create a loop. Fold the two ends outward.

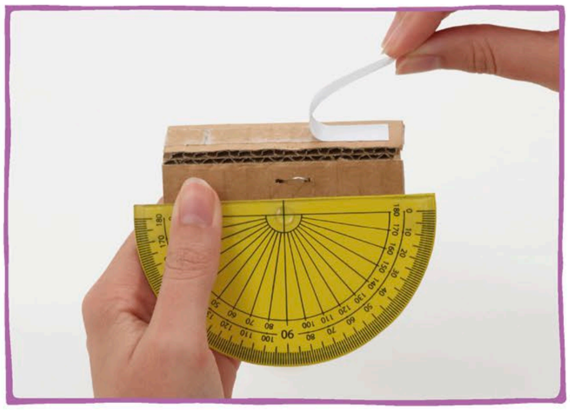
8 Draw around the protractor onto colored paper or use the template in the back of this book. Cut out the semicircle shape.



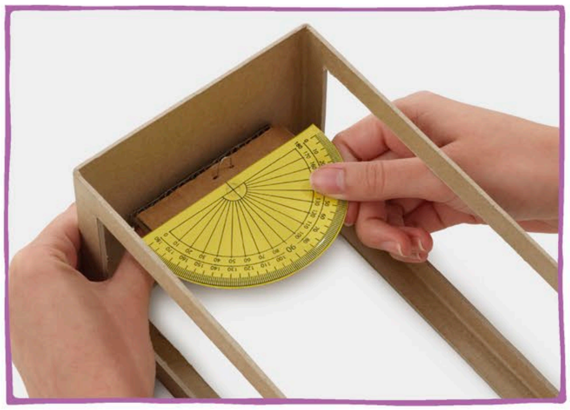
9 Stick two pieces of double-sided tape onto the semicircle. Peel off the protective strips and secure the paper to the protractor.



10 Use another piece of double-sided tape to stick the protractor onto the rectangle so the curved side hangs down.



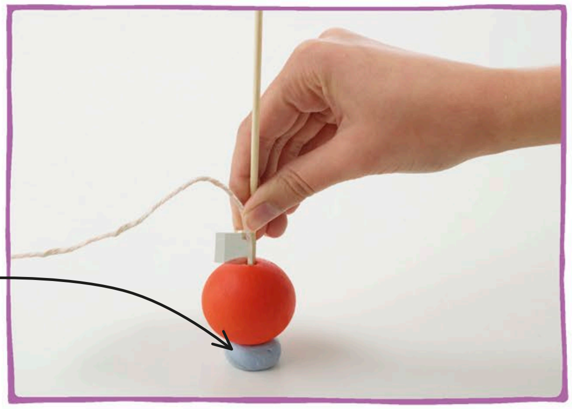
11 Now you need one last piece of double-sided tape to make the other side of the cardboard rectangle sticky. Peel off the protective strip.



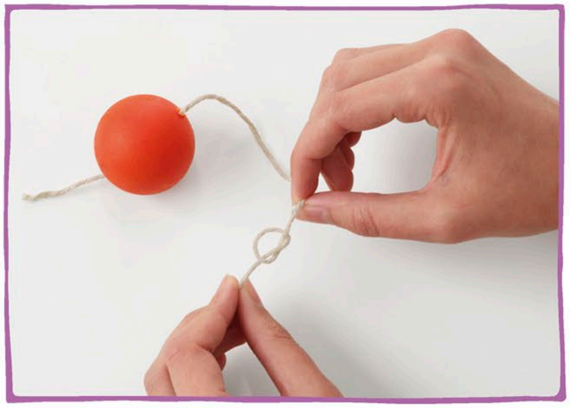
12 Attach the cardboard rectangle to the inside of one end of the box, as shown.

13 Paint the entire cardboard frame and then the ping-pong ball. Don't paint the protractor! Let them dry.

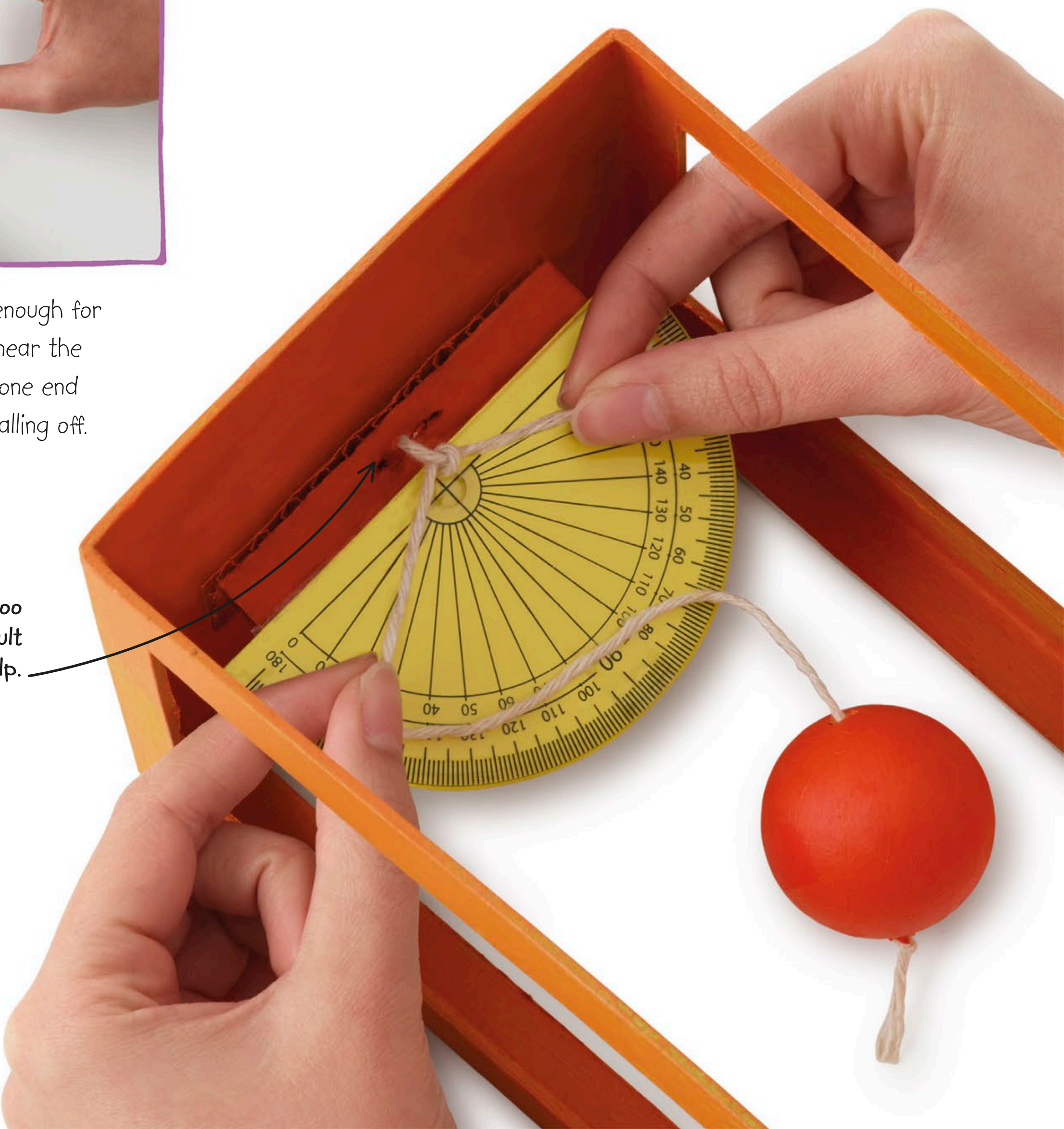
Use a piece of adhesive putty to protect the table.



14 With string taped to its pointed end, poke the skewer through the ping-pong ball and out the other side. When the string appears, keep hold of it, then remove the tape, and pull the skewer out. You can now throw the skewer away.

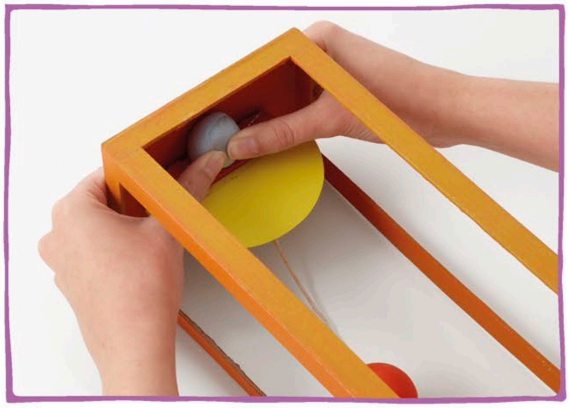


15 Cut the string so it is long enough for the ping-pong ball to hang near the bottom of the frame. Tie a knot at one end of the string to stop the ball from falling off.

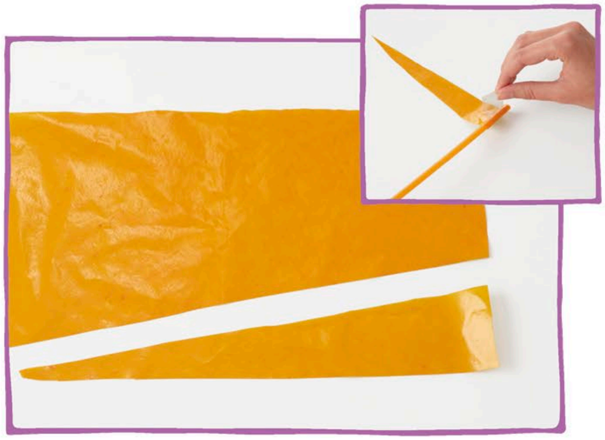


If this part is too tricky, ask an adult for help.

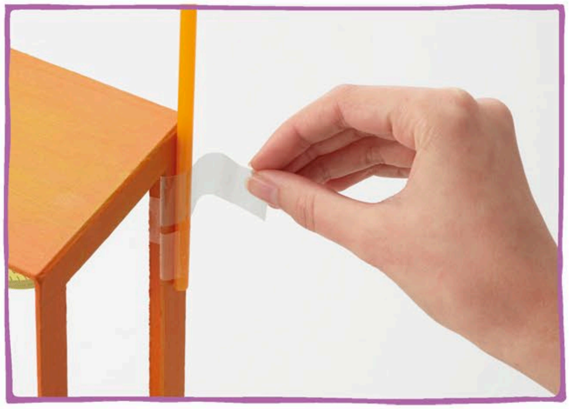
16 Tie the free end of the string around the paper-clip loop.



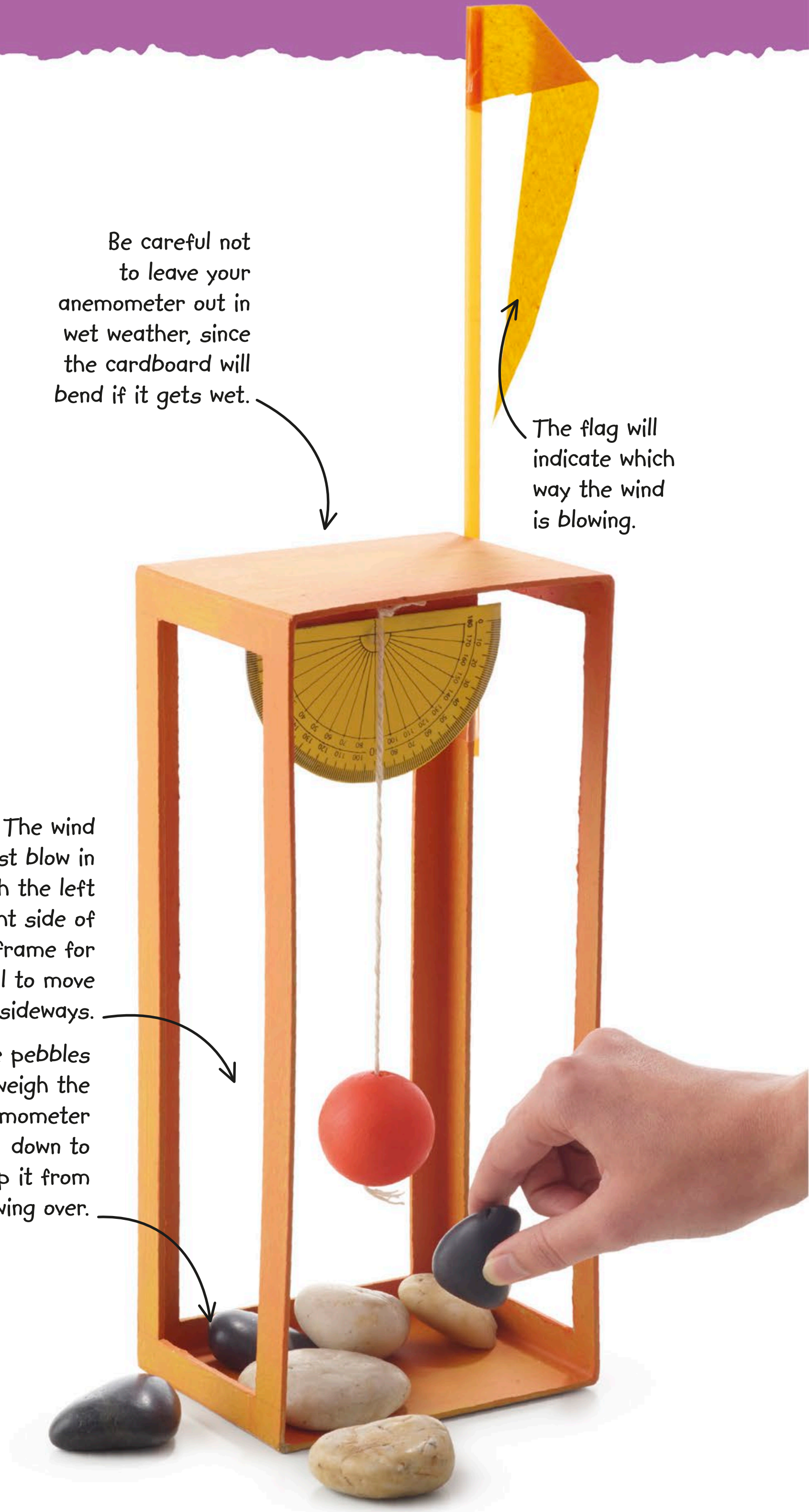
17 Press a piece of adhesive putty behind where the protractor meets the frame to make sure it hangs down vertically.



18 Cut a small flag shape from a plastic bag and stick it to the top of a straw with adhesive tape.



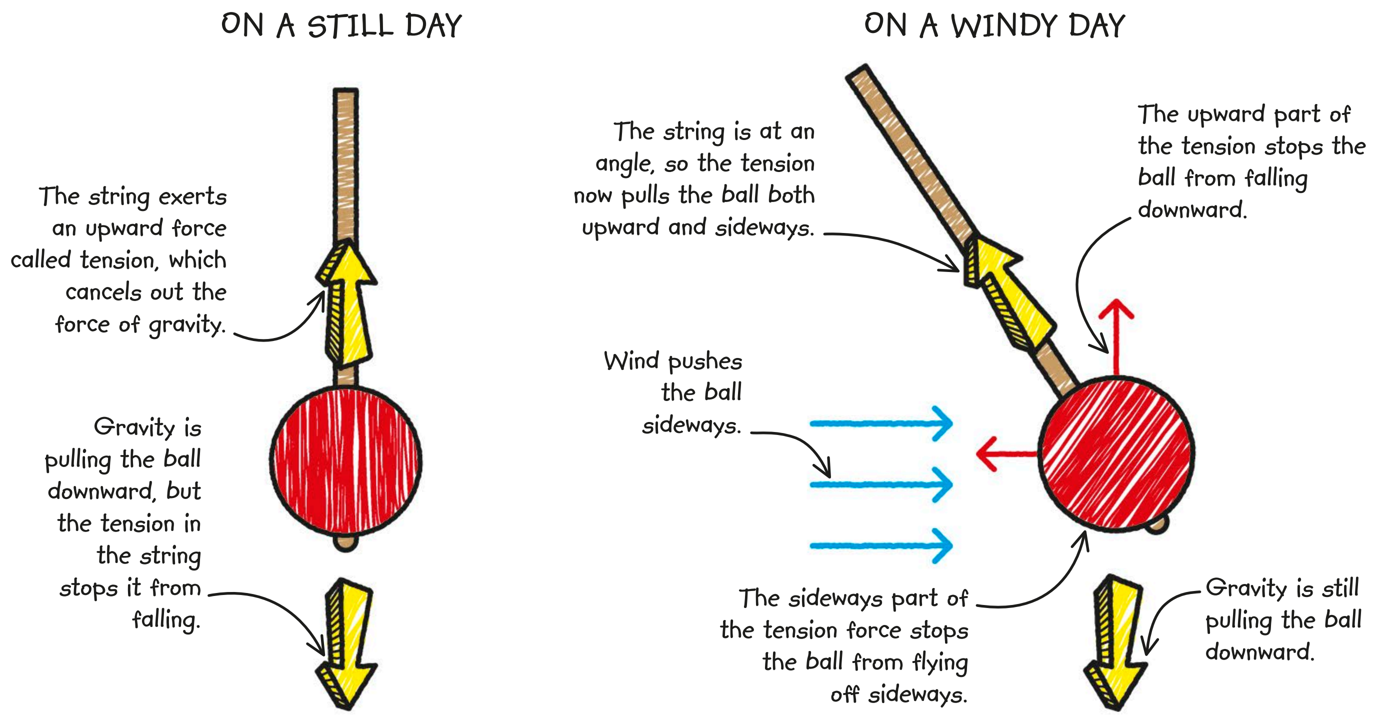
19 Use adhesive tape to secure the straw near the top of one edge of the frame. Take your anemometer outside.



20 Position your anemometer so that the flag points left or right as you are looking at the protractor. To get an accurate measurement, don't position it too close to buildings or trees. Place pebbles in the base, then watch the ball swing diagonally upward, pushed by the wind. Note the angle that the string reaches, and check the table on the opposite page to find out the equivalent wind speed.

HOW IT WORKS

When the wind blows—when air is moving—it pushes the ping-pong ball sideways. The ball is supported by the string, so it swings upward as it is pushed sideways. The faster the wind blows, the stronger the push, and the more the ping-pong ball swings upward. You can estimate the speed of the wind from the angle the string indicates on the protractor, by looking at the table below.



Angle of string		90°	85°	80°	75°	70°	65°	60°	55°	50°	45°	40°	35°	30°	25°	20°
Wind speed	(mph)	0	5½	8	10	12	13½	15	16	18	20	21	23½	26	28½	32
	(km/h)	0	9	13	16	19	22	24	26	29	32	34	38	42	46	52

REAL-WORLD SCIENCE
MEASURING WIND SPEED

A weather station is a place where meteorologists (weather forecasters) observe and track weather conditions over time. Meteorologists use a type of anemometer called a cup anemometer, which has three or four cups mounted on a vertical pole. The wind pushes the cups around, which in turn causes a generator attached to the pole to rotate. The faster the wind blows, the more electricity is produced by the generator. A computer analyzes the amount of electricity generated to record the wind speed.

CRACKING ROCKS

This experiment explores "freeze-thaw action," a process that starts when water gets into the tiny cracks of a rock. As the temperature falls at night and rises during the day, this water freezes, then melts... then freezes and melts again. Water is one of the few liquids that expands when it freezes, so, over time, this constant freezing and thawing splits the cracks wider and wider, until eventually even the hardest rock will break into pieces.

The balloon inside this "rock" just has air in it, so the rock didn't break.

AIR AND WATER

Some of these plaster of paris "rocks" have blue balloons full of water inside them to simulate the effect of freeze-thaw action. Erosion—the wearing down of rocks—is an incredibly slow process, but your "rocks" will break open overnight.

HOW TO MAKE CRACKING ROCKS

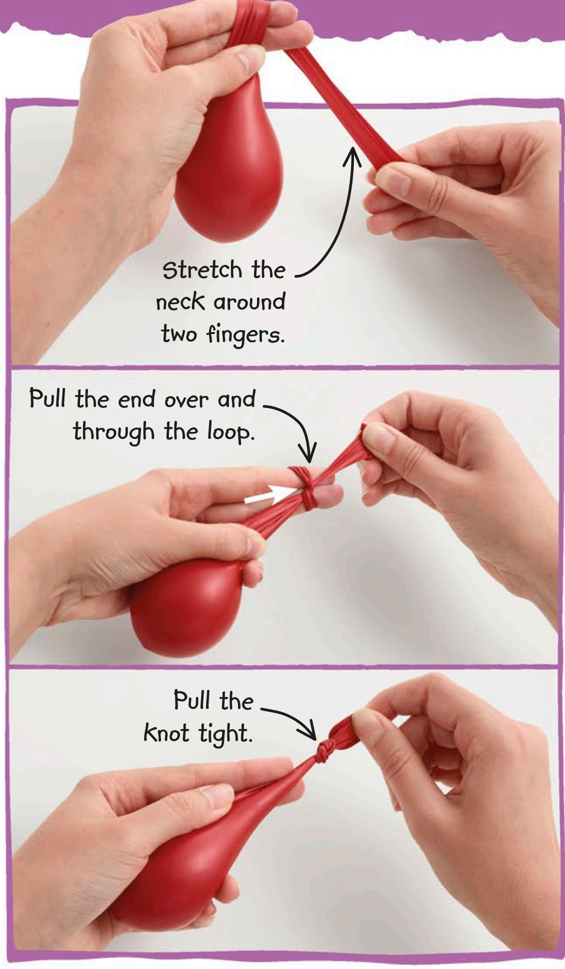
This activity needs patience. You'll be leaving the plaster of paris to set overnight and then keeping it in the freezer the next night. If you have sensitive skin, you should wear protective gloves when handling the plaster of paris.

Time
30 minutes plus 48 hours for drying and freezing

Difficulty
Hard

Warning
Get an adult to help when using plaster of paris

WHAT YOU NEED



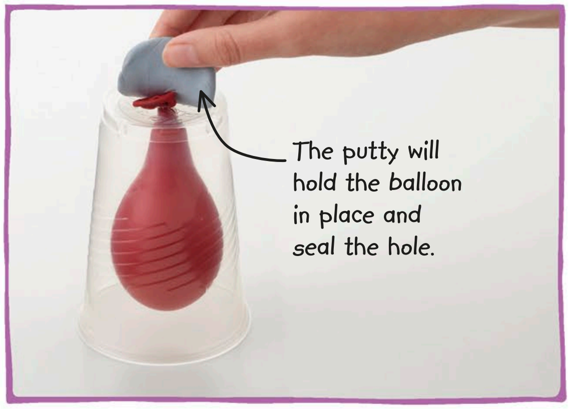
1 Blow up the red balloon just a little and tie a knot in its neck. To do this, stretch the neck around two fingers to make a loop, then pass the end over and through that loop, using the groove between your fingers, and pull it tight. If you have trouble, ask an adult for help.

2 Pour water into the blue balloon, until it's about the same size as the red balloon. Tie a knot in it—try not to spill any water!

3 Rest a plastic cup on the adhesive putty and make a hole in the bottom using the pencil. Repeat this step with a second cup.

4 Using the pencil, push the red balloon's knot through the hole in the bottom of one of the cups. Do the same with the blue balloon.

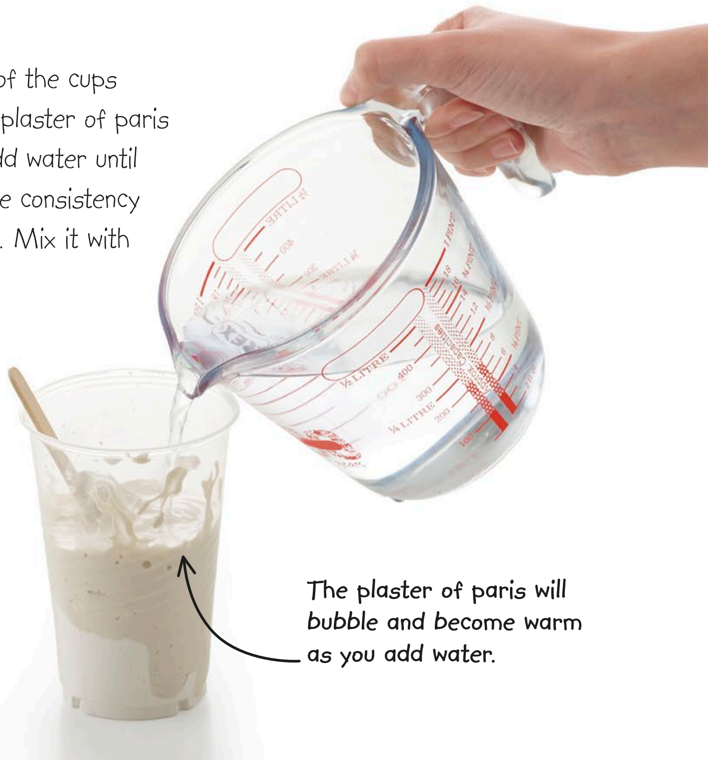
5 Stand the cups upside down. Make sure the balloons aren't so big that they touch the sides of the cups.



6 Make two flat disks from adhesive putty and press one firmly over each balloon knot.

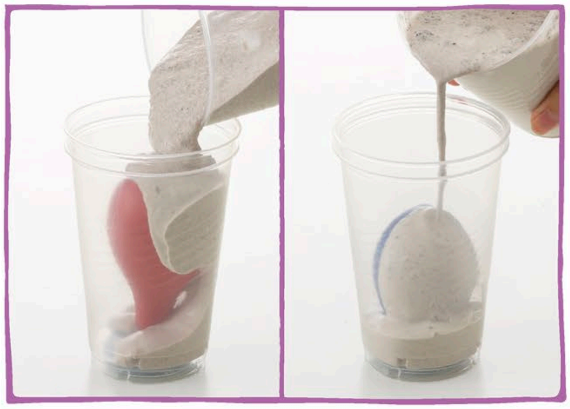
7 Put each cup you have just prepared inside another cup, to prevent the plaster of paris from leaking in the next step.

8 Take one of the cups containing plaster of paris and gradually add water until the plaster is the consistency of thick pudding. Mix it with the craft stick.



If the plaster becomes too thick, add a little more water and stir.

9 Add some sand and then some soil to your plaster. Mix it well with the craft stick.



10 Pour your plaster mixture over the red balloon. Now take the second cup with plaster of paris in it. Repeat steps 8 and 9, but this time pour the mixture over the blue balloon.

11 You'll now have two cups, each full of plaster, soil, and sand, with the red balloon inside one cup and the blue balloon inside the other. Let them set overnight in a place where they won't get knocked over.

12 The next day, the plaster should feel as hard as rock. Remove the outer cups and pull off the adhesive putty covering the balloon knots.

13 Cut off the excess rubber above the knot of each balloon. Be careful not to cut off the knot itself or the balloons might leak.

14 Cut a slit in each plastic cup with the scissors, and peel away the plastic to leave your "rocks" with the balloon ends sticking out.

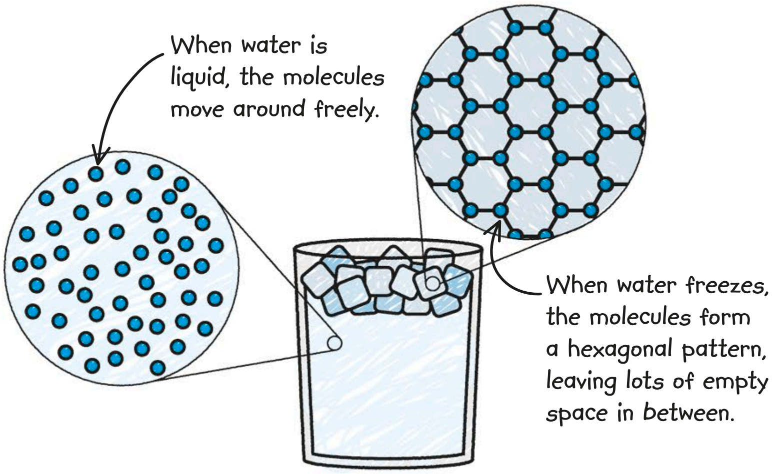
Be careful of the sharp edges when cutting off the cup.

15 Place both rocks in the freezer and leave them there overnight. You could put them on a tray to avoid any mess. The temperature of the water, the air, and the plaster will fall below the freezing point. The water in the balloon will freeze.

16 The next day, take your two rocks out of the freezer and examine them. You should find the water-filled blue balloon has expanded and broken the plaster.

HOW IT WORKS

Water is made of extremely tiny particles called molecules. Even in a tiny drop, there are trillions of water molecules. When water is liquid, the molecules move around each other, but when it freezes, they lock together in a regular hexagonal pattern. This pattern takes up more space than the molecules did when the water was liquid, which is why the water expands in the freezer, breaking the plaster. By contrast, air molecules pull closer together as they get colder, so the red balloon doesn't affect the plaster at all.



REAL-WORLD SCIENCE
CRACKED ROCKS

Freeze-thaw action frequently happens in deserts, where the temperature can reach 122°F (50°C) during the day, but regularly falls below freezing at night. Freeze-thaw action doesn't just affect rocks, however. The expansion of water as it freezes can crack water pipes in homes, too. It can even break car engines, so people often put antifreeze into their car engine's cooling system during the winter, which prevents the water from freezing.

WATER POWER

The projects in this chapter give you the chance to experiment with perhaps the most important and fascinating *substance* on Earth: water. As a liquid, water has some amazing properties, and you'll be working with them in lots of different ways—including making your very own giant *bubbles*. But you'll get to experiment with ice, too, by making your own ice cream!

FLOATING AROUND

Small bubbles have very tight, perfectly spherical surfaces, and they tend to fall quite quickly to the ground because they contain hardly any air. Bigger bubbles, on the other hand, contain loads of air, so they float longer. The surfaces of big bubbles are less tight than those of smaller bubbles, which means they create all sorts of wobbly shapes.

GIANT BUBBLES

It's wonderful to watch huge, colorful bubbles float gracefully through the air. In this activity, you'll learn how to make a really great bubble mixture and a bubble maker, so you can make enormous, glistening bubbles. These bubbles can make a sticky mess when they burst, so this is definitely an activity you'll need to do outside!

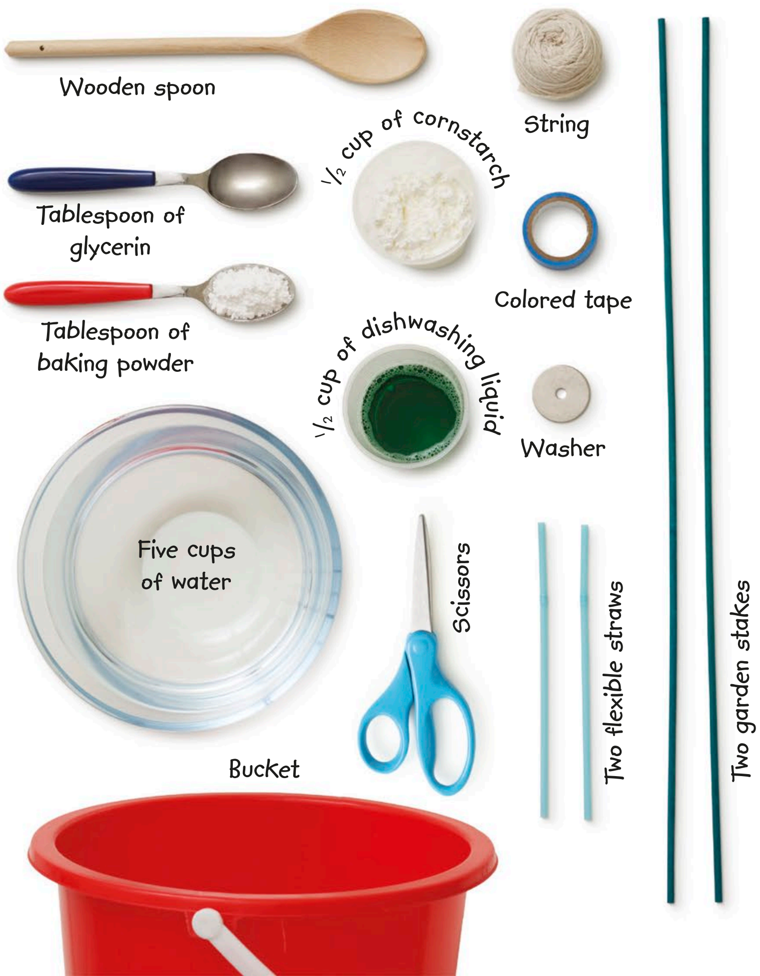
HOW TO CREATE
GIANT BUBBLES

You'll have the best chance of making large, long-lasting bubbles if the air is humid, just before or after rainy weather. Air is humid if it has lots of water vapor in it. When there's lots of water in the air, the water in the soap film evaporates much more slowly—that's why the bubbles last longer.

Time
90 minutes

Difficulty
Medium

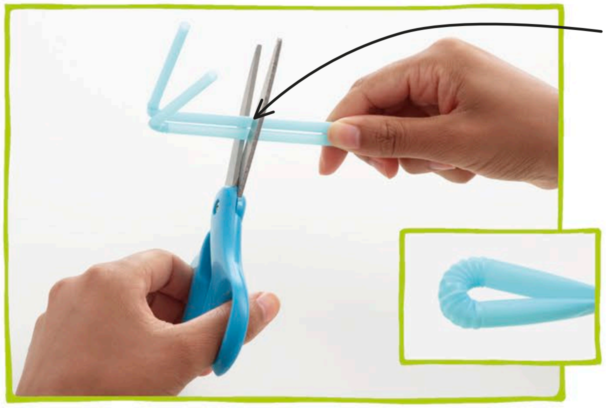
WHAT YOU NEED



1 Add the water to the bucket. The water should be a little bit warm to help the ingredients mix.

2 Mix the cornstarch into the water and stir it in using the wooden spoon. If it sinks to the bottom, just stir it up again.

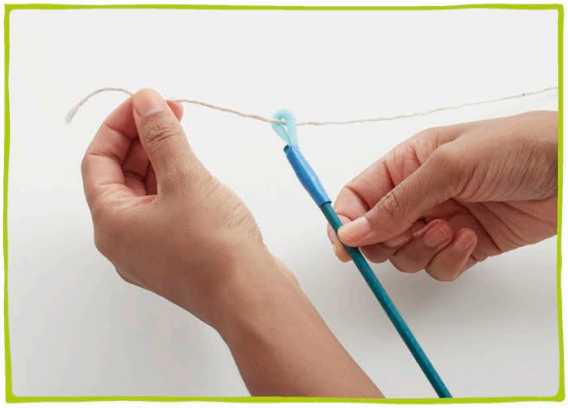
3 Pour in the glycerine, baking powder, and dishwashing liquid. Stir gently, trying not to create too much foam. Let the mixture rest for about an hour, but stir it occasionally.



4 Now you can build the bubble maker. Cut two straws in half, then fold each half in half again at the flexible part to create a loop.

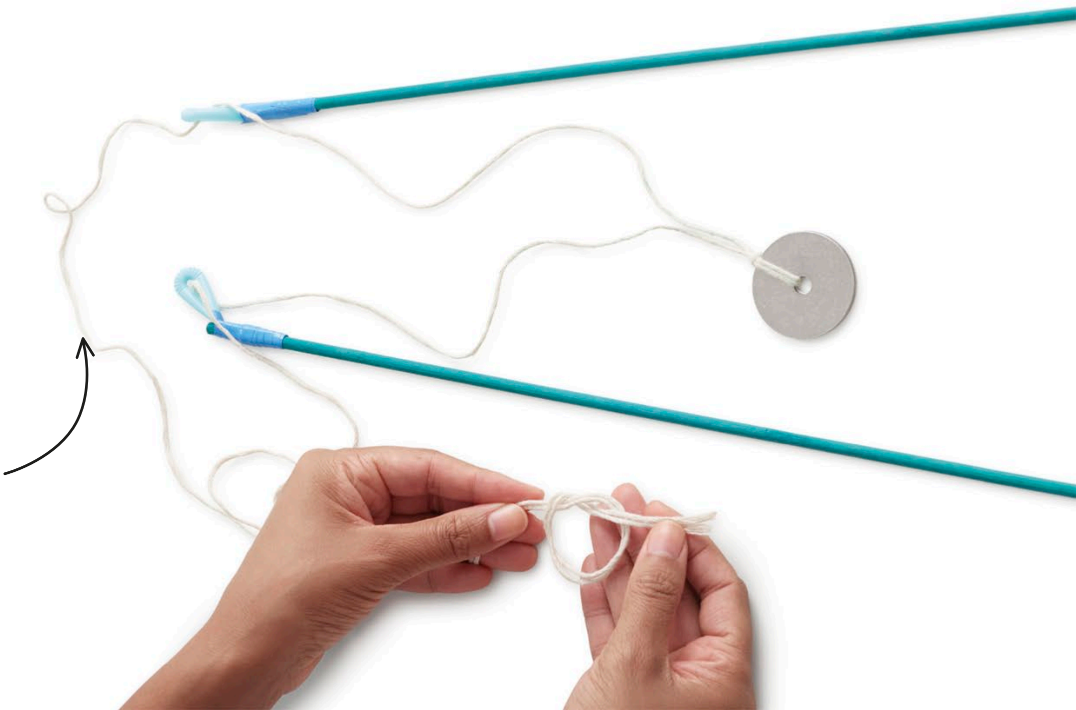
5 Press the loop against the top of one garden stake, then tightly wrap a piece of tape around both to hold the loop in place. Repeat for the other garden stake.

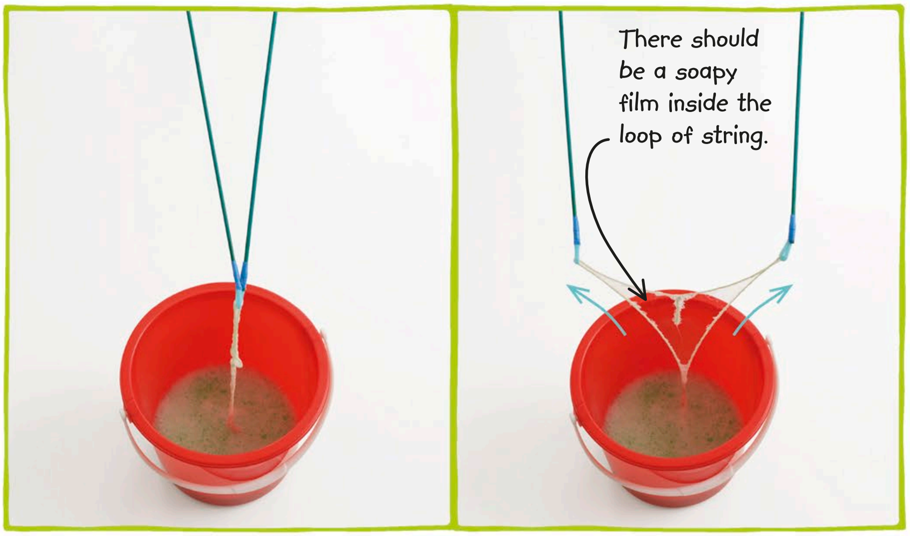
6 Cut a piece of string 6½ ft (2 m) long. Tie the washer onto the string at the halfway point with a knot or a loop, so that it creates a weight to pull the string down.



7 Thread one end of the string through each of the loops.

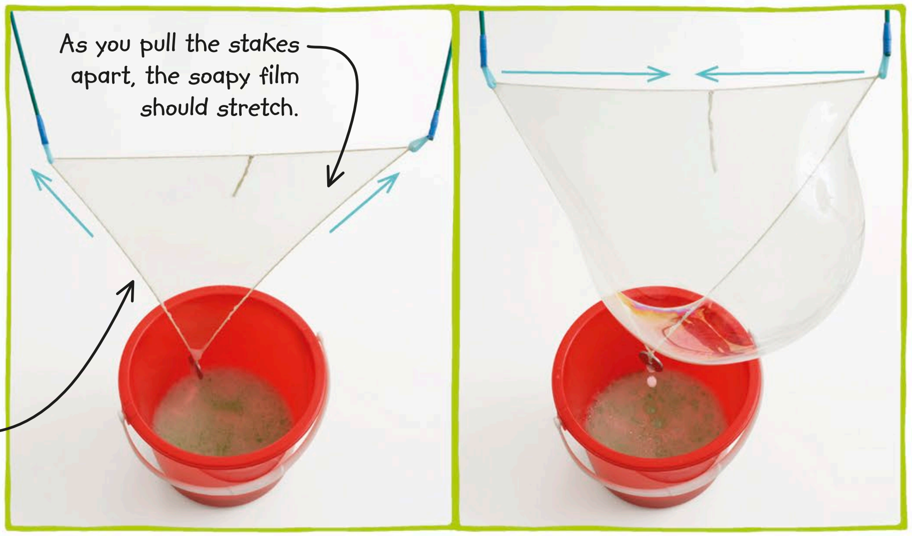
8 Tie the two ends of the string together so that the string makes a complete loop. Your bubble maker is ready—it's time to make some giant bubbles.





9 Dip the string into the mixture and swirl it around. Lift the string from the bubble mixture by gently pulling the stakes out of the bucket. Keep the stakes fairly close together for now, and make sure the string has been soaked with the mixture.

10 Once you have fully lifted the bubble maker out of the mixture, slowly move the stakes apart. You might need to practice a little bit. As you pull the stakes apart, take a step backward to trap some air inside the soapy film. To close up a bubble, bring the stakes closer together.



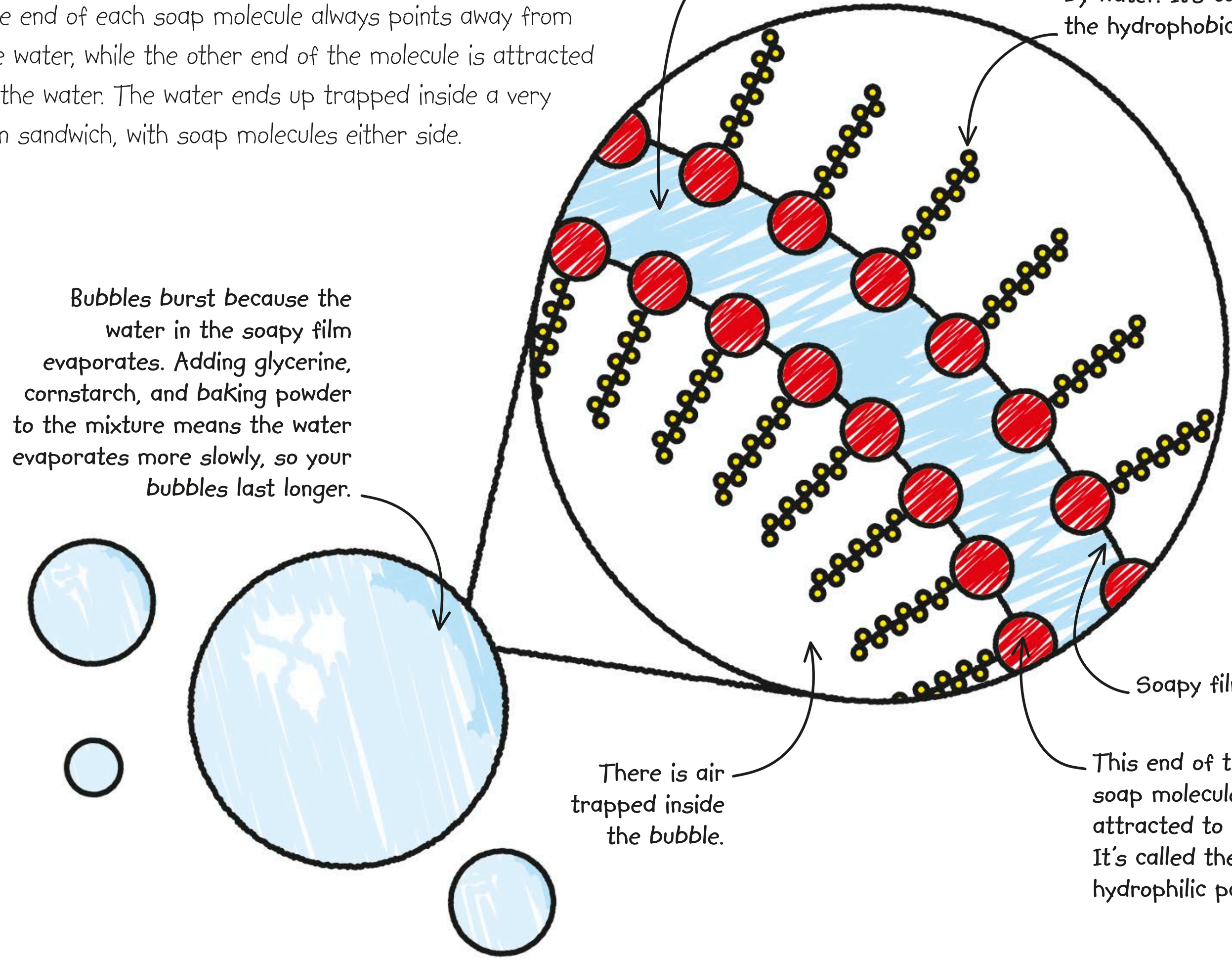
You can experiment with different string types for the bubble maker, or add different ingredients to the mixture.

TAKE IT FURTHER

Try putting your hand through the soapy film inside the loop of string—the film will burst, but only if your hand is dry. When your dry hand makes a hole in the film, the water pulls back in all directions, and the film breaks. But with a wet hand, the water in the film clings to the water on your hand. When you pull your hand out, the film reseals behind you. The bubble mixture might irritate your skin, so you might want to wear protective gloves for this part.

HOW IT WORKS

A bubble is like a balloon, but instead of stretchy rubber holding the air inside, there is a stretchy film of soapy water. Water by itself won't make a bubble because water molecules cling together too strongly, forming droplets instead of a film. But adding soap changes that. One end of each soap molecule always points away from the water, while the other end of the molecule is attracted to the water. The water ends up trapped inside a very thin sandwich, with soap molecules either side.



REAL-WORLD SCIENCE

BUBBLES IN NATURE

Bubbles are often found in nature. Some substances produced by plants or animals dissolve in water and act a bit like soap. They form thin films of water and air gets trapped inside. Bubbles happen where there is splashing—like at the bottom of a waterfall—and some animals even produce them on purpose. This violet snail blows bubbles in its mucus to make a floating raft, which it uses to drift across the open sea for hundreds of miles.

SPINNING WHIRLPOOL

When water empties down a drain or an oar is pulled through water, you'll see spiraling, funnel-shaped whirlpools, or "vortices." These twisting currents also form in lakes, rivers, and the oceans, where waves and tides create streams of water moving in opposite directions. With just two plastic bottles, food coloring, strong tape, and some water, you can make your own mesmerizing whirlpool device.

WHIRLING WATER

These whirlpool devices each use two bottles taped together, one on top of the other. One of the bottles is full of water, and the other is full of air. Turn the device so that the water is collected in the top bottle, and give it a slight shake. The water will start spinning and a whirlpool will form. You can use your device again and again—just turn it the other way around each time!


A force called centripetal force acts on the water, causing it to spin inward toward the center.
The water spins fastest at the center of the vortex.

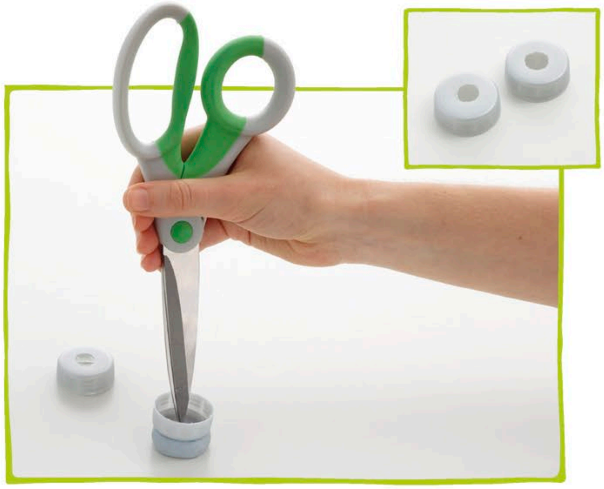
HOW TO CREATE A
SPINNING WHIRLPOOL

Time
15 minutes

Difficulty
Medium

These whirlpool devices are a bit like hourglasses, but they contain water instead of sand. They are easy to make. You will need two large plastic bottles and some colored water. You'll need to make sure the point where the bottles meet is watertight to avoid any leaks.

WHAT YOU NEED



1 Place a bottle cap upside down on a piece of adhesive putty. Using the scissors, make a neat hole in it about ½ in (1 cm) in diameter with the scissors. Repeat with the other cap.

2 Fill the measuring cup with water and add some food coloring. You'll need enough water to fill a large bottle nearly to the top, so you'll probably have to fill the cup more than once.

3 Pour colored water into one of the bottles, almost to the top. Make sure you do this outside or over a sink. Leave the other bottle empty.

4 Screw on the caps of both bottles tightly enough to make a watertight seal. An adult can help you with this step.

5 Place the bottle that's filled with just air upside down on top of the bottle containing water. Try to line up the holes in the two caps.

6 Wrap strong tape around both bottles' lids. Pull it tight, so it holds the bottles firmly together and won't allow water to leak out.

7 Turn the device upside down. If you don't disturb the water too much, it should stay in the top bottle, even though it's heavier than the air below.

The water is pressing down on the air in the bottom bottle.

If you've taped the bottles securely, they shouldn't leak, but it's a good idea to do this experiment outside, just in case.

The bottom bottle might look empty, but it's not—there is air inside pushing back against the water.

Some water may drip into the bottom bottle as you steady your whirlpool device.

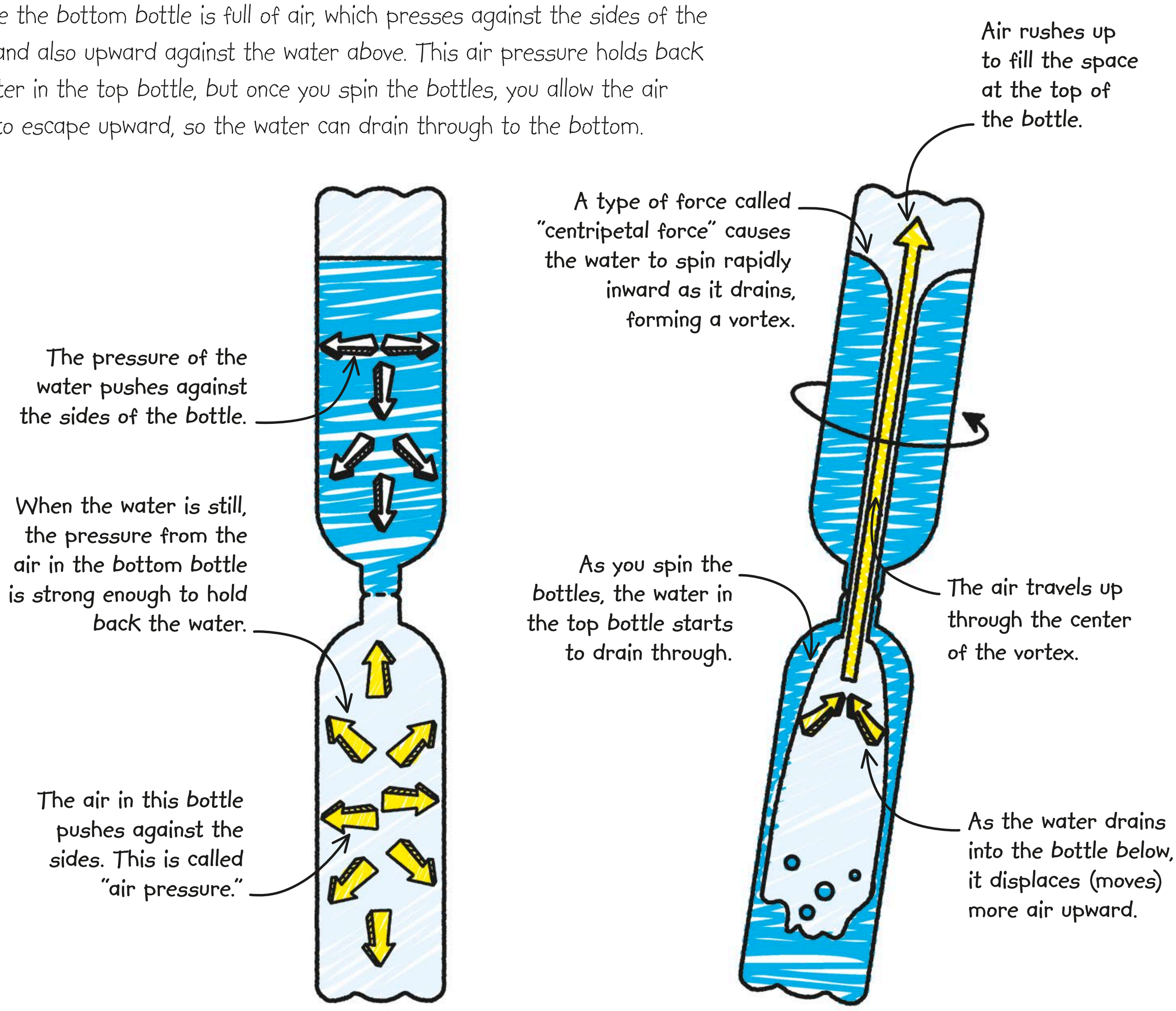
8 Hold the bottles and twirl them around. Rotating the bottles causes the water to spin, creating a vortex. The water will slowly begin to pour through the connection.

As the water drains through, what shape does it make?

This whirlpool has already been spinning for a while, so there is lots of water in the bottom bottle.

HOW IT WORKS

When you first tip the whirlpool device upside down, the water doesn't drain through, even though it's heavier than the air in the bottle below. This is because the bottom bottle is full of air, which presses against the sides of the bottle and also upward against the water above. This air pressure holds back the water in the top bottle, but once you spin the bottles, you allow the air a way to escape upward, so the water can drain through to the bottom.



REAL-WORLD SCIENCE

TORNADOES

The vortex you've created in your whirlpool bottles looks a lot like another kind of vortex: a tornado. These dangerous and terrifying swirling winds extend down from the base of thunderclouds and can destroy trees, houses, and cars. A tornado forms when a downward current of air from a thundercloud draws in air from all around it, creating a rapidly spinning column with very fast winds.

Stick colored pencils through a bag full of water without spilling a drop!

WHAT IS WATER?

Water is made of extremely tiny particles called water molecules. These molecules are so small that even a drop of water is made of trillions and trillions of them. In liquid water, the molecules move around each other freely, which is why water flows. But water molecules also cling to each other, which is why you see droplets if you spill some water.

WONDERFUL WATER

We use water every day—to wash, cook, and drink, to water plants, and to swim in. It fills Earth's rivers, lakes, and oceans, and we often see it fall as rain—so we're all familiar with how water feels and behaves. Yet water can still surprise us, as these three activities demonstrate. You'll need to do these experiments outside, or at least over a kitchen sink—you might get wet!

Learn about density with these colorful jars of saltwater.

When these pins are pulled out, what do you think will happen?

HOW TO MAKE A
WATERTIGHT WONDER

Here's an amazing science trick that looks like magic: stick pencils right through a plastic bag filled with water... without any of the water leaking out! But do this activity outside because the water will spill when you pull the pencils out. The tricky part is pouring the water into the zippered plastic bag, so ask someone if they can hold the bag open for you.

Time
15 minutes

Difficulty
Easy

WHAT YOU NEED

1 Set the bag on a flat surface, then slowly and carefully fill it nearly to the top with water. Ask someone to hold the bag open for you if you need.

2 Seal the top of the bag tightly and securely, trying not to spill any water.

Make sure your pencil is sharp.

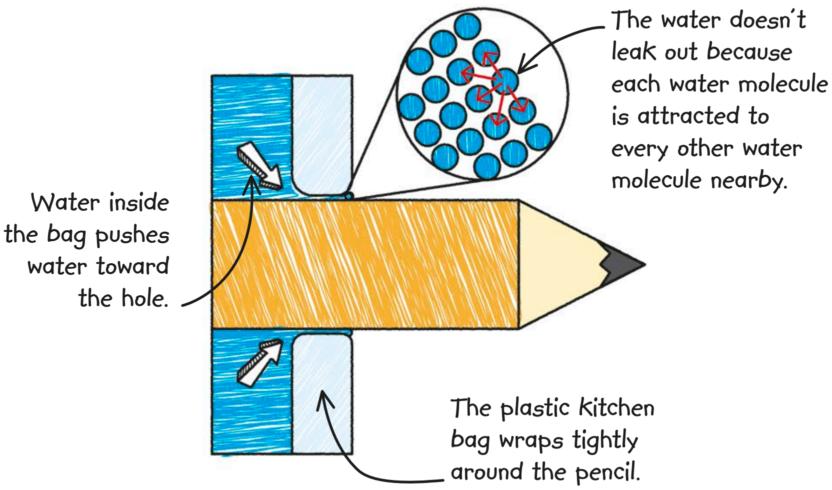
3 Holding the bag at the top with one hand, push a pencil, sharpened end first, through the bag in one smooth movement.

Water molecules are cohesive, which means they are attracted to each other.

4 Stick all your pencils through the bag one by one. Still no water leaks out! Remember, go outside or hold the bag over a sink when you remove the pencils.

HOW IT WORKS

Plastic kitchen bags are made of polyethylene, a strong but flexible material. When the pencil makes a hole through it, the polyethylene wraps tightly around the pencil, but leaves a tiny gap—a hole through which water could escape. Water molecules cling together, so if a hole is small enough, the clinging force between the water molecules near the hole is strong. If it's stronger than the push from the water molecules inside, the water won't escape. Make the hole much bigger and the molecules can't hold back the pressure from inside, and the water leaks out.



REAL-WORLD SCIENCE
WATER DROPLETS

The way water molecules pull together explains why water forms around droplets whenever it can. Without a strong pull of gravity, water droplets are perfectly round and hang in the air, like this droplet hanging in the air in the International Space Station.

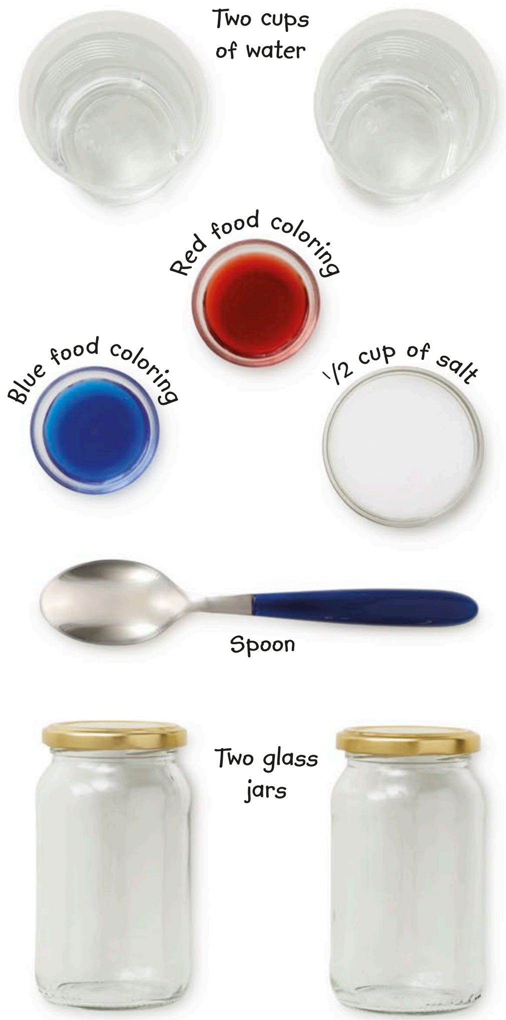
HOW TO MAKE
SALTWATER JARS

Time
15 minutes

Difficulty
Easy

In this activity, you will add salt to a cup of water until no more will dissolve. Adding salt increases the density of the water because you've packed more mass (stuff, or "matter") into the same volume (how much space the water takes up). Mixing the salty water with pure water in two different ways will give surprising results.

WHAT YOU NEED



1 Pour blue food coloring into one of the plastic cups of water. Stir it with the spoon until the water is completely blue.

2 Pour red food coloring into the other cup of water and use the spoon to stir it.

3 Add salt to the red water and stir it to help it dissolve. You've added enough salt when no more will dissolve.

4 Pour half the blue nonsalty water into one of the glass jars, and half the red salty water into the other.

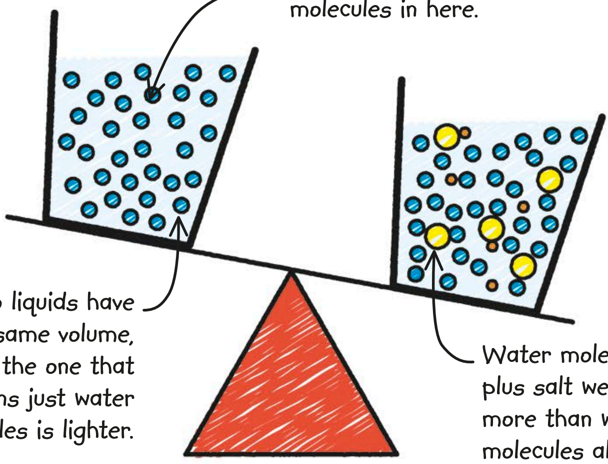
5 Now it's time to top up the jar containing blue water. So you don't disturb it, slowly add the rest of the red water into the jar by pouring it over the back of the spoon.

6 Carefully pour the rest of the blue water onto the back of the spoon and into the jar containing the red water.

7 Let the two jars stand for a while. You should see that in one jar the two colors mix together, but in the other jar the colors remain separate.

HOW IT WORKS

Adding salt to the red water hardly changes its volume, but it does add lots of mass, making it denser than the blue nonsalty water. When the denser red water is poured on top of the blue water, it sinks through it and the two colors mix. When you pour it the other way around—the red water before blue—the blue water floats on top because it has been placed on a liquid with a higher density.



REAL-WORLD SCIENCE
UNDERWATER LAKES

In this picture, the diver is swimming above a lake of very salty water—but that lake is under water! Just as happened in the activity, the salty water stays at the bottom because it is more dense than the freshwater above it. Salty water is called brine, and underwater lakes of salty water are called brine pools.

HOW TO MAKE A
PIN BOTTLE

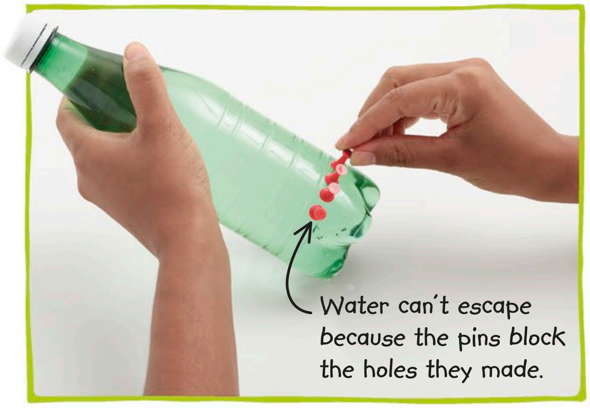
Learn how to make water defy gravity! You can make holes in a full bottle of water without the water leaking out, as long as the cap stays firmly closed. This simple but surprising activity lets you explore the forces of water pressure and air pressure. Make sure you recycle the bottle after you finish the experiment.

Time
15 minutes

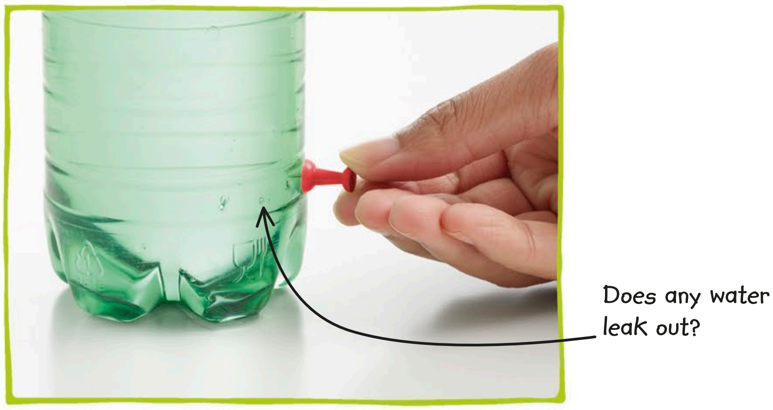
Difficulty
Easy

WHAT YOU NEED

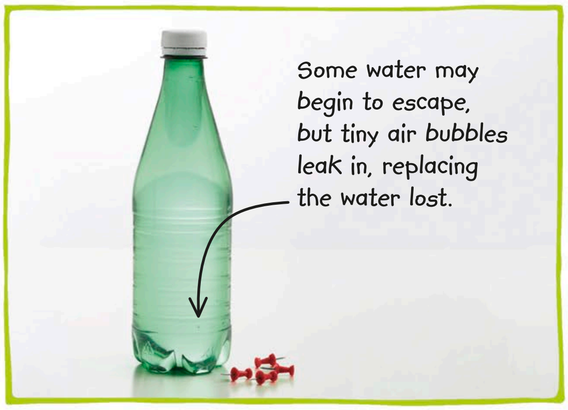
1 Take your bottle full of water and poke a pin carefully through the bottle near the bottom, leaving the pin in place.



2 Add more pins, pushing them straight in, not at an angle. You can put the pins wherever you like. Here they are placed in a line near the bottom of the bottle.



3 Now for the tricky part. Carefully remove the pins one by one. Pull them straight out, not at an angle, so that the holes they leave behind are small and round.



4 Once all the pins are out, watch the bottle for a few moments. You should find that almost no water escapes, despite the fact that there are holes in the bottle.

Atmospheric pressure stops the water from streaming out.

5 Try to do this step over a sink or outside, if you can, because it's messy. Unscrew the bottle's cap. Water will start pouring out through the holes!

What happens when you make the holes vertically above each other instead of horizontally alongside each other?

Water streams out, pushed down by the water above.

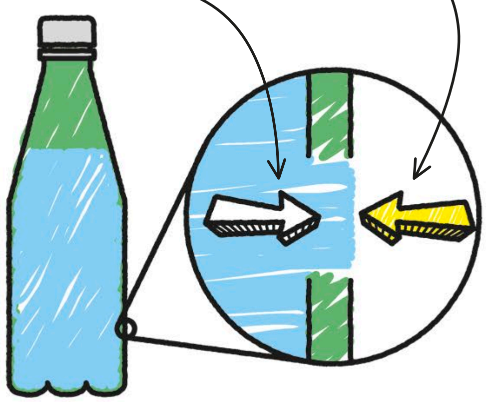
HOW IT WORKS

There are two forces acting on the water at the bottom of the bottle, just inside the holes. First, there is atmospheric pressure—the push of the air outside the bottle. Second, there is the force of the water at the top of the bottle, which eventually pushes the water at the bottom through the pinholes. Atmospheric pressure is enough to stop the water from escaping through the holes... until you unscrew the cap. When the cap is removed, air rushes into the bottle. This air pushes down on the top of the water, which causes it to start leaking out.

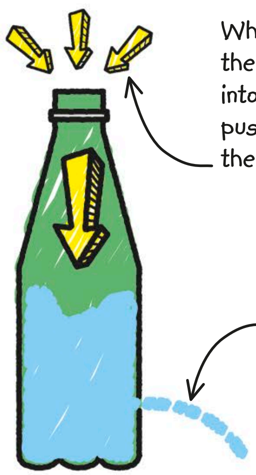
CAP ON THE BOTTLE

Water pressure pushes from this side.

Atmospheric pressure pushes against the water.



CAP OFF THE BOTTLE



When you unscrew the cap, air rushes into the bottle, pushing down on the water.

Water streams out of the pinholes—that's why it's best to do this outside!

ICE CREAM

Everyone knows that a tasty bowl of ice cream is a delicious treat on a hot summer's day. But did you know that making your own ice cream is just as fun as eating it? All you need is some science, a few simple ingredients—milk, cream, and sugar—and lots of energy to shake and mix the ingredients together. You can even add chocolate chips or strawberries to re-create your favorite flavors, and sprinkles for decoration.

TASTY TREAT

Ice cream is a mixture of milk and cream that has been cooled to below freezing. As the temperature drops, the water in the milk and cream freezes into tiny ice crystals, giving the ice cream its distinctive texture.

Add sprinkles or candy to your ice cream for extra crunch.

Small pieces of strawberry in your mixture will give your ice cream a splash of color.

HOW TO MAKE
ICE CREAM

This mouthwatering activity is straightforward but it can get a little messy, so it's best to do it outside. First of all, before handling the ingredients, you'll need to wash your hands. And remember to check that all of the bags are securely sealed before shaking and throwing, so that none of your ice-cream mixture or salty ice escapes.

Time
40 minutes

Difficulty
Medium

WHAT YOU NEED

1 Hold open one of the small zippered bags and pour the heavy cream into it. Cream is made of water, with droplets, or globules, of fat mixed in.

2 Pour the milk into the same bag. Like cream, milk is mostly water, but it has fewer globules of fat.

3 To make your ice cream taste sweet, add the sugar. The sugar helps stop the ice crystals that form in the mixture from getting too big.

Seal part of the bag, then squeeze the air out of the opening.

Make sure both bags are sealed securely. You can add tape if you need to.

4 The final ingredient is a dash of vanilla extract. You don't need to stir the bag's contents, but be sure to squeeze the air gently from the bag before sealing it securely.

5 Place the bag containing the ingredients in the second small bag. Protecting the ice cream mixture inside an extra bag ensures that it won't mix with any of the ice and salt you'll use next.

Carefully pour the ice into the large empty bag.

6 Fill the large zippered bag with ice, then put your bag of ice cream ingredients inside. The ice will start to draw heat from the milk and cream immediately, but by itself, it won't take away enough heat to freeze the ice cream.

7 When your ice-cream mixture is nestled in among the ice, pour in the salt and seal the bag. Putting salt into the bag causes the ice to draw much more heat away from the milk and cream. In fact, the temperature of the ice can drop to a chilly -6°F (-21°C), so be careful not to touch it.

Pour the salt into the large zippered bag, over the ice.

Inside, the ice and salt mixture is already drawing heat from the milk and cream.

A thick plastic bag is best.

8 Wrap the bag in a double layer of dish towels like a package. This will protect your hands from getting too cold and make your ice-cream mixture easier to throw and catch, too.

9 Place the package into a plastic bag, keeping the dish towels tightly wrapped around the sealed bag of ice.

Ice cream is a mixture of solids, liquids, and gases.

10 Tie a knot in the open end of the plastic bag, and then shake, massage, whirl, and throw the bag around for about 15 minutes. Keep the mixture moving while it cools, otherwise the ice crystals in the milk and cream will grow too large, and the ice cream won't be smooth and creamy.

11 Wash your hands, then untie the plastic bag and unwrap the dish towels. Carefully unseal the large zippered bag to avoid spilling any melted ice. Finally, take out the smaller zippered bags and open them to reveal your very own homemade ice cream!

If the ice cream is too soft, seal everything back up and shake it for a few more minutes.

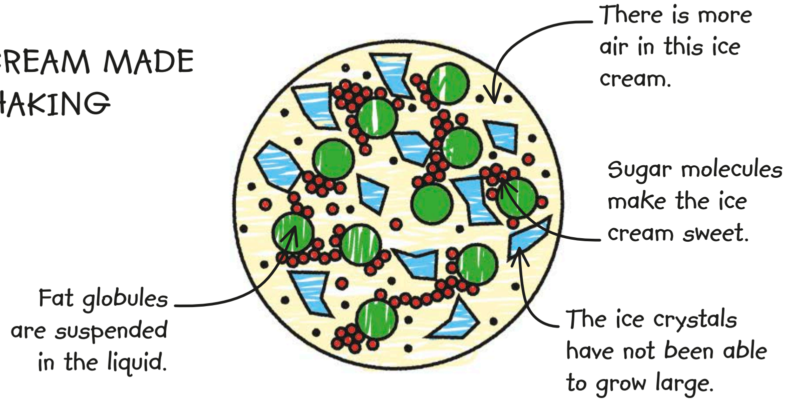
TAKE IT FURTHER

The steps in this experiment will make enough vanilla ice cream to share with three friends, but if you want to make more, just double the amounts of the ingredients and use bigger zippered bags. For a bit of variety, and to make your vanilla ice cream taste even better, try introducing different flavors by putting little pieces of fresh fruit or chocolate chips into the mixture before freezing it. Once it's ready to eat, serve up your scoops of ice cream in a bowl, or in a cone if you prefer.

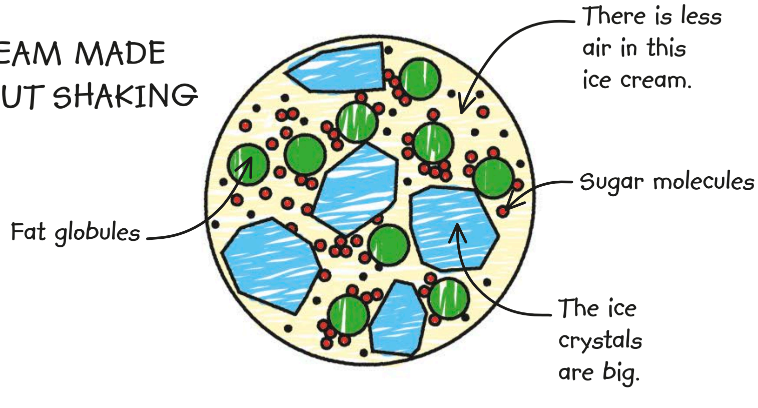
HOW IT WORKS

There are three states of matter: solid, liquid, and gas. Even though its temperature is below freezing, ice cream is actually not a solid. It's a type of substance called a colloid: a mixture in which small pieces of one substance are mixed evenly into another. Ice cream is made of ice crystals (solid), fats (liquid), and tiny bubbles of air (gas). Shaking it around while it cools down means the ice crystals don't grow too big, ensuring your ice cream is smooth and creamy.

ICE CREAM MADE BY SHAKING



ICE CREAM MADE WITHOUT SHAKING



REAL-WORLD SCIENCE
TYPES OF COLLOID

Many of the substances we use every day are different types of colloid. Whipped cream is a type of colloid called a foam: a mixture of tiny gas bubbles in liquid. Mayonnaise is a mixture of tiny droplets of oil in water, a colloid known as an emulsion. Mist and fog are made of tiny water droplets suspended in the air. This type of colloid is called an aerosol.

MARBLED PEBBLES

Add splotches of shiny nail polish to a bowl of water and then dip pebbles in to create these swirly, marble-effect patterns. These pebbles will make a unique gift or an eye-catching display in a garden. It's possible because nail polish is immiscible with water—this means they won't mix. Instead, the polish floats in a colorful film on the water's surface, ready for you to dip your pebble in.

The bright patterns on these pebbles are made by dipping them in nail polish and water.

COLORFUL PIGMENTS

Nail polish is a suspension: a liquid containing tiny droplets or solid particles that are hanging, or "suspended," so that they don't easily settle. The suspended particles are tiny grains of pigment, the compounds that give the polish its color.

HOW TO CREATE
MARBLED PEBBLES

Most nail polishes are very smelly, and breathing too much in can be harmful. Because of this, try to do this activity outside on a dry day or in a well-ventilated room. Also, put paper down, in case you knock over a bottle. If you do spill some nail polish, ask an adult to help clean it up.


Time
20 minutes


Difficulty
Medium

WHAT YOU NEED


Bowl of water
(an old bowl is best)


Adhesive putty


Toothpicks


Different-colored nail polishes


Pebbles

1 Before you begin, press the adhesive putty onto one side of a pebble. This will act as a handle, so you won't get nail polish on your fingers.

2 Pour small amounts of different colors of nail polish onto the surface of the water. Keep the polish in the middle of the bowl. Gel polishes won't work in this experiment.

3 Use the end of a toothpick to swirl the colors around gently to create a pattern. Be quick, since the polish will soon dry.

4 Pick up the pebble by its adhesive putty handle, and dip the pebble gently through the layer of nail polish into the water.

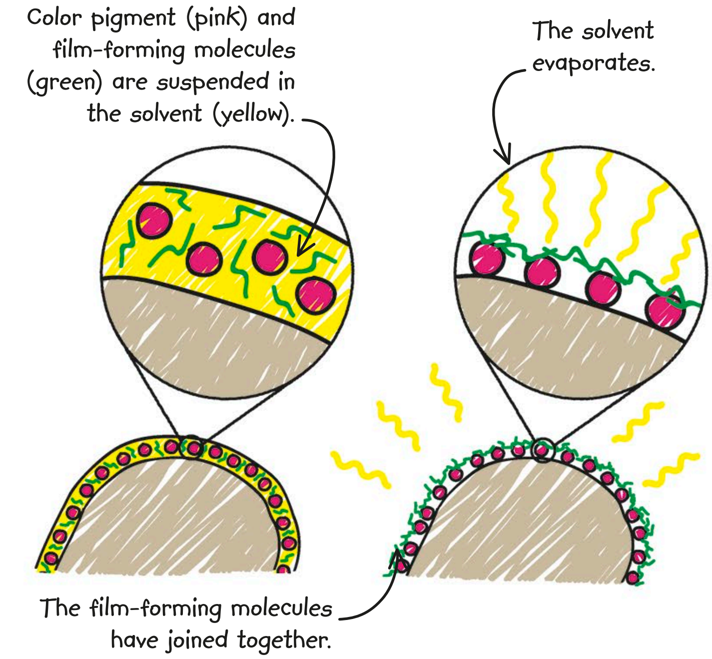
5 After just a second or two, slowly lift the pebble from the water. Hold it above the surface for a few seconds for water to drip off it.

6 Turn the pebble over and push the other end of the putty onto a flat surface. Let the pebble dry. Then try again with another pebble!

HOW IT WORKS

Nail polish is less dense than water, which is why it floats on, but won't dissolve in, water—the two substances are immiscible (unmixable). Nail polish contains three main ingredients: a pigment (this gives the polish its color), film-forming molecules (which form a hard protective film), and a solvent (a liquid in which all the other ingredients dissolve). The solvent evaporates quickly into the air, giving nail polish its smell and allowing it to dry quickly.

CROSS SECTION OF PEBBLE



REAL-WORLD SCIENCE

OIL SPILLS

Crude oil, from which gasoline and most plastics are made, is immiscible with water. When large ships carrying crude oil spill some, the oil floats on the ocean's surface. The oil sticks to the feathers of seabirds, and it can poison turtles and whales that come to the surface and swallow it.


40

EARTH AND SKY

The great outdoors! In this chapter, you'll be reaching for the sky—and finding out about the forces the air exerts—by making helicopters, a kite, and even a rocket! You'll also learn about planet Earth, with a sundial that tells the time using the sun's position in the sky and a magnetic compass that will help you find your way. You'll get a chance to make beautiful mineral crystals called geodes that normally form over thousands or millions of years!

TWIRLING HELICOPTER

The helicopter is a remarkable form of transportation. It can take off from a standing start, without the need for a runway, and perform intricate maneuvers in all directions. Using just a drinking straw and a piece of paper or card stock, you can make a simple helicopter model to explore the forces produced by helicopter rotors.

SPINNING WINGS

A helicopter rotor blade is a bit like an airplane's wing—it generates an upward force called lift as it moves through the air. But unlike an airplane's wing, which must travel forward to create lift, a helicopter's rotor blade rotates rapidly, so it can generate lift even when the helicopter is hovering in one place.

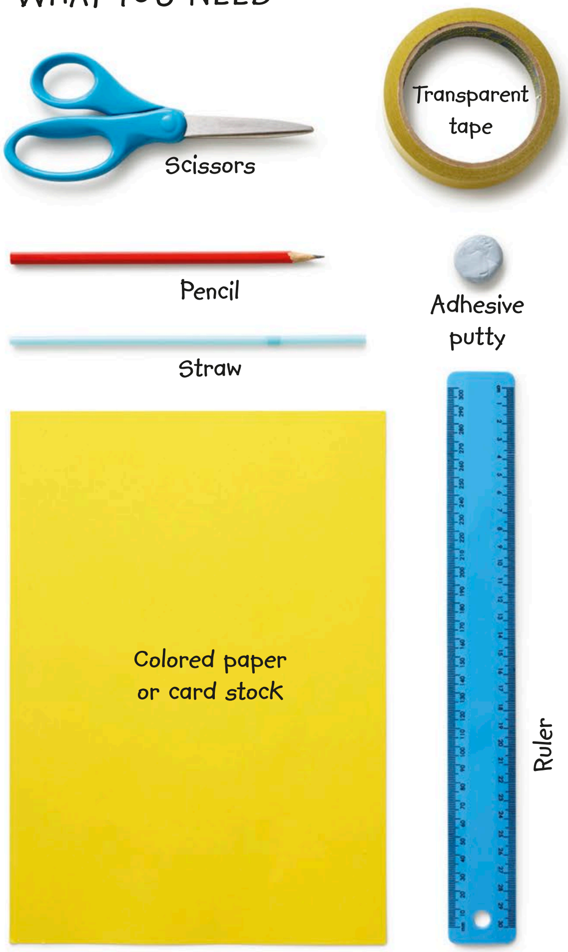
HOW TO MAKE A
TWIRLING HELICOPTER

Follow the instructions to make your own helicopter. It might need a bit of flight testing and adjustment. A snip off the ends of the rotor blade, or a slightly longer straw, could make a big difference. You can also test how different weights of paper and card stock affect your helicopter's flight.


Time
20 minutes


Difficulty
Medium

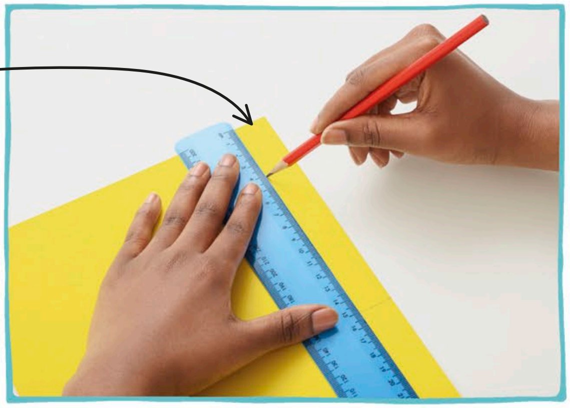
WHAT YOU NEED



You'll also find a template at the back of this book that you could trace, if you prefer.

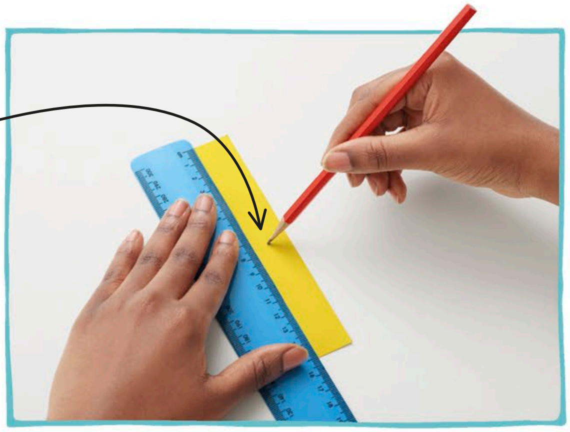
1 If you have a flexible straw, cut it off just below the bend. You'll need a straight piece of straw to make your helicopter stable as it flies.

2 Using the scissors, cut into the end of the straight piece of straw to a depth of about ½ in (1 cm). This will create two tabs that will hold the rotor blade in place.

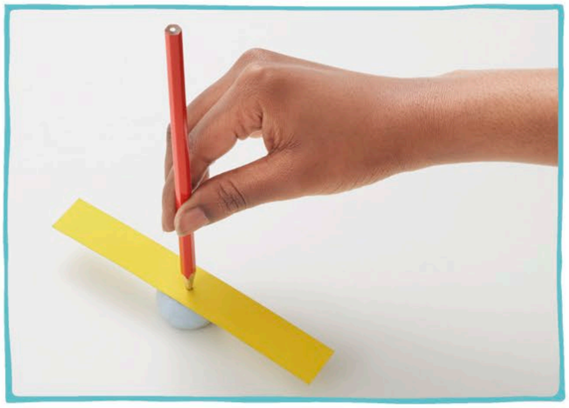


3 To make the rotor blade, lay the paper or card stock on a table and draw a rectangle in one corner, 1 in (2 cm) wide by 5½ in (14 cm) long.

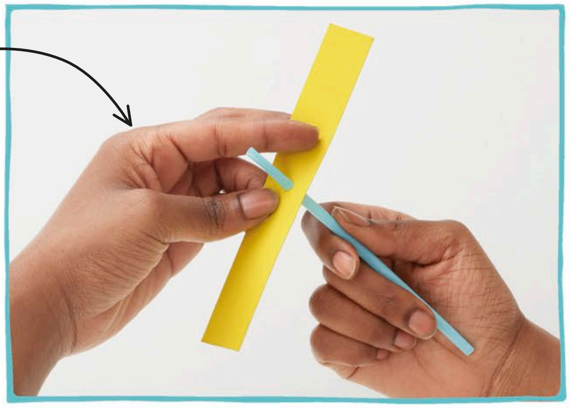
4 Cut out the rectangle you drew on the paper or card stock, trying not to bend it at this stage.



5 Measure halfway along the long side of the rectangle you just cut out—2¾ in (7 cm) from one end—and make a mark in the center.

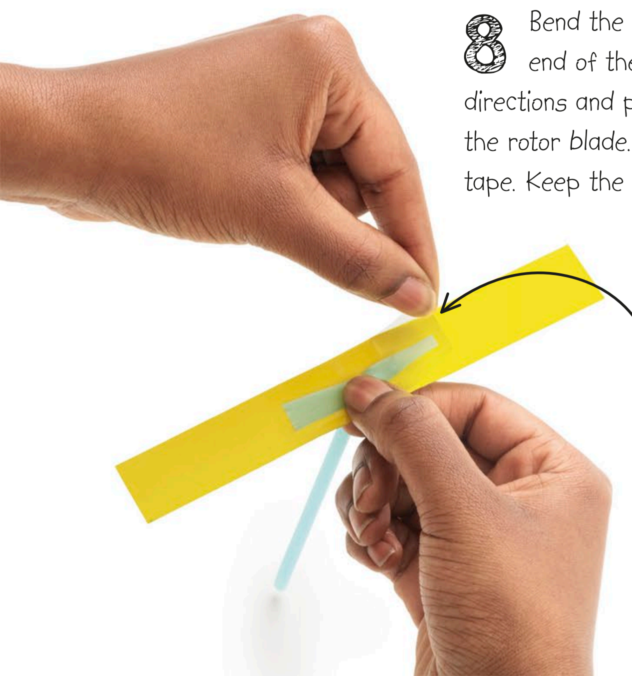


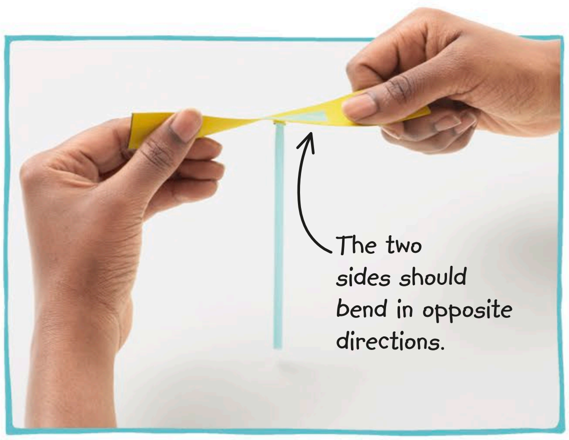
6 Place your rotor blade on top of the adhesive putty. Use the sharp end of a pencil to make a hole at the center point you have marked.



7 Push the cut end of the straw through the hole. If the hole is not quite big enough, carefully make it a bit bigger with the pencil.

8 Bend the two halves of the end of the straw in opposite directions and push them flat onto the rotor blade. Secure them with tape. Keep the rotor blade flat.





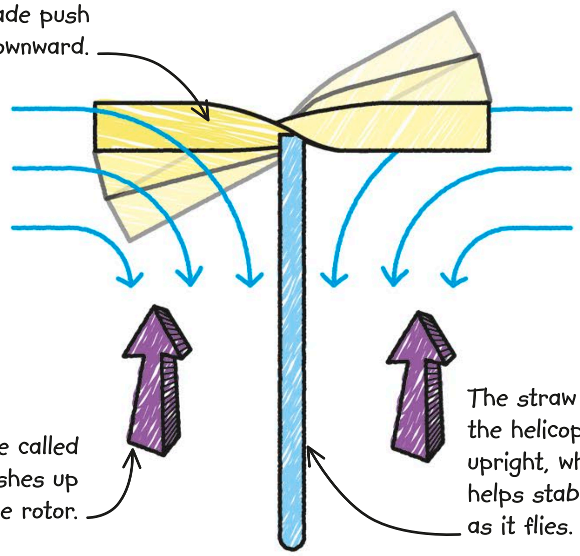
9 Now, finally, you can bend the rotor blade—otherwise your helicopter won't take off. Gently twist clockwise with each hand.

10 Your helicopter is ready! To make it fly, you need to hold the straw between your two palms, push your right palm forward, and release.

A helicopter rotor pushes air downward to create upward lift.

HOW IT WORKS

As the helicopter's rotor blade spins, its angled edges push the surrounding air downward, creating an area of high pressure air below it (and lower pressure above it). The higher pressure air pushes the rotor blade upward. This force is called "lift." Try making different helicopters to find the best combination of the length and width of the rotor, how much it is bent, and the length of the straw.



REAL-WORLD SCIENCE
UNPILOTED AERIAL VEHICLES

Unpiloted aerial vehicles (UAVs, or drones) have rotor blades similar to your helicopter. Electric motors propel the rotor blades, keeping them spinning—and generating lift. The faster they turn, the more lift they generate. To make the UAV change direction, the rotors on one side turn faster than the rotors on the other side.

DIAMOND KITE

When a breeze picks up, there's no better way to experience the power of wind than to fly a kite. The wind can take a kite soaring up high, while you're in control of it down on the ground. In this activity, you can make your own colorful kite that really flies, using things you have at home. If you are inspired by flying your kite, there are lots of other designs you can try. What about using different materials to make the sail? How about making a kite that's much bigger than this one, or one that has a much longer string?

LET'S GO FLY A KITE

Kite flying takes practice and patience, but you'll find it's worth the effort. A beach is a good place to fly a kite, if it isn't too crowded, because you'll often find a steady breeze on the beach. Don't fly a kite in a storm or if it's really windy, and never fly a kite near power lines or airports.

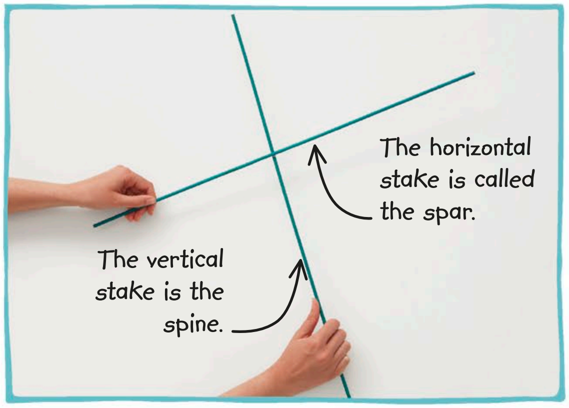
HOW TO MAKE A
DIAMOND KITE

To make your kite's sail, which catches the wind, you need to use a light, flat, and flexible material. This kite is made from two plastic bags. You'll need two stakes that are strong but flexible, and lots of string to tether the kite as it climbs into the sky!

Time
45 minutes

Difficulty
Hard

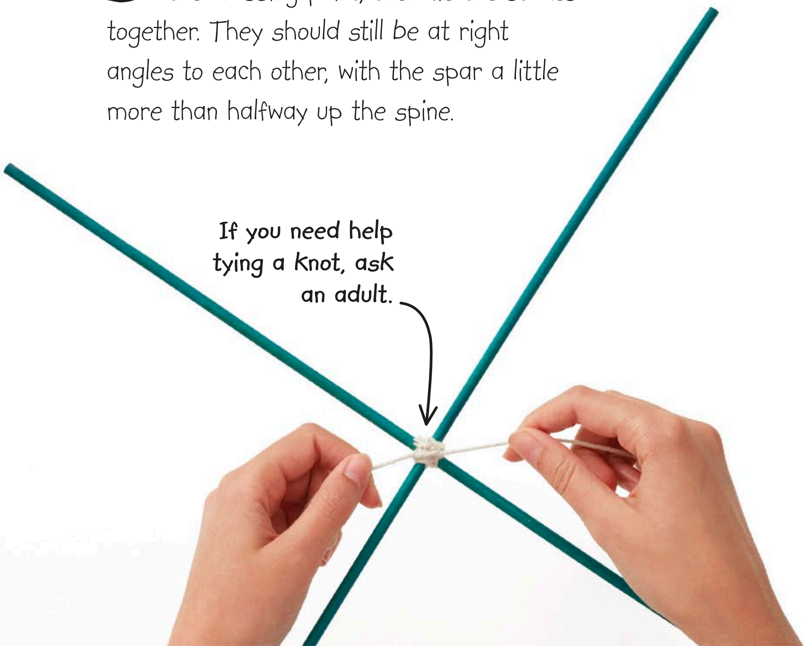
WHAT YOU NEED

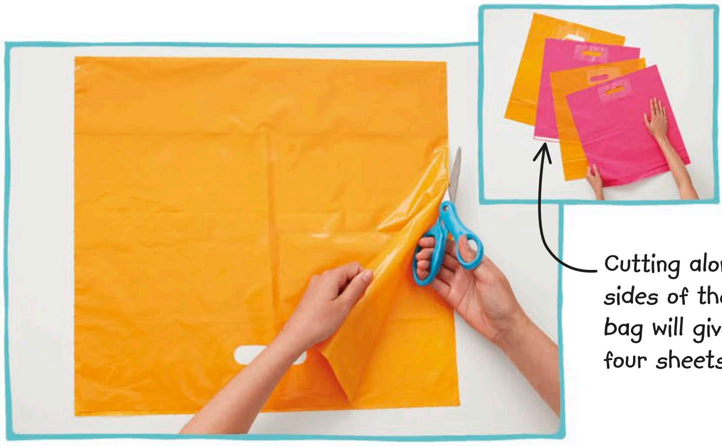


1 Place the two stakes at right angles to each other, with the horizontal one (the spar) a little more than halfway up the vertical stake (the spine).

2 Cut about 16 in (40 cm) of string, which you'll use to tie the spar and the spine together.

3 Wrap the string a few times around the crossing point, then tie the stakes together. They should still be at right angles to each other, with the spar a little more than halfway up the spine.

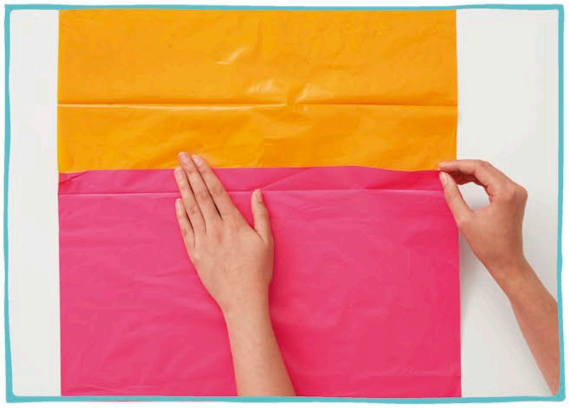




Cutting along the sides of the plastic bag will give you four sheets.

4 Cut open both sides of each plastic bag, and then cut across the bottom, so that you end up with four pieces the same size and shape.

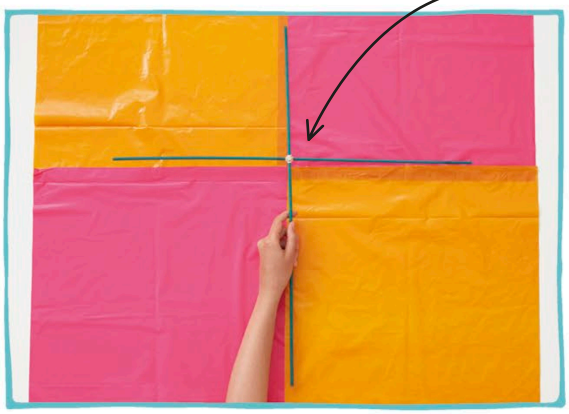
5 Stick double-sided tape along the bottom of one of the bags. Lay the tape as flat as you can. Peel back the protective layer.

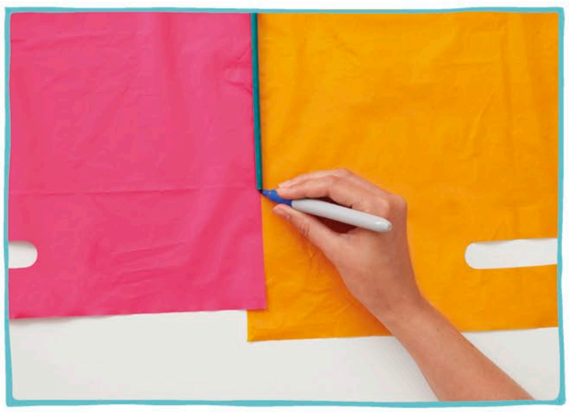


6 Attach a different colored piece of plastic by carefully placing it onto the double-sided tape on the first piece and pressing down.

7 Make a patchwork pattern, as shown, with all four pieces stuck together with double-sided tape. Make each seam as smooth as possible.

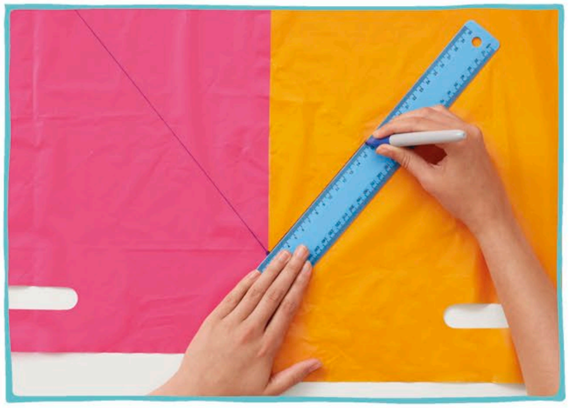
If the spar and the spine are at right angles, they should line up with the seams.





8 Lay the crossed stakes onto the patchwork pattern, so that the point at which the stakes cross is on top of the center of the plastic pieces.

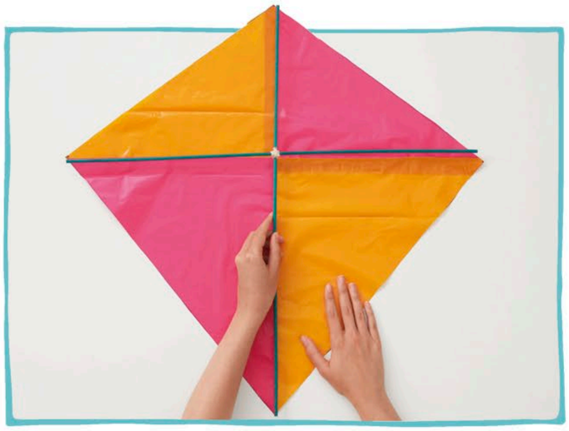
9 With the stakes still in place, mark the position of each end of each stake with the felt-tip pen. Then set the stakes aside.



10 Using a ruler and the felt-tip pen, draw straight lines between the four marks you just made to create the outline of your sail.

Keep these pieces of plastic—you'll need them to make the tail for your kite.

11 Neatly cut along the straight lines to reveal your diamond-shaped sail.



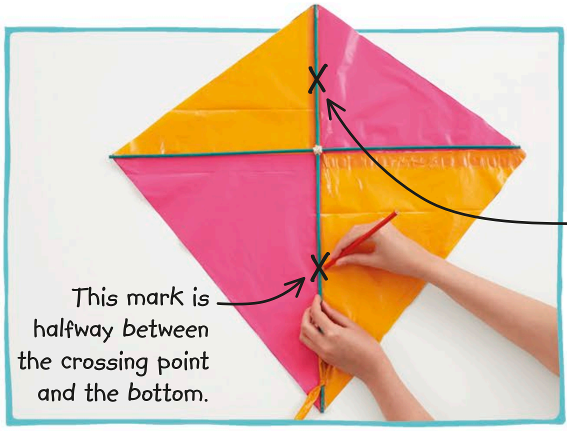
12 Carefully lay the crossed stakes on the sail so that the ends of the stakes line up with the points of the diamond shape.

13 Secure the ends of the stakes to the sail with tape. Make sure they are stuck firmly, otherwise your kite may fall apart in the wind!

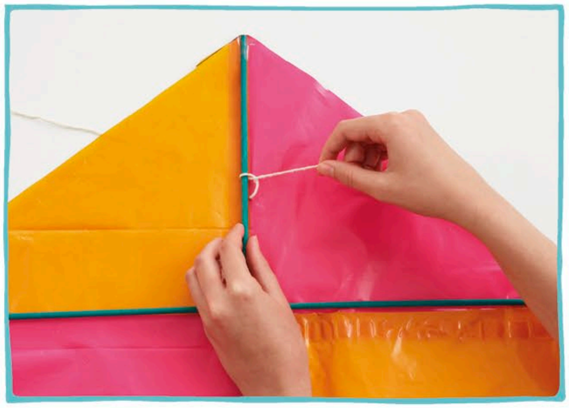
Tie each strip together with a knot.

14 To make the tail, cut strips from the leftover pieces of plastic and tie the strips together, alternating the colors.

15 Knot one end of the tail tightly to the spine, and slide it down to the bottom.



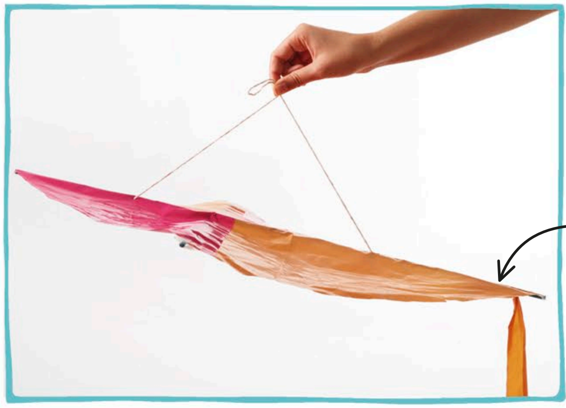
16 Mark one point halfway between the top, or nose, and the crossing point of the kite. Then add a second point halfway between the crossing point and the bottom, or tail. Place adhesive putty underneath and make a small hole in the sail at each mark using the pencil.



17 Cut a piece of string as long as the kite's spine, and thread the ends through the holes in the plastic sheet. Tie the string to the spine at the two points you marked.

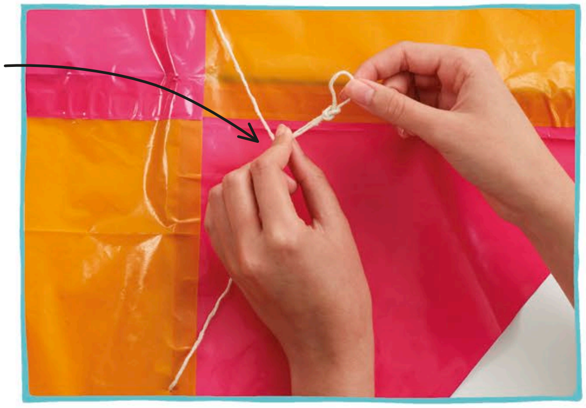
18 Turn the kite over and pull the string over to one side, moving your fingers along the string until they are over the spar. Keep hold of the string.

A kite is flown at an angle to the wind, so that air is forced underneath it.



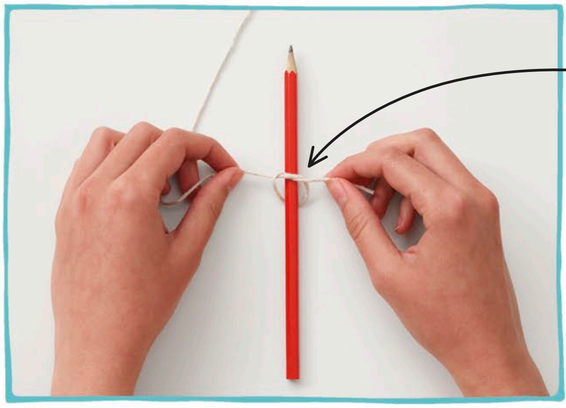
The tail end of the kite should be lower than the nose.

19 Still holding the string, hang your kite from your fingers. It should hang at an angle, with the nose higher than the tail.



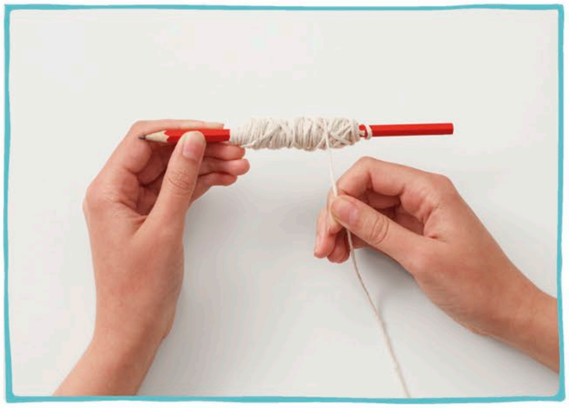
Ask an adult for help if you find this too tricky.

20 Tie a small loop in the string at the point you were holding with your fingers. This is where you will attach the flying line.



Make sure the string is securely attached to the pencil.

21 Cut a very long piece of string—or maybe even use the rest of the ball of string. Tie one end to the middle of the pencil, which will be your handle while your kite flies.

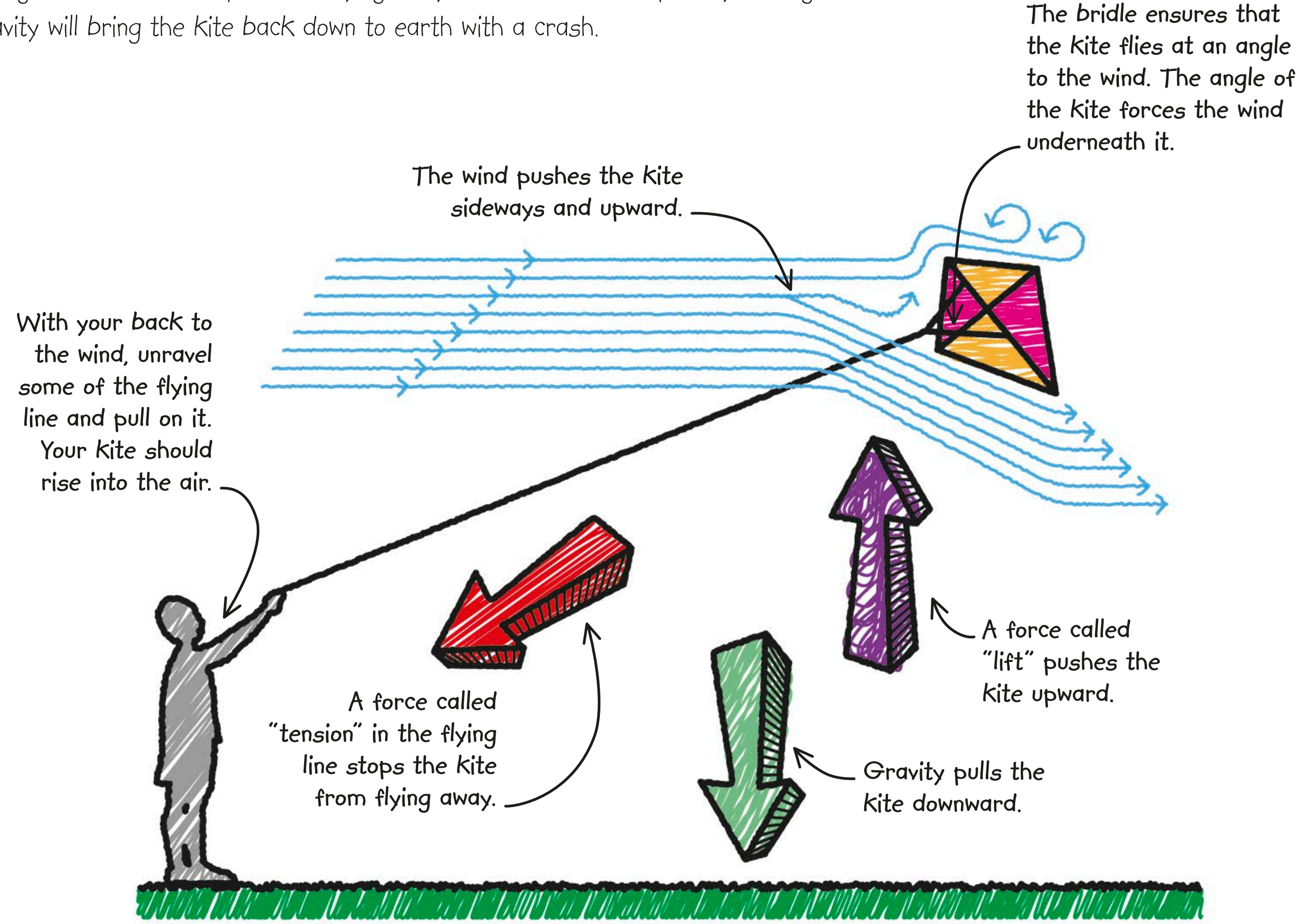


22 Wind the entire length of string around the pencil. As the kite climbs higher in the air, you'll be able to let out more string.

23 Tie the other end of the long piece of string to the loop you made in the bridle. Now your kite is ready to fly! On a breezy day, but never in a storm, take your kite out to an open space—on high ground is ideal.

HOW IT WORKS

The wind that lifts your kite is simply moving air. Because your kite is at an angle, the moving air is forced downward under the sail. As the kite pushes the air downward, the air pushes the kite upward—this force is called "lift." While the wind is pushing the kite both upward and forward, the flying line that you hold pulls the kite downward and backward. The stronger the wind, the more you have to tug on the kite to stop it from flying away, but if the wind stops or you let go, gravity will bring the kite back down to earth with a crash.

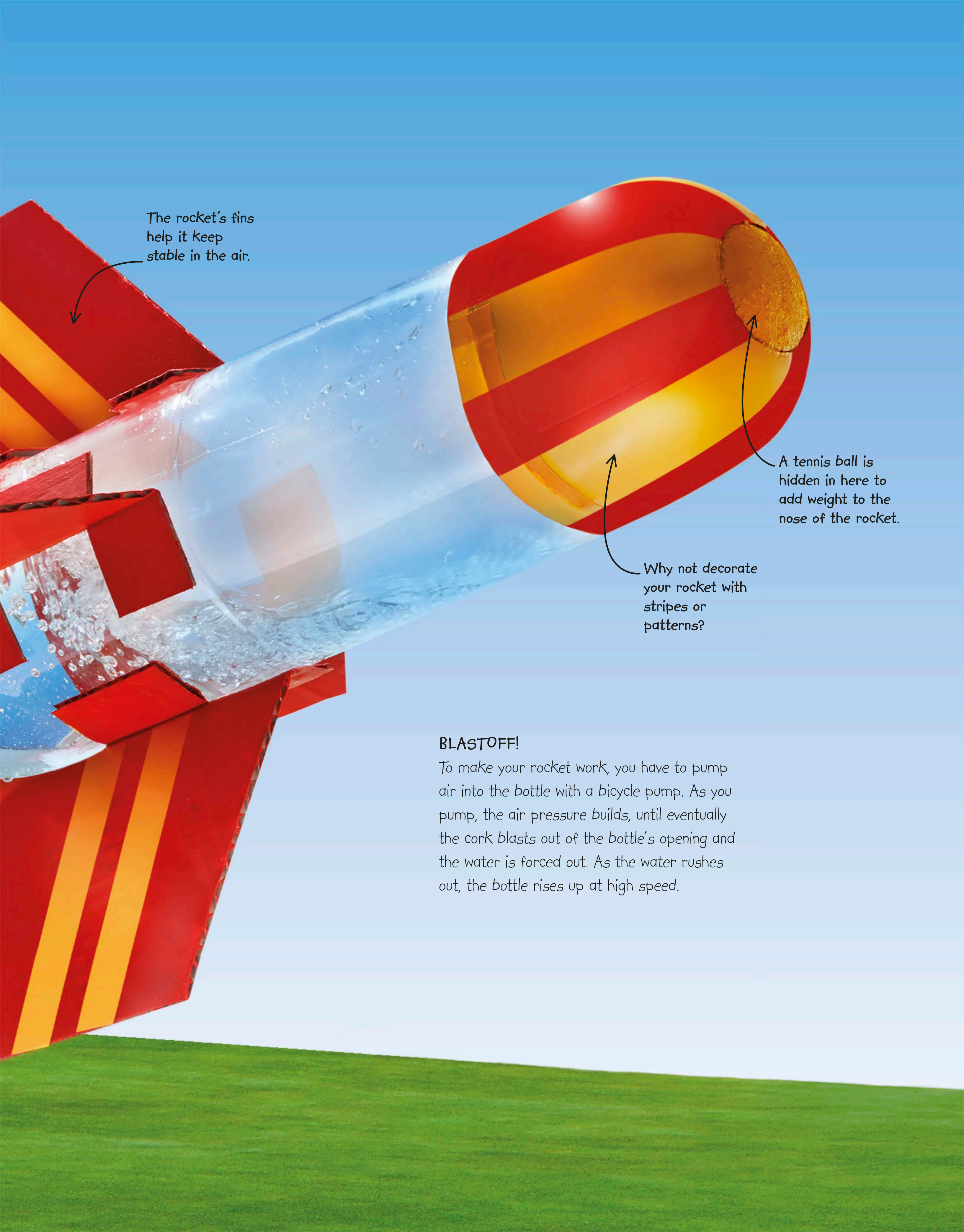


REAL-WORLD SCIENCE
KITE SURFING

A kite surfer uses a large sports kite attached at the waist to speed through the sea on a surfboard. A sports kite is more complicated than your kite. It has two strings instead of just one, which gives the person flying it more control. Pulling on one string or the other makes the kite twist and turn, changing its direction as the air flows over each side of the kite differently. The sports kite can lift the kite surfer high into the air, making it possible for them to perform difficult tricks, such as jumps, flips, and spins.

WATER ROCKET

Five ...four ...three ...two ...one ...blastoff! You can make a powerful rocket that shoots up into the air at high speed, without using a drop of rocket fuel! This rocket uses air, water, and muscle power to launch a plastic bottle high into the air. Your rocket won't quite reach the stars, but you'll be impressed at how fast and high it can go. So gather what you need and prepare for liftoff.



BLASTOFF!

To make your rocket work, you have to pump air into the bottle with a bicycle pump. As you pump, the air pressure builds, until eventually the cork blasts out of the bottle's opening and the water is forced out. As the water rushes out, the bottle rises up at high speed.

HOW TO MAKE A
WATER ROCKET

The sky's the limit with this experiment, which uses air pressure to launch your very own water rocket. Two plastic bottles make the rocket—one for the rocket's body and another to make the nose cone at the top of the rocket. This experiment is a bit tricky, but no one said rocket science was easy!

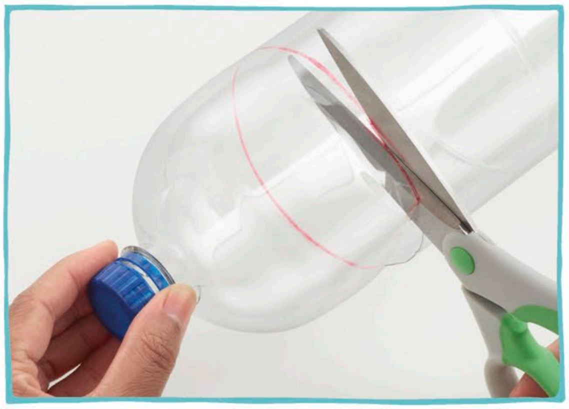
Time
1 hour

Difficulty
Hard

WHAT YOU NEED

1 With the marker, make a mark 4 in (10 cm) down from the cap of one plastic bottle.

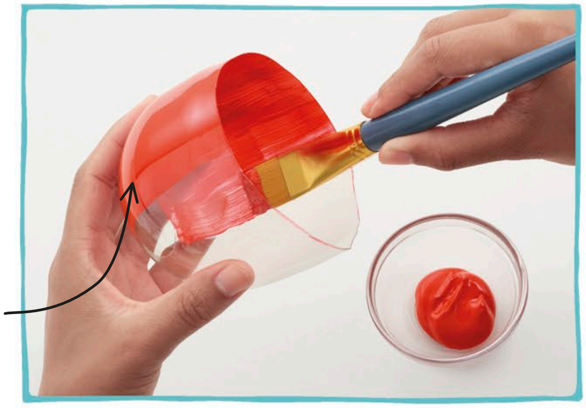
2 Wrap the sheet of card stock around the bottle where you marked it, and draw a straight line around the bottle.



3 Cut all the way along the line you've drawn. Be careful, and if you have any trouble, ask an adult for help.

4 Ask an adult to cut off the very top of the bottle, making sure the hole is smaller than the tennis ball.

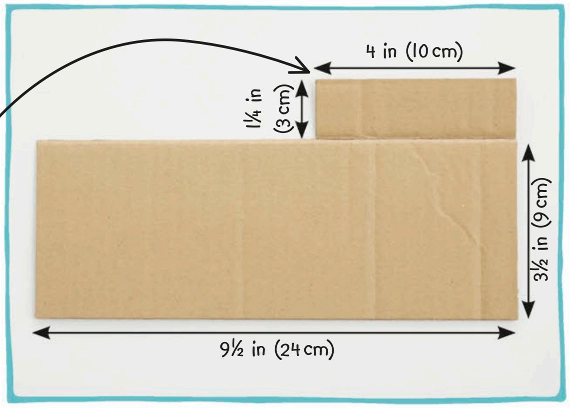
Painting the inside of the nose cone creates a shiny effect on the outside.



5 Paint the inside of the round shape you have made. Your nose cone is almost complete.

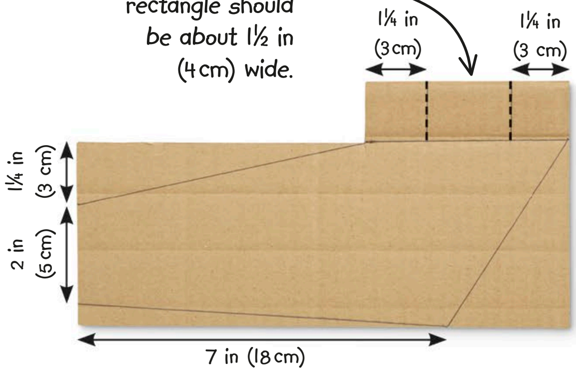
6 Paint the tennis ball. Only part of the ball will show, so you only have to paint half of it.

This tab will stick the fin to your bottle.



7 Draw two rectangles on cardboard, one on top of the other. Make one 4 in (10 cm) by 1¼ in (3 cm) and the other 9½ in (24 cm) by 3½ in (9 cm). Cut along the lines so you end up with a shape like this.

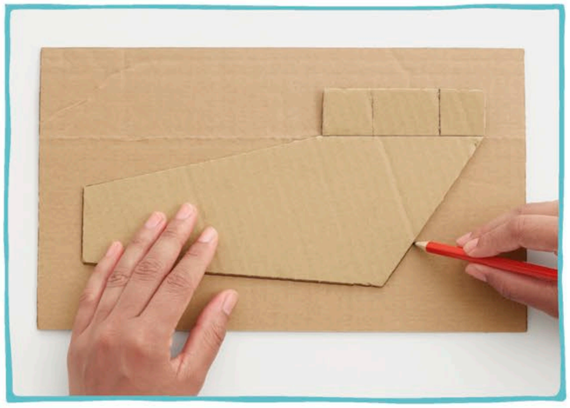
The middle rectangle should be about 1½ in (4 cm) wide.



8 Draw the shape of a fin on the large rectangle, like the one shown here. Draw two dotted lines on the small rectangle, 1¼ in (3 cm) in from each side

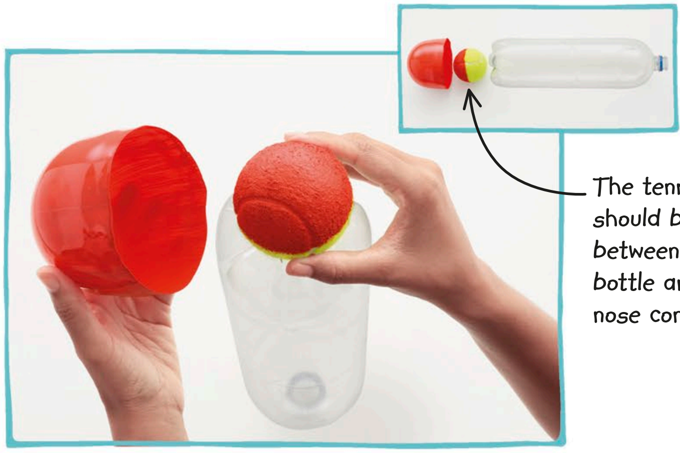
9 Cut out the fin and then along the dotted lines to create three separate tabs.

You can find a template for the fins at the back of the book.



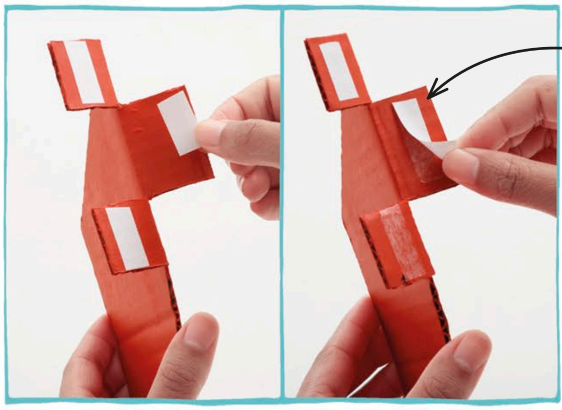
10 Make three more fins. Use the first one as a template to make sure all your fins are the same shape and size.

11 Paint all four fins on both sides and let them dry. This design is red, but you could decorate your rocket however you like.



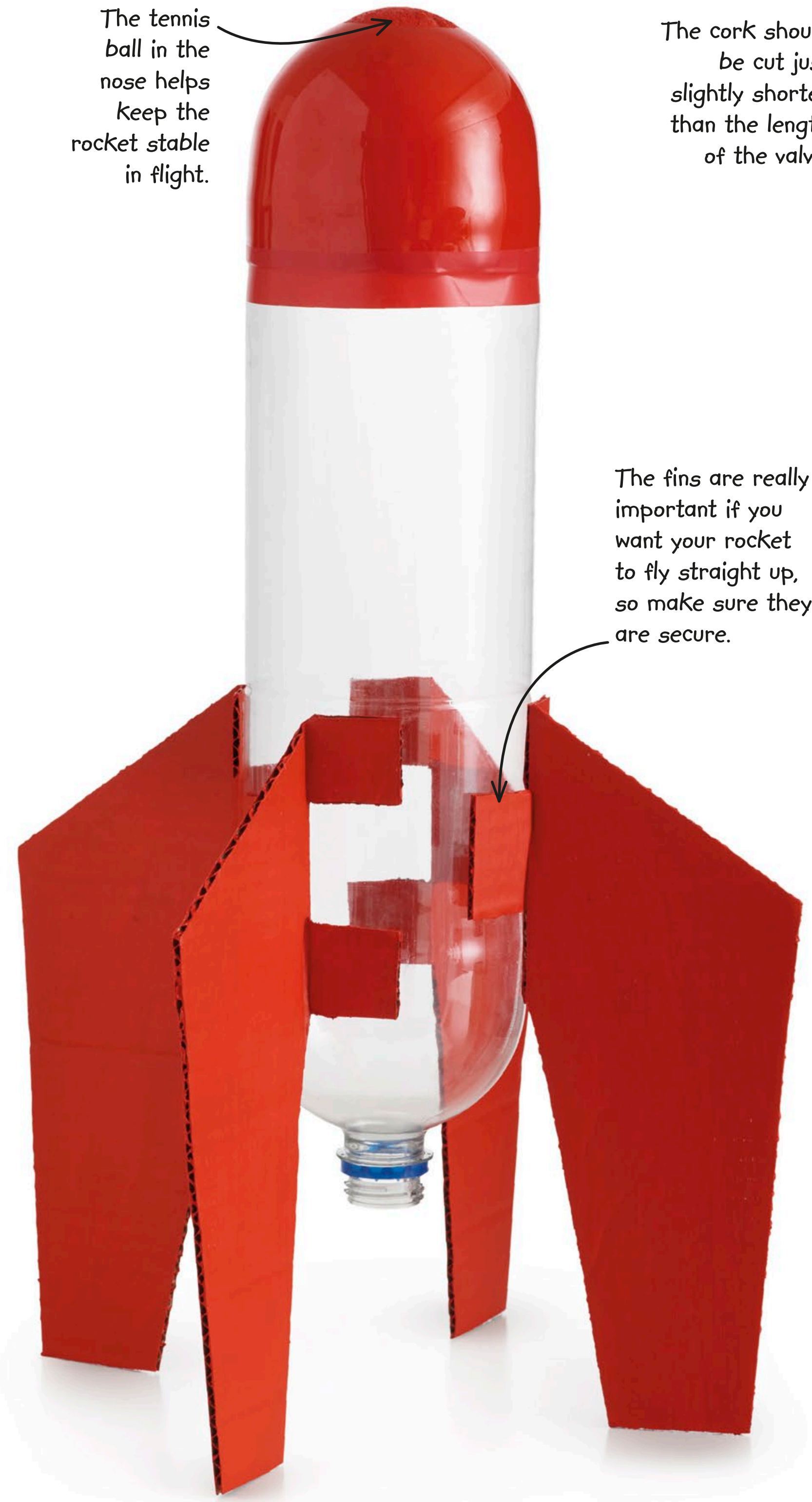
12 Balance the tennis ball on the flat end of the second large, plastic bottle, and place the painted cone on top, making sure that the ball lines up with the hole in the top of the cone.

13 Use coloured tape to secure the nose cone in place. Make sure you attach it firmly—you don't want it to fall off in mid-flight!



14 Fold the fins' top and bottom tabs to the left, and the middle tab to the right. Apply double-sided tape to the underside of each tab.

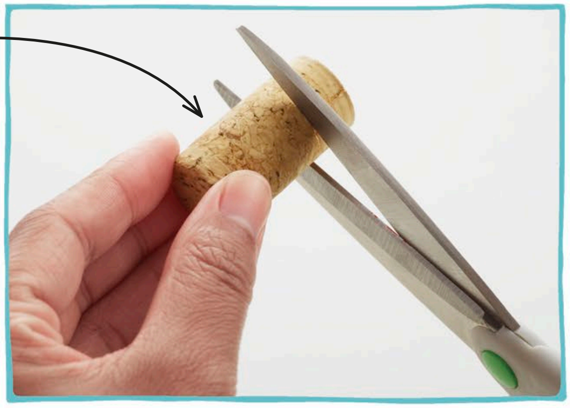
15 Stick the fins low down on the rocket, so that they extend well beyond the neck of the bottle.



The tennis ball in the nose helps keep the rocket stable in flight.

The fins are really important if you want your rocket to fly straight up, so make sure they are secure.

16 Make sure the bottom of each fin lines up with the others, so that the rocket can stand up straight. Your rocket should now look something like this.



The cork should be cut just slightly shorter than the length of the valve.

17 Check your cork fits in the opening of your bottle, and then ask an adult to help you cut a quarter off at the thinner end.

18 Push the valve into the middle of the wide end of the cork until it pokes out the other side. Put a piece of adhesive putty on one end so you don't damage the table.

19 Screw the valve into the foot pump. This is how you'll pump air into the rocket.

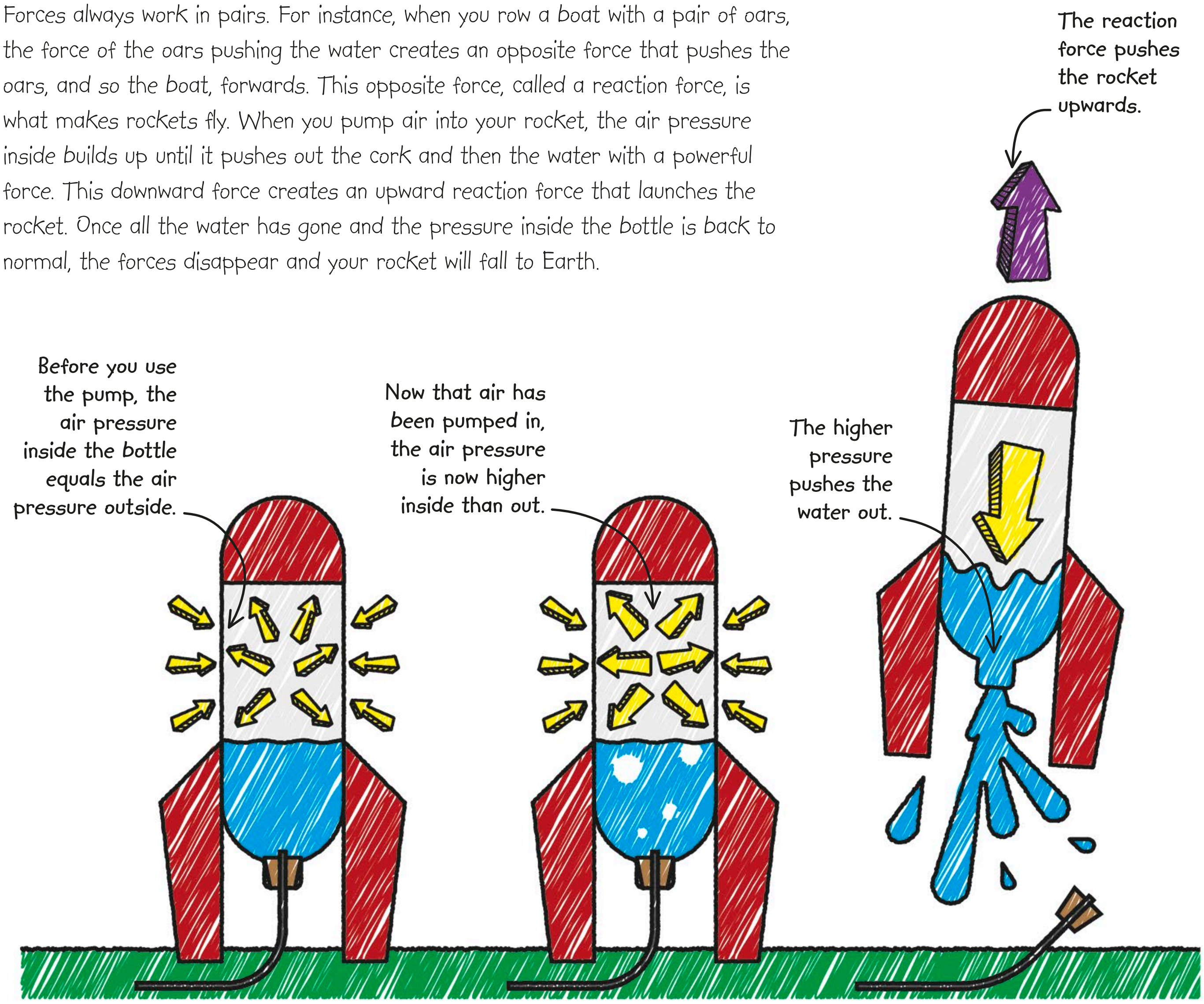
20 Turn the rocket upside down and use the small bottle to pour in about 2 cups (500 ml) of water. Your rocket should be about one-quarter full.

21 Push the cork firmly into the upturned rocket, being careful not to bend the fins. You are almost ready for launch!

22 Stand the rocket on its fins on level ground and, without knocking the bottle over, begin pumping. Keep going until the rocket blasts off.

HOW IT WORKS

Forces always work in pairs. For instance, when you row a boat with a pair of oars, the force of the oars pushing the water creates an opposite force that pushes the oars, and so the boat, forwards. This opposite force, called a reaction force, is what makes rockets fly. When you pump air into your rocket, the air pressure inside builds up until it pushes out the cork and then the water with a powerful force. This downward force creates an upward reaction force that launches the rocket. Once all the water has gone and the pressure inside the bottle is back to normal, the forces disappear and your rocket will fall to Earth.



REAL-WORLD SCIENCE
ROCKET FUEL

A real space rocket works in the same way as your water rocket—but it's not a bicycle pump that increases the pressure inside the rocket. Instead, rocket fuel burns very quickly, producing huge amounts of exhaust gas. As new gas is produced, it pushes down on the gas already there, and that pushes the rocket upward.

AIR CANNON

Put the power of moving air in your hands with this amazing air cannon. Pull back the cardboard circle, let go, and the big plastic sheet will snap forward, sending a burst of air out through a hole in the front. From how far away can you knock over a tower of plastic plant pots, shake the leaves on a tree, or ruffle a friend's hair? Once you've built this design, try thinking of a way to make a much bigger, more powerful air cannon.

This blast is powerful enough to knock over a tower of plastic plant pots!

THROUGH THE AIR

There's a problem with blasting air across a distance: there's already air in the way! The burst of air fired from the cannon soon loses energy, and slows down—but before it does, it drags in air from all around, passing its energy on to that air. The incoming air creates a vortex ring, an incredible invisible spinning ring of air that moves forward.

On a really foggy day, you might be able to see the vortex ring moving through the air.

HOW TO MAKE AN

AIR CANNON

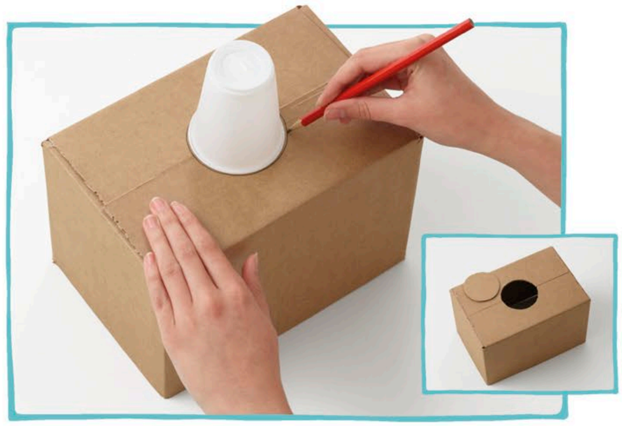
You'll need really strong tape for this tricky activity because you need to pull pretty hard on one part of the cannon. It's also very important to let all the glue dry before you use your air cannon.

Time
45 minutes
plus drying time

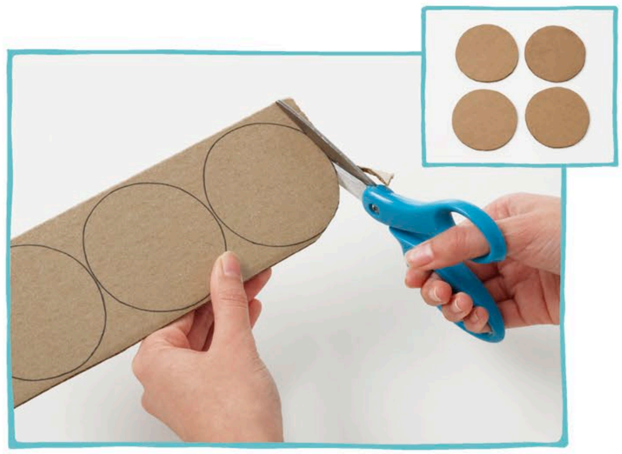
Difficulty
Hard

WHAT YOU NEED

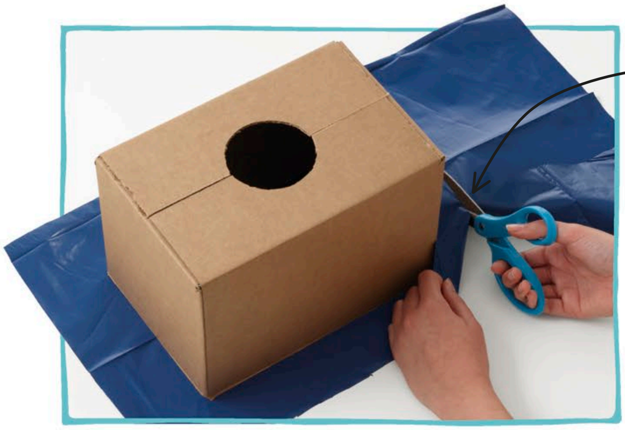
1 Carefully cut off all four flaps from the cardboard box. Keep them safe because you'll need them later.



2 Turn the box upside down and place a plastic cup upside down on the center of it. Draw around the cup and cut out the circle to make a hole in the box. Ask an adult if you find this tricky.

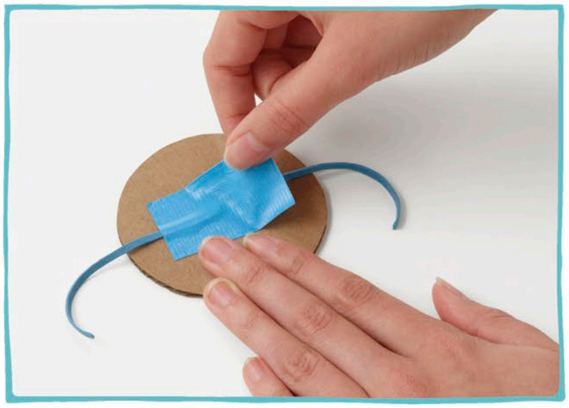


3 Using the upside-down cup as a template again, cut cardboard circles from the box flaps, so that you have four altogether.



4 Place the box on the plastic bag and cut around it, leaving a space of roughly 4 in (10 cm) around the box.

5 The rubber band will store the energy needed to fire the cannon. Cut it in one place, so that it's no longer a closed circle.



6 Stick the rubber band onto the middle of one of the cardboard circles with strong tape. Make sure it is secure, since you'll be pulling on it quite hard.

7 Place the cardboard circle in the middle of the plastic sheet. Stick it down with four pieces of tape.

8 Glue together the other three cardboard circles to create a stack of circles that you'll use as a handle to blast your cannon. Let it dry.

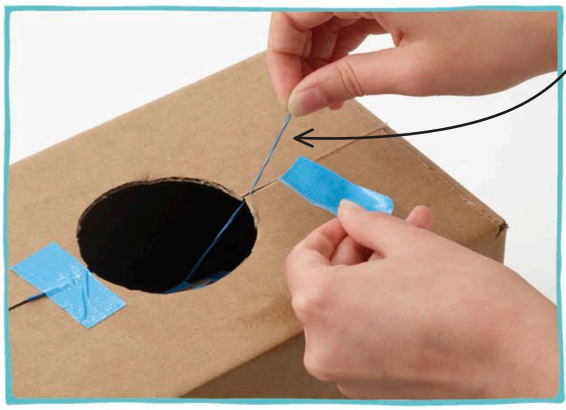
9 Turn the plastic sheet over, and glue the stack of circles you made to the middle, so it's stuck exactly over the cardboard circle that's attached to the other side.

Let the plastic sink into the box.

10 Stand the box upright with the round hole facing downward onto the table. Place the plastic sheet—with the cardboard circle facing upward—over the top of the box. The sheet should be big enough to sink into the middle of the box.

11 Seal the edges of the plastic sheet around the top of the box, using strong tape. Make sure the plastic sheet still sinks in the middle.

When you stretch the rubber band, be careful not to snap it.



12 Turn the box over, and reach in through the hole. Pull the ends of the rubber band out, and stick them securely to the outside of the box.

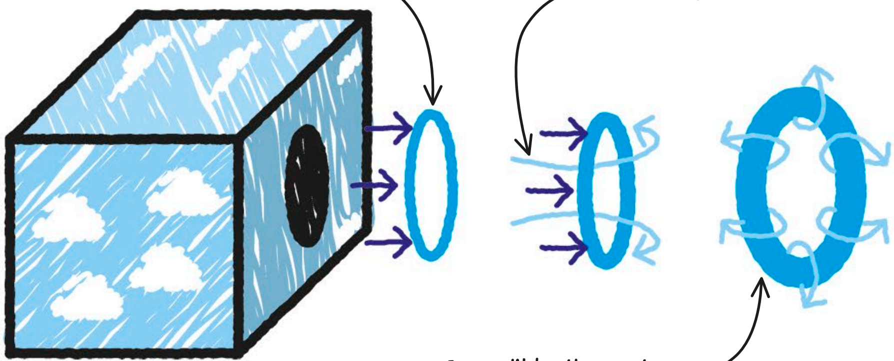
13 If you want, paint your box with a colorful design, such as the blue-sky pattern shown here. Let the blue paint dry before painting the white clouds.

14 To make the air cannon work, point it at a target—maybe some fallen leaves or plastic cups. Pull back the cardboard circle attached to the plastic sheet, then let go! But remember—never point your cannon in people's faces.

When you let go of the cardboard circle, the rubber band pulls the plastic sheet forward quickly, producing a vortex ring.

HOW IT WORKS

The energy you use to pull on the cardboard circle is stored in the stretched rubber band. When you release the circle, the rubber band releases its energy, pulling the plastic sheet forward. The plastic sheet's rapid movement passes the energy to the air inside the box, creating a burst of air that is forced out through the hole. This burst of air pushes the stationary air in front of the box out of the way, but, as it passes by, it also drags some along with it, causing the air all around to start spinning in a shape known as a "vortex ring."



Air bursts out of the hole at the front of the air cannon. It's forced out of the box by the plastic sheet's forward movement.

As the air moves forward, it drags the surrounding air with it. The air starts to spin in the shape of a "vortex ring."

Incredibly, the vortex ring moves through the air long after the original burst of air stopped moving.

REAL-WORLD SCIENCE
VORTEX RINGS IN NATURE

A fluid is anything that flows—liquids or gases—and vortex rings can happen in any fluid. Sometimes they happen naturally. Occasionally, a volcano with a circular vent (opening) will puff out multiple smoke rings, made of steam and gas. The vortex rings drift upward because they are produced by rising hot air from within the volcano. Dolphins can also blow out air to create vortex rings under water, which they chase and try to swim through for fun!

MAGNETIC FORCES

In this activity, you will make a magnet by magnetizing a pin. Any magnet that can turn around freely will line up so that one end points north and the other end points south. This is because Earth itself is a huge magnet, with one end or "pole" near the North Pole, and another end near the South Pole.

Take your compass needle camping or hiking and you'll always be able to use it to navigate.

COOL COMPASS

Long before satellite navigation was invented, people relied on compasses to find their way around. A compass has a needle that always points north or south to match up with Earth's magnetic field. You can make your own compass needle using just a ball pin, a plastic cup, and a lid, but you'll need to magnetize the pin for it to work.

As the plastic disk floats in the water, the compass needle can turn freely.

HOW TO MAKE A

COOL COMPASS

The most important part of your compass is the compass needle. This activity uses a ball pin, but you could use any thin steel object, such as a needle or the point of a paper clip. The compass needle must be magnetized to make it point north or south, and for that you'll need a magnet.

Time
20 minutes

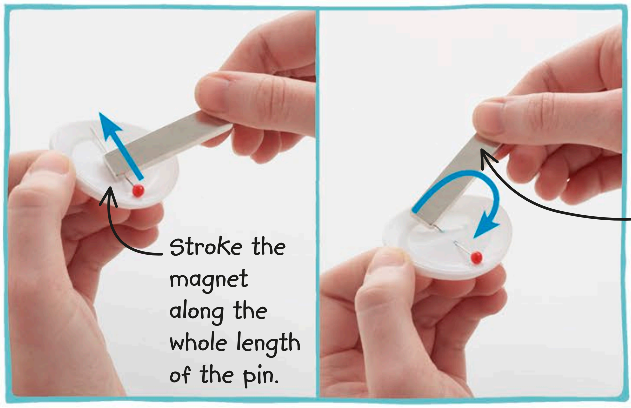
Difficulty
Medium

WHAT YOU NEED

1 Using the scissors, cut off the base of the plastic cup. This part will float in the water, so that your compass needle can turn freely.

2 Using a felt-tip pen, draw two dots about ½ in (1 cm) apart, one on either side of the center of the plastic disk.

3 Rest the disk on a lump of adhesive putty and poke the pin through each dot. Push the pin down through one hole and up through the other.

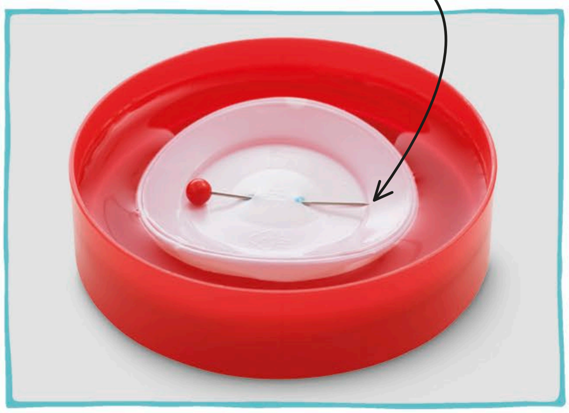


4 Now you need to magnetize your pin to make it into a compass needle. Use the magnet to stroke the pin all the way along its length around 40 to 50 times, in one direction only, lifting the magnet away from the end of the pin each time. Always use the same end of the magnet.

5 Pour water from the bowl into the plastic lid. It doesn't need to be full, but there must be enough water for the disk to float freely.

One end of a compass needle points north, the other end south.

Your compass needle will turn around to line up with Earth's magnetic field.



6 Float the disk on the surface of the water. If your needle doesn't turn, stroke the magnet over it a few more times. It may not be magnetized yet.

7 Make sure you place your compass away from strong winds, and not right next to electrical appliances or large metal objects.

7 You can't tell yet if your needle points north or south, so use a smartphone to find north (or ask an adult). Note which end of the pin points north and mark N, E, S, and W on the plastic disk.

8 Once you have marked the four compass points, decorate the plastic disk with a compass rose.

TAKE IT FURTHER

If you have your magnetized pin, but you don't have the plastic disk, you can still use it as a magnetic compass by floating it on a leaf in a puddle—as long as you know whether the point points north or south. In fact, you can use all sort of different materials that float in a puddle, such as cork, polystyrene, or the cap of a plastic bottle. One other thing to try: what happens when you move your magnet close to your floating compass needle?

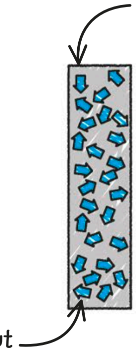
9 Your compass is now finished and ready to use. Keep a magnet nearby in case you need to magnetize the needle again.

HOW IT WORKS

Every magnet has a magnetic field around it and two ends, or "poles," where the field is strongest. Your compass needle is made of steel, which is formed from lots of tiny crystals called domains. Each domain is a tiny magnet, but normally they are jumbled up and their individual magnetic fields cancel each other out. When you stroke the needle, you make all the domains line up, so the magnetic fields point in the same direction.

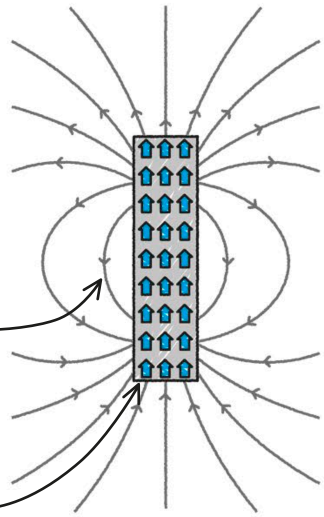
UNMAGNETIZED STEEL

The domains (blue arrows) are jumbled up and point in different directions.



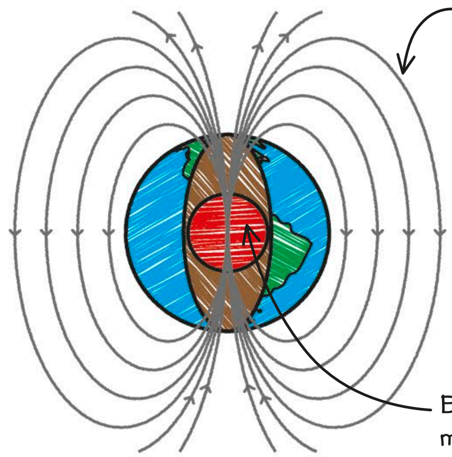
MAGNETIZED STEEL

After you stroke the ball pin with the magnet, the domains (blue arrows) point the same way.



EARTH'S MAGNET

Molten (liquid) iron at Earth's core acts as a strong magnet with a huge magnetic field. Like any magnet, it has two poles—one near the North Pole and one near the South Pole. The two poles of your magnetized pin line up with Earth's magnetic field: the "north-seeking" pole is pulled toward Earth's north magnetic pole, and the "south-seeking pole" is pulled toward the south magnetic pole.



REAL-WORLD SCIENCE
ANIMAL MAGNETIC COMPASS

Many animals have their own magnetic compasses, though not with magnetized metal needles. They have tiny organs that can detect Earth's magnetic field and use it to find their way around. Pigeons use their magnetic supersense to help them navigate across long distances, and find their way home.

GORGEOUS GEODES

Sometimes, geologists—scientists who study the solid parts of our planet—are rewarded with beautiful surprises. When they break open rocks, they might find hollow spaces inside, packed with stunning crystals. These rock formations are called geodes, and while real ones take thousands of years to form, you can make yours in just a couple of days!

You could make your eggshell geodes in loads of different colors.

COLORFUL CRYSTALS

Instead of breaking open rocks in the hope of finding a geode, you'll be using an empty eggshell, some food coloring, and a chemical compound called alum to make yours. The alum forms crystals on the surface of the eggshell, and the food coloring will make them bright and colorful.


The crystals have flat faces, which glisten as they catch the light.
Crystals grow on the inside surface of the eggshell, and sometimes around the edges too.
The color of the crystals will depend on what food coloring you use.

HOW TO CREATE
GORGEOUS GEODES

The secret ingredient you need to create your own geodes is a chemical compound called alum. You can buy it cheaply at a pharmacy or on the internet. It's safe to use in small amounts, but don't put any in your mouth, and make sure you wash your hands after handling it.

Time	Difficulty	Warning
1 hour plus 24 hours to grow	Hard	Don't put alum in eyes or mouth.

WHAT YOU NEED

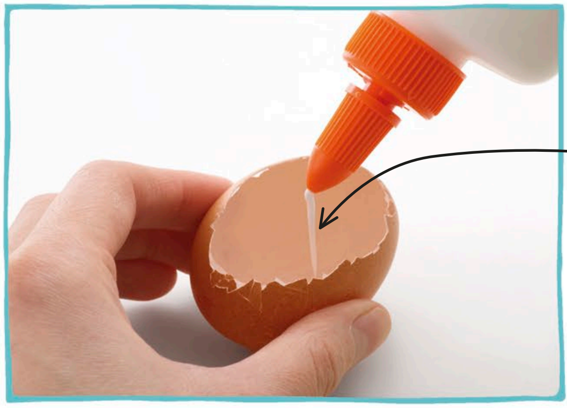
1 Before you start, wash your hands. Gently crack the egg against the edge of the bowl and pick away around the crack, to create a hole. You might want to wear protective gloves.

You can keep the inside of the egg for cooking.

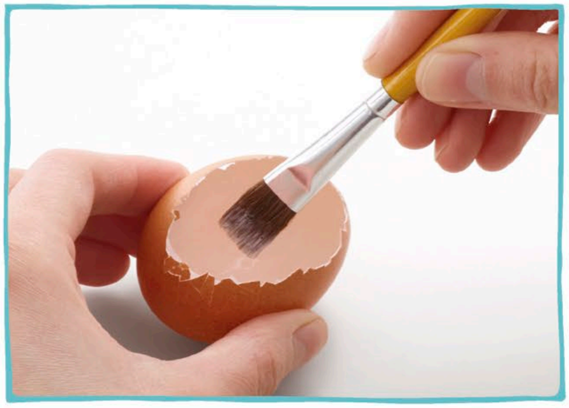
2 Empty the contents of the egg into the bowl. Break a few bits of shell inward and you should be able to begin to remove the delicate skin, or membrane, that lines the inside of the shell.

Be careful not to break the egg shell.

3 Wash the shell under running water to remove as much of the membrane as possible. Then wash your hands again.



The glue will provide a sticky surface for the alum.



4 Pour a little bit of glue into the clean, empty eggshell.

5 Use the paintbrush to spread the glue evenly around the inside of the eggshell.

6 Use the spoon to sprinkle some alum into the eggshell. Pour out any alum that doesn't stick. You may want to wear gloves for this part, if not, be sure to wash your hands afterwards.

7 Gradually pour the remaining alum into the warm water and stir with the spoon. Keep adding alum until no more will dissolve, to make sure the solution is really concentrated.

Make sure you stir the mixture to help the alum dissolve.

8 Add some food coloring—enough to give the the alum solution a deep color. Stir the mixture again.

9 Pour the alum solution into the plastic cup. The solution should be deep enough for you to submerge the eggshell completely.

10 Submerge the eggshell in the alum solution. Gently push it down with the spoon to fill the eggshell with solution, being careful not to break it.

11 Leave the eggshell in the solution for about 24 hours. It will work best somewhere warm and dry. Afterward, carefully lift it out of the cup.

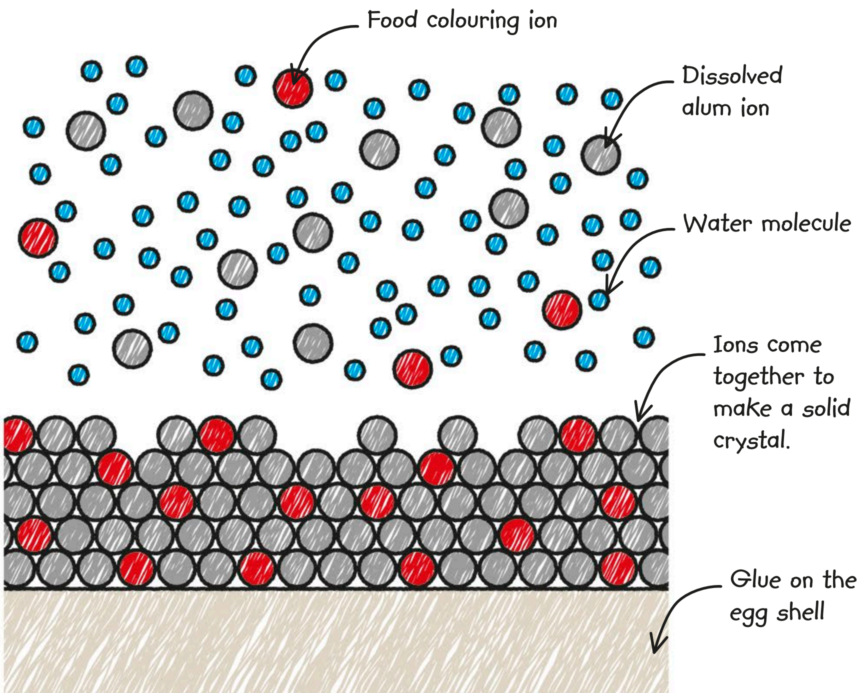
12 Gently place the egg onto the paper towel.

13 Take a close look at your egg geode. The alum and the food coloring should have formed lots of small, shiny crystals.

Throw away any remaining alum solution, then wash your hands.

HOW IT WORKS

When you dissolve the alum in the water, the alum breaks down into tiny parts called ions that mix with the water. The food coloring is already dissolved in water, and that also exists as ions. Every so often, the different ions will meet and may stick together, forming solid crystals. They connect in a regular pattern, which is what gives the crystals their distinctive shape.



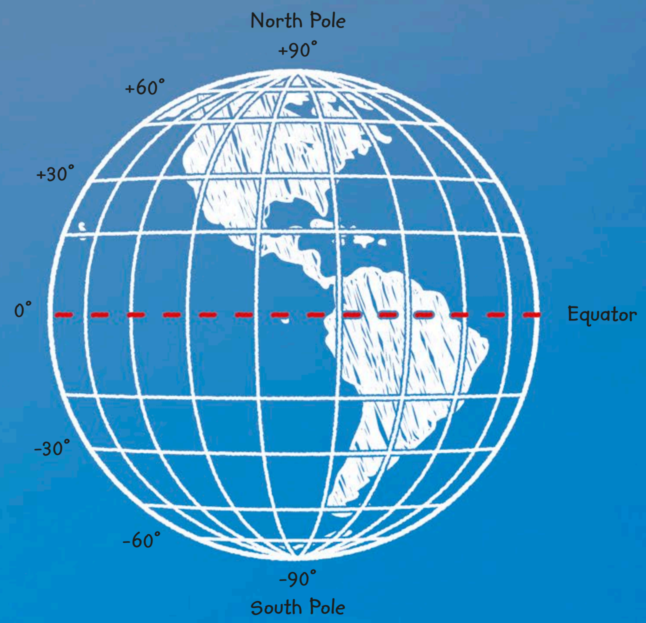
REAL-WORLD SCIENCE
REAL GEODES

Geodes form inside holes in rocks. Often the holes are caused by big bubbles of air that form inside the molten lava that pours from a volcano. These bubbles become trapped as the hot lava solidifies into rock. As water seeps through the ground, minerals dissolve in it, and those minerals crystallize inside the holes, creating these beautiful crystals.

To use your latitude locator, you'll have to go out at night and find a locator star or stars. These stars will be different depending on where you are in the world.

LATITUDE LOCATOR

Early sailors used the stars to figure out exactly where they were on Earth. In the system they created, a location is defined by just two numbers, called latitude and longitude. Your latitude is how far north or south of the equator you are, while your longitude is how far around the planet you are. In this activity you'll make a device that will give your latitude wherever you are in the world.



WHAT'S YOUR LATITUDE?

Around the middle of planet Earth, at an equal distance from the North Pole and the South Pole, is an imaginary line called the equator. If you live at the equator, your latitude is 0°. If you live at the North Pole, your latitude is 90° north (or +90°), while if you live at the South Pole, it's 90° south (or -90°). Chances are your latitude is somewhere in between. If you go on vacation somewhere much closer to or farther from the equator, you can use your latitude locator to record your new latitude.


0°
10°
20°
30°
40°
50°
60°
70°
80°

HOW TO MAKE A

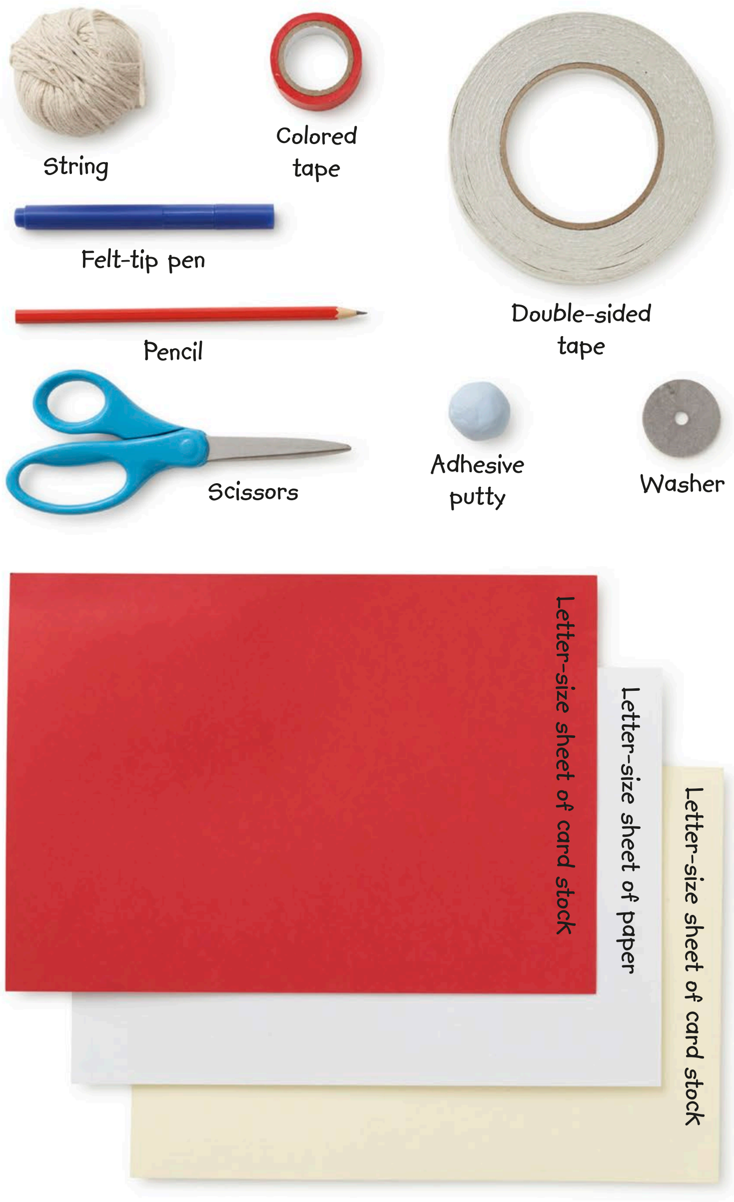
LATITUDE LOCATOR

It's really easy to make this latitude locator. First, turn to the back of this book to find the template for the scale you'll need. Trace the template onto a sheet of paper (or photocopy it) and cut it out. Then it just takes a bit more cutting and gluing.

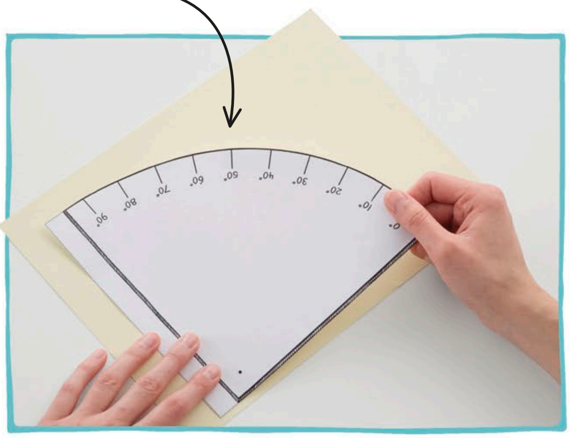
Time
30 minutes

Difficulty
Medium

WHAT YOU NEED

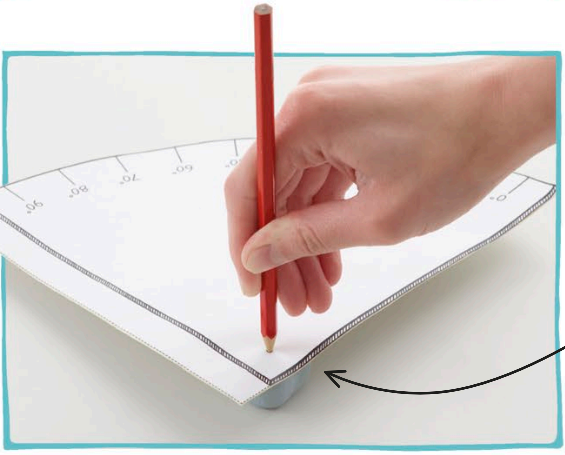


The piece of card stock you use can be any color.



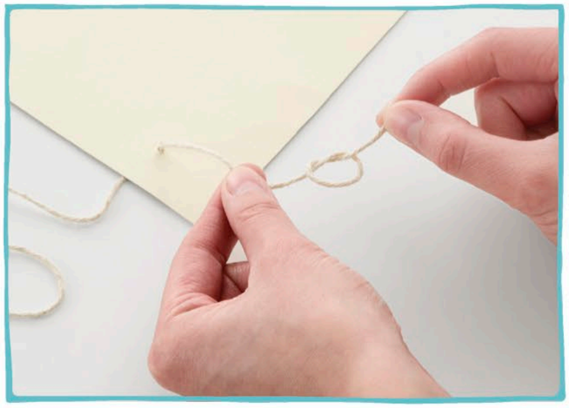
1 Stick several pieces of double-sided tape to the back of the paper. Peel off the protective strips, and stick down onto a piece of card stock.

2 Carefully cut the card stock around the edge of the paper with a pair of scissors. Remember to recycle any leftover pieces of card stock.



The putty makes it easier to push the pencil through the paper.

3 Put a piece of adhesive putty underneath the dot in the corner of your scale. Then use the sharp end of the pencil to make a small hole.



4 Cut an 8 in (20 cm) length of string. Thread one end through the hole and tie a double knot, near the end of the string at the back of the card stock.

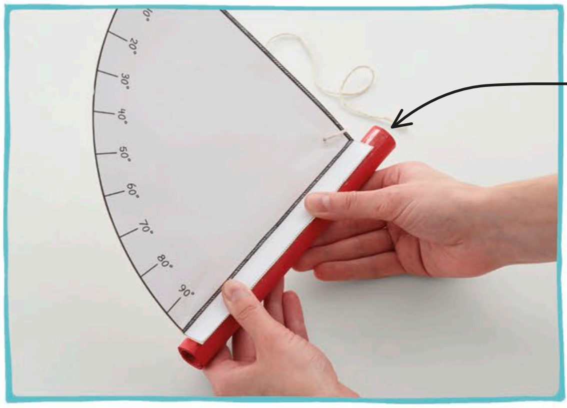
Latitude affects how many hours of sunlight a location gets each day.

5 Roll the other piece of card stock tightly around the felt-tip pen, to make a narrow tube. This will be your sighting tube, which you will look through when measuring your latitude.

Make sure the card stock is wrapped tightly around the felt-tip pen to stop it from unraveling.

6 Use one side of a piece of double-sided tape to stick the tube closed. Hold an end up to your eye to check that you can see through it.

7 Peel off the protective strip from the double-sided tape. This will let you stick the sighting tube to the latitude scale in the next step.

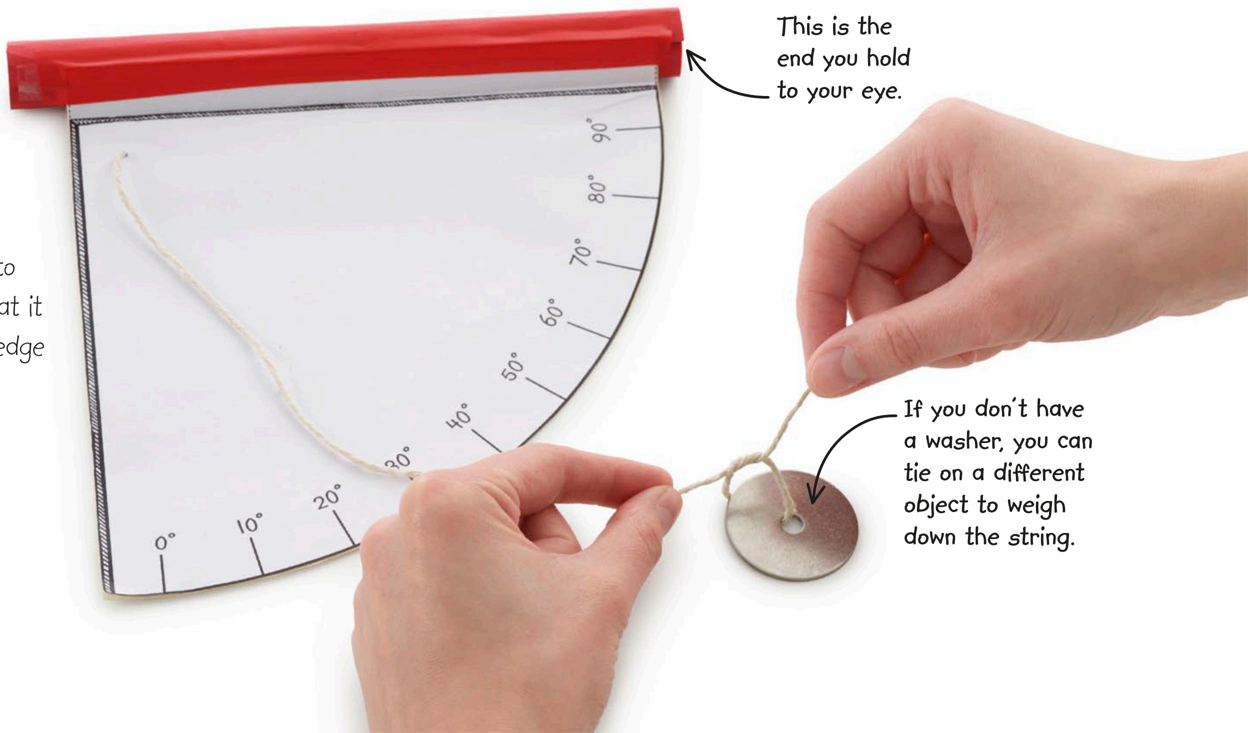


Be careful not to squash the tube when you attach the scale.

8 Find the tab along the edge of the latitude scale, fold it, and press it firmly against the double-sided tape running along the sighting tube.

9 Use a length of colored tape to stick down the tab of the latitude scale to the sighting tube. This will firmly secure the scale to the tube.

10 Tie the washer to the string, so that it will hang down below the edge of the latitude scale.



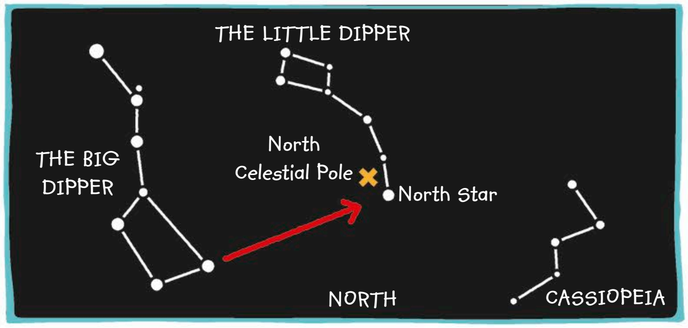
This is the end you hold to your eye.

If you don't have a washer, you can tie on a different object to weigh down the string.

HOW TO USE IT

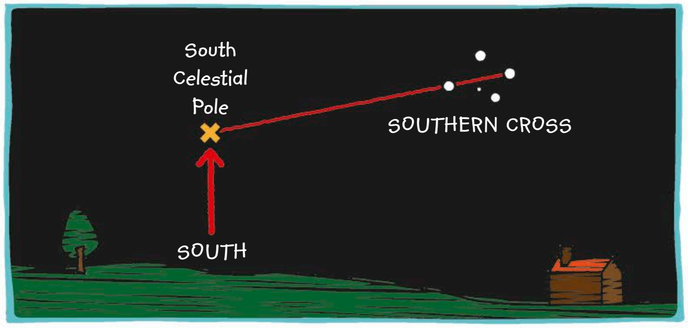
To use the latitude locator, go outside with an adult on a clear night, preferably to an open space away from street lighting. You then need to find a point in the sky. This point will be the North Celestial Pole if you are in the Northern Hemisphere, or the South Celestial Pole if you are in the Southern Hemisphere. To find these points, use the directions given below—it will really help if you have a compass to find north or south. Look at that point in the sky through your sighting tube and make sure the washer is hanging freely. Your latitude is the angle shown at the point where the string crosses the scale.

NORTH CELESTIAL POLE



If you live in the Northern Hemisphere, stand facing north, look up, and find the bright constellation known as The Big Dipper. Follow the line made by the edge of the front of The Big Dipper to find the North Star—which is very close to the North Celestial Pole.

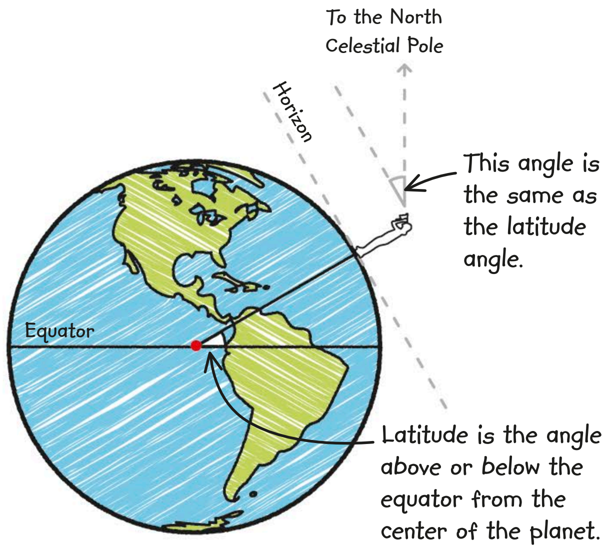
SOUTH CELESTIAL POLE



If you live in the Southern Hemisphere, there is no bright star close to the South Celestial Pole. Instead, you need to locate a group of stars called the Southern Cross. Trace a line from the two stars that are farthest apart. Where that line crosses another imaginary line coming up from the horizon at due south is where you need to point your latitude locator.

HOW IT WORKS

Gravity is a force that pulls everything on Earth downward toward the center of the planet. As a result, your latitude locator's washer makes the string hang down vertically. If you live at the equator, whether you are looking at the North or South Celestial Pole, you will be looking at the horizon—and you will read your latitude as 0°. If you are at one of the Poles, you will have to look directly above your head to see the Celestial Pole, and so your string will show your latitude as 90° north or south. Your home is probably somewhere in between these extremes.



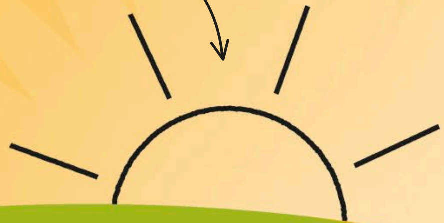
REAL-WORLD SCIENCE
NAVIGATING AT SEA

Before satellite navigation, sailors would find their latitude using a sextant, a smart device that measures angles between objects. The sextant is still used today, and it can also help sailors figure out their longitude, so they have a really good idea of exactly where they are in the world.

PAPER SUNDIAL

As the sun moves across the sky during the day, the shadows cast by objects move too. With a sundial, you can use these shadows to tell the time. It's easy to make your own sundial using a drinking straw and a piece of paper, but you'll only be able to use it between spring and fall. During the winter, the sun is too low in the sky for the straw to cast a shadow on the paper.

The sun will soon set, in the west.



READING THE SUNDIAL

You may have to adjust the time the sundial shows for daylight saving time, a period when clocks are changed to give more daylight in the evening. Ask an adult if and when that applies to your location. When it does, you'll usually have to add an hour to the time shown on the sundial.

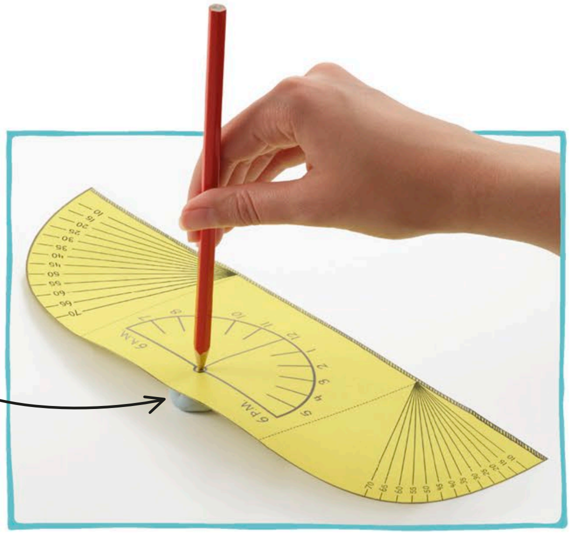
HOW TO MAKE A PAPER SUNDIAL

Time
15 minutes

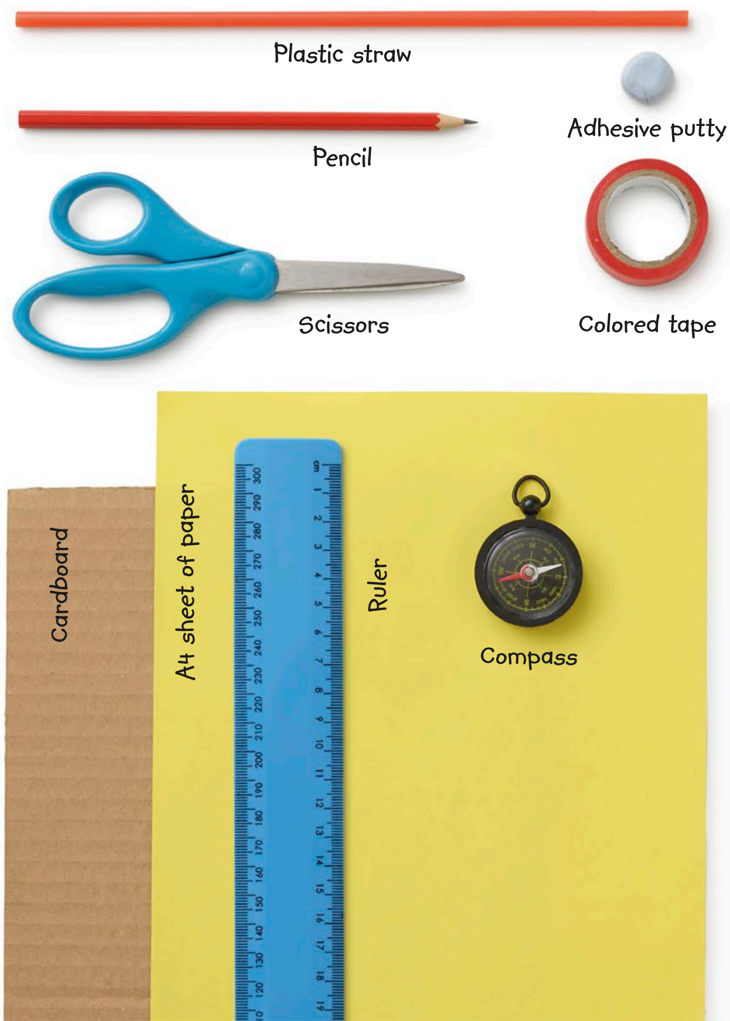
Difficulty
Medium

First you'll need to trace or photocopy one of the templates at the back of this book. There is one template for use in the Northern Hemisphere and another for the Southern Hemisphere. Make sure you use the correct version. If you don't know which hemisphere you live in, ask an adult. You'll also need to find out a number called your latitude: you can ask an adult, look online, or make your own latitude locator to find out—see pages 144–149!

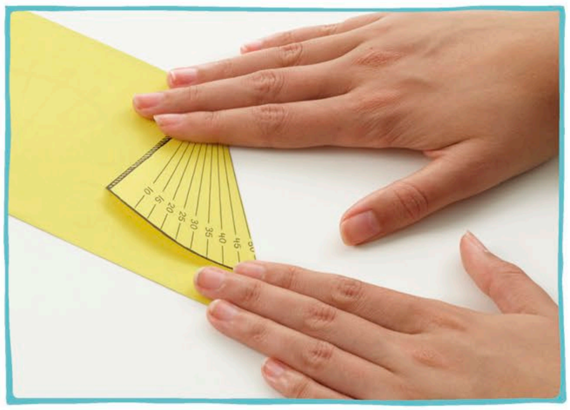
The adhesive putty helps protect the work surface.



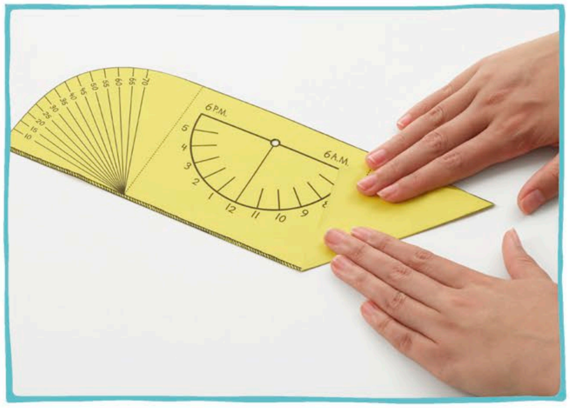
WHAT YOU NEED



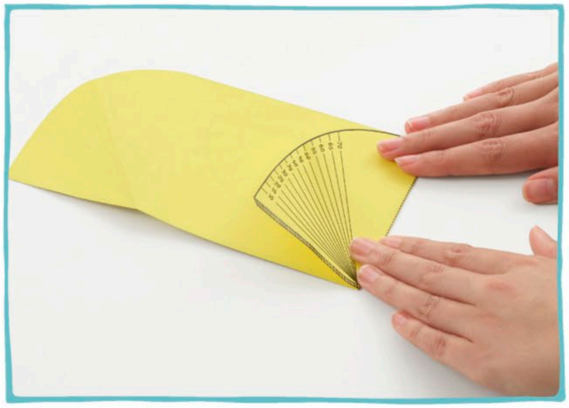
1 Make sure you have a copy of the right template. Cut it out and put some adhesive putty under where the dot is at the top of the hour scale. Make a hole with the pencil through the dot.



2 Find your angle of latitude along the scale at the side of the paper. Fold and crease along that angle (50° latitude in the example).

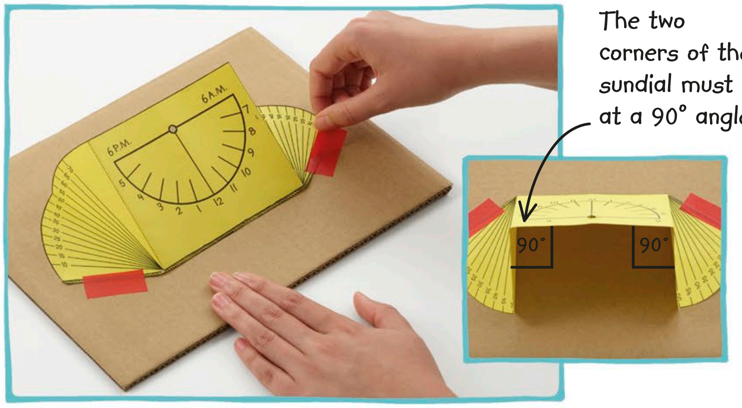


3 Turn the template over and fold again along the crease you created. Repeat steps 2 and 3 for the scale on the other side of the template.



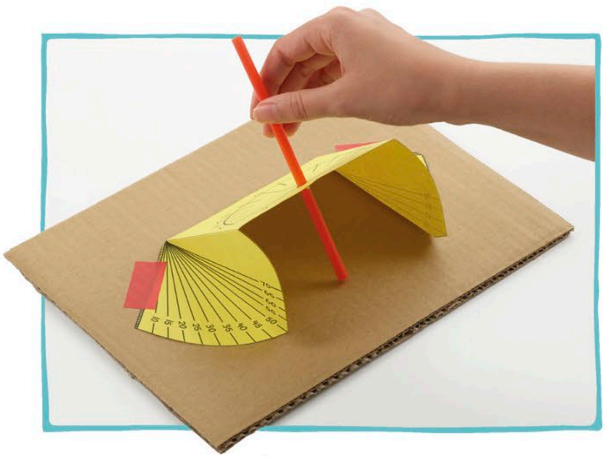
4 Now unfold the angled sides, then fold and crease along the dotted straight lines on either side of the sundial's main panel.

The two corners of the sundial must be at a 90° angle.



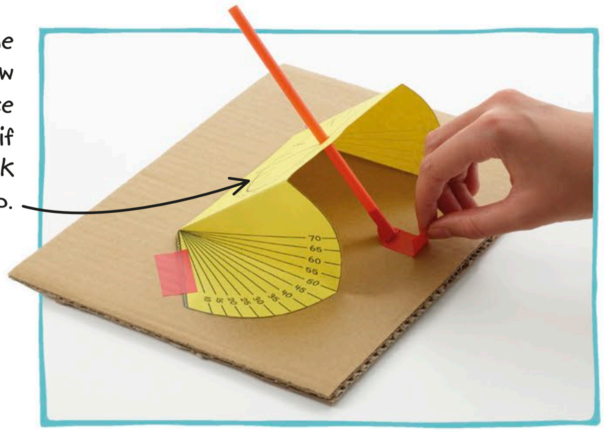
5 Using tape, attach the creased sundial template to the piece of cardboard. Make sure the sides of the sundial are vertical.

6 Cut a piece of the straw about 6 in (15 cm) long. This will be the "gnomon"—the piece of the sundial casting the shadow that tells the time.



7 Carefully push the straw through the hole in the sundial's face, from the top down to the cardboard. Make sure it's at right angles to the face.

Keeping the paper and straw in the right place can be tricky—if you get stuck ask an adult for help.

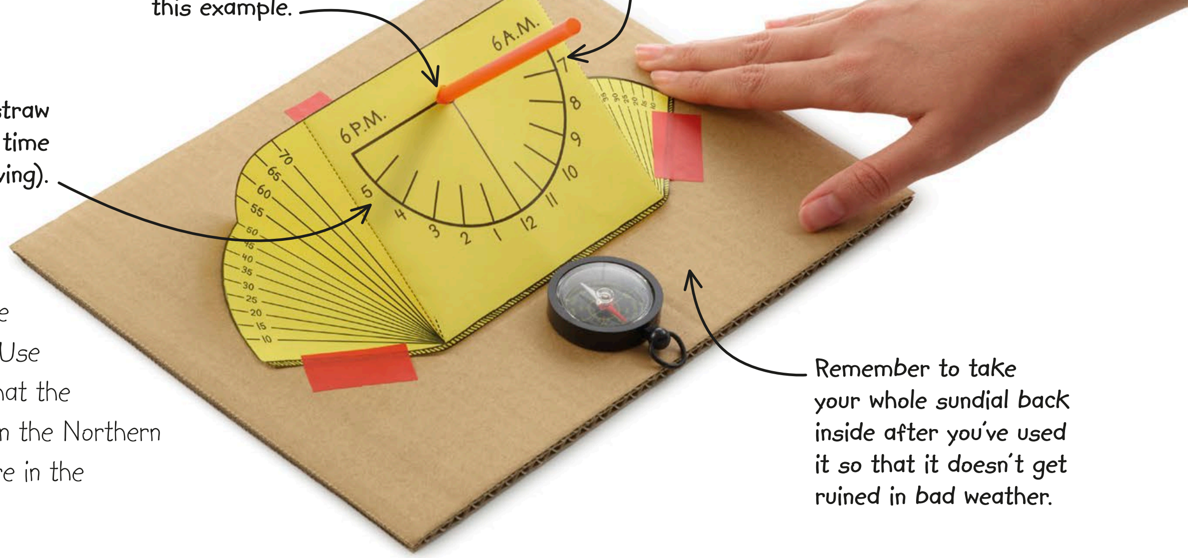


8 Secure the straw to the cardboard base, making sure that the sundial's face remains flat and that the straw is still at right angles to it.

The straw needs to point north if you're in the Northern Hemisphere, as in this example.

The numbers will be reversed if you're in the Southern Hemisphere.

The shadow of the straw shows the approximate time (without daylight saving).



Remember to take your whole sundial back inside after you've used it so that it doesn't get ruined in bad weather.

9 Place your sundial somewhere flat outside where sunlight can reach it. Use the compass to align it so that the straw points north if you're in the Northern Hemisphere or south if you're in the Southern Hemisphere.

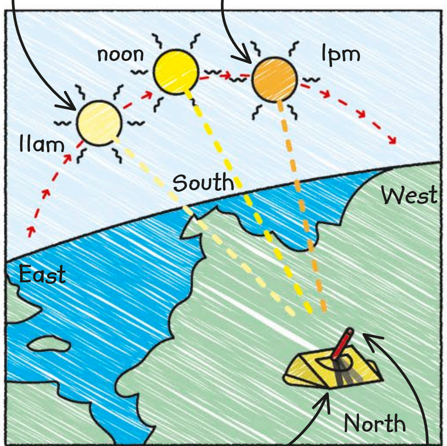
HOW IT WORKS

Planet Earth is spinning, and as a result, the sun moves across the sky. It rises in the east, at noon it reaches its highest point, and then sets in the west. Earth takes 24 hours to make one complete rotation (360°)—so it turns 15° per hour, and the shadows created by the sun shift by 15° per hour. The lines on the sundial are spaced 15° apart, so the space between each line represents one hour.

NORTHERN HEMISPHERE

The sun moves 15° across the sky each hour.

In the Northern Hemisphere, the sun is to the South.



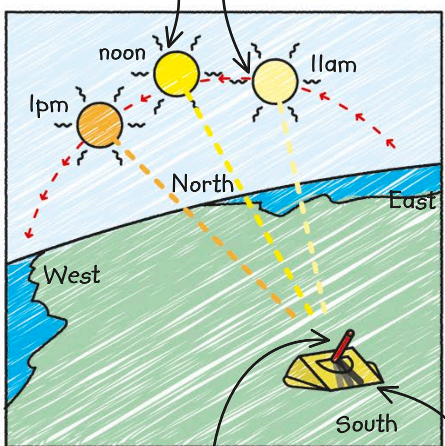
The shadow moves 15° each hour.

The straw points north.

SOUTHERN HEMISPHERE

The sun is at its highest at noon.

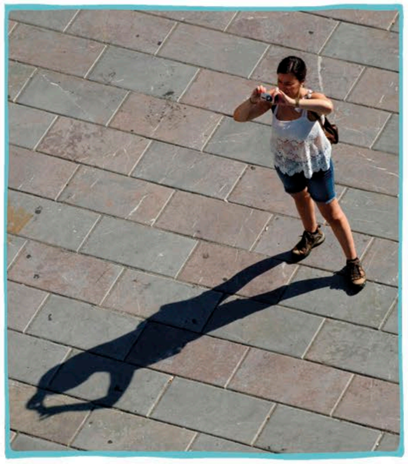
In the Southern Hemisphere, the sun is to the North.



The straw points south.

At noon, the shadow will point due south.

REAL-WORLD SCIENCE SHADOWS

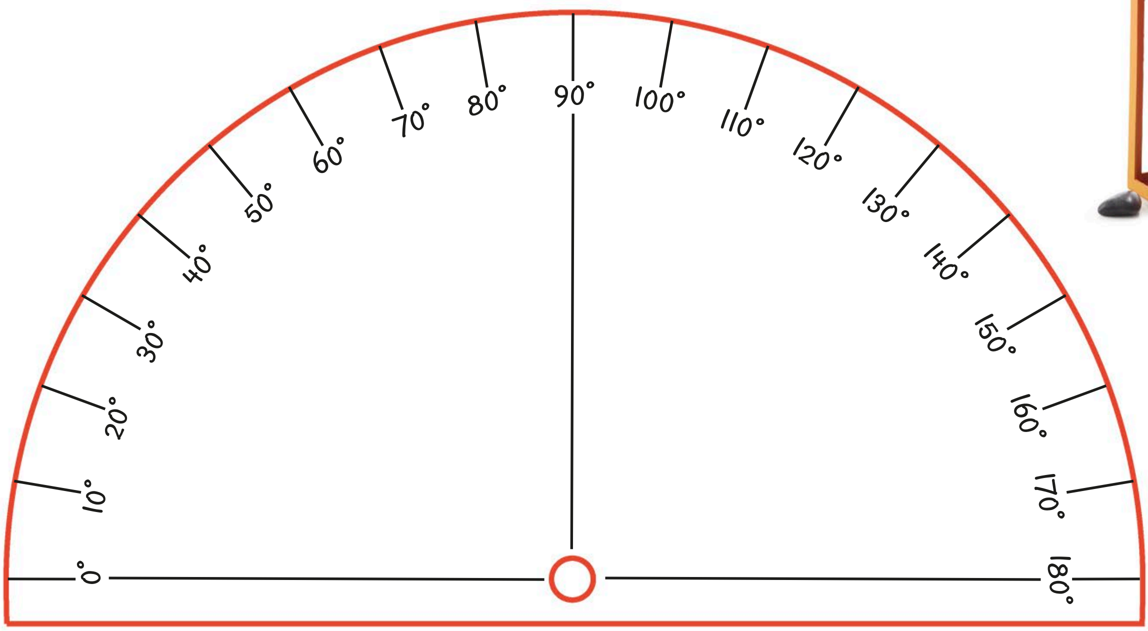


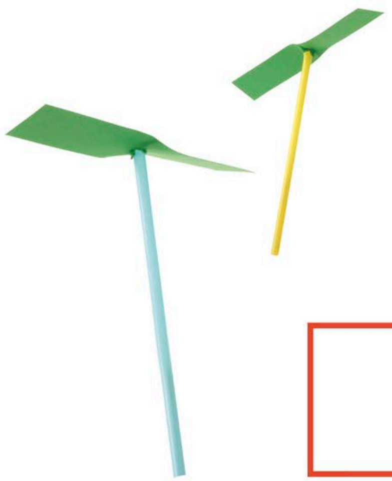
Your own shadow is very long just after sunrise and just before sunset, when the sun is low in the sky. Your shadow is shortest at noon. If you stood at the equator at noon on midsummer's day, you would have no shadow at all, because the sun would be directly overhead.

TEMPLATES

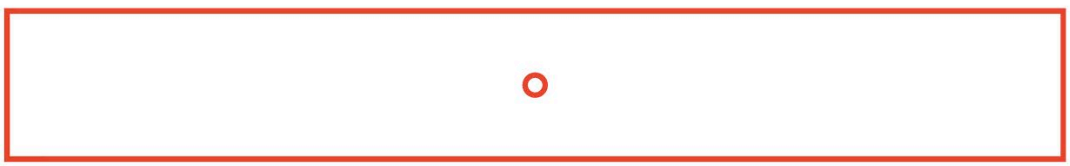
These are the templates you need for the anemometer, twirling helicopter, water rocket, latitude locator, and sundial. You can either trace the lines onto a piece of paper or photocopy the page you need. For the sundial, make sure you use the correct template—one is designed for use in the Northern Hemisphere, and the other is designed for use in the Southern Hemisphere.

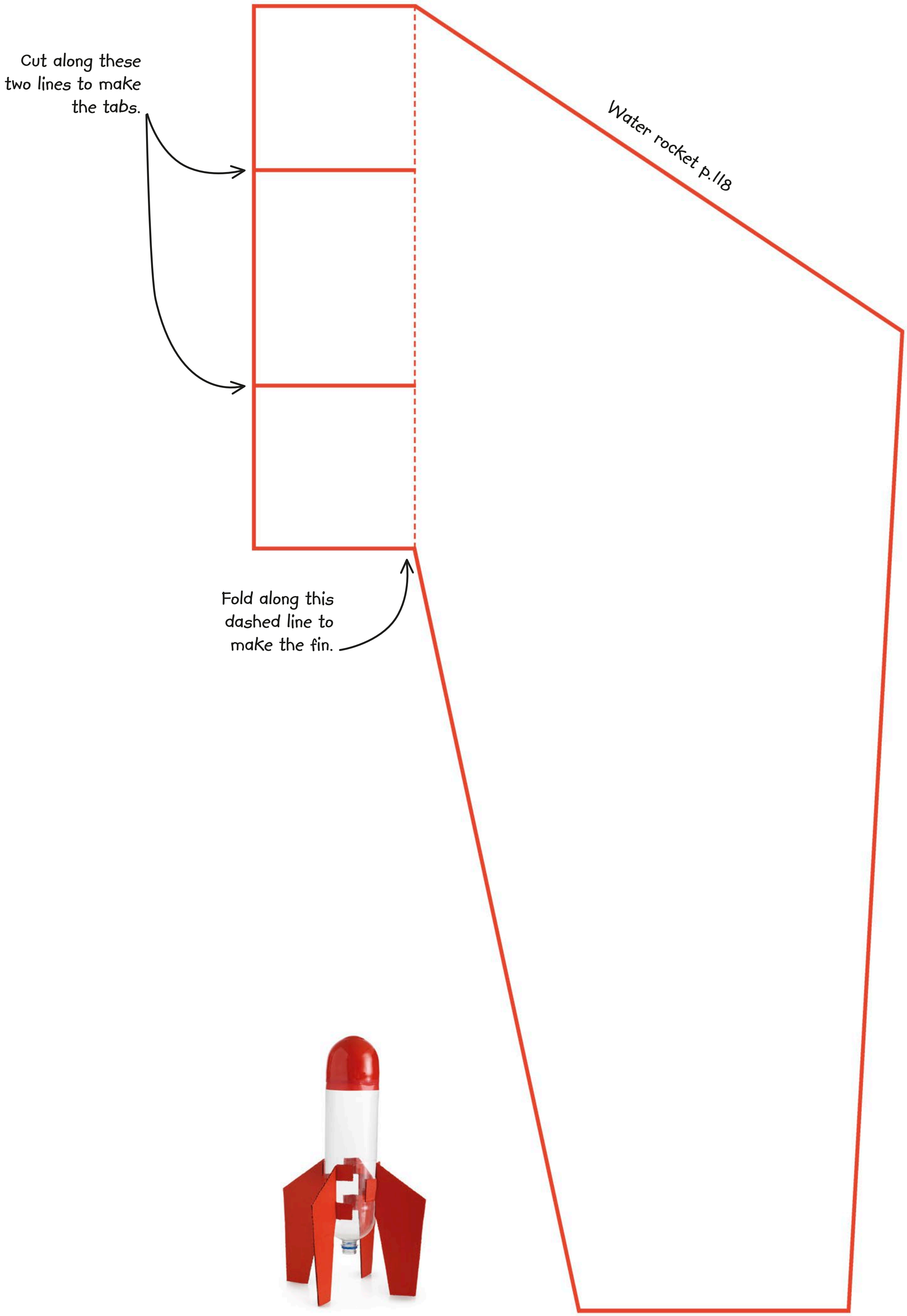
Anemometer p.58





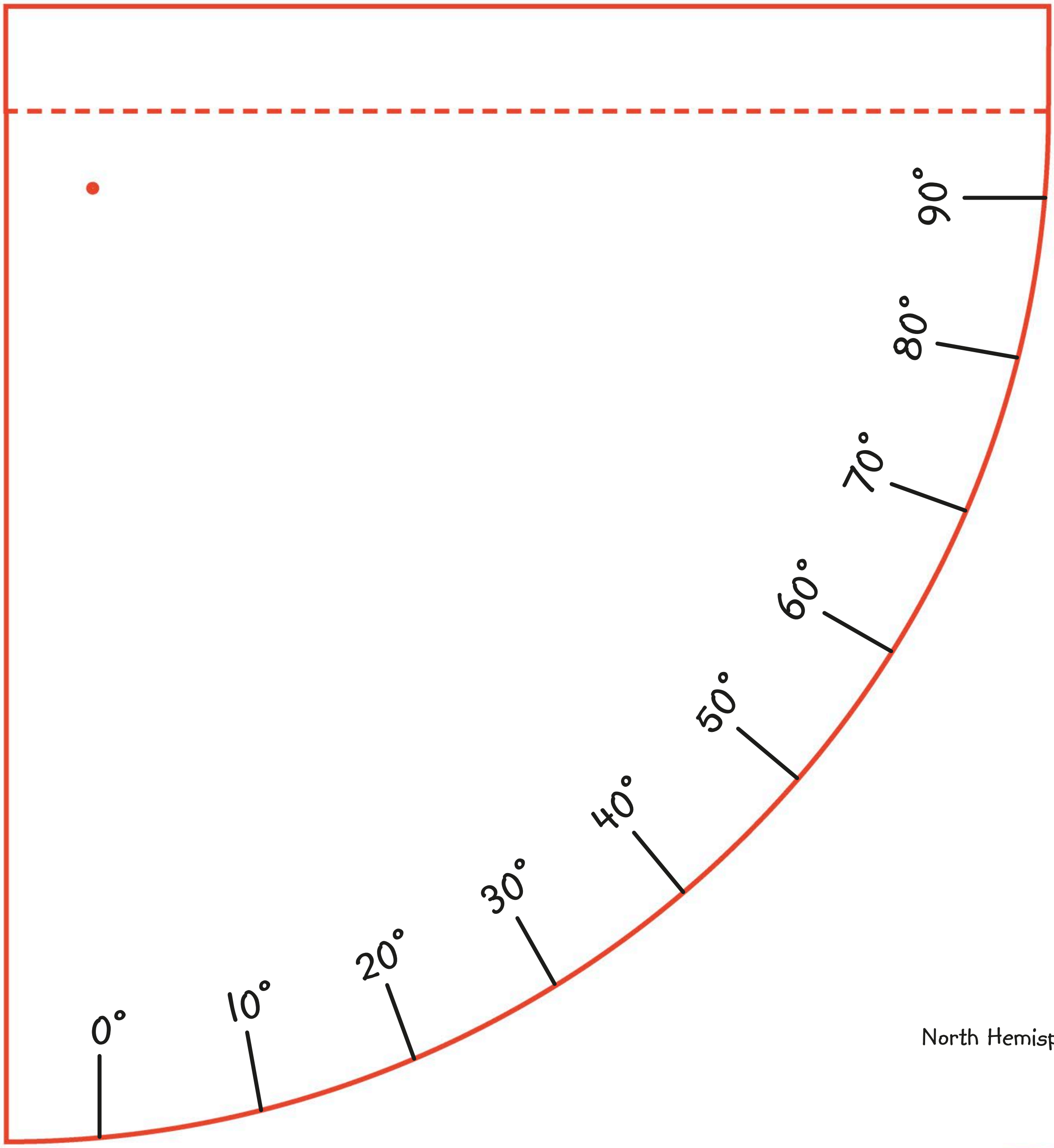
Twirling helicopter p.106



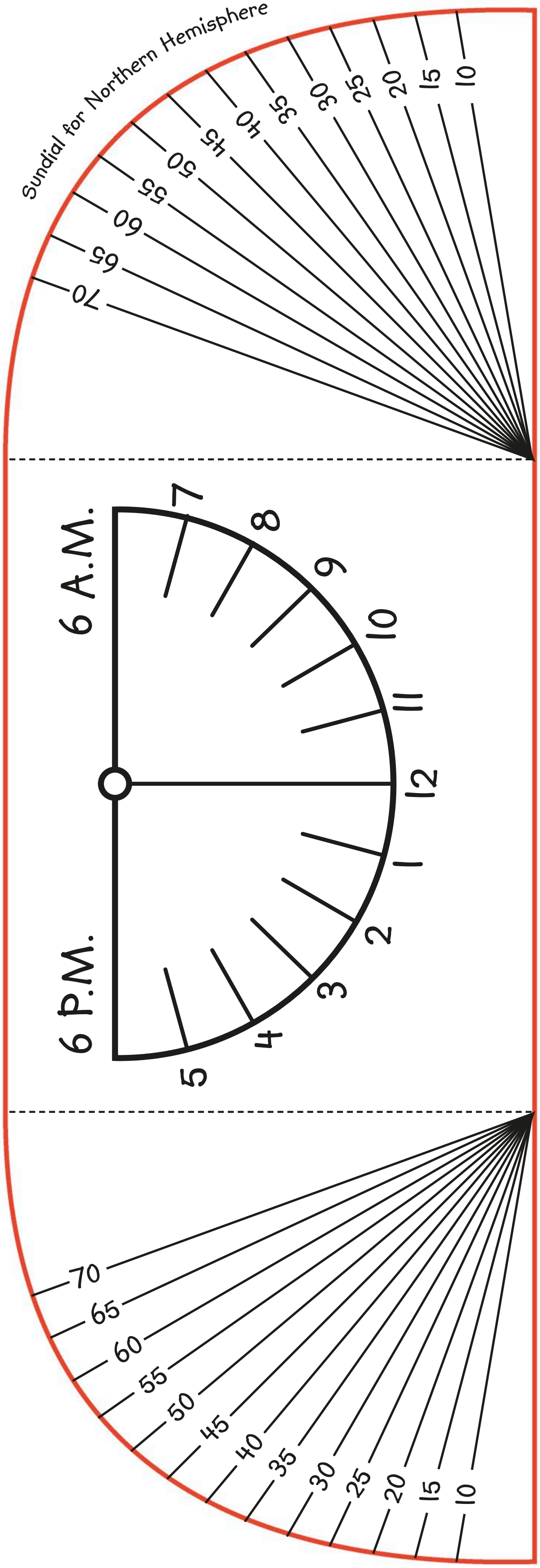

Cut along these two lines to make the tabs.
Water rocket p.118
Fold along this dashed line to make the fin.

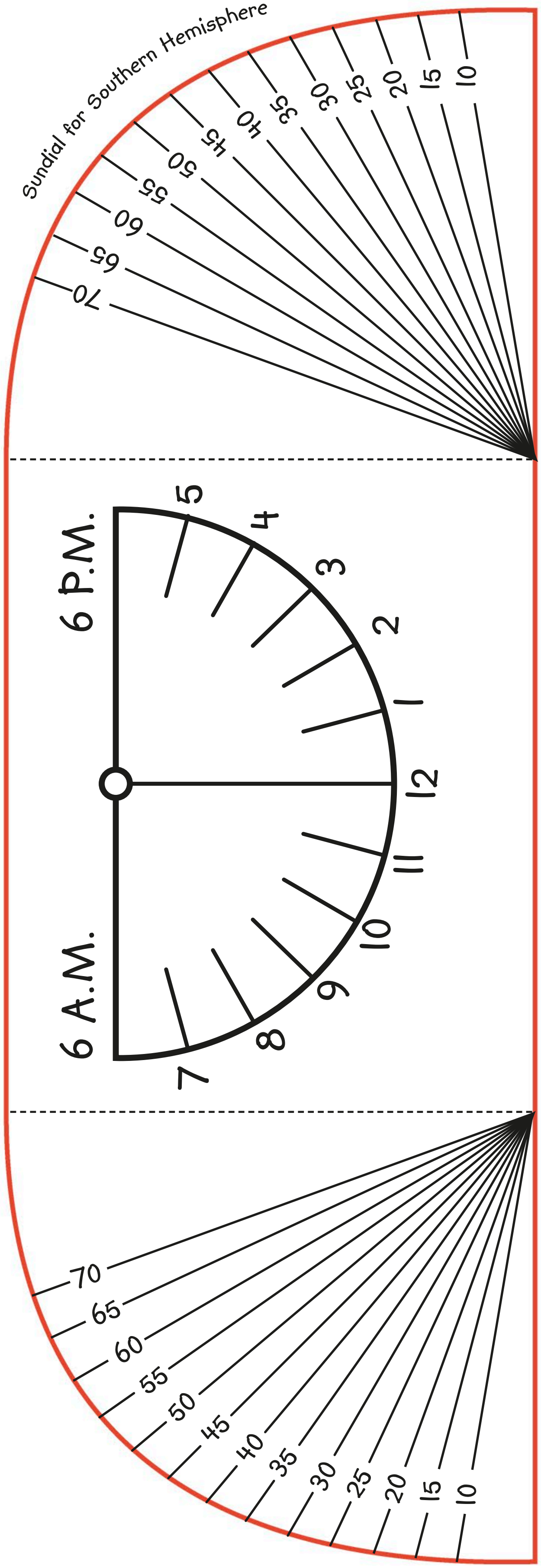
Latitude locator p.144

Fold along this dashed line to make a tab that will attach the locator to the viewing rod.



North Hemisphere Sundial


Sundial for Northern Hemisphere
10
15
20
25
30
35
40
45
50
55
60
65
70
6 A.M.
6 P.M.
7
8
9
10
11
12
1
2
3
4
5


Sundial for Southern Hemisphere
10
15
20
25
30
35
40
45
50
55
60
65
70
6 P.M.
6 A.M.
5
4
3
2
1
12
11
10
9
8
7

GLOSSARY

ANEMOMETER
A device meteorologists use to measure wind speed, normally in miles per hour or kilometers per hour.

ATMOSPHERIC PRESSURE
The pressure of the air around you, caused by the weight of the layer of air around our planet called the atmosphere.

BACTERIA
Tiny living things too small to be seen without a microscope. Some bacteria are useful—for example in cheese making—but others can cause disease or cause food to go bad.

BAROMETER
A device meteorologists use to measure atmospheric pressure.

CALIBRATION
Putting numbers on the scale of a measuring device such as a barometer, so that you can take actual readings, instead of just "higher and lower."

CAMOUFLAGE
Colors or patterns that match an object's surroundings, making it harder to see. Many animals have camouflaged fur or skin to hide from predators.

CELL
The smallest part of a living thing that is alive. All living things are made of cells. Some, such as bacteria, are just single cells, while a tree is made of trillions of cells, and so are you.

CELLULOSE
A substance produced by plants that forms their cell walls and strengthens the tiny tubes that carry water up the stem and into leaves.

COLLOID
If two chemicals mix well but don't entirely dissolve, they form a colloid. Colloids usually consist of tiny droplets or bubbles of one chemical dispersed in another.

COMPOUND
A substance containing chemically combined atoms of two or more different elements.

CONTRACTION
Getting shorter. Muscles work by contracting—in fact they can only contract.

CRYSTAL
A solid with a regular shape, often with flat faces and straight edges, such as a diamond. Crystals have regular shapes because their atoms are arranged in a repeating pattern.

CYLINDER
A three-dimensional shape that has a circle as a cross section. A cardboard tube is a cylinder.

DENSITY
A measure of how much mass (stuff) is present in a certain volume. Rock is much more dense than water, for example.

DOMAIN
A small part of a magnetic material, such as iron. Each domain has its own magnetic field, and when the material is magnetized, the domains' fields all line up.

EQUATOR
An imaginary line around the middle of Earth, halfway between the North Pole and the South Pole.

EROSION
Wearing away. Rocks and soil can be eroded by wind and rain.

FORCE
A push or a pull. Forces change the way objects move, making them speed up, slow down, or change direction. They can also change the shape of an object

FUNGUS
A type of living thing, neither a plant nor an animal, that feeds on rotting matter, such as dead wood. Mushrooms are the part of a fungus that grows above ground.

GEOLOGY
The scientific study of solid parts of Earth, such as rocks, soil, and mountains, and how they form.

GRAVITY
The force that keeps you on the ground. Gravity pulls everything down, toward the center of our planet, and gives things weight.

HABITAT
Where living things live.

HEMISPHERE
One half of a sphere. In particular, it is used to describe the half of our planet above or below the equator.

HUMIDITY
A measure of how much water vapor is in the air. When the humidity is high, there is a good chance of rain or fog.

HYDROPHILIC
Means "water-loving," and describes one end of a soap molecule that is pulled to water molecules.

HYDROPHOBIC
Means "water-hating," and describes one end of a soap molecule that is pushed away from water molecules.

HYDROPONICS
Growing plants without soil. Plants grown hydroponically get all the nutrients they need from their water supply. A plant would normally find these nutrients in the soil.

IMMISCIBLE
Means "unmixable," and describes two liquids that will not mix, such as oil and vinegar.

ISOBAR
A line on a weather map that connects all the places where the atmospheric pressure is the same.

LATITUDE
A measure of how far north or south of the equator you are. The latitude of the equator is 0°, while the North Pole has a latitude of +90° and the South Pole, -90°.

MAGNETIC FIELD
The region around a magnet, in which another magnet or a magnetic material will experience a force.

MASS
A measure of the amount of matter (stuff) in an object.

METEOROLOGIST
A scientist who studies the weather, such as a weather forecaster.

MOLECULE
A tiny particle of matter, made up of two or more atoms joined together. All water molecules are made of two hydrogen atoms joined to an oxygen atom, for example (H_2O). All molecules of a particular substance are identical.

MUCUS
A slimy solution produced by living things, made from water and other substances. In your body, mucus helps food slide through your digestive system and catches bacteria in your nose, which stops them from getting into your lungs.

MULCH
Dead leaves and other plant matter that is laid on top of soil where plants are growing, to help protect the soil.

MYCELIUM
The main part of a fungus, made of fine threads that are often hidden from view. Mushrooms grow out of mycelium hidden in the ground.

PRESSURE
The force of air or water pushing on things. Air pressure falls as you climb a mountain, and water pressure rises as you dive deeper underwater

PROBOSCIS
A tube through which butterflies and other insects suck in their food. A proboscis can also be a snout or a trunk on mammals such as elephants.

RECYCLE
To make something new from the materials of something that is no longer needed. Plastic and metal are often melted down, so that they can be made into new items.

ROTOR
The spinning part of a helicopter, which produces an upward force called lift as it moves through the air.

SOAP FILM
The thin layer of soapy water that forms the outside of a soap bubble.

SOLUTION
A substance broken down into individual molecules or atoms and thoroughly mixed in with the molecules of a liquid—as happens when sugar dissolves in water.

SOLVENT
A liquid that dissolves things easily, to form solutions. Often the word refers to liquids that evaporate quickly into the air, leaving behind whatever was dissolved in it.

SPHERICAL
Round like a ball. A sphere is a three-dimensional object.

VOLUME
The amount of space something takes up, normally measured in milliliters, liters, or cubic meters.

VORTEX
A region of a liquid or gas that is spinning, such as the swirling water that forms when water goes down a drain. You form invisible vortices every time you move through the air.

WATER VAPOR
When water evaporates it forms an invisible gas in the air, called water vapor.

WEIGHT
The downward force on an object caused by gravity. The more mass something has, the more it weighs.

INDEX

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