LESSON PLAN Step 2
Bernoulli Brain-Teasers

In this lesson your students will conduct a series of hands-on experiments that will help them to understand the role of lift in fixed-wing flight. Students will observe the flow of air and water around several surfaces and then consider the dynamics of airflow around an aircraft wing.

You may wish to begin the activity by telling your students that, although air is invisible to the human eye, it is made up of physical matter—real "stuff." This means that air exerts a force that helps to keep an airplane up in the air.

Tell your students that the experiments in this lesson will demonstrate what Swiss mathematician Daniel Bernoulli discovered in the early 1700s: When flowing air or water changes speed, its pressure also changes.

With each activity, ask your students to consider what is going on. Is air slowing down or speeding up? How might air pressure be changing? How might the flow of air (and its changing pressure) help to keep an aircraft up in the air?

Direct your students to the "Use Your Lips to Levitate" and "Balloons That Boggle" activities on page 8. What happens when air is blown over the paper or between the balloons? Ask students what they think causes the paper and balloons to move.

After your students have finished the activities, direct them to the "What's Going On? The Simple Explanation" section on page 10. (*You may wish to have several students alternately read this section aloud.*) Use the questions in the text as the basis for a class discussion. Be sure that students understand that air loses pressure when it speeds up.

Ask your students to begin the "Squeeze the Stream" activity. Explain that this activity is more complex than the previous two activities and will require teamwork. (*You may wish to have three or four experiments going simultaneously, so that all students can observe the water movement first-hand.*) Stress that although this experiment uses water, air flows in a similar manner.

Direct your students to the "What's Going On? The Advanced Explanation" section on page 10. (*You may wish to have several students alternately read this section to the class.*) Conclude the activity by reinforcing these important concepts: (1) Air speeds up as it moves around an object. (2) When air moves faster, its pressure drops and it pushes less. (3) When an airplane flies, air speeds up more above the wing than below it. As a result, the air above an airplane wing pushes less than the air below the wing. The higher pressure below the wing pushes the wing (and the airplane) up.

ACTIVITY SET 2
Bernoulli Brain-Teasers

To pilots, *lift* means the way that air holds up airplanes and other flying objects. These activities will show you how this force works—and they don't require a pilot's license.

USE YOUR LIPS TO LEVITATE

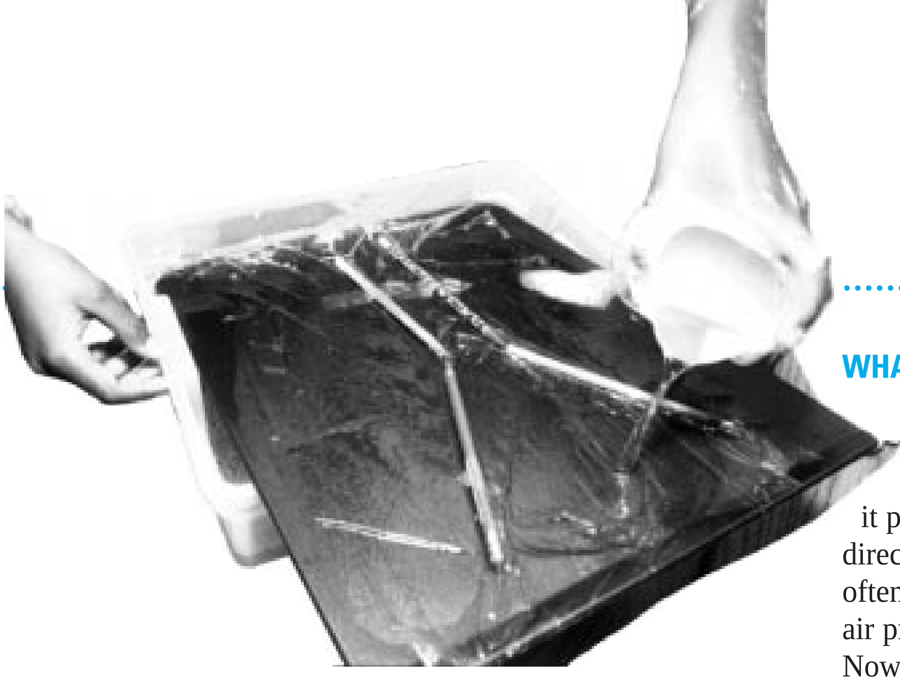
Materials
- Piece of paper

Hold a piece of paper between your thumb and forefinger, as shown in the picture below. Now blow over the paper. What happens?

BALLOONS THAT BOGGLE

Materials
- Balloons
- String
- Water

Try this activity with a friend. Blow up two balloons and tie each one to a string. Hold the balloons a few inches apart and try to blow them together. Can you do it? What happens? Try different ways of blowing on the balloons to see what happens. (*Hint: Squirt a little water into the balloons before you blow them up. This will help steady them.*)



SQUEEZE THE STREAM

Materials

- Cookie sheet
- Pencils
- Tape
- Plastic wrap
- Sink or tub
- Water
- Small scraps of paper or Styrofoam (optional)

Fluids, such as air and water, change speed as they flow between and around objects. To see how this happens, build a tiny stream channel. Tape pencils to a cookie sheet so that they make a channel that starts out wide and then narrows. Drape the pencils and cookie sheet with plastic wrap; this creates a waterproof channel. Now barely tilt the cookie sheet against the sink and slowly pour soapy water into the channel. Does the speed of the water change? How? When? (*Hint: You may want to add small scraps of paper or Styrofoam to the water to help you observe the current's flow.*)

SO WHAT'S A BERNOULLI?

In the early 1700s, a Swiss mathematician named Daniel Bernoulli discovered that when flowing air or water changes its speed, its pressure also changes.

As you do these activities, can you figure out how the pressure changes? How does this help airplanes stay in the air?

WHAT'S GOING ON?

The Simple Explanation…

Air is pretty pushy stuff. It never pulls or sucks; it pushes. Air is pushing on you right now from every direction. We're so used to air being around us that we often don't notice it. This constant push of air is called air pressure. It allows us to breathe—not a bad thing! Now think about what was happening in the activities you just finished. Why did the balloons come together when you blew between them? Why did the paper lift up when you blew over it? Air must be pushing these things, but how?

Even before you blew at the balloons, they were surrounded by air pressure. If you tried blowing between them, you disturbed this push in a very special way. How? Think about this: Either the air between has stopped pushing as hard or the air on the outer sides is pushing harder. Which do you think happened? Which air did you disturb, the air between the balloons or on the outer sides of the balloons?

Can you figure out what happened with the paper? Now you know that the paper was surrounded by air pressure. How did you change the air when you blew over the paper? Remember, air can't suck up anything, but it can push. Did you change the push of air on the top or the bottom of the paper?

Okay, enough questions! Here's what was going on: In both the balloon and paper activities, air lost pressure and stopped pushing as hard. This happened because you blew the air, and it had to "squeeze" between or around the objects. As it "squeezed" through, it sped up, lost pressure, and stopped pushing as hard.

The Advanced Explanation...

Now that you know about push and lift, can you see how these forces might relate to airplanes? If we can make air speed up over a wing, the pressure of the air over the wing will drop. The higher pressure air below the wing then pushes the airplane up. How would you shape a wing so that the air moves more quickly over the top than under the bottom?

The “Squeeze the Stream” activity shows what happens when a fluid is forced to flow from a wide space through a narrower channel. For the water to squeeze through a thinner space, something must either compress the water (think of pulling a sponge through a bottle neck) or speed it up. Freely flowing water does not compress easily. Instead, it speeds up as the channel narrows. Water also speeds up as it moves around an object, such as a rock in a river. Air is a fluid, too, and it behaves like water when it moves through a narrow channel or around an object: It speeds up. As you saw with the other activities, when air moves faster, its pressure drops and it pushes less.

When an airplane flies, it pushes air out of the way. That air must go somewhere—so it “squeezes” between the wings and the surrounding air. The wings are shaped and tilted so that the air moving over the top has less room than the air moving below the wings. Because it has less room, the air moving over the top must speed up more than the air below the wing. As it moves faster, the air on top of the wing also loses pressure and push. The slower moving air below the wing maintains more of its pressure, which pushes the wing, and the plane, up.

An airplane wing affects moving air much like a rock in a stream affects moving water. Remember that the space around the wing is already jammed full of air, so there’s no empty space for more air to move into. As oncoming air hits the wing and moves either over or under it, it speeds up and “squeezes” between the wing and the surrounding air.

The Wrong Explanation...

Many books state that air speeds up over a wing because it has further to travel than air moving under the wing. This explanation implies that air separates at the front of the wing (point A) and rejoins behind the wing (point B), but this isn’t true. Air moving over the top of a wing speeds up so much that it arrives at point B sooner than air that travels beneath the wing.