USING THE UNIT 2 OPENER

TEACHING STRATEGIES

- **Begin the Lesson**—Ask students what kinds of human-powered transportation they are familiar with. Some possible responses include bicycles, unicycles, tricycles, quadricycles, "busycles," pedal boats, kayaks, canoes, in-line skates, roller skates, skateboards, ice skates, kick scooters, cross-country skis. Ask them "What does it mean to you to fly?" Have them brainstorm why human-powered aircraft are rarely seen in the skies. Early attempts at human-powered flight involved ornithopter designs (an aircraft that flies by flapping its wings), but human arms cannot generate the power required to achieve and maintain flight in this manner (humans are too heavy and their arms are too weak). Later attempts used airplane designs powered by pedal power. These flights required a lot of human power.

  The *Gossamer Albatross* shown in the unit opener image used a pedal-powered propeller. It crossed the English Channel in just under 3 hours. The MIT *Daedalus 88* holds the current distance record for human-powered flight. It flew a total distance of 115 km in 1988. In 1989, the first human-powered helicopter took off for 7.1 seconds. It reached a height of 20 cm. The current record holders achieved the same height, for 19 seconds. An extremely high power-to-weight ratio is required for a helicopter to become and remain airborne.
- **After Teaching**—Have students brainstorm a list of factors engineers would have to consider when designing a human-powered aircraft. The *Gossamer Condor*, another plane designed by the same team in 1977, was the first human-powered aircraft considered capable of sustained, controlled flight.

UNIT 2

Flight

Amateur cyclist Bryan Allen had never dreamed of becoming a pilot. But on June 12, 1979, the cyclist did just that. In addition to piloting the plane, he also provided the fuel for the first successful human-powered flight across the English Channel. The plane he flew was called the *Gossamer Albatross*. It used pedal power to rotate its large, double-bladed propeller. Using just the power produced by Allen's body, the plane crossed the 35.8 km channel of water in less than 3 hours.

The *Gossamer Albatross* was especially designed to fly using only the small amount of power a human being could produce. The plane had a mass of only 32 kg without a pilot. Its long, thin wings were like those of a glider. Because of its lightweight design, the plane was vulnerable to wind and air currents. During the design process, the engineers had to consider the forces that act on an object during flight. This unit will introduce you to these forces. You will discover how aircraft are able to achieve and maintain flight. You will find out how the design of an aircraft helps it master the forces that act upon it. Finally, you will build, modify, and test your own aircraft.

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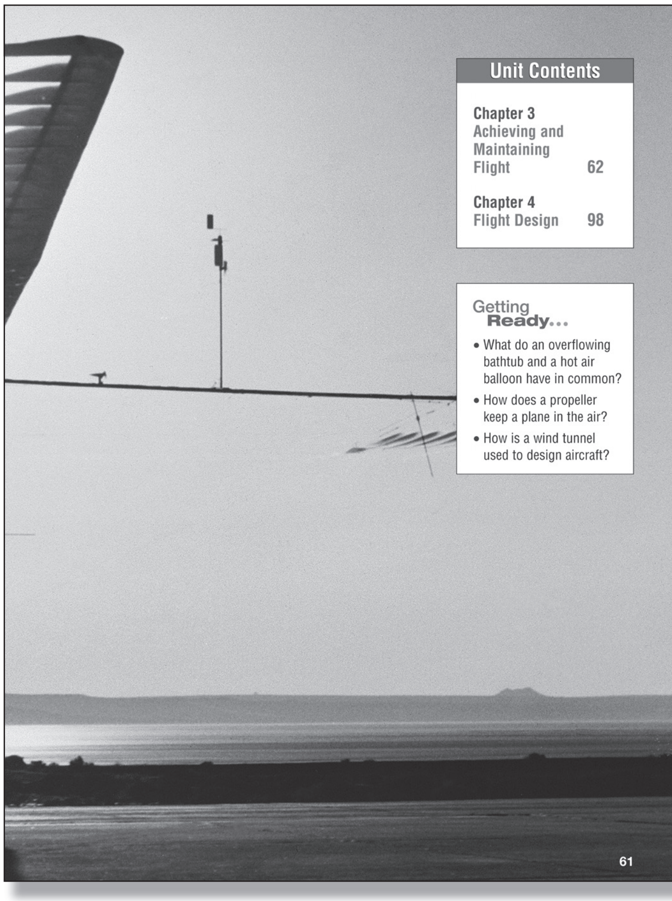
ATTENTION Grabber to Introduce Unit 2

- The Oscar*-winning documentary *The Flight of the Gossamer Condor* illustrates the struggles of a design team involved in getting the human-powered plane off the ground. It is available on video/DVD.



Getting Ready Answers

- **What do an overflowing bathtub and a hot air balloon have in common?** You displace (literally, take the place of) water when you sit down in a bathtub. If the tub is too full, it overflows. Similarly, the warm air in a hot air balloon displaces the cooler air around it.
- **How does a propeller keep a plane in the air?** The tips of the propeller blades spin faster than the centre of the propeller. This creates an air-pressure difference that pushes air backwards. The air strikes other air particles, which apply a force back, resulting in the forward motion of the plane. Illustrate the point about the blades by reminding students that the person at one end of a line of skaters can stand almost still while the person at the other end of the line is moving very fast. To illustrate the point about air pressure, ask students to hold their palm flat and slap the air in front of them. They should feel the air pushing back at their hands.
- **How is a wind tunnel used to design aircraft?** A wind tunnel determines how air flows around an aircraft. Designers may modify their designs based on the results of a wind-tunnel test. Ask students, "Do you think a car manufacturer would use a wind tunnel? How would it help them design a car?"

Connecting to the World Outside the School

- Ask how many students have flown in an aircraft. How many of these students flew in a plane? What about a helicopter, balloon, or other aircraft? Ask students to describe their experience.
- *ICT Option:* Nova Scotia's aviation industry is linked to maritime aviation. Take students to visit the Shearwater Aviation Museum in Shearwater, Nova Scotia, either in person or online, to help them connect their studies to Nova Scotia's aviation industry. For links, go to www.mcgrawhill.ca/links/ns+science6.
- Local airports such as Greenfield Yarmouth, Greenwood, Waterville, or Truro often have staff who can help teachers with tours and demonstrations.

Cross-Curricular Connections

- Literacy: reading, writing, and communicating results through drawings, charts, and presentations
- Mathematics: using charts and measurements of flight; creating and using data
- Health Education: active learning using parachutes for movement activities

Promoting Positive Attitudes

- Have a class discussion about attitudes to flying in general. Ask students to suggest reasons why they might want to fly and why they might be afraid to fly. Assess if suggested fears are realistic. Students may be surprised to find out that it is actually safer to travel by plane than by car. Many more people lose their lives in car crashes than in plane crashes. A possible logbook question is, "Why do you think this is so?" This is an opportunity to pose a good probability question, or discuss or do some research to compare the hazards of flying to driving.
- Brooke Knapp is a woman who became a pilot to overcome her fear of flying. She enjoyed it so much that she eventually broke many aviation speed records. In 1983 and 1984, she set world speed records for circumnavigating the globe. Her flight in 1984 raised almost one million dollars for UNICEF. During her flight, she delivered letters of friendship and peace from American children to children around the world.
- Ask students how air travel influences their lives. For example, food and other products are transported by air. Ask students what is meant by "The world is a much smaller place due to air travel." Friends and relatives that live far away can visit them (and vice versa) or they may one day live or work in a foreign country. On the downside, diseases such as SARS and the flu can be spread around the world much more quickly than before.

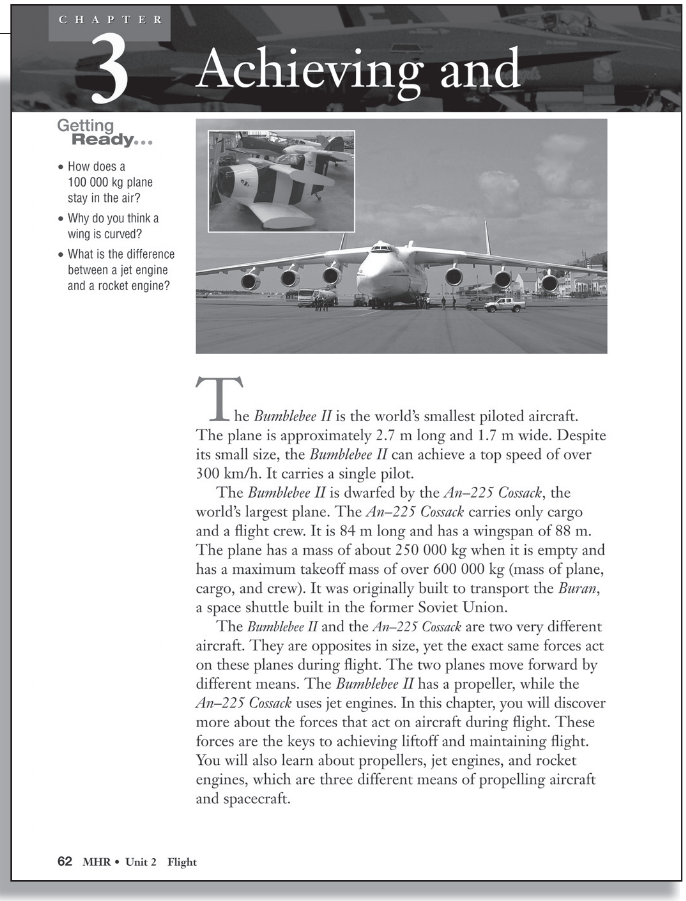
USING THE CHAPTER 3 OPENER

TEACHING STRATEGIES

- **Begin the Lesson**—Have students answer more questions to determine what they know about flight. Possible questions include:
  – What kinds of organisms and machines can fly?
  – How does a hot air balloon become airborne and stay in the air?
  – How does a plane (or helicopter) become airborne and stay in the air?
  – How does a bird (or insect) become airborne and stay in the air?
  – Have students share their logbooks in small groups. As each new section is explored, have students ask new questions and record their responses in their logbooks. These will be revisited upon completion of the chapter. Use Learning Skills Rubric 2, Science Logbook to assess the logbooks.
  – Have students build their own key terms lists by defining the key terms in their own words before beginning each section and updating their definitions after the section is finished. Use BLM 3.1 Key Terms to assess students' definitions of key terms.
- **During Teaching**—Refer to the chapter opener figure, and ask students what these two planes might have in common. Complete the Getting Ready questions as a class. Encourage students to express their opinions and prior knowledge about each point. Review the What You Will Learn, Why It Is Important, and Skills You Will Use sections with students before beginning the chapter.
- **After Teaching**—The same forces act on the two planes shown in the chapter opener figure during flight. Ask students what they think these forces might be. You may want to ask guiding questions such as, "What force causes a ball that is thrown into the air to fall to Earth again?" to help spark ideas.

Getting Ready Answers

- **How does a 100 000 kg plane stay in the air?** There are four forces that act on a plane in flight: lift, drag, thrust, and gravity. Drag is the backward force, thrust is the forward force, lift is the upward force, and gravity is the downward force. In order for an airplane to fly, thrust must be greater than drag. As well, lift must be greater than gravity. As long as these conditions are met, the mass of the plane does not matter.
- **Why do you think a wing is curved?** A wing is curved to create lift. Air flows faster over the upper curved surface of the wing than under the flat lower surface. The faster-flowing air decreases in pressure, and the higher-pressure air flowing under the wing lifts the wing up.



CHAPTER 3 Achieving and

Getting Ready...

- How does a 100 000 kg plane stay in the air?
- Why do you think a wing is curved?
- What is the difference between a jet engine and a rocket engine?

The *Bumblebee II* is the world's smallest piloted aircraft. The plane is approximately 2.7 m long and 1.7 m wide. Despite its small size, the *Bumblebee II* can achieve a top speed of over 300 km/h. It carries a single pilot.

The *Bumblebee II* is dwarfed by the *An–225 Cossack*, the world's largest plane. The *An–225 Cossack* carries only cargo and a flight crew. It is 84 m long and has a wingspan of 88 m. The plane has a mass of about 250 000 kg when it is empty and has a maximum takeoff mass of over 600 000 kg (mass of plane, cargo, and crew). It was originally built to transport the *Buran*, a space shuttle built in the former Soviet Union.

The *Bumblebee II* and the *An–225 Cossack* are two very different aircraft. They are opposites in size, yet the exact same forces act on these planes during flight. The two planes move forward by different means. The *Bumblebee II* has a propeller, while the *An–225 Cossack* uses jet engines. In this chapter, you will discover more about the forces that act on aircraft during flight. These forces are the keys to achieving liftoff and maintaining flight. You will also learn about propellers, jet engines, and rocket engines, which are three different means of propelling aircraft and spacecraft.

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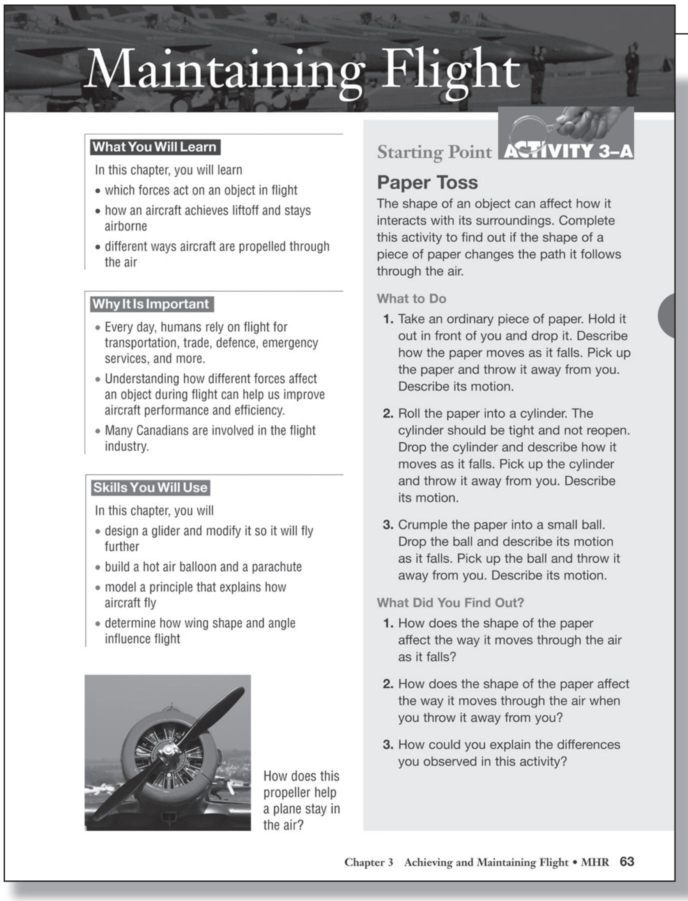
- **What is the difference between a jet engine and a rocket engine?** A jet engine has a fan that pulls in lots of air. Air is compressed, increasing its temperature and pressure. This air is then mixed with fuel and ignited. The gases that form expand rapidly and shoot out the rear of the engine. This causes the plane to move forward. A rocket engine carries its own special chemical to create gases instead of using air. The chemical reacts with fuel to create hot gases that shoot out the rear of the engine. When the engine throws the gas out in one direction, this moves the rocket forward. Ask students if they can explain why the two engines are so different. (Space is a vacuum.)
- **Further question: How does a hot air balloon fly?** The air in a hot air balloon is heated (with a gas burner). As the balloon fills, the warm air displaces the cool air around it. This displaced air exerts pressure back on the balloon. Since the warm air inside the balloon is lighter than the cool air around the balloon, the balloon rises. As altitude increases, air pressure decreases. As a result, there is less pressure acting on the balloon. The balloon eventually stops rising.



Maintaining Flight

What You Will Learn

In this chapter, you will learn
- which forces act on an object in flight
- how an aircraft achieves liftoff and stays airborne
- different ways aircraft are propelled through the air

Why It Is Important

- Every day, humans rely on flight for transportation, trade, defence, emergency services, and more.
- Understanding how different forces affect an object during flight can help us improve aircraft performance and efficiency.
- Many Canadians are involved in the flight industry.

Skills You Will Use

In this chapter, you will
- design a glider and modify it so it will fly further
- build a hot air balloon and a parachute
- model a principle that explains how aircraft fly
- determine how wing shape and angle influence flight

How does this propeller help a plane stay in the air?

Starting Point ACTIVITY 3–A

Paper Toss

The shape of an object can affect how it interacts with its surroundings. Complete this activity to find out if the shape of a piece of paper changes the path it follows through the air.

What to Do

1. Take an ordinary piece of paper. Hold it out in front of you and drop it. Describe how the paper moves as it falls. Pick up the paper and throw it away from you. Describe its motion.
2. Roll the paper into a cylinder. The cylinder should be tight and not reopen. Drop the cylinder and describe how it moves as it falls. Pick up the cylinder and throw it away from you. Describe its motion.
3. Crumple the paper into a small ball. Drop the ball and describe its motion as it falls. Pick up the ball and throw it away from you. Describe its motion.

What Did You Find Out?

1. How does the shape of the paper affect the way it moves through the air as it falls?
2. How does the shape of the paper affect the way it moves through the air when you throw it away from you?
3. How could you explain the differences you observed in this activity?

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You can illustrate this movement with hot and cold water. Place hot water with food colouring in a jar; put an index card on top of the jar; and invert another jar of cold water on the mouth of the hot-water jar. Remove the card, and watch the hot water rise into the cold water.

STARTING POINT ACTIVITY 3-A PAPER TOSS

Purpose
- Students investigate how the shape of an object affects the path it takes when it is dropped or tossed.

Advance Preparation

WHEN TO BEGIN	WHAT TO DO
1 day before	– Gather enough paper for the class to complete the activity. This paper should be of a variety of different textures and compositions.

MATERIALS
Per student: – piece of paper

Suggested Time
- 20 min

Safety Precautions
- Make sure students do not throw their paper at each other during this activity.

HINTS & HELPS
- Group students into teams of two or three to reduce the amount of time required.
- Provide clear instructions on how you want this activity to be conducted.
- You can bring in pieces of photocopy paper from the recycling bin to use in this activity.

Implementing the Activity
- If using groups, assign each student a role in this activity. For example, one student could do step 1, while the second records the group's observations and the third retrieves the piece of paper.
- Rotate students through the remaining step 2 and step 3 so each gets a chance to drop the paper.
- If you have a stairwell in your school, dropping the pieces of paper down the stairwell will give students more time to observe what is happening during the drop part of each step in the procedure. You could also have them use a stopwatch to time how long it takes each piece of paper to reach the floor. However, extra safety precautions and procedures would have to be implemented to ensure that no one falls down the stairs.

Adaptations
- Students with physical disabilities should be able to play a role in a team and complete this activity.

Activity Wrap-Up
- Ask students to make a connection between the flight path of the paper in each configuration and an example of something they've seen in flight. For example, the flight path of the paper in step 1 might remind them of a parachute, while step 3 might remind them of a falling rock or meteorite.
- Ask students to consider the question, "Why do most things that fly have "wings?"

What Did You Find Out? Answers

1. The more compact the piece of paper is, the faster it falls.
2. The more compact the piece of paper is, the further you can throw it.
3. More compact objects strike fewer air particles as they move (experience less air resistance) and, therefore, fall faster.

SECTION 3.1 FORCES THAT ACT DURING FLIGHT: GRAVITY AND LIFT

What Students Do in Section 3.1

- design and construct a paper airplane and evaluate the design of their model
- construct a hot air balloon
- design and construct a winged vehicle that will become airborne when rolled down a ramp
- demonstrate Bernoulli's principle and explain how this principle generates lift on a curved wing

BACKGROUND INFORMATION

- The forces that act on all objects during flight are gravity (downward), lift (upward), drag (backward), and thrust (forward). Buoyant objects, such as hot air balloons, are also subject to the force of buoyancy (upward). Buoyancy and lift work opposite gravity. Gravity, buoyancy, and lift are discussed first; drag and lift are discussed in the second section.

TEACHING STRATEGIES

- **Begin the Lesson**—There are many films that deal with flight, the history of flight, and aircraft. The following are available at the Nova Scotia DOE Learning Resources and Technology Division:
  – 22447, *Birds* (videorecording), Dorling Kindersley, Inc., 1994.
  – 21223, *Fundamentals of Aeronautics Technology* (videorecording), Shopware Educational Systems, 1994.
  – 21234, *Aircraft Design* (videorecording), Public Broadcasting System, 1990.
- Available from the Nova Scotia Book Bureau:
  – 13522, *Flying Aces*, Pearson Education Canada, 2000. This title has great photographs and illustrations, making it accessible to transitional readers in guided or independent reading.
- **During Teaching**—Draw students' attention to Figure 3.1 on page 64. Ask students to compare the dragonfly to a human-engineered aircraft. Similarities include: both fly, both have wings, and both are streamlined. Differences include: they are made of different materials, have different masses and sizes, the dragonfly has two sets of wings (most planes have one), the dragonfly is living and a plane is not. Guide students' responses to the fact that a dragonfly flaps its wings to fly while planes don't. The same forces act on a dragonfly and an aircraft in flight. Do students think an aircraft could fly by flapping its wings? Could a human? (Insects have very strong wing muscles that enable them to flap their wings very quickly and for a long time. Humans don't.)

CHAPTER 3

Section 3.1 **Forces That Act During Flight: Gravity and Lift**

Key Terms
buoyancy
lift
Bernoulli's principle

Have you ever wondered how a plane stays in the air? What about a hot air balloon or a dragonfly? All aircraft are subject to forces that act on an object in flight. These forces work in four directions: downward, upward, backward, and forward. They act upon all things that fly, from the smallest insect to the largest jumbo jet. In the next few pages, you will learn more about these forces and how they affect an object during flight. How do you think these forces will affect a paper glider as it flies through the air?

Figure 3.1 The same forces that act on a large passenger jet act on all objects during flight, including this dragonfly.

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Draw students' attention to the fact that the same four forces act on the dragonfly and a plane in flight. This means that it is possible to use many designs to achieve flight, even though the forces are the same. This is a great lead-in to Find Out Activity 3-B My Flying Machine.

- **After Teaching**—To discuss the forces of gravity and lift, remind students that gravity exerts a downward force on all objects. Ask them what force helps a bird soar in the air or causes a kite to fly. Students may recognize that how air travels under the wing has something to do with this. Identify this upward force as lift.

FIND OUT ACTIVITY 3-B MY FLYING MACHINE

Purpose

- Students design, construct, and test paper gliders.

Advance Preparation

WHEN TO BEGIN	WHAT TO DO
1 week before	– Gather books or Internet information on paper gliders and glider design. – Book the gym or larger area to test the paper gliders.
3 days before	– Gather a class set of materials.

Find Out ACTIVITY 3–B

My Flying Machine

Build a paper glider of your own design in this activity.

What You Will Need

paper, various types and sizes
books about paper gliders

What to Do

1. Design and construct a paper glider. You can use the design books provided for inspiration. Your glider can be any shape or size. Your teacher will provide different types of paper for you to choose from.
2. As a class, brainstorm a list of ways you could compare how each glider flies. With your classmates, choose two of these factors to compare when you fly your gliders. Determine how you will measure these factors.
3. Fly your glider. Measure or observe one of the factors you chose as a class in step 2. Record your findings in your notebook.
4. Repeat step 3 for the other factor.
5. Compare your measurements or observations with your classmates.

What Did You Find Out?

1. Explain how your measurements or observations compared with those of your classmates for the two factors. How might your design have affected your glider's performance in each case?
2. Suggest two design changes you could make to your glider (such as smaller wings). How do you think the glider's performance would change if you made each design change?
3. Describe a change you could make that might make your glider fly further.

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MATERIALS
Per group: – paper, various types and sizes – books about paper gliders

Suggested Time

- 30 min

Safety Precautions

- Some designs have a relatively hard, pointed nose area that could damage another student's eye if contact is made.

HINTS & HELPS

- Have a variety of different textures and sizes of paper available. Include loose-leaf paper, photocopy paper, tissue paper, Manila paper, used file folders, tracing paper, construction paper, and waxed paper. The goal is to get students thinking about flight, not to design the perfect glider.
- Remind students that the goal is to get the glider to fly smoothly. This can be achieved by a firm throw rather than a forceful throw.
- Students will likely choose flight time or flight distance as one of the factors they will measure. Have timers and measuring tapes on hand.
- Activity could be completed as partners. Some students have had no experience with this type of activity.

Implementing the Activity

- Discuss step 2 with the class. Agree on the factors to be tested. Flight time and distance may be the easiest to measure, but the class may suggest more subjective criteria such as smoothness of flight (wobble), speed, or if glider does tricks. As long as students can determine ways to measure the criteria, encourage them to experiment.
- Ensure each student is clear about what he or she will be testing and how the test will be performed. If data such as flight time or flight distance is being recorded, have students do several trials and then find the average.

Adaptations

- Use preferential grouping when organizing students to allow those students with fine motor difficulties to participate.
- You may wish to pre-build different gliders that fly well for students who have trouble designing their own planes or reading instructions.

Activity Wrap-Up

- Have students post a class set of data. Explain that the more data they collect, the more accurate and reliable the results.
- Compare students' designs perhaps by passing around the planes that scored the highest for the factors being measured. Ask students why they think these planes flew better.

Assessment Option

- Use Science Skills Checklist 15, Making Observations and Inferences to assess student work in Find Out Activity 3-B My Flying Machine

What Did You Find Out? Answers

1. *Sample answer:* The first factor we measured was the distance the plane flew. My plane did not fly very far. I think the paper I used slowed the glider down because it wasn't very stiff. The second factor we measured was how smoothly the plane flew. My plane hardly wobbled. If I had used stiffer paper, it might not have wobbled at all.
2. Design changes students might make include: changing wing shape and size, adding flaps, changing paper type, changing overall size and design, or adding weight. Students may suggest using a different technique for throwing/tossing their airplanes, although it is not technically a design change. Students should only change one factor at a time.
3. Accept any reasonable answer. Students might suggest changing the wing length or using stronger paper. This question leads into the next My Flying Machine Activity (3-F on page 79 in the student textbook) in which students design gliders for distance.

GRAVITY

BACKGROUND INFORMATION

- Gravitational attraction occurs between any two objects. The force of gravity depends on the mass of each object and the distance between their centres of mass. Gravitational force increases as the mass of the objects increases and the distance between them decreases.
- Gravity is responsible for keeping the Earth and the other planets in their orbits around the Sun, for keeping the Moon in its orbit around the Earth, for the formation of tides, for convection (by which hot fluids rise), for heating the interiors of stars and planets that are forming to very high temperatures, and for various other phenomena.

TEACHING STRATEGIES

- **Begin the Lesson**—Take students into the gym or out on the school field and have them toss or kick a ball. Ask them what force keeps the ball from flying off into outer space. How would a game of soccer or volleyball be different if they were playing in a place with a gravitational force that was much weaker than Earth's? What if the force was much stronger?
- **During Teaching**—Examine Figure 3.2 on page 66 with students. Ask students to explain the image in terms of gravitational pull. Students should be able to explain that the teacup and the glass of juice both exert gravitational pull on the other. This pull is extremely small due to the small size of the objects. However, Earth's pull on both of these objects is much larger, due to its large size, and that pull keeps the objects from flying into space.
- **After Teaching**—Have students think about the two questions at the end of the reading before they carry out the activity that follows, Conduct an Investigation 3-C Build a Balloon. How do balloons overcome the force of gravity to rise into the air? What factors might affect how high a balloon rises?
- *ICT Option:* There are web sites available that provide students with an opportunity to try to launch a cannonball into orbit. These types of web sites can be used to provide a visual representation of the effects of gravity. For links, go to www.mcgrawhill.ca/links/ns+science6.

Gravity

When you flew your glider in the last activity, no matter what design you used or how hard you threw it, it still fell to the ground eventually. The force of gravity, which pulled your glider to the ground, acts on all objects. Gravitational attraction pulls all objects with mass toward each other. However, only very large objects, such as a planet or star, have a noticeable gravitational pull. This is because the force of gravity is very small.

The force of gravity acts in a downward direction. If an object is released above the ground, it will always fall downward due to Earth's gravitational pull. Gravity acts on all objects during flight. However, other forces also act on these objects. Some of these forces keep aircraft from falling. In the next activity, you will build several hot air balloons. How do they overcome the force of gravity to rise into the air? What factors might affect how high a balloon rises?

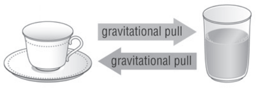

Figure 3.2 All objects that have mass are influenced by gravity. Any two objects will always attract each other with gravitational force.

Figure 3.3 Because the force of gravity is very small, only very large objects, such as our planet, have a noticeable gravitational pull.

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Common Misconceptions

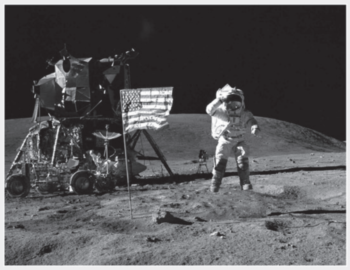
- Students may also believe that the force of gravity only affects large objects, like planets. Remind students that gravitational attraction pulls all objects with mass toward each other. However, only very large objects, such as a planet or star, have a noticeable gravitational pull because the force of gravity is very small.

Type of Force
- Gravity

Direction of Force
- Downward

How does it work?
- Gravitational attraction pulls all objects with mass toward each other. However, the force of gravity is small. This means that only very large objects, such as Earth, have a noticeable gravitational pull. Earth pulls all objects toward it.

Examples:
- If you toss an object in the air, it will always fall downward eventually.
- You can jump much higher on the Moon than you can on Earth. This is because the Moon has less mass than Earth. Its gravitational pull is much smaller.



Off the Wall Have you ever let go of a helium balloon and watched it float away? Like hot air balloons, helium balloons can overcome the force of gravity and rise into the air. When you hold onto a helium balloon, your mass keeps it from floating up into the atmosphere. If enough are used, helium balloons can lift you off the ground. In 1982, a man filled 45 large weather balloons with helium. He tied them to his lawn chair and quickly became airborne. He had risen over 4800 m when passing jet planes spotted him and alerted air traffic controllers to the flight hazard. The man landed safely after deflating some of the balloons with shots from a pellet gun. He was fined $4000 for his unauthorized flight.

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GRAVITY FILE CARD INSET

BACKGROUND INFORMATION

- The Moon's diameter is about 25 percent of Earth's diameter, and its volume is 2 percent of Earth's. Consequently, its gravitational pull is only 16.6 percent (1/6th) of the gravitational pull we experience on Earth. Thus, an object weighs much less on the Moon, even though its mass stays the same.
- Astronauts in space are still experiencing Earth's gravitational pull. However, they experience a sense of "weightlessness" because when in orbit, they are falling toward Earth at the same speed as their spaceship. The astronauts do not press against anything, as we press against the ground when on Earth. Nothing stops their fall, so they feel weightless. Students might recall feeling a similar sensation when in a fast-moving elevator or going downhill in a roller coaster.

TEACHING STRATEGIES

- **Begin the Lesson**—*ICT Option:* The National Geographic web site has archived videos of astronauts walking on the Moon. Show clips of this historic event and focus students' attention on how the astronauts "walked" on the Moon. Have your students compare the images of the astronauts to their own ideas about how gravity affects objects. For links, go to www.mcgrawhill.ca/links/ns+science6.
- **During Teaching**—Challenge students to think of times when they were able to overcome gravity. For example, jumping in the air overcomes gravity for a brief instance. What force is working against gravity in this case? A hang-glider and a parachute can reduce the effects of gravity for a slightly longer period of time. What forces come into play? (This question links to the other forces that affect flight, such as lift and drag, which are explored in the next section.) A hot air balloon overcomes gravity for a long period of time. What force do students think is involved in this case? (The last question links nicely to the spread on buoyancy in the student textbook, on pages 70–72.)
- **After Teaching**—Draw students' attention to the figure of the astronaut jumping on the moon. Get students to estimate how high they can jump on Earth. Then get them to guess how high they could jump on the Moon, considering the Moon's gravity is approximately 1/6 that of Earth's. Or have students actually jump and measure the distance. Then use this to figure out how high they can jump on the moon or other planets.

Common Misconceptions

- Students may believe that gravity only exits on Earth. In reality, gravity also affects objects in space. For example, the Moon and human-made satellites orbit the Earth as a consequence of Earth's gravitational pull. Students may be interested to know that gravity is responsible for holding the solar system and galaxy in its current form.

Off the Wall

- *ICT Option:* The individual referred to in this feature is Larry Walters of Los Angeles, California. You can find out more about his adventure by going to the Darwin Awards web site. There are actual photographs of his lighter-than-air contraption. You might want to mention to students that this individual was very lucky to have survived this adventure. Airplane pilots are advised not to fly without supplemental oxygen at an altitude of 3000 m. Mr. Walters was at 4800 m for more than 14 hours. For the link, go to www.mcgrawhill.ca/links/ns+science6.
- Bring in some helium-filled balloons. Challenge your students to design an experiment to determine how much mass it takes to keep a balloon floating at a specific altitude.

CONDUCT AN INVESTIGATION 3-C BUILD A BALLOON

Purpose
- Students investigate buoyancy by making hot air balloons out of different materials.

Advance Preparation

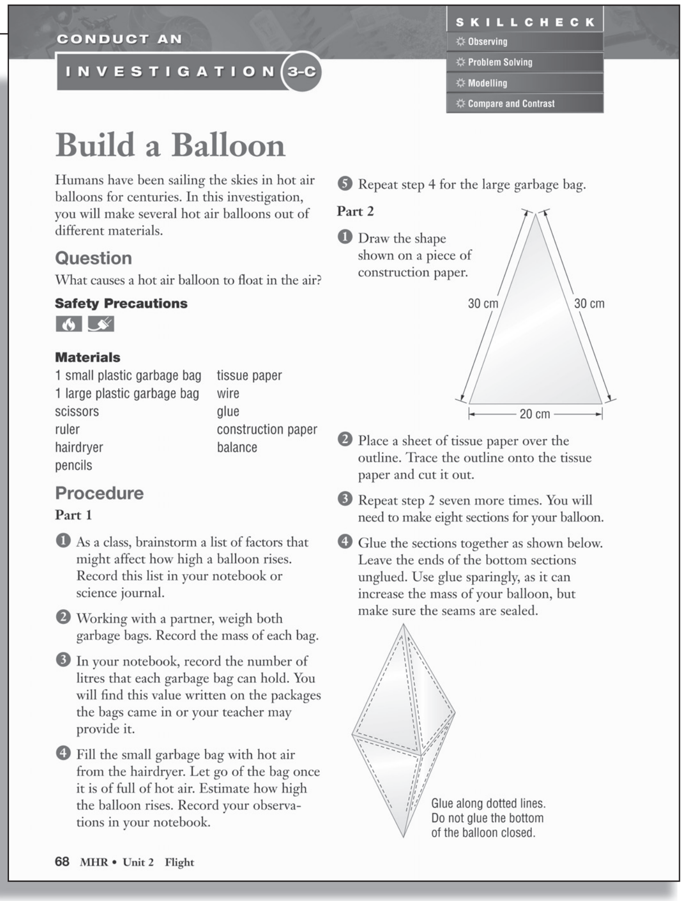
WHEN TO BEGIN	WHAT TO DO
3 days before	– Gather a class set of materials.

MATERIALS	
Per group:	
– 1 small plastic garbage bag	– scissors
– 1 large plastic garbage bag	– ruler
– tissue paper (use crepe tissue paper)	– hair dryer
– wire	– pencils
– glue	– balance
– construction paper	

Suggested Time
- Part 1: 20 min
- Part 2: 60 min

Safety Precautions
- Remind students to use caution when handling hot hair dryers and plugging in electrical devices.
- This can be a loud activity. Ensure that ear protection is available for students with sound sensitivity.
- Advise students to handle scissors with care.

HINTS & HELPS
- Choose crepe tissue paper for completing Part 2 of this experiment. This tissue paper is sturdier than the standard tissue paper used for gift packaging and is easier for students to cut and glue without tearing.
- When gluing the tissue-paper balloon together in step 4 of Part 2, have students begin by gluing an upward pointing triangle to a downward pointing one. Repeat for the rest of the triangles until the students have four diamonds. Then have students glue the lengthwise seams together to create the balloon. This method is easier than having students create the top and bottom half of the balloon separately and then try to stick them together.


CONDUCT AN INVESTIGATION 3-C

SKILLCHECK
- Observing
- Problem Solving
- Modelling
- Compare and Contrast

Build a Balloon

Humans have been sailing the skies in hot air balloons for centuries. In this investigation, you will make several hot air balloons out of different materials.

Question

What causes a hot air balloon to float in the air?

Safety Precautions

Materials

1 small plastic garbage bag	tissue paper
1 large plastic garbage bag	wire
scissors	glue
ruler	construction paper
hairdryer	balance
pencils	

Procedure

Part 1

1. As a class, brainstorm a list of factors that might affect how high a balloon rises. Record this list in your notebook or science journal.
2. Working with a partner, weigh both garbage bags. Record the mass of each bag.
3. In your notebook, record the number of litres that each garbage bag can hold. You will find this value written on the packages the bags came in or your teacher may provide it.
4. Fill the small garbage bag with hot air from the hairdryer. Let go of the bag once it is of full of hot air. Estimate how high the balloon rises. Record your observations in your notebook.
5. Repeat step 4 for the large garbage bag.

Part 2

1. Draw the shape shown on a piece of construction paper.
2. Place a sheet of tissue paper over the outline. Trace the outline onto the tissue paper and cut it out.
3. Repeat step 2 seven more times. You will need to make eight sections for your balloon.
4. Glue the sections together as shown below. Leave the ends of the bottom sections unglued. Use glue sparingly, as it can increase the mass of your balloon, but make sure the seams are sealed.

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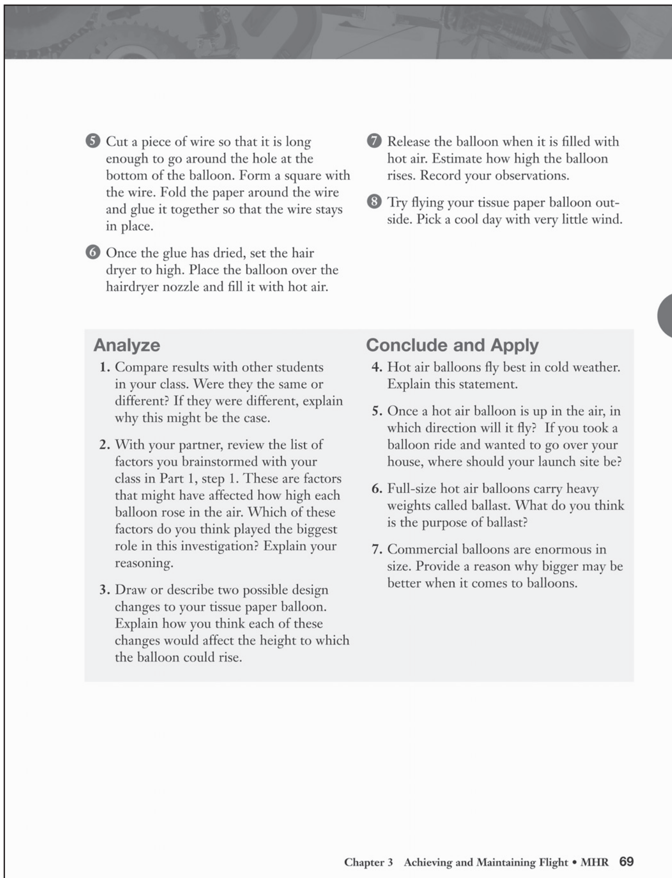
Implementing the Investigation
- This activity works well when students work in pairs.
- Students may have some difficulties creating the balloon from this design. In Analyze question 3, they are asked to suggest ways to improve the design. You may also opt to have students actively try to improve the design of the balloon by using this question as a procedure step that challenges students to create a better balloon.
- Describe the activity before beginning. Have students predict what they think will happen in Part 1.

Adaptations
- Students with coordination difficulties should be grouped with individuals who can cut and glue the tissue paper to create the balloon.
- You may wish to read the procedure aloud to help students with literacy difficulties.



5. Cut a piece of wire so that it is long enough to go around the hole at the bottom of the balloon. Form a square with the wire. Fold the paper around the wire and glue it together so that the wire stays in place.
6. Once the glue has dried, set the hair dryer to high. Place the balloon over the hairdryer nozzle and fill it with hot air.
7. Release the balloon when it is filled with hot air. Estimate how high the balloon rises. Record your observations.
8. Try flying your tissue paper balloon outside. Pick a cool day with very little wind.

Analyze

1. Compare results with other students in your class. Were they the same or different? If they were different, explain why this might be the case.
2. With your partner, review the list of factors you brainstormed with your class in Part 1, step 1. These are factors that might have affected how high each balloon rose in the air. Which of these factors do you think played the biggest role in this investigation? Explain your reasoning.
3. Draw or describe two possible design changes to your tissue paper balloon. Explain how you think each of these changes would affect the height to which the balloon could rise.

Conclude and Apply

4. Hot air balloons fly best in cold weather. Explain this statement.
5. Once a hot air balloon is up in the air, in which direction will it fly? If you took a balloon ride and wanted to go over your house, where should your launch site be?
6. Full-size hot air balloons carry heavy weights called ballast. What do you think is the purpose of ballast?
7. Commercial balloons are enormous in size. Provide a reason why bigger may be better when it comes to balloons.

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Investigation Wrap-Up

- You may wish to create a tissue-paper balloon yourself that successfully flies.
- Return to students' predictions of what would happen in Part 1 of the investigation (floating plastic-bag balloons). Were their predictions correct? Ask students to try to explain why they got the results they did in Part 1.
- After student reports have been evaluated and returned to students, discuss and review the Analyze and Conclude and Apply sections.
- Use this activity as an introduction to the concept of buoyancy explored in the student textbook following this investigation.

Assessment Option

- Use Science Skills Rubric 19, Conduct an Investigation to assess student work in Investigation 3-C Build a Balloon

Analyze Answers

1. Students' answers should clearly explain why their results differed from those of other students, if they did. You may also wish students to speculate on why the results might have differed.
2. Sample answer 1: I think the factor that played the biggest role in getting the balloon to rise was how warm the air was. Our balloon did not rise into the air at first because the air from our hair dryer was not very warm. Our teacher gave us another hair dryer that was hotter and the balloon rose into the air.
   Sample answer 2: I think the factor that played the biggest role in getting the balloon to rise was whether the balloon was tightly sealed. Our balloon did not rise at first because we didn't glue the seams very well. After we glued the seams better, it rose.
3. Some possible design changes include using a lighter material to construct the balloon, changing the design so it uses less material or glue and weighs less, changing the design so there are fewer gaps for air to escape, using nylon instead of paper to cover it (students may argue that air could escape through the tissue paper), adding an onboard source of heat so the balloon keeps rising higher and higher, making the balloon smaller so it weighs less, and making the balloon larger so it will hold more air. Accept any reasonable suggestions. Answers should clearly explain how the changes would affect how high the balloon rises.

Conclude and Apply Answers

4. Accept any reasonable answer. Hot air balloons fly best in cold weather because the air outside is a lot colder than the air inside the balloon. The colder air exerts more pressure on the balloon than warm air does, and the balloon receives a better "lift" and rises faster.
5. A hot air balloon will fly in the same direction the wind is blowing. If you wanted to fly over your house in a balloon, your launch site must be upwind of your house.
6. Ballast is used to stabilize a balloon during flight. It can also be thrown out to achieve a greater height.
7. Some possible answers: Bigger balloons can hold more air, are more stable, can lift more weight, and can carry more fuel. Accept any reasonable answer.

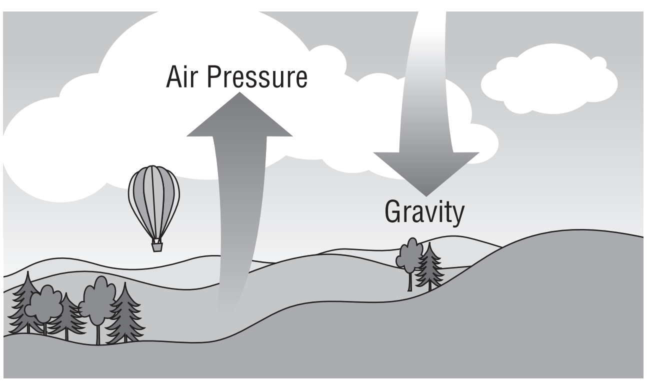
BUOYANCY

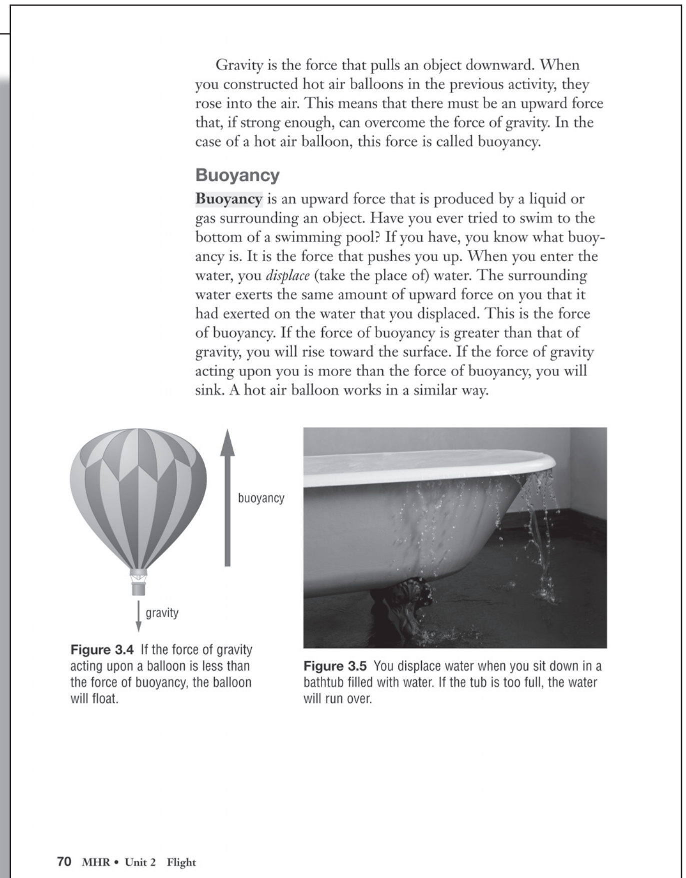
BACKGROUND INFORMATION

- Air pressure is highest right at Earth's surface because this air is supporting the mass of all the air above it. As you move up through levels of the atmosphere, the air has less air mass above it. This explains why air pressure decreases as the altitude increases.

TEACHING STRATEGIES

- **Begin the Lesson**—Ask students to describe their experiences of trying to swim to the bottom of a swimming pool or lake. Did they have difficulty reaching the bottom? Ask them to explain why they think they may or may not have had difficulty. What did students feel as they descended? Link this discussion to the concept of buoyancy.
- **During Teaching**—Use Figures 3.4 and 3.5 on page 70 to help explain the concept of buoyancy.
- **After Teaching**—Challenge students to explain why air pressure decreases with altitude (which causes a balloon to stop rising at a certain altitude). Use the background information provided above to explain this concept to students.




Gravity is the force that pulls an object downward. When you constructed hot air balloons in the previous activity, they rose into the air. This means that there must be an upward force that, if strong enough, can overcome the force of gravity. In the case of a hot air balloon, this force is called buoyancy.

Buoyancy

Buoyancy is an upward force that is produced by a liquid or gas surrounding an object. Have you ever tried to swim to the bottom of a swimming pool? If you have, you know what buoyancy is. It is the force that pushes you up. When you enter the water, you *displace* (take the place of) water. The surrounding water exerts the same amount of upward force on you that it had exerted on the water that you displaced. This is the force of buoyancy. If the force of buoyancy is greater than that of gravity, you will rise toward the surface. If the force of gravity acting upon you is more than the force of buoyancy, you will sink. A hot air balloon works in a similar way.

Figure 3.4 If the force of gravity acting upon a balloon is less than the force of buoyancy, the balloon will float.

Figure 3.5 You displace water when you sit down in a bathtub filled with water. If the tub is too full, the water will run over.

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- Ask students to explain the differences between lighter-than-air crafts and heavier-than-air crafts. Challenge students to create a list of as many aircraft as they can think of that fall under each heading. As a class, brainstorm possible factors that might help a heavier-than-air craft become and remain airborne. This discussion provides an introduction to Design Your Own Investigation 3-D Winged Vehicles.

Both buoyancy and gravity act on a hot air balloon. Instead of being immersed in water, a balloon is surrounded by air. Both liquids and gases produce buoyancy. When the air in a hot air balloon is heated, several things happen.

- First, the air particles in the balloon gain energy when they are heated. They move around and bump into each other. As they collide, the particles move apart and the air expands, taking up more room. It displaces the air that was there before. The surrounding air exerts the same pressure on the balloon that it had exerted on the air that was displaced. Since the balloon is lighter than the air it displaced, this pressure causes the balloon to rise.
- Second, as the balloon rises, its altitude increases. As altitude increases, air pressure decreases. As a result, there is less pressure acting on the balloon. The balloon eventually stops rising.

READING Check

Use the term buoyancy to explain how a balloon rises.

Figure 3.6 Air pressure decreases as altitude increases.

Figure 3.7 Ballooning is a balancing act. A balloon continues to rise until the forces of gravity and buoyancy acting on the balloon are equal.

READING Check The air particles in the balloon gain energy when they are heated. They move around and often collide. As they collide, the particles move apart and the air expands, taking up more room and displacing the air that was there before. The surrounding air exerts the same pressure on the balloon that it had exerted on the air that was displaced. Because the balloon is lighter than the displaced air, the pressure will create an upward force (buoyancy) that is greater than gravity.
This force causes the balloon to rise.

BUOYANCY FILE CARD INSET

BACKGROUND INFORMATION

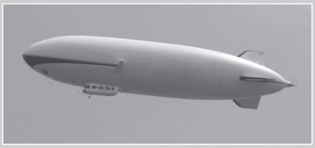
- In 1783, brothers Joseph-Michel and Jacques-Étienne Montgolfier built the world's first hot air balloon. They reasoned that the same force that caused embers to rise from a fire could be used to lift a balloon (and people) into the air. By heating the air in the balloon with a wood fire, they were able to lift the craft into the air. The balloon's first flight was a success.
- Early balloonists quickly learned how altitude and the atmosphere were related and experimented with hydrogen in sealed balloons as an alternative construction. Over time, the balloon evolved. The name "balloon" was dropped in favour of "airship," which was applied to a more sophisticated construction that could be steered. In 1884, the La France airship made the world's first fully controlled balloon flight powered by an electric motor. It was the predecessor to the blimps we are familiar with today.

TEACHING STRATEGIES

- **Begin the Lesson**—Before reading this card, ask students to work with a partner to write an explanation of buoyancy based on what they have already read.
- **During Teaching**—Have students evaluate their knowledge of buoyancy as determined in their writing. Get students to correct their explanations based on the summary provided.
- **After Teaching**—In 1999, Bertrand Piccard (Switzerland) and Brian Jones (Britain) were the first to fly around the world non-stop in a balloon. Their balloon, the *Breitling Orbiter 3*, flew at altitudes over 11 000 m. The pilots lived in a sealed capsule below the enormous balloon, which was as tall as the Tower of Pisa and could hold the equivalent of seven Olympic-sized swimming pools worth of gas.
- *ICT Option:* You may wish to have students explore the student-friendly web site about the *Breitling Orbiter 3* and its journey (Go to www.mcgrawhill.ca/links/ns+science6.) The site provides information about the balloon's design, life on board for 20 days, and more.

Type of Force
- Buoyancy

Direction of Force
- Upward



How does it work?
- A liquid or gas is displaced by an object, such as a body in water or a hot air balloon in air. The surrounding liquid or gas exerts the same pressure on the object that it had exerted on the displaced liquid or gas. If the object is lighter than the liquid or gas that it displaced, the pressure will create an upward force. If this force (buoyancy) is greater than that of gravity, the object rises.

Examples:
- The hot air in a balloon displaces the cooler, heavier air around it. The surrounding air exerts the same pressure on the balloon that it had exerted on the displaced air. Because the balloon is lighter than the air it displaced, the pressure causes it to rise.
- A blimp is essentially a balloon filled with a gas that is lighter than air. The force of buoyancy is greater than the force of gravity, and the blimp rises.

The hot air in a balloon is lighter than the cooler air outside the balloon. For this reason, a balloon is called a lighter-than-air aircraft. What about aircraft that are heavier-than-air, such as gliders, planes, helicopters, rockets, and even living things? How do these aircraft take off and stay airborne? How do they overcome the force of gravity?

Off the Wall Not all would-be aircraft are able to take off and stay airborne. Many of the earliest aircraft designers unsuccessfully tried to mimic the flight of birds. These flying machines, known as ornithopters, flapped their wings to fly. Large ornithopters, such as the one shown below, cannot stay in the air for long. However, that does not keep people from building them. In 2006, a team from the University of Toronto launched one from a jet. It made a 14-second flight before falling to the ground!

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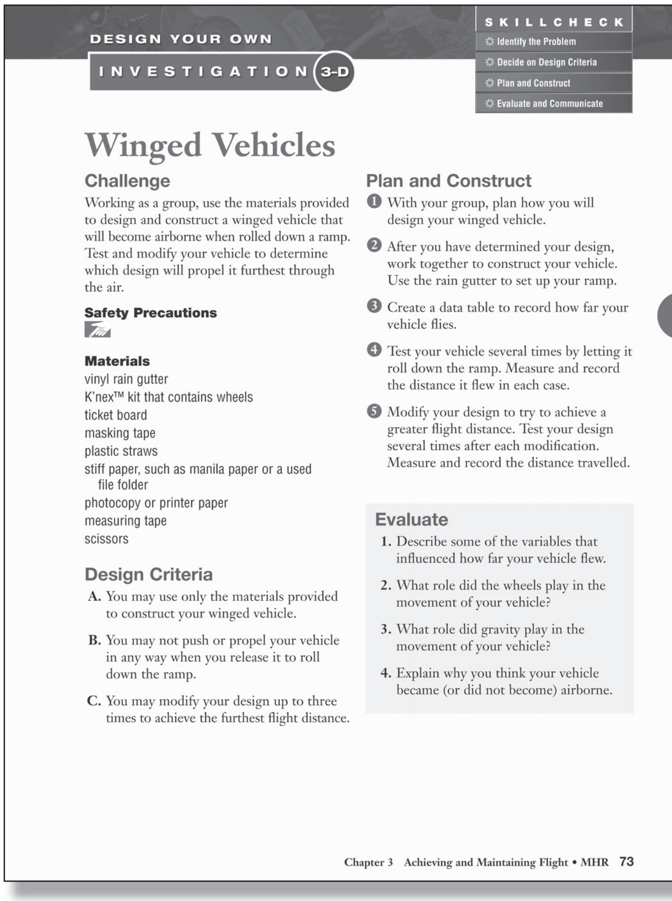
Off the Wall
- Many of the earliest aircraft designs involved humans flapping a set of wings like birds. Students may be interested in hearing about the Greek myth of Icarus, the youth who flew too close to the Sun with wings made of feathers and wax. The Sun melted the wax, and Icarus fell to his death. You may also want to ask students to brainstorm possible reasons why ornithopters cannot stay in the air for long.
- As a kinesthetic activity, ask students to let their arms hang at their sides and raise them up and down as quickly as they can while a partner times them with a stopwatch. Have them count how many times they can flap their arms in 10 seconds. How many flaps did they complete? Students may be interested to learn that insects flap their wings up to 1000 times per second when flying!

DESIGN YOUR OWN INVESTIGATION 3-D WINGED VEHICLES

Purpose
- Students investigate the flight of heavier-than-air aircraft by designing a winged cart that becomes airborne when rolled down a ramp. Students test and modify their vehicle to determine which design will propel it furthest through the air.



DESIGN YOUR OWN
INVESTIGATION 3-D

SKILLCHECK
Identify the Problem
Decide on Design Criteria
Plan and Construct
Evaluate and Communicate

Winged Vehicles

Challenge

Working as a group, use the materials provided to design and construct a winged vehicle that will become airborne when rolled down a ramp. Test and modify your vehicle to determine which design will propel it furthest through the air.

Safety Precautions

Materials
vinyl rain gutter
K'nex™ kit that contains wheels
ticket board
masking tape
plastic straws
stiff paper, such as manila paper or a used file folder
photocopy or printer paper
measuring tape
scissors

Design Criteria
A. You may use only the materials provided to construct your winged vehicle.
B. You may not push or propel your vehicle in any way when you release it to roll down the ramp.
C. You may modify your design up to three times to achieve the furthest flight distance.

Plan and Construct
1. With your group, plan how you will design your winged vehicle.
2. After you have determined your design, work together to construct your vehicle. Use the rain gutter to set up your ramp.
3. Create a data table to record how far your vehicle flies.
4. Test your vehicle several times by letting it roll down the ramp. Measure and record the distance it flew in each case.
5. Modify your design to try to achieve a greater flight distance. Test your design several times after each modification. Measure and record the distance travelled.

Evaluate
1. Describe some of the variables that influenced how far your vehicle flew.
2. What role did the wheels play in the movement of your vehicle?
3. What role did gravity play in the movement of your vehicle?
4. Explain why you think your vehicle became (or did not become) airborne.

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Advance Preparation

WHEN TO BEGIN	WHAT TO DO
3 days before	– Prepare a complete set of materials for each group.

MATERIALS	
Per group:	
– K'NEX™ kit that contains wheels	– masking tape
– ticket board	– measuring tape
– photocopy or printer paper	– scissors
– plastic straws	– rain gutters
– stiff paper, such as Manila paper or a used file folder	– stepladders

Suggested Time
- 60 min

Safety Precautions
- Remind students to be careful when handling scissors.

HINTS & HELPS
- Have students create a data table in their logbooks based on the steps indicated in the student textbook. Ask them to give it a title. You may wish to have students create tables the day before and help familiarize students with the investigation ahead of time.

Implementing the Investigation
- This investigation works best in groups of no more than three students.
- Review the design criteria with students before beginning to make sure they are clear about the guidelines for designing their vehicle.
- Remind students that they may modify their designs up to three times to achieve the furthest flight distance. The goal of this investigation is not to make the perfect winged vehicle on the first attempt but to learn how design changes affect the vehicle's ability to become and remain airborne.

Adaptations
- Students with coordination difficulties should be teamed with individuals who can cut and glue the materials to make the winged vehicles.

Investigation Wrap-Up
- After student reports have been evaluated and returned to the students, discuss and review the Evaluate answers.
- Have students display their winged vehicles with their flight statistics.
- Use this activity as an introduction to the concept of lift, which is explored in the student textbook following this investigation.
- Encourage students to share their findings (both successes and failures) and ideas in a debriefing after this activity. Can they come up with the best class design for a flying cart?

Assessment Option
- Use Science Skills Rubric 20, Design an Investigation for Investigation 3-D Winged Vehicles

Evaluate Answers
1. Possible variables students may describe include the weight of the vehicle; whether it was pushed or just let go before descending; the size, strength, and shape of the wings; the wing angle; the stiffness and strength of material used for the wings; the location of the wings (under or above the cart); the angle of the rain gutter; the takeoff speed; and the number of sets of wings.
2. The wheels allowed the vehicle to reach speeds that generated enough movement of air past the wings to allow it to rise in the air. Students who have read ahead may refer to this as lift.
3. Gravity provided the force that caused the vehicle to roll down the ramp. Students who have read ahead may refer to this as thrust.
4. Students are likely to understand that the air flowing under the wings caused the vehicle to become airborne. They may not realize, however, that airflow over the wing can also play a role. Reasons why the vehicle did not become airborne could refer to any of the variables described in question 1. Accept any well-reasoned answer.

LIFT

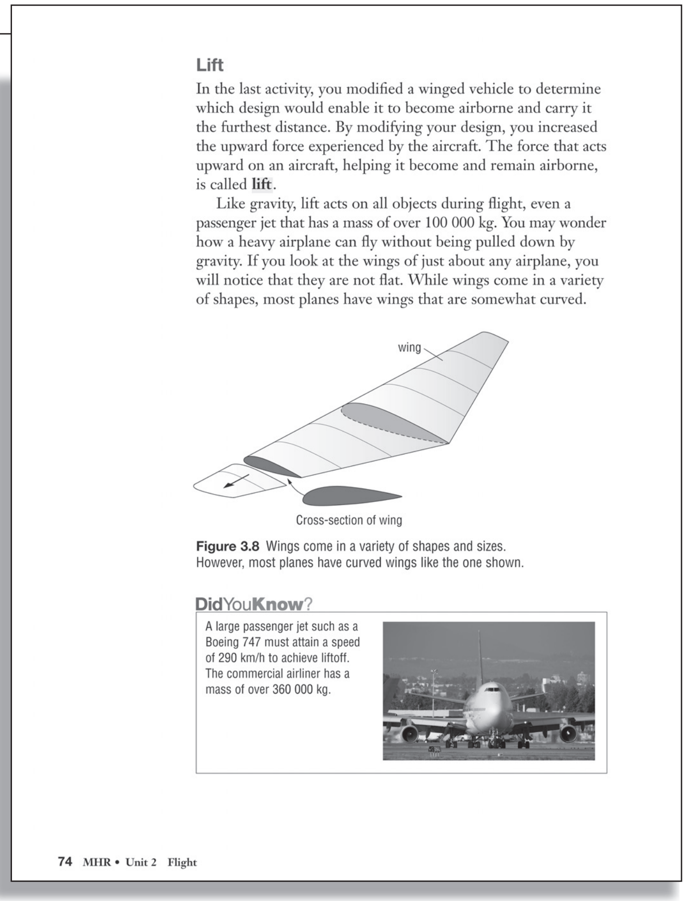
BACKGROUND INFORMATION

- The cross-section of a wing is also referred to as an airfoil. Airfoils come in a variety of shapes. The Wright brothers' *Wright Flyer* was the first aircraft to achieve powered, sustained, controlled flight (1903). The plane had a thin, curved airfoil. The airfoils of aerobatic planes, on the other hand, are curved on both sides (known as symmetrical airfoils) so planes can fly upside down and perform maneuvers.

TEACHING STRATEGIES

- **Begin the Lesson**—In Design an Investigation 3-D Winged Vehicles, students answered question 4, Explain why you think your vehicle became (or did not become) airborne. Use students' responses to these questions to introduce the concept of lift.
- **During Teaching**—Ask students if any of their winged vehicle designs had curved wings. If so, how did it affect the distance the vehicle flew?
- **After Teaching**—Distribute BLM 3.2 A Variety of Wing Designs to students who show a greater interest in this topic. This BLM shows the main wing cross-sections (airfoils) used in aircraft and which type of plane each is used for.

DidYouKnow? In addition to the mass of the plane, other factors that affect the speed required for takeoff include the shape and angle of the wing, the ambient temperature, the distance the airstrip is above sea level, the wind speed and direction, and wing loading (the loaded mass of the aircraft divided by the area of the wing).



Lift

In the last activity, you modified a winged vehicle to determine which design would enable it to become airborne and carry it the furthest distance. By modifying your design, you increased the upward force experienced by the aircraft. The force that acts upward on an aircraft, helping it become and remain airborne, is called **lift**.

Like gravity, lift acts on all objects during flight, even a passenger jet that has a mass of over 100 000 kg. You may wonder how a heavy airplane can fly without being pulled down by gravity. If you look at the wings of just about any airplane, you will notice that they are not flat. While wings come in a variety of shapes, most planes have wings that are somewhat curved.

Figure 3.8 Wings come in a variety of shapes and sizes. However, most planes have curved wings like the one shown.

DidYouKnow?

A large passenger jet such as a Boeing 747 must attain a speed of 290 km/h to achieve liftoff. The commercial airliner has a mass of over 360 000 kg.

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Bernoulli's Principle

As an airplane flies, air travels over and under its wings. Because the wings are curved, air that passes over the wing travels further than the air that passes under the wing. However, the air passing over the wing reaches the back of the wing at the same time as the air passing under it. This means it has to travel faster. It must cover a greater distance in the same amount of time. You can compare this to taking a detour to get to a destination. The detour means you have to travel a greater distance. To get to your destination in the same amount of time as the direct route took, you need to travel faster.

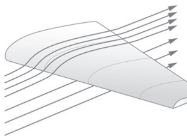

Figure 3.9 An airplane's wings are rounded. This means that the air passing over the wing travels faster than the air passing under it.

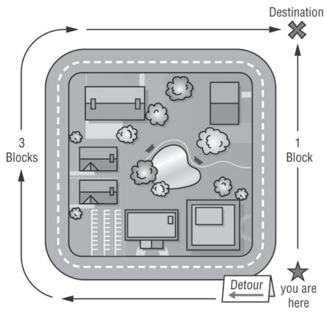

Figure 3.10 When you take a detour, you have to travel a greater distance to get to your destination. If you want to make it there in the same amount of time, you need to travel faster. When air travels around the curve of a wing, it travels further. It must therefore travel faster to reach the back of the wing at the same time as the air travelling under the wing.

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BERNOULLI'S PRINCIPLE

BACKGROUND INFORMATION

- Bernoulli's principle can be seen in action in daily life. For example, if you create an air current as you walk quickly by a curtain, the curtain moves towards you. By increasing the speed of the air as you passed, you created a low-pressure area. High-pressure, still air moves into the low-pressure area, drawing the curtain with it. Similarly, if you are riding your bicycle on the road and a large truck passes you at high speed, you may feel yourself being drawn towards the truck. The air speed around the truck has increased, again creating a low-pressure area.

TEACHING STRATEGIES

- **Begin the Lesson**—Ask students if they can predict why the shape of a wing is an important aspect of lift.
- **During Teaching**—Use Figures 3.9 and 3.10 on page 75 to help explain lift.
- **After Teaching**—As a kinesthetic activity, have students act out Figure 3.10 on page 75 to see how much faster they have to travel along a detour route to get to the finish line at the same time as a person travelling a straight route. The detour route should ideally be about three times as long as the straight route and curved, so students have to move about three times faster. Some students can run the detour route, others can time the race, and still others can observe the race to see which runners are travelling the fastest and if they can make it to the finish line at the same time as the person travelling the straight route. This works best if the teacher travels the straight route so that he or she can adjust his or her speed to allow the students running the detour route to reach the finish line at the same time as he or she does.

Common Misconceptions

- Some students may think that lift is simply generated as air under the wing "lifts" the wing up. Remind them that the air travelling over the wing plays a role in lift as well.

BERNOULLI'S PRINCIPLE (CONTINUED FROM PREVIOUS PAGE)

BACKGROUND INFORMATION

- Daniel Bernoulli died in 1782. At this time, winged aircraft had not yet been developed. However, a year after his death, the world's first hot air balloon took to the skies.

TEACHING STRATEGIES

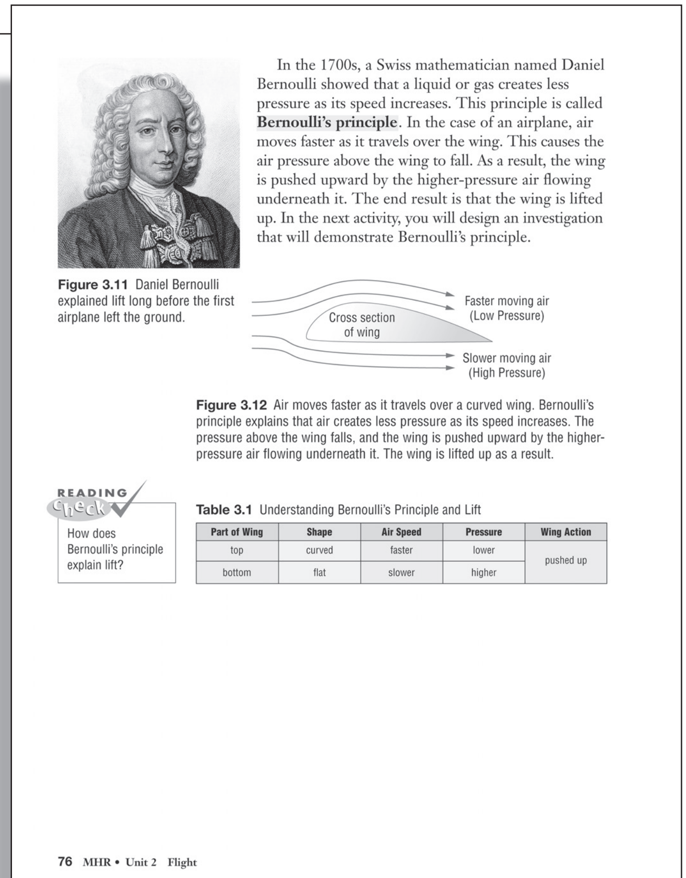
- **During Teaching**—Use Figure 3.12 on page 76 to explain how Bernoulli's principle helps generate lift. This figure is also available in the top half of BLM 3.3 Figure 3.12 Bernoulli's Principle, which can be copied as an overhead.
- **After Teaching**—Use the bottom of BLM 3.3 to show Table 3.1 Understanding Bernoulli's Principle and Lift.
  - Have students reflect on and evaluate what they have learned. Do they think that the shape of an aircraft's wing is the only factor that influences lift? Have they seen any planes that do not have curved wings? How would these planes generate lift? Have students write their ideas in their science logbooks, share them with a partner or discuss these questions as a class. In chapter 4, students will learn about angle of attack, the other factor that influences lift.

READING Check Bernoulli's principle shows that a liquid or gas creates less pressure as its speed increases. In the case of an airplane, air moves faster as it travels over a curved wing. This causes the air pressure above the wing to fall. The wing is pushed upward by the higher-pressure air flowing underneath it and is lifted up.

LIFT FILE CARD INSET

BACKGROUND INFORMATION

- Birds initially flap their wings to rise into the air, providing thrust, one of the four forces that affect flight (this force is discussed in the next section). Birds also twist their wings as they flap them, a movement that increases air motion. However, other factors are also involved in bird flight. Like aircraft wings, the shape of a bird's wing is curved. As a result, air travels faster over the top of the wing, creating a pressure difference that plays a role in lift. The angle of the bird's wing also influences lift. This concept, called angle of attack, will be covered in chapter 4. Birds also use their wings to soar. Soaring birds such as eagles take advantage of rising air currents called thermals to glide through the air for long periods of time without flapping their wings.



In the 1700s, a Swiss mathematician named Daniel Bernoulli showed that a liquid or gas creates less pressure as its speed increases. This principle is called **Bernoulli's principle**. In the case of an airplane, air moves faster as it travels over the wing. This causes the air pressure above the wing to fall. As a result, the wing is pushed upward by the higher-pressure air flowing underneath it. The end result is that the wing is lifted up. In the next activity, you will design an investigation that will demonstrate Bernoulli's principle.

Figure 3.11 Daniel Bernoulli explained lift long before the first airplane left the ground.

Figure 3.12 Air moves faster as it travels over a curved wing. Bernoulli's principle explains that air creates less pressure as its speed increases. The pressure above the wing falls, and the wing is pushed upward by the higher-pressure air flowing underneath it. The wing is lifted up as a result.

READING Check How does Bernoulli's principle explain lift?

Table 3.1 Understanding Bernoulli's Principle and Lift

Part of Wing	Shape	Air Speed	Pressure	Wing Action
top	curved	faster	lower	pushed up
bottom	flat	slower	higher	

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TEACHING STRATEGIES

- **Begin the Lesson**—Ask students to explain Bernoulli's principle to a partner in their own words. Then have students refer to the summary in the file card to see if they have explained the principle correctly.

Common Misconceptions

- Some students may think that birds need to flap their wings to stay in the air. In fact, there is a lot more to flying than flapping wings. Share some of the details on bird flight provided in the Background Information above with students to help them comprehend how birds fly. Use BLM 3.5 A Bird's Wing and an Airplane Wing to help illustrate the role lift plays in bird flight.

Type of Force
• Lift

Direction of Force
• Upward

How does it work?
• Because wings are curved, air passes over a wing more quickly than air passes under it. A liquid or gas creates less pressure as its speed increases. The air pressure above the wing falls. The higher-pressure air flowing underneath the wing pushes it upward. As a result, the wing is lifted up.

Examples:
• An owl's wing has a curved shape. Air travels faster over the top of the wing, creating a pressure difference that lifts the wing.
• A Boeing 747 is hundreds of thousands of times heavier than an owl. However, it experiences the same lift as a bird does.

Find Out ACTIVITY 3–E

Demonstrate Bernoulli's Principle

Bernoulli's principle explains how a wing generates lift. If you were Daniel Bernoulli, could you demonstrate your principle to other scientists?

What You Will Need

materials for your demonstration, different for each group
activity handout

What to Do

1. Review the activity handout provided by your teacher. You will be performing this activity to demonstrate Bernoulli's principle to your classmates. With your group, discuss how you will carry out your demonstration.
2. As a group, gather the materials you need to complete your demonstration. Set up your demonstration. Practise it before you present it to your class.
3. Assign one group member as recorder. As a group, determine how your activity demonstrates Bernoulli's principle. Have the recorder write down your ideas. Review the ideas to make sure all group members agree on them.
4. Present your demonstration to your class. Have the recorder explain how your activity demonstrates Bernoulli's principle.

What Did You Find Out?

1. How could you modify your demonstration to improve it? Explain your reasoning.
2. Describe the demonstrations presented by other groups. How does each demonstration illustrate Bernoulli's principle?

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FIND OUT ACTIVITY 3-E DEMONSTRATE BERNOULLI'S PRINCIPLE

Purpose

• Students create a demonstration to illustrate lift.

Advance Preparation

WHEN TO BEGIN	WHAT TO DO
1 week before	– Organize students into groups. – Distribute and review activity handout BLM 3.6 Demonstrate Bernoulli's Principle. – Have groups decide which demonstration they will complete.
3 days before	– Gather material each group requires to complete their demonstration.

MATERIALS
Per group: – materials for demonstration, different for each group – activity handout (BLM 3.6 Demonstrate Bernoulli's Principle)

Suggested Time

• 20 min to review activity handout and decide on demonstrations
• 30 minutes to set up demonstration and record ideas
• 5 minutes per group presentation

HINTS & HELPS

• Groups of four students work well for this activity.
• If possible, have each group do a different demonstration.
• You may wish to have students set up their demonstration in pre-designated areas that the class can see easily. That way they do not have to move their demonstration in order to complete their presentation.

Implementing the Activity

• Remind groups to designate one student as recorder after they have set up their demonstration.
• Challenge students to go beyond the suggested demonstrations and try to complete this activity in other ways.
• Ask students to predict what they think will happen in each demonstration before each group starts their presentation.

Adaptations

• Encourage students who do not normally speak up in class to act as recorder or presenter.
• Use preferential grouping to allow all students, including those with fine motor or literacy difficulties, to fully participate in the activity.

Activity Wrap-Up

• Ask students to relate the movement they observed in the demonstration to the lift experienced by a wing.
• What Did You Find Out? question 1 could be answered as a group and then shared as a class. Question 2 lends itself well to class discussion.

Assessment Option

• Use Learning Skills Rubric 3, Co-operative Group Work for Find Out Activity 3-E Demonstrate Bernoulli's Principle

What Did You Find Out? Answers

1. Accept any answers that include students' reasoning. Sample answer: In our demonstration, we used a fan to show that pressure decreases when the fan makes air travel faster. This causes the surrounding higher-pressure air to move towards the fast-moving, lower-pressure air. This was demonstrated by hair that moved closer to the blowing air. Our demonstration might have worked better if the person had longer hair and sat closer to the fan.
2. Student answers should clearly describe the demonstrations put on by other groups and explain how they illustrated lift.

SECTION 3.1 SUMMARY

Review the section summary as a class. Make sure that students update the flight section in their logbooks and key terms list. Have students share some of their definitions of the key terms with the class and compare different interpretations of the same words.

✓ ASSESSMENT OPTIONS FOR SECTION 3.1

- Collect and review science logbooks, using Learning Skills Rubric 2, Science Logbook to evaluate them.
- Ask students to complete BLM 3.4 Bernoulli's Principle Review
- Use the following rubrics to assess student work:
  - – Science Skills Checklist 15, Making Observations and Inferences to assess student work in Find Out Activity 3-B My Flying Machine
  - – Science Skills Rubric 19, Conduct an Investigation to assess student work in Investigation 3-C Build a Balloon
  - – Science Skills Rubric 20, Design an Investigation for Investigation 3-D Winged Vehicles
  - – Learning Skills Rubric 3, Co-operative Group Work for Find Out Activity 3-E Demonstrate Bernoulli's Principle

Section 3.1 Summary

The forces that act on an object during flight work in four directions: downward, upward, backward, and forward. These forces act on both flying organisms and machines.

- Gravitational attraction pulls all objects with mass toward each other. Only very large objects, such as a planet or star, have a noticeable gravitational pull. This is because the force of gravity is very small. Earth's gravitational pull pulls objects downward.
- Buoyancy is an upward force that is produced when an object displaces a liquid or gas. A hot air balloon or blimp floats when its buoyancy is greater than the force of gravity acting on it.
- The upward force that acts on an object in flight is called lift. Bernoulli's principle explains lift. This principle states that a moving liquid or gas creates less pressure as its speed increases.

Key Terms

buoyancy
lift
Bernoulli's principle

Check Your Understanding

1. Use the term buoyancy to explain why a hot air balloon rises.
2. A robin breaks its wing. When it heals, the wing is no longer curved. Do you think the songbird is still able to fly? Explain your reasoning.
3. The *An–225 Cossack* has a mass of about 250 000 kg when it is empty. How does such a heavy plane achieve liftoff and remain airborne?
4. Draw and label an example of a situation that demonstrates Bernoulli's principle.
5. Gravitational attraction pulls all objects with mass toward each other. The Sun has a mass that is much greater than Earth. Explain why an aircraft is pulled toward Earth and not the Sun during its flight.

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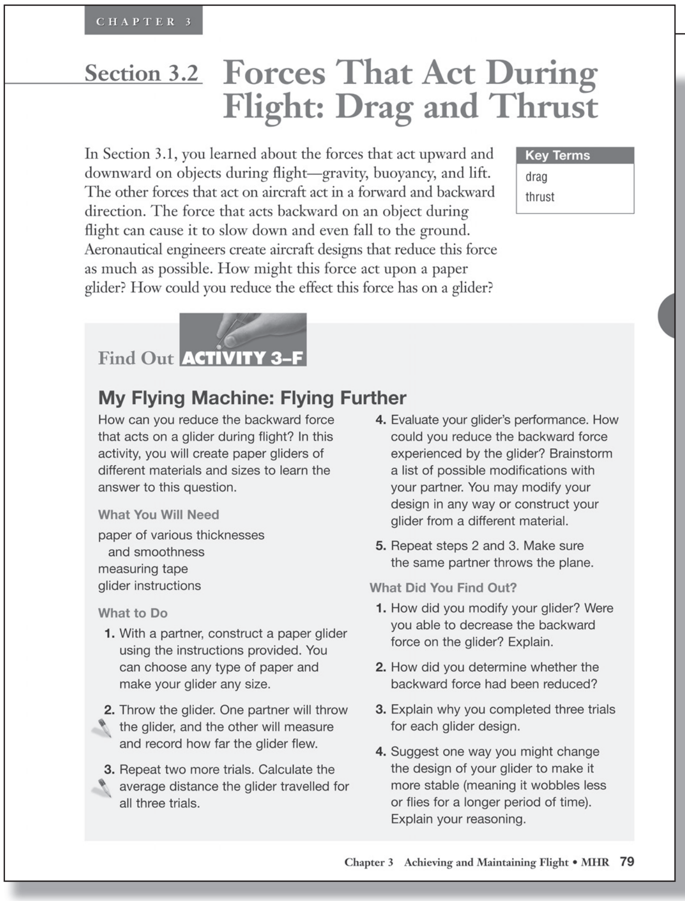
Check Your Understanding Answers

1. The air particles in a hot air balloon gain energy when they are heated. Because of this extra energy, they move around and collide more. As they collide, the particles move apart and the air expands. The air now takes up more room. It displaces the air that was there before. The surrounding air exerts the same pressure on the balloon that it had exerted on the displaced air. Since the hot air balloon is lighter than the displaced air, the pressure creates an upward force (buoyancy) that is greater than gravity. Due to this buoyant force, the hot air balloon rises.
2. Bernoulli's principle plays a role in generating lift. A moving liquid or gas creates less pressure as its speed increases. In the case of a curved wing, the air travels faster over the wing than under it. This causes the air pressure above the wing to fall. The wing is pushed up by the higher-pressure air flowing underneath it and is lifted up. If the bird's wing is no longer curved, the lift generated may be reduced or may disappear all together. Some students may recognize that lift may be generated by other means than pressure difference (for instance, flapping the wings or changing the angle of the wings).
3. Both lift and gravity act on a plane in flight. Lift is the upward force that enables an aircraft to become airborne. Gravity is the downward force that pulls an aircraft toward the ground. In order for a 250 000 kg airplane to fly, lift must be greater than gravity. If lift is greater than gravity, the plane will take off and stay airborne. The mass of the plane does not matter.
4. Students will most likely draw and label air flowing around the wing of an aircraft during flight or one of the demonstrations completed in Find Out Activity 3-E Demonstrating Bernoulli's Principle. These include straw and water blowing demo, ping-pong ball demo, and hair drawn in as fan blows.
5. The Sun is larger than Earth, but it is so far away that aircraft are pulled toward Earth and not the Sun during flight.


CHAPTER 3

Section 3.2 Forces That Act During Flight: Drag and Thrust

In Section 3.1, you learned about the forces that act upward and downward on objects during flight—gravity, buoyancy, and lift. The other forces that act on aircraft act in a forward and backward direction. The force that acts backward on an object during flight can cause it to slow down and even fall to the ground. Aeronautical engineers create aircraft designs that reduce this force as much as possible. How might this force act upon a paper glider? How could you reduce the effect this force has on a glider?

Key Terms
drag
thrust

Find Out ACTIVITY 3–F

My Flying Machine: Flying Further

How can you reduce the backward force that acts on a glider during flight? In this activity, you will create paper gliders of different materials and sizes to learn the answer to this question.

What You Will Need

paper of various thicknesses and smoothness
measuring tape
glider instructions

What to Do

1. With a partner, construct a paper glider using the instructions provided. You can choose any type of paper and make your glider any size.
2. Throw the glider. One partner will throw the glider, and the other will measure and record how far the glider flew.
3. Repeat two more trials. Calculate the average distance the glider travelled for all three trials.
4. Evaluate your glider's performance. How could you reduce the backward force experienced by the glider? Brainstorm a list of possible modifications with your partner. You may modify your design in any way or construct your glider from a different material.
5. Repeat steps 2 and 3. Make sure the same partner throws the plane.

What Did You Find Out?

1. How did you modify your glider? Were you able to decrease the backward force on the glider? Explain.
2. How did you determine whether the backward force had been reduced?
3. Explain why you completed three trials for each glider design.
4. Suggest one way you might change the design of your glider to make it more stable (meaning it wobbles less or flies for a longer period of time). Explain your reasoning.

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SECTION 3.2 FORCES THAT ACT DURING FLIGHT: DRAG AND THRUST

What Students Do in Section 3.2

- modify a paper glider to reduce the amount of backward force (drag) it experiences during flight
- design and modify a parachute to increase the amount of backward force (drag) it experiences
- compare the movements of different organisms as they fly or glide
- compare the four forces that work on an object during flight

BACKGROUND INFORMATION

- The force that acts backward on an object during flight is called drag. Suggest students think about a cyclist in a race. How would the cyclist overcome drag? Conversely, thrust propels an airborne object forward. How does a cyclist move the bike forward? What things can a rider adjust to increase speed? Like gravity and lift, these two forces work in opposition on an object during flight.

TEACHING STRATEGIES

- **During Teaching**—Ask if any students can name the forces that work backward and forward on an object during flight. Some students may be familiar with the concept of drag. Ask students to define "drag" in their logbooks.
- **After Teaching**—Ask students to brainstorm different ways to reduce the effect of the backward force (drag) on the glider they will be building in Find Out Activity 3-F My Flying Machine: Flying Further. How could they test the glider to find out if they have reduced the effect of this force? What could be causing this backward force?

FIND OUT ACTIVITY 3-F MY FLYING MACHINE: FLYING FURTHER

Purpose

- Students create paper gliders of different materials and sizes. They modify and test the gliders to determine the best way to decrease the backward force (drag) that acts on an object during flight.

Advance Preparation

WHEN TO BEGIN	WHAT TO DO
1 week before	– Book the gym or larger area to test the paper gliders.
3 days before	– Gather a class set of materials. – Photocopy a class set of BLM 3.7 Flying Machine: Flying Further (Glider Instructions)

MATERIALS
Per group: – paper of various thickness and smoothness – measuring tape – glider instructions

Suggested Time

- 45 min

Safety Precautions

- Ensure students avoid hitting each other in the face or eye area with their gliders.

HINTS & HELPS

- Remind students to make sure that the same student throws the glider in each trial to ensure they have a fair test. You may wish to review students' answers to What Did You Find Out? question 3 (page 79) to introduce the current activity.

(continued) ➜

Implementing the Activity

- This activity should be done in partners.
- Review the concept of a fair test with students. Ask them to explain how this activity meets the requirements of a fair test.
- Have students review how their design changes in Activity 3-B affected their glider. Students can use those observations to spark ideas about design improvements.

Activity Wrap-Up

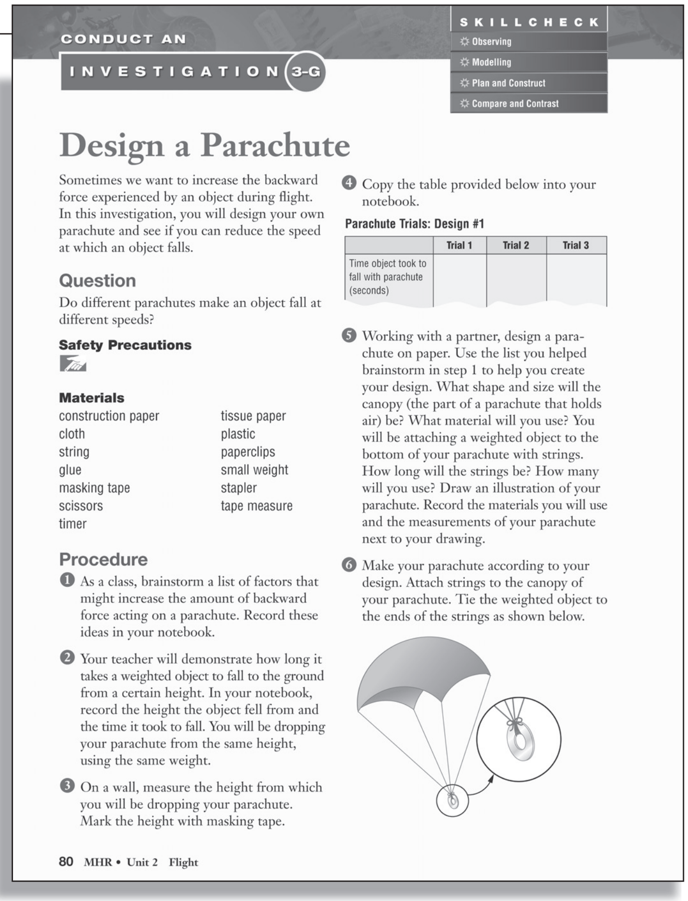
- Examine the three gliders that flew the furthest distance. How are they similar? How do they differ? What characteristics do they have that enabled them to fly the furthest?
- Use this activity to introduce the concept of drag. Ask students to explain how distance travelled is linked to the backward force acting on the glider during flight.

Assessment Option

- Use Process Skills Rubric 11, Problem Solving for Find Out Activity 3-F My Flying Machine: Flying Further

What Did You Find Out? Answers

1. Accept any answers that clearly describe the modifications, as well as an explanation of whether or not the drag on the glider was reduced and how they determined this was the case.
2. If the glider flew further after it was modified, it is likely that drag was reduced. (However, it is also possible that the forward force was increased.)
3. Students should understand that the difficulty in replicating their activity will affect their results in each throw. If students are flying their gliders outside, irregular airflow can also be a factor. By calculating the average distance flown for three trials, distance discrepancies due to any irregular flights are moderated.
4. This question is designed to get students thinking about stability during flight, which is covered in the next My Flying Machine Activity, rather than to get a correct answer.



CONDUCT AN INVESTIGATION 3-G

SKILLCHECK
- Observing
- Modelling
- Plan and Construct
- Compare and Contrast

Design a Parachute

Sometimes we want to increase the backward force experienced by an object during flight. In this investigation, you will design your own parachute and see if you can reduce the speed at which an object falls.

Question

Do different parachutes make an object fall at different speeds?

Safety Precautions

Materials

construction paper, cloth, string, glue, masking tape, scissors, timer, tissue paper, plastic, paperclips, small weight, stapler, tape measure

Procedure

1. As a class, brainstorm a list of factors that might increase the amount of backward force acting on a parachute. Record these ideas in your notebook.
2. Your teacher will demonstrate how long it takes a weighted object to fall to the ground from a certain height. In your notebook, record the height the object fell from and the time it took to fall. You will be dropping your parachute from the same height, using the same weight.
3. On a wall, measure the height from which you will be dropping your parachute. Mark the height with masking tape.
4. Copy the table provided below into your notebook.

Parachute Trials: Design #1

	Trial 1	Trial 2	Trial 3
Time object took to fall with parachute (seconds)			

5. Working with a partner, design a parachute on paper. Use the list you helped brainstorm in step 1 to help you create your design. What shape and size will the canopy (the part of a parachute that holds air) be? What material will you use? You will be attaching a weighted object to the bottom of your parachute with strings. How long will the strings be? How many will you use? Draw an illustration of your parachute. Record the materials you will use and the measurements of your parachute next to your drawing.
6. Make your parachute according to your design. Attach strings to the canopy of your parachute. Tie the weighted object to the ends of the strings as shown below.

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CONDUCT AN INVESTIGATION 3-G DESIGN A PARACHUTE

Purpose

- Students investigate the backward force acting on an object during flight (drag) by designing and modifying parachutes to reduce the speed at which an object falls.

Advance Preparation

WHEN TO BEGIN	WHAT TO DO
3 days before	– Gather a class set of materials.
1 day before	– Have students copy the chart in the student textbook into their notebooks.

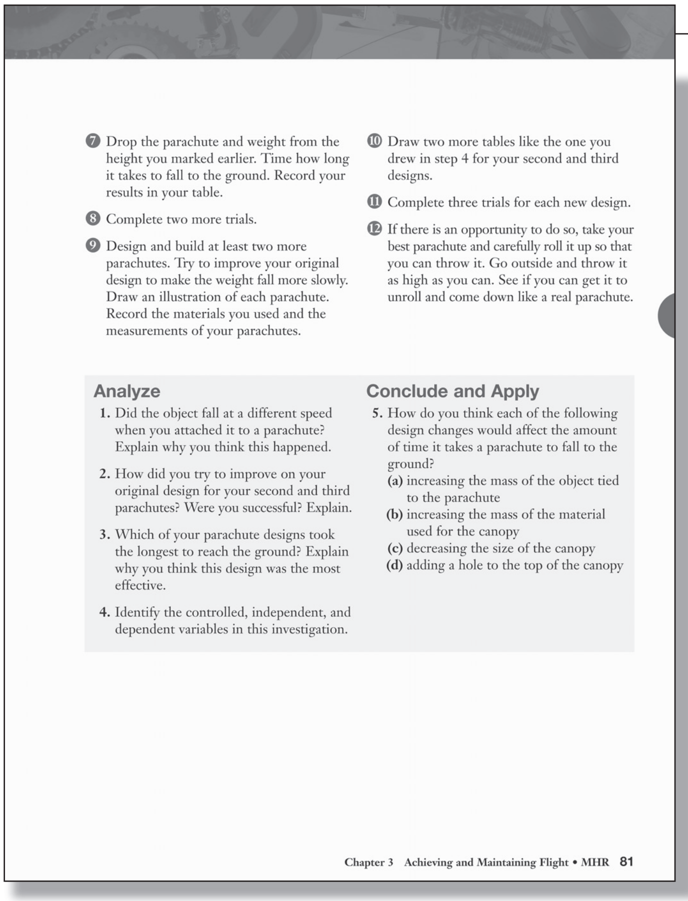
MATERIALS		
Per group:		
– construction paper	– scissors	– paperclips
– cloth	– timer	– small weight
– string	– tissue paper	– stapler
– glue	– plastic	– tape measure
– masking tape		

Suggested Time

- 60 min

Safety Precautions

- Remind students to be careful when handling scissors.



7 Drop the parachute and weight from the height you marked earlier. Time how long it takes to fall to the ground. Record your results in your table.

8 Complete two more trials.

9 Design and build at least two more parachutes. Try to improve your original design to make the weight fall more slowly. Draw an illustration of each parachute. Record the materials you used and the measurements of your parachutes.

10 Draw two more tables like the one you drew in step 4 for your second and third designs.

11 Complete three trials for each new design.

12 If there is an opportunity to do so, take your best parachute and carefully roll it up so that you can throw it. Go outside and throw it as high as you can. See if you can get it to unroll and come down like a real parachute.

Analyze

1. Did the object fall at a different speed when you attached it to a parachute? Explain why you think this happened.
2. How did you try to improve on your original design for your second and third parachutes? Were you successful? Explain.
3. Which of your parachute designs took the longest to reach the ground? Explain why you think this design was the most effective.
4. Identify the controlled, independent, and dependent variables in this investigation.

Conclude and Apply

5. How do you think each of the following design changes would affect the amount of time it takes a parachute to fall to the ground?
   (a) increasing the mass of the object tied to the parachute
   (b) increasing the mass of the material used for the canopy
   (c) decreasing the size of the canopy
   (d) adding a hole to the top of the canopy

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HINTS & HELPS

- Record the ideas students brainstorm in step 1 on the board so students can easily transfer them to their logbooks.
- In step 2, be sure to drop the weight from a height that all students can easily reach without jumping or climbing on a chair, as they will be dropping their own parachutes from this height. Drop the weight three times and use the average time to reduce the influence of any delay in starting or stopping the timer.

Implementing the Investigation

- Students should complete this investigation in partners.
- Have students copy the chart in the student textbook into their logbooks the day before the investigation.

Adaptations

- Students with fine motor difficulties should be grouped with individuals who can cut and glue the materials to create parachutes.
- You may wish to read the instructions aloud before beginning the investigation to help students with literacy difficulties.

Investigation Wrap-Up

- Review how this investigation was a fair test.
- Conclude and Apply question 5 also lends itself well to class discussion.

Assessment Option

- Use Science Skills Rubric 19, Conduct an Investigation to assess student work in Investigation 3-G Design a Parachute

Analyze Answers

1. In most cases, the object will have fallen more slowly when attached to a parachute. The parachute slowed the object's fall because it increased the air resistance or drag the object experienced during flight. Students will likely describe this effect by using descriptive terms, such as "held more air" or "filled with air" rather than the correct terms.
2. Accept all answers that clearly explain the design changes that were made. *Sample answer:* I thought my parachute was too small in my first design so I made it larger. The object fell more slowly after I made this change. For my next design, I made the parachute out of tissue paper instead of the cloth I used before, and it fell even more slowly.
3. Accept all answers in which students clearly explain reasons why this particular design might have been the most effective. *Sample answer:* I think my last design was the most effective because it was the largest and I added pleats that caused the parachute to catch more air as it fell.
4. Students should identify the size and weight of the object dropped and the distance from which it was released as controlled variables. The independent variable was the design of the parachute. The dependent variable was the time it took the weight and parachute to reach the ground.

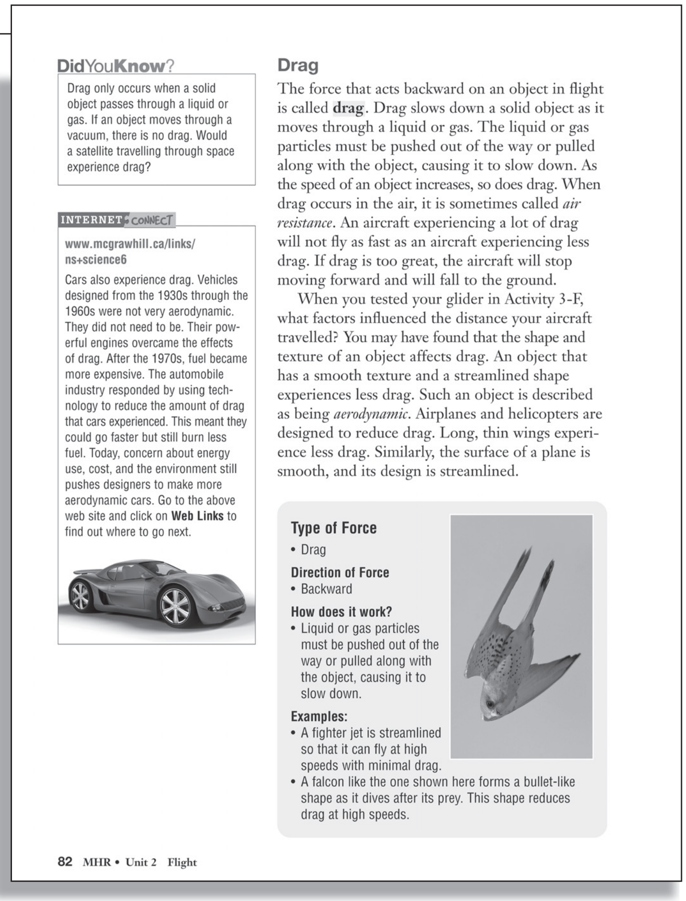
Conclude and Apply Answers

5. (a) Increasing the mass of the object tied to the parachute would decrease the time it takes for the parachute to reach the ground.
   (b) Increasing the mass of the canopy would also decrease the time it takes for the parachute to reach the ground, as the parachute would now be heavier.
   (c) Decreasing the size of the canopy would decrease the time it takes for the parachute to reach the ground since a smaller canopy would "hold less air" (provide less resistance).
   (d) A parachute falls to the ground faster if the canopy has a hole in it, as less air is trapped in the canopy. The larger the hole, the more air escapes.

DRAG

BACKGROUND INFORMATION

- Drag acts backward on an object during flight. Several different types of drag act upon an aircraft. Drag is created when air *flows over* the aircraft or its wings. This type of drag results in air turbulence that opposes forward motion. Streamlining the aircraft can reduce this form of drag. Parts that cannot be streamlined are typically covered to create a streamlined shape.
- Another type of drag is created by *contact between* air particles and the surface of the aircraft. This type of drag results in friction that opposes forward motion. Polishing and cleaning the smooth surface of the aircraft regularly can decrease this type of drag. Another type of drag occurs due to lift. The high pressure under the wing causes vortexes of air to occur at the tips of the aircraft's wings, reducing the forward motion of the plane. The steeper the angle of the wing (this angle, known as angle of attack, will be covered in chapter 4), the greater the force of this type of drag.
- In the ninth century, an Arabic inventor called Abbas Ibn Firnas completed the first successful "parachute" jump. The inventor launched himself from a tall building wearing a wing-like cloak with wooden supports that held it open. He escaped with non-life-threatening injuries. Not content with this early success, the inventor also attempted the first human flight in a hang glider and was badly injured. More than five centuries later, Leonardo da Vinci sketched a design for a parachute but never tested it. In 2000, over 500 years after Leonardo da Vinci designed his parachute, it was built and tested successfully. It had a mass of 85 kg, but its flight was apparently smoother than that of modern parachutes.
- There are several different types of modern parachutes, some of which provide lift in addition to increasing drag.
  (1) Round parachutes have dome-shaped canopies that make them look a lot like jellyfish. (They are sometimes referred to as jellyfish chutes.) These parachutes only increase drag. They are used by the military in emergency situations and to drop cargo.
  (2) Annular parachutes have a similar shape but are flatter on the top. They are very light parachutes made from specially shaped triangular segments.



DidYouKnow?

Drag only occurs when a solid object passes through a liquid or gas. If an object moves through a vacuum, there is no drag. Would a satellite travelling through space experience drag?

INTERNET CONNECT

www.mcgrawhill.ca/links/ns+science6

Cars also experience drag. Vehicles designed from the 1930s through the 1960s were not very aerodynamic. They did not need to be. Their powerful engines overcame the effects of drag. After the 1970s, fuel became more expensive. The automobile industry responded by using technology to reduce the amount of drag that cars experienced. This meant they could go faster but still burn less fuel. Today, concern about energy use, cost, and the environment still pushes designers to make more aerodynamic cars. Go to the above web site and click on **Web Links** to find out where to go next.

Drag

The force that acts backward on an object in flight is called **drag**. Drag slows down a solid object as it moves through a liquid or gas. The liquid or gas particles must be pushed out of the way or pulled along with the object, causing it to slow down. As the speed of an object increases, so does drag. When drag occurs in the air, it is sometimes called *air resistance*. An aircraft experiencing a lot of drag will not fly as fast as an aircraft experiencing less drag. If drag is too great, the aircraft will stop moving forward and will fall to the ground.

When you tested your glider in Activity 3-F, what factors influenced the distance your aircraft travelled? You may have found that the shape and texture of an object affects drag. An object that has a smooth texture and a streamlined shape experiences less drag. Such an object is described as being *aerodynamic*. Airplanes and helicopters are designed to reduce drag. Long, thin wings experience less drag. Similarly, the surface of a plane is smooth, and its design is streamlined.

Type of Force
- Drag

Direction of Force
- Backward

How does it work?
- Liquid or gas particles must be pushed out of the way or pulled along with the object, causing it to slow down.

Examples:
- A fighter jet is streamlined so that it can fly at high speeds with minimal drag.
- A falcon like the one shown here forms a bullet-like shape as it dives after its prey. This shape reduces drag at high speeds.

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  (3) Ribbon or ring parachutes are similar in design to annular parachutes. However, they are designed for use at supersonic speeds. They have a hole in the top of the canopy that releases pressure that would typically cause parachutes to burst at these speeds.
  (4) Cruciform or square parachutes were designed to reduce motion, such as swinging, during a descent. They also slow the rate of descent, reducing the risk of injury upon landing.
  (5) Ram-air parachutes are the modern, self-inflating parachutes many of us are most familiar with. These parachutes consist of air-filled cells sandwiched between two layers. They allow for control of direction and speed and look similar to the parafoils used by paragliders.

Sometimes we design things to increase drag, rather than to reduce it. We do this when we want objects to fall more slowly. When you designed a parachute earlier, you were able to reduce the speed at which an object falls. The canopy of a parachute provides a large surface area. It is not streamlined, so it increases drag, slowing its fall so that the object or person it is carrying lands safely. Some parachute designs do more than increase drag. They have wing-like properties that allow skydivers to control where they land (see Figure 3.14).

Aircraft need to generate a forward force that overcomes the backward force of drag if they want to become and stay airborne. Living things such as birds, insects, and other flying and gliding organisms also need to generate this force. What force opposes the force of drag? How do living things create enough forward force to overcome drag?

Figure 3.13 A parachute is designed to increase drag. This allows things to fall slowly.

Figure 3.14 Modern parachutes have wing-like properties that allow skydivers to land on very specific targets.

TEACHING STRATEGIES

- **Begin the Lesson**—Ask students what they already know about air resistance and drag. Some students may already be familiar with the concept of air resistance in fast-moving vehicles. Ask students, "How can you create air resistance?"
- **During Teaching**—Draw students' attention back to Find Out Activity 3-F My Flying Machine: Flying Further (page 79 in the student textbook). Ask students what factors increased or decreased drag in their gliders.
- **After Teaching**—Ask students to compare the shape of a car that needs to go fast, such as a race-car, and one that is built for another purpose, such as a pickup truck. How might the shape of these vehicles affect drag?
  - As a springboard to Think & Link Investigation 3-H Two Flying Organisms, ask students how different flying organisms overcome drag while airborne.

DidYouKnow? A satellite travelling through space would not experience drag because it is travelling through a vacuum.

INTERNET CONNECT Aerodynamic features of today's cars that reduce drag include a tapered rear end, reduced-angle windshields, a smooth underbody, minimal body seams, and aerodynamic air intakes and other components.

DRAG FILE CARD INSET

BACKGROUND INFORMATION

- Peregrine falcons can reach a speed of up to 250 km/h when dropping to Earth in a streamlined, bullet shape. This makes the bird the fastest organism on Earth. Peregrine falcons were listed as an endangered species in Canada in 1978, as their numbers dwindled due to use of DDT and other pesticides.

  Peregrine falcons were reintroduced in Canada in the 1980s and 1990s. This involved moving one-month-old chicks from a hatching facility in Alberta to artificial nests near traditional cliff nesting areas. Of the 105 falcons released in Nova Scotia, many have been spotted all over the world. However, only a few have migrated back to Nova Scotia.

TEACHING STRATEGIES

- **Begin the Lesson**—Ask students to use their own words to explain drag to a partner. Then have students refer to the summary in the file card on page 82 to see if they have explained the force correctly.

THINK & LINK INVESTIGATION 3-H TWO FLYING ORGANISMS

Purpose

- Students investigate thrust by comparing the movement of different organisms as they fly or glide.

Advance Preparation

WHEN TO BEGIN	WHAT TO DO
1 day before	– Photocopy a class set of BLM 3.8 Two Flying Organisms.

MATERIALS
Per group: – activity handout

Suggested Time

- 30 min to complete Procedure steps 1 to 4
- 30–60 min to complete Procedure step 5

HINTS & HELPS

- Encourage students to choose two organisms that travel through the air in different ways (e.g., a gliding animal and a flying animal) to allow for a better comparison.

Implementing the Investigation

- This activity works well when completed in groups of three or four students.

Investigation Wrap-Up

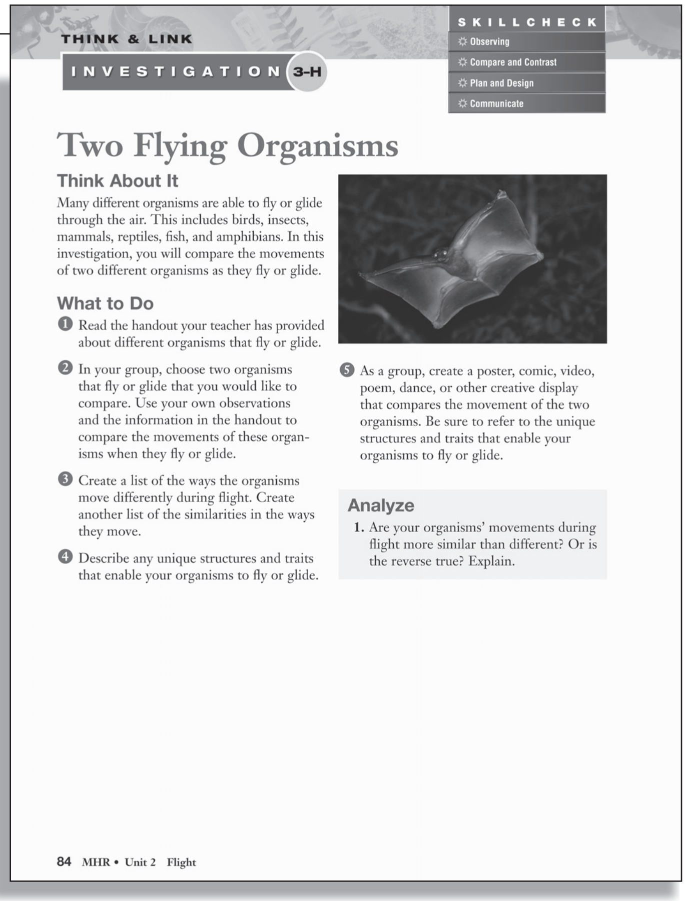
- You may wish to set aside 5 minutes per group for presentation of students' creative displays.
- Analyze question 1 may be answered as part of a class discussion wrapping up the activity.

Assessment Option

- Use Science Skills Checklist 15, Making Observations and Inferences to assess student work in Think & Link Investigation 3-H Two Flying Organisms

Analyze Answer

1. Most students will find that their organisms' movements during flight are quite similar. Answers should explain which movements the organisms have in common and/or which differ.



THINK & LINK INVESTIGATION 3-H

SKILLCHECK
- Observing
- Compare and Contrast
- Plan and Design
- Communicate

Two Flying Organisms

Think About It

Many different organisms are able to fly or glide through the air. This includes birds, insects, mammals, reptiles, fish, and amphibians. In this investigation, you will compare the movements of two different organisms as they fly or glide.

What to Do

1. Read the handout your teacher has provided about different organisms that fly or glide.
2. In your group, choose two organisms that fly or glide that you would like to compare. Use your own observations and the information in the handout to compare the movements of these organisms when they fly or glide.
3. Create a list of the ways the organisms move differently during flight. Create another list of the similarities in the ways they move.
4. Describe any unique structures and traits that enable your organisms to fly or glide.
5. As a group, create a poster, comic, video, poem, dance, or other creative display that compares the movement of the two organisms. Be sure to refer to the unique structures and traits that enable your organisms to fly or glide.

Analyze

1. Are your organisms' movements during flight more similar than different? Or is the reverse true? Explain.

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THRUST

BACKGROUND INFORMATION

- Airborne organisms have a variety of means of generating thrust. Insects, birds, and bats use their wings to generate thrust. Gliding organisms (including squirrels, snakes, fish, ants, and squid) use gravity to generate thrust, as they glide rather than fly through the air.
- Scientists know little about insect flight. Insects often have two sets of wings that are made of thin membranes held up by strong, branching supports. The design of insect wings has changed little over time. For example, the earliest dragonfly fossil has wings with the same structure as those of its smaller, more modern relatives. The prehistoric dragonfly had a wingspan of almost 74 cm.
- Bats and birds also developed wings capable of flight. Bats are the only true flying mammals. A bat's wing is made up of a stretchy membrane pulled tightly over a claw-like skeleton. It is much more flexible than a bird's wing. A bat can actually change the shape of its wings to help it maneuver in flight. A bird's wing is much stronger than that of a bat. Additionally, a bird's bones are hollow (air-filled), making them very light in weight.

Thrust

As you saw in the last activity, living things use different means to generate a forward force to overcome drag. This force is known as thrust. **Thrust** pushes a flying machine or organism forward during flight.

Wings get their lift when air flows around them. However, the air must be set in motion for this to happen. This means that an airplane must be moving forward in order to experience lift. It must have thrust to become airborne. In order to stay aloft, a plane must experience more thrust than drag. Without thrust, an aircraft cannot remain in the air. It will crash to the ground. Propellers, jet engines, rocket engines, wing muscles, and even gravity can generate thrust.

In the next section, you will learn more about the different ways aircraft generate thrust. You will explore how advances in technology have helped humans generate enough thrust to not only fly through the air but also into space.

Figure 3.15 How does this bat (A) generate thrust? How about this plane (B)?

Type of Force
- Thrust

Direction of Force
- Forward

How does it work?
- A force is generated by wings, propellers, or other means. This force overcomes drag and moves the object forward through the air.

Examples:
- A bee flaps its wings about 190 times per second to generate the thrust it needs to take off and fly forward.
- A rocket uses its powerful engines to create the thrust it needs to escape Earth's gravitational pull and enter orbit.

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- Gliding is not a new evolutionary development. Pterosaurs may have been the largest gliders that Earth has ever known. Living 65 to 228 million years ago, the largest pterosaur fossil found had a wingspan of 15 metres. Some scientists think that pterosaurs had wing muscles that were strong enough to allow them not only to glide but also to fly, while other scientists believe that the reptiles were purely gliders.

  There are also many modern gliders. Flying squirrels have two flaps of fur-covered skin on both sides of their body from wrist to ankle that they extend to glide through the air in a spread-eagle position. There are also 50 different types of "flying" fish that have enlarged fins that allow them to glide through the air. Flying fish can glide for hundreds of metres using drafts of air that pass over waves.

TEACHING STRATEGIES

- **Begin the Lesson**—Review students' comparisons of flying and gliding organisms in Think & Link Investigation 3-H to introduce the concept of thrust.
  - Define thrust and see how many different means of generating thrust students can come up with before reading the text.
- **During Teaching**—Have students answer the questions posed in Figure 3.15 on page 85 (see below for answers).

Figure 3.15 (page 85)

A. A bat generates thrust by flapping its membrane-covered wings.

B. The plane in the figure generates thrust by spinning its propeller. The propeller forces air towards the rear of the plane. The air "pushes back" (exerts an equal and opposite force), causing the plane to move forward.

THRUST FILE CARD INSET

BACKGROUND INFORMATION

- Most insects beat their wings very quickly, a task that requires enormous muscle power. Some beat their wings faster than others. Midges have the fastest wing beats, coming in at just over 62 000 beats per minute. Conversely, the swallowtail butterfly flaps its wings a mere 300 times per minute.

TEACHING STRATEGIES

- **Begin the Lesson**—Ask students to try to explain thrust to a partner in their own words. Then have students refer to the summary in the file card on page 85 to see if they have explained the force correctly.
- **During Teaching**—In groups of five, have each student read a different file card for each of the forces presented in sections 3.1 and 3.2 (gravity, buoyancy, lift, drag, and thrust). Then have the students share what they have learned with other members of their group.

THRUST (CONTINUED FROM PREVIOUS PAGE)

TEACHING STRATEGIES

- **During Teaching**—Figure 3.16 and Table 3.2 on page 86 can be used to summarize the different forces studied in sections 3.1 and 3.2. They are also available as a BLM that can be used as an overhead (BLM 3.9 Forces That Act on a Wing During Flight).
- **After Teaching**—Have students use Table 3.2 to create a brief quiz with answers. Questions can then be exchanged with a partner.

READING Check If thrust is less than drag, drag will slow the aircraft down so that air does not rush across its wings fast enough. As a result, the wings will not experience enough lift to stay airborne and gravity will pull the plane toward Earth. This question links all four forces that act on a wing to aircraft flight.

READING Check

Why must thrust be greater than drag for an aircraft to stay in the air?

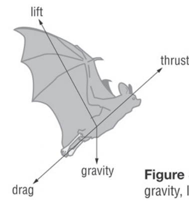
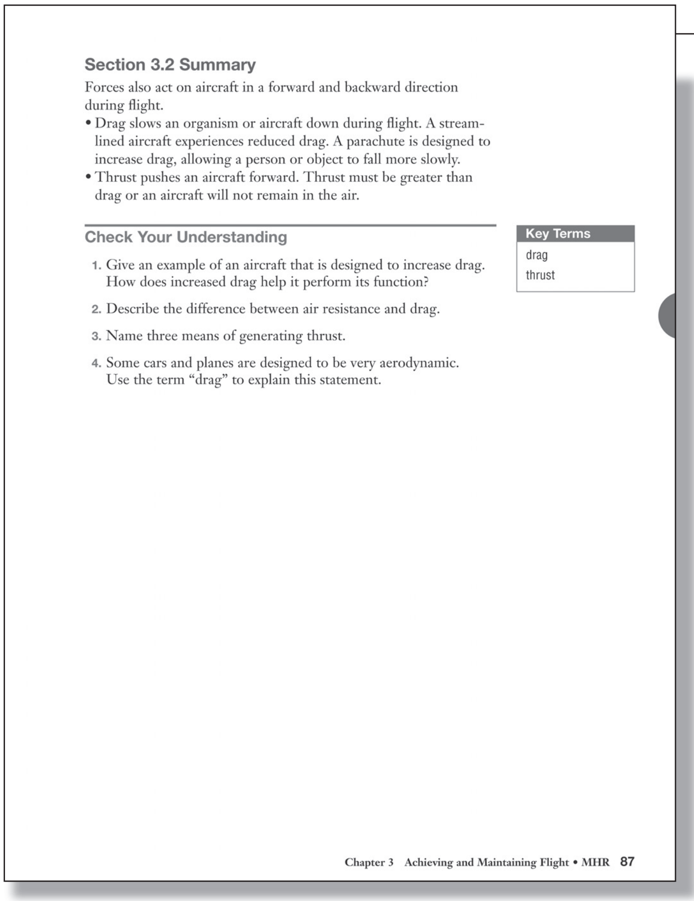


Figure 3.16 A wing experiences the forces of gravity, lift, thrust, and drag while in flight.

Table 3.2 Comparing the Forces That Act During Flight

Force	Direction	How It Works
gravity	downward	• Earth pulls all objects downward. • Only very large objects, such as Earth, have a noticeable gravitational pull.
buoyancy	upward	• An object displaces a liquid or gas (for example, a hot air balloon displaces air). • The surrounding liquid or gas exerts the same pressure on the object that it had on the liquid or gas that was displaced. If the object is lighter than the liguid or gas it displaced, the pressure will cause it to rise.
lift	upward	• Wings are curved. • Air passes over a curved wing more quickly than under it, as it must travel further. • Air pressure decreases as air speed increases. • Higher-pressure air flowing under the wing pushes it upward. • The wing is lifted up.
drag	backward	• Liquid or gas particles must be pushed out of the way or pulled along with the object, causing it to slow down. • As the speed of an object increases, so does drag.
thrust	forward	• Force is generated by wings, propellers, or other means. • If the force overcomes drag, the plane moves forward through the air.



Section 3.2 Summary

Forces also act on aircraft in a forward and backward direction during flight.

- Drag slows an organism or aircraft down during flight. A streamlined aircraft experiences reduced drag. A parachute is designed to increase drag, allowing a person or object to fall more slowly.
- Thrust pushes an aircraft forward. Thrust must be greater than drag or an aircraft will not remain in the air.

Key Terms
drag
thrust

Check Your Understanding

1. Give an example of an aircraft that is designed to increase drag. How does increased drag help it perform its function?
2. Describe the difference between air resistance and drag.
3. Name three means of generating thrust.
4. Some cars and planes are designed to be very aerodynamic. Use the term “drag” to explain this statement.

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SECTION 3.2 SUMMARY

Review the section summary as a class and discuss any questions students may have. Make sure that students update the flight section in their logbooks and key terms list. Have students share some of their definitions of the key terms with the class and compare different interpretations of the same words.

✓ ASSESSMENT OPTIONS FOR SECTION 3.2

- Collect and review science logbooks, using Learning Skills Rubric 2, Science Logbook.
- Distribute BLM 3.10 Comparing the Forces That Act During Flight—Fill in the Blanks. This BLM provides a version of Table 3.2 with certain information missing. Either ask students to complete the table, or create an overhead from this BLM and fill in the blanks as a class.
- Ask students to complete BLM 3.11 Forces That Act During Flight Review
- Use the following rubrics to assess student work:
  – Process Skills Rubric 11, Problem Solving for Find Out Activity 3-F My Flying Machine: Flying Further
  – Science Skills Rubric 19, Conduct an Investigation to assess student work in Investigation 3-G Design a Parachute
  – Science Skills Checklist 15, Making Observations and Inferences to assess student work in Think & Link Investigation 3-H Two Flying Organisms

Check Your Understanding Answers

1. A parachute is designed to increase drag. Increased drag slows the parachute’s fall so that the person or object it is carrying is not harmed when landing on the ground.
2. Drag is the force that acts backward on an object as it moves through a liquid or gas. This is different from air resistance, which only refers to drag that occurs as an object moves through the air.
3. Answers could include three of the following: propellers, jet engines, rocket engines, wing muscles, and gravity.
4. Cars and planes that are designed to be aerodynamic experience less drag due to design features such as a smooth body and a streamlined shape.

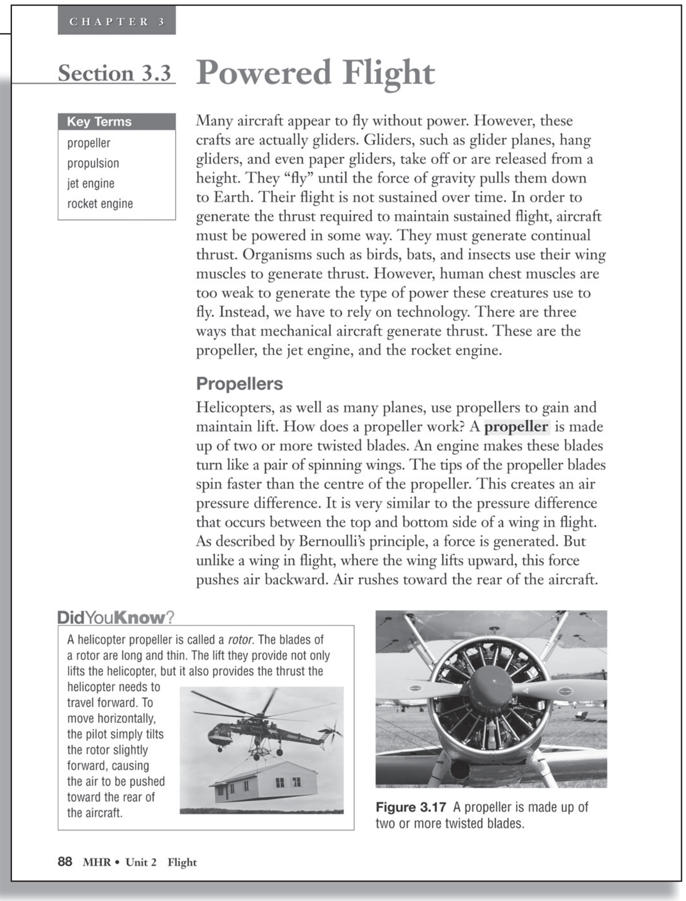
SECTION 3.3 POWERED FLIGHT

What Students Do in Section 3.3

- define and distinguish between the three main types of aircraft propulsion: propellers, jet engines, and rocket engines
- build and modify an aircraft that uses a propeller as a means of propulsion
- use balloons to demonstrate the force that propels a jet plane forward
- identify different means of propulsion by comparing a variety of airborne organisms and aircraft

BACKGROUND INFORMATION

- Powerless, gliding airplanes are generally referred to as sailplanes. Sailplanes are towed into the air behind a powered airplane. The towrope is released once sufficient altitude is achieved. Once released, sailplanes rely on thermals of rising warm air to generate lift. Sailplanes are designed with long, thin wings to maximize lift. The planes can be lifted thousands of metres by thermals and may remain in the air for up to 6 hours.


CHAPTER 3

Section 3.3 Powered Flight

Key Terms
propeller
propulsion
jet engine
rocket engine

Many aircraft appear to fly without power. However, these crafts are actually gliders. Gliders, such as glider planes, hang gliders, and even paper gliders, take off or are released from a height. They "fly" until the force of gravity pulls them down to Earth. Their flight is not sustained over time. In order to generate the thrust required to maintain sustained flight, aircraft must be powered in some way. They must generate continual thrust. Organisms such as birds, bats, and insects use their wing muscles to generate thrust. However, human chest muscles are too weak to generate the type of power these creatures use to fly. Instead, we have to rely on technology. There are three ways that mechanical aircraft generate thrust. These are the propeller, the jet engine, and the rocket engine.

Propellers

Helicopters, as well as many planes, use propellers to gain and maintain lift. How does a propeller work? A **propeller** is made up of two or more twisted blades. An engine makes these blades turn like a pair of spinning wings. The tips of the propeller blades spin faster than the centre of the propeller. This creates an air pressure difference. It is very similar to the pressure difference that occurs between the top and bottom side of a wing in flight. As described by Bernoulli's principle, a force is generated. But unlike a wing in flight, where the wing lifts upward, this force pushes air backward. Air rushes toward the rear of the aircraft.

DidYouKnow?

A helicopter propeller is called a *rotor*. The blades of a rotor are long and thin. The lift they provide not only lifts the helicopter, but it also provides the thrust the helicopter needs to travel forward. To move horizontally, the pilot simply tilts the rotor slightly forward, causing the air to be pushed toward the rear of the aircraft.

Figure 3.17 A propeller is made up of two or more twisted blades.

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TEACHING STRATEGIES

- **Begin the Lesson**—Have a brainstorming session with students to see how many means of propulsion they can come up with before reading the text. Ask students to write their ideas in their logbooks before the class discussion and to provide examples of aircraft or organisms that use each type of propulsion.
- **After Teaching**—If you live near Shearwater, Nova Scotia, do not miss the opportunity to take your students to see the planes at the Shearwater Aviation Museum. They have several propeller aircraft, military jets, and a helicopter on display. Any airfield in the province will also have a variety of aircraft to view.
  - Students could prepare a free verse, a drawing, or a paragraph about their preferred method of propulsion.

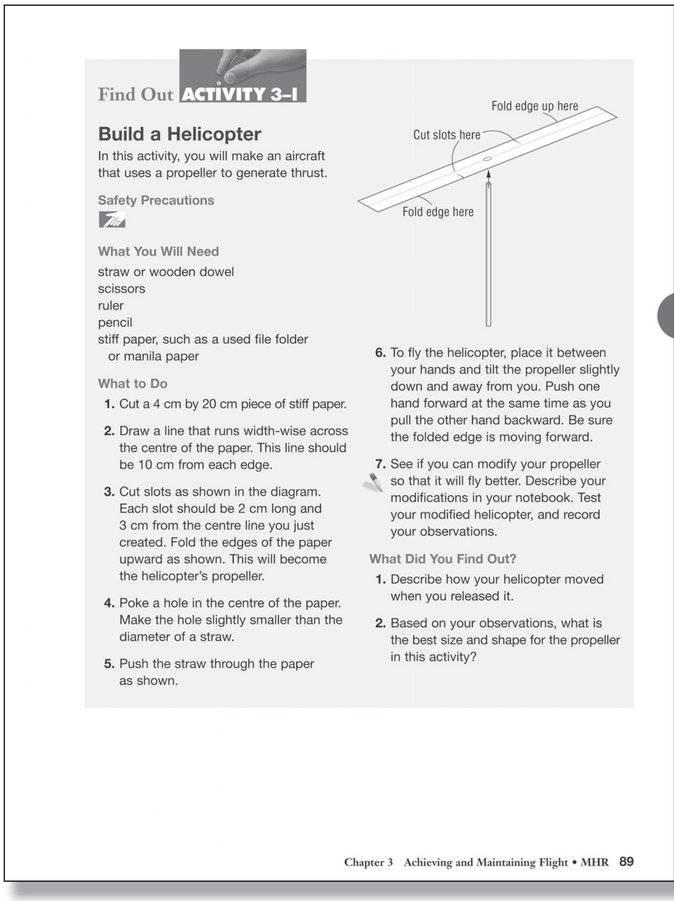
PROPELLERS

BACKGROUND INFORMATION

- In December 1903, the Wright brothers made what is now a historic flight. On the beach at Kitty Hawk, North Carolina, the two brothers flew the *Wright Flyer* in the world's first flight of a fully controlled, heavier-than-air craft. The Wright brothers designed the innovative propeller used on the plane—a propeller designed as if it were a rotary wing. They reasoned that if they used the same curved surface of a wing but turned it on its side and rotated it, a forward force (thrust) would be created in the same way an upward force is created as air flows over a wing (lift). They were correct, and the original design they created is still used as the basis for today's aircraft propellers. The Wright brothers' propeller design is only 5 percent less efficient than modern propellers.

TEACHING STRATEGIES

- **Begin the Lesson**—Review Bernoulli's principle and the role it plays in generating lift. Ask students to define lift in their science logbooks using words and/or images.
- **During Teaching**—Ask students to describe the shape of the propeller in Figure 3.17 on page 88. How is it similar to a wing? How is it different?
- **After Teaching**—Bring in several elastic-band-powered planes so students can experience how a propeller generates forward thrust. Ask students why they think the plane moves forward.


Find Out ACTIVITY 3–I

Build a Helicopter

In this activity, you will make an aircraft that uses a propeller to generate thrust.

Safety Precautions

What You Will Need

straw or wooden dowel
scissors
ruler
pencil
stiff paper, such as a used file folder or manila paper

What to Do

1. Cut a 4 cm by 20 cm piece of stiff paper.
2. Draw a line that runs width-wise across the centre of the paper. This line should be 10 cm from each edge.
3. Cut slots as shown in the diagram. Each slot should be 2 cm long and 3 cm from the centre line you just created. Fold the edges of the paper upward as shown. This will become the helicopter's propeller.
4. Poke a hole in the centre of the paper. Make the hole slightly smaller than the diameter of a straw.
5. Push the straw through the paper as shown.

6. To fly the helicopter, place it between your hands and tilt the propeller slightly down and away from you. Push one hand forward at the same time as you pull the other hand backward. Be sure the folded edge is moving forward.
7. See if you can modify your propeller so that it will fly better. Describe your modifications in your notebook. Test your modified helicopter, and record your observations.

What Did You Find Out?

1. Describe how your helicopter moved when you released it.
2. Based on your observations, what is the best size and shape for the propeller in this activity?

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Common Misconceptions

- Students may believe that propeller planes are old-fashioned and are not capable of high speeds. This is not true. The fastest propeller-driven plane in the world is the Tupolev Tu-114. It can achieve a speed of 870 km/h.

DidYouKnow? The helicopter in the photo on page 88 is a Sikorsky helicopter that is frequently used in construction. (Russian-American Igor Sikorsky was a pioneer in the field of helicopter aviation.) A giant Sikorsky Skycrane helicopter was used to place antenna on the CN Tower in Toronto when it was built. The helicopter, nicknamed Olga, made 55 lifts to carry parts of the antenna to workers at the top of the building. There is a Sikorsky helicopter on exhibit at the Shearwater Aviation Museum in Shearwater, Nova Scotia. The Canadian Forces base in Shearwater is also home to the Maritime Helicopter Training Facility where pilots train to fly Sikorsky CH-148 Cyclone Maritime Helicopters. Students can also look at the photo of a helicopter shown on page 3 of Unit 1.

FIND OUT ACTIVITY 3-I BUILD A HELICOPTER

Purpose

- Students build a helicopter to investigate how a propeller generates thrust.

Advance Preparation

WHEN TO BEGIN	WHAT TO DO
3 days before	– Gather a class set of materials.

MATERIALS
Per group: – straw or wooden dowel – scissors – ruler – pencil – stiff paper, such as a used file folder or Manila paper

Suggested Time

- 30 min

Safety Precautions

- Remind students to use caution when handling scissors.

HINTS & HELPS

- If student helicopters flip upside down, they can increase the weight of the bottom of the helicopter by pushing a paperclip into the bottom of the straw. Have a supply of paperclips available in case this occurs.
- Create several functional sample helicopters that students can modify if they have trouble getting their original helicopter to fly.

Implementing the Activity

- This activity works best if students work in partners.
- Set up a class display to compare modifications and their results.
- If possible, bring in maple keys/seeds and test them by sending them aloft.

Adaptations

- Use preferential grouping when organizing students to allow all students, including those with fine motor or literacy difficulties, to fully participate in the activity.

Activity Wrap-Up

- As a class, explain the flight of the helicopters in terms of the forces that act on an object in flight.
- Students could use their science logbooks to answer the question "What is a helicopter?"

Assessment Option

- Use Science Skills Checklist 15, Making Observations and Inferences for Find Out Activity 3-I Build a Helicopter.

What Did You Find Out? Answers

1. Students should have found that their helicopter moved upward and continued spinning.
2. Students should not only state which size and shape is the best, but why this is the case. For example, does it fly further, higher, or longer?

PROPELLERS (CONTINUED FROM PREVIOUS PAGE)

BACKGROUND INFORMATION

- On February 23, 1909, a young engineer named John McCurdy took flight from the frozen waters of Baddeck Bay, Nova Scotia, in the first motorized flight in Canada and the British Empire. His plane, the *Silver Dart*, generated thrust with a propeller. McCurdy worked with Dr. Alexander Graham Bell of Baddeck to develop the motorized plane.

TEACHING STRATEGIES

- **During Teaching**—Students may require some help in grasping the concept that when a particle pushes against another particle, the second particle will react by applying the same force back. This comes from Newton's third law, which states that for every action, there is an equal and opposite reaction. Students will encounter this law in later grades. For now, it may be helpful to use analogies to relate the concept to the everyday world. For example, ask students what happens when they push off from a wall in a swimming pool. Their legs are pushing in one direction against the wall, and they move in the opposite direction.

Common Misconceptions

- Students may be surprised to learn that propellers do not have to be at the front of an aircraft. The most obvious example of this is the placement of propellers on a helicopter. Although they are not common, some aircraft even obtain thrust from a rear propeller.

Off the Wall You may wish to ask students how they think propellers were first developed before they read this Off the Wall.

Off the Wall

Propellers were used in ships long before they played a role in flight. The first propellers were not very efficient. Surprisingly, propellers used to be shaped a lot like screws. Then one day, the tip of a pointed propeller broke off in the water. Amazingly, the boat travelled much more quickly with the broken propeller. Since then, propellers have been designed with a flat front.

Why do you think a plane moves forward when air moves toward the rear of the plane? When a particle pushes against another particle, the second particle will react by applying the same force back. When air is forced backward, away from the propeller, it strikes other air particles. These air particles apply a force back. This force is thrust. It is exactly as strong as the force of the air that was pushed backward by the propeller. Thrust results in the **propulsion**, or forward motion, of the plane. The amount of thrust and propulsion a propeller creates depends on the angle of the blades and how quickly they spin.

Aircraft also use jet engines as a means of propulsion. How does a jet engine work? Can you create a model of a jet engine and show how it generates thrust?

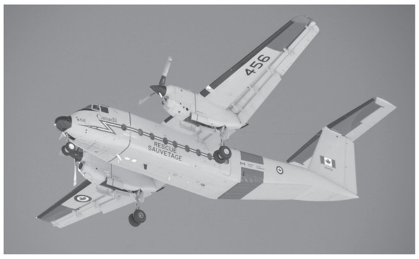

Figure 3.18 Many planes, such as this Canadian-designed de Havilland Buffalo, use propellers.

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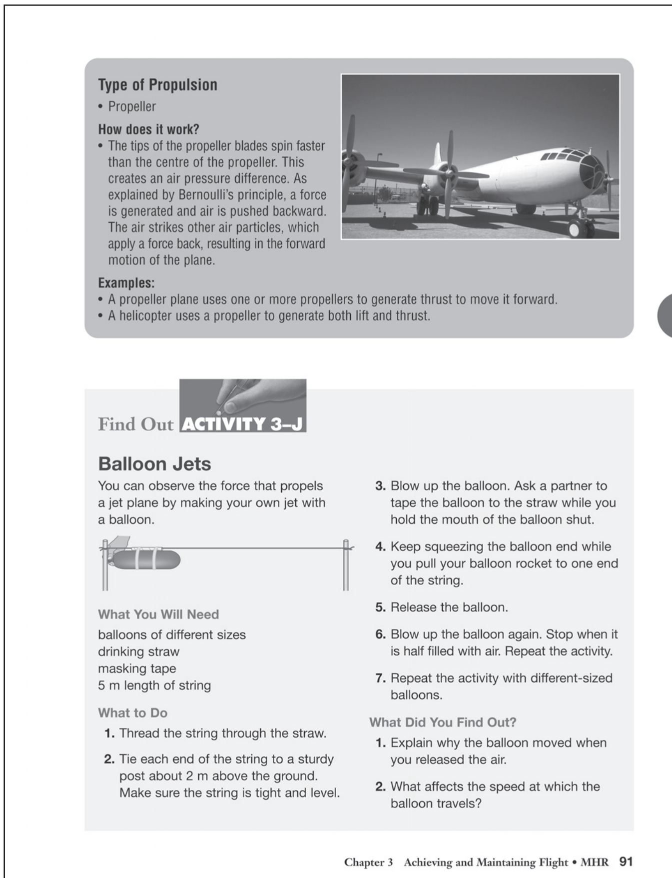
PROPELLER FILE CARD INSET

BACKGROUND INFORMATION

- The design of a helicopter allows it to master travel in three dimensions in a way airplanes are unable to. Helicopters have two main propellers. The rotating wing assembly above the helicopter is called the main rotor. The main rotor is constructed of two or more blades that are connected to a shaft. The blades have a similar shape to the wings of an airplane, although they are longer and thinner. By rotating the shaft, the "wing" is kept in continuous motion. Air flows over the blades, and lift is generated.

  In addition to providing lift, the spinning blades of the rotor also cause the helicopter to rotate. To counteract this motion, a tail rotor is added at the rear of the helicopter. The tail rotor provides horizontal thrust that counterbalances the spin of the helicopter. The blades of the tail rotor are much shorter than those of the main rotor.

  Both the main rotor and tail rotor are adjustable. Adjusting the tail rotor allows the helicopter to rotate to varying degrees. Adjustments to the main rotor allow the helicopter to makes turns, change its vertical position, and change its lateral position.



Type of Propulsion
• Propeller
How does it work?
• The tips of the propeller blades spin faster than the centre of the propeller. This creates an air pressure difference. As explained by Bernoulli's principle, a force is generated and air is pushed backward. The air strikes other air particles, which apply a force back, resulting in the forward motion of the plane.
Examples:
• A propeller plane uses one or more propellers to generate thrust to move it forward.
• A helicopter uses a propeller to generate both lift and thrust.

Find Out ACTIVITY 3–J

Balloon Jets

You can observe the force that propels a jet plane by making your own jet with a balloon.

What You Will Need
balloons of different sizes
drinking straw
masking tape
5 m length of string

What to Do
1. Thread the string through the straw.
2. Tie each end of the string to a sturdy post about 2 m above the ground. Make sure the string is tight and level.
3. Blow up the balloon. Ask a partner to tape the balloon to the straw while you hold the mouth of the balloon shut.
4. Keep squeezing the balloon end while you pull your balloon rocket to one end of the string.
5. Release the balloon.
6. Blow up the balloon again. Stop when it is half filled with air. Repeat the activity.
7. Repeat the activity with different-sized balloons.

What Did You Find Out?
1. Explain why the balloon moved when you released the air.
2. What affects the speed at which the balloon travels?

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TEACHING STRATEGIES

- **Begin the Lesson**—Ask students to use their own words to explain how a propeller works to a partner. Then have students refer to the summary in the file card on page 91 to see if they have explained it correctly.
- **During Teaching**—Ask students why it might be beneficial to have several propellers (e.g., four instead of one).

FIND OUT ACTIVITY 3-J BALLOON JETS

Purpose
- Students use a balloon to model a jet engine.

Advance Preparation

WHEN TO BEGIN	WHAT TO DO
3 days before	– Gather a class set of materials.

MATERIALS
Per group: – balloons of different sizes – drinking straw – masking tape – 5 m length of string

Suggested Time
- 20 min

Safety Precautions
- Caution students not to pop the balloons.

HINTS & HELPS
- Have different sizes of balloons available for students to experiment with.
- Desk legs can be used as posts in step 2.
- Remind students to make sure their string is tight before launching their balloon jets.

Implementing the Activity
- This activity works well when completed in partners.
- You can also do this activity as a demonstration if time is short.

Adaptations
- Students with fine motor difficulties should be teamed with other students to complete this activity.

Activity Wrap-Up
- What Did You Find Out? questions can be answered in a class discussion to wrap up the activity.

Assessment Option
- Use Science Skills Checklist 15, Making Observations and Inferences for Find Out Activity 3-J Balloon Jets.

What Did You Find Out? Answers
1. Students should be able to grasp the idea that when they released air from the balloon, the air moved backward out of the balloon, forcing the balloon forward.
2. The speed of the balloon depends on the volume of air. The more air in the balloon, the faster it travels.

JET ENGINES

BACKGROUND INFORMATION

- Governments spent large sums of money on the development of aircraft during World War II. Perhaps the most important advancement was the development of jet planes. British Engineer Frank Whittle had been working on a design for a jet engine since 1928 but was unable to interest the British government in his design until the war made it a useful invention. In 1935, German engineer Hans von Ohain began work on a similar design. Unlike Whittle, a major aircraft industrialist backed him and his invention. As a result, the world's first jet plane, the German *He 178* took flight in 1939. The British jet took to the air in 1941. Von Ohain's engine used hydrogen as a fuel, while Whittle's jet engine used gasoline.
- A bird strike is a collision between an airborne organism, such as a bird, and an aircraft. Bird strike has caused numerous aircraft accidents. In once such incident, several dozen people were killed. A bird strike is especially dangerous when a bird is sucked into a jet engine. When a bird strikes one of the blades in the engine, it can displace another blade. This domino effect can cause the engine to fail. Bird strike is most dangerous during takeoff, when jet engines turn at extremely high speeds. Most bird strikes occur in an airport environment at low altitudes. However, high-altitude bird strikes have also been reported.

TEACHING STRATEGIES

- **Begin the Lesson**—Review how a propeller works before reading about jet engines.
- **During Teaching**—Draw students' attention to Figure 3.19 on page 92. Ask students why the air intakes at the front of the jet engines are important to their function. What would happen if one of the air intakes were blocked?
- **After Teaching**—In a class discussion, compare the similarities and differences between a propeller and a jet engine.

Jet Engines

A **jet engine** uses expanding gases to propel a plane. A fan at the front of the engine pulls in large volumes of air. Some of this air goes into a compressor, which increases the air's temperature and pressure. The hot, high-pressure air is mixed with fuel. The mixture is then ignited. The gases expand and shoot from the back of the engine. This causes the plane to move forward.

Why do you think the plane moves forward when gas shoots out the back of the engine? The same reason the balloons shot forward when you released air from them in the previous activity. When air shoots out of the back of a jet engine, it strikes other air particles. These air particles apply a force back. This force is exactly as strong as the force released by the jet engine. It causes the plane to shoot forward. This is very similar to the way a plane moves forward when a propeller pushes air toward the rear of a plane.

READING Check

How does a jet engine work?

Figure 3.19 A World War II jet bomber. Notice the air intakes at the front of the jet engines.

Figure 3.20 The Concorde is a passenger jet that can fly faster than the speed of sound. However, due to high operational costs, the plane has been grounded.

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READING Check A jet engine uses expanding gases to propel the plane. A fan at the front of the engine pulls in large volumes of air. Some of this air goes into a compressor that increases the air's temperature and pressure. This hot, high-pressure air is combined with fuel.

The mixture is ignited and the gases expand and shoot from the back of the engine. This causes the plane to move forward.

Type of Propulsion
- Jet engine

How does it work?
- A fan at the front of the engine pulls in large volumes of air. Some of this air goes into a compressor, which increases the air's temperature and pressure. The hot, high-pressure air is mixed with fuel, and the mixture is ignited. The gases expand and shoot from the back of the engine, propelling the plane forward.

Examples:
- The *SR-71 Blackbird* can fly at three times the speed of sound. This jet-propelled aircraft is the fastest in the world.
- The *Airbus A380*, shown below, is the largest passenger jet in the world. It uses jet engines to transport up to 840 people per flight.

Rocket Engines

Jet engines allow humans to travel through the atmosphere at great speeds. Sometimes these speeds are even greater than the speed of sound. However, jet engines cannot travel into space. Their use is limited because they use air to generate propulsion. This is where **rocket engines** fill an important role.

Rocket propulsion is similar to jet propulsion in that expanding gases are responsible for thrust. However, rocket engines are designed differently from jet engines. Jet engines take in and compress air. The gases shoot out of the rear of the engine, and the plane moves forward. There is no air in space. This limits the height at which a jet can fly.

Rocket engines work in the atmosphere too. But unlike jet engines, they also work in space. Rocket engines are

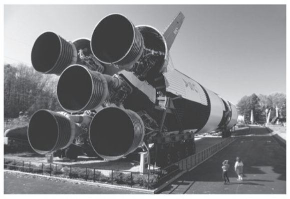

Figure 3.21 A rocket engine creates enormous thrust that carries it into space.

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JET ENGINE FILE CARD INSET

BACKGROUND INFORMATION

- The *SR-71 Blackbird* can fly at speeds greater than 3000 km/h (over three times as fast as the speed of sound). It can fly from coast to coast in just over an hour. However, during this hour, it will burn almost 24 000 kg of fuel, a high cost in terms of fuel prices and pollution.
- The *Airbus A380* made its first commercial flight in 2007. This enormous plane has 50 percent more floor space than a Boeing 747. It often goes by the nickname "superjumbo."

TEACHING STRATEGIES

- **Begin the Lesson**— Ask students to use their own words to explain how a propeller works to a partner. Then have students refer to the summary in the file card on page 93 to see if they have explained it correctly.
- **During Teaching**—Ask students who have flown on a jet plane to describe the sights, sounds, and sensations they experienced.
- **After Teaching**—Bring in books on jet planes for students to explore. Some students may have never seen a jet plane in flight. Show a video or DVD on jet planes to share this experience with students. If you have a major airport nearby, you may want to arrange a tour.

ROCKET ENGINES

BACKGROUND INFORMATION

- Early rockets were not used for space travel. The Chinese first used rockets 1000 years ago, in firework displays and in battle. Rockets continue to be used in battle. In the late 1800s, Konstantin Tsiolkovsky, a Russian scientist, first wrote about the use of rockets to carry people into space. Robert Goddard, an American scientist, first experimented with and built rockets that used liquid fuel in the early nineteenth century. In 1926, he launched the first controlled, liquid-fuelled rocket.
- Wernher von Braun may have been the true father of rocket design. Von Braun was a scientist who designed and built rockets for the German army during World War II. After the war, however, he came to America and was responsible for most of the early rocket designs that NASA used to put astronauts in space.

TEACHING STRATEGIES

- **Begin the Lesson**—Review how a jet engine works with students before reading about rocket engines. Ask students to draw the process in their logbooks.
- **During Teaching**—Draw students' attention to Figure 3.21 on page 93. Ask students why there are no air intakes on rocket engines as there are at the front of the jet engines. How is this difference important to the function of a rocket engine in space?
- **After Teaching**—In class discussion, compare the similarities and differences between a jet engine and a rocket engine.

ROCKET ENGINES (CONTINUED FROM PREVIOUS PAGE)

BACKGROUND INFORMATION

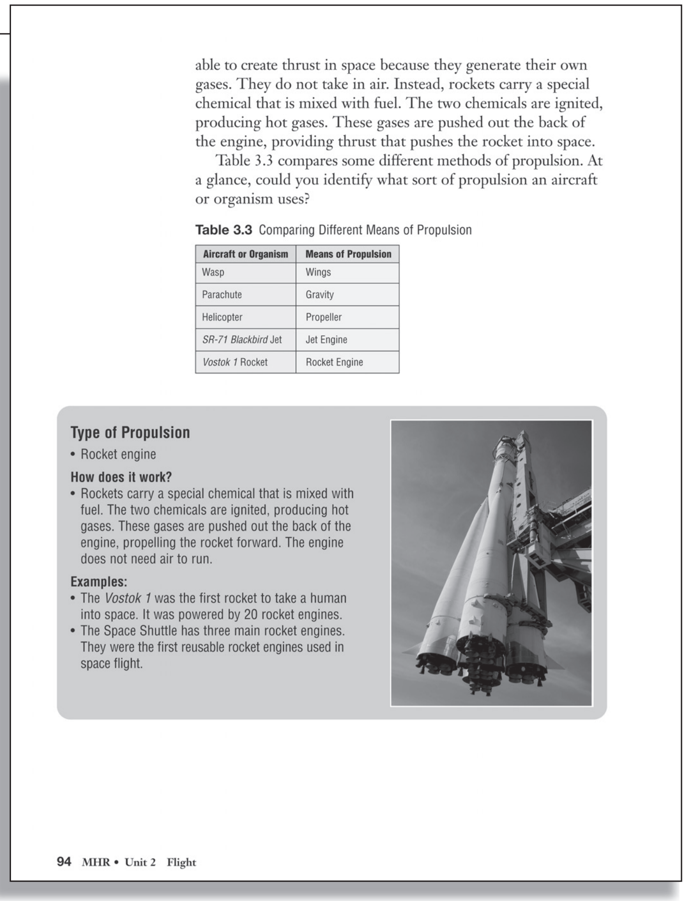
- Rockets use a variety of fuel types. Robert Goddard's first rocket used liquid oxygen and gasoline. This combination was used also used in *Saturn V* (the rocket that took astronauts to the Moon) and many other rockets. The Space Shuttle is propelled by liquid oxygen and liquid hydrogen.
- The fuel in a rocket ignites and generates an enormous force in one direction, which pushes the vehicle in the opposite direction (Newton's third law).
- The explosive force of a rocket engine is needed to escape Earth's atmosphere. Once the vehicle enters the near-vacuum of space, there is little resistance and the spacecraft "coasts." In earlier space launches, the booster rockets were dropped once their fuel was burned.

TEACHING STRATEGIES

- **Begin the Lesson**—In class discussion, develop a list of possible ways that a rocket engine might work. Have students use their logbooks to brainstorm ideas before the discussion.
- **After Teaching**—Table 3.3 compares different means of propulsion. Use this table to introduce the next activity, Think & Link Investigation 3-K Propulsion.

Common Misconceptions

- Some students may believe that a rocket moves forward due to interactions between the exhaust and air particles in the atmosphere. Use the Background Information above to explain to students why this cannot be the case.



able to create thrust in space because they generate their own gases. They do not take in air. Instead, rockets carry a special chemical that is mixed with fuel. The two chemicals are ignited, producing hot gases. These gases are pushed out the back of the engine, providing thrust that pushes the rocket into space.

Table 3.3 compares some different methods of propulsion. At a glance, could you identify what sort of propulsion an aircraft or organism uses?

Table 3.3 Comparing Different Means of Propulsion

Aircraft or Organism	Means of Propulsion
Wasp	Wings
Parachute	Gravity
Helicopter	Propeller
SR-71 Blackbird Jet	Jet Engine
Vostok 1 Rocket	Rocket Engine

Type of Propulsion
- Rocket engine

How does it work?
- Rockets carry a special chemical that is mixed with fuel. The two chemicals are ignited, producing hot gases. These gases are pushed out the back of the engine, propelling the rocket forward. The engine does not need air to run.

Examples:
- The *Vostok 1* was the first rocket to take a human into space. It was powered by 20 rocket engines.
- The Space Shuttle has three main rocket engines. They were the first reusable rocket engines used in space flight.

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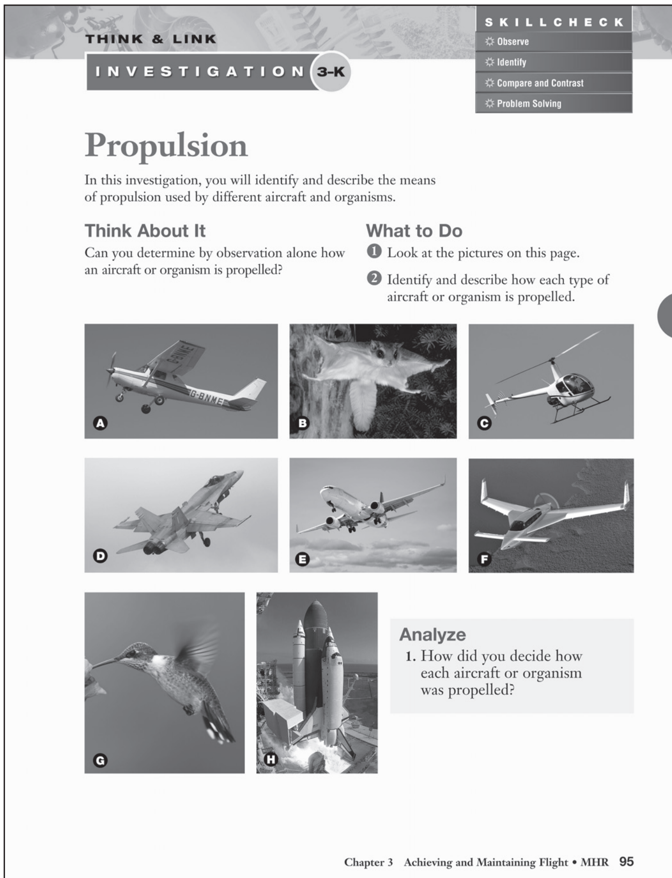
ROCKET ENGINE FILE CARD INSET

BACKGROUND INFORMATION

- The *Vostok 1* carried Russian cosmonaut Yuri Gagarin in the first space flight with a human passenger in 1961. The cosmonaut orbited Earth once in the 108-minute flight. He landed safely, having ejected from the capsule about 7 km above the ground. The capsule's parachute landing was not gentle enough for a human being to land safely.
- The Space Shuttle has three main components at launch point: a rust-coloured fuel tank, two white booster rockets, and the spaceship itself, which is called the orbiter. The rocket engines in the orbiter are reusable, as are the two booster rockets. However these have to undergo extensive refitting after each launch. The fuel tank is not reusable.



THINK & LINK

INVESTIGATION 3-K

SKILLCHECK
- Observe
- Identify
- Compare and Contrast
- Problem Solving

Propulsion

In this investigation, you will identify and describe the means of propulsion used by different aircraft and organisms.

Think About It

Can you determine by observation alone how an aircraft or organism is propelled?

What to Do

1. Look at the pictures on this page.
2. Identify and describe how each type of aircraft or organism is propelled.

A B C D E F G H

Analyze

1. How did you decide how each aircraft or organism was propelled?

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TEACHING STRATEGIES

- **Begin the Lesson**—Ask students to use their own words to explain to a partner how a rocket engine works. Then have students refer to the summary in the file card on page 94 to see if they have explained it correctly.
- **During Teaching**—Arrange students into groups of three. Have each student read one of the three file cards in the section (propeller, jet engine, rocket engine). Then have each student explain what he or she has read to the others.

THINK & LINK INVESTIGATION 3-K PROPULSION

Purpose
- Students identify and describe the means of propulsion used by different aircraft and organisms.

Suggested Time
- 15 min

HINTS & HELPS
- Students may have difficulty identifying gravity as the means of propulsion for Figure B, the flying squirrel. Students may also need assistance in identifying Figure F. This plane uses a rear propeller rather than the typical front propeller to generate thrust.

Implementing the Investigation
- Table 3.3 compares different means of propulsion. Use this table to introduce the investigation.
- Students can do this activity on their own or in partners.
- This activity also works well as a class discussion.

Adaptations
- This is an excellent activity for students with literacy difficulties.
- Students who are visually impaired should be paired with a partner who can describe the images to them.

Investigation Wrap-Up
- As an additional activity, students may wish to prepare a computer slide-show presentation with photos of other airborne organisms and aircraft and get fellow students to identify the modes of propulsion.
- Ask students which of the organisms and aircraft in the photographs they have seen. Many students will probably have seen the airplanes in Figures A and E, as well as the helicopter in Figure C. Some students may have seen a hummingbird before as well (Figure G). It is unlikely that they have seen any of the other organisms or aircraft.

Assessment Option
- Use Science Skills Checklist 15, Making Observations and Inferences for Think & Link Investigation 3-K Propulsion.

What to Do Answer

2. Means of propulsion for each image are as follows: a: propeller, b: gravity, c: propeller, d: jet engine, e: jet engine, f: propeller, g: wing muscles, and h: rocket engine.

Analyze Answer

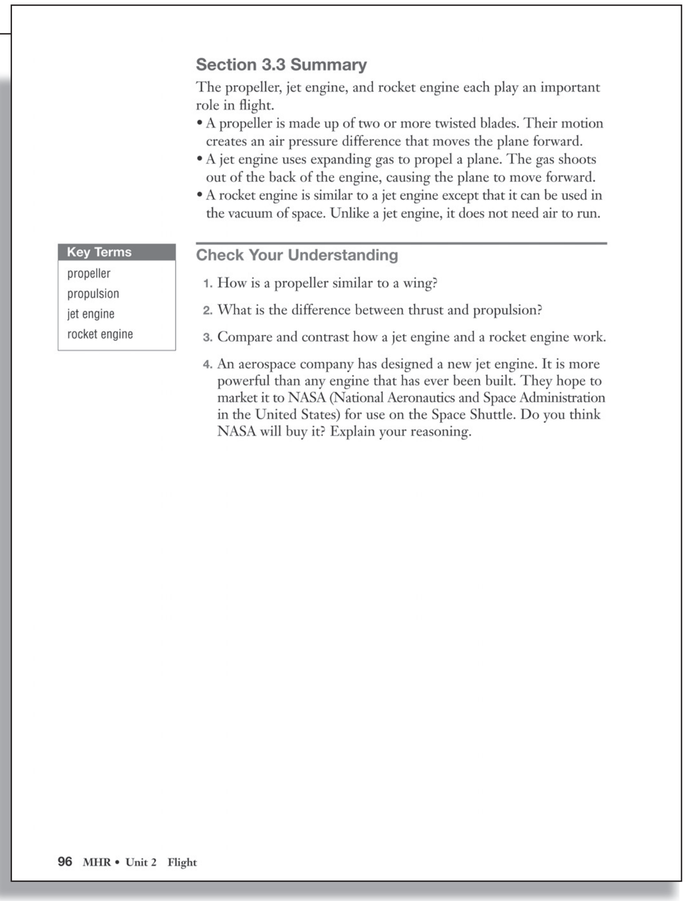
1. Students should explain that they tried to determine what was actually causing the aircraft or organism to move through the air. This is obvious for some of the figures but is a bit tricky for others, such as the flying squirrel.

✓ ASSESSMENT OPTIONS FOR SECTION 3.3

- Collect and review science logbooks, using Learning Skills Rubric 2, Science Logbook.
- Use the following checklists and rubrics to assess student work:
  – Science Skills Checklist 15, Making Observations and Inferences for Find Out Activity 3-I Build a Helicopter, Find Out Activity 3-J Balloon Jets, and Think & Link Investigation 3-K Propulsion.

SECTION 3.3 SUMMARY

Review the section summary as a class. Make sure that students update their science logbooks and key terms lists. You may wish to have students sketch a graphic organizer to summarize what they have learned in Section 3.3. Students could also make posters showing the different aircraft they encountered in this section, explaining their means of propulsion. To review the vocabulary for the chapter, have students create a crossword puzzle or word search using key terms and other terms that were new to them. Students can also complete the Getting Ready questions at the beginning of the chapter on their own to review some of the key chapter concepts.



Section 3.3 Summary

The propeller, jet engine, and rocket engine each play an important role in flight.

- A propeller is made up of two or more twisted blades. Their motion creates an air pressure difference that moves the plane forward.
- A jet engine uses expanding gas to propel a plane. The gas shoots out of the back of the engine, causing the plane to move forward.
- A rocket engine is similar to a jet engine except that it can be used in the vacuum of space. Unlike a jet engine, it does not need air to run.

Key Terms

propeller
propulsion
jet engine
rocket engine

Check Your Understanding

1. How is a propeller similar to a wing?
2. What is the difference between thrust and propulsion?
3. Compare and contrast how a jet engine and a rocket engine work.
4. An aerospace company has designed a new jet engine. It is more powerful than any engine that has ever been built. They hope to market it to NASA (National Aeronautics and Space Administration in the United States) for use on the Space Shuttle. Do you think NASA will buy it? Explain your reasoning.

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Check Your Understanding Answers

1. A propeller is actually similar to a pair of spinning wings. The tips of the propeller blades spin faster than the centre of the propeller. This is similar to how air behaves as it moves around a wing. The air travelling over the upper, curved surface of the wing moves faster than air travelling along the flat, lower surface. In both cases, an air pressure difference develops and a force is generated. The wing experiences upward lift while the propeller-plane experiences forward thrust.
2. Thrust is the force that pushes an aircraft or organism forward during flight. Thrust results in propulsion, the forward motion of the aircraft. Without thrust, propulsion would not occur.
3. A jet engine uses expanding gases to propel a plane. A fan at the front of the engine pulls in large volumes of air. Some of this air goes into a compressor, which increases the air's temperature and pressure. The hot, high-pressure air is mixed with fuel. The mixture is then ignited. The gases expand and shoot from the back of the engine. This causes the plane to move forward. Rocket engines are similar to jet engines except they do not need air to ignite the fuel. Instead, they carry a special chemical that is mixed with the fuel. The two chemicals are ignited, producing hot gases. Like in a jet engine, these gases expand and shoot out the back of the engine, propelling the rocket forward.
4. NASA would probably not buy the jet engine for use on the Space Shuttle because a jet engine needs air to work. It cannot operate in the vacuum of space. If it was a lot more powerful than a rocket engine, however, they might purchase it to use while the Space Shuttle is flying through the atmosphere and then use the rocket engines in space. Accept any well-reasoned answer that mentions that the jet engine cannot be used in space.

Prepare Your Own Chapter Summary

Summarize Chapter 3 by doing one of the following:
- Create a graphic organizer.
- Produce a poster.
- Write a summary to include key chapter ideas.

Here are a few ideas to use as a guide:
- Make a chart that compares the forces that act on an object during flight. Next to each force, give the direction in which it acts.
- Draw a flow chart that shows what happens when the air in a hot air balloon is heated.
- Create a poster that illustrates the three ways in which thrust is generated in aircraft and spacecraft.
- Draw a diagram to show how lift is generated using Bernoulli's principle.

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Prepare Your Own Chapter Summary

Student summaries should incorporate the following main ideas:

- The forces that act on all objects during flight are gravity, lift, drag, and thrust. Buoyancy acts on certain objects during flight, such as hot air balloons.
- The force of gravity acts in a downward direction. An object always falls down due to Earth's gravitational pull.
- Buoyancy is an upward force that is produced by a liquid or gas surrounding an object.
- If the force of buoyancy acting on a hot air balloon is greater than that of gravity, the hot air balloon will rise. If the force of gravity acting on the balloon is more than the force of buoyancy, it will sink.
- Lift provides an upward force on an object during flight.
- Bernoulli's principle states that air pressure increases with speed. In the case of an airplane, air moves faster as it travels over the wing. This is because its upper surface is curved. The air pressure above the wing falls. The wing is pushed upward by the higher-pressure air flowing underneath it. The wing is lifted up as a result.
- Drag slows down an object as it travels through a liquid or gas. This means it acts backward on an object during flight. If drag is too large, an aircraft will stop moving forward and fall to the ground.
- Thrust pushes an aircraft forward during flight. Propellers, jet engines, rocket engines, wing muscles, and gravity all generate thrust.
- A propeller is made up of two or more twisted blades that turn like a pair of spinning wings. The tips of the blades spin faster than the centre of the propeller. This creates an air pressure difference that pushes air backward. The air "pushes back" on the plane, and it moves forward.
- In a jet engine, a fan at the front of the engine pulls in air. Some of this air is compressed. This increases the air's temperature and pressure. The hot, high-pressure air is mixed with fuel. The mixture is then ignited. The gases expand and shoot from the back of the engine. This causes the plane to move forward.
- Rocket engines get their thrust from expanding gases. These engines can create thrust in space because they do not use air. Instead, they carry their own gases.