Understanding Flight in Birds

‘Flight’ Experiment

Developed by EM Date-Huxtable
Photo credit: Lene Parashou

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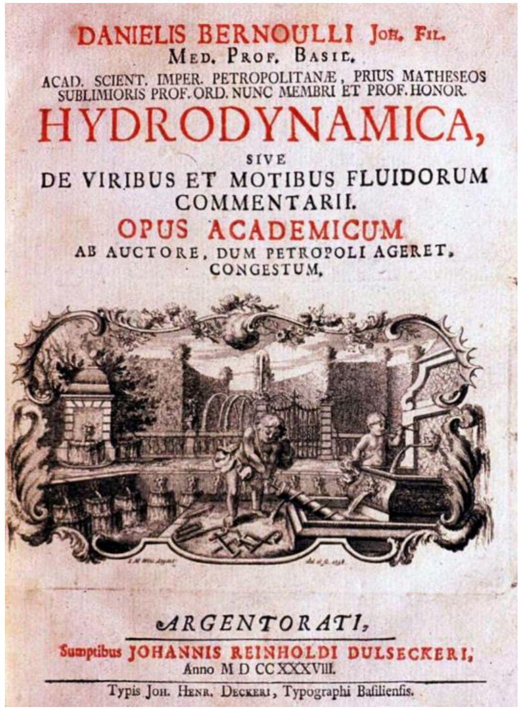
Birds and Bernoulli’s Principle

Birds have been applying Bermoulli’s principle in their everyday lives for millions of years – not consciously, of course, but through a necessity to survive. Every flying bird learns to fly by using its body to maneuver in the air. Flight might not be possible if Earth’s atmosphere were different in density and weather patterns. Birds must instantaneously apply enough force with their wings to lift themselves into the air and to produce enough forward movement to keep themselves in the air – all because of Bernoulli’s principle!

Photo credit: Lene Parashou

Bernoulli’s Principle

Bernoulli's principle can be applied to observations of **fluid dynamics** or fluid flows of gases and liquids under normal atmospheric conditions. It states that an increase in the speed of a fluid occurs simultaneously with a decrease in pressure (on the object over which the fluid flows). The principle is named after Daniel Bernoulli who published it in his book Hydrodynamica in 1738.



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Bernoulli's Principle

Bernoulli's principle can be derived from the **Principle of Conservation of Energy**. This states that, in a steady flow, the sum of all forms of energy in a fluid along a streamline is the same at all points on that streamline. This requires that the sum of kinetic energy, potential energy and internal energy remains constant. Therefore, an increase in its kinetic energy – implying an increase in the speed of the fluid – occurs with a simultaneous decrease in its potential energy – including a decrease in the pressure – and internal energy.

Bernoulli’s Principle

Bernoulli's principle can also be derived directly from **Newton's Second Law of Motion**. If a small volume of fluid is flowing horizontally from a region of high pressure to a region of low pressure, then there is more pressure behind than in front. This gives a net force on the volume, accelerating it along the streamline.

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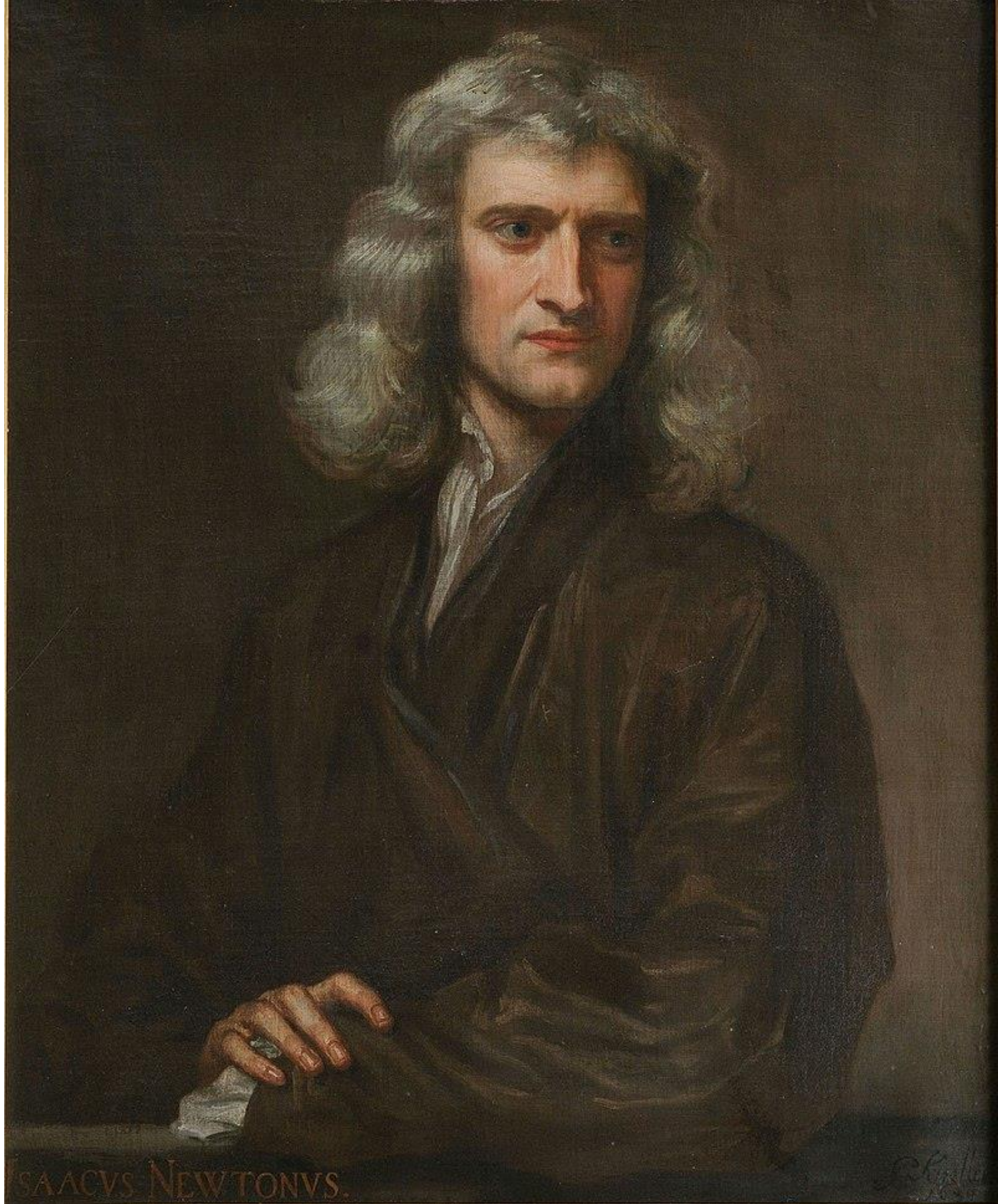


Bernoulli’s Principle

Fluid **particles** are subject only to pressure and their own weight. In a fluid flowing horizontally along a section of a streamline, an increase in the flow speed can only be because the fluid on that section is moving from a region of higher pressure to a region of lower pressure; and if its speed decreases, it can only be because it is moving from a region of lower pressure to a region of higher pressure.

Understanding How a Kite 'Flies'

Think about when you last flew a kite:

- What key environmental factor enabled you to 'fly' it?
- What does the kite usually do when you launch it into the air?
- What happens when there isn't enough of this key factor?
- Can you explain the kite's behaviour using Bernoulli's principle?

Image credit: cocoparisienne CC0

Explaining How a Kite ‘Flies’

As air (which is a fluid) moves (which is a fluid flow, i.e., wind) around an object, it creates different pressures on that object. The air movement across the lower surface is impeded because the kite is angled obliquely to the flow, and it moves more slowly than air moving across the upper surface. Faster air means less pressure on the upper surface of the kite. Slower air means more pressure on the lower surface, which is ‘lift’ and the kite floats upwards. Therefore, the key to flight is creating pressure upwards on the kite to keep it in the air. The principle is basically similar for a bird’s wings.

Understanding How a Glider 'Flies'

Learning Outcomes:

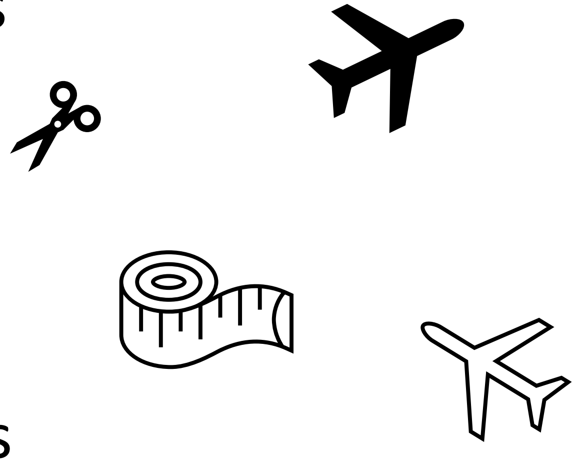
- To understand the role of observing and explaining 'flight' in a toy glider as a simple model of a bird
- To understand how changing the length and width of the glider's wings changes its 'flight performance'

‘Flight’ Experiment:

You will use a toy glider as a simple ‘bird’. Firstly, observe the shape of the glider’s wings and tail.

Experiment: Materials

1. Toy foam glider purchased from a toy or department store
2. Discarded styrofoam packaging, eg. from a new fridge or washing machine
3. Sharp knife for cutting and paring the styrofoam
4. Discarded cardboard, eg. cereal and pizza boxes
5. Scissors and sticky tape
6. Digital scales that measure in tenths of a gram
7. Toy catapult and 25m measuring tape
8. Small fan with several (at least 3) speed settings

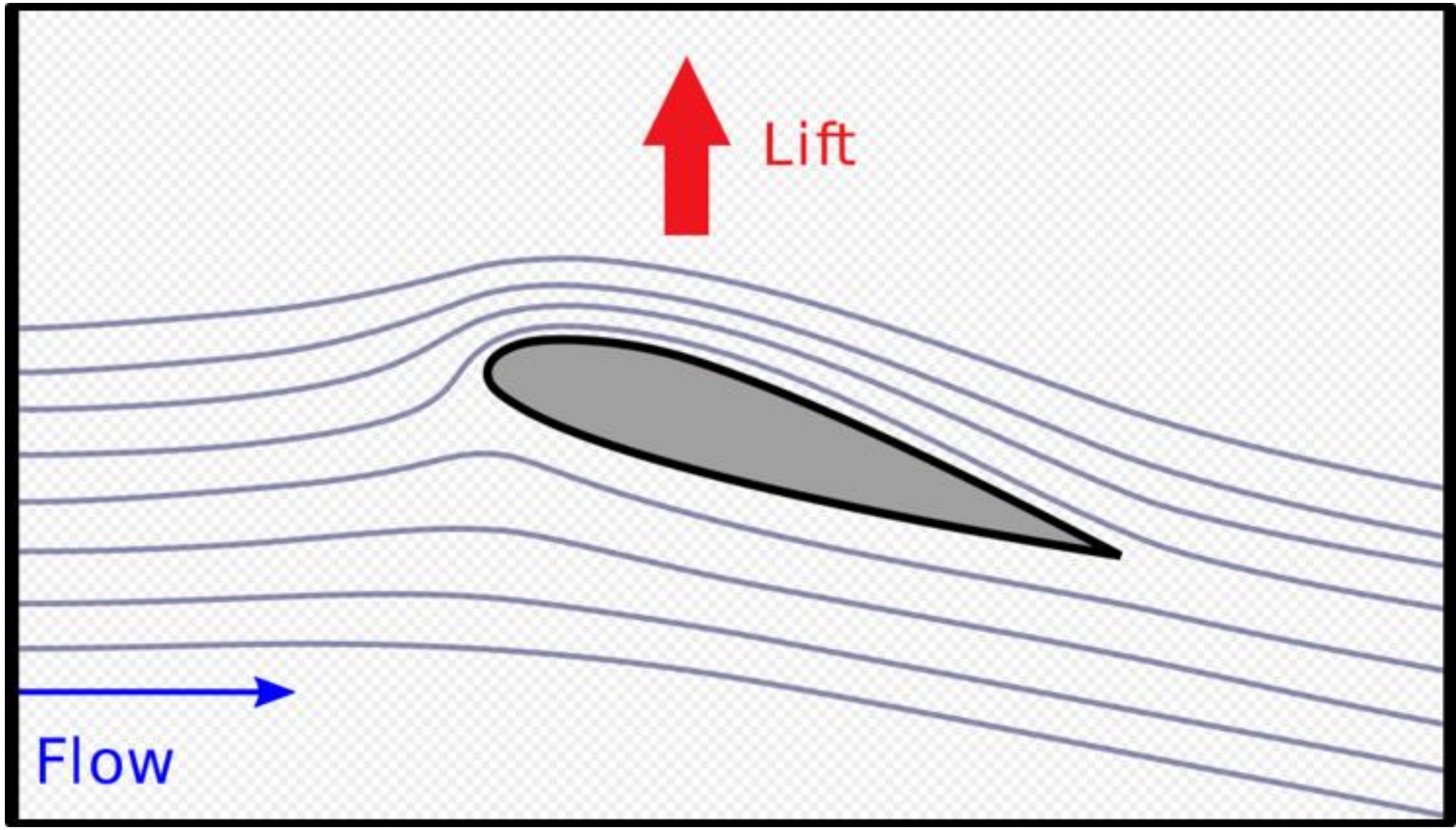


Experiment: Methods

1. Assemble the glider by following the instructions on the box. 'Test fly' it and observe how far and high it glides when you launch it with different force or 'thrust'. Now observe what happens when you launch the toy glider after you change the area of its wings.

Experiment: Methods

2. Cut and pare the styrofoam to make two wings, each the same width as the originals but twice as long (see below); shape the styrofoam so that the lower surface remains relatively flat and the upper surface is curved like an airfoil (see diagram of airfoil cross-section).



Experiment: Methods

3. Using the catapult, launch the glider and measure with 25m tape how far it glides (or throw ‘javelin-style’); repeat 10 times from the same point and calculate the mean distance it ‘flies’.

4. Suspend the glider so that the belly just touches the ground, point the fan at its nose and switch it on to the lowest speed, then the next fastest and so on, and record what happens to the glider.

Experiment: Methods

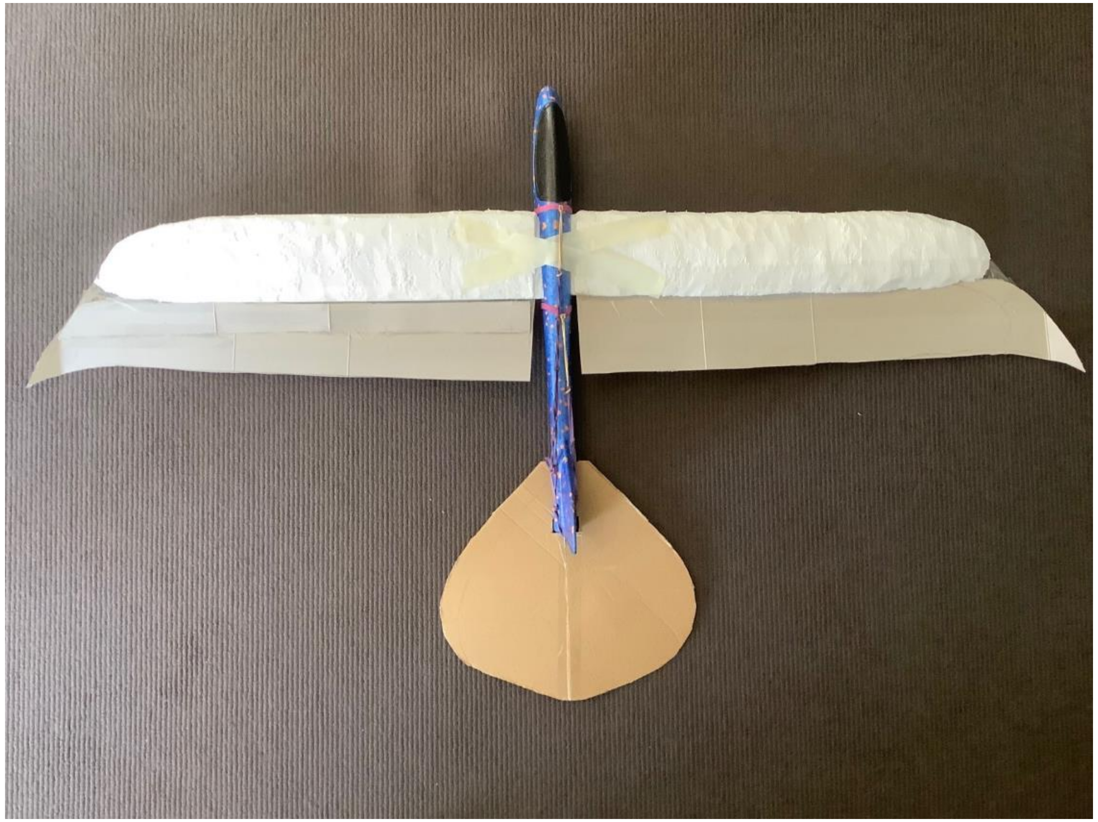
5. Trace the 2D shape of the Styrofoam wings on to cardboard, cut the cardboard ‘wing extensions’ out and attach them with sticky tape to the back edge of the Styrofoam, use the scales to decide how to adjust the weight of the wings so that they are approximately equal (within 1g difference) by adding a strip of cardboard to the lighter wing along the back edge of the Styrofoam on the upper surface.

6. Repeat steps 3. & 4.

7. What difference did you observe in the glider’s flight path between the two modifications? Try explaining the difference using Bernoulli’s principle.

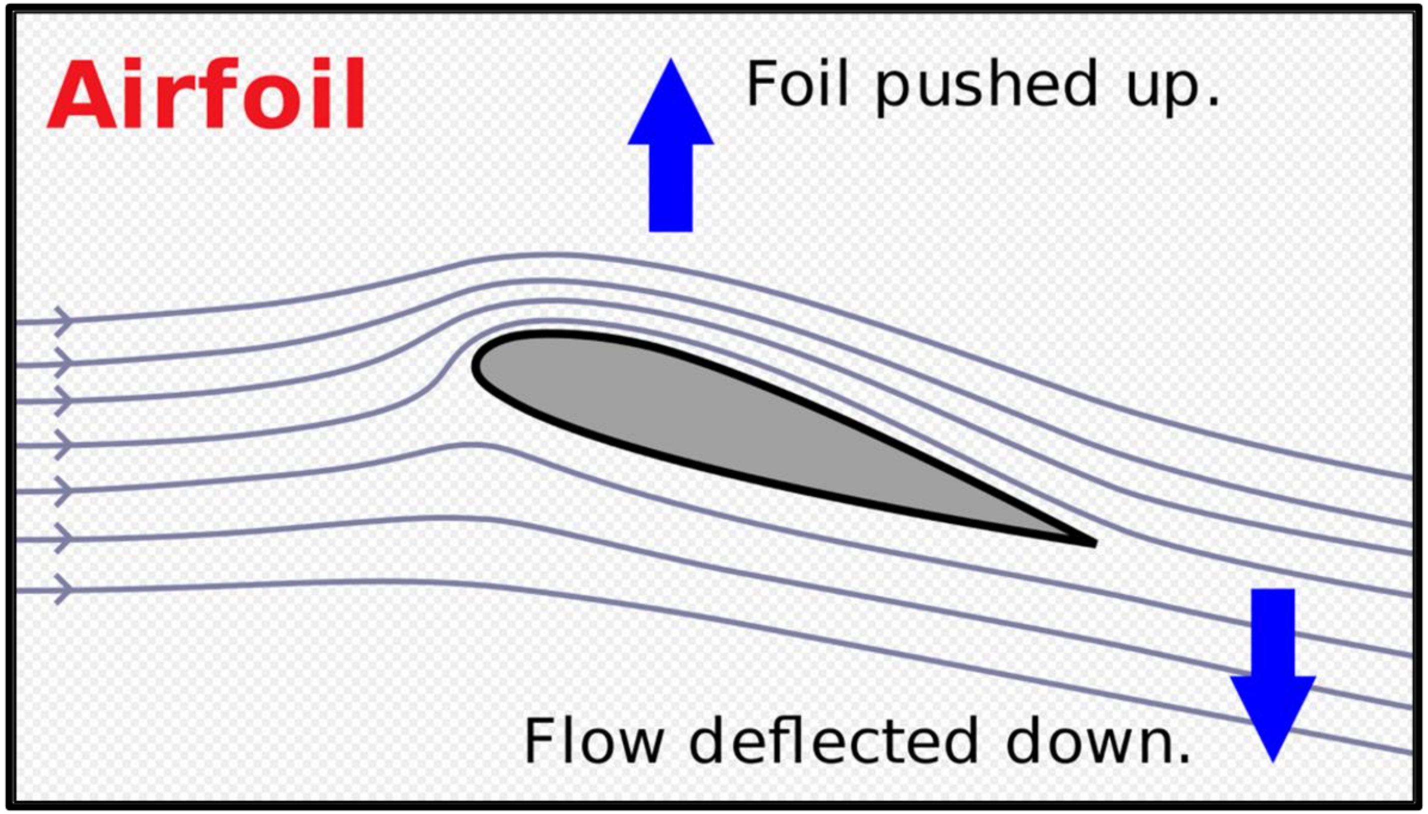
Experiment: Methods

8. Try making some tail modifications (see below) and test fly/glide again (repeat steps 3. & 4.)



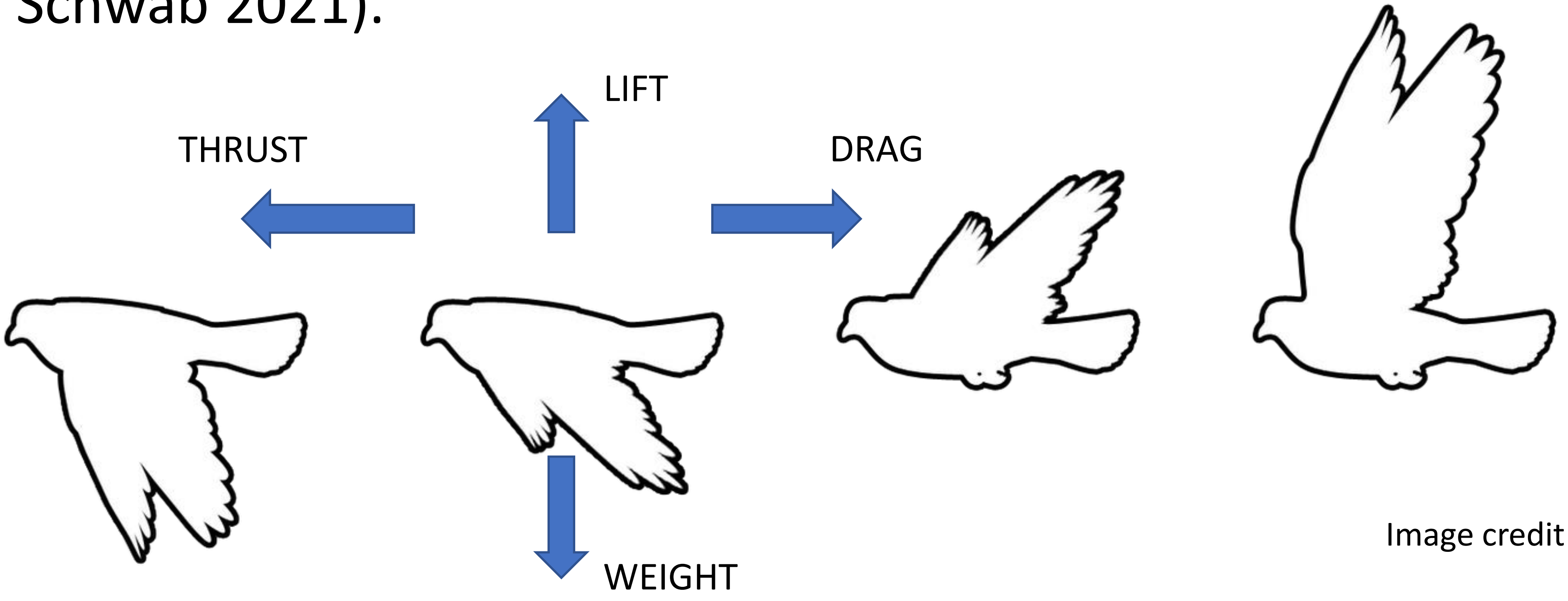
Explaining Flight using Bernoulli's Principle

When air flows over an airfoil (wing), the air flows faster over the top of the wing and slower under the wing. The faster flowing air exerts a lower pressure than the slower moving air. The pressure difference causes an upward force called lift, which enables the bird to fly.



Explaining Flight using Forces

There are four main forces on a bird in flight. **Weight** is a force produced by gravity in the downward direction, and every bird has to produce **lift** with its wings to counteract weight. A wing moving through air also experiences **drag**, which slows it down, so the bird must be a forward-moving force, called **thrust**, to oppose the force of drag. These two pairs of forces weight and lift, drag and thrust have to be roughly balanced in order for a bird to fly (Tong & Schwab 2021).



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‘Flight’ Experiment

Results and Conclusions:

- Describe differences in flight path and lift you observed between the wing shapes/sizes quantitatively and qualitatively
- Evaluate the Experiment
- Design and Plan another Investigation, using the wing shapes available and/or other wing designs
- Develop a method to collect primary data for a practical investigation about the effect of wing shape on flight performance
- Evaluate how observation is limited by the observational tools available

… cont. in ‘Wing Shapes’ presentation