# Understanding How Birds Fly: Teacher's Notes

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## Background: Curriculum Links

This activity embeds learning outcomes of the New South Wales curriculum in a science activity about flight in birds. It addresses the following learning outcomes of the Stage 3 Science and Technology syllabus (and Australian Curriculum learning outcomes in parentheses):

**Working Scientifically Skills: ST3-1WS-S**
plans and conducts scientific investigations to answer testable questions, and collects and summarises data to communicate conclusions

- pose testable questions (ACSIS231)
- make and justify predictions about scientific investigations (ACSIS232)
- identify questions to investigate scientific ideas
- plan and apply the elements of scientific investigations to answer problems
- identify potential risks in planning investigations
- manage resources safely (ACSIS086, ACSIS103)
- decide which variable(s) is to be changed, measured and kept the same, in fair tests
- select appropriate measurement methods, including formal measurements and digital technologies, to record data accurately and honestly (ACSIS087, ACSIS104)
- reflect on and make suggestions to improve fairness, accuracy and efficacy of a scientific investigation (ACSIS091, ACSIS108)
- construct and use a range of representations, including tables and graphs, to represent and describe observations, patterns or relationships in data
- employ appropriate technologies to represent data (ACSIS090, ACSIS107)
- compare data with predictions
- present data as evidence in developing explanations (ACSIS218, ACSIS221)
- communicate ideas, explanations and processes, using scientific representations including multimodal forms (ACSIS093, ACSIS110)

**Knowledge and Understanding: Living World ST3-4LW-S**
examines how the environment affects the growth, survival and adaptation of living things
**'Adaptations of living things'**
**Inquiry question:** How do the structural and behavioural features of living things support survival?
Students:

- describe adaptations as existing structures or behaviours that enable living things to survive in their environment (ACSSU043) **SciT**
- describe the structural and/or behavioural features of some native Australian animals and plants and why they are considered to be adaptations, for example: **ComT SciT**

**Knowledge and Understanding: Physical World ST3-9PW-ST**
investigates the effects of increasing or decreasing the strength of a specific contact or non-contact force

**'Transfer and transformation of energy'**
**Inquiry question:** What types of energy transformations can be observed?
Students:

- identify different types of energy transformations, for example: (ACSSU097)
  - mechanical energy to energy of movement

By following the guided 'Flight Experiment' below, the teacher can encourage their students to observe how a toy glider 'flies', using distance measures and flight path descriptions, including when the dimensions of the wings are changed. Year 5 students can be encouraged to use technical terms, such as lift and thrust, air flow and air pressure to explain why the flight of the glider differs between wing shapes. Year 6 students can be encouraged to define questions to test the flight of the glider with different wing shapes and to predict likely outcomes. They can design fair tests of wing shape effect on 'flight performance', identify variables of 'flight performance' and methods to quantify it. They can organise the data collected, tabulating the flight path differences and graphing the flight distances for different wing shapes, interpreting these results to reflect on their predictions, draw conclusions and develop explanations about flight performance differences based on differences in wing length and width. They can be encouraged to think about the changes in weight of the glider with increased wing size that might also affect flight performance.

During the 'flight experiment', students can be encouraged to explain how energy is transformed during flight, from wings flapping to creating lift and thrust and to describe the difference between contact and non-contact forces, such as air flow and air pressure differences on the bird's wing creating lift (contact) and gravity acting on the bird's weight and against lift (non-contact). In the second and third activities, which explore the variety of wing shapes in birds and the flight patterns of these birds, students examine how environmental conditions and structural features of birds affect their adaptations to different environments.

## Understanding How a Kite 'Flies'

This section provides the rationalé for studying flight in birds with the example of 'flying' a kite (see presentation) before exploring the 'flight' of a toy glider in an observational experiment.

As air moves (i.e., wind) around an object, such as a kite that's in the air, it creates different pressures on that object. The air moving across the lower surface is slowed down by the kite being tilted towards the air flow, so it moves more slowly than the 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. This creates a force called 'lift', which makes the kite float upwards. Therefore, the key to flight is creating pressure upwards on the kite to keep it in the air. This is called Bernoulli's Principle after Daniel Bernoulli who published it in his book Hydrodynamica in 1738. The principle is basically similar for a bird's wings.

## 'Flight' Experiment

During the 'flight' experiment the learning objective is to encourage students to use proportional reasoning in thinking about the relationship between wing shape/design and glider flight performance. Based on how well the gliders perform, ask them to try and describe and compare the performances, and then to try to explain them scientifically:

- Why do you think the glider with longer wings tends to 'nose-dive'? (And the original glider and the one with longer and wider wings don't?)
- What would improve its performance? (eg., greater launch speed, lighter weight, wider wings)
- What happens when you try to launch the glider that has longer and wider wings with more force (=thrust)?

**Learning Outcomes:**

- To understand how changing the length and width of the glider's wings changes its 'flight performance'
- To explain the forces acting on the glider when it is 'flying'

**Instructions**: You will use a toy glider as a 'simple' bird. Firstly, observe the shape of the glider's wings and tail.

**Materials required:**

1. Toy foam glider purchased from a toy or department store (~$3)
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 (kitchen) scales that measure in tenths of a gram
7. 25m measuring tape
8. Small fan with several (at least 3) speed settings

**Method:**

1. Assemble the glider (follow the instructions on the box). 'Test fly' the glider 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.
2. Ask a parent or teacher to help you cut and pare the styrofoam to make two wings (**Teacher's Note**: the wings can be made by adults beforehand), each the same width as the originals but twice as long; 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 in presentation).
3. Fit the new wings on to the glider and launch it (throw 'javelin-style'), measure with 25m tape how far it glides, repeat 10 times and calculate the average distance that it 'flies'
4. Suspend the glider so that the belly just touches the ground (see below), 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
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 (see below), 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 (**Teacher's Note**: the wing extensions can be made by adults beforehand)
6. Repeat steps 3. & 4.
   - A variation of longer wider wings made of styrofoam only was instructive as it doesn't work – it tends to 'backflip' when launched
   - The prototype with longer wider wings, note how the glider is suspended as per 4. above

Students are then asked to record their qualitative and quantitative observations during the experiment with the toy gliders and to address questions about the scientific methods in the context of the 'flight' experiment.

7. What difference did you observe in the glider's flight path between the two modifications? (**Teacher's Note**: Ask your students to try explaining the difference using Bernoulli's Principle &/or Changing Forces on the glider).
8. Try making some tail modifications and test fly/glide again (repeat steps 3. & 4.)

| Wing Shape/Size | Distances 'Flown' | Wing Shape/Size | 'Distances Flown' |
|---|---|---|---|
| | | | |
| | | | |

- Describe differences in flight path and lift you observed between the wing shapes/sizes

Evaluate the Experiment (year 6 only):

- What was the experimental question asked?
- Identify the variables in the experiment.
- After completing the guided experiment, what can you predict about the effect of wing size on flight performance?
- Do you think the experiment was a fair test of the question? Why or why not?

Design and Plan another Investigation, using the wing shapes available and/or other wing designs (year 6 only):

- New Question
- Variables
- Method of Measurement
- Predicted Results

## Explaining Flight Using Science/Forces

This section uses scientific explanations (Bernoulli's Principle and Newton's Third Law of Motion) to provide a rationale for flight in gliders and birds (see presentation).

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.

Looking at flight from a physics point of view, there are four main forces. **Weight** is a force produced by gravity in the downward direction, and every flyer has to produce **lift** in order to counteract weight. Anything moving through air also experiences **drag**, which slows it down, so there 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).

## Bird Wing Shapes

During this activity, encourage students to describe accurately what they observe during the video footage about different types of birds that have differing body and wing proportions and that show different flight behaviours.

**Learning Outcome**: To accurately observe and describe wing shape and flight behaviour of some birds

- Watch David Attenborough's 'The Life of Birds', Episode 2 'The Mastery of Flight'
- Observe the different types of birds and their wing shapes. Try to describe each bird's body size and shape, such as long and thin, short and round, large and torpedo-shaped, jetfighter-shaped, etc. Try to describe the wing shape. Also note the way the feathers are shaped at the outer ends of the wings. For example, an albatross has very long

wings that are relatively narrow, many flight feathers that are also short relative to wing length, and the wing feathers are pointed at the outer end: therefore, their wings are 'very long, narrow and pointed'

- Try to describe the main flying behaviour(s), such as soaring, flapping, diving with wings partly folded, undulating or alternately flapping and gliding, high-speed flying, hovering, etc. How do birds use their body, wings and tail to adjust their flying speed and direction?
- Observe the 'flight environment' for each different bird. Is it windy? Hot or cold weather? Are there lots of obstacles in the way like trees? Do the birds appear to use updrafts and thermals?
- Tabulate your observations

**Activity** (Table 1 is completed for reference in Appendix)

| Species | Body size and shape | Wing shape | Outer wing feather arrangement | Observed flight environment | Observed flight pattern |
|---|---|---|---|---|---|
| Albatross | Large, torpedo-shaped | Long and narrow | Pointed | Very windy | Mostly soaring |
| … | … | … | … | … | … |

## Classifying Wing Shape and Predicting Flight Pattern

This section explains a bird's wing structure and its ability to bear its own body weight on its wings during sustained flight (see presentation). The aim is to encourage students to start thinking quantitatively about the effect of a bird's wing and body proportions on flight performance, and the implications of Bernoulli's Principle for birds.

It is adapted from David Hyrenbach's 'Wing Ecomorphology Lab', Seabird Ecology and Conservation course, Hawai'i Pacific University, accessed 7th August 2021, downloaded from https://www.pelagicos.net/classes_seabirds_fa18.htm

**Learning Outcome**: To classify wing shape descriptively and numerically

**Activity: Classify Wing Shapes and Predict Flight Patterns**

In this activity students are asked to record and interpret their qualitative observations during the collection of primary data during the video 'The Mastery of Flight' and their quantitative observations during the analysis of secondary data sourced from Higgins *et al*. (1990-2006) Handbook of Australian, New Zealand and Antarctic Birds.

**Instructions:**

- Watch the presentation about wing shape classification and measurement
- Add a column called 'Wing Shape Type' to Table 1 from the previous activity and classify the wing shape of each species according to the four wing shapes described in this activity
- Plot Wingspan (y-axis) against Wing Chord (x-axis) for the Australian bird species in Table 2 below (and worksheet) and label the points by their Avian Order (use codes below the table)
- Classify each species according to Wing Shape type and add to Table 2 (**Hint**: use reference images to assist in classifying)
- Interpret from the graphs the range of values of Wingspan and Wing Chord that characterise each wing shape type:
    - High Aspect Ratio
    - High Speed
    - Slotted High Lift
    - Elliptical
    - Do any species not fit into the four categories? How would you describe their wing shape?
- Predict the flight pattern of each species; to inform your answer, use the position of each species relative to other species on the graph:

- High Aspect Ratio
- High Speed
- Slotted High Lift
- Elliptical
- Do any species not fit into the four categories? How would you describe their flight pattern?

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**APPENDIX: Teacher's Notes**: Table 1 has been completed for reference

| **Species** | **Body size and shape** | **Wing shape description** | **Outer wing feather arrange-ment** | **Observed flight environment** | **Observed flight pattern** | **Wing Shape Type** |
|---|---|---|---|---|---|---|
| Albatross | Large, torpedo-shaped | Very long and narrow | Pointed | Very windy, launch by taxiing/ running, updrafts from waves/cliffs | Mostly soaring, some shallow flapping, controlled crash to land | High Aspect Ratio |
| Wedge-tailed Shearwater | Large, torpedo-shaped | Long and narrow | Pointed | Windy, launch from sloping tree | Mostly soaring, some shallow flapping | High Aspect Ratio |
| Domestic Pigeon | Medium and barrel-shaped | Medium length and width | Slightly slotted | Calm, launch by jumping and two very strong flaps | Fast flapping, some gliding | High Speed |
| Knot | Small to medium, bullet-shaped | Medium length and narrow | Pointed | Clam to windy | Fast shallow flapping, half folded upstroke | High Speed |
| Mallard (Duck) | Large, heavy and boat-shaped | Medium length and wide | Slightly slotted | Calm to windy | Fast shallow flapping ~70kph (40mph) | High Speed |
| Osprey | Long and medium build | Long and wide | Slotted | Calm | Slow strong flaps, carries fish straight | Slotted High Lift |
| Pelican | Very large and round | Very long and wide | Slotted | Calm to windy, uses thermals | Slow strong flaps, flying in formation, strong flaps to land | Slotted High Lift |
| Griffin Vulture | Long and medium build | Very long and wide, highly curved | Slotted | Use of thermals, spiralling updrafts | Soaring, tiny movements of wing feathers and tail, lands by swooping upwards and tilting back | Slotted High Lift |
| Mute Swan | Very large, heavy and round | Long and wide | Slotted | Landing only on water, calm | Strong flaps to land and feet out to brake | Slotted High Lift |
| Peregrine Falcon | Medium length and thin | Medium length, narrow and back swept | Pointed | Calm or some wind | Strong flaps after 'stooping' with half folded back swept wings for | High Speed |

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|---|---|---|---|---|---|---|
| | | | | | maximum speed when hunting | |
| Barn Owl | Medium length and medium build | Long, wide, curved | Rounded, fluffy margins | Calm | Strong, slow flaps and gliding when hunting | Rounded High Lift (silent) |
| Kestrel | Small and thin | Medium length and narrow | Pointed | Gentle wind | Hovering, sometimes shallow flapping when hunting | High Speed |
| Hummingbird | Very small and thin, hibernates every night | Short and narrow, symmetrical (not curved), create down draft, flap in any direction, steer with tail | Pointed | Mostly calm | Vertical posture, beating forwards and backwards in figure of 8 25+/sec, flicking wing over on back stroke, moves in any direction | High Speed |
| Western Sandpiper (migrating) | Small and bullet-shaped | Medium length and narrow | Pointed | Winds from north | Fly in formation during migration | High Speed |
| Hawks (migrating) | Medium length and build | Medium length and width | Slotted | Thermals over land | Soaring to great heights and gliding southwards repeatedly | Slotted High Lift |
| Snow Goose (migrating) | Long and very round | Long and wide | Slotted | Any | Strong shallow flapping, flying in formation | Slotted High Lift |
| Dicksissel (migrating) | Small and thin | Short and wide | Rounded | Any | Strong continuous flapping, flying in enormous flocks | Elliptical |

**Teacher's Notes**: Table 2 has been completed for reference

| Species | Code | Wingspan (S) cm | Wing Chord (C) cm | Wing Shape Type |
|---|---|---|---|---|
| Australasian Grebe | W | 39 | 7.67 | Moderate Aspect Ratio/Speed |
| Wandering Albatross | O | 350 | 23.66 | High Aspect Ratio |
| Little Pied Cormorant | W | 90 | 14.99 | Moderate Aspect Ratio/Speed |
| Great Frigatebird | O | 230 | 21.72 | High Aspect Ratio |
| Straw-necked Ibis | W | 120 | 14.50 | Moderate Aspect Ratio/Lift |
| Magpie Goose | LW | 180 | 29.95 | Moderate Aspect Ratio/Lift |
| Wandering Whistling-Duck | W | 90 | 15.96 | High Speed |
| Musk Duck | W | 87 | 14.41 | High Speed |
| Black Swan | LW | 200 | 30.30 | Moderate Aspect Ratio/Lift |
| Australian Shelduck | W | 132 | 19.57 | High Speed |
| Maned/Wood Duck | W | 80 | 15.48 | High Speed |
| Pacific Black Duck | W | 100 | 15.32 | High Speed |
| Hardhead | W | 70 | 12.89 | High Speed |
| Wedge-tailed Eagle | R | 230 | 41.41 | Slotted High Lift |
| Peregrine Falcon | AF | 105 | 15.42 | High Speed |
| Australian Brush-Turkey | G | 85 | 26.39 | Elliptical |
| Painted Button-Quail | G | 38 | 7.33 | High Speed |
| Purple Swamphen | W | 88 | 20.53 | High Speed |
| Eurasian Coot | W | 64 | 11.65 | High Speed |
| Pacific Golden Plover | S | 72 | 7.32 | High Speed |
| Bar-tailed Godwit | S | 75 | 10.56 | High Speed |
| Little Tern | S | 55 | 7.95 | High Speed |
| Wompoo Fruit-Dove | PD | 70 | 17.12 | Elliptical |
| White-headed Pigeon | PD | 70 | 17.28 | Elliptical |
| Diamond Dove | PD | 32 | 7.09 | Elliptical |
| Sulphur-crested Cockatoo | P | 103 | 28.99 | Elliptical |
| Rainbow Lorikeet | P | 46 | 8.45 | High Speed |
| Budgerigar | P | 30 | 5.02 | High Speed |
| Fan-tailed Cuckoo | C | 42 | 8.58 | Elliptical |
| Channel-billed Cuckoo | C | 107 | 20.20 | Elliptical |
| Powerful Owl | R | 140 | 29.69 | High Lift/ Elliptical |
| Barn Owl | R | 100 | 17.35 | High Lift/ Elliptical |
| Tawny Frogmouth | N | 95 | 20.96 | Elliptical |
| Australian Owlet-Nightjar | N | 50 | 9.35 | Elliptical |
| White-throated Needletail | AF | 49 | 6.03 | High Speed |
| Sacred Kingfisher | KR | 37 | 7.24 | Elliptical |
| Dollarbird | KR | 65 | 12.61 | Elliptical |
| Superb Lyrebird | E | 76 | 29.90 | Elliptical |
| Southern Emu-wren | E | 19 | 4.78 | Elliptical |
| Yellow-faced Honeyeater | E | 26 | 7.49 | Elliptical |
| Brown Thornbill | E | 16 | 4.87 | Elliptical |
| Grey-crowned Babbler | E | 35 | 10.86 | Elliptical |
| Golden Whistler | E | 30 | 8.22 | Elliptical |

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|---|---|---|---|---|
| Grey Fantail | E | 22.5 | 6.61 | Elliptical |
| Australian Magpie | E | 85 | 18.69 | Elliptical |
| Zebra Finch | E | 17 | 4.65 | Elliptical |
| Welcome Swallow | AF | 31 | 5.79 | High Speed |

W=waterbird, LW=large waterbird, O=ocean-going, R=raptor, AF=aerial forager, G=ground, S=shorebird, PD=pigeon/dove, P=parrot, C=cuckoo, N=nightjar, KR=kingfisher/roller, E=perching bird

**Teacher's Notes:** Graph of Wingspan vs Wing Chord for reference (can be enlarged).