Understanding Flight in Birds

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Hunter Bird Observers Club

'Flight' Experiment

Learning Outcomes:

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

Instructions: you will use a toy glider as a simple 'bird'. Firstly, observe the shape of the glider's wings. After assembling it, '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.

Materials required:

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 (kitchen) 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

Method:

1. Assemble the glider (follow the instructions on the box)
2. Cut and pare the styrofoam to make two wings (the wings can be made 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 on powerpoint presentation).
3. Fit the new wings on to the glider and launch it (using catapult or 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, 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, 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 (the wing extensions can be made by adults beforehand)
6. Repeat steps 3. & 4.
7. What difference did you observe in the glider's flight path between the two modifications?
8. Try making some tail modifications and test fly/glide again (repeat steps 3. & 4.)

Results:

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:

What was the experimental question asked? Can you formulate the hypothesis that was tested?

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 valid and reliable test of the question/hypothesis? Why or why not?

Design and Plan another Investigation, using the wing shapes available and/or other wing designs:

Pose further questions that can be investigated

Discuss the role of the variables used and other possible variables (those that were controlled but can be varied)

Determine the independent and dependent variables

Formulate a hypothesis that links the independent and dependent variables

Describe at least three variables that should be controlled in order to increase the validity of the investigation

Develop a method to collect primary data for a practical investigation about the effect of wing shape on flight performance by:

Describe how to change the independent variable

Determine the characteristics of the measurements that will form the dependent variable

Describe how the data will be collected

Describe how the controlled variables will be made consistent

Describing how risks can be minimised

Evaluate how observation is limited by the observational tools available (in the first practical investigation: tape measure vs description from observation, and in your planned investigation)

Bird Wing Shapes and Bernoulli's Principle

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

Instructions:

- 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'.
- Describe the main flying behaviour(s), such as soaring, flapping, diving with wings partly folded, undulating or alternately flapping and gliding, high-speed flying or soaring, 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 primary data about Birds' Wing Shapes collected from video footage (Table 1 below)

Species	**Body size and shape**	**Wing shape**	**Outer wing feather arrangement**	**Observed flight environment**	**Observed flight pattern**
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

Maths Activity: Classifying bird wing shapes and flight behaviours using Aspect Ratio, Wing Loading and Cruising Speed

Learning Outcomes:

- to use observations as evidence in explaining differences in wing shape and flight performance between birds
- to describe wing shape and flight performance quantitatively, calculating 'Aspect Ratio', 'Wing Loading', and 'Cruising Speed', aerodynamic variables that measure a bird's wing structure, a bird's ability to bear its own body weight on its wings during sustained flight and the minimum cruising speed of flight required to maintain lift

Instructions:

- Watch the presentation about wing shape measurement and classification

Inquiry question: How does observation instigate scientific investigation?

- Discuss and evaluate the characteristics of observations made about birds compared to inferences drawn from the practical investigation with toy gliders

Inquiry question: What are the benefits and drawbacks of qualitative and quantitative observations?

- Analyse the quantitative data from the following information sources: primary data collected during a guided 'flight' experiment and secondary data about wing shape and wing loading

- Evaluate the differences between qualitative and quantitative observations and data and where these are used in making inferences about flight patterns in birds

Inquiry question: How does the collection and presentation of primary data affect the outcome of a scientific investigation?

- Apply conventions for collecting and recording observations to qualitatively and quantitatively analyse the primary (and secondary) data **[use Microsoft Excel to assist with calculations and graphs]**
    - tabulating **secondary data** and calculating Aspect Ratio, Wing Loading (in Newtons per m^2 not grams per cm^2) and Cruising Speed for the Australian species listed (Table 2 below)
    - graphing **secondary data** in Maths Activity: Classifying Wing Shape [Norberg 2002] and Predicting Flight Pattern [Tennekes 2009]
        a. Plot Aspect Ratio (y-axis) against Wing Loading (x-axis) and label the points by their Avian Order (use codes below table)
        b. Plot Weight (y-axis) against Cruising Speed (x-axis) and label by Avian Order (use codes below table)
        c. Compare your graphs with Norberg's (2002) and Tennekes' (2009) results
    - Classifying each species according to Wing Shape type and add to the Table 2 (**Hint**: use reference images to assist in classifying)

- Interpret from the graphs the range of values of Aspect Ratio, Wing Loading and minimum Cruising Speed that characterise each wing shape type. Explain the flight performance capable of each wing shape type using Benoulli's Principle; to inform your answer, use the results of your calculations and the position of each species relative to other species on the graphs of Aspect Ratio vs Wing Loading and Weight vs Cruising Speed:

  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 and flight performance?

  Optional:

  - visual representations that use a toy glider as a model of a bird
  - digital representations using bird flight simulators (see Extension Activities)

- Compare the usefulness of observations recorded in the initial practical activity with the primary data gathered in the planned practical investigation

Inquiry question: How do conclusions drawn from the interpretation of primary data promote further scientific investigation during the planned experiment?

- draw conclusions from the analysis of the primary data collected in the practical investigation
- evaluate the process of drawing conclusions from the primary data collected
- assess the findings of the scientific investigation in relation to the findings of other related investigations
- assess the need to make further observations by gathering data about other phenomena arising from the practical investigation

Table 2. Australian Bird Species' body and wing measurements for calculation of values of aerodynamic variables, plotting and interpretation of graphs. Use Microsoft Excel to calculate values and plot graphs (secondary data from Higgins *et al*. 1990-2006).

Order	Species	Body Length cm	Wingspan (S) cm	Wing Chord (C) cm	Aspect Ratio (R=S/C)	Body Mass (m) kg	Body Weight (W) N [W=ma, a=9.8]	Wing Area (A=S*C) m^2	Wing Loading (L=W/A) N m^{-2}	Cruising Speed (V) m s^{-1}	Wing Shape Type
Podicipediformes (W)	Australasian Grebe	23-25	39	7.67		0.096-0.22					
Procellariformes (O)	Wandering Albatross	110-135	250-350	23.66		6-11					
Pelicaniformes (W)	Little Pied Cormorant	55-65	85-90	14.99		0.41-0.9					
(O)	Great Frigatebird	85-105	205-230	21.72		0.95-1.95					
Ciconiiformes (W)	Straw-necked Ibis	60-70 (35-40)	100-120	14.50		1.15-1.57					
Anseriformes (LW)	Magpie Goose	70-90	125-180	29.95		2.07-2.83					
(W)	Wandering Whistling-Duck	55-60	80-90	15.96		0.45-0.98					
(W)	Musk Duck	55-66	72-87	14.41		0.99-3.12					
(LW)	Black Swan	110-140 (55-70)	160-200	30.30		4.6-8.7					
(W)	Australian Shelduck	56-72	94-132	19.57		0.99-1.98					
(W)	Maned/Wood Duck	47-48	78-80	15.48		0.66-0.98					
(W)	Pacific Black Duck	47-60 (32-40)	80-100	15.32		0.6-1.4					
(W)	Hardhead	45-60 (30-40)	65-70	12.89		0.53-1.1					
Falconiformes (R)	Wedge-tailed Eagle	85-105	185-230	41.41		2.03-5.3					
(HS)	Peregrine Falcon	35-50	80-105	15.42		0.36-0.99					
Galliformes (G)	Australian Brush-Turkey	60-70	85	26.39		1.07-2.45					
Turniciformes (G)	Painted Button-Quail	17-23	28-38	7.33		0.072-0.134					

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Gruiformes (W)	Purple Swamphen	44-48	70-88	20.53		0.77-1.25					
(W)	Eurasian Coot	35-39	56-64	11.65		0.52-0.57					
Charadriiformes (S)	Pacific Golden Plover	23-26	60-72	7.32		0.11-0.18					
(S)	Bar-tailed Godwit	37-39, Bill 8-10.8	62-75	10.56		0.237-0.504					
(S)	Little Tern	20-28	45-55	7.95		0.035-0.06					
Columbiformes (PD)	Wompoo Fruit-Dove	35-45	~65-70	17.12		0.22-0.5					
(PD)	White-headed Pigeon	38-42	65-70	17.28		0.22-0.5					
(PD)	Diamond Dove	20-24	30-32	7.09		0.036-0.066					
Psittaciformes (P)	Sulphur-crested Cockatoo	48-55	103	28.99		0.5-1.02					
(P)	Rainbow Lorikeet	28-32	46	8.45		0.075-0.157					
(P)	Budgerigar	17-18	25-30	5.02		0.012-0.04					
Cuculiformes (C)	Fan-tailed Cuckoo	24-28	34-42	8.58		0.037-0.062					
(C)	Channel-billed Cuckoo	56-70	88-107	20.20		0.45-0.94					
Strigiformes (R)	Powerful Owl	50-60	110-140	29.69		0.99-2.22					
(R)	Barn Owl	29-38	70-100	17.35		0.25-0.47					
Caprimulgiformes (N)	Tawny Frogmouth	35-50	75-95	20.96		0.123-0.555					
(N)	Australian Owlet-Nightjar	19-25	34-50	9.35		0.035-0.065					

Order	Species	Body Length cm	Wingspan (S) cm	Wing Chord (C) cm	Aspect Ratio (R=S/C)	**Body Mass (m) g (convert to kg)**	Body Weight (W) N [W=ma, a=9.8]	Wing Area (A=S*C) m2	Wing Loading (L=W/A)	Cruising Speed (V) m s^{-1}	Wing Shape Type
Apodiformes (HS)	White-throated Needletail	20-22	49	6.03		47-120					
Coraciiformes (KR)	Sacred Kingfisher	21-23	33-37	7.24		28-75					
(KR)	Dollarbird	26-29	55-65	12.61		51-180					
Passeriformes (E)	Superb Lyrebird	78-103, Tail 25-71	68-76	29.90		721-1200					
(E)	Southern Emu-wren	13.5-19	9-19	4.78		5-9					
(E)	Yellow-faced Honeyeater	15-17.5	21.5-26	7.49		12-20.5					
(E)	Brown Thornbill	9-11.5	12.5-16	4.87		5-12					
(E)	Grey-crowned Babbler	23-26.5	35	10.86		52-88					
(E)	Golden Whistler	16-19	25-30	8.22		15-37					
(E)	Grey Fantail	14-16.5	18-22.5	6.61		5.7-11.8					
(E)	Australian Magpie	37-43	65-85	18.69		190-410					
(E)	Zebra Finch	9-11.5	12.5-17	4.65		9.4-16.2					
(HS)	Welcome Swallow	14-16	26-31	5.79		9-20					

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