Looking Towards the Sky to Inspire Aviation Innovation

Michelle Rearick
Miami University
Ohio, USA

Abstract

While the strategies and mechanisms for flight are similar, flight has evolved independently in birds, mammals, insects, reptiles, and plants. Historically, man has found inspiration from these flying organisms, especially birds, and as a result we have been able to create our own flying machines. Biomimicry is innovation inspired by nature, and man-made flight embodies this modern field of science. From creating a helicopter by watching the hovering capabilities of a hummingbird, to developing a search and rescue drone inspired by the mosquito, the inspiration in nature and applications for human use are bountiful and are just beginning to evolve themselves. The purpose of this project is to develop a lesson plan linking aviation innovation and the field of biomimicry. The lesson will be incorporated into a local summer camp, ‘Flying Aces’, which introduces 10-13 year-old students to the principles of flight as well as the history of man-powered flight in Dayton, OH. The lesson consists of interactive discussions and games that strive to create a positive learning experience in an informal setting. While the majority of the lesson will be completed in two days, a design challenge in which students get to call on nature to design their own flying machine will span the length of the camp.

Keywords: Biomimicry, flight, design challenge

Looking Towards the Sky to Inspire Aviation Innovation

The human aspiration to fly began as a deep desire to conquer the sky. Legends, myths and pictures of flying people are prominent throughout history with the earliest depiction of human flight, the shepherd Etana riding an eagle, dating between 2350 and 2150 BC (Foster, 2012). The story of Daedalus and Icarus is one of the most popular Greek myths in which Daedalus crafted a pair of wings for himself and his son in order to escape King Minos' labyrinth (Greek Myths & Greek Mythology, 2016). Historically, humans attributed the ability to fly to deities, mythical figures and demons; perhaps these attributions expressed the dreams and wishes of the human urge to fly themselves.

It is not a surprise that early attempts to fly started with what humans obviously lack: wings. We thought that with wings it should be possible to gain the same supremacy in the air as birds and insects. Leonardo Da Vinci, perhaps one of the most recognizable scientists and artists in our history, made numerous sketches in his notebooks for flying inventions which consisted of flapping mechanisms to provide lift (Gray, 2003). While it isn't known if attempts to build, let alone fly, these machines were made, the ideas Da Vinci presented on flight helped pave the way for future scientists and engineers in the next four decades. It wasn't until 1903, when Orville Wright became the first man to successfully achieve flight with the Wright Flyer in Kittyhawk, North Carolina.

Da Vinci and the Wright Brothers were both known to take inspiration from birds and other flying animals, like bats, when sketching their ideas for human flight. Pioneers of a field of science before it even existed, biomimicry is innovation inspired by nature, or the copying of successful strategies employed by nature to solve our own problems (Benyus, 1997). The history of man-powered flight and biomimicry go hand-in-hand.

Natural flight, including gliding and parachuting, evolved independently in many lineages of organisms from insects, dinosaurs, birds, reptiles and mammals to plant seeds. This type of movement provided an energy efficient means to explore new habitats and resources, thus driving the evolution of a plethora of wing structures. Scientists debate whether flight initially began from the ground up, or from the canopy down; regardless, it began with a leap in the air during which aerodynamic force first became a strong selective force on the evolution of organismal body plans (Lentink & Biewener, 2010).

Just over 100 years old, human-designed aircraft have barely taken off on an evolutionary timescale. Even after conquering different types of man-powered flight, biomimicry continues to fuel the research being done to advance aircraft technology. Having solved problems in speed, stealth, and efficiency, humans are most recently using biomimicry in aviation research in the form of unmanned air vehicles (Grose, 2013; Lentink & Biewener, 2010; Thompson, 2015).

Developing Positive Attitudes Towards Science Through Informal Education

Often negative opinions or attitudes of science are a result of experiences from a young age (Rogers & Ford, 1997). Many young people have developed stereotypes of science and scientists; often when asked to draw what a scientist looks like, a student will depict a white male with unruly hair wearing a lab coat and holding a test tube (Settlage & Southerland, 2007). Negative terms like "nerd" or "mad scientist" are common descriptive words for scientists; most people, however, cannot name a modern-day scientist because they do not fit the stereotype that is so commonly imagined (Highfield, 2011; Mooney & Kirshenbaum, 2009). It has been suggested that such negative attitudes develop from poor experience(s) with an instructor or within a course, lack of motivation, perception for a lack of needed scientific reasoning skills, home backgrounds, and biases of peer groups to name a few (Rogers & Ford, 1997).

Developing positive attitudes towards science is a critical part of science learning. Student’s attitudes are linked to their achievement in science and their motivation to persist in science courses in high school and beyond. For girls, the goal of fostering positive attitudes towards science is of particular importance. Girls’ overall attitudes towards science are often less positive than boys’ and decline significantly with age. Also, studies have found that even when girls enjoy and excel in science, they perceive their level of competence in the subject to be lower or less than that of their male classmates (Brotman & Moore, 2008).

Informal learning emphasizes the central role that experience plays in the learning processes instead of acquisition, manipulation, or the recall of abstract symbols as in other learning styles (Kolb, 1984). It is a holistic approach to learning that combines experience, perception, cognition, and behavior (Kolb & Kolb, 2005; Kolb 1984). Several models of the learning process have been suggested. While slightly different from each other, they have common perspectives on learning which can be summarized into six propositions:

- Learning is best conceived as a process, not in terms of outcomes
- Learning is a continuous process grounded in experience

- The process of learning requires the resolution of conflicts between dialectically opposed modes of adaptation to the world
- Learning is a holistic process of adaptation to the world
- Learning involves transactions between the person and the environment
- Learning is the process of creating knowledge

(Kolb and Kolb, 2005; Kolb 1984)

Experiential learning has great potential for a positive and lasting learning experience. Biomimicry is a great topic to introduce in an informal setting because it allows students to explore their own interests and make deeper connections with the world around them while drawing on nature for inspiration to solve problems. It is an open-ended field, and allows students to think creatively and explore their own ideas without feeling restricted. Simply stated, biomimicry is fun and engaging, and learning about nature in the context of this field is interesting for students.

Developing a Lesson Plan focusing on Biomimicry and Aviation Innovation

Dayton, Ohio has a rich history in aviation innovation. Home to Orville and Wilbur Wright, Huffman Prairie Flying Field, where they tested their aircraft after the historic first flight in Kittyhawk, North Carolina, as well as the modern day Air Force Museum, Dayton is a destination for people of all ages wanting to learn more about flight. One such way to do so is by enrolling in ‘Flying Aces’, a week-long summer camp on flight put on by the City of Kettering’s Parks Department. The purpose of this project is to create a lesson plan for ‘Flying Aces’ to demonstrate how man has been inspired by nature’s flying organisms and ways that this inspiration has been incorporated into past and present aircraft design. This lesson will be appropriate for students ages 10-13 and will be incorporated into the previously established curriculum taught at the summer camp. The lesson consists of interactive discussions and games that strive to create a positive learning experience in an informal setting. While the majority of the lesson will be completed in two days, a design challenge in which students get to call on nature to design their own flying machine will span the length of the camp (Appendix A).

Conclusion

Nature has been evolving independently for 3.8 billion years and holds great potential for humans to learn from her. While some of these lessons will be used for our gain as a species, what is important is our ability to live life sustainably and *with* nature. Biomimicry holds great potential to bring together individuals with diverse technical backgrounds as well as to help connect the public to science in engaging ways. Flight is a natural bridge between the interests of the public and biomimicry. It is the hope of this researcher that a student who experiences this lesson on biomimicry and aviation innovation will have a lasting positive experience that will help fuel a life-long interest in science and a respect for nature.

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Appendix A

Lesson Plan: Looking Towards the Sky to Inspire Aviation Innovation

Instructor: Michelle Rearick

Program: Flying Aces Summer Camp (Age 10-13)

Instructor Input: 2, 75 minute learning blocks and additional time throughout the week for students to complete independent design challenge. Design challenges will be shared at the end of the week, with presentations taking approximately 30 minutes, depending on the number of students.

Previous lessons: Lesson will be broken in to two teaching sessions within the week-long summer camp. They should be incorporated early in the week, ideally days one and two, but should occur after students have had a thorough introduction to the principles of flight as well as the history of man-powered flight.

Objectives:

The student will:

- Successfully define biomimicry
- Explain in a simple and general way how difference in wing size and shape affect the capabilities such as speed, gliding, and maneuverability of a bird or plane
- Cite examples of animals that have inspired specific man-powered aircrafts
- Explain the different flight strategies between birds, insects, and mammals
- Design their own aircraft taking inspiration from a flying organism

Assessment: Students will share their projects with their peers both verbally and visually.

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Web Resources for Teachers

Flight of Birds / Biomimicry Applications
http://www.birds.cornell.edu/physics/lessons/elementary/flight
https://web.stanford.edu/group/stanfordbirds/text/essays/Wing_Shapes.html
https://web.stanford.edu/group/stanfordbirds/text/essays/Soaring.html
www.sciencedaily.com/releases/2007/04/070427113243.htm
www.sciencedaily.com/releases/2005/08/050824080722.htm
http://sciencelearn.org.nz/Contexts/Flight/Science-Ideas-and-Concepts/How-birds-fly

Flight of Insects / Biomimicry Applications
http://www.asknature.org/strategy/3a00f0a263e4abce2a4ae6077581389e
http://www.asknature.org/strategy/1b8448f36e9a978dcf79d1dd82e72ab2

http://teacher.scholastic.com/activities/explorations/bug/libraryarticle.asp?ItemID=115&SubjectID=134&categoryID=4

Flight of Mammals
Bats
http://www.livescience.com/1245-bats-efficient-flyers-birds.html
http://www.ucmp.berkeley.edu/vertebrates/flight/bats.html
http://www.earthlife.net/mammals/bat-flight.html
https://www.theengineer.co.uk/bat-wing-membranes-inspire-development-of-micro-air-vehicles/
http://www.slashgear.com/new-mav-membrane-wings-use-electricity-to-change-shape-19427983/

Flying Squirrels (Gliding)
http://www.smithsonianmag.com/science-nature/how-squirrels-fly-37372905/?no-ist
http://www.asknature.org/strategy/5dae2ebfc4aec31c05a8cbafb86dc5ee
http://www.asknature.org/strategy/1714ef0a2a5940d371f856086a7f06dd
http://hubpages.com/sports/wing-suit

Flight of Plants
http://www.asknature.org/product/5bbcfdce044e828d8d15101bbd46daf6
http://www.asknature.org/strategy/afae7a7ebdb3191e376cd230463a6705
http://theseedsite.co.uk/sdwind.html
http://www.popsci.com/military-aviation-amp-space/article/2009-06/inspired-spinning-maple-seeds-tested-robofly

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Session 1: Day 1, Afternoon block 2, 2:45-4PM (75 minutes)—"Flight of Birds"

Materials: White board and dry erase marker, computer / projector, "Animal Flight Matching Game" (Appendix B), "Wings of Flight" matching game (Appendix C), student notebooks, writing utensils and colored pencils.

1. Begin the lesson by brainstorming different animals that fly. Use the white board to write down their examples. Encourage the students to be specific (citing specific birds for example instead of "bird"). Ask if the students can describe the animal's flight behavior? Encourage terms like "flapping", "gliding", "soaring", "diving" etc.

2. Next, have the students brainstorm different man-made machines capable of flying. Again, ask for specific examples, instead of "airplane". Remind students of different types of flight and to recall different flying machines mentioned in the "History of Flight" lesson ("balloon", "glider", "kite", etc.). Can they cite specific examples of flight behavior? For example, a helicopter can hover.

3. Look at both lists and compare. Are there birds and airplanes that have been described with similar words?

4. The earliest man-made flying machines were inspired by watching birds fly in the sky. Leonard Da Vinci and the Wright Brothers were both known to take inspiration for their inventions by watching the flight of birds.

    - **Biomimicry** is defined as innovation inspired by nature.
    - Humans have looked for ways to emulate the success of birds and other flying animals. By copying designs and manufacturing processes used in nature, we too have been able to take to the sky.

5. Show “The Mastery of Flight”, a BBC documentary on the flight of birds.

    https://www.youtube.com/watch?v=JUIdarVPpsQ

    Clips: TBD

6. Discuss the physical adaptations mentioned in the movie which allow birds to fly. Ask for student participation.

    - Lightweight, smooth feathers to reduce the forces of weight and drag
    - A beak, instead of heavy, bony jaws and teeth to reduce the force of weight
    - An enlarged breastbone called a sternum for flight muscle attachment
    - Birds’ bones are basically hollow with air sacs and thin cross pieces to make bones stronger. While hollow, the rigid skeleton provides firm attachments for powerful muscles.
    - A streamlined body helps reduce the force of drag
    - Wings enable the force of lift.

7. Explore bird wings in greater detail. Introduce students to wing loading, and wing aspect ratio.

    The shape of a bird’s wing is important for producing lift. The increased speed over a curved, larger wing area creates a longer path of air. This means the air is moving more quickly over the top surface of the wing, reducing air pressure on the top of the wing and creating lift. Also, the angle of the wing (tilted) deflects air downwards, causing a reaction force in the opposite direction and creating lift.

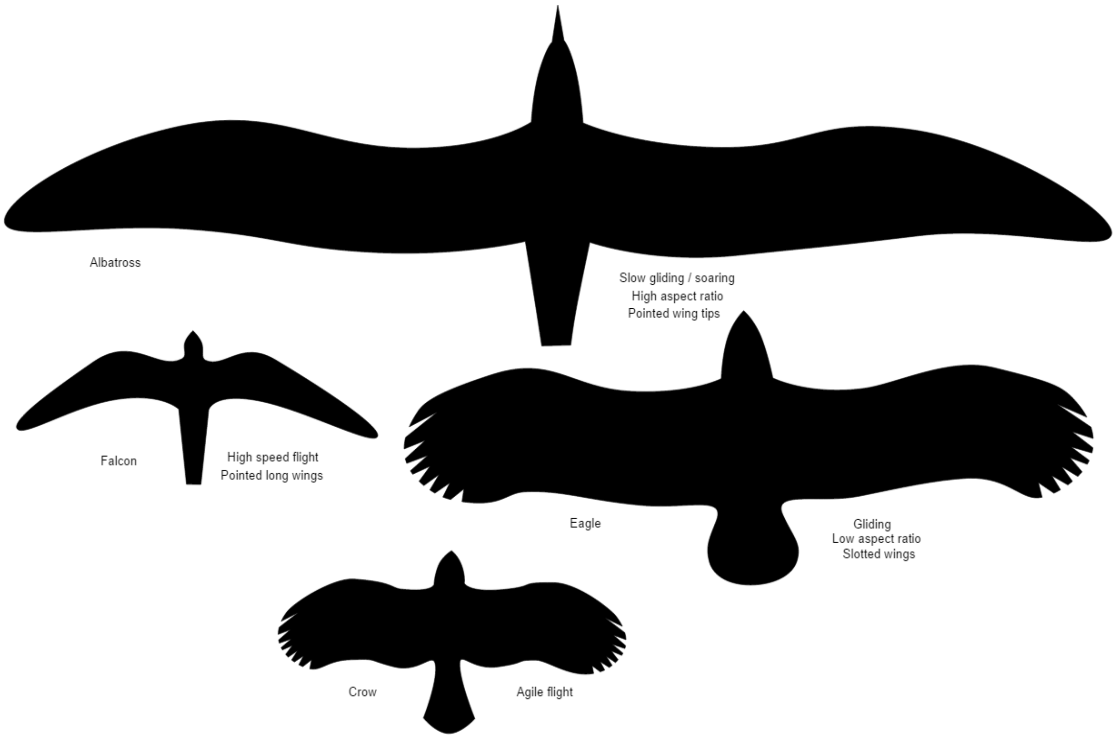
    Larger wings produce greater lift than smaller wings. So smaller-winged birds (and planes) need to fly faster to maintain the same lift as those with larger wings.

    Wing loading tells you how fast a bird or plane must fly to be able to maintain lift: wing loading = weight/wing area (kilograms per square meter).

    A smaller wing loading number means the bird/plane can fly more slowly while still maintaining lift and is more maneuverable.

    The wing shape can also be described in terms of the **wing aspect ratio**. A high aspect ratio indicates long, narrow wings. A low aspect ratio indicates short, wide wings. Generally, high aspect ratio provides slightly more lift and enables sustained endurance flight. A low aspect ratio is better for swift maneuverability.

8. Discuss the four common types of bird wings and think about how different wing shapes help these animals fly. Have students work in small groups to complete "Animal Flight Matching Game" (McArthur, 2015)(Appendix B).



Wing Shape	***Kind of Flight***	***Examples***
Very long, narrow	Gliding for long distances using air currents for lift	Albatrosses, gulls, gannets
Broad, slotted feathers	Soaring, climbing upward currents of air	Eagles, hawks, herons, storks
Short, round (elliptical)	Short bursts of speed; good for the forest	Crows, robins, blackbirds, sparrows; also bats
Long, thin	High-speed, long distance	Swifts, ducks, falcons, terns, and sandpipers

- Short videos of different types of flight can be shared:

  http://www.birds.cornell.edu/physics/lessons/elementary/flight

9. Distribute "Wings of Flight" cards (Appendix C), one per student. Instruct them to walk around and find the match to their card, matching the bird and flying machine with similar flight behaviors. More than one set can be distributed if necessary. Upon completion, check results and discuss findings.

10. Before finishing for the day, have students reflect on what they learned in their student notebooks. Have them write or draw pictures of what they found interesting and what they are still curious about.

Session 2: Day 2, Morning block 1, 9:15-10:30AM (75 minutes)—"Flight of Insects and Mammals"

Materials: White board and dry erase marker, computer / projector, insect collection, hand lenses, "I Can Fly" Activity Sheet (Appendix D), toilet paper tubes, tape, student notebooks, writing utensils, white paper, art supplies

1. Begin the lesson by reviewing how birds fly. Brainstorm what other animals are capable of flight. Ask the students if they recognize similarities in the flight of birds and these other animals. What about differences?

2. Investigate the flight of insects in more detail.

    - Pass around insect collection specimens and hand-lenses for students to observe. Do all insects have the same shape or number of wings? Flight in insects is approximately 350 million years old and many species have independently evolved different flying strategies (Ellington, 1999).

    - Have students hypothesize how insects move their wings. Insect wings do not contain muscles. Most insect wings are made of very thin membranes, thinner than tissue paper. The insect's midsection, the thorax, is where the muscles used to move the wings for flight are located. These muscles contract and relax, causing the thorax to change shape as it produces each wing movement. Students can demonstrate this by creating their own insect fliers (Appendix D).

    - To support their body weight, an insect must produce 2-3 times more lift than can be accounted for by conventional aerodynamics (like birds use)(Ellington, 1999).

    - Insects create a vortices by flapping their wings and creating air pressure which travels to the leading edge of the wing. This allows the insect to hover and maneuver (Sane, 2013; Wootton, 1992).

    - Biomimicry Applications: Insects are inspiring advances in modern man-made flight, especially as it relates to un-manned air vehicles (UAV) and micro-air vehicles (MAV). They are showing particular promise as it relates to military reconnaissance and search and rescue.

        i. This brief video introduces the concept:

https://www.youtube.com/watch?v=XyCIqo4ij7Q

ii. Visual aids for several biomimetic devices (Rojratsirikul, n.d.)

iii. Mosquito Drone: (Grose, 2013): This brief article details a new drone that mimics the flight capabilities of mosquitos. Mosquitos fly somewhat carelessly and often collide with other objects mid-flight. Researchers modeled this by encasing a drone in a cage of sorts, which protects the drone in the event of collision. This has applications in search and rescue.

iv. Dragonfly biomimicry: Dragonflies are impressive fliers, capable of moving in all directions as well as hovering. Researchers are looking at Dragonfly wings to produce materials that are lightweight and flexible which could lend to lower energy flight machines. (Asknature.org)

3. Investigate the flight of mammals in more detail.

- Bats

i. Their motions might seem erratic and graceless, but bats are more efficient flyers than birds because they generate more lift while using less energy.

ii. Unlike insects and birds, which have relatively rigid wings that can move in only a few directions, a bat's wing contains more than two dozen joints that are overlaid by a thin elastic membrane that can stretch to catch air and generate lift in many different ways. This gives bats an extraordinary amount of control over the three-dimensional shape their wings take during flight. Insects can move the joint at the insect equivalent of a shoulder, but that's the only place where they can exert force and control movement. Birds have many more joints in their wings, but it's nothing compared to bats.

iii. During the down stroke, the air vortex—which generates much of the lift in flapping-wing flight—closely tracks the animals' wingtips. But in the upstroke, the vortex appears to come from another location entirely, perhaps the wrist joint. The researchers think this unusual pattern helps to make bat flight more efficient and credit it to the tremendous flexibility and articulation of the wing.

iv. Bats use muscles to stiffen and relax their wings as needed. The shape of the wing can be changed in response to changing wind conditions. This is attractive in terms of biomimetics because membranes have no mechanical parts, and alter their shape in response to the forces acting upon them, making them more efficient and easier to maintain than traditional rigid wings.

v. Biomimicry Applications: Bats are inspiring UAVs and MAVs with flexible membranes which mimic bat wings.

1. In Ground UAV video:

   https://www.youtube.com/watch?v=B0nER8iOqAI

2. Membrane Wing MAVs: Preliminary studies show steeper lift slopes and higher power efficiency compared to rigid-wing counterparts. Also shown to improve stability (Rojratsirikul, n.d.).

- Flying Squirrel

  i. These mammals cannot actually fly. They develop no thrust. They're arboreal, and they use their gliding skills for sailing from tree to tree.

  ii. The squirrels have floppy skin attached to their wrists and ankles, which they can stretch out to produce lift, thus enabling the squirrels to glide. The animals also appear to be able to control their gliding through rapid movements while in the air. Squirrels also have a little flap on their patagium, a sort of winglet which curls upward, like the tips on many aircraft wings. It is likely that the winglet increases flight efficiency and helps stabilize the glide.

  iii. Glides vary by species, but can range from 160 ft. to 500 ft.

  iv. Biomimicry Applications:

     1. Aerial photography applications: Looking at how flying squirrels control flight or reduce drag on small objects which can be applied to small flying drones

     2. Wing Suit: The wing suit mimics the squirrel's action by having nylon, and stretchy fabric from your wrist to your feet, making it easier for a skydiver to maneuver than a regular parachute. Suits are also being utilized for BASE jumping.

4. Investigate flight of plants in more detail.

- Some tall trees produce seeds with stiff wings covering the seed that enable them to fly long distances. The wings are twisted and balanced so that the seed spins around as it is carried along by the wind. These natural adaptations for using the wind to transport the weight of the seed must be technically accurate. This system only works well in a good wind, and from a tall tree.

- A leading edge vortex (LEV) is created when the seed falls. This vortex reduces pressure above the wing's surface. The low pressure virtually sucks the wing up, doubling the lift it would normally achieve. Vortices also slow the fall of the seed which allows for greater dispersal from the parent tree.

- Applications in Biomimicry: Applications in UAV and MAV development, as well as fan blades and wind energy blades.

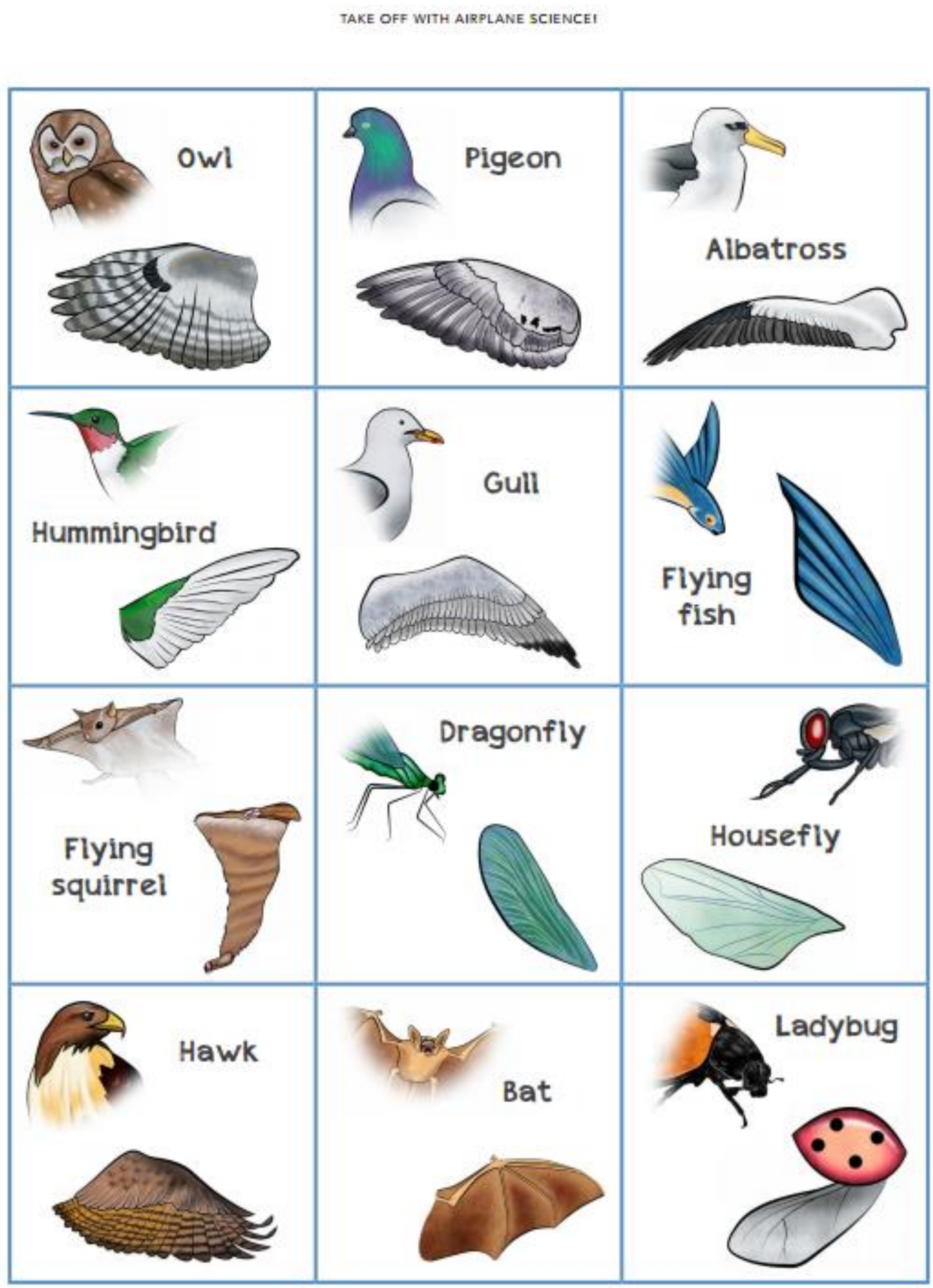
i. The monocopter: “If you want to design very effective, efficient micro- or nano-scale air vehicles, it is better to aspire to the vortex created by the maple seed than the vortex created by an insect”, (David Lentink) Existing functions include aerial surveillance or remote sensing. These are typically done with expensive aircraft, or professional pilots. As a micro-copter the change in platform and cost allows significant savings of energy and materials for similar performance. It reduces the need for professional training, and removes heavy and costly equipment

5. Introduce students to the Flight Design Challenge

- Have students think back to the flying organisms that have been reviewed in the last two days. Is there something unique that they found inspiring? To complete this challenge, students should think of a flying organisms and think of one (or more) characteristic(s) about its flight behavior, body structure, or processes. Then, the students will incorporate these traits in to a man-made aircraft. Projects can be researched, if necessary, throughout the remainder of the week during lunch with the help of an adult. Students should be encouraged to be as creative as possible. A visual should be made and can include a drawing or model of the aircraft. Brief presentations are to be completed by Friday morning, with each student verbally sharing the inspiration from their model organism and their visual.

Appendix B

Animal Flight Matching Game (McArthur, 2015)



1 **Wings:** broad **Flight:** silent, swooping **Habitat:** forest, fields **Food:** small animals	2 **Wings:** short, round **Flight:** fast, short-distance **Habitat:** city, urban **Food:** seeds, bugs	3 **Wings:** long, narrow **Flight:** gliding **Habitat:** open ocean **Food:** fish
4 **Wings:** broad **Flight:** soaring **Habitat:** open fields **Food:** small animals	5 **Wings:** narrow **Flight:** hovering **Habitat:** where there are flowers (but only in the Americas!) **Food:** flower nectar	6 **Wings:** narrow, thin **Flight:** gliding **Habitat:** shoreline **Food:** fish, shellfish, bugs
7 **Wings:** fins (not true wings) **Flight:** gliding (not true flying) **Habitat:** ocean **Food:** small fish, plankton	8 **Wings:** broad, stretched skin **Flight:** quick flapping **Habitat:** many different **Food:** bugs, nectar, or fish	9 **Wings:** stretched skin (not true wings) **Flight:** gliding (not a true flyer) **Habitat:** forest **Food:** nuts, seeds
10 **Wings:** 4 long, narrow wings **Flight:** darting **Habitat:** near fresh water **Food:** bugs	11 **Wings:** 2 long wings, 2 small rudders (called halteres) **Flight:** fast, short-distance **Habitat:** house **Food:** garbage, human food	12 **Wings:** 2 wings under 2 protective shields (called elytra) **Flight:** buzzing **Habitat:** gardens, near plants **Food:** bugs, aphids

Answer Key:

Owl (1); Pigeon (2); Albatross (3); Hawk (4); Hummingbird (5); Gull (6); Flying Fish (7); Bat (8); Flying Squirrel (9); Dragonfly (10); Housefly (11); Ladybug (12)

Appendix C

Animal Flight and Man-powered Flight Matching Game

Peregrine Falcon

(Front)

Falcon: Falcons are the fastest animals on Earth with the Peregrine Falcon reaching speeds of over 320 kph. They can tuck their wings to reduce drag.

(Back)

Swing-wing Bomber

(Front)

Swing-wing bomber (B1B): This bomber has adjustable wings that can be swept back for high speed. The tight angle of the wings helps reduce drag, giving it supersonic speed capability.

(Back)

King Vulture

(Front)

King vulture: High aspect wing ration allow king vultures to spend hours in flight, soaring slowly without flapping their wings. They search for carcasses while riding thermals.

(Back)

Spy Plane

(Front)

Spy plane: The high aspect ration wings of a spy plane allow it to move slowly, not using much energy. This means it can stay airborne for extended periods of time while obtaining aerial visuals.

(Back)

Cooper's Hawk

(Front)

Cooper's Hawk: Hawks' wings are wide and rounded at the ends. This low aspect ratio, elliptical shape with separated or slotted feathers at the end allows for precise maneuverability.

(Back)

Spitfire

(Front)

Spitfire: The elliptical shape of the wings (short and rounded low aspect ratio) give the Spitfire the excellent maneuverability. They allow the plan to turn sharply while still flying at high speeds.

(Back)

Albatross

(Front)

Albatross: Wandering albatrosses have the longest wingspan of any bird. The long, narrow, pointed wings couples with low wing loading enable the birds to glide effortlessly – sometimes for months at a time

(Back)

Glider

(Front)

Glider: A glider's long, slim wings and low wing loading maximizes lift, enabling the gliding action.

(Back)

Hummingbird

(Front)

Hummingbird: Hummingbirds have the ability to hover in one place by rotating their wings in a figure 8.

(Back)

Helicopter

(Front)

Helicopter: The helicopter has the ability to rotate its wings, enabling it to hover in one place.

(Back)

Godwit

(Front)

Godwit: Migratory birds like godwits have high aspect ratio wings equipped for long ranges and endurance at a relatively fast speed.

(Back)

Airbus Passenger Plane

(Front)

Airbus passenger plane: Airplanes, such as the Airbus or Boeing 747, with high aspect ratio wings have long ranges and endurance at fast speeds.

(Back)

Appendix D

‘I Can Fly’ Activity Sheet

ACTIVITY SHEET

I CAN FLY!

NAME ________________________________

1. Cut out the two airplane propeller shapes below.
2. Slide the wings through the slits in the tube.
3. Put a piece of tape on each side of the tube near the slit to keep the wing from sliding.
4. Squeeze the tube gently to move the wings.