Hypersonics STEM Curriculum

Aircraft Design is for the Birds

Grade	Time	Subject Area	Key Concepts
High School	60 min	Life Science	adaptations

Lesson Overview

In this lesson, students will use a variety of online resources to learn about different bird wing shapes and the strengths and weakness of each shape. Students will then read an article about how research on bird wings is applied to other areas of science such as in the design of aircraft wings. Finally, students will apply their knowledge of bird wings to aircraft wings and brainstorm a hypersonic aircraft wing design.

NGSS Standards

HS-LS4-1 Communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence.

HS-LS4-4 Construct an explanation based on evidence for how natural selection leads to adaptation of populations.

Learning Objectives

By the end of this lesson, students will be able to:

- Explain the strengths and weaknesses of different shapes of bird wings.
- Explain how different aircraft wings were modeled after bird wings.
- Apply their knowledge of bird wings in their design of a wing for a hypersonic aircraft.

Essential/Overarching Question

How do scientist use bird research to design aircrafts?

Key Vocabulary

Adaptation – a change where an organism becomes better suited for its environment.

Evolve – to undergo a change or development.

Speed – the rate at which an object is moving. Speed is calculated by dividing the distance travelled by the time it took to travel that distance.

Speed of Sound – the rate at which sound moves through a medium. The speed of sound depends on both the density and the temperature of the medium. The speed of sound through air at 20° C (68° F) at sea level is 343 m/s (767 mph).

Mach – the ratio of the speed of an object to the speed of sound or how many times the speed of sound an object is moving. It is often followed by a number indicating the ratio; for

example: Mach 1 is the speed of sound, Mach 2 is twice the speed of sound, Mach 5 is five times the speed of sound.

Sonic – speeds equal to the speed of sound (Mach 1).

Subsonic – speeds smaller than the speed of sound (less than Mach 1).

Transonic – speeds near (Mach 0.8-1.2) the speed of sound where drag is highest (e.g. sound barrier).

Supersonic – speeds greater than the speed of sound (Mach 1 and greater).

Hypersonic – speeds greater than five times the speed of sound (Mach 5 and greater).

Fluid – a substance with no fixed shape; a liquid, gas, or plasma. A substance that flows when an external force is applied to it.

Flow – the motion of a fluid (liquid, gas, or plasma) when it experiences unbalanced forces.

Science Concepts Overview

All animals adapt and evolve to survive in their environment. These changes usually happen as a result of a change in environment, weather, food sources, shelter, and/or predators. In some cases, these adaptations lead to new species. In this lesson, students are specifically looking at differences within the bird class of the animal kingdom. Birds come with a variety of beaks, bodies, wings, feathers, and feet that serve different purposes for different birds. Beak shape, for example, depends on food type. Seed eaters tend to have short, thick beaks while predatory meat eaters tend to have hooked beaks. Just like beaks, different wings serve different purposes. There are four or five (depending on the categorization) shapes of bird wings, each with their own purpose: passive soaring wings, active soaring wings, elliptical wings, high speed wings, and hovering wings.

Passive soaring wings, or high lift wings, are broad wings with long feathers. There are gaps, or slots, between the feathers that help catch vertical air thermals, allowing the bird to generate more lift with less energy expended. Passive soaring wings are ideal for generating lift for take-off and landing as well as maneuverability. Because of the design of the wings, these birds can more easily pick up and carry objects away quickly and are commonly found on birds of prey.

Active soaring wings, also known as long soring wings, are long and narrow wings. This wing design allows birds to soar using wind currents for long periods of time without flapping their

wings and are typical of sea birds. These birds depend on wind currents more so than birds with other wing shapes.

Elliptical wings have a rounder shape and are ideal for short bursts of fast flight. These wings are also great for maneuverability. The speed and maneuverability combine as great wings for escaping predators and are typically seen on small, forest dwelling birds. Elliptical wings require a lot of flapping, making longer flights more difficult.

High speed wings are long and thin, but not as long as active soaring wings. These wings combine the speed of the elliptical wings with the aerodynamics of the active soaring swings, allowing them to maintain their high speed for longer periods of time. This wing is typical of migratory birds. Birds with high-speed wings struggle to stay airborne at low speeds.

And finally, some sources add hovering wings as the fifth type of wing. These wings are small and quick which allows birds to hover over one location. Flapping wings this quickly requires a lot of energy.

Scientists use research on bird wings and flight to design better aircraft wings. They not only look at the shape and size of the wings, but also how the birds use and change the shape their wings in flight for different aspects of flight.

Materials List

- ☐ Aircraft Design is for the Birds handout (one per student)
- ☐ Devices with access to the internet (one per student)

Lesson Preparation

Prior to the lesson, the instructor should make copies of the Aircraft Design is for the Birds handout and ensure that the devices that the students will be using to do the lesson are charged and connected to the internet.

If possible, the instructor should provide students with either an electronic copy of the Aircraft Design is for the Birds handout and/or links to the websites through whatever learning platform is used at their school. This will help students more easily and quickly get to the correct resources.

Safety

There are no additional safety concerns beyond normal classroom procedures for this lesson.

Procedure

Engage (10 minutes)

1. Pose the following questions to the class as either a class discussion, a think pair share, or an individual writing prompt:

- What is a change in your environment that you experienced recently (change in school, new home, change in friends, joined a new team or group or class, etc.)?
- What is an adaptation to your behavior that you had to make as a result of that change?

2. Individually, or as a class, read the Introduction on the Aircraft Design is for the Birds handout.

Explore (20 minutes)

3. Ideally, students would work individually on this lesson. If there is not a one-to-one student to electronic device ratio, students can work in groups.
4. In the Bird Wing Shapes section, students will use a variety of online resources to learn about the different shapes of bird wings: passive (high lift) soaring wings, active (long) soaring wings, elliptical wings, high speed wings, and hovering wings.

Explain (10 minutes)

5. As students are exploring the resources, they will sketch, give examples of, and explain the strengths and weaknesses of each wing type.

Elaborate (15 minutes)

6. In the Aircraft Wings Section of the Aircraft Design is for the Birds handout, students are asked to read an article on how scientists are studying birds and applying their research to aircraft design.
7. After students read the article, they will be asked to elaborate on the ideas from the article in the following questions:
    - What is the difference between stable and unstable flight? Why is it important?
    - What aspect of gull flight are scientists interested in? Why are they interested in it?
    - The researcher notes that “there are so many open questions about bird flight.” What is one question you have about bird flight?
8. Students will be given a set of images of aircrafts and asked to share which bird wing may have been the inspiration for that aircraft wing. They are also asked to elaborate on their reasoning and any assumptions that they made in making their decision.

Evaluate (5 minutes)

9. In the Hypersonics Aircraft Wings section of the lesson, students are given scenario and are asked to apply their knowledge of bird wings to design wings that aircraft: A growing area of research is hypersonics. Hypersonics studies objects moving faster than five times the speed of sound (Mach 5 = 1715 m/s = 6147 km/h = 3836 mph). Researchers are working on new hypersonics data collection aircraft. This aircraft needs to maintain high speeds for extended periods while using as little fuel (energy) as possible but also needs to be able to be easily maneuvered. The aircraft will be launched from a platform and will use parachutes as it lands in a body of water. This means that the aircraft wings will not need to be capable of take-off and landing.

- Given those requirements, and what you learned about bird wings, how would you design the wings of a hypersonic aircraft? Sketch a picture of your design as well as explaining your reasoning.
- If the aircraft now needs to take-off and land with the assistance of its wings, how would you modify your original design? What makes you say that?
- In addition to wing shape, what are other aspects of birds could be studied to help inspire the design of hypersonic aircrafts?

STEM Career Connections

- Aerospace Engineering
- Mechanical engineer
- Pilot
- Ornithology

Extensions

As an additional *elaborate*, the class could work together to create a bird adaptations guidebook. Each student would pick a different bird to research how the bird's wings, body, feathers, beak, and feet have adapted for its environment. Then each student would create a slide on the bird of their choice in a shared document.

References & Resources

ACS Distance Education. (n.d.). *Bird wings*. ACS Distance Education. https://www.acsedu.co.uk/info/environment/environmental-science/bird-wings.aspx

Allegheny College ENVSC 321: Birds, Ecosystems & People. (2017, March 10). *The four different types of bird wings* [Video]. YouTube. https://www.youtube.com/watch?v=hmYOwHE9dMs

Editorial Team. (n.d.). *9 types of aircraft wings in depth*. Aerocorner. https://aerocorner.com/blog/types-of-aircraft-wings/

Manatee County Parks & Natural Resources. (2020, December 11). *Explorers' activity: Bird wings shapes* [Video]. YouTube. https://www.youtube.com/watch?v=FSYBSTg_ELM

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SKYbrary. (n.d.). *Planform*. SKYbrary. https://skybrary.aero/articles/planform

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University of California - Davis. (2022, September 5). *Engineers study bird flight*. ScienceDaily. www.sciencedaily.com/releases/2022/09/220905160941.htm

Wynns, S. (2018, May 26). *The remarkable adaptations of birds to their environment*. National Park Service. https://www.nps.gov/cabr/blogs/the-remarkable-adaptations-of-birds-to-their-environment.htm

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Aircraft Design is for the Birds

✈ Introduction

All current members of the animal kingdom have evolved and adapted to survive and thrive in their environment. These adaptations happened over time because of a change in environment, weather, food sources, shelter, etc. And sometimes, as animals adapt to new settings, new species are formed.

Within the bird class of the animal kingdom, different birds have different shaped wings, bodies, feathers, beaks, and feet depending on where they live, what they eat, and who they need to protect themselves from. For example, beaks have adapted based on food type. Short, thick beaks are ideal for breaking seeds while hooked beaks are ideal for predatory birds. In this lesson, we will focus on how different bird wing shapes have adapted for different purposes.

By the end of this lesson, you should be able to describe the different shapes of bird wings and their purposes. You should also be able to apply your knowledge of bird wings to hypersonic aircraft design.

✈ Bird Wing Shapes

Explore the following resources to learn more about different shapes of bird wings and their use. For each wing shape, sketch the wing, list a couple birds with that wing type, and then list the pros and cons of that shape.

ACS Distance Education. (n.d.). *Bird wings*. ACS Distance Education. https://www.acsedu.co.uk/info/environment/environmental-science/bird-wings.aspx

Allegheny College ENVSC 321: Birds, Ecosystems & People. (2017, March 10). *The four different types of bird wings* [Video]. YouTube. https://www.youtube.com/watch?v=hmYOwHE9dMs

Manatee County Parks & Natural Resources. (2020, December 11). *Explorers' activity: Bird wings shapes* [Video]. YouTube. https://www.youtube.com/watch?v=FSYBSTg_ELM (Stop at 2:45)

Mitch Waite Group. (n.d.) *Browse birds by wing shape*. WhatBird.com. https://www.whatbird.com/browse/attribute/birds_na_147/100/Wing%20Shape/

Smithsonian Channel. (2016, April 8). *How the fastest animal on Earth attacks its prey* [Video]. YouTube. https://www.youtube.com/watch?v=ovocT91G1ww

The Cornell Lab of Ornithology. (n.d.) *Birds and their wing shape*. The Cornell Lab. https://dnr.maryland.gov/wildlife/Documents/Wing-Adaptations.pdf

Wing Shape (sketch & example)	Strength of Wing Shape	Weakness of Wing Shape
Passive (High Lift) Soaring Wings		
Active (Long) Soaring Wings		
Elliptical Wings		
High Speed Wings		
Hovering Wings		

✈ Aircraft Wing Shapes

As mentioned in some of the resources on the different shapes of bird wings, scientists use birds as inspiration when designing aircrafts. Read following article and answer the questions on how one specific research group is studying birds to help better design aircrafts.

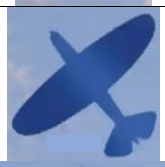
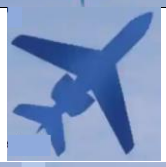
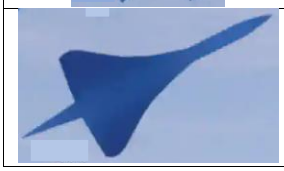
University of California - Davis. (2022, September 5). *Engineers study bird flight*. ScienceDaily. www.sciencedaily.com/releases/2022/09/220905160941.htm

1. What is the difference between stable and unstable flight? Why is it important?

2. What aspect of gull flight are scientists interested in? Why are they interested in it?

3. The researcher notes that "there are so many open questions about bird flight." What is one question you have about bird flight?

In the table below, there are pictures of different aircrafts. For each aircraft, note which bird wing shape you think inspired that aircraft's wing design. Share your reasoning as well as any assumptions you made about that aircraft that led to your decision.

Aircraft Wing	Bird Wing Shape Inspiration	Reasoning and Assumptions
		
		
		
		
		

Images from https://skybrary.aero/articles/planform

Hypersonic Aircraft Wings

A growing area of research is hypersonics. Hypersonics studies objects moving faster than five times the speed of sound (Mach 5 = 1715 m/s = 6147 km/h = 3836 mph). Researchers are working on new hypersonics data collection aircraft. This aircraft needs to maintain high speeds for extended periods while using as little fuel (energy) as possible but also needs to be able to be easily maneuvered. The aircraft will be launched from a platform and will use parachutes as it lands in a body of water. This means that the aircraft wings will not need to be capable of takeoff and landing.

1. Given those requirements, and what you learned about bird wings, how would you design the wings of a hypersonic aircraft? Sketch a picture of your design as well as explaining your reasoning.

2. If the aircraft now needs to take off and land with the assistance of its wings, how would you modify your original design? What makes you say that?

3. In addition to wing shape, what are other aspects of birds could be studied to help inspire the design of hypersonic aircrafts?