CONQUEST OF THE SKIES

EDUCATOR GUIDE

GRADES 3-5

With Adaptations and Extensions for Grades 1-2 and 6-8

COLOSSUS PRODUCTIONS

SERENGETI ENTERTAINMENT

ABOUT

COLOSSUS PRODUCTIONS

Colossus Productions is the 3D-specialist production company formed by Atlantic Productions (see below) with Sky in 2011. The joint venture was created to develop and produce high-end 3D films for UK and international audiences. Emerging from Atlantic Production's record in producing award-winning content, Colossus has already released to cinemas worldwide, in IMAX and Giant Screen, such diverse educational and entertaining films as *Flying Monsters 3D, Penguins 3D*, and *Galapagos 3D: Nature's Wonderland*. Colossus' most recent IMAX/Giant Screen films are *Museum Alive* and *Amazing Mighty Micro Monsters* which were released in late 2016, and the newest Colossus production, *Conquest of the Skies,* has just been released in IMAX and Giant Screens worldwide.

ATLANTIC PRODUCTIONS

Atlantic Productions is one of the world's leading factual production companies. Their many BAFTA and Emmy award-winning films and content are regularly seen in over 100 countries around the world. Founded in 1992, Atlantic has built a reputation for world-class storytelling, enhanced by the latest techniques and technologies including the building of pioneering cross-platform and digital experiences. Atlantic Productions leads a group of companies that make television programs, theatrical and IMAX films, apps (Atlantic Digital), visual effects (Zoo VFX) and now, immersive virtual reality experiences (Alchemy VR).

CREDITS

Writer
Samantha Zuhlke, Creative Management Solutions

Editors
Christina Riska Simmons, educator consultant
Jessica Shea, M.S. Ed. Childhood Education, JLS Writing and Editing

Expert Reviewers
Adrea Gonzalez-Karlsson, Ph.D., postdoctoral scholar
Robert D. Stevenson, Associate Professor, Department of Biology, University of Massachusetts Boston

Educator Reviewers
Garrick Humphrey, M.S.Ed. Literacy, elementary educator
Colleen Humphrey, M.S.Ed. Curriculum and Instruction, secondary math educator

Fact Checker
Bob Connelly

Designer
Mara Shaughnessy, Little Monster

Project Manager
Samantha Zuhlke, Creative Management Solutions

This guide was developed as a companion to the Colossus Productions film, *Conquest of the Skies*.

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WELCOME LETTER

The spectacular story of how animals rose up and conquered the skies

Dear Educator,

The ability to fly is one of the greatest wonders in the natural world. Millions and millions of creatures soar above our heads today, using an incredible variety of techniques to defy gravity and master the aerial environment. *Conquest of the Skies* uses the latest science and stunning special effects to showcase the beauty and excitement of animal life in the skies. Which were the first creatures to fly? What factors drove them to the skies? How are these fliers related to the ones we know today? These questions and more are answered as students traverse the more than 300-million-year history of flight with *Conquest of the Skies*.

Filmed on location in the United Kingdom, Borneo, Spain, Italy, and Ecuador, students will witness the mechanics of animal flight as never before. Uncover how groups of animals—insects, amphibians, pterosaurs, birds, and mammals—all adapted their own distinct ways of moving through the air. Now, with the latest aerial filming equipment, we can follow them skyward and see their dazzling natural abilities at work. Students' innate curiosity about flying creatures makes them an excellent STEM gateway, and provides numerous opportunities for geographic cross-curricular connections.

This guide includes standards-based activities designed for use with upper elementary students, with adaptations for both younger and older students. Worksheets and handouts are provided for all activities that require them, and educators will also find additional activity ideas following the main activities in the guide.

Students will be entranced by spectacular flight sequences, among them deadly peregrine falcons, agile dragonflies, night-hunting bats, synchronized starlings, soaring vultures, gorgeous butterflies, and powerfully graceful swans. Enter the world of these amazing aviators, and leave the theater stunned and thrilled by the story of how animals conquered the skies.

Sincerely,

Colossus Productions
& the Conquest of the Skies team

Education Standards and Skills Addressed

The activities in this guide are designed to target the following national standards and key skills:

National Standards

- National Science Education Standards
- Next Generation Science Standards
- Common Core State Standards for Mathematics
- Common Core State Standards for English Language Arts

Key Skills

- 21st Century Student Outcomes
- 21st Century Themes
- Critical Thinking Skills
- Science and Engineering Practices

HOW TO USE THIS GUIDE

This guide is intended for use by both museum and classroom educators.

Classroom educators will find activities to deepen learning by introducing students to the content before they view the film and expanding on what they learned afterward. The activities are primarily designed for students in grades 3-5, but adaptations and extensions broaden their use to grades 1-8. Museum educators can make these activities available to classroom educators via their organization's website.

Museum educators will also find suggestions on how to share information about the Conquest of the Skies film with educators in their area, as well as additional activity ideas to engage students on-site before and after viewing the film. Although the material is copyrighted, educators may reproduce instructional assets in this guide for non-commercial purposes in order to share with fellow educators and students.

SPREAD THE WORD ABOUT THE FILM

Use the following text in your social media, newsletter, or website to share information about *Conquest of the Skies*:

Embark on an extraordinary journey to unravel the evolution of flying animals, from the first flying creatures to the organisms we know today. Learn more with *Conquest of the Skies*! **30 WORDS**

Conquest of the Skies follows the more than 300-million-year history of flight as it details the specific innovative adaptations of organisms that took to the skies. Through stunning film and intuitive animation, discover what makes insects, pterosaurs, birds, and bats capable aviators. Students' innate curiosity about flying organisms makes birds, bats, and others an excellent gateway to STEM content like evolution, adaptation, and physical science. **65 WORDS**

Conquest of the Skies is a thrilling international exploration of the aerial realm. Trek back more than 300 million years to discover the first flying animals and follow the rise of monstrous winged reptiles. Then, analyze the birds, bats, and insects we are familiar with today to reveal the mechanics of their ability to fly. Students will be entranced by spectacular flight sequences, among them the deadly peregrine falcon, agile dragonflies, night-hunting bats, synchronized starlings, soaring vultures, gorgeous butterflies, and powerfully graceful swans. Thanks to the latest filming technology, students will truly enter the amazing world of these remarkable animal aviators and leave the theater stunned by the spectacle of *Conquest of the Skies*. **114 WORDS**

FEATURED CREATURES

- ✔ bat
- ✔ beetle
- ✔ butterfly
- ✔ Draco lizard
- ✔ dragonfly nymph & dragonfly
- ✔ falcon
- ✔ fly
- ✔ hummingbird
- ✔ owl
- ✔ *Microraptor* (feathered dinosaur)
- ✔ pterosaur (flying prehistoric creature)
- ✔ starling
- ✔ tree frog
- ✔ vulture
- ✔ whooper swan

DID YOU KNOW?

There are more than 350,000 known types of beetles. That's around a quarter of all animal species on Earth.

There are more than 160,000 species of moths and butterflies known in the world today. Moths and butterflies have some of the largest wings compared to body size—10x larger than other insect wings!

A blowfly's wingbeat is 50 times faster than a blink of a human eye! The blowfly's speed and agility make them jet fighters of the insect world.

A

Painted lady butterflies (*Vanessa cardui*) have one of the longest known migratory paths of any insect. They travel between Africa, northern Europe, and back again! This 15,000 kilometer (9,000 mile) journey lasts approximately 6 generations.

B

Dragonflies can move each of their four wings independently, and they can fly at speeds of 48 kilometers (30 miles) per hour!

The peregrine falcon is the fastest-moving animal on the planet. It can reach speeds of over 320 kilometers (200 miles) per hour.

The griffon vulture is one of the largest birds that flies, and can soar for hours without flapping its wings. They use an approximately 2.5 meter (8 feet) wing span and warm columns of air (thermals) to keep them aloft.

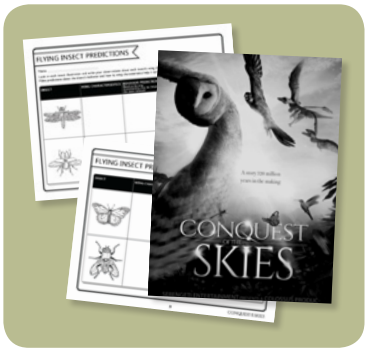
Pterosaur means "winged lizard." They are a group of extinct flying creatures. They are not dinosaurs. Pterosaurs and dinosaurs are two different groups of organisms that evolved separately and have their own sets of characteristics.

Quetzalcoatlus is a pterosaur dated to around 68 million years ago. With a wingspan of almost 11 meters (36 feet), it may be the largest known animal to ever fly. That's as long as a school bus!

The largest hummingbird, *Patagona gigas*, beats its wings 10 times per second. Some of the smallest hummingbirds beat their wings up to about 80 times per second when hovering.

ACTIVITIES TO BUILD CONTENT KNOWLEDGE

BEFORE VIEWING THE FILM



ACTIVITY 1: Winging It

GUIDING QUESTION

How and why did wings evolve?

ACTIVITY DESCRIPTION

Using their knowledge of adaptation, students predict how insects' wing characteristics inform their behavior. Students evaluate their predictions after watching the film, *Conquest of the Skies*.

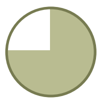
CONNECTION TO FILM

The film introduces invertebrates as the first group of animals to develop wings and fly. The ability to fly developed later in vertebrates such as pterosaurs, birds, and bats. Building students' background knowledge about adaptation and evolution in one group of animals (invertebrates) sets the stage for a deeper understanding of the film and a later exploration of convergent evolution within multiple groups of animals—a main focus and takeaway of the film. It's important to note that even within these animal groups (insects and vertebrates), the ability to fly developed independently within different lineages.

LEARNING GOALS

- identify how the characteristics of wings serve various survival functions
- make observations about animals to compare the diversity of life in different environments
- practice making and evaluating predictions

TIME NEEDED



45 minutes

PREPARATION

No special preparation is needed for this activity.

VOCABULARY

- adaptation
- diversity
- evolve
- invertebrate
- prediction
- survival
- vertebrate

MATERIALS LIST

- *Conquest of the Skies* poster (1)
- Timer or stopwatch
- Student notebooks
- Flying Insect Predictions worksheet

DIRECTIONS

1. **Introduce the film *Conquest of the Skies* and practice making a prediction.**
   Tell students they will watch a film called *Conquest of the Skies*. Show them the poster for the film. Ask students to make **predictions** about the film, using the poster as evidence. Remind students that a prediction is an educated guess about an unknown. Ask: *What do you think this film will be about?* Tell students that one of the things they will learn in the film is how animals developed the ability to fly. Ask: *How do our predictions compare to what the film is about?* Assure students that it is okay to make predictions that are incorrect. After reflecting on their own predictions, invite volunteers to share their ideas about how or why wings **evolved**.

2. **Have students brainstorm and classify a list of animals that fly.**
   Brainstorm a class list of flying animals, and write the list on the board. Then have students classify them by four animal types: insects, reptiles, birds, and mammals.

3. **Build background knowledge on vertebrates and invertebrates.**
   Explain to students that almost all animals fall under one of two categories: vertebrates and invertebrates. A **vertebrate** is an animal that has a backbone. An **invertebrate** is an animal that does not have a backbone. Ask: *Which of our four types of flying animals are vertebrates?* (reptiles, birds, mammals) *Which are invertebrates?* (insects) Tell students that there are more invertebrates than vertebrates living on our planet. One group of invertebrates, insects, is the largest group of animals on the planet. In addition, insects are an incredibly **diverse** animal group.

4. **Explore the diversity of winged insects and their behaviors in a timed brainstorming game.**
   Explain to students that insects were the first animal group to develop wings and fly. The ability to fly allowed insects to spread across the globe, and they now come in a huge variety of shapes and sizes.

   Break students into pairs, and direct their attention back to the list on the board. Give pairs two minutes to work together to brainstorm as many additional examples of winged insects as possible. When time is up, group student pairs together (making groups of four) and have them share their lists with each other. Ask groups to discuss the diversity of the wings of the insects on each of their lists. Tell students that they are going to a do a series of brainstorms, each one minute long, to categorize and add to their insect lists.

Give small groups one minute for each task to compare specific wing characteristics by doing the following:

- Order their list from smallest to largest wings
- Order their list from least number of wings to most number of wings
- Categorize their list by grouping similar wing colors together

Students may not know the distinct characteristics of each insect they brainstormed. Prime them for this by instructing them to use their best guess. The brainstorm game is an exercise in collaboration.

After, ask students to speculate about these characteristics. Ask: *Why might insects have different types of wings?* Elicit from students that different types of wings serve different purposes beyond flight and support an insect's behavior. For example, a butterfly's wings can help camouflage it from predators, while a dragonfly's wings allow it to fly in a way that make it a ferocious hunter.

Ask each group to return to their list of insects for one final one-minute brainstorm. Ask groups to think of as many behaviors of these insects as they can. After, invite groups to share some of their behaviors. Review with students that as fliers, insects can travel very long distances in order to find food, mates, and better environments. Many insects migrate in order to find these things seasonally.

5. **Build background knowledge on adaptation.**
   Ask: *Why do insects look for food, mates, and better environments?* Elicit from students that behaviors are motivated by **survival**.

   Share the definition of adaptation with students, and have them record it in their notebooks. An **adaptation** is a modified physical or behavioral characteristic of an organism that helps the organism survive in a place or situation. Explain that paleontologists (people who study life from earlier geologic periods using fossils) and other scientists know from studying both fossils and living things today that organisms change, or adapt, over time. Explain that many animals, including insects, have adaptations that help them survive. Ask: *Are insect wings adaptations? Why or why not?* (Insect wings are adaptations because they help insects survive in their environment.)

6. **Have students make predictions about insect behavior based on wing characteristics.**
   Distribute a copy of the Flying Insect Predictions worksheet to each student. Remind students of their practice making a prediction in Directions Step 1. Explain that they are going to make predictions about the behavior and survival of each insect based on their observations about each insect's wing characteristics or adaptations. Explain to students that they will have a chance to compare their predictions to information from the film, *Conquest of the Skies*. Working in their small groups, have students complete the Flying Insect Predictions worksheet.

7. **Students watch the film, *Conquest of the Skies*.**

8. **Have students compare their predictions to information from the film.**
After students have watched the film, ask them to recall information about each of the animals on the Flying Insect Predictions worksheet. Ask students about the insects' behavior and environments, and record this on the board. Then have a wrap-up discussion. Ask: *How do our predictions compare to what we learned in the film about these animals? Was anything surprising? How did the insect's behavior relate to its adaptations?*

ADAPTING THE ACTIVITY FOR YOUNGER STUDENTS

In Directions Step 1, spend additional time defining the terms prediction, evidence, and observation. Focus more on what a prediction is, why people make them, how they are sometimes incorrect, and that it is okay to be incorrect. For the Flying Insect Predictions worksheets, give students more support when brainstorming behavior by prompting them with specific survival reasons such as food, defense, or finding a mate.

An additional modification for working with younger students on the Flying Insect Predictions worksheet is to project the illustrations on the worksheet, and work as a group to identify insect features. Discuss the similarities and differences of insect wings as a group.

EXTENDING THE ACTIVITY FOR OLDER STUDENTS

Following Directions Step 8, have students write a one-page essay for homework comparing their predictions about insect wing types to what they saw in the film, *Conquest of the Skies*. Their essays should compare and contrast their predictions with what students learned, using information they recall from the film.

An additional extension for working with older students is to introduce the evolution of flight in vertebrates prior to seeing the film. Following Directions Step 8, ask students to recall the order of the evolution of flight in vertebrates (amphibians and pterosaurs were the next groups to develop the ability to fly, followed by birds, then finally, mammals such as bats). Make sure students recognize that none of these organisms are directly related; each independently evolved the ability to fly as a result of having to adapt to similar environmental pressures. Ask: *What environmental pressures influenced the evolution of wings after insects?* Elicit from students that the evolution of wings in other organisms happened for the same survival reasons they just explored in insects.

CROSS-CURRICULAR CONNECTION

Geography Following Directions Step 8, have a class discussion about different environments. Ask: *What do each of the environments featured in the film have in common? What is different about each one? How did these different environments contribute to insects' evolution of wings?*

KEY SKILLS

21st Century Themes
- ✓ Environmental Literacy

Critical Thinking Skills
- ✓ Remembering
- ✓ Understanding
- ✓ Applying
- ✓ Evaluating

21st Century Student Outcomes

Learning and Innovation Skills
- ✓ Communication and Collaboration

Information, Media, and Technology Skills
- ✓ Media Literacy

Life and Career Skills
- ✓ Flexibility and Adaptability
- ✓ Social and Cross-Cultural Skills

Science and Engineering Practices
- ✓ Analyzing and Interpreting Data
- ✓ Engaging in Argument From Evidence
- ✓ Obtaining, Evaluating, and Communicating Information

CONNECTIONS TO STANDARDS

National Science Education Standards

(K-4) A-2: Understandings About Scientific Inquiry
(K-4) C-1: The Characteristics of Organisms
(K-4) C-3: Organism and Environments
(K-4) E-2: Understanding About Science and Technology

(5-8) A-2: Understandings about scientific inquiry
(5-8) C-3: Regulation and Behavior
(5-8) C-5: Diversity and Adaptations of Organisms
(5-8) G-2: Nature of Science

Next Generation Science Standards

3-LS3-2. Use evidence to support the explanation that traits can be influenced by the environment.

3-LS4-3. Construct an argument with evidence that in a particular habitat some organisms can survive well, some survive less well, and some cannot survive at all.

4.LS1-1. Construct an argument that plants and animals have internal and external structures that function to support survival, growth, behavior, and reproduction

Common Core State Standards for English Language Arts

CCSS.ELA-Literacy.W.3.8 – 5.8
Recall information from experiences or gather information from print and digital sources; take brief notes on sources and sort evidence into provided categories.

CCSS.ELA-Literacy.SL.3.1 – 5.1
Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on *grade 3, 4, or 5 topics and texts*, building on others' ideas and expressing their own clearly.

BEFORE VIEWING THE FILM

ACTIVITY 2: The Forces of Animal Flight

GUIDING QUESTION
How do birds fly?

ACTIVITY DESCRIPTION
Students explore the four forces of flight—lift, thrust, gravity, and drag—in the context of bird flight. They analyze how the size and shape of different bird wings provide lift, power, and maneuverability in the air. Students apply what they learn through paper airplane trials and share their conclusions.

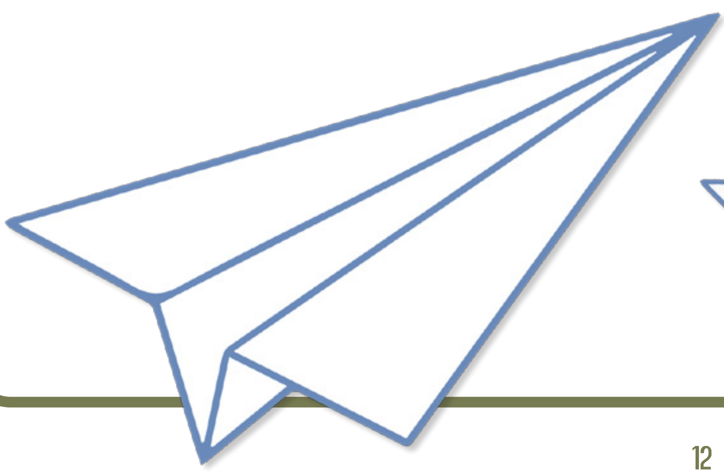
CONNECTION TO FILM
The film celebrates animals' ability to defy gravity and launch into the sky. All students will benefit from an introduction or review of the basic physical science concepts related to flight, through the lens of bird flight. Ensuring that students have an understanding of lift, drag, thrust, and gravity prior to viewing the film will enhance many of the film's animal adaptation examples, giving students a richer understanding of why these adaptations are so amazing and effective.

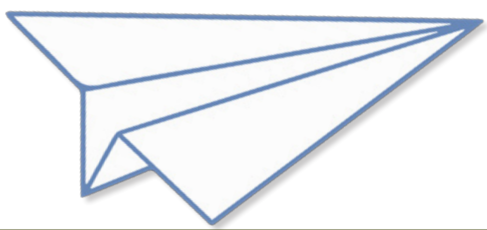
LEARNING GOALS
- distinguish between the forces of lift, thrust, drag, and gravity
- describe how different wings characteristics support different flight functions
- apply knowledge of these concepts by designing and testing a paper airplane

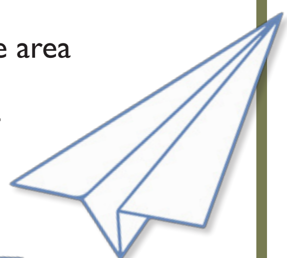
PREPARATION
Before conducting the activity, print one set of worksheets for each student. If space allows, set up four areas for the Bird Paper Airplane Trials.

TIME NEEDED
90 minutes

VOCABULARY
- adaptations
- drag
- force
- gravity
- lift
- surface area
- thrust
- weight

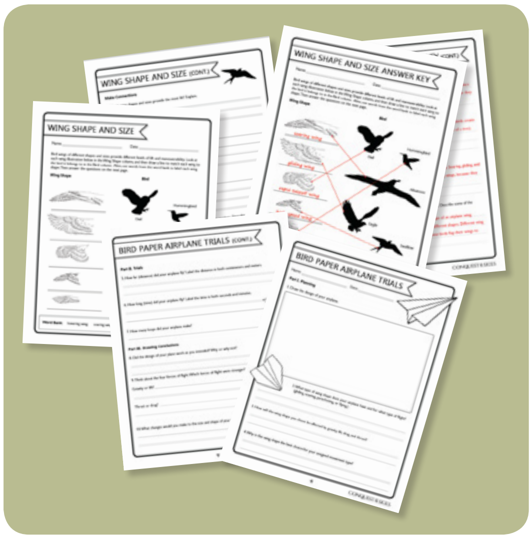






MATERIALS LIST

- Student notebooks
- One magazine page for each student
- Tissue box
- Wing Shape and Size worksheet
- Wing Shape and Size Answer Key
- Paper or graph paper for designing paper airplanes
- Bird Paper Airplane Trials worksheet
- Tape measure (1 per small group)
- Timer or stop watch (1 per small group)
- Scissors
- Transparent tape
- washer bolts (1 per small group)
- grocery bags (at least 1 per small group)
- string



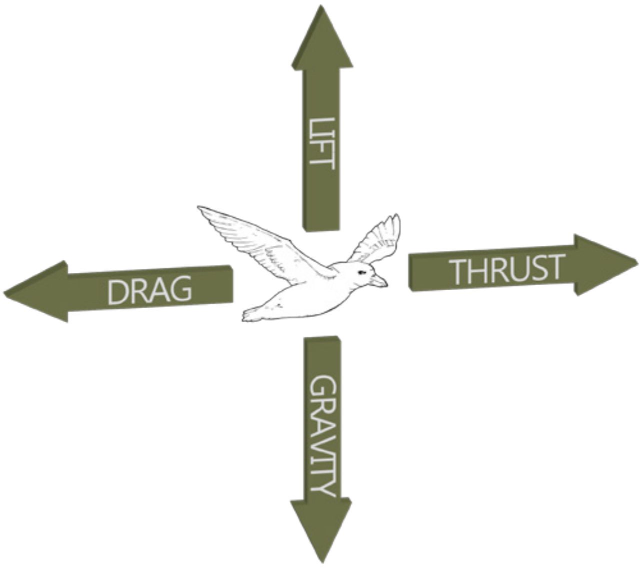
DIRECTIONS

1. **Activate prior knowledge about animal flight through a competitive brainstorm.**
Have a whole-class discussion about types of flying animals and types of flight. First, brainstorm a class list of flying animals. Divide student into four teams: insects, reptiles, birds, and mammals. Give students two minutes to brainstorm as many flying animals in their assigned category as possible. Tell them they are competing against the other teams to see which team can list the most flying animals. After two minutes is up, have each team share their list and record it on the board. If an animal students listed is not correct (i.e. doesn't fit in their assigned category or does not fly), do not record it on the board—it is not counted.

   Then ask students if they can name different ways animals move through the air. Elicit gliding, parachuting, hovering, soaring, and flying from students. Explain that different types of flight depend on a bird's manipulation of different forces of flight.

2. **Introduce the paper airplane trials.**
Explain that students are going to participate in a series of paper airplane trials for the following types of movements: gliding, parachuting, soaring, and flying. First, they will examine the forces of flight and how wings of different shapes support different movement types. They will apply this knowledge to construct their paper airplanes. Explain that flying animals' wings have different characteristics that provide lift and maneuverability in the air. Some wing types are better suited for different types of movement. An understanding of these principles will help them build successful airplanes for different types of aerial movement.

3. **Have students record a force diagram in their notebooks.**
Use a document camera to project the diagram below, or draw it on the board:



Explain that there are four forces of flight that affect all flying animals. A **force** is an invisible push or pull. Students will already be familiar with gravity. Explain that **gravity** is one of four forces that affects things that fly. Have students demonstrate gravity by holding out their writing utensils and dropping them. Ask the class to identify the force arrow on the diagram that represents gravity (the downward arrow), and whether gravity is pushing or pulling on their writing utensil (pulling). Then, have students record the word "gravity" on the diagram in their notebooks.

4. **Have students explore lift with a simple experiment.**
Explain to students that they will focus on the next force of flight—lift—during this activity. Ask: *What is it that gets birds off the ground and lets them fly and glide through the air?* There is an upward force, called **lift**, which is caused by air moving over and under wings. Distribute a piece of magazine paper to each student. Direct them to hold the short edge of the paper up to their mouth using both hands. Ask: *What do you think will happen if you blow hard across the top of the paper? Will it go down or up?* Give students a few seconds to conduct the experiment. Then ask: *What happened? Were you surprised?* Tell students that in most cases a person would think the paper would go down and not lift up when they blow air across the top. Have students repeat the experiment using the long edge of the paper. What happened? Explain that larger wings produce more lift. This means they don't have to flap as much as smaller wings, which can quickly maneuver or change direction making it difficult for predators to catch them. Some birds can glide for hours without flapping their wings, by riding special air currents—this is called soaring.

Ask the class to identify the force arrow on the diagram that represents lift (the upward arrow). Then, have students record the word "lift" on the diagram in their notebooks. Even though this may not be what they expected, this is what birds and planes do to lift off the ground and fly.

5. **Review how movement is affected when forces are balanced or unbalanced.**
   Ask students why their pencils fell when they dropped them. Explain that the pencils fell because the force of gravity acting on the pencil was stronger than the force of lift acting on it. When forces acting on an object are unbalanced, or unequal, an object will move. Demonstrate this with two student volunteers. Ask one student to hold the bottom of a tissue box. Have the other student place their hand on top of the box. When the two volunteers push equally on the box, the box remains suspended. This is an example of balanced forces.

   Ask the student holding the bottom of the box which direction he or she is pushing (upwards). Ask the student holding the top of the box which direction he or she is pushing (downwards). Have the student remove his or her hand from the top of the box while the other student remains pushing upward. Ask students which direction the box moved (upwards). Next, have the student remove his or her hand from the bottom of the box while the other student remains pushing downward. Ask students which direction the box moved (downwards). Have students make the connection between the direction of the force that is stronger, and the direction the box moved (The direction of the stronger force and the direction of the box's movement are they same). This is an example of unbalanced forces.

   If an electric fan is available, allow students to explore this concept further by pushing their hands toward and against the airstream.

   *

6. **Have students make predictions about thrust and drag by returning to the types of movements they generated in Directions Step 1.**

   Return to the force diagram on the board. Explain to students that thrust is the force that moves an object forward. Drag is the force that works against thrust, pulling against the direction of motion. Ask the class to identify the force arrows on the diagram that represent thrust (the arrow pointing toward the bird's forward direction) and drag (the arrow pointing against the bird's direction). Have students record the words "thrust" and "drag" on the diagram in their notebooks. Ask: *If a bird is moving forward, are the forces acting on it balanced or unbalanced?* (They are unbalanced.) *Which force is stronger: thrust or drag?* (Thrust). Explain that some birds use gravity (e.g., jumping from a tree) to give them forward thrust for flight. Others may use a running take-off from the ground.

7. **Investigate bird wing shape and size.**
   Ask students to consider how wing shape and size affect the four different types of movement through the air. Explain that one thing that affects drag is the shape of the object. Ask: *How does a bird's specific wing shape help it fly?* Shape helps the wind or air glide over the wing more easily. This affects the force of lift. Distribute a copy of the Wing Shape and Size worksheet to

each student. Read aloud the directions and have students complete the worksheet. Regroup as a class and ask: *Which wing types produce the most thrust? Which wing types experience high levels of drag?* Invite volunteers to share their thinking with the class and to support their hypotheses with information they've learned.

8. Have students design and build paper airplanes that reflect the wing shapes they learned about.
Using what they learned about wing shapes and sizes, have students design and build four paper airplanes for four purposes: gliding, soaring, parachuting, and flight. Divide students into groups of four, give each student a copy of the Bird Paper Airplane Trials worksheet, and give each group a washer bolt, grocery bag, scissors, and string. Assign each student in the group a movement type, so that each student represents either gliding, soaring, parachuting, or flight. Groups can help each other with their designs, but each student will act as lead for their particular airplane.

Review testing methods for each airplane type. Explain that "parachuters" will test their design using the washer bolt with a timed fall. The longer the weight stays in the air, the more successful the plane. "Gliders" and "soarers" will also be timed based on how long and far their flight takes. "Flyers" will be measured based on the number of loops their plane makes during flight. In all cases, a maximum air time implies a better design.

Provide graph paper to students as construction material instead of regular paper. If graph paper is available, have each student count or calculate the area of their airplane's wings.

Make sure students have the supplies they need and give them ample time to create their planes. Have students independently complete Part I of their Bird Paper Airplanes Trials worksheet.

9. Have students test their bird paper airplanes.
Conduct the flight trials by movement type: gliding, soaring, parachuting, and flight. Group students by movement type. (Note: This means the original groups of four will temporarily disband.) Provide the gliding, soaring, and flight groups with a measuring tape and a timer or stopwatch. Provide the parachuting groups with a chair, to drop their weights from, and a timer or stopwatch. On the Bird Paper Airplane Trials worksheet, ask them to complete Part II independently during testing, and then return to their original groups of four.

10. Have students draw conclusions about how wing shape and size impact flight.
Have students report the results of their flight trials in their groups of four. Ask students to discuss which wing shape and size created the airplane that flew the farthest and which wing shape and size flew for the longest amount of time. Direct them to complete Part III of their Bird Paper Airplanes Trials worksheet together, and then ask groups to share their answers to Part III with the whole class.

ADAPTING THE ACTIVITY FOR YOUNGER STUDENTS

Replace Directions Steps 3, 4, and 6 by defining force for students in a simple way. Explain to students that an object at rest will remain at rest unless a force acts upon it. A force can be described as an invisible push or pull. Demonstrate force for students, or have students demonstrate force using an object at their desk. Ask students to place an object in front of them, so that it is standing still. Ask: *What will the object do if you leave it alone?* (It will remain standing still.) Ask: *What will happen if you push the object?* (It will move.) Explain that when we push objects, we exert a force on the object. The same is true when birds move through the air. Forces are pushing on them, but they are invisible. For example, a force called gravity pulls down on birds and a force called lift pushes up against gravity. Provide the names of other forces, and draw or project the diagram from Directions Step 3 if students ask further questions. Otherwise, once students understand that forces push and pull on objects, have them build their paper airplanes and hold trials as a large group.

EXTENDING THE ACTIVITY FOR OLDER STUDENTS

This can be used as a pre-activity to Activity 4 later in this guide. To make the transition, insert the following task between Directions Steps 3 and 4 in Activity 4: Have students further investigate details about the mechanics of flight. Using drawings, compare the structural characteristics of a bird's wing to the wing of an airplane. Describe some of the significant similarities and differences between the two wing types. If students have been exposed to physics or natural science classes, they might include notes about weight, wingspan, and wingbeat frequency.

CROSS-CURRICULAR CONNECTION

Geography Instruct students to use library resources to find information about your state bird, including its characteristics, habitat, feeding, and geographic range. Have students answer the following questions:

- ✓ *What wing shape does it have?*
- ✓ *How does that wing shape suit the environment of your state, and the ecosystem in which the bird lives?*
- ✓ *How does this compare to birds from nearby states? From far away states?*
- ✓ *How might the environment of those states be related to the shape of the birds' wings?*

KEY SKILLS

21st Century Themes

- ✓ Environmental Literacy

Critical Thinking Skills

- ✓ Understanding
- ✓ Applying
- ✓ Creating

21st Century Student Outcomes

Learning and Innovation Skills

- ✔ Creativity and Innovation
- ✔ Critical Thinking and Problem Solving

Science and Engineering Practices

- ✔ Asking Questions (for Science) and Defining Problems (for Engineering)
- ✔ Developing and Using Models
- ✔ Planning and Carrying Out Investigations
- ✔ Obtaining, Evaluating, and Communicating Information

CONNECTIONS TO STANDARDS

National Science Education Standards

(K-4) A-2: Understandings About Scientific Inquiry
(K-4) B-2: Position and Motion of Objects
(K-4) C-3: Organisms and Environments
(K-4) E-1: Abilities of Technological Design

(5-8) B-2: Motion and Forces
(5-8) E-1: Abilities of Technological Design

Next Generation Science Standards

3-PS2-1. Plan and conduct an investigation to provide evidence of the effects of balanced and unbalanced forces on the motion of an object.

4.LS1-1. Construct an argument that plants and animals have internal and external structures that function to support survival, growth, behavior, and reproduction.

3-5-ETS1-1. Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.

3-5-ETS1-2. Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.

3-5-ETS1-3. Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.

Common Core State Standards for Mathematics

CCSS.MATH.CONTENT.4.MD.A.1
Know relative sizes of measurement units within one system of units including km, m, cm; kg, g; lb, oz.; l, ml; hr, min, sec. Within a single system of measurement, express measurements in a larger unit in terms of a smaller unit. Record measurement equivalents in a two-column table.

CCSS.MATH.CONTENT.5.MD.A.1
Convert among different-sized standard measurement units within a given measurement system (e.g., convert 5 cm to 0.05 m), and use these conversions in solving multi-step, real world problems.

CCSS.MATH.CONTENT.5.G.B.4
Classify two-dimensional figures in a hierarchy based on properties.

Common Core State Standards for English Language Arts

CCSS.ELA-LITERACY.SL.3.1 – 5.1
Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on *grade 3, 4, or 5 topics and texts*, building on others' ideas and expressing their own clearly.

CCSS.ELA-LITERACY.W.5.2 Write informative/explanatory texts to examine a topic and convey ideas and information clearly.

AFTER VIEWING THE FILM

ACTIVITY 3: Convergent Evolution

GUIDING QUESTION
Why are some animals that are not closely related similar in appearance?

ACTIVITY DESCRIPTION
Students examine an example of convergent evolution (birds and bats) and apply what they learn about adaptations and environments to identify an additional example of convergent evolution (flying squirrels and sugar gliders).

CONNECTION TO FILM
Though not identified by name, the film addresses the concept of convergent evolution by describing the separate ways flight evolved in insects, ancient vertebrates, and vertebrates after the dinosaurs. Defining convergent evolution provides a framework for a deeper understanding of Earth's history and how environmental pressures influenced organisms' ability to fly. Additionally, reviewing convergent evolution will prevent students from developing the misconception that birds evolved directly from pterosaurs, and that pterosaurs evolved directly from insects. (Students may develop this misconception based on the film's storyline.)

LEARNING GOALS
- identify the connection between environment and animal adaptation
- describe convergent evolution
- cite an example of convergent evolution related to flight

PREPARATION
Before conducting the activity, print one set of worksheets for each student. For older students, see Adapting the Activity for Older Students on page 18 for an optional pre-activity.

MATERIALS LIST
- Comparing and Contrasting Birds and Bats worksheet
- Comparing and Contrasting Birds and Bats Answer Key
- Apply: Comparing and Contrasting Mammals worksheet
- Apply: Comparing and Contrasting Mammals Answer Key

TIME NEEDED
45 minutes

VOCABULARY
- adaptation
- characteristic
- convergent evolution
- habitat
- organism

DIRECTIONS

1. **Have students imagine animal adaptations based on environmental demands.**
Tell students to individually draw an imaginary animal. Students should not look at each other's drawings. Once students have completed their drawings, tell them to adjust their animal's physical characteristics so that it can get food from a high place, such as the top of a tall tree. If a student's animal already has the ability to get food from a high place, ask them to embellish and circle the physical features that make this feat possible. Once students have completed their editing, have them reveal their drawings. Ask: *What are some common physical features among animals in the drawings?* Explain that sometimes animals develop similar physical features because they live in similar environments. When these similar animals are not related, and these features develop independently from each other, it is called **convergent evolution**. Tell students that this activity will focus on how convergent evolution occurs.

2. **Have students recall information from *Conquest of the Skies*.**
Ask students to recall animals and their **habitats** from the film *Conquest of the Skies* and write them on the board in a single column. (A few examples are dragonflies and ponds, Draco lizards and jungles, bats and caves.) Ask: *What do animals need from these habitats in order to survive?* Elicit responses from students such as air, water, nutrients, light, and shelter, and write them on the board in a second column. Explain that even though the habitats students listed are different, they still provide the same basic needs. Ask students to add habitat features on their own drawings from Direction Step 1.

3. **Review the definition of *adaptation* with students.**
Return to the list of **organisms** that students generated in Directions Step 2. For each animal listed, have students list one behavior they associate with that animal from the film. After, have students recall a specific **adaptation** that each of the organisms had that enables this behavior and helps them live in their habitat. Write the adaptation next to the organism in the first column, and ask student volunteers to draw a line connecting the adaptation to the associated survival need in the second column. (Many examples from the film will connect to nutrients, or food.) Ask: *How did the adaptations help the animals get what they need from the environment in order to survive?* Note that it is common for students to think that adaptation means that individuals change in major ways in response to environmental changes (that is, if the environment changes, individual organisms deliberately adapt). Address this by explaining that adaptation happens over many generations of organisms, rather than in a single lifespan. This process is called evolution; organisms gradually change over long periods of time. Ask: *How do adaptations help organisms get what they need in order to survive in their environment?*

4. **Define convergent evolution.**
   Review the definition of **convergent evolution**.
   Remind students that evolution is a process in which organisms develop and change over long periods of time. Explain that convergent evolution is a type of evolution. Convergent evolution is when groups of unrelated animals develop similar characteristics because they evolve in similar environments. This means that two animals that look the same, or have similar physical characteristics, did not evolve from the same ancestor. These animals are unrelated and evolved similar characteristics independently from each other in order to meet a survival need in their habitat.

   > It may be useful to break down the word into two definitions; "convergent" and "evolution." Have students use beginner dictionaries or glossaries to look up the definitions of both words. Then ask students what they think they the words mean combined.

   Returning to the list that students made on the board, ask: *Which adaptations are similar? Which are different? Why are they similar or different?* (Adaptations are similar because they suit similar survival needs.) Elicit from students that similar survival needs may produce similar adaptations. Similar environments provide similar survival opportunities.

5. **Ask students to analyze an example of convergent evolution.**
   Distribute the Comparing and Contrasting Birds and Bats worksheet. Explain that birds and bats are not related. Have students complete their worksheets. After, divide students into pairs and have them discuss their answers to the worksheet questions: *What features do birds and bats have in common? What features are different? How do their common features help them get what they need to survive from their environments?*

6. **Encourage students to apply what they've learned about convergent evolution to an additional animal pair example.**
   Explain to students that they are going to apply what they learned in order to determine whether another animal pair is an example of convergent evolution. Show students a world map. Ask students to identify North American and Australia. Explain that the flying squirrel lives in North America, and the sugar glider lives in Australia. Tell students that scientists believe these animals are unrelated, even though they are both mammals. Distribute the Apply: Comparing and Contrasting Mammals worksheet. Ask students to work in pairs to complete this worksheet and determine whether flying squirrels and sugar gliders are an example of convergent evolution.

7. **Have students discuss their verdict about sugar gliders and flying squirrels.**
   Ask pairs to share whether they think flying squirrels and sugar gliders are an example of convergent evolution. Have students share their reasoning. Reveal that flying squirrels and sugar gliders are an example of convergent evolution. Ask: *Why are some animals that are not closely related similar in appearance?*

ADAPTING THE ACTIVITY FOR YOUNGER STUDENTS

Rather than focusing on convergent evolution, use this activity to have students recall direct experiences with living things, reinforce information about habitats and environments, and identify characteristics of organisms. Ask students to recall the animals they saw in the film, and focus student attention on the environments that the animals live (or lived) in. Use the illustrations on the Bird and Bat Comparison worksheet to have students practice identifying size, shape, and number of animal characteristics. Work as a class to complete a Venn diagram of similarities and differences between the organisms. Discuss how these characteristics help organisms relate to their habitats.

EXTENDING THE ACTIVITY FOR OLDER STUDENTS

Replace Directions Step 6. Have students work in pairs to conduct their own research in order to identify additional examples of convergent evolution and answer the following questions:

- ✔ What features do these animals have in common? What features are different?
- ✔ How do their common features help the animals get what they need to survive in their environments?
- ✔ Why are the animals you researched an example of convergent evolution?

Have pairs report back to the class with their findings, showing visuals of the animals if possible. Following these presentations, continue with the concluding question from Directions Step 7 to wrap up the activity.

CROSS-CURRICULAR CONNECTION

Geography Convergent evolution can happen across time as well as environments. There are many prehistoric examples of convergent evolution that exist in the fossil record. For a geography connection, have students conduct a virtual fossil hunt on the Internet using Google Image search. There, they can find images of fossils of insects, pterosaurs, fish, mammals, etc. Remind students that extinction is common, and that most of the species that have lived on Earth no longer exist. Have students identify a fossil image of an animal that once flew and research the type of environment that that animal lived in. If possible, have them identify the location where the fossil was found. Print the images, and have students place them all on a world map in their classroom (a digital map, such as Google Maps, will also work).

Once the fossil map is complete, ask the class to compare and contrast the organisms found in similar environments. Ask: *Which organisms have similar adaptations? Which have different adaptations? What is the relationship between environment and organism adaptations?* Have the class identify potential cases of convergent evolution. Pair those students together, and have them research whether their predictions are correct. Have each student pair report their findings back to the class.

KEY SKILLS

21st Century Themes

- ✔ Environmental Literacy

Critical Thinking Skills

- ✔ Remembering
- ✔ Understanding
- ✔ Applying
- ✔ Analyzing

21st Century Student Outcomes

Learning and Innovation Skills

- ✔ Communication and Collaboration

Science and Engineering Practices

- ✔ Analyzing and Interpreting Data
- ✔ Engaging in Argument from Evidence

CONNECTIONS TO STANDARDS

National Science Education Standards

(K-4) C-1: The Characteristics of Organisms
(K-4) C-3: Organism and Environments

(5-8) C-3: Regulation and Behavior
(5-8) C-5: Diversity and Adaptations of Organisms

Next Generation Science Standards

3-LS3-1. Analyze and interpret data to provide evidence that plants and animals have traits inherited from parents and that variation of these traits in a group of similar organisms.

3-LS3-2. Use evidence to support the explanation that traits can be influenced by the environment.

3-LS4-3. Construct an argument with evidence that in a particular habitat some organisms can survive well, some survive less well, and some cannot survive at all.

4.LS1-1. Construct an argument that plants and animals have internal and external structures that function to support survival, growth, behavior, and reproduction.

Common Core State Standards for English Language Arts

CCSS.ELA-LITERACY.W.3.8
Recall information from experiences or gather information from print and digital sources; take brief notes on sources and sort evidence into provided categories.

CCSS.ELA-LITERACY.W.3.2 – 5.2
Write informative/explanatory texts to examine a topic and convey ideas and information clearly.

CCSS.ELA-Literacy.SL.3.1 – 5.1
Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on *grade 3, 4, or 5 topics and texts*, building on others' ideas and expressing their own clearly.

AFTER VIEWING THE FILM

ACTIVITY 4: Biomimicry: Inspired by Nature

GUIDING QUESTION
What have humans, specifically engineers, learned from nature?

ACTIVITY DESCRIPTION
Students define biomimicry and how engineers often imitate nature while designing innovative products. Students demonstrate their knowledge of biomimicry by developing an idea for a new flying machine, drawing inspiration from the animals featured in the film.

CONNECTION TO FILM
The film describes innovations in wings and flight as "marvels of natural engineering." Students may not realize how often engineers use the natural world as inspiration for design. This is an opportunity to extend the film's message about the evolution of animal flight by having students use the engineering process to make connections between innovations in the natural world and innovative solutions to modern engineering challenges.

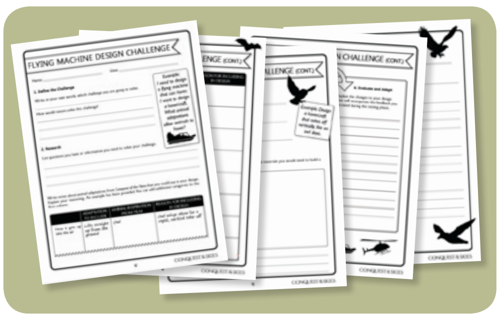
LEARNING GOALS
- define biomimicry
- identify modern examples of biomimicry inspired by flying animals
- use biomimicry and the engineering process to develop an idea for a new flying machine
- practice peer review

TIME NEEDED
90 minutes

VOCABULARY
- biomimicry
- engineering
- engineering process

PREPARATION
Before conducting the activity, print one set of worksheets for each student.

MATERIALS LIST
- Flying Machine Design Challenge worksheet
- Peer Review Feedback worksheet
- Large sheets of paper



DIRECTIONS

1. **Brainstorm human flying machines.**
   On the board, draw a simple T-chart. Label the left column "Human-Made Flying Machines." Leave the right column unlabeled for the time being. Ask students to brainstorm a list of human-made flying machines and write them in the left column. Possible answers include planes, helicopters, jets, drones, paragliders, and so on.

2. **Define biomimicry.**
   Write the word *biomimicry* on the board. Ask students what they think it means. Draw a line between the Greek root "bio" and the word "mimicry" and elicit from students that "bio" means life and "mimicry" means to imitate. Explain that **biomimicry** means imitating, or copying, the special characteristics of organisms in human-made designs and products.

This idea will really come alive for students if you can show them examples of biomimicry, like Velcro © and a photograph of burdock.

*

3. **Add examples of biomimicry inspired by flying animals.**
   Ask students to recall animals from the film that are compared to or similar to the machines that they brainstormed (planes: birds, helicopters: dragonflies, jets: flies, drones: insects, paragliders: Draco lizards). Write them in the right column next to the associated human-made flying machine.

4. **Divide students into groups and introduce the design approach.**
   Divide students into groups of up to four students. Explain that students are going to work as a group to design a flying machine inspired by animal adaptations from the film *Conquest of the Skies*. Groups may choose to work with one or multiple animal adaptations from the film. Distribute the Flying Machine Design Challenge worksheet to each student. As a class, fill out Step 1 of the engineering process: Define the Challenge. Ask groups to pick one of three engineering challenges to solve:
   - ✔ Design a flying machine that can cross large distances using low energy.
   - ✔ Design a flying machine that can quickly take off, straight up.
   - ✔ Design a flying machine that can hover in one place in the air.

5. **Have students complete Step 2 of the engineering process.**
   Have students work in their groups to complete Step 2 of the worksheet by listing questions they have, recalling animals and their adaptations from the film and explaining their reasoning for including the adaptation in their design. Prompt students using the list the class generated on the board for reference. Have each student fill out their own copy of the worksheet.

6. **Give groups ample time to design something that flies.**
Have students continue to work in their groups on Steps 3 and 4. When they reach a stopping point, ask them to check in with you to get approval on their design. Use additional prompts to assess whether students are on track. By the end of Step 4, students should have developed a clear group design. Ask them to articulate what animal adaptations they are drawing inspiration from. If there are no clear inspirations and they need help remembering specifics from the film, jog their memory by asking questions about the film's animals using the Featured Creatures list on page 5 of this guide.

7. **Students prepare to review each other's designs.**
Once a group's designs are approved, give each group a large, clean sheet of paper. Have them redraw, annotate, and post a version of their design on the paper for their peers to view. Explain that students will do a gallery walk of all the projects, followed by a question and answer session for each group to get feedback on their idea. Assign each group a number (or let them pick a team name), and have them write it on their designs, along with a brief description of the design.

8. **Review how to give constructive feedback with students.**
Distribute a Peer Review Feedback worksheet to each group, and assign them one group's design to critique.

Remind students that they should provide feedback in a constructive way. Destructive criticism negatively impacts other's hard work and feelings.

> Have groups critique all other groups' designs if time and student ability allows.
> *

9. **Conduct the gallery walk.**
Have groups view other groups' designs and complete feedback forms for their assigned group.

10. **Host a question and answer session for each group.**
As part of the review process, each group will need to answer a question from the group that is providing feedback on their design. Have each group ask their question from the Peer Review Feedback worksheet.

> If groups reviewed more than one design, collect the Peer Review Feedback worksheets from all the groups and give them to the appropriate teams. Have group members work together to summarize the feedback they received and to pick a question to answer for the class. Groups should record their summarized feedback in Step 5 of the Design Challenge worksheet in Directions Step 11.
> *

11. Groups work together to summarize their individual feedback forms.
Following the question and answer session, give the Peer Review Feedback worksheets to the teams. Have them record this feedback in Step 5 of the Flying Machine Design Challenge worksheet. Explain that for the class' purposes, the review process took the place of the testing phase of the engineering process. Often, testing means to physically test a 3D version of the design to see if it solves the problem.

12. Have groups complete Step 6 of the engineering process.
Give students time to evaluate and adapt their designs based on the feedback they received.

13. Lead a wrap-up discussion and ask students to reflect on what they learned.
Ask: *What similarities and differences did you notice among the designs during the gallery walk? What was the strongest example of biomimicry? Explain. How was that design inspired by nature? After the gallery walk and question and answer session, how did your group adapt your design? Why? What questions do you still have about how nature can inform engineering design?*

ADAPTING THE ACTIVITY FOR YOUNGER STUDENTS

Rather than having students create their own design, come up with a design as a class. Take a vote on which of the three challenges to solve, and work through the steps of the engineering process collaboratively as a large group.

For very young students, provide a photograph or physical model of a human-made flying machine, such as a plane or hovercraft. Ask students to identify characteristics of the human-made flying machine and compare these features to the features of animals.

EXTENDING THE ACTIVITY FOR OLDER STUDENTS

If time and budget allow, have students build a complete model of their project following the feedback phase of the project in order to more accurately follow the engineering process. To do this:

- Consider limiting the students to one challenge in Directions Step 3
- If timing allows, introduce this activity prior to seeing the film *Conquest of the Skies*. Tell students they are going to need to build a flying machine that resembles one or more animal adaptations, and slot the film into the Research section of the engineering process. As they watch, have students take notes about adaptations they could draw inspiration from.
- Ask students to include and cite two credible sources in addition to the film during the research phase of the project.
- Introduce the concepts of constraints (limitations) and considerations (desired but optional elements) during the design phase of the project. Be sure to provide students with a list of available building materials.

- Have students either make their design drawings to scale with a version from the front view and a version from the side view or build a model. Have them include measurements and units on their drawings. Alternatively, have students use software such as Google's SketchUp or Geometer's Sketchpad to design a scale model of their flying machine.
- Have students test their models, alter their designs, and retest.
- Have a concluding discussion about the engineering process.

CROSS-CURRICULAR CONNECTION

Geography Ask students to think about temperature and climate by having them revisit their designs to make sure they could work in extremely hot or cold temperatures. How would extreme climates cause alterations to their designs? What live in these extreme temperatures that students might draw inspiration from? Remind students to consider weather, temperature, and climate in their revisions.

KEY SKILLS

21st Century Themes
- Environmental Literacy

Critical Thinking Skills
- Remembering
- Understanding
- Applying
- Analyzing
- Evaluating
- Creating

21st Century Student Outcomes

Learning and Innovation Skills
- Creativity and Innovation
- Communication and Collaboration

Information, Media, and Technology Skills
- Information, Communications, and Technology (ICT) Literacy

Science and Engineering Practices
- Asking Questions (for Science) and Defining Problems (for Engineering)
- Developing and Using Models
- Constructing Explanations (for Science) and Designing Solutions (for Engineering)
- Obtaining, Evaluating, and Communicating Information

CONNECTIONS TO STANDARDS

National Science Education Standards

(K-4) C-3: Organisms and Environments
(K-4) E-1: Abilities of Technological Design
(K-4) E-2: Understanding About Science and Technology

(K-4) E-3: Abilities to Distinguish Between Natural Objects and Objects Made by Humans
(K-4) E-5: Science and Technology in Local Challenges
(5-8) E-1: Abilities of technological design
(5-8) E-2: Understanding About Science and Technology
(5-8) G-2: Nature of Science

Next Generation Science Standards
3-LS3-1. Analyze and interpret data to provide evidence that plants and animals have traits inherited from parents and that variation of these traits in a group of similar organisms.

3-LS3-2. Use evidence to support the explanation that traits can be influenced by the environment.

3-LS4-3. Construct an argument with evidence that in a particular habitat some organisms can survive well, some survive less well, and some cannot survive at all.

4.LS1-1. Construct an argument that plants and animals have internal and external structures that function to support survival, growth, behavior, and reproduction.

3-5-ETS1-1. Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.

3-5-ETS1-2. Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.

3-5-ETS1-3. Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.

4-LS1-1. Construct an argument that plants and animals have internal and external structures that function to support survival, growth, behavior, and reproduction.

Common Core State Standards for English Language Arts
CCSS.ELA-Literacy.W.3.8 – 5.8
Recall information from experiences or gather information from print and digital sources; take brief notes on sources and sort evidence into provided categories.

CCSS.ELA-LITERACY.RF.3.3 – 5.3
Know and apply grade-level phonics and word analysis skills in decoding words.

CCSS.ELA-LITERACY.W.3.2 – 5.2
Write informative/explanatory texts to examine a topic and convey ideas and information clearly.

CCSS.ELA-LITERACY.W.3.7 – 5.7
Conduct short research projects that build knowledge about a topic.

CCSS.ELA-Literacy.SL.3.1 – 5.1
Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on *grade 3, 4, or 5 topics and texts*, building on others' ideas and expressing their own clearly.

ADDITIONAL ACTIVITY IDEAS

Use these quick, 5-10 minute additional activity ideas for a variety of purposes. Use them as warm-up activities to introduce students to topics or as learning extensions in museums, classrooms, or at home.

SCIENCE

Have students create, write, and illustrate field journals. Take sheets of blank paper, fold them in half width-wise, and staple them to create booklets. Have students record their observations of fliers, including labels, illustrations, additional observations, and predictions. Have them note the insects, birds, and any other flying animals they see. Tell students to make observations about the animals' flight patterns (Does the organism fly in a straight line? Does it fly up and down? And so on). (skills necessary for science)

Have students act as paleontologists to practice their observation skills by working with a fossil. If a physical fossil (or a cast or mold of one) is available, allow students to sketch it and take notes about what they see in its features. If a physical fossil is not available, provide an image of a fossil for students to do the same. Remind students that most things that have lived on Earth are now extinct. Scientists called paleontologists study fossils to learn about the past. After observing their fossils, have students make guesses about how that organism might have behaved based on its physical features. (skills necessary for science)

BIOLOGY

Show students a photograph of a bird that flies, such as an owl, and a photograph of a flightless bird, such as a penguin. Ask students to compare and contrast the two organisms. Which features do they have in common? Which features are different? What survival purpose do each of their adaptations serve? Ask students to speculate on reasons for why the flightless bird evolved to be flightless. (adaptation, organism characteristics)

As a class, create a series of bird weights that can be used to demonstrate the weight of birds. Gather resealable bags, sand, and a scale to measure. Ask student volunteers to create weights for a hummingbird (roughly 4–5 grams or 0.14–0.17 ounces), red-tailed hawk (roughly 1 kilogram or 2.4 pounds), bald eagle (3–6.4 kilograms or 6.6–14 pounds) by weighing sand and putting it into the resealable bags. Have students guess which bag represents which bird. Then, ask them if they think a bird that is flightless would weigh more or less than a bird that flies. Explain that flightless birds weigh more because of their heavier bone structure. (organism characteristics)

Review the definition of *metamorphosis* with students. **Metamorphosis** means a major change in appearance during a change in a life cycle. In the film, a dragonfly nymph undergoes metamorphosis to become a dragonfly. Review the stages of this metamorphosis with students: egg, larva, pupa, and adult. (animal life cycles)

ECOLOGY

Starlings form murmurations—huge flocks of birds that swirl in the sky and produce mesmerizing patterns and shapes. Show students a photograph or video of a mumuration and ask them to guess why starlings move in this way. How do they know where to fly? (Scientists think that these murmurations help to confuse predators and so reduce an individual starling's chance of being caught.) (animal behavior)

Show students a clock and ask them to read the time. Ask: *Would a diurnal species be awake now? Would a nocturnal species be awake now?* Review the definitions of nocturnal (active at night) and diurnal (active during the day) with students, and repeat this a few times, asking students to identify which species types would be awake at various times. (behavior)

Play a game of predator-prey tag with a large group of students. Select one or two students as predators. The rest of the students are prey. Predators stand in the middle of the game space and try to tag prey as they cross from one side to another. (Prey should start on one side of the room, similar to the game *What time is it Mr. Fox?*). If prey are tagged, they become predators as well. (predator-prey relationships)

TECHNOLOGY

Discuss with students: *What role did technology play in the film's storytelling? What specific tactics did filmmakers use to tell the stories of these fliers?* Explore how filmmakers used close-up shots, slowed-down or sped-up footage, and other tactics to present an inside view of flight. If students have cameras or equipment such as smartphones available, give them a small object and have them practice taking various types of shots. How did their type of media affect how they presented the object? (storytelling craft and structure; technology creativity and innovation)

Have students debate the benefits of different sensory systems flying animals have, such as sonar, eyesight, etc. Assign a sensory system to each student. Ask students to discuss their respective systems with each other, share the systems' pros and cons, and discuss which environments are better for these systems. Then, ask students to think of ways humans have recreated or mimicked these systems in technology. (engineering, biomimicry)

Have students research insect fossils (either casts, molds, or photos). If a 3D printer is available, provide or have students recreate and print fossilized insect wings. If a 3D printer is not available, images will do. A quick Google search will provide images of fossilized insects. Review with students what a fossil is and how it forms. (fossils, investigation)

ENGINEERING

Explain that animals are not the only organisms that have capitalized on the ability to fly. Many plants have adaptations that capitalize on the wind to carry seeds far away from the parent plant. Have students go outside at home, at school, or at a local green space, and collect seedpods. Back in the classroom, have them compare and contrast the pods. Ask: *How does shape affect their movement through the air? How are they similar or different to wing shapes seen in Conquest of the Skies?* (skills necessary for science, organism characteristics)

Create a set of biomimicry cards that pair organisms from the film with human-made flying machines they inspire, for example, a dragonfly and a helicopter would be a pair Play a game of memory using these cards. (skills necessary for science, biomimicry)

MATH

Practice ratios by comparing the size of gliders to their body mass. Have students compare a Draco lizard, the colugo, a flying fish, and the flying frog (*Rhacophorus* genus). Ask students to compare the ratios. Ask: *Are there any similarities between these organisms? Any differences? How does surface area of gliders skin relate to their body mass? Why might this matter in terms of organisms' ability to glide?* (ratios, interpretation of data)

Have students practice visualizing information using bird information. Have students research or provide the weight and wingspan of local birds. Then, have students their practice graphing skills by plotting this information on a graph. (data visualization)

The largest hummingbird, *Patagona gigas*, beats its wings 10 times per second. Some of the smallest hummingbirds beat their wings up to about 80 times per second when hovering. Time students. Give them one second to try and clap as many times as they can. Can anyone clap 10 times? How about 80 times? (organism characteristics, counting)

GEOGRAPHY

Soaring, though similar to gliding, is a different type of movement. Soaring animals depend on thermals, or rising warm air, to keep them at a constant elevation. For example, griffon vultures are obligate soaring birds—meaning they rely on rising air currents to stay airborne. They have broad wings with a wingspan of approximately 2.5 meters (8 feet), producing a huge area to catch this rising air. Demonstrate warm air rising and cold air falling for students. Gather a 1-liter soda bottle, a balloon, and two temperature-safe bowls. Attach the balloon to the top of an empty bottle. In one bowl, pour hot or boiling water. Put ice in the second bowl. Place the bottle and balloon into the hot water bowl. Ask: *What happens to the balloon? Why?* (The balloon will fill, because the water warms the air in the bottle and warm air rises.) Place the bottle and balloon into the ice bowl. Ask: *What happens to the balloon? Why?* (The balloon will deflate, because the ice cools the air in the bottle and cool air sinks.)

Using the Featured Creatures list on page 5, have students each pick one animal and research its range and draw it on a communal map. Ask: *What similarities and differences are there between fliers found in similar places? In fliers found in different places?* Have students compare these animals to non-fliers in the region. Ask: *How does the ability to fly affect resource ranges?* (animal ranges and characteristics)

The painted lady butterfly (*Vanessa cardui*) is thought to have one of the longest known migratory paths of any insect. They travel between Africa, northern Europe, and back again! This 15,000 kilometer (9,000 mile) journey lasts approximately six generations. Have students plot this migration on a map. Have them use the map scale to estimate distances. (mapping skills)

APPENDIX

WORKSHEETS AND HANDOUTS

BEFORE VIEWING THE FILM

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Flying Insect Predictions 35

Activity 2: Forces of Animal Flight

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Wing Shape and Size Answer Key 39
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AFTER VIEWING THE FILM

Activity 3: Convergent Evolution

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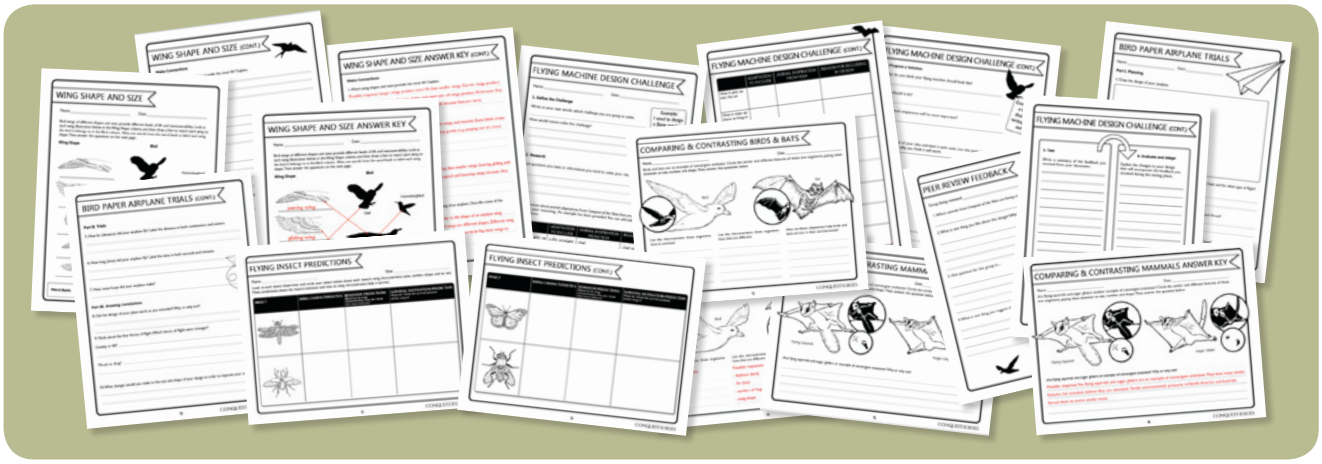
Apply: Comparing and Contrasting Mammals Answer Key 46

Activity 4: Biomimicry: Inspired by Nature

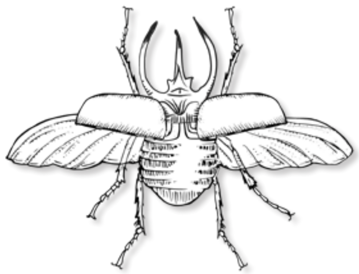
Flying Machine Design Challenge 47
Peer Review Feedback 51



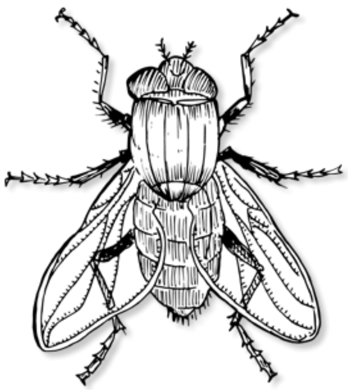
FLYING INSECT PREDICTIONS

Name: ______________________________ Date: ______________________________

Look at each insect illustration and write your observations about each insect's wing characteristics (size, number, shape, and so on). Make predictions about the insect's behavior and how its wing characteristics help it survive.

INSECT	WING CHARACTERSISTICS	BEHAVIOR PREDICTIONS *Based on its wing characteristics, how do I think this insect behaves?*	SURVIVAL MOTIVATION PREDICTION *What do I think the survival purpose of this wing is?*
			
			

FLYING INSECT PREDICTIONS (CONT.)

INSECT	WING CHARACTERSISTICS	BEHAVIOR PREDICTIONS *Based on its wing characteristics, how do I think this insect behaves?*	SURVIVAL MOTIVATION PREDICTION *What do I think the survival purpose of this wing is?*
			
			

WING SHAPE AND SIZE

Name: ________________________________ Date: ________________________________

Bird wings of different shapes and sizes provide different levels of lift and maneuverability. Look at each wing illustration below in the Wing Shape column, and then draw a line to match each wing to the bird it belongs to in the Bird column. After, use words from the word bank to label each wing shape. Then answer the questions on the next page.

Wing Shape **Bird**

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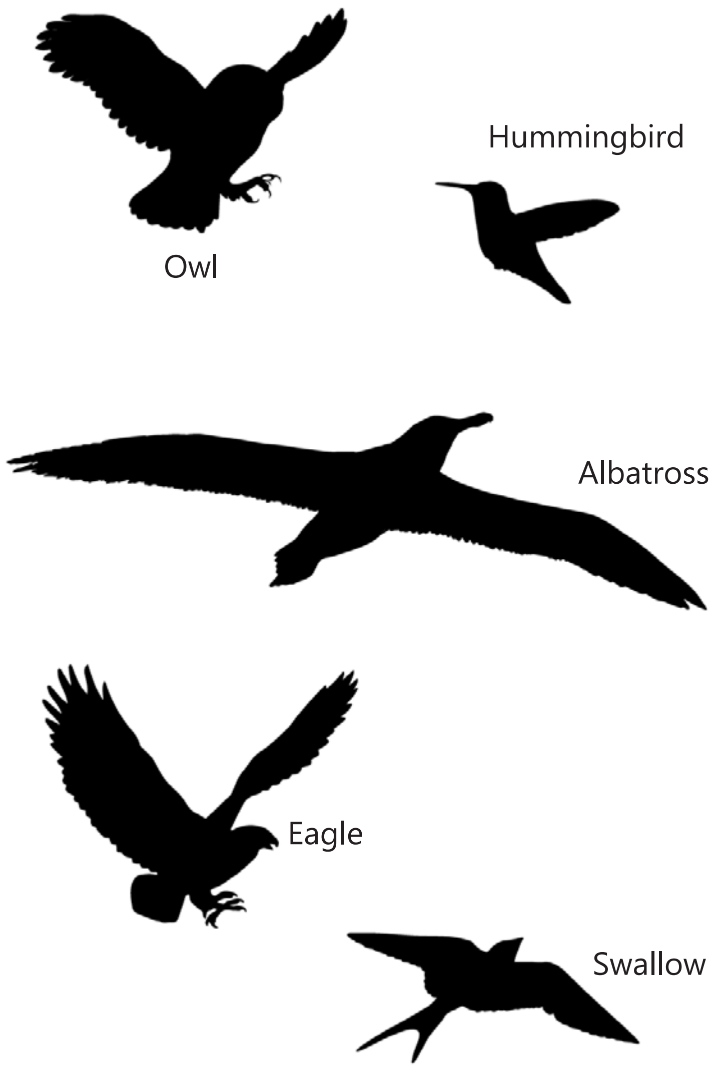


Word Bank: hovering wing soaring wing rapid takeoff wing high-speed wing gliding wing

WING SHAPE AND SIZE (CONT.)

Make Connections

1. Which wing shapes and sizes provide the most lift? Explain.

2. Which produce the most thrust? Explain.

3. Which experience high drag? Explain.

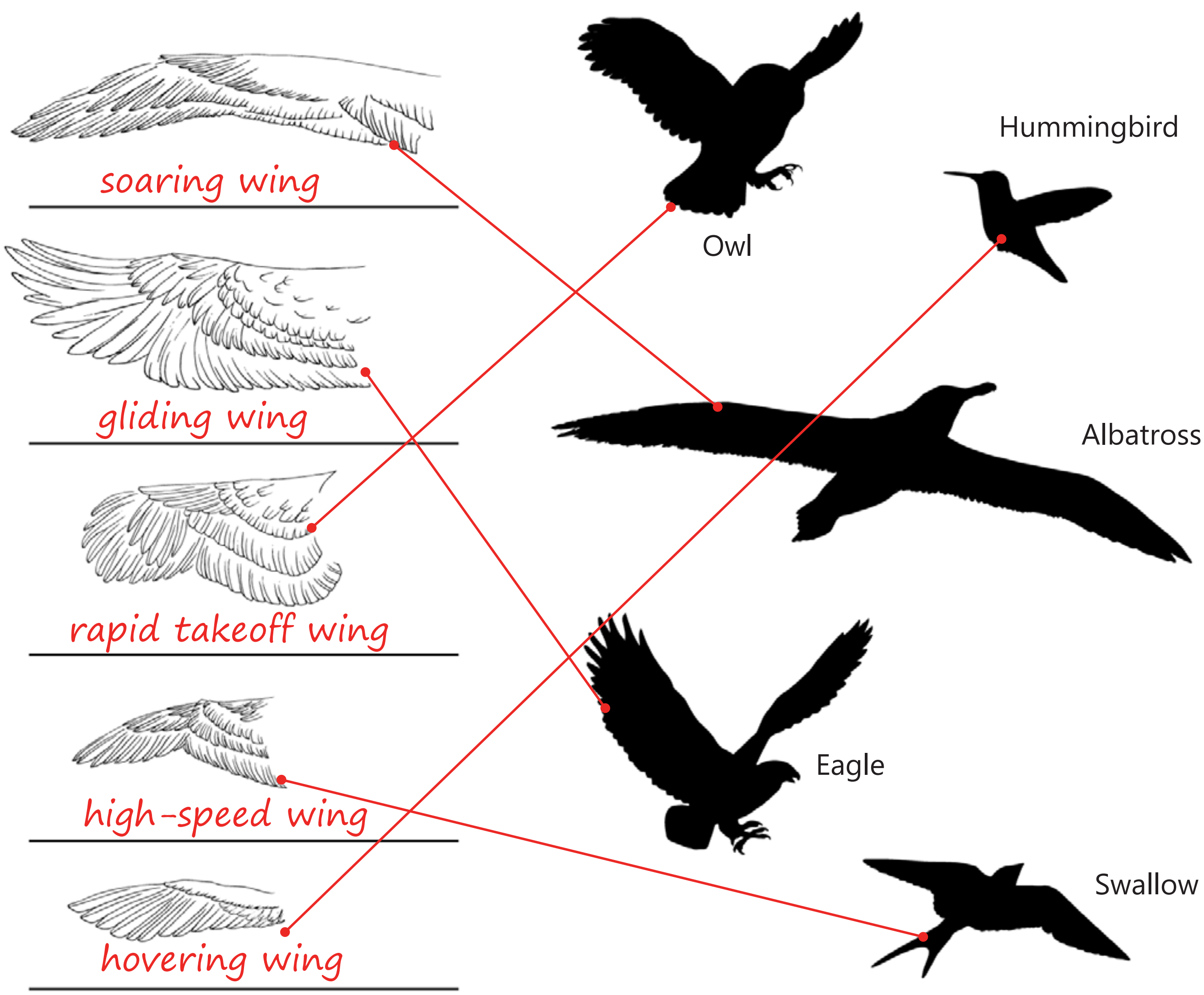
4. Compare the characteristics of a bird's wing to the wing of an airplane. Describe some of the similarities and differences.

WING SHAPE AND SIZE ANSWER KEY

Name: ______________________________ Date: ______________________________

Bird wings of different shapes and sizes provide different levels of lift and maneuverability. Look at each wing illustration below in the Wing Shape column, and then draw a line to match each wing to the bird it belongs to in the Bird column. After, use words from the word bank to label each wing shape. Then answer the questions on the next page.

Wing Shape **Bird**



Word Bank:	hovering wing	soaring wing	rapid takeoff wing	high-speed wing	gliding wing

WING SHAPE AND SIZE ANSWER KEY (CONT.)

Make Connections

1. Which wing shapes and sizes provide the most lift? Explain.

Possible response: Larger wings produce more lift than smaller wings. Curvier wings produce more lift than straight wings. Soaring, gliding and rapid take off wings produce lift because they are large. High-speed and rapid takeoff wings produce lift because they are curvy.

2. Which produce the most thrust? Explain.

Possible response: All birds can create thrust using their wings and muscles. Some birds create thrust by flapping their wings. Others create thrust using gravity (e.g. jumping out of a tree).

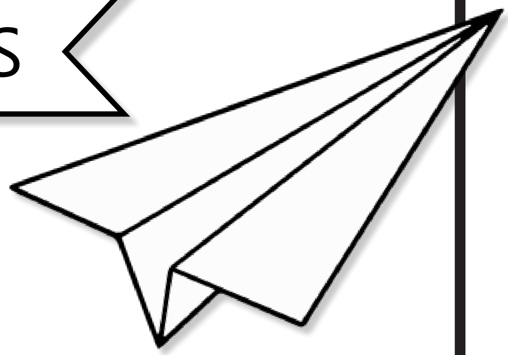
3. Which experience high drag? Explain.

Possible response: Larger wings experience higher drag than smaller wings. Soaring, gliding, and rapid-take off wings experience more drag than high-speed and hovering wings, because they are larger.

4. Compare the characteristics of a bird's wing to the wing of an airplane. Describe some of the similarities and differences.

Possible response: The shape of a bird's wing is similar to the shape of an airplane wing. Airplane wings can be different shapes, just like bird wings are different shapes. Different wing shapes serve different purposes. Airplane wings do not flap. Some birds flap their wings to create thrust.

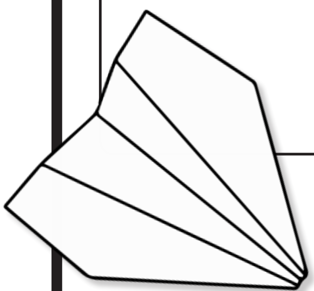
BIRD PAPER AIRPLANE TRIALS



Name: ______________________ Date: __________________

Part I. Planning

1. Draw the design of your airplane.



2. What type of wing shape does your airplane have and for what type of flight? (gliding, soaring, parachuting, or flying.)

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3. How will the wing shape you chose be affected by gravity, lift, drag, and thrust?

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4. Why is this wing shape the best choice for your assigned movement type?

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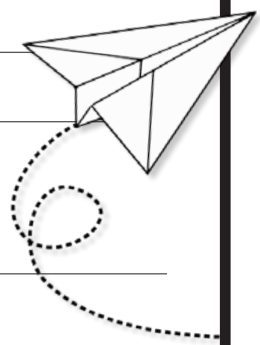
BIRD PAPER AIRPLANE TRIALS (CONT.)

Part II. Trials

5. How far (distance) did your airplane fly? Label the distance in both centimeters and meters.

6. How long (time) did your airplane fly? Label the time in both seconds and minutes.



7. How many loops did your airplane make?

Part III. Drawing Conclusions

8. Did the design of your plane work as you intended? Why or why not?

9. Think about the four forces of flight. Which forces of flight were stronger?

Gravity or lift?

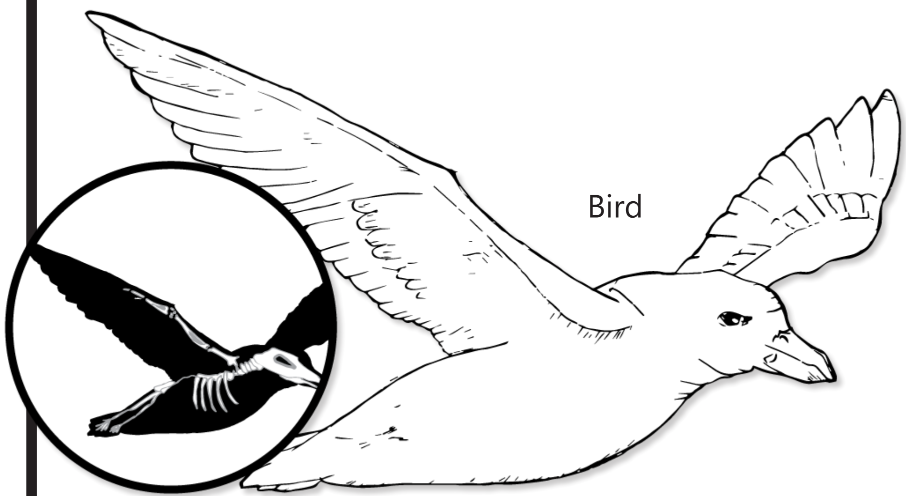
Thrust or drag?

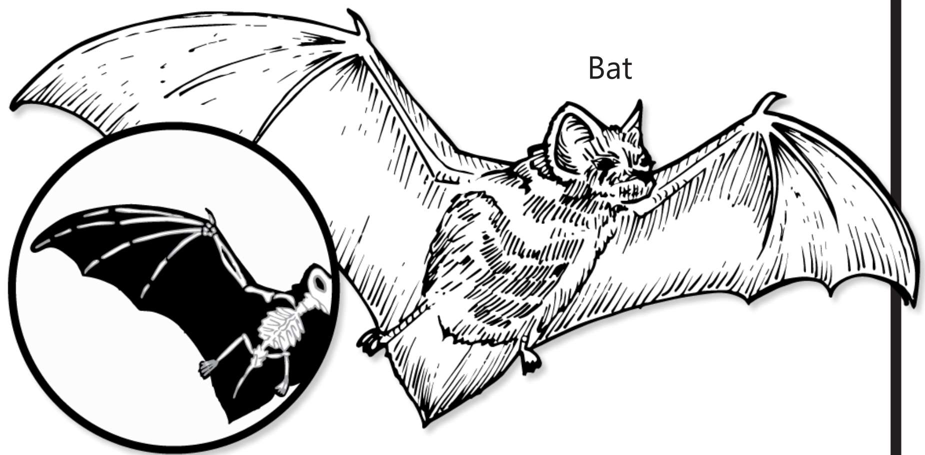
10. What changes would you make to the size and shape of your design in order to improve your results?

COMPARING & CONTRASTING BIRDS & BATS

Name: ______________________________ Date: ______________________________

Birds and bats are an example of convergent evolution. Circle the similar and different features of these two organisms, paying close attention to size, number, and shape. Then, answer the questions below.





List the characteristics these organisms have in common:

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List the characteristics these organisms have that are different:

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How do these adaptations help birds and bats survive in their environments?

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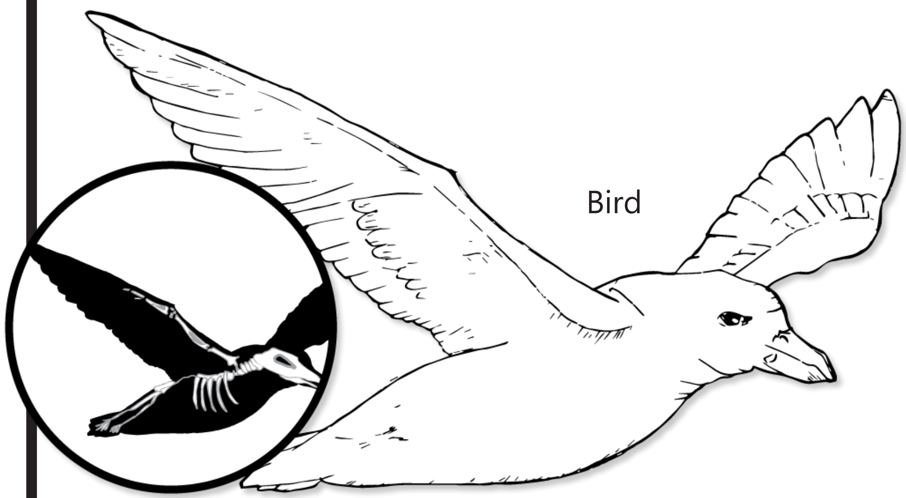
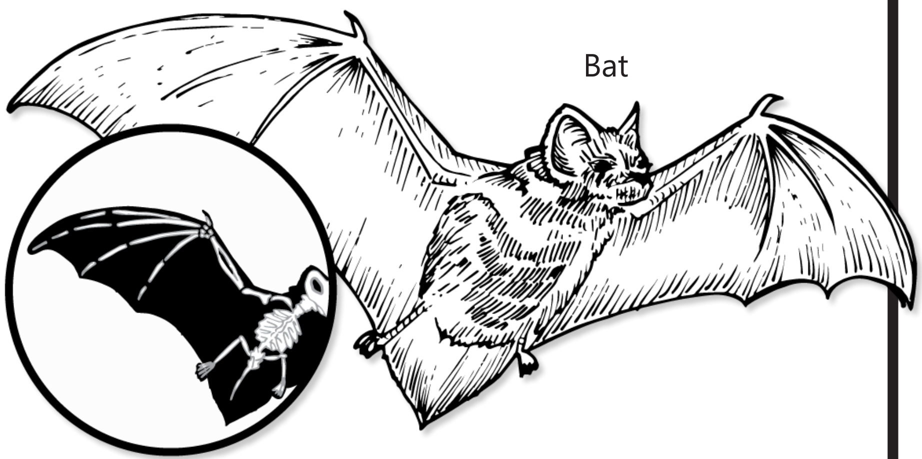
COMPARING & CONTRASTING BIRDS & BATS ANSWER KEY

Name: ______________________________ Date: ______________________________

Birds and bats are an example of convergent evolution. Circle the similar and different features of these two organisms, paying close attention to size, number, and shape. Then, answer the questions below.





List the characteristics these organisms have in common:

Possible responses:

- wings
- bones
- backbones
- legs

List the characteristics these organisms have that are different:

Possible responses:

- feathers (bird)
- fur (bat)
- number of fingers
- wing shape

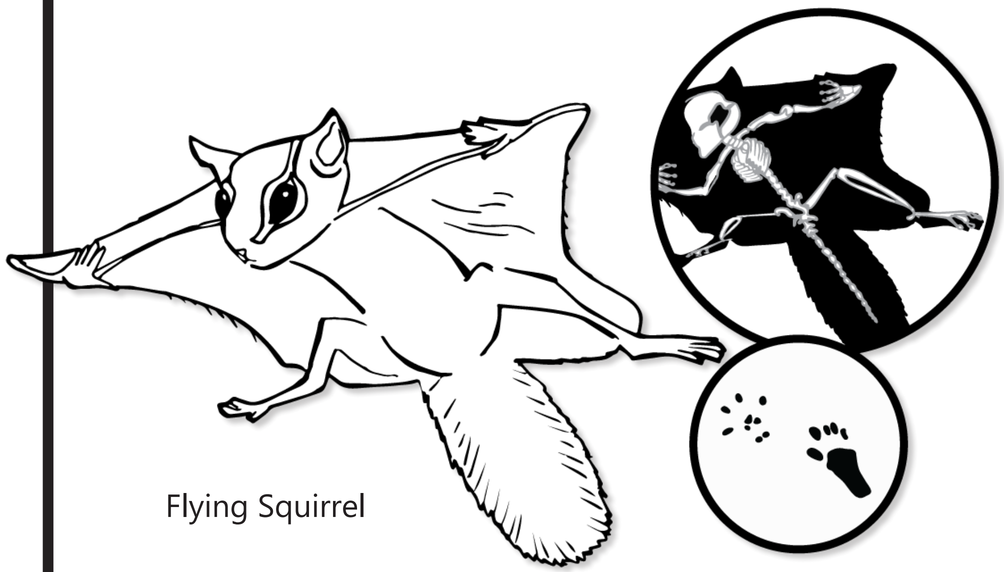
How do these adaptations help birds and bats survive in their environments?

The ability to fly helps birds and bats find food and escape predators.

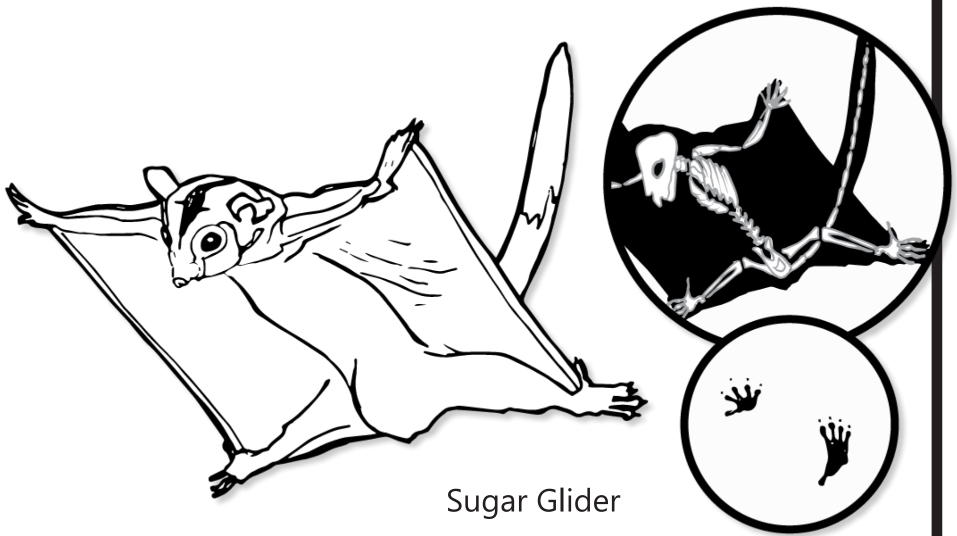
COMPARING & CONTRASTING MAMMALS

Name: ______________________________ Date: ______________________________

Are flying squirrels and sugar gliders another example of convergent evolution? Circle the similar and different features of these two organisms, paying close attention to size, number, and shape. Then, answer the question below.



Flying Squirrel



Sugar Glider

Are flying squirrels and sugar gliders an example of convergent evolution? Why or why not?

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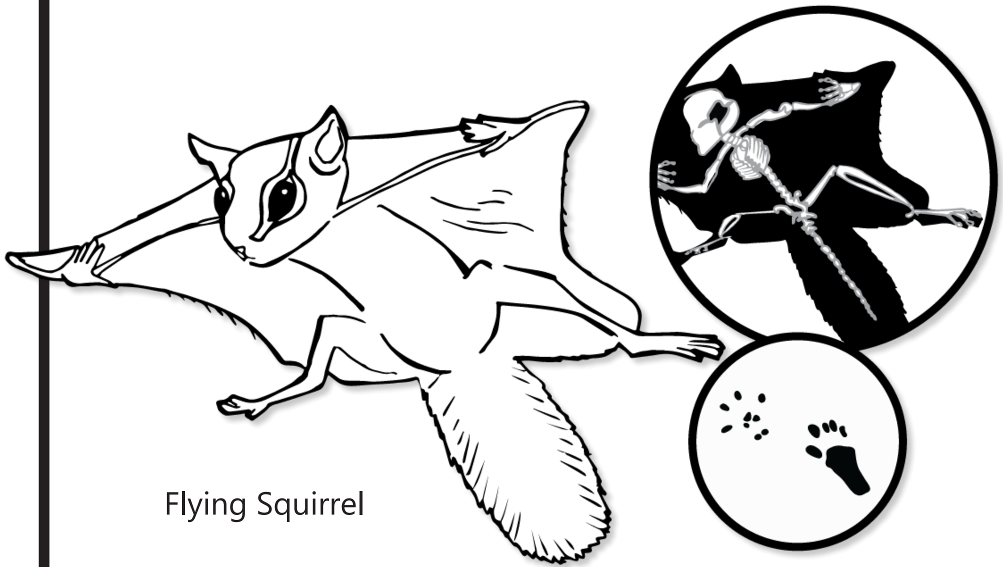
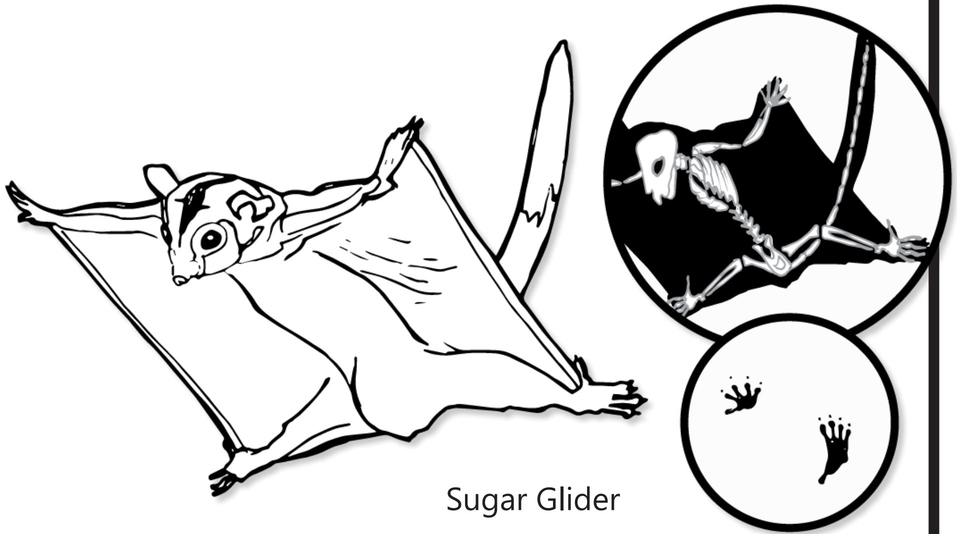
COMPARING & CONTRASTING MAMMALS ANSWER KEY

Name: ______________________________ Date: ______________________________

Are flying squirrels and sugar gliders another example of convergent evolution? Circle the similar and different features of these two organisms, paying close attention to size, number, and shape. Then, answer the question below.



Flying Squirrel



Sugar Glider

Are flying squirrels and sugar gliders an example of convergent evolution? Why or why not?

Possible response: Yes, flying squirrels and sugar gliders are an example of convergent evolution. They have many similar features, but scientists believe they are unrelated. Similar environmental pressures in North America and Australia forced them to evolve similar traits.

FLYING MACHINE DESIGN CHALLENGE

Name: ______________________________ Date: ______________________________

1. Define the Challenge

Write, in your own words, which challenge you are going to solve.

____

How would nature solve this challenge?

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Example:
I need to design a flying machine that can hover. I want to design a hovercraft. What animal adaptations allow animals to hover?

2. Research

List questions you have or information you need to solve your challenge.

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Write notes about animal adaptations from *Conquest of the Skies* that you could use in your design. Explain your reasoning. An example has been provided. You can add additional categories to the first column.

	ADAPTATION TO INCLUDE	ANIMAL INSPIRATION FROM FILM	REASON FOR INCLUDING IN DESIGN
How it gets up into the air	*Lifts straight up from the ground*	*Owl*	*Owl wings allow for a rapid, vertical take-off*

FLYING MACHINE DESIGN CHALLENGE (CONT.)

	ADAPTATION TO INCLUDE	ANIMAL INSPIRATION FROM FILM	REASON FOR INCLUDING IN DESIGN
How it gets up into the air			
How it stays up there as long as it needs to			
How it moves in the direction it needs to go			
How it comes back down safely			
How it lands			

FLYING MACHINE DESIGN CHALLENGE (CONT.)

Example: Design a hovercraft that takes off vertically, like an owl does.

3. Propose a Solution

What do you think your flying machine should look like?

____

What should it do?

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What animal adaptations will be most important?

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4. Design

Draw a picture of your idea and label it with units. List the materials you would need to build a model. Explain why you think it will work.

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FLYING MACHINE DESIGN CHALLENGE (CONT.)

5. Test

Write a summary of the feedback you received from your classmates.

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6. Evaluate and Adapt

Explain the changes to your design that will incorporate the feedback you received during the testing phase.

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PEER REVIEW FEEDBACK

Group being reviewed: ______________________________

1. Which animals from *Conquest of the Skies* are being used in the design?

2. What is one thing you like about this design? Why?

3. One question for this group is…

4. What is one thing you suggest changing about this design? Why?

GLOSSARY

adaptation	*noun.* a modified physical or behavioral characteristic of an organism that helps the organism to survive in a place or situation.
biomimicry	*noun.* imitating, or copying, naturally occurring characteristics of organisms in nature and recreating these features in human-made designs and products.
characteristic	*noun.* feature or quality.
convergent evolution	*noun.* the development of similar characteristics by unrelated organisms through evolution.
diversity	*noun.* difference.
drag	*noun.* one of the four forces that affects things that fly.
engineering	*noun.* problem solving.
engineering process	*noun.* a problem solving process.
evolve	*verb.* to develop gradually through a process of adaptation and natural selection.
force	*noun.* an invisible push or pull.
gravity	*noun.* one of the four forces that affects things that fly.
habitat	*noun.* environment where an organism lives or naturally occurs.
invertebrate	*noun.* organism without a backbone.
lift	*noun.* one of the four forces that affects things that fly.
organism	*noun.* living or once living thing, such as a type of plant, animal, or fungus.
prediction	*noun.* educated guess about an unknown.
surface area	*noun.* amount of area on the surface of an object.
survival	*noun.* continuous ability to live.
thrust	*noun.* one of the four forces that affects things that fly.
vertebrate	*noun.* organism with a backbone or spine.
weight	*noun.* the measure of the force of gravity acting on the mass of an object.