# LIFT AND ANGLE OF ATTACK

PRE-PLANNING

## OBJECTIVE
What will your students be able to do?

Students will be able to explain how lift is generated by a flat plate wing.

## KEY CONCEPTS AND VOCABULARY
What three-five key points will you emphasize?

- How lift is generated
- How angle of attack is related to lift
  - Stall angle
- Vocabulary – Lift, Span, Chord, Airfoil, Angle of Attack.

## CONNECTION TO THE BIG IDEA
How does the objective connect to the big idea?

Lift is the main reason why birds are able to fly. Different birds need different amounts of lift at different stages of flight (whether taking off, landing, gliding, flapping, etc.). Several factors affect lift, such as angle of attack, wing span (and surface area), velocity, and density. It should also be noted that the same relations are valid not only in air but also in other mediums, such as water.

## ASSESSMENT
How will you know whether your students have made progress toward the objective? How and when will you assess mastery?

Exit Slip Questions:

1. When a bird is coming into land, it is flying very slowly. How do you think the bird can increase its lift so that it doesn't fall?
2. What 3 things can you change about your model bird that will help it to fly longer?
3. What 3 things can you change about an airfoil and the medium it is flying in so that it generates more lift?

LESSON

## OPENING (2 min)
How will you communicate *what* is about to happen? How will you communicate *how* it will happen?
How will you communicate its *importance*? How will you communicate *connections* to previous lessons?

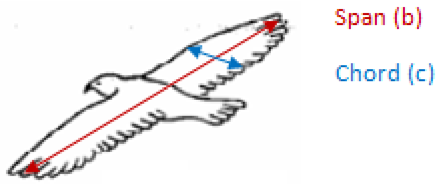
*Hello! How is everyone? Think about the first image that comes into your mind when I say the word "flight." Did you think of an airplane or a bird? Both have similarities: both consist of a body (fuselage), wing, and tail, though the exact shapes differ. Which would go further when you throw it? A paper airplane or a small stone (of the same weight)? Why do you think so? What is the main difference between the two?* (Yes! Wings!) *And how do wings help the plane to fly?* (someone will say "Lift"). *So let's experiment a little… a paper airplane has wing made of flat pieces of paper… but what would happen if we were to throw a flat piece of paper? Would it fly?* (demonstrate)*… So today we are going to find out how wings generate lift so that a paper airplane, a bird or an airplane can fly.*

## MATERIALS
What materials will you need for your lesson?

- Per plane:
  - poster board
  - scissors
  - tape
  - clay
- LCD projector
- Print outs of concept maps

## DIRECT INSTRUCTION (8 min)
What key points will you emphasize and reiterate?
How will you ensure that students actively take-in information?
How will you vary your approach to make information accessible to all students?
Which potential misunderstandings will you anticipate?
How will your students be using a Concept Map or other structured tool?

First, let's think about a bird. The main part of the bird that helps it fly is its wings. Here are some parts of the wing:

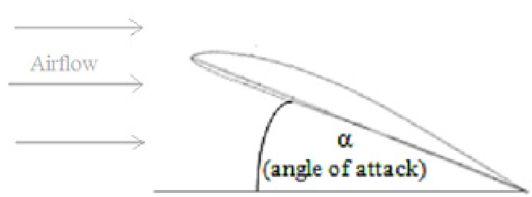



So let's look at a wing more closely. Imagine looking at the side of a bird down along the *span* of the wing. If we simplify it, it will look like this:

This shape is called an **airfoil,** and it can be used to more simply analyze the forces on a bird's wing. Air will flow around the airfoil (both above and below). The air will follow the shape of the airfoil; since the airfoil is curved, the air is pushed downward by the airfoil.

Show simulation/youtube video…
http://www.youtube.com/watch?v=7jTeiz_f1iY
http://www.grc.nasa.gov/WWW/K-12/airplane/foil2.html

*There is a law (called Newton's laws that you will learn about a little later) that says if the air is pushed down by the airfoil, then the airfoil is pushed up by the air. You may have heard this being said…"for every action, there is an equal and opposite reaction". In other words, every force exerted has an equal and opposite force exerted back. We can demonstrate this by using a skate board and a basketball. Can anyone guess how we would demonstrate this law? Right! If you stand on the skate board with the basketball, then throw the basketball in the direction of the skate board wheels, then you and the skate board will move in the opposite direction. Equal and opposite. What do you think you can change so that you move faster? Right! The faster you throw the ball, the faster you'll move.*
*Can you think of other examples of action-reaction? Have you noticed what happens to fan blades when a fan starts to move? The blades are pushing air down (that's how you feel cool)… and the blades actually curve up. So if we have a flat plate like this* (demonstrate with a piece of paper at no angle)… *and air is rushing past it… do you think there is any lift being generated? What can we change so that air is pushed down by the paper and lift is generated? Right! We can put it at an angle – this angle is called **Angle of Attack**. The angle of attack is the angle that the chord makes with the direction of airflow.*




*But what will happen if we increase the angle too much?*
Show video: http://www.youtube.com/watch?v=N_fMaey-lRU

*This is called **Stall Angle**…and the bird or airplane will lose its lift and fall! So what do you need to look out for when you test fly your plane?*
*What other things can you change about your model that will help it fly longer?*
(Elicit span and chord of the wing)

DIRECTIONS FOR EXPERIMENT(5 min)

How will you clearly state and model behavioral expectations?
How will you give 3-5 clear directions for the activity and model them?

*We are going to design and build bird-shaped and sized models. How do you think we will know whether a model is well designed?* (elicit range or hang-time)
*Everyone will build different wings for your models; you will each build two models (one with zero angle of attack, and one with some positive value of angle of attack).*

EXPERIMENT (40-60 min)

What kind of activity can be performed by students that directly relates to your objective and the big idea?
How will you engage students and capture their interest to explore the concept?
What exactly will your students be doing during the activity? What will you be doing?
How will your students be using a Concept Map or other structured tool?

Students will build aircraft using poster board for the fuselage, wing, and tail. Students can choose what size of a wing they wish to build. They should be documenting the dimensions of their wing. Students will test the performance of the aircraft by measuring the gliding distance and then compare the first set of results with a wing set at a higher angle of attack. Students should tell a difference in performance of the two wing settings. They should also compare their results with other students to see the effect of wing shape on performance.

REFLECTION (5 min)

How will students summarize what they learned?
How will students be asked to state the significance of what they learned?
How will students relate what they learned back to your objective and big idea using key vocabulary?

*What did you notice about the glide distances for different wing sizes? How about the angle of attack? Who thinks that his/her plane flew the farthest? Why do you think this configuration went the farthest? What else could we have changed (besides wing shape and angle of attack) to improve the performance of these planes?*

Students should write down the dimensions of their aircraft and the corresponding glide distances obtained with and without their wing set at a positive angle of attack. Students should then write down the results of two other groups that used a different sized wing and compare results. Students should draw conclusions about the effect of span, chord, and angle of attack on performance (glide distance).

# DRAG

## PRE-PLANNING

### OBJECTIVE
What will your students be able to do?

Students will be able to explain the difference between the different types of drag, what components affect drag, and how to improve the L/D for a bird/aircraft.

### KEY CONCEPTS AND VOCABULARY
What three-five key points will you emphasize?

- Drag (parasite, induced)
- Vocabulary – Parasite Drag, Induced Drag, L/D, Aspect Ratio

### CONNECTION TO THE BIG IDEA
How does the objective connect to the big idea?

We will understand why birds' bodies have particular shapes, why birds change wing shape when flying at different speeds, why birds with long, narrow wings can glide so far and for so long etc.

### ASSESSMENT
How will you know whether your students have made progress toward the objective? How and when will you assess mastery?

Exit Slip Questions:

1. Drag slows down (or holds back) an object, so what are two things that a bird can do to decrease its drag?
2. What are the differences in flight characteristics of a pigeon and a seagull? Why do you think there are these differences?

## LESSON

### OPENING (2 min)
How will you communicate *what* is about to happen? How will you communicate *how* it will happen?

How will you communicate its *importance*? How will you communicate *connections* to previous lessons?

*Hello! How is everyone? Do you remember what we talked about last week? Right, lift! What are some of the factors that affect lift?* (AoA, span, chord) *Do we remember why there is lift?* (Equal and opposite forces) *But there are other forces besides just lift. What do you think some of these forces could be? Yes! One force is drag. Can anyone tell me what drag is? Yes! Drag is a force that slows you down (or drags you back). So if a bird is flying to the left, can anyone tell us in which direction the drag force will be acting?*

### DIRECT INSTRUCTION (8 min)
What key points will you emphasize and reiterate?

How will you ensure that students actively take-in information?

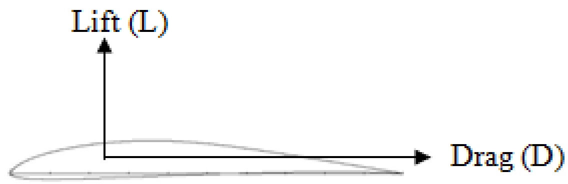
How will you vary your approach to make information accessible to all students?

Which potential misunderstandings will you anticipate?

How will your students be using a Concept Map or other structured tool?

### MATERIALS
What materials will you need for your lesson?

- Per plane:
  - poster board
  - scissors
  - tape
  - clay
- LCD projector
- Print outs of concept maps
- Meter stick (or measuring tape)




*There are actually two main types of drag. One is* ***parasite drag****. Can anyone guess what Parasite Drag could be? Parasite drag is the drag caused by the air molecules rubbing against the bird. Think about all the tiny air molecules everywhere; when I stand here, the air molecules are bumping into me because I'm in their way. What do you think would happen if the bird was in a vacuum?*

*What do you think we can do to reduce parasite drag? Right! We can STREAMLINE our shape (kind of like what birds' bodies are like)… and we can smoothen out our bodies as well. Have you noticed how smooth a birds' body or wing can be? It's so that the parasite drag is minimum. Can you think of some other examples of reducing parasite drag?*

*The other type of drag is* ***induced drag****.*

*I am going to show you some pictures and videos and then we are going to try and discover the answer to why these wings are good. So watch carefully as the pictures and videos will give you clues to help solve the mystery of induced drag!*

Show ppt slide of wing tip vortices and videos of wing tip vortices. *Ok! So lets try and figure this out… What is happening in this picture? There are lots of these tiny air particles (molecules) on one side and not so many on the other. Can you guess in which direction this bar will move? Now what if this bar was a wing? Which direction would the wing move? Right! Up! So that is what is happening on a wing of a bird or an airplane. We have high pressure on the bottom – that is lots of air molecules on the bottom and fewer on the top. We don't have time to go into why that is so today, but you can learn about it when you study aerospace engineering ☺ or you can ask me for some good books and websites afterwards if you are interested. So when we have high pressure at the bottom and low pressure on top, what do you think will happen at the wing tip? Look at the pictures again for clues! Right! We have some leakage. This leakage is called induced drag. So how can we reduce this induced drag? Right! By having long, narrow wings or HIGH ASPECT RATIO wings. Can anyone tell me what kind of a wing would have no leakage ☺?*

*An infinite wing!*

*Here's a question: how do you judge how good a wing is? How should we compare wings? Engineers have a way to compare using what is called the* ***aerodynamic efficiency****. This is* ***L/D*** *(or lift divided by drag). One simple way to measure L/D is to divide the forward glide distance by the downward sink distance.*

DIRECTIONS FOR EXPERIMENT(5 min)

How will you clearly state and model behavioral expectations?

How will you give 3-5 clear directions for the activity and model them?

*We are going to design and build bird-shaped and sized models similar to those we made last week.  We are going to build one set of high aspect ratio wings and one set of low aspect ratio wings to place on the aircraft.   We are going to measure L/D (glide distance / sink distance = horizontal / vertical) and see which type of wing (high vs. low aspect ratio) produces the best aerodynamic performance.*

## EXPERIMENT (40-60 min)

What kind of activity can be performed by students that directly relates to your objective and the big idea?

How will you engage students and capture their interest to explore the concept?

What exactly will your students be doing during the activity?  What will you be doing?

How will your students be using a Concept Map or other structured tool?

Students will build aircraft using poster board for the fuselage, wing, and tail. Students will build a total of two wings (a high aspect ratio wing and a low aspect ratio wing).  For each test flight, students will measure the glide distance as well as the sink distance (distance from ground to the start of the plane's trajectory).  Students will calculate L/D for each test flight and draw conclusions about the relationship between L/D and aspect ratio.

## REFLECTION (5 min)

How will students summarize what they learned?

How will students be asked to state the significance of what they learned?

How will students relate what they learned back to your objective and big idea using key vocabulary?

*How different were your values for L/D for your four test flights?  Does a larger aspect ratio wing or smaller aspect ratio wing seem to be more aerodynamically efficient (higher L/D)?  What does this tell you about birds with long narrow wings? What about birds with short, wide wings?*

# REYNOLDS NUMBER AND VISCOSITY

## PRE-PLANNING

### OBJECTIVE
What will your students be able to do?

1. Students will be able to define what viscosity is.
2. Students will be able to define Reynolds number as inertial over viscous forces
3. Students will be able to use Reynolds number to explain how size affects whether an organism sees a sticky or inertial environment.

### KEY CONCEPTS AND VOCABULARY
What three-five key points will you emphasize?

- Viscosity is the stickiness of a fluid
- Animals move differently depending on how viscous (sticky) or (inertial) dense a fluid is
  - Reynolds number is inertia/viscosity
- The size of an animal changes its Reynolds number
- Animals develop different adaptations in accordance with their Reynolds Number

### CONNECTION TO THE BIG IDEA
How does the objective connect to the big idea?

The same fluid (air, water etc) can feel different to animals of different sizes. This phenomena can be represented by the Reynolds Number. Animals develop different adaptations in accordance with their Reynolds Number. Thus if we know the Reynolds Number of a particular bird, we can predict how the fluid will feel to it and what type of wing features it would have. Inversely if we see some particular wing features, then we can predict what the Reynolds Number of that bird could be. Thus if we wanted to design a model of a particular size, we would first estimate its Reynolds Number, look to nature to see what specific wing/fin features are suited to that Reynolds Number and then incorporate those into our design.

### ASSESSMENT
How will you know whether your students have made progress toward the objective? How and when will you assess mastery?

Exit Slips:

1. How do you think the air would feel to you if you were as small as a bumblebee? How do you think the air would feel to you if you were as big as an albatross? How does this relate to the type of forces the bumblebee and albatross feel?
2. Can you draw and show the difference between the molecules in a dense and viscous fluid?

## LESSON

### OPENING (2 min)
How will you communicate *what* is about to happen? How will you communicate *how* it will happen?

How will you communicate its *importance*? How will you communicate *connections* to previous lessons?

*Hello! Does anyone remember what we learned in the last two sessions? What did we learn that we could apply to our models to make them fly better? Right! If we put our wings at an angle of attack, they would generate more lift. If we had long, narrow (or high aspect ratio) wings, we would have lesser induced drag.*

*Today we are going to learn about how different sized birds develop different adaptations that make them fly better. We will learn two new terms – viscosity and Reynolds Number and then experiment with different sized bird models.*

### MATERIALS
What materials will you need for your lesson?

Per wing:

- 2 pieces of construction paper
- Tape
- Thread or thin

| | | |
|---|---|---|
| | DIRECT INSTRUCTION (8 min)<br>What key points will you emphasize and reiterate?<br>How will you ensure that students actively take-in information?<br>How will you vary your approach to make information accessible to all students?<br>Which potential misunderstandings will you anticipate?<br>How will your students be using a Concept Map or other structured tool? | pieces of tissue paper<br>• Scissors<br>• Miscellaneous objects to attach to wing (feathers, additional paper, etc) |
| | *Can anyone tell me what they think viscosity is? Right! Viscosity is how sticky a fluid is. We call a really viscous fluid a really sticky fluid. Can anyone think of a sticky fluid?* molasses, honey, syrup, jelly, peanut butter. *These are all fluids that are very sticky.*<br><br>*Let's draw a picture of it on the board. We have a bunch of molecules in some volume. Let's call this water. These molecules are bound together by really small forces that hold molecules together, called electromagnetic forces. We will draw these forces as strings that hold the molecules together. These strings are sticky, you can think of them like spider web strings. Viscosity is a measure of how many strings hold a fluid together. So this fluid, water, has about 2 strings coming from each molecule.*<br><br>*Let's draw air now. Air is much less viscous than water. How many strings should we draw for one air molecule?*<br><br>*Now different fluids will move at different speeds because they have different properties. When a fluid is more dense, there are more molecules close together. To move through a really dense fluid requires more force, since you have to push more molecules out of your way. Likewise, when a fluid is really viscous, there are a lot of sticky strings. To move through a really viscous fluid also requires more force, because you have to fight through more strings. So a more dense or a more viscous fluid requires more force but for different reasons, either because of the molecules or because of the strings. What we want to know is which one of these forces is more important, and to understand that, we use something called a Reynolds number.*<br><br>*Reynolds number is the ratio of inertial forces to viscous forces. What does this mean? Well, inertia is another way of saying forces that depend on density, and viscous forces are about viscosity. So this is a ratio of our dense- like stuff to viscous like fluids. This is also a ratio of the number of molecules in our fluid to the number of strings in our fluid.*<br><br>*Reynolds number is very important, because how big you are depends on what sort of forces you feel in a fluid. Ok, lets draw an elephant trying to get through a fluid. Here's the fluid, with molecules and strings. The elephant is huge, here is its head. He is so big, that he doesn't even notice the strings, all he notices is the number of molecules he has to push to the side when he moves through the fluid. So a big object only feels density forces, or inertial forces. We say big objects like elephants are at a high Reynolds number.*<br><br>*Now let's say you are a tiny bumblebee. When this small insect tries to move through the fluid, the molecules are so big that what the insect notices is just the strings between the molecules. What matter to a small object is the viscosity. Because of this, we say small insects are at a low Reynolds number.*<br><br>*When you are at a higher Reynolds number, the flow appears very chaotic and turbulent. Can anyone predict how the flow would appear if you were at a low* | |

*Reynolds number. Right! Its very orderly and slow. Such flow is called laminar.*

*Small insects and birds have many interesting modifications that help them to change this slow, laminar flow to a faster, turbulent flow as they generate more lift if the flow is going faster.*

*So for example, if you observe carefully, a bird's feathers rise when its coming into land. The bird's speed is low and so the flow is laminar. So when its feathers rise, the flow tries to go around the feathers and becomes turbulent.*

*Dragonfly wings have similar "turbulators". Their wings are corrugated, causing the flow to bump along and become more turbulent.*

*Can anyone think of how a bat's wings are similar to these examples?*

## DIRECTIONS FOR EXPERIMENT(5 min)

How will you clearly state and model behavioral expectations?

How will you give 3-5 clear directions for the activity and model them?

Today's challenge is going to be design tiny flying models with turbulators that will help them fly better.

## EXPERIMENT (40-60 min)

What kind of activity can be performed by students that directly relates to your objective and the big idea?

How will you engage students and capture their interest to explore the concept?

What exactly will your students be doing during the activity? What will you be doing?

How will your students be using a Concept Map or other structured tool?

Students will build small models of birds and insects, adding components (stickers, feathers, flaps, etc) to the wings to make the models fly.

## REFLECTION (5 min)

How will students summarize what they learned?

How will students be asked to state the significance of what they learned?

How will students relate what they learned back to your objective and big idea using key vocabulary?

Students should be able to point out how additional features to the wing can affect performance of an aircraft. Students should connect the performance with the way air flows around the wings (laminar vs. turbulent). Students should also describe and think of ways that birds and insects can change the air flow around their wings during flight and why they would do so.

*I'd like to go through our Reynolds Number poster/T-shirt with them at the end.* Starting at small sizes, we have bacteria with flagella to move around. Ciliates use a similar structure called a cilia to move. The copepods use their antennae, its still very stringy, but it looks like a paddle. The dragonfly uses wings as flat surfaces to fly. The fish and bird have even bigger, more developed surfaces. Finally the whale has a big tailfin to push water behind it when it swims.

| | | |
|---|---|---|
| | As humans, we move through fluids. We move through air when we run, or water when we swim. We are big animals, at high Reynolds number. When we swim, we open the big fat paddle we call our hand to push as much mass of fluid behind us as we can. This is an inertial way of moving. Think about trying to swim or walk in a pool of honey, or molasses. In the low Reynolds number, or viscous, fluid like honey, our normal swimming motion would get us nowhere. But if we had a rope like a bacteria's flagella that we could whip around in a circle, it would work much better.<br>By looking at the size of animal, we can tell how it swims. And by looking at how an animal swims, you can tell if it sees an inertial or viscous fluid. Next time you see an animal moving through a fluid, see if you can tell where it fits on this chart, just by watching how it moves. | |

# FLAPPING FLIGHT

PRE-PLANNING

## OBJECTIVE
What will your students be able to do?

Students will be able to explain how lift is generated when birds flap their wings. Students will also be able to explain why birds pitch and flex their wings at certain points of the flap cycle.

## KEY CONCEPTS AND VOCABULARY
What three-five key points will you emphasize?

- Three main motions of flapping flight: flap, pitch, and flex
- Flap consists of down stroke and up stroke
- Pitch is used to change the angle of attack of the wing
- Flex is used to change the surface area (wing size)

## CONNECTION TO THE BIG IDEA
How does the objective connect to the big idea?

We will try and understand how the flapping motion generates lift and thrust and helps a bird to fly.

## ASSESSMENT
How will you know whether your students have made progress toward the objective? How and when will you assess mastery?

Exit Slip Questions:

1. What design changes would you make to your arms and legs so that you can swim better? What scientific principles are your changes based on?
2. Why do you think a pigeon's wing is this shape and an albatross' wing is this shape?

LESSON

## OPENING (2 min)
How will you communicate *what* is about to happen? How will you communicate *how* it will happen?
How will you communicate its *importance*? How will you communicate *connections* to previous lessons?

*Does everyone remember the two topics that we have covered so far? (Lift and Drag.) Can anyone share what they think are the best wing designs to have? What are some common wing characteristics among birds that glide? What about smaller birds? How do they tend to fly?* (Mostly flap rather than glide.) *So today we will try and understand how flapping birds are able to fly….*

## DIRECT INSTRUCTION (8 min)
What key points will you emphasize and reiterate?
How will you ensure that students actively take-in information?
How will you vary your approach to make information accessible to all students?
Which potential misunderstandings will you anticipate?
How will your students be using a Concept Map or other structured tool?

(Show some videos of different birds – both large gliders and small flappers).

## MATERIALS
What materials will you need for your lesson?

Per ornithopter:

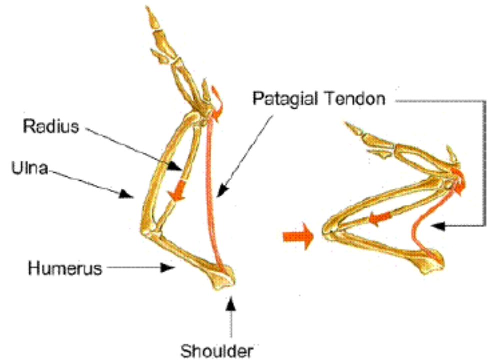
- 1 bottle CA glue
- fds
- Coffee stirring sticks:
  - 1 in. (2)
  - 1.5 in (2)
  - 2.5 in. (1)
  - 3.5 in. (3)
  - 4.5 in. (1)
  - 5 in. (2)

*What do you notice about all the birds that are gliding? What do you notice about all the birds that are flapping?*

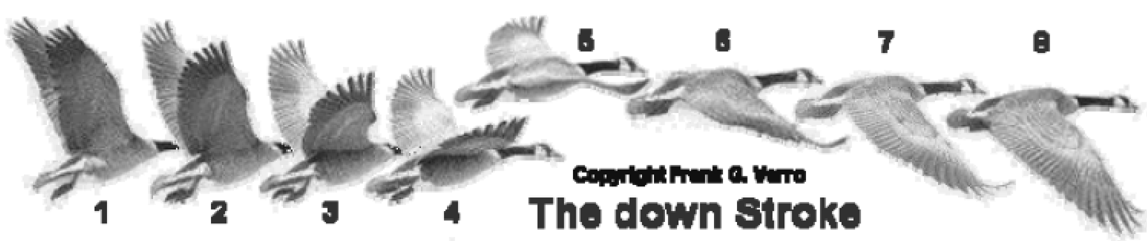
*For the past two lessons, we've been dealing with gliding flight, which is suited for larger birds. Now let's take a look at flapping flight (that is more commonly seen in smaller birds).*

*There are three main movements in flapping flight:*

1. ***Flap** (up and down movement of the wing about the shoulder joint)*
2. ***Pitch** (rotating the wing along the span to change angle of attack)*
3. ***Flex** (lengthening and shortening the wing)*




There are two main strokes: the **down stroke** and the **up stroke**.




*If you recall the action-reaction principle, can you predict which stroke would help the bird to lift up?*
*A similar example is when you are swimming in water.*
*Flapping motion is quite similar to a "swimming" motion in air. Let's look at a different animal under water and compare its motion with that of a bird. (Play video of turtle swimming through water.)*
*When you want to get from the bottom of the pool to the surface, you would push downward with your arms (and legs) because when you push down, your body goes up.*
*Also, what do you do (while swimming) so that your body moves forward? Right! You move your arms back and thus go forward. Same thing for a bird, except that it is in air, not water.*

*Now…what do you think is the difference between the upstroke and the downstroke? Let's look at some videos to see…*
(videos of flapping flight – notice how down stroke lasts longer than up stroke.)

*Lets observe the videos a bit more carefully… what do you observe about the wing's angle? Right! It changes and rotates…*

- Paper clips
  - 2.25 in (1)
  - 2 in (2)
  - 1.25 in (1)
- Rubber band
- Beads
- Tissue paper or plastic bag

*The rotation of the wing along the span is called **pitch**. Can anyone share why they think a bird will pitch its wing during a flap cycle? Right! To change its AoA to get better lift!*

*Lets observe even more closely! What do you notice the bird doing on the up stroke? (Yes, it bends – flexes – its wing). What do you think **flexing** helps the bird to do? (Yes, it makes the wing smaller.) Remember when we experimented with small and large wings and measured the aerodynamic efficiency? Which wing experiences more drag – a large wing or a small wing? A larger wing will have more drag, so a bird will "shrink" its wing during the upstroke to minimize drag.*

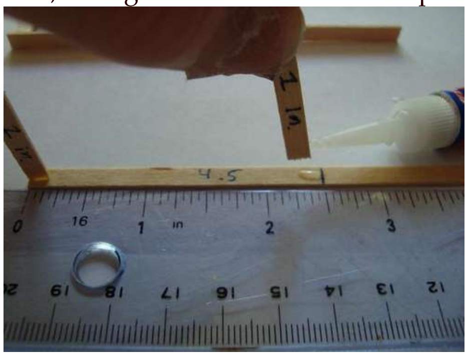
DIRECTIONS FOR EXPERIMENT(5 min)
How will you clearly state and model behavioral expectations?
How will you give 3-5 clear directions for the activity and model them?

*We are going to build our own flapping birds today. A flapping mechanism is called an **ornithopter.** This word comes from the Greek words, "Ornithos" ("bird") and "Petron" ("wing").*
*We are going to then measure the overall glide distance of this and see if the distance is comparable to that of our gliding models.*

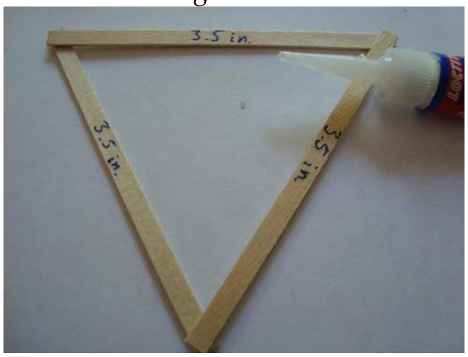
EXPERIMENT (40-60 min)
What kind of activity can be performed by students that directly relates to your objective and the big idea?
How will you engage students and capture their interest to explore the concept?
What exactly will your students be doing during the activity? What will you be doing?
How will your students be using a Concept Map or other structured tool?

Directions:
(Note: wires will be pre-bent already.)

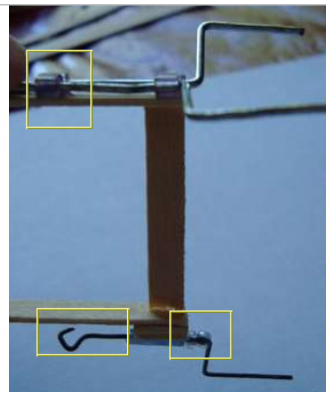
1. Glue 1-in sticks to 4.5-in stick, then glue 2.5-in stick across top:



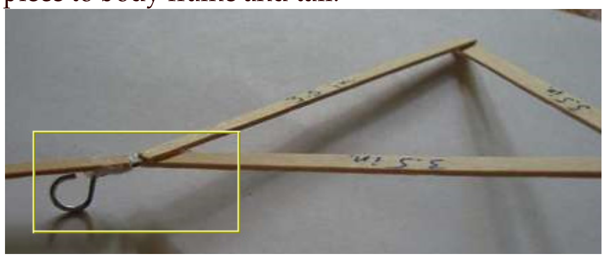

2. Glue the 3.5-in sticks together into a triangle:



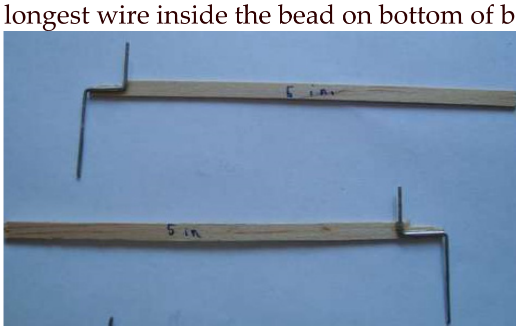

3. Glue beads on the body frame:

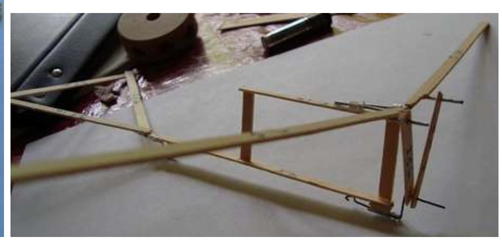


4. Glue smallest wire piece to body frame and tail:

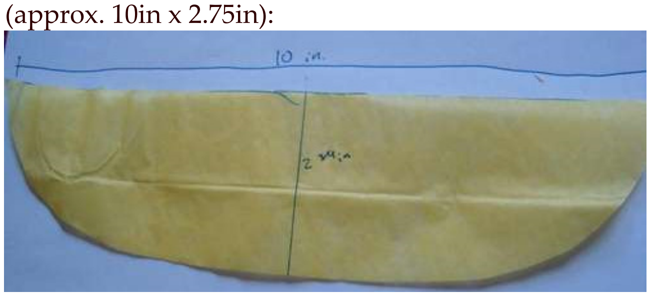


5. Attach other wires to 5-in sticks (wing structure) and punch two holes with those wires into the 1.5-in sticks. Punch the longest wire into both of the 1.5-in sticks, and insert this longest wire inside the bead on bottom of body frame.



6. Cut out the wing (approx. 10in x 2.75in):




7. Glue wing to wing spars (5-in sticks):

8. Attach rubber band on the two wires, wind, and let go to fly.

REFLECTION (5 min)

How will students summarize what they learned?
How will students be asked to state the significance of what they learned?
How will students relate what they learned back to your objective and big idea using key vocabulary?

*What did you notice about the performance of the ornithopter compared to the glider from last week? What are some ways in which you can improve your design?*