

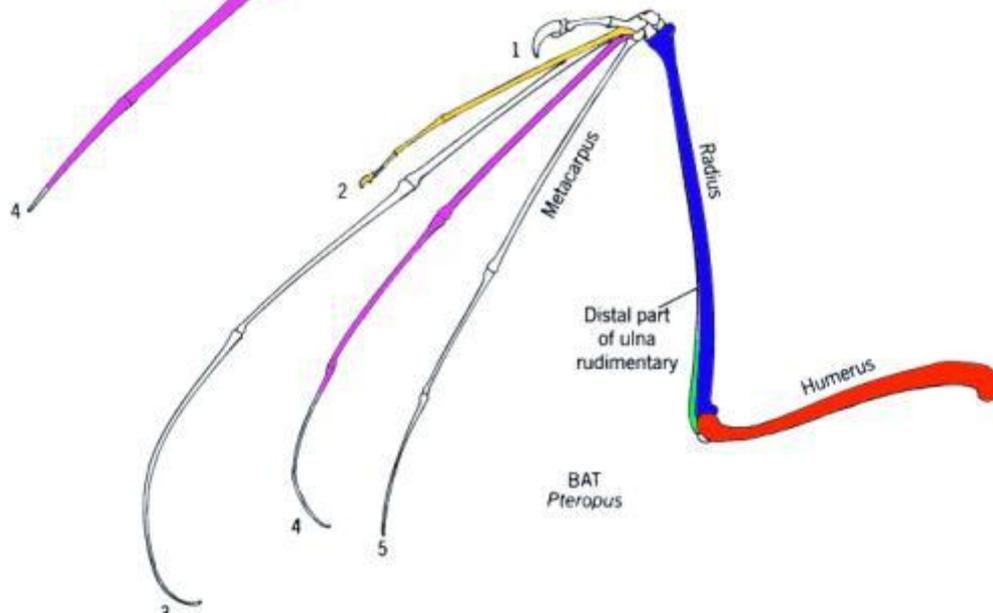
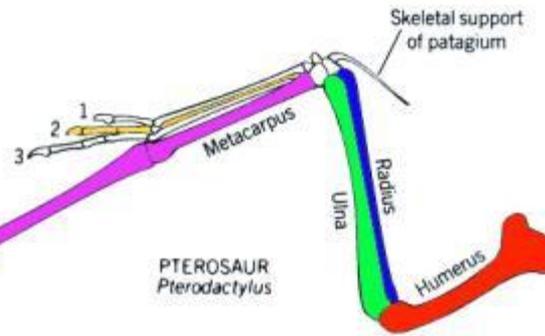
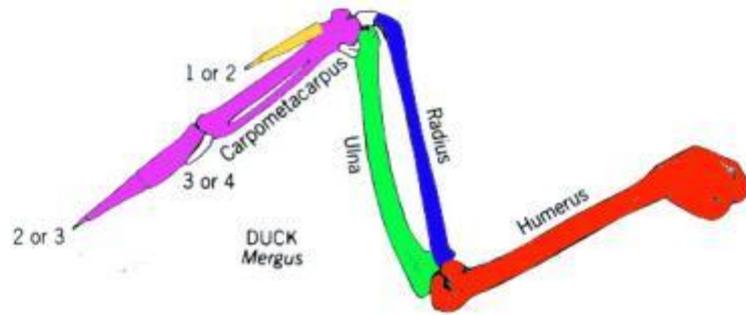
# Biology 342

## Flight

Stuart S. Sumida / Kathleen Devlin

# FLIGHT...FOUR TIMES

- Birds
- Bats
- [Extinct] Flying Reptiles
- Bugs



## GENERAL REQUIREMENTS OF CREATURES MOVING THROUGH A FLUID MEDIUM (INCLUDING FLYING THROUGH AIR)

- Reduce drag – convergence on a fusiform body shape.
- Propulsion – thrust
- Maintain stability – maneuver, brake, stop (land)

## REQUIREMENTS OF CREATURES THAT FLY

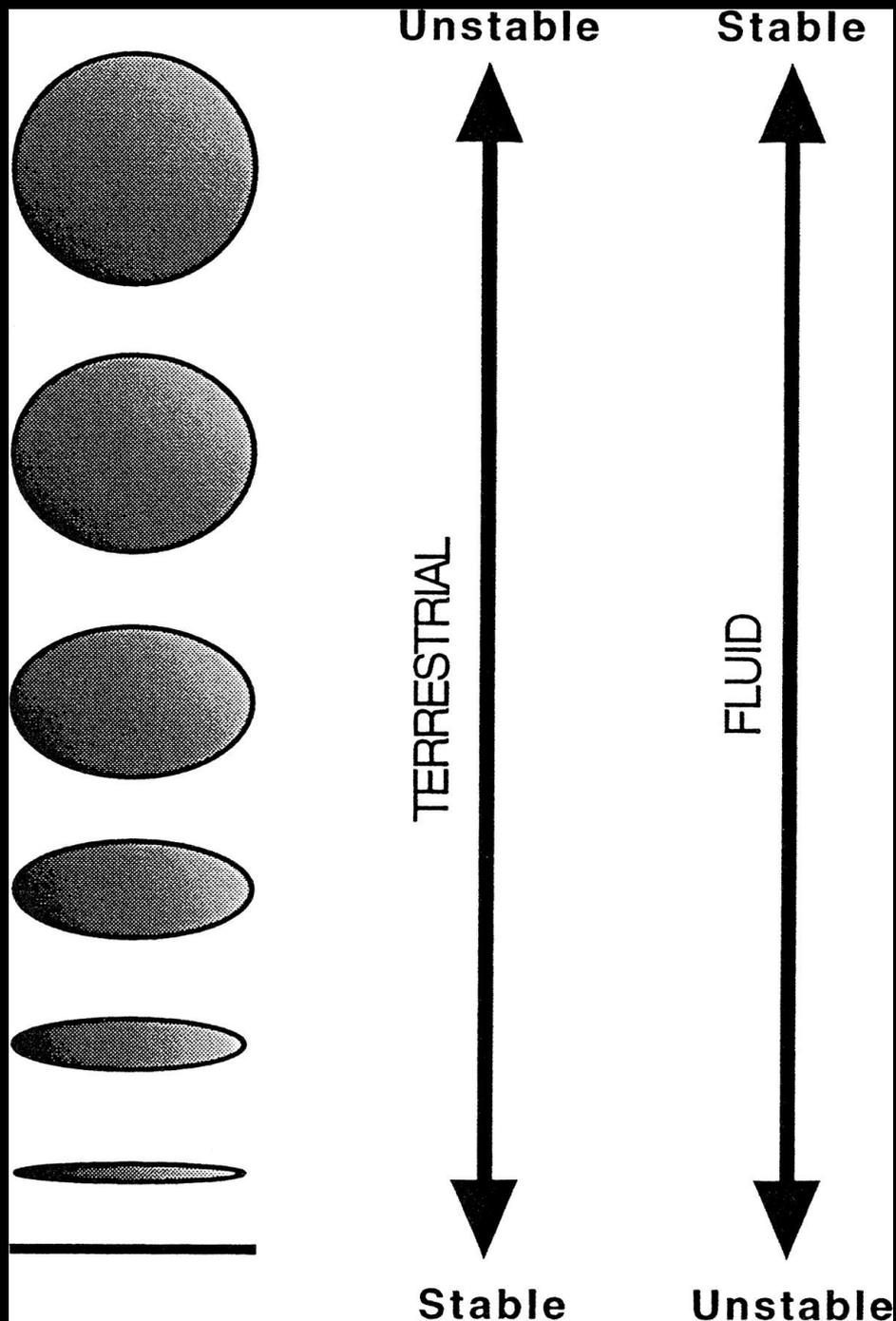
- Generate enough lift to counteract gravity (don't fall)
- Light weight
- Relatively stiff trunk

# DRAG

- Drag is the resistance that air (or any other fluid) imposes on the motion of the flying creature.
- Drag is reduced by reducing friction – smooth skin, feathers laid down close to body.
- Drag is reduced by a fusiform body shape.
- Drag is reduced by reducing surface area presented to fluid/air. (More on that in flapping flight.)
- Drag is reduced by having narrow wing tips with pointed wings (like a jet fighter).

# THE FUSIFORM BODY SHAPE

- Generally torpedo shaped.
- Blunter nose than tail
- Appendages detract from completely fusiform body shape and so must compensate by generating lift.



Gradient of cross-sectional morphologies. In a terrestrial environment, stability is gained in transition from a circular to flattened design. The reverse occurs in a fluid environment (*i.e.*, air, water) with the flatten profile being unstable. If canted at angle, the flat plate will produce lift which will destabilize its position, whereas no lift is incurred for the circular profile

# FORCES ACTING ON A FLYING CREATURE:

- Downward force – GRAVITY (falling)
- Upward force – LIFT
- Backward force – DRAG
- Forward force – PROPULSION

# LIFT – I

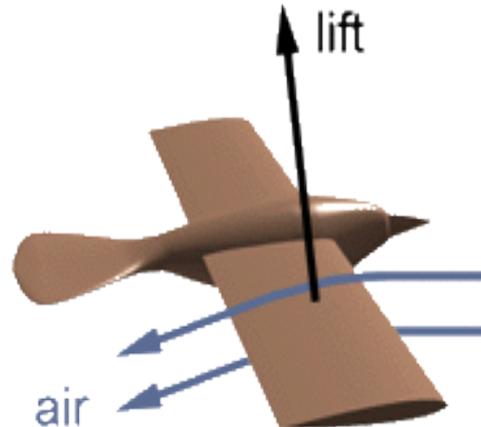
## (MOSTLY ABOUT LIFT)

- A common myth about birds and other flying things is that they flap their wings to produce lift.
- Actually, they produce lift in the same way as an airplane, simply by their forward motion through the air and the air's movement past the lift mechanism (wing).
- What the flapping does is continue that forward motion.
- To understand how a wing produces lift, consider example of simple gliding flight first.

## LIFT – II

### GLIDING FLIGHT

- When just gliding, a creature moves forward through the air, wings held in a fixed position.
- Wings are at a slight angle, so they deflect the air gently downward. Pushing the air downward causes a reaction force in the opposite direction.
- The reaction force is called LIFT. Lift is a force that acts roughly perpendicular to a wing surface and keeps the creature from falling.



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- In gliding flight, a creature's wings deflect air downward, causing a lift force that holds the creature up in the air.

## DRAG – I

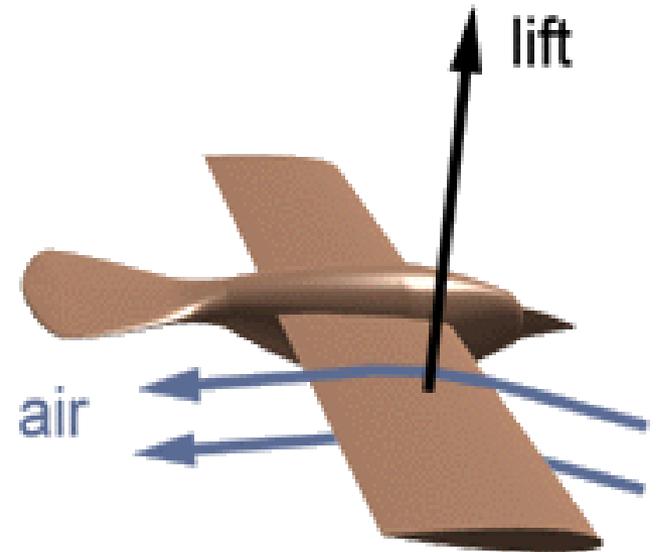
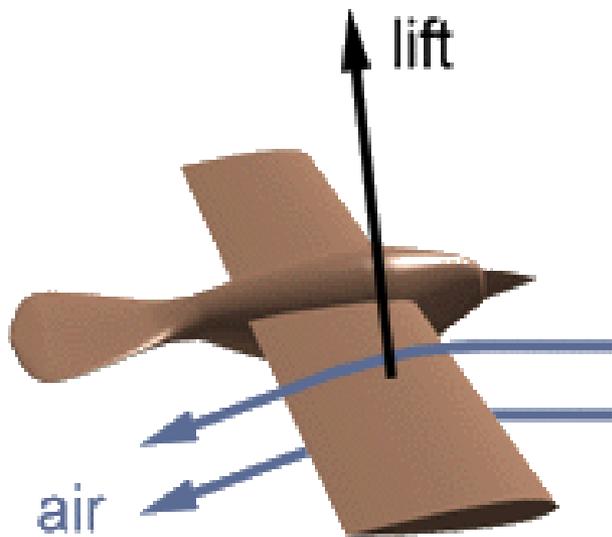
- There is also air resistance or drag on the body and wings of a flying creature.
- This force would eventually cause the creature to slow down, and then it wouldn't have enough speed to fly.
- To compensate, the bird can lean forward a little and go into a shallow dive.
- That way, the lift force produced by the wings is angled forward slightly and helps the bird speed up.
- Really what the creature is doing here is giving up some height in exchange for increased speed.
- Thus the creature must always lose altitude, relative to the surrounding air, if it is to maintain the forward speed that it needs to keep flying.

## LIFT – III; ANGLE OF ATTACK

- Recall that the wings are angled slightly, which allows them to deflect the air downward and produce lift.
- The slight angle of the wings is called the ANGLE OF ATTACK.
- If the angle of attack is too great, the wing will produce a lot of drag.
- If the angle is too small, the wing won't produce enough lift.
- (The best angle depends on the shape of the wing, but it's usually just a few degrees.)
- Note(!) What matters is the angle relative to the direction of travel, not relative to the horizon.

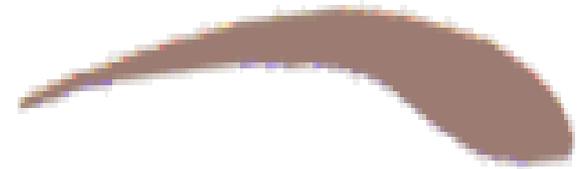
By tilting forward and going into a slight dive, the bird can maintain forward speed.

This is called changing the **ANGLE OF ATTACK**





The angle of attack determines the amount of lift and drag made by the wing.



The creature has a cambered, or curved, cross-section.

## LIFT – IV

### BERNOULLI EFFECT – 1

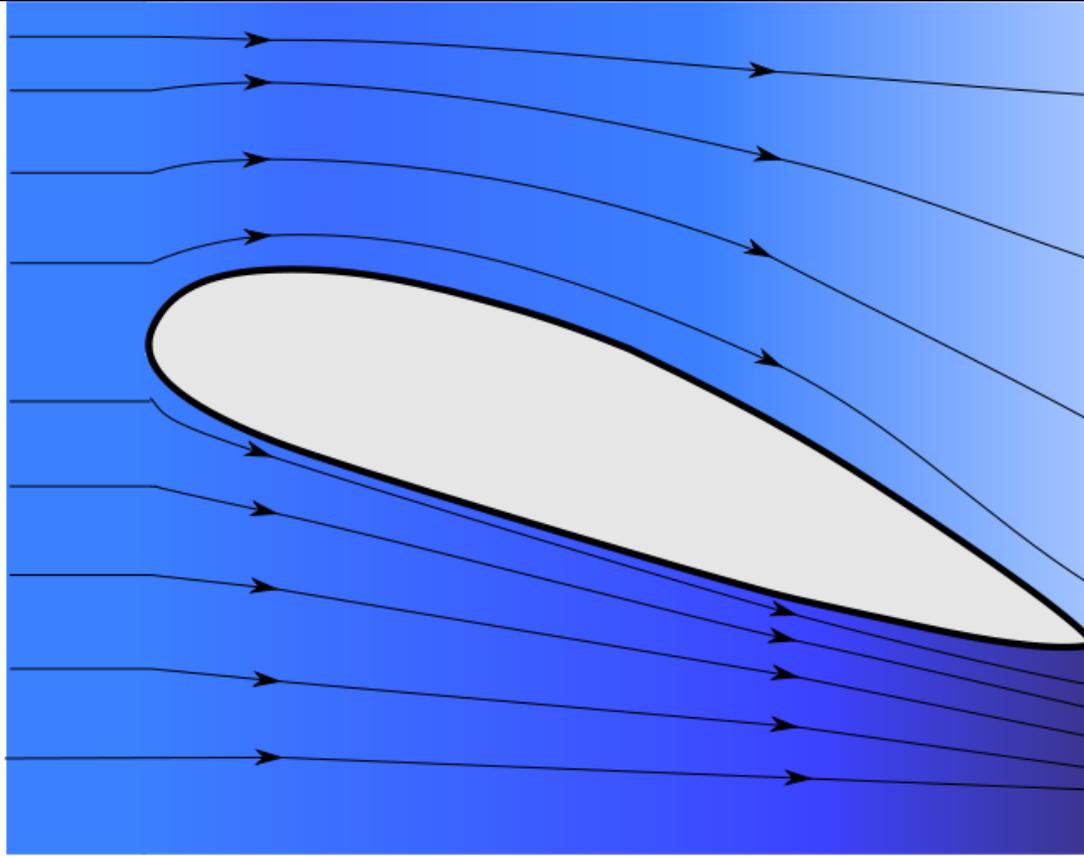
- With no angle of attack, air/fluid moves past wing, air flows equally under and over the wing.
- Thus, there is no upward force.

## LIFT – V

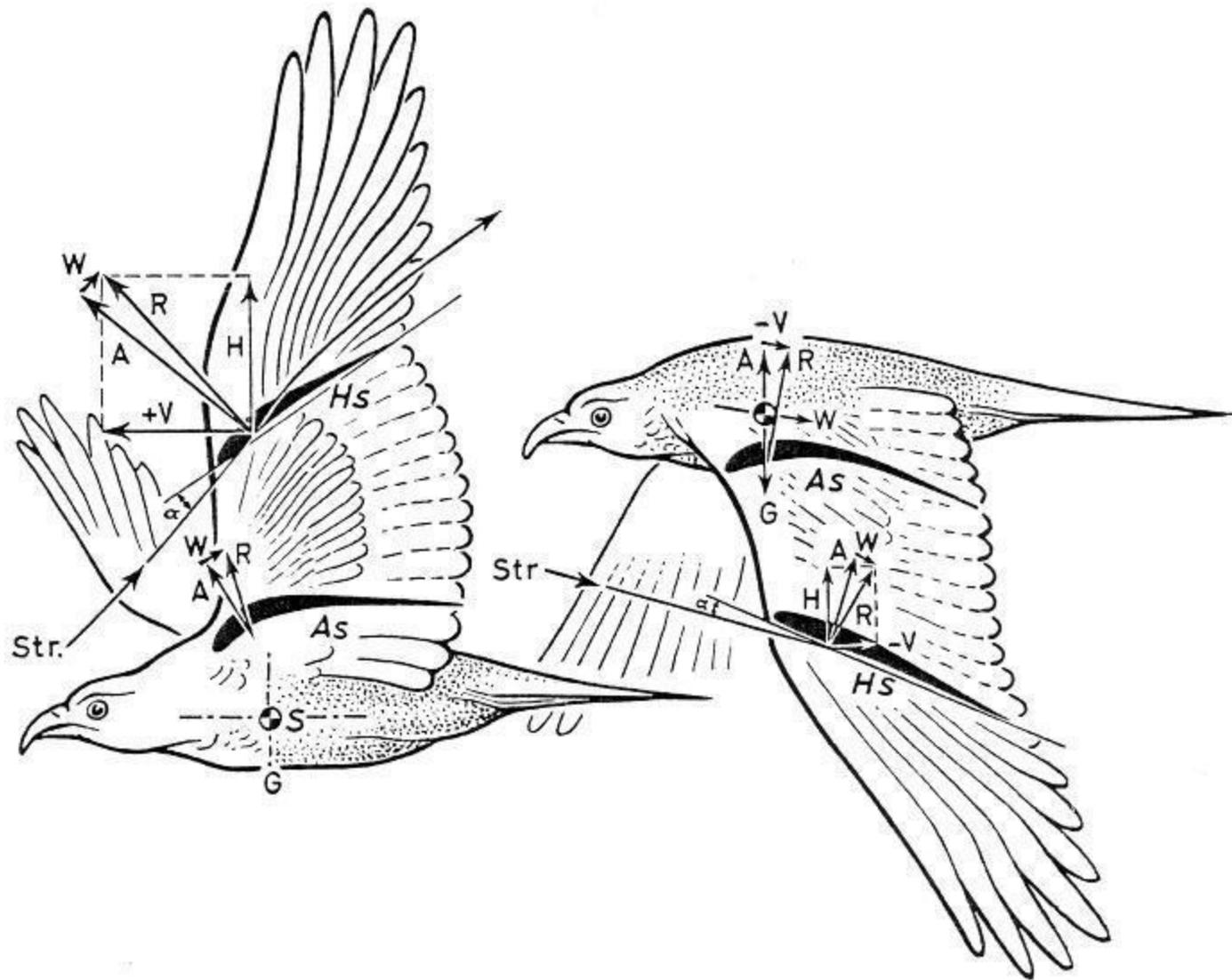
## BERNOULLI EFFECT – 2

- With an increased angle of attack, air/fluid moving past the wing air flowing over the wing flows farther and faster than the air below the wing.
- Pressure is lower above the wing, greater below the wing.
- The greater pressure from below pushes up on the wing – creating “LIFT”. This lift counters downward force, or gravity.
- The greater the angle of attack, the greater the lift produced.

With an increased angle of attack, air/fluid moving past the wing air flowing over the wing flows farther and faster than the air below the wing.



An airfoil's cross-section, showing the pressure gradient created by the passing air. The foil is moving toward the left (which is why it looks like the air is moving to the right). The closer together the lines, the higher the pressure



## LIFT – VI

### SEPERATION OF LIFT AND THRUST

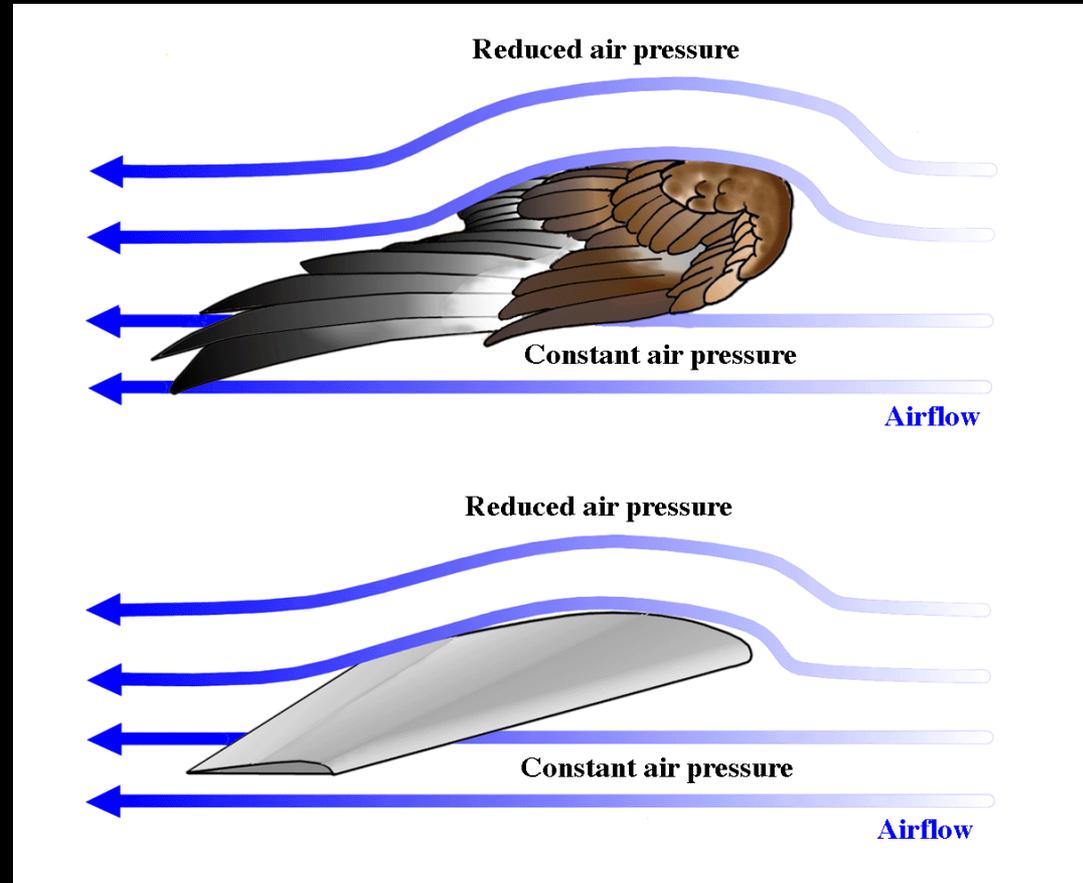
- So note, lift is generated by the wing's forward movement through the air/fluid.
- Propulsion is generated by the flapping of the wings. This is why simply animating wings to go up and down (...cough...Avatar...) doesn't look like real flight.
- You must also have the forward thrust of the wings. This will demand a sophisticated approach to wing/airfoil movement.

## LIFT – VII ; WING CAMBER

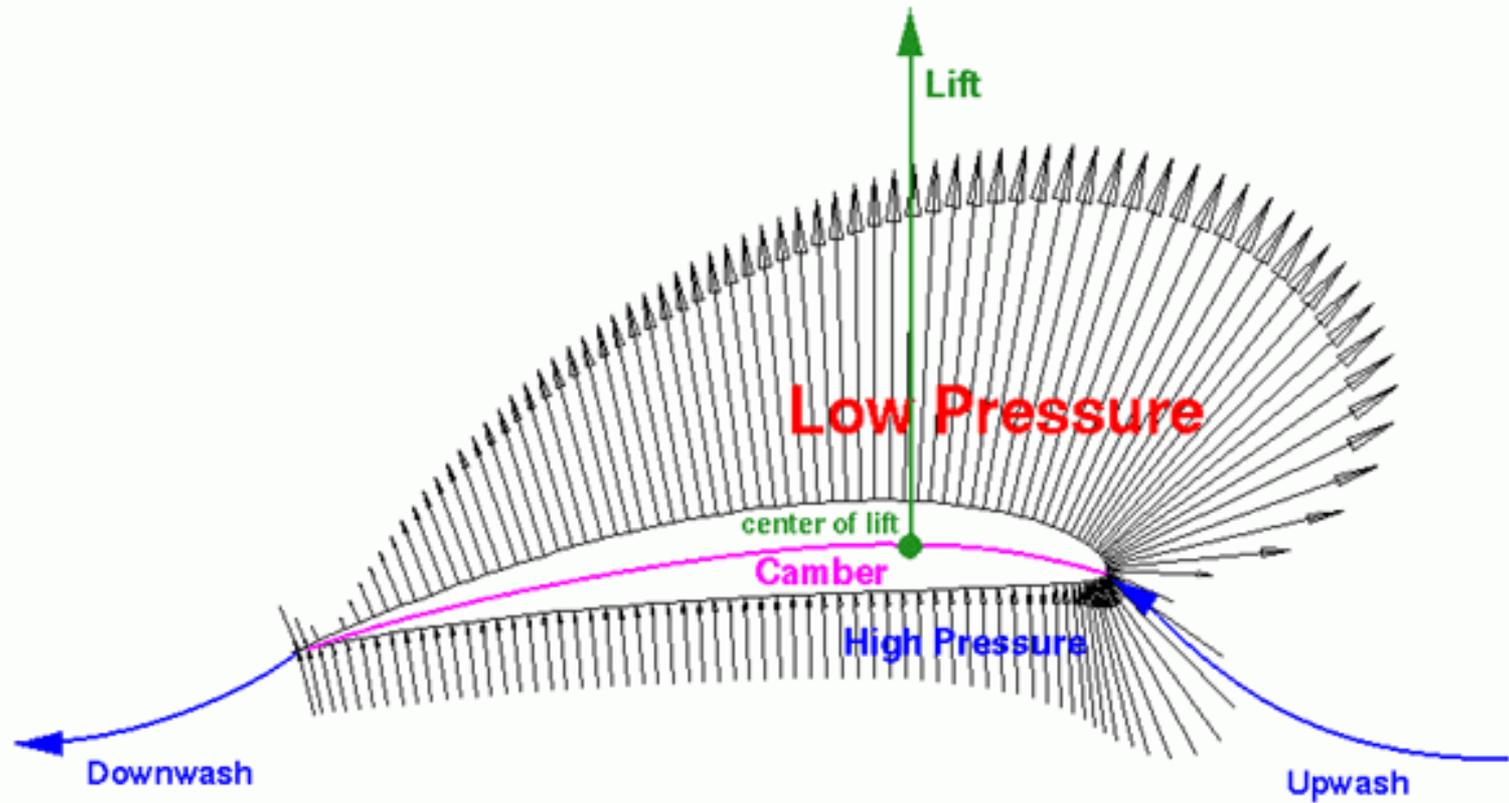
- The wing is usually thin and usually has a curved or cambered shape when it pushes against the air.

- (The meat and bone of vertebrates is placed more forward in a wing, resulting in a rounded leading edge to help reduce air resistance.)

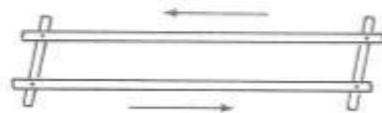
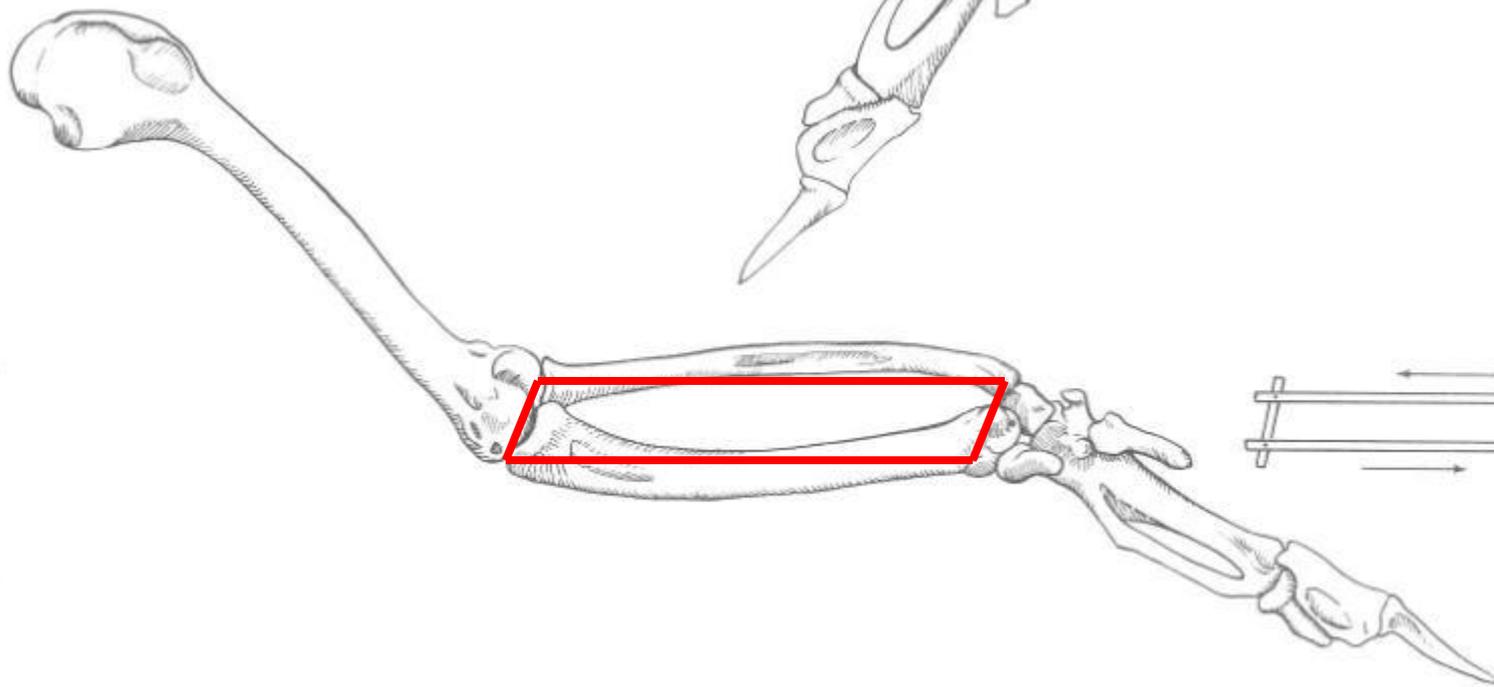
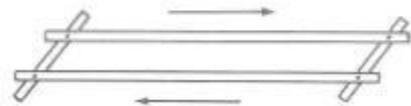
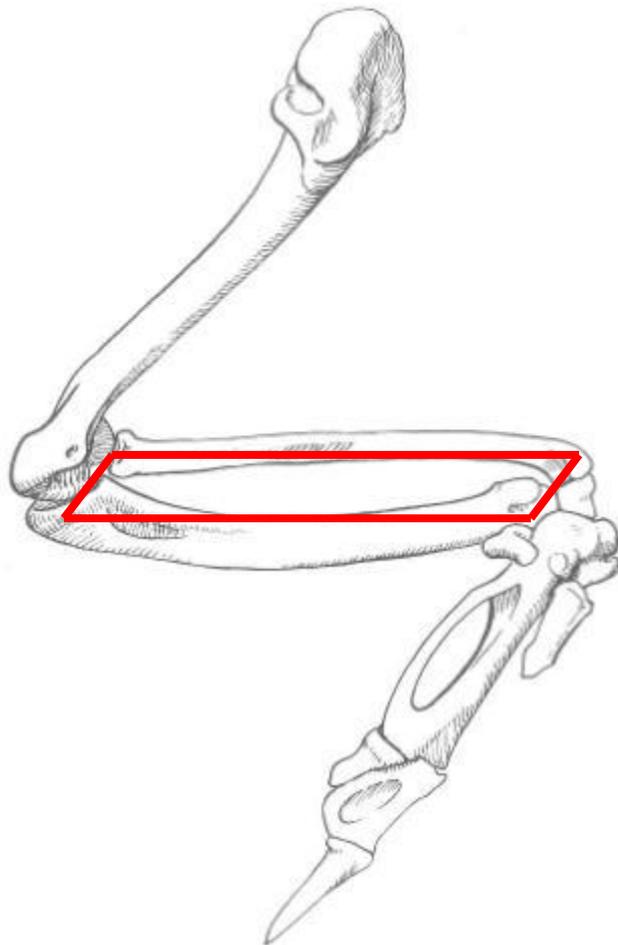
- The inner part of the wing, near the bird's body, is more curved than the outer part.



- Camber increases the velocity of the air passing above the wing – thus decreasing the pressure. Relatively greater pressure below results in greater lift.



Pressure vectors and flow over a cambered section.



# PROPULSION – GLIDING AND SOARING – I

- This is generally done by gradual downward movement (loss of altitude).
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- Loss of altitude is traded for net forward movement.
- This downward trajectory is the **GLIDE ANGLE**, or **GLIDE PATH**.

## FLAPPING FLIGHT – II

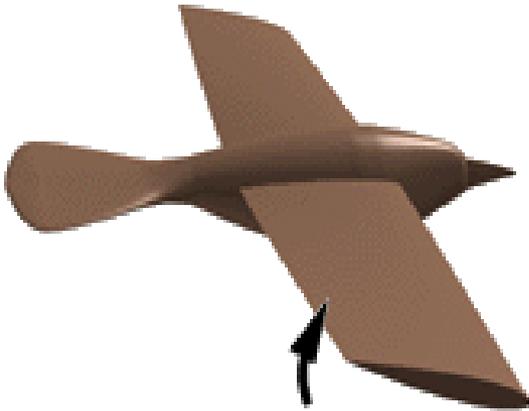
### MAINTAINING ANGLE OF ATTACK

- The outer part of the wing moves up and down more steeply than the inner part of the wing.
- Thus, the wing has to twist, so that each part of the wing can maintain just the right angle of attack. They twist automatically.
- The wing must twist – rotate forward – in the downstroke, to keep each part of the wing aligned with the local direction of travel.

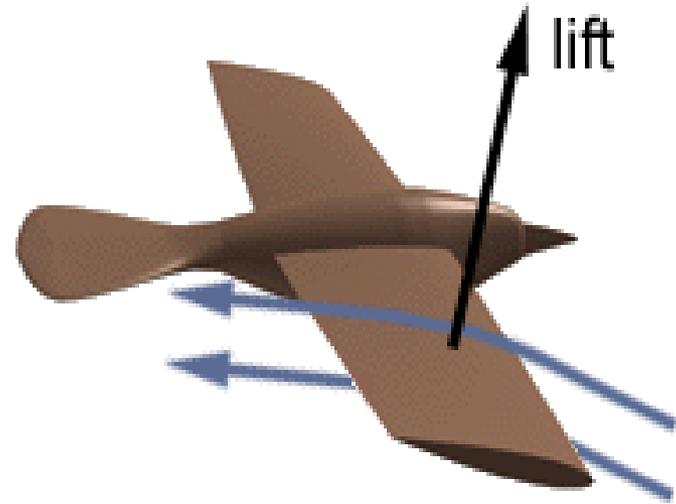
## FLAPPING FLIGHT – II

### MAINTAINING ANGLE OF ATTACK

The wing must twist – rotate forward – in the downstroke, to keep each part of the wing aligned with the local direction of travel.



The wing twists as shown to maintain the correct angle of attack for the downstroke.



The bird's wing produces lift and thrust during the downstroke.

## FLAPPING FLIGHT – III

### DOWNSTROKE DOES NOT CANCEL OUT UPSTROKE

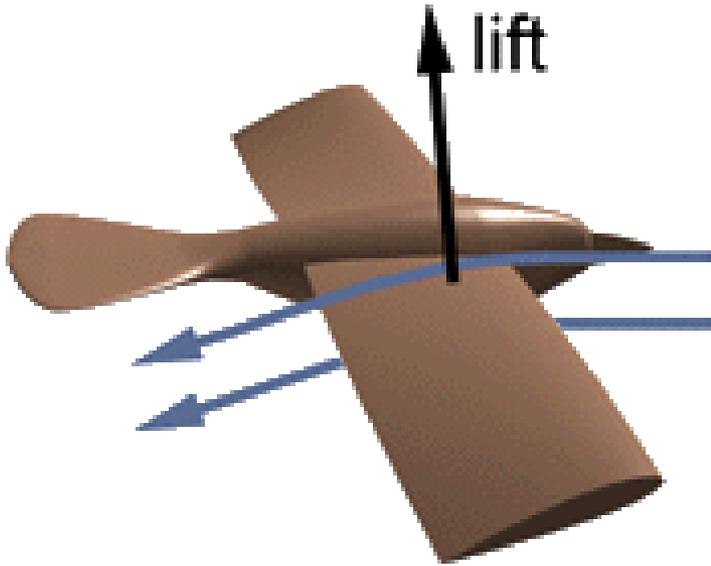
- The force produced depends on the angle of attack. It can be controlled.
- The outer part of the wing points straight along its line of travel so it can pass through the air with the least possible resistance. In other words, the angle of attack is reduced.
- The bird partially folds its wings upon upstroke.** This reduces the wingspan and eliminates the draggy outer part of the wing. (This is not strictly necessary though. Most insects lack this ability.)



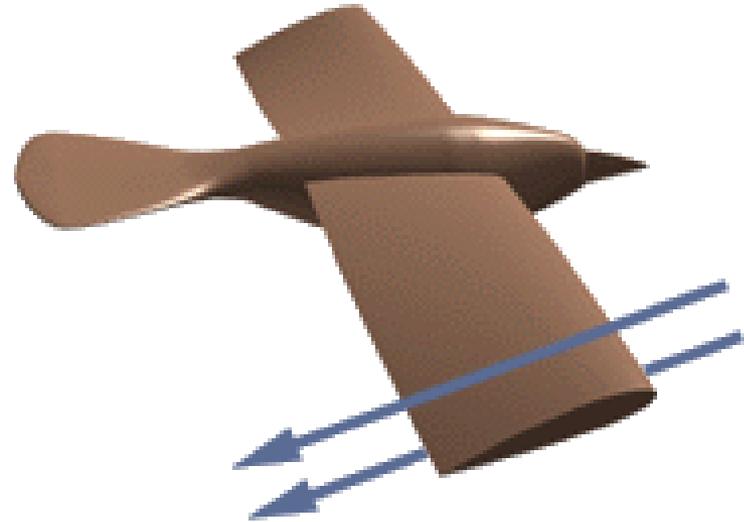
## FLAPPING FLIGHT – III

### DIFFERENT PARTS OF THE WING DO DIFFERENT THINGS!

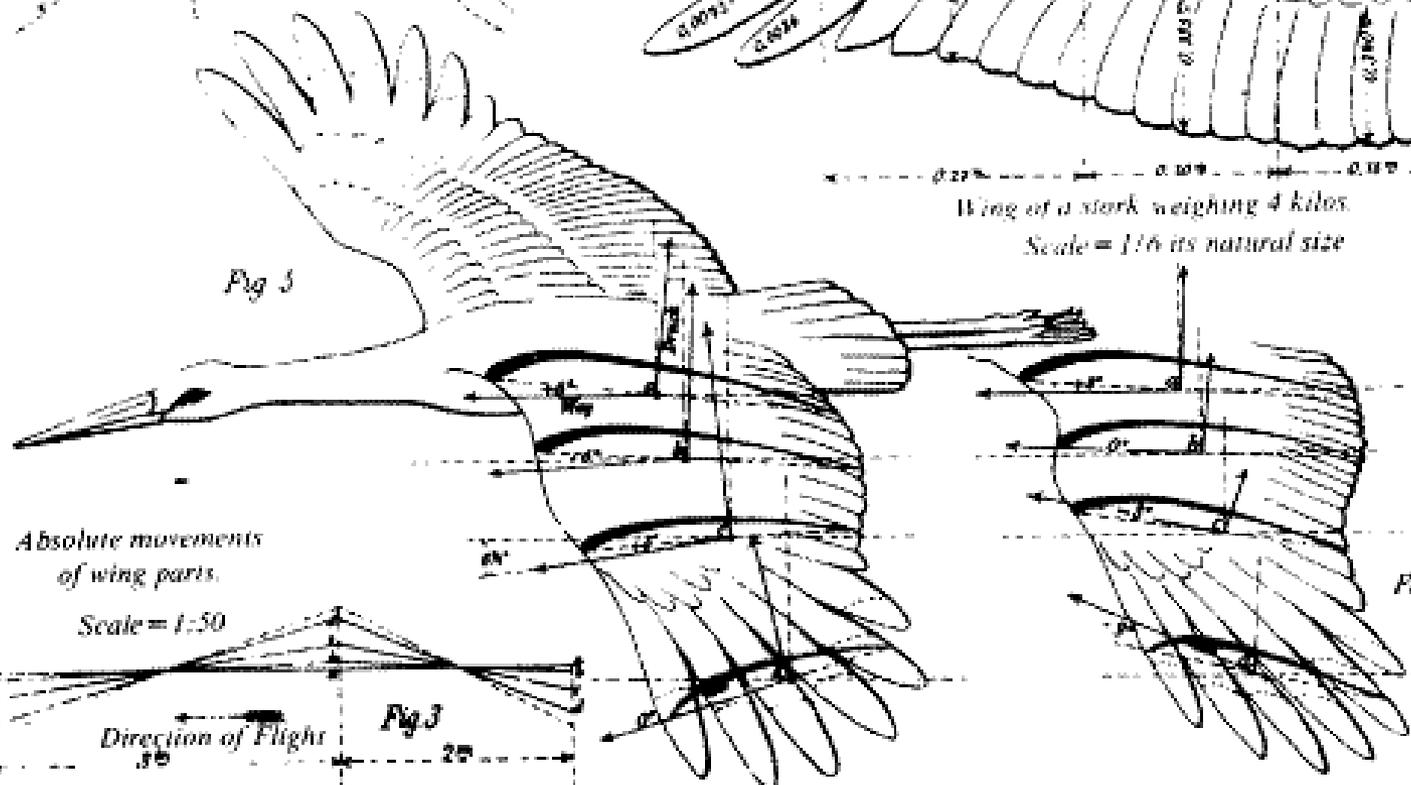
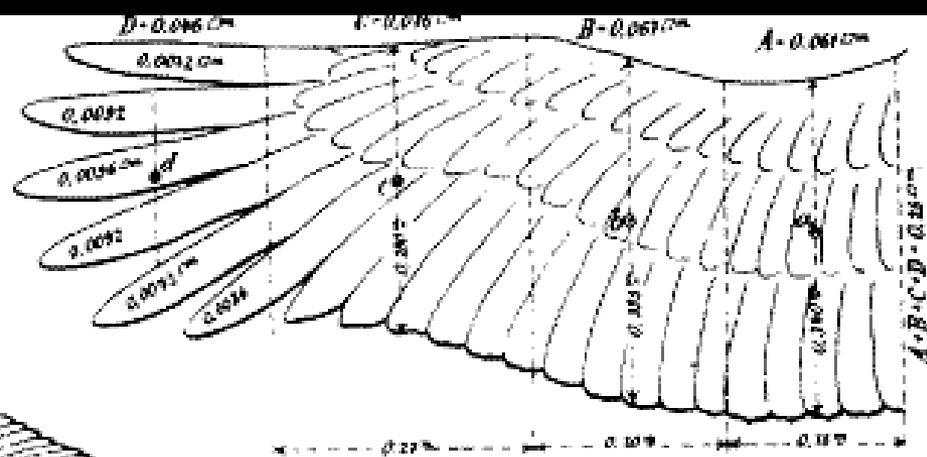
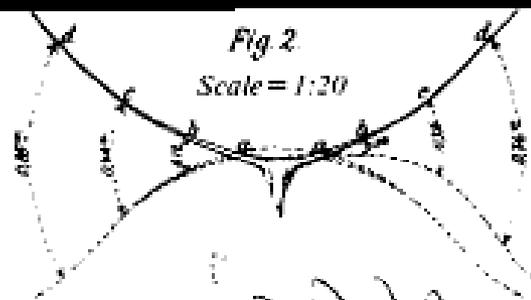
- The inner part of the wing is different from the outer part.
- There is little up-and-down movement of inner wing, so that part of the wing continues to provide lift just as a result of its forward motion.
- Only the inner part of the wing produces lift in the upstroke, so the upstroke as a whole offers less lift than the downstroke.
- As a result, the creature's body will bob up and down slightly as it flies. If you don't put this in when you animate, then it looks highly artificial. (You'll see this when dolphins swim too.)
- So, like an airplane, lift and thrust functions are separated. The outer part of the wing provides thrust. The inner part of the wing produces lift.



The inner part of the wing produces lift, even during the upstroke.



The outer part of the wing is angled to pass through the air with little resistance.



Wing of a stork weighing 4 kilos.  
Scale = 1/16 its natural size

Fig. 4

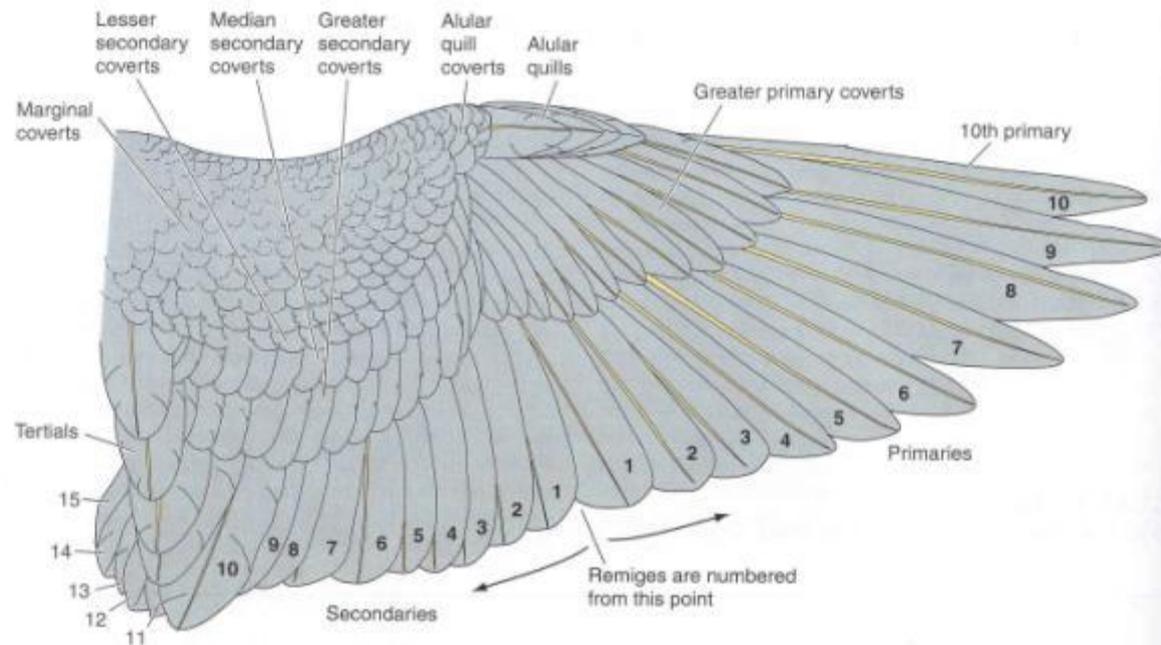
On Downbeat

On Upbeat

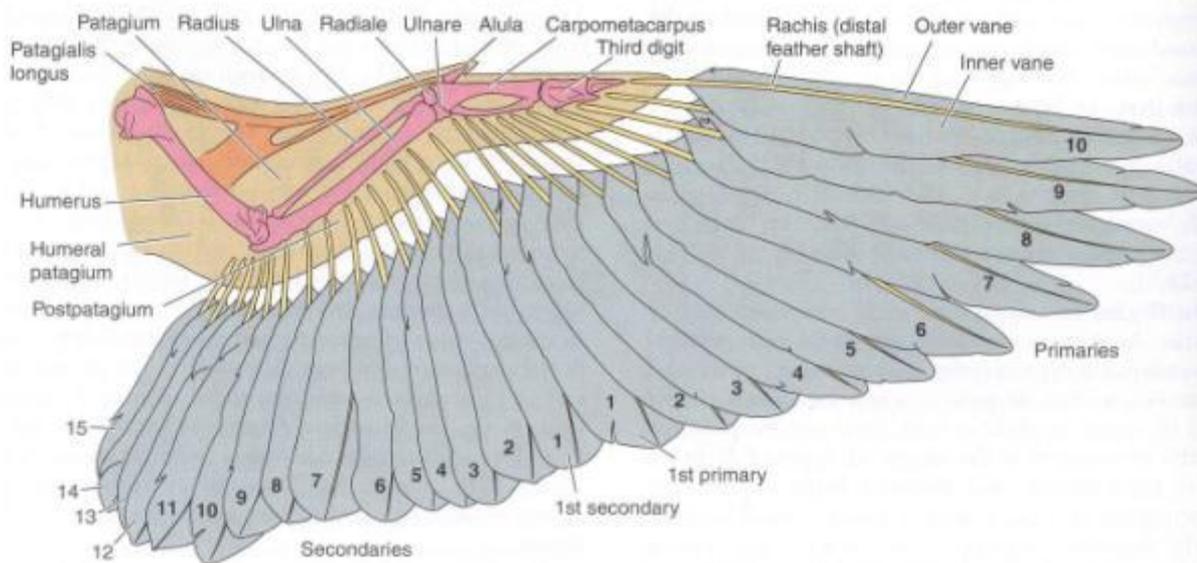
# THE ANATOMY OF FLIERS – BIRDS

- Wings feather covered.
- Great variety of feet, beaks, wings depending on function and lifestyle.
- Body feathers (contour feathers) reduce friction and are a pain to model)





A. Dorsal view of wing surface showing coverts, alular quills and flight feathers (= remiges)



B. Ventral view of wing after removal of covert feathers

# Flight Stroke

Apex

Mid-Downstroke

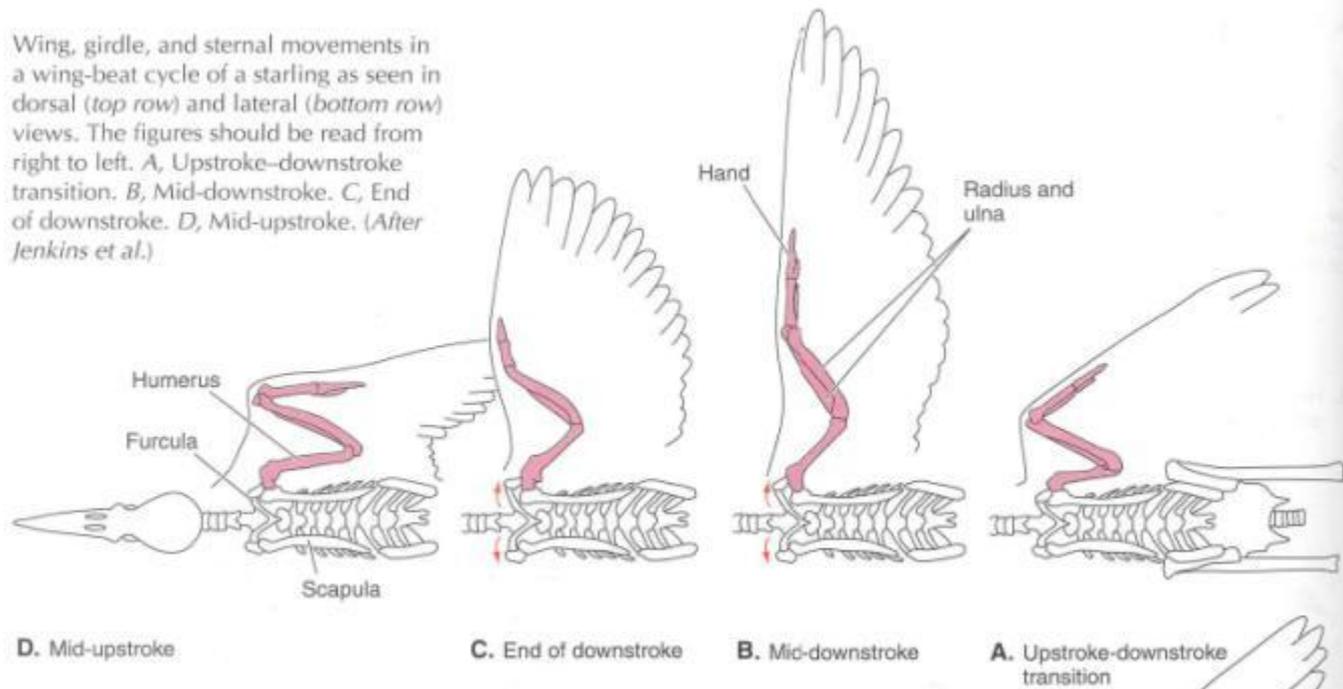
End Downstroke

Mid-Upstroke

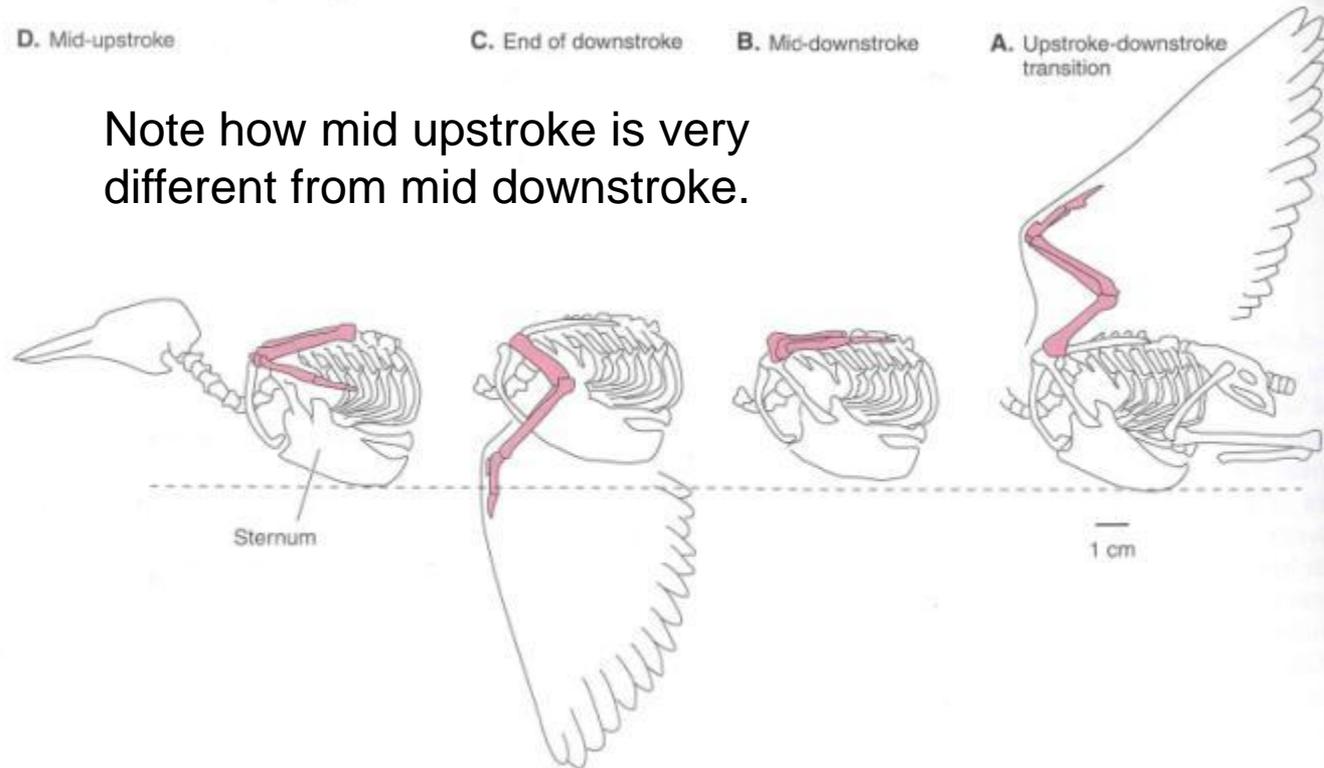
End Upstroke

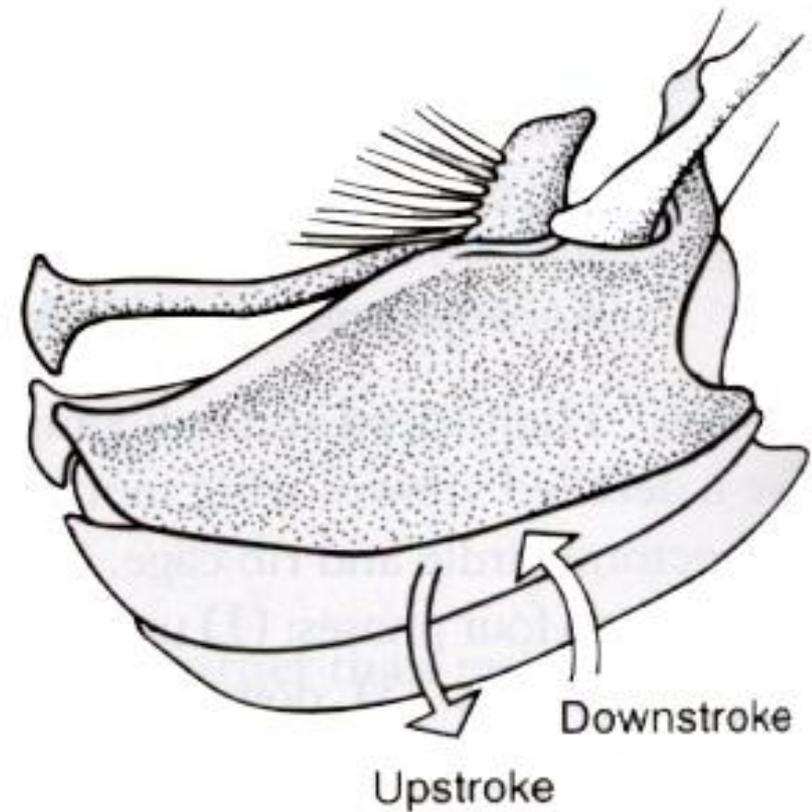
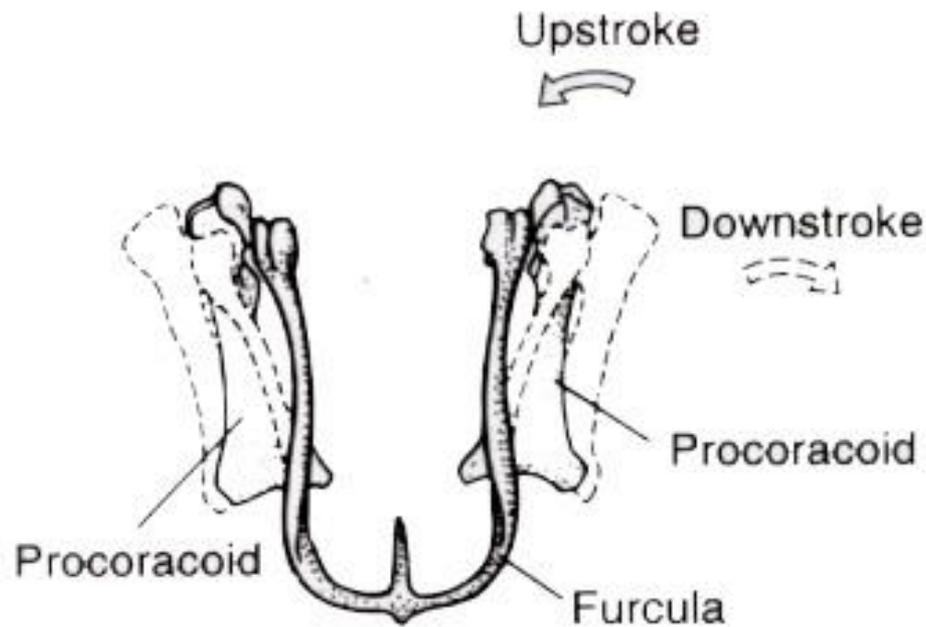
Apex

Wing, girdle, and sternal movements in a wing-beat cycle of a starling as seen in dorsal (top row) and lateral (bottom row) views. The figures should be read from right to left. A, Upstroke-downstroke transition. B, Mid-downstroke. C, End of downstroke. D, Mid-upstroke. (After Jenkins et al.)



Note how mid upstroke is very different from mid downstroke.



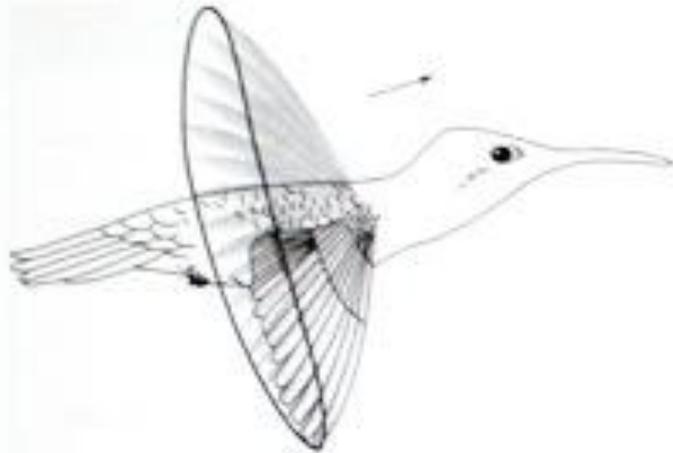


Upon downstroke, the sternum is pushed up as pectoralis (chest muscle) between sternum and humerus contracts. It moves down upon upstroke as pectoralis relaxes.

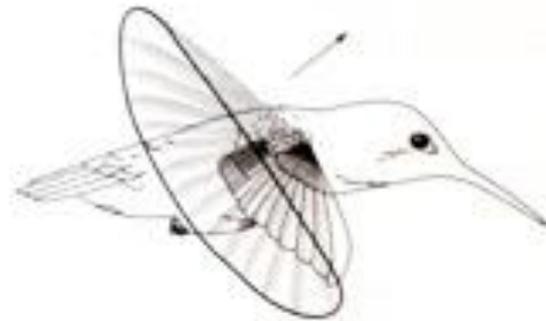
## HOVERING FLIGHT

- Very few birds do true hovering.
- In hovering flight, a bird generates its own lift by means of rapid wingbeats.
- Body is nearly vertical; wings are firmly flexed at the elbow joint.
- A hovering bird moves its wing surfaces forward and back in a horizontal plane.
- Each of the two phases of the stroke generates lift.

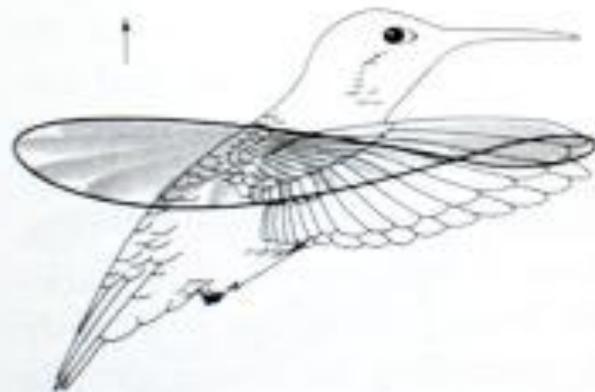




Forward 26 miles per hour  
(top speed)



Forward 8.6 miles per hour



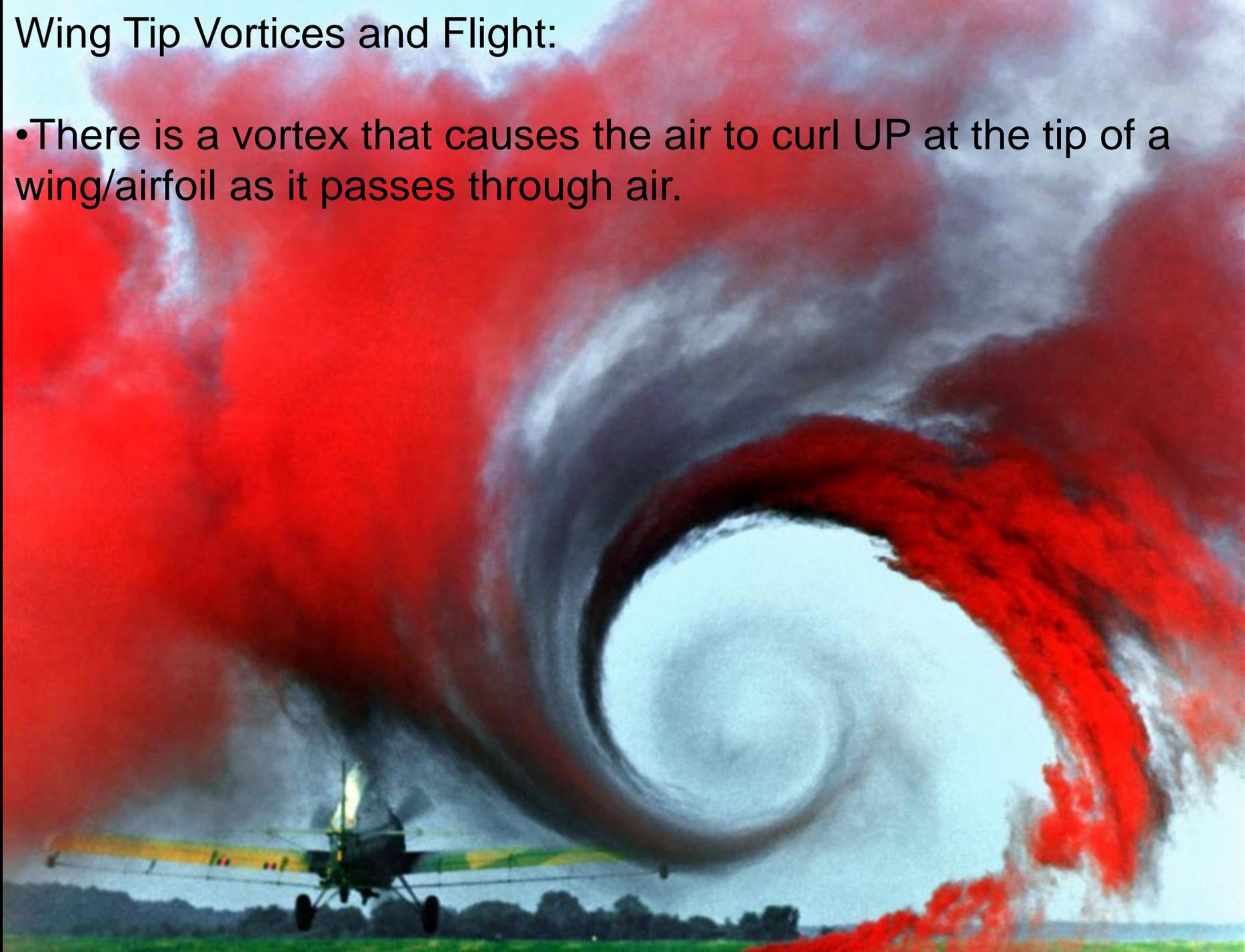
Hovering

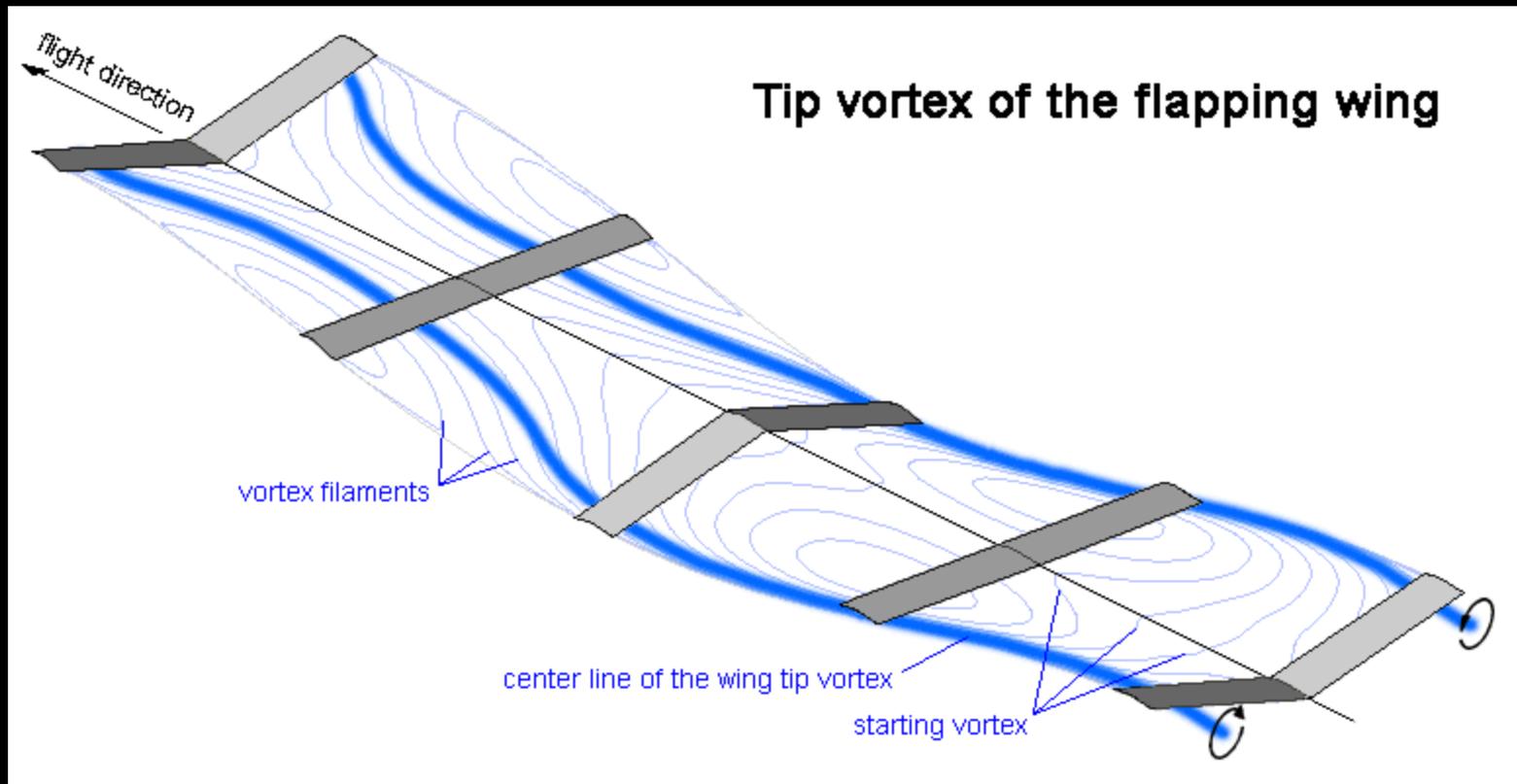
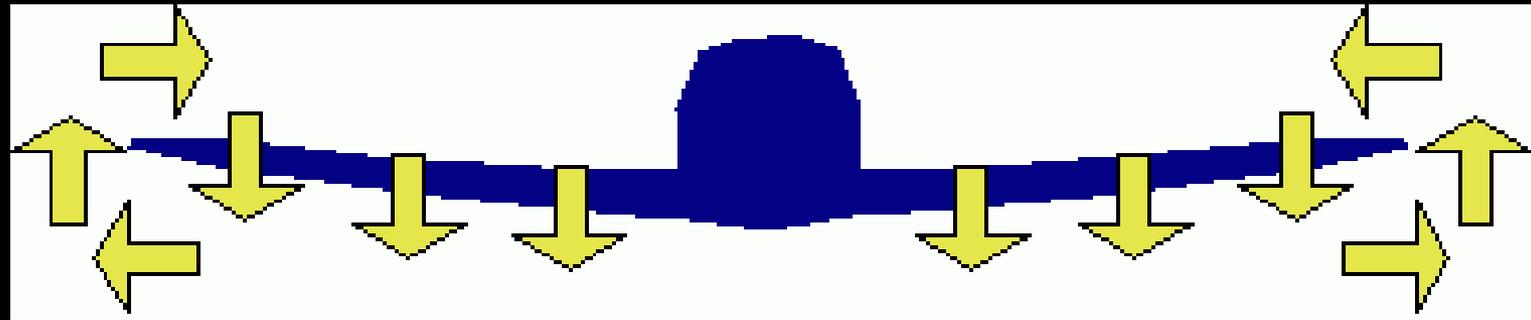


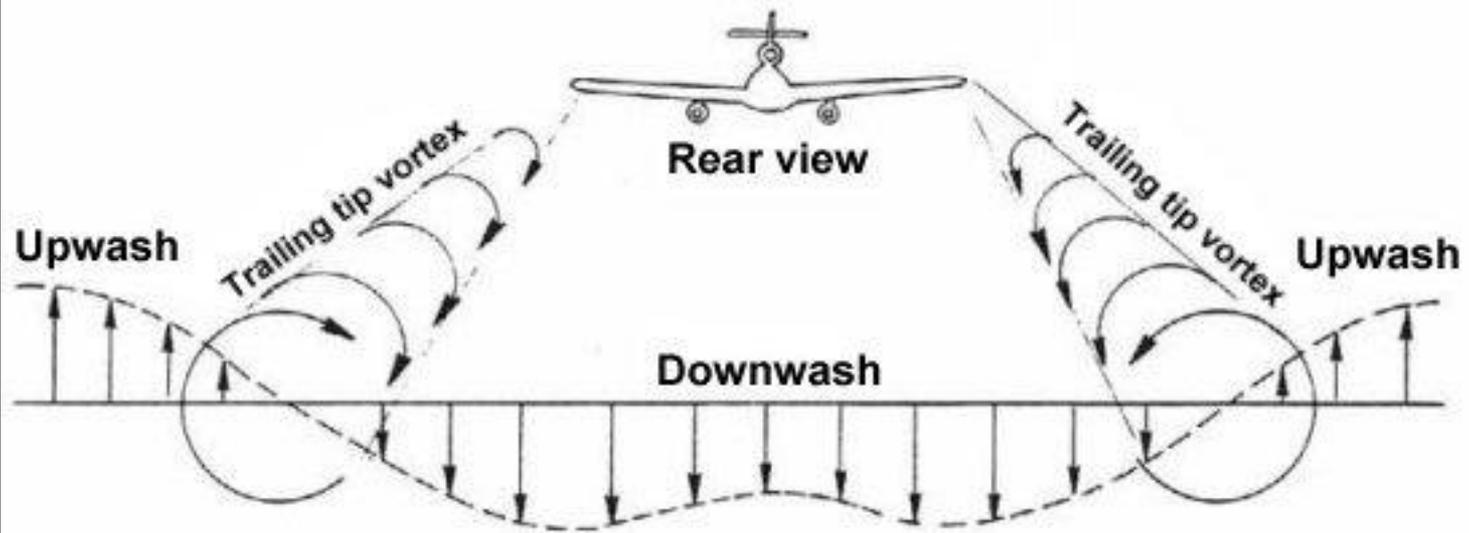
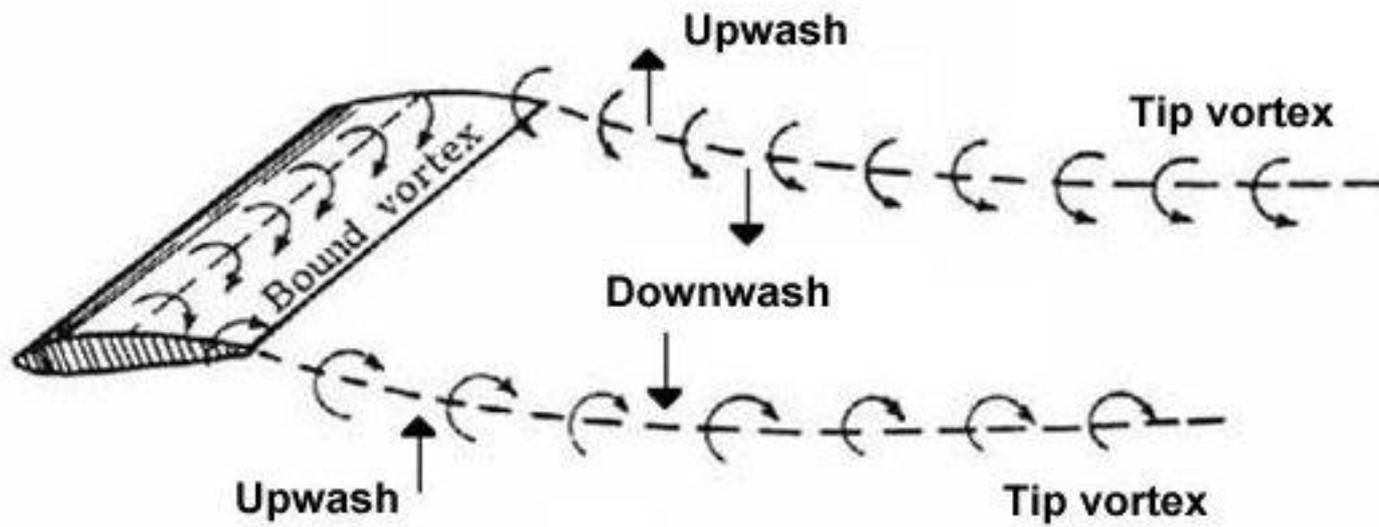
Backward flight

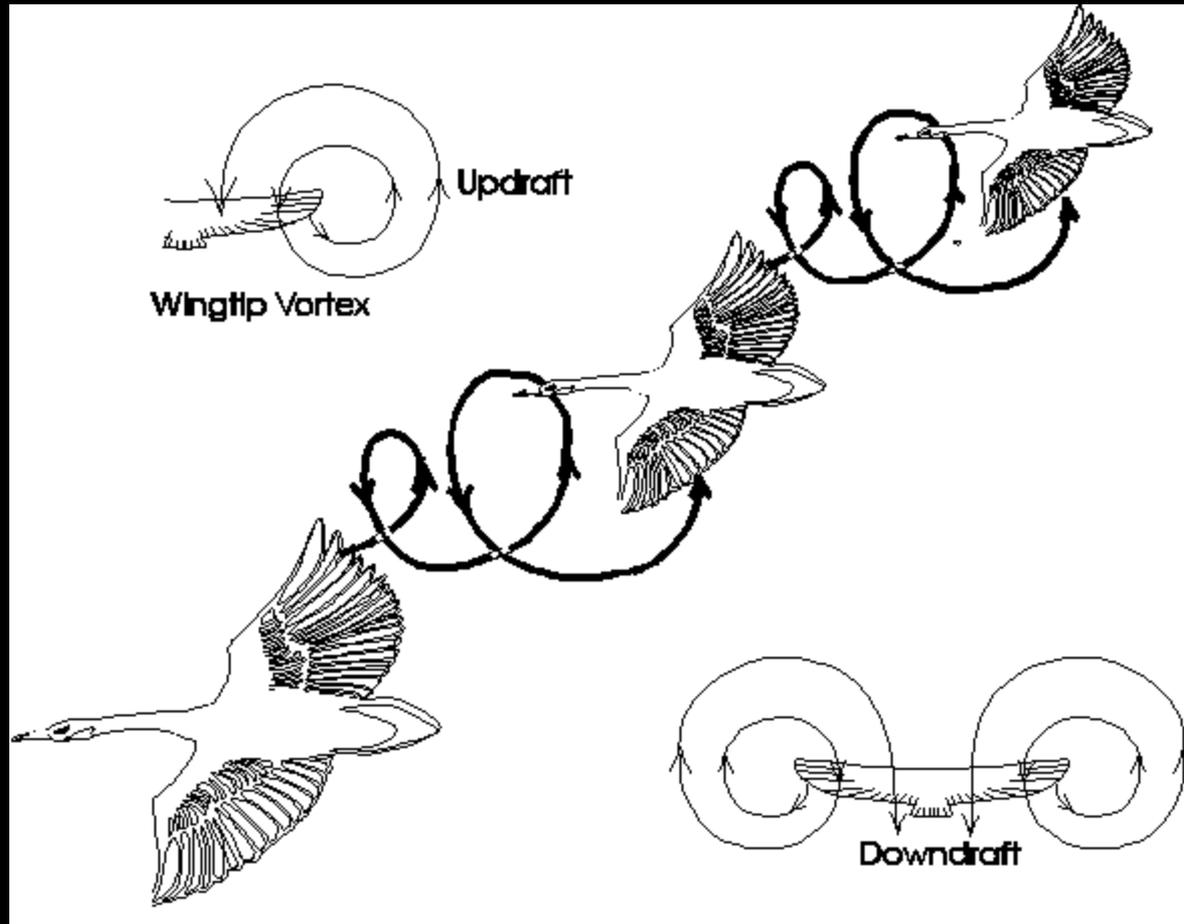
## Wing Tip Vortices and Flight:

- There is a vortex that causes the air to curl UP at the tip of a wing/airfoil as it passes through air.









Birds and other fliers use this upward movement of air to make their flight easier as they position their wingtip behind that of the animal in front of them.