DOUG DANIEL
PilotsOnlineAcademy.com

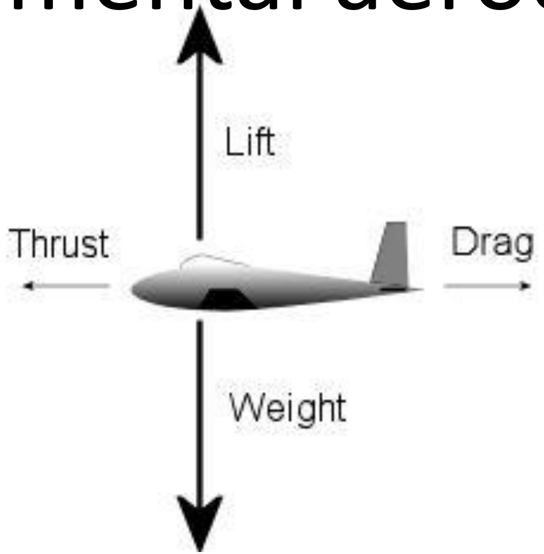
Making Superior Piloting Simple

Module 2 of Phase 1

Fundamentals:

Lift & Drag

The four fundamental aerodynamic forces are:



Here's What to Expect

- You will learn what causes the most subtle and important of the four basic forces that operate on an airplane – lift & drag.
- You need this to understand all maneuvers including stalls.
- The other two basic forces – thrust and weight – will be covered in flight dynamics.

Let’s see what happens when wind blows past any object.

A wing seems like a practical object to start with.

First we look at the wind blowing *over* the wing.

Keep in mind that atmospheric pressure keeps air against the wing.

Since the air is forced against the wing and the wind is blowing past it, a parcel of air that strikes the front of the wing should follow the shape of the wing all the way to the back.

And that is exactly what happens <u>most</u> of the time.

This parcel of air interacts with the wing two ways. The most obvious is to pull back on the wing as it rubs against it.

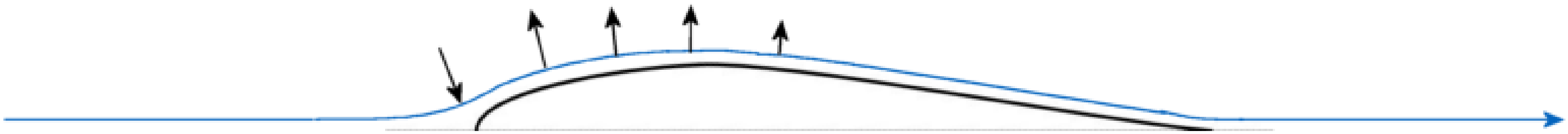
We call this kind of drag *skin friction*.

But another thing happens that is not quite so obvious.

To follow the surface of the wing, the parcel must follow a curved path.

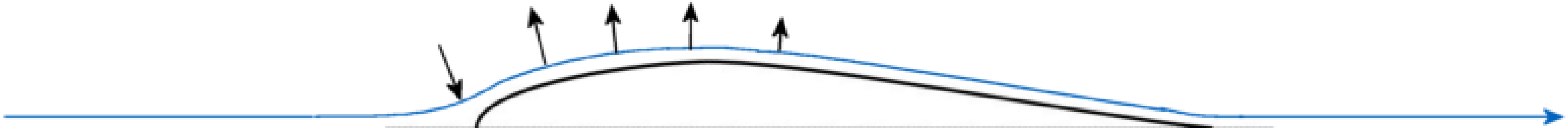
Anything, including air, that follows a curved path experiences centrifugal force in the opposite direction of the curve.

Centrifugal force creates lift.



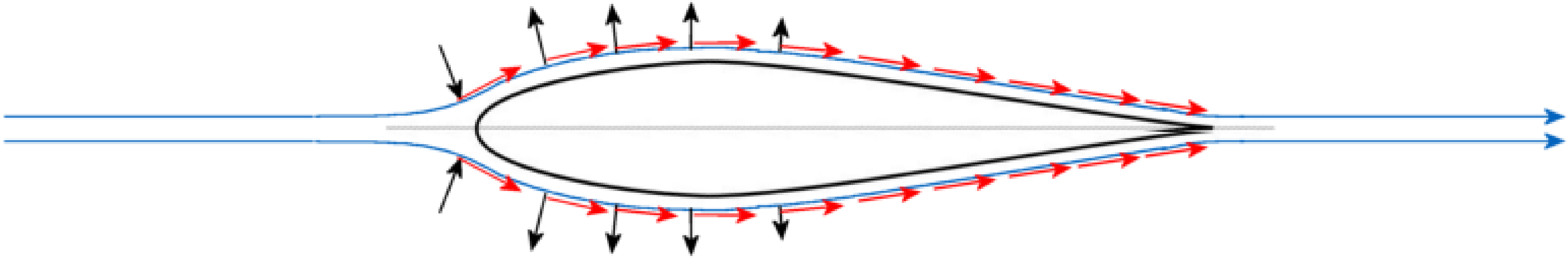
As the air passes over the wing, centrifugal force tries to pull it away from the surface.

As long as the atmospheric pressure is greater than the centrifugal force, the wind stays against the wing and the air pressure drops.



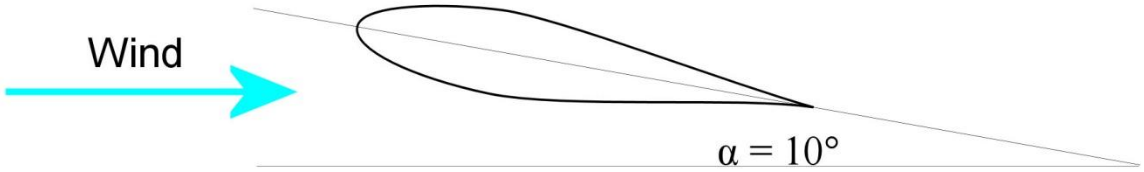
It sucks the wing up.

If the wing is symmetric, and the wind blows straight on, the wind blowing across the bottom exactly off sets the wind blowing across the top and the wing has no net lift, just drag.

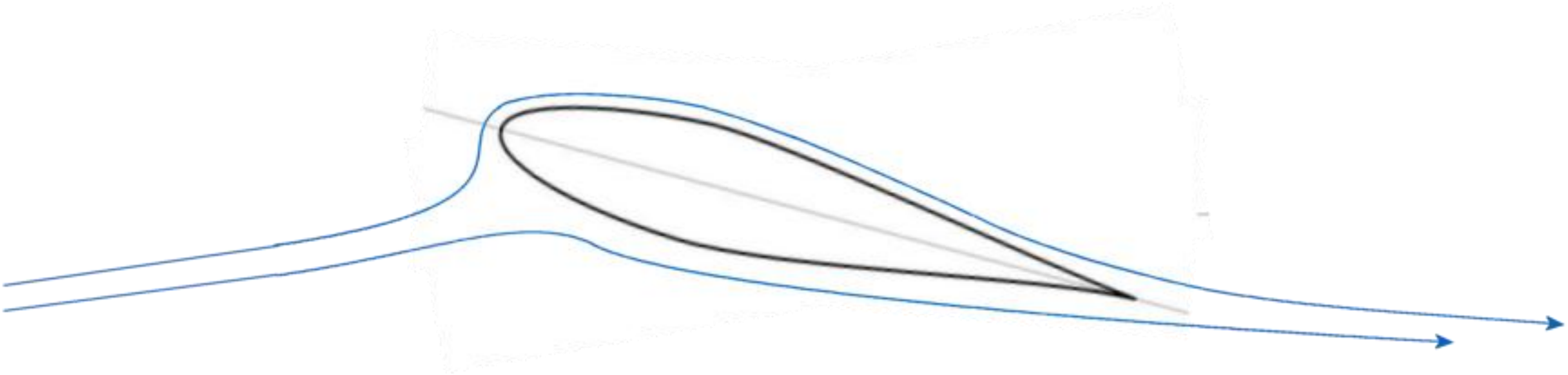


Now, suppose the wind attacks the wing at a different angle.

Let’s pitch the wing up 10^o

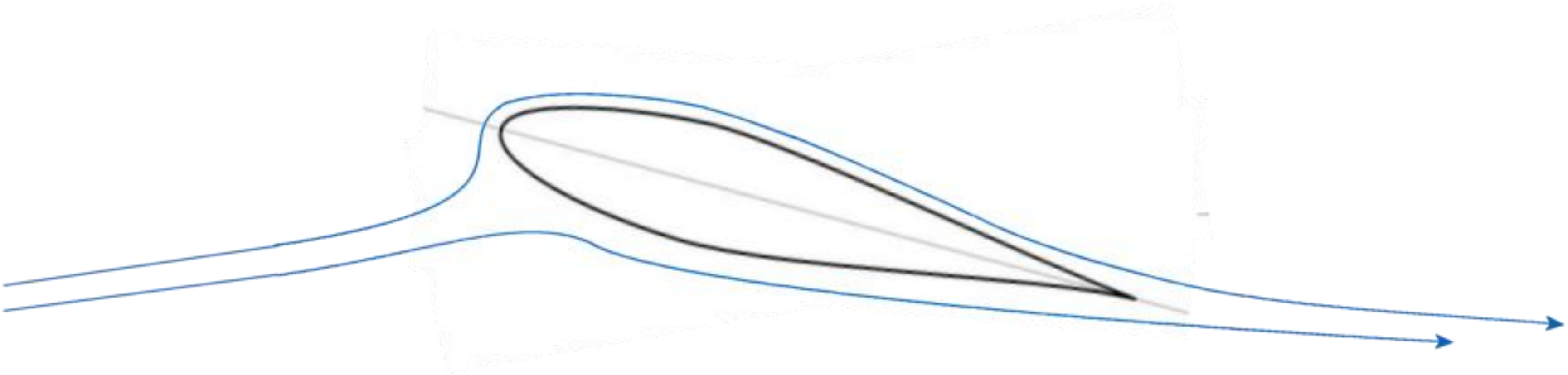


The wind passing over the top of the wing follows a more curved path than below it.

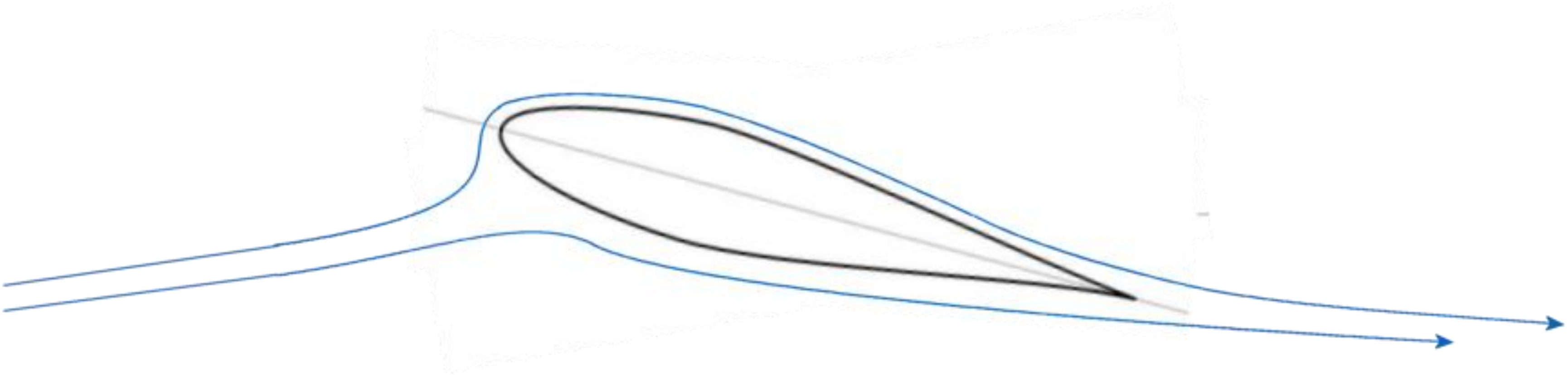


The net lift of the wing is now **up**.

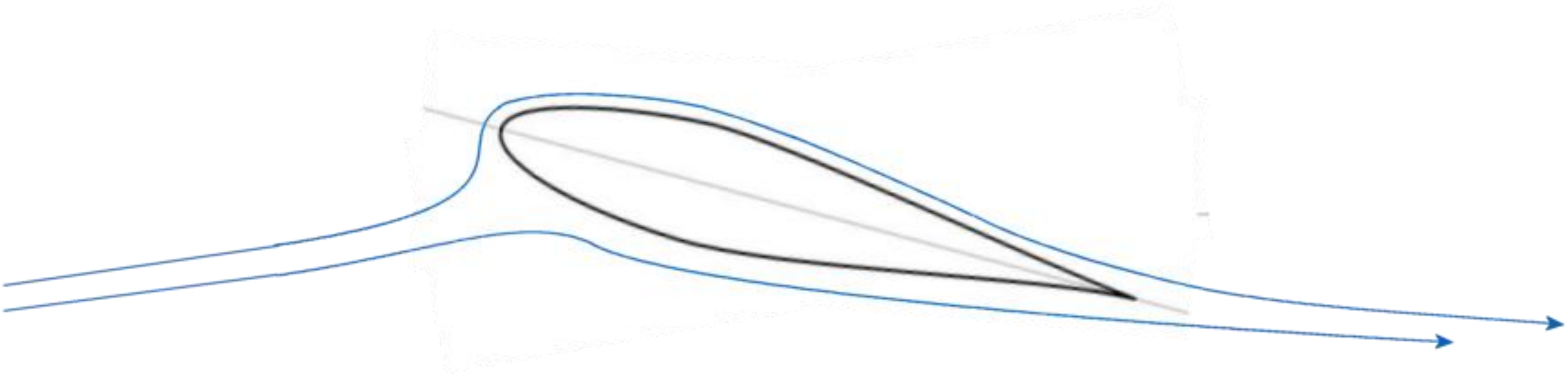
But the wing is presenting more area to the oncoming wind, causing the air to build up pressure on the bottom.



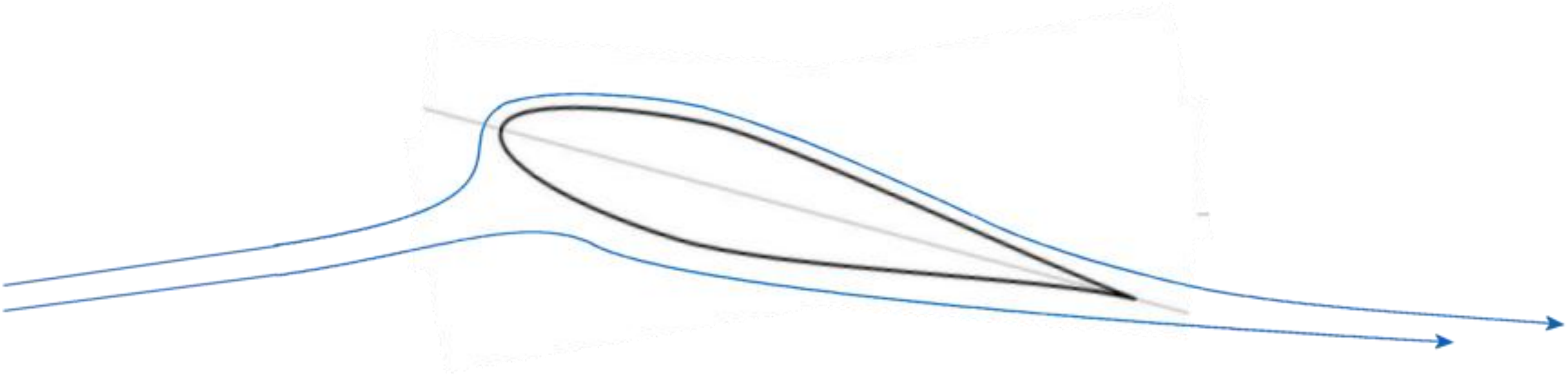
Eventually we have only high pressure pushing up and back.



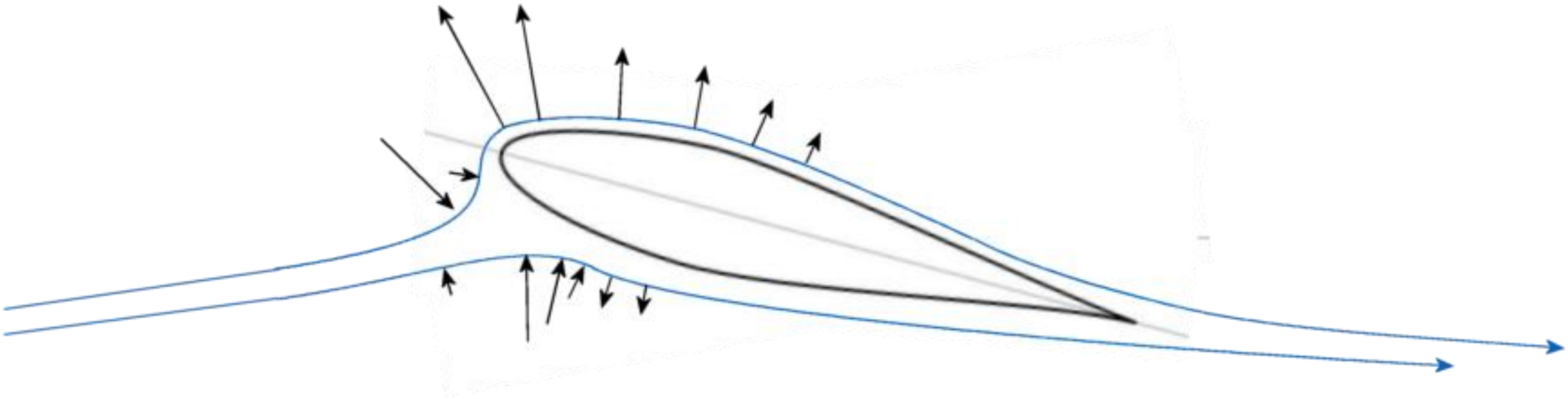
In contrast, on the top there is only low pressure pulling up and back.



And we still have the drag caused by wind rubbing against the surfaces.



When you look at the lift at various points of the wing, you see that it is often pulling back on the wing.



Just to keep things simple, let's add up all of the force pulling ***up*** perpendicular to the wind, and call that sum 'lift.’

Then we add up all of the force that pushes, pulls, or drags the wing ***back*** with the wind, and call that sum 'drag.’

That’s the convention.

I need to be as clear as I can because this can be confusing, but it <u>is</u> important.

Lift is <u>always</u> perpendicular to the wind and drag is <u>always</u> parallel with the wind.

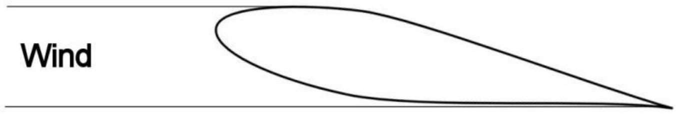
As you have already seen, the wind blows in different directions at different points on or near the wing's surface.

I would like to call the lift and drag at those points *local lift* and *local drag*.

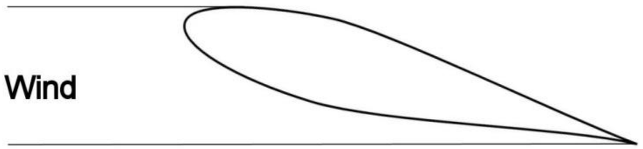
When we view the wing on a macro level, long before it has disturbed the air, we can discuss the wing's *total lift* and *total drag* in a meaningful way.

Here's why the difference is important: At almost every point on a wing's surface, local lift either adds to or takes away from a wing's total drag. So you can't just add up all the local lift and say that's total lift.

Let's look at what happens as the wind attacks the wing at a steeper angle.



Let's look at what happens as the wind attacks the wing at a steeper angle.



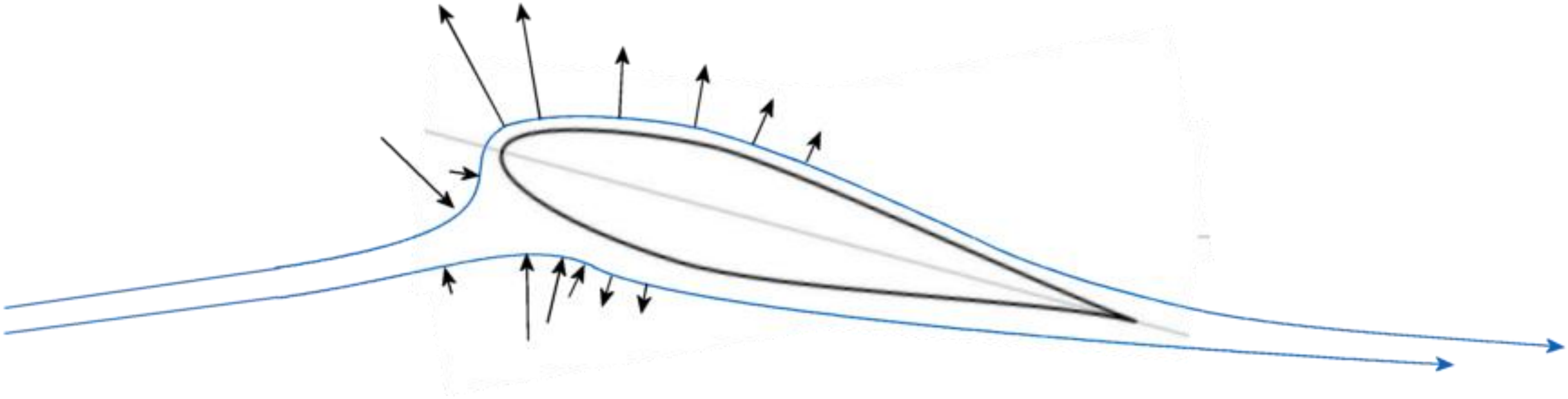
The pressure on the top gets lower;
the pressure on the bottom gets higher;
and the forces pushing, pulling, and dragging on the wing increase.

Conclusion: as lift increases, drag increases.

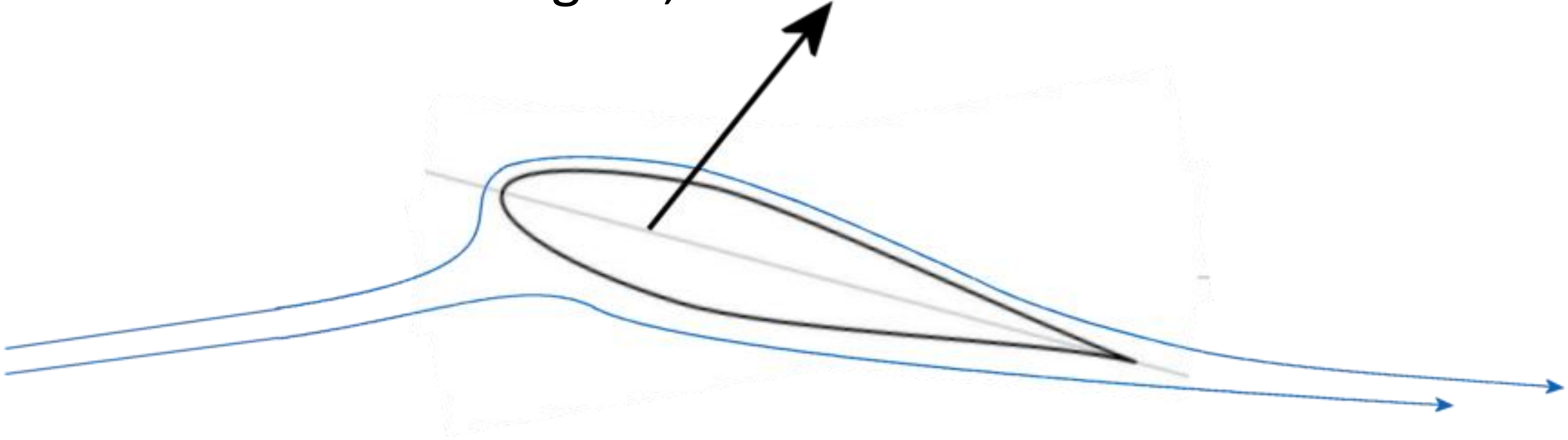
Caution: lift does not always increase as drag increases.

As we pitch up the wing more, lift gets stronger as long as the atmospheric pressure overwhelms the centrifugal force.

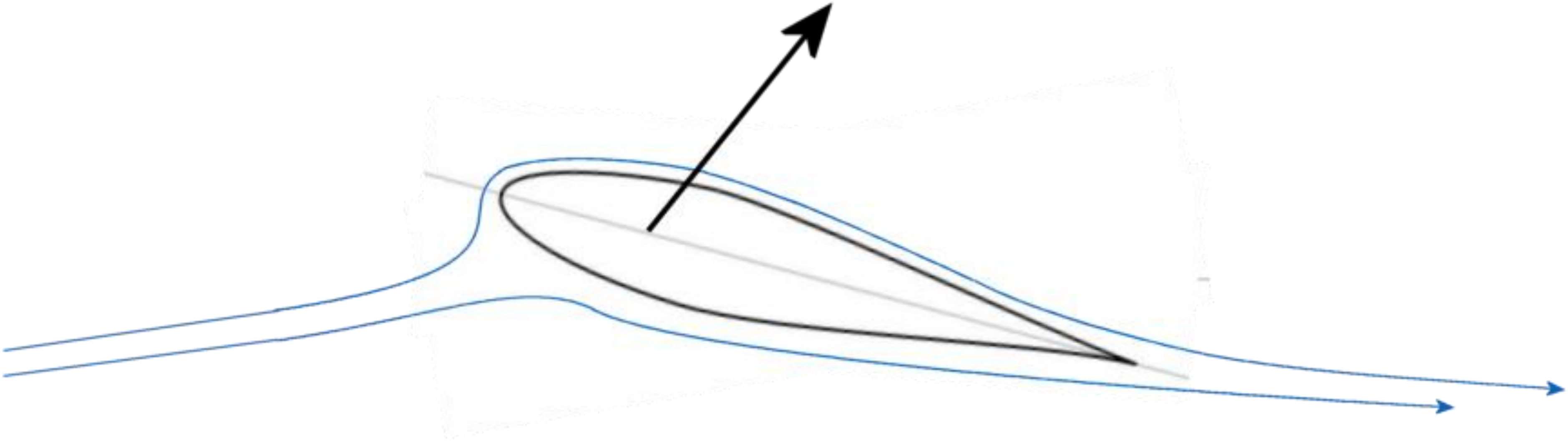
Unfortunately, as the wing pitches up, the direction of local lift rotates with it, point more and more toward the rear.



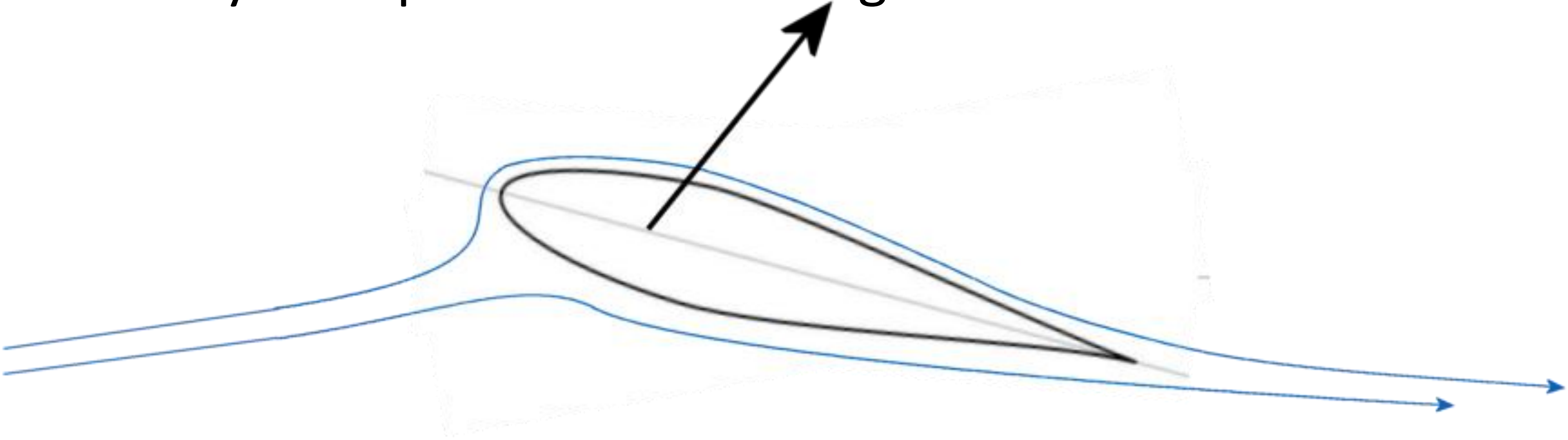
If we were to accumulate all of the local lift into one big force for the wing, it would always point back to some degree, never forward.



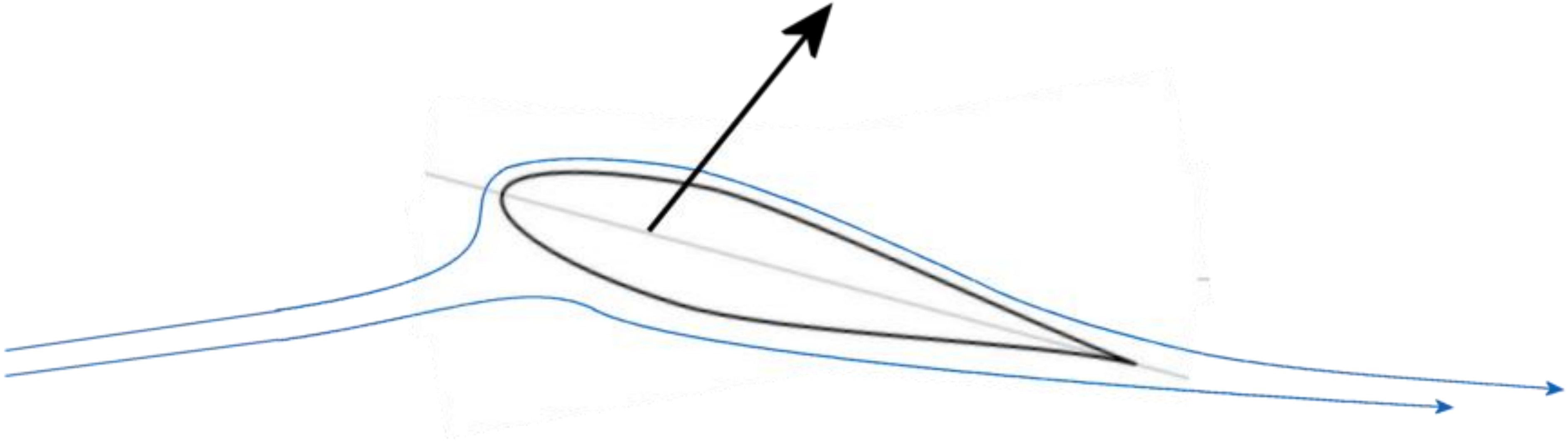
The greater the *angle of attack*, the greater the force and the farther back it points.



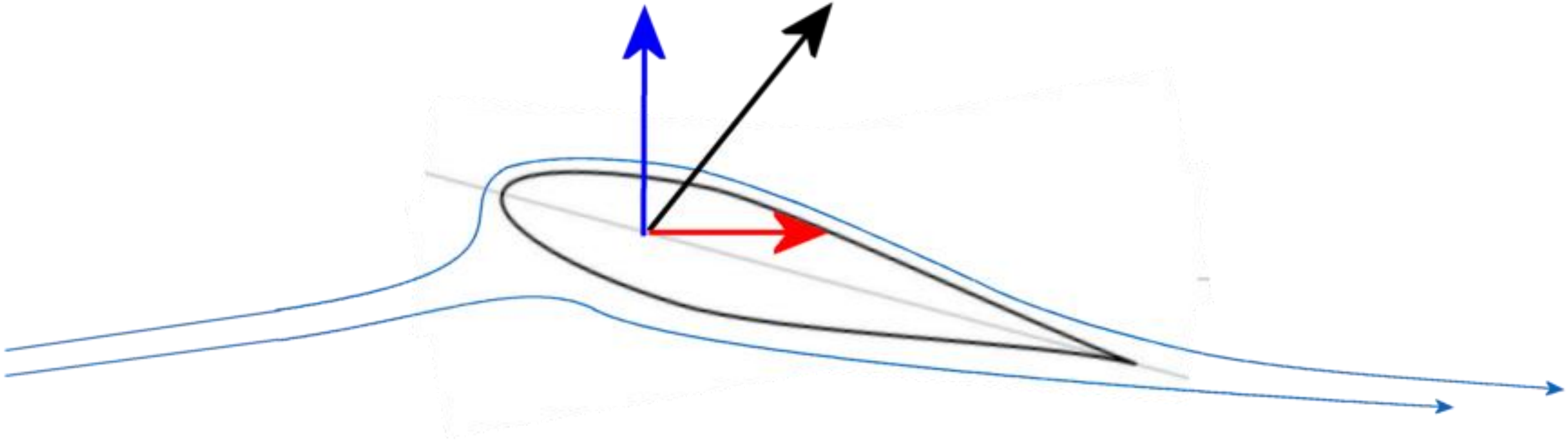
If you noticed that the consolidation of all local lift into one big force is <u>not</u> the wing's total lift, good for you. It points in the wrong direction.



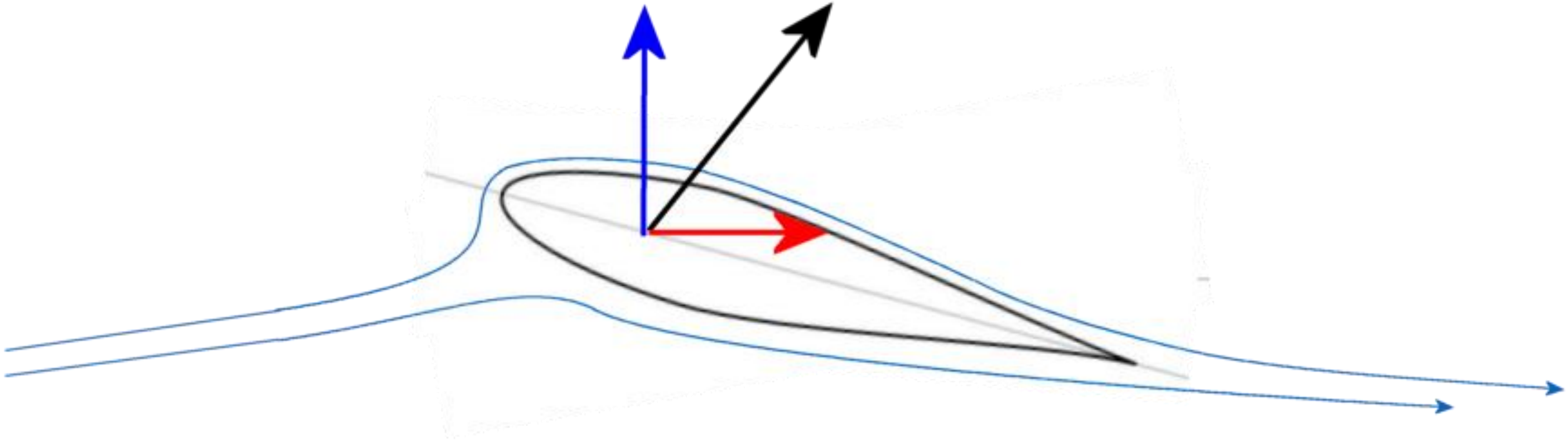
We need to separate this force into its two components: aerodynamic lift and drag.



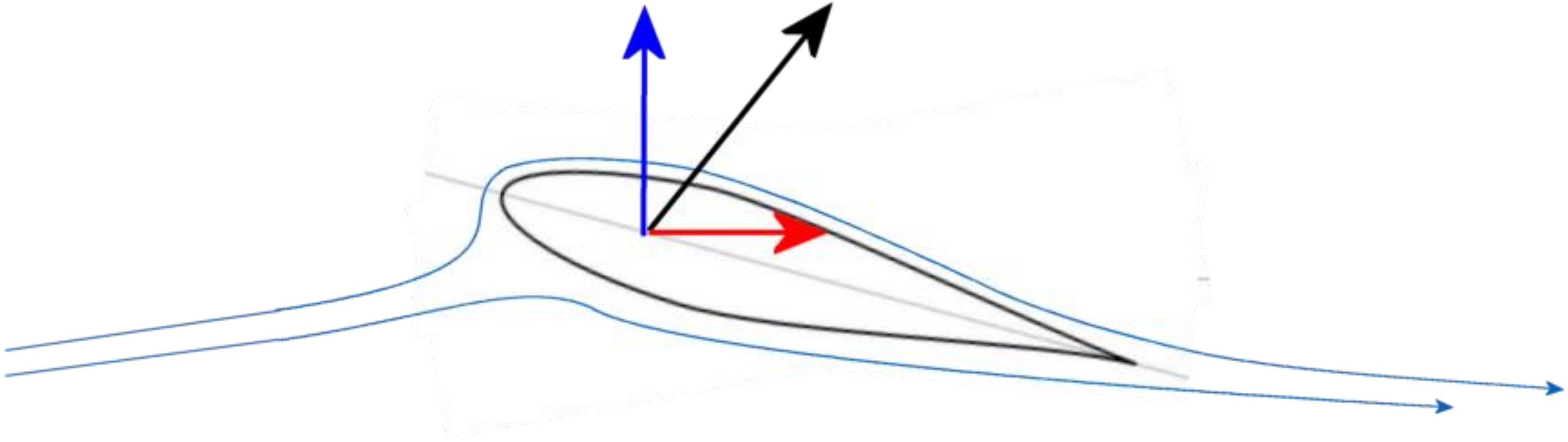
The blue force is perpendicular to the undisturbed wind, so it must be *lift*.



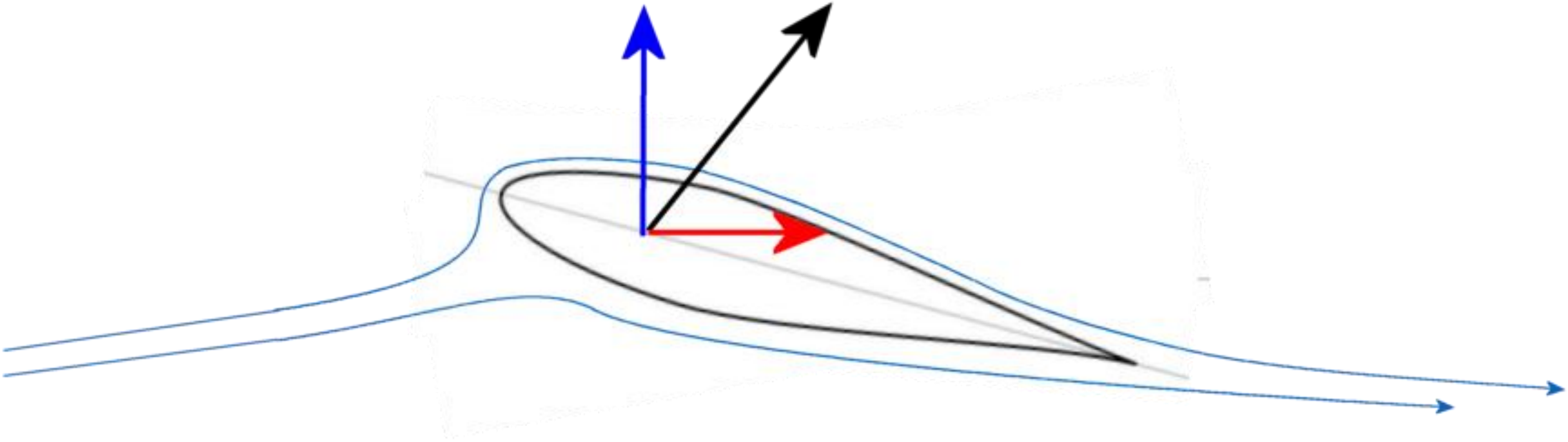
The red force is parallel to the undisturbed wind, so it must be *drag*.



No matter the shape of wing or its angle of attack, there will always be some aerodynamic drag.



Another way of looking at this is that the same physical effect that produces lift can also produce drag.



- We now know that skin friction creates drag,
- that the same effect that produces lift also produces drag,
- and that the greater the lift, the greater the drag.
- Now let’s see what happens to lift and drag if we try to get too much lift out of a wing.

Most of the time, the greater the angle of attack, the greater the lift and the greater the drag.

But there is limit.

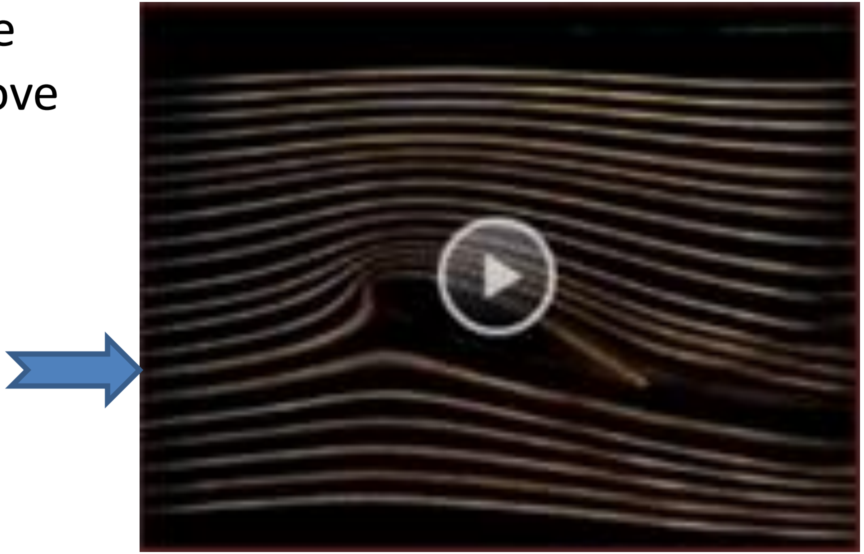
That limit is when the layer of air next to the wing – the boundary layer – is subjected to such a strong centrifugal force that atmospheric pressure can no longer hold it against the wing.

This is a wing section in a wind tunnel at Cambridge University.

Off camera to the left, the white smoke trails enter the tunnel evenly spaced vertically. The wind blows horizontally from left to right.

The blue arrow points to the smoke trail that passes nearest to and above the wing section.

Follow that trail with your eye. Notice that it enters the picture very low but is pulled up by the low pressure over the wing then almost dissipates by the trailing edge.



The dissipating smoke trail tells us that the upper boundary layer is becoming turbulent.

To be turbulent means to be all stirred up.

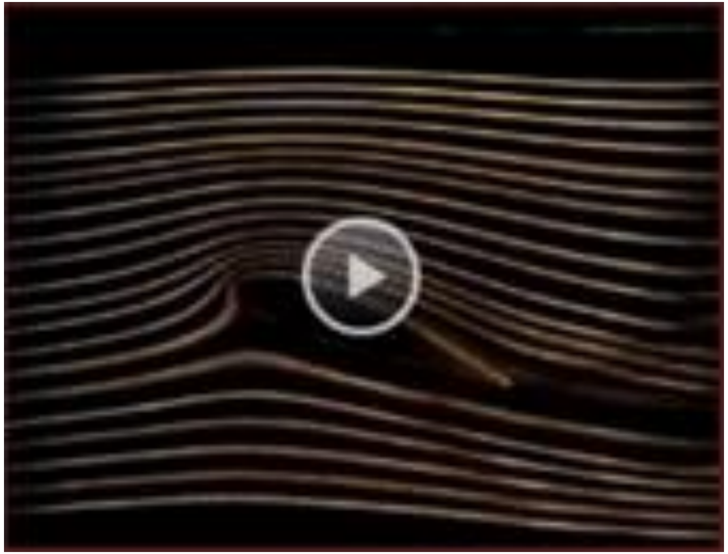
Imagine that you just poured milk into coffee.

You can see a clear boundary between the milk and the coffee.

As you stir the coffee, you notice two phenomenon. The boundary vanishes as the coffee turns beige.

You also notice that you need energy to make the coffee turbulent.

The fact that the coffee settles down doesn't matter. You need energy to create turbulence.



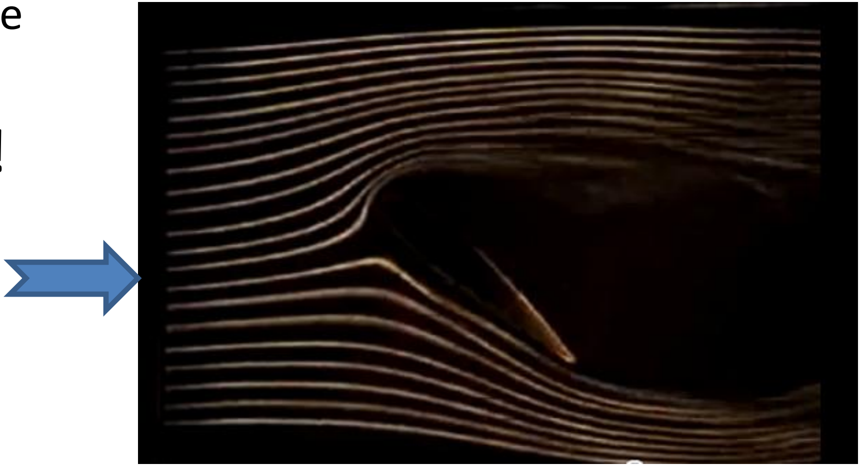
We'll follow up with this turbulence creation in a moment. But first, let's look at the picture below.

The wing is not lifting much because the upper boundary layer is no longer following a well defined curved path over the top.

It has most definitely separated! We have *boundary layer separation*.

This is the infamous wing stall!

Stalls **only** happen when a wing exceeds its **critical** angle of attack!

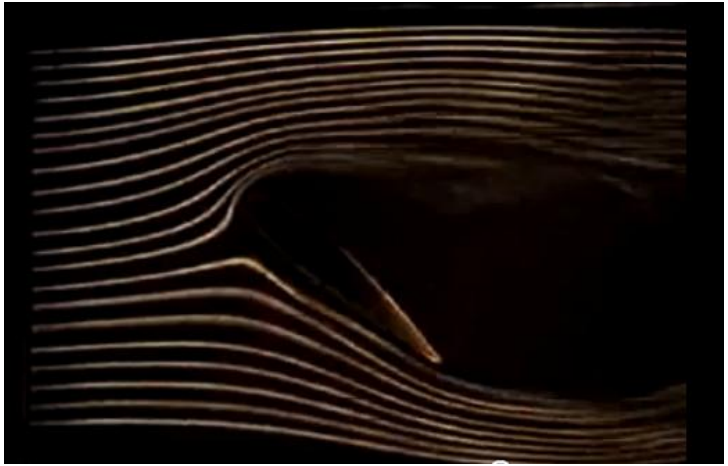


The blank space downwind of the wing is not a vacuum, it is just stagnate air moving along with the wing.

Turbulence creation: There is only one source of energy for an airplane to create turbulence – its motion through the atmosphere.

This means that the more the airplane stirs up the air, the more energy it takes from its airspeed and puts into the atmosphere.

This means that anything that you do to create turbulence creates drag.



Not only does a wing stall create massive drag, deploying flaps, landing gear, spoilers, ailerons, etc. creates drag.

We now know three causes of drag:

1. Skin Friction
2. Local lift
3. Turbulence

Two more definitions:

1. *parasitic drag* – drag that is always present no matter what the pilot does e.g., skin friction, drag caused by the shape of the airplane
2. *induced drag* – drag caused by the pilot’s action e.g., extending flaps or landing gear, putting the airplane into a tight turn, etc.

You have learned:

1. Causes of lift
2. Causes of drag
3. Cause of stall
4. That the sum of all of the aerodynamic forces on any object can never pull the object into the oncoming wind

In the next video, you will learn:

1. How a propeller produces thrust
2. That the weight of an airplane is not always caused by gravity
3. Why most propeller airplanes want to turn left during takeoff and climb.

DOUG DANIEL

PilotsOnlineAcademy.com

Making Superior Piloting Simple

Legal disclaimer:

Refer to the Terms of Service and other legal documents for limitations on liability and other important information. Terms of Service can be found at our http://www.PilotsOnlineAcademy.com website. The information presented is for illustrative and informational purposes only. Use these techniques and procedures at your own risk. Making decisions on my advice should be made with the knowledge that since I am not present to judge your abilities or performance, that you or other persons could experience losses, injury or death. You agree that I am not, to any degree, responsible for your actions or the consequences of your actions. This presentation may contain affiliate links or recommend products or services that I may have an affiliate relationship with. That means that if you buy something from them I may get paid an affiliate commission.