How is LIFT created?

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I join the group of people, saying: "*there are misconceptions about how LIFT is created*".
See: https://www.grc.nasa.gov/www/k-12/airplane/presar.html

Misconceptions:
WRONG: Bernoulli's Law creates lift on upper airfoil surface (it plays a role but not as original reason)
WRONG: Newton's Third Law: bouncing air particles at bottom side, or the existing Downwash
("*every action has a reaction*", "*bouncing stone*" theory, Newtown's Third Law)
WRONG: the Venturi Tube effect as an airfoil as a 'half tube'

Instead:

Lift is a force generated by TURNING a moving fluid.

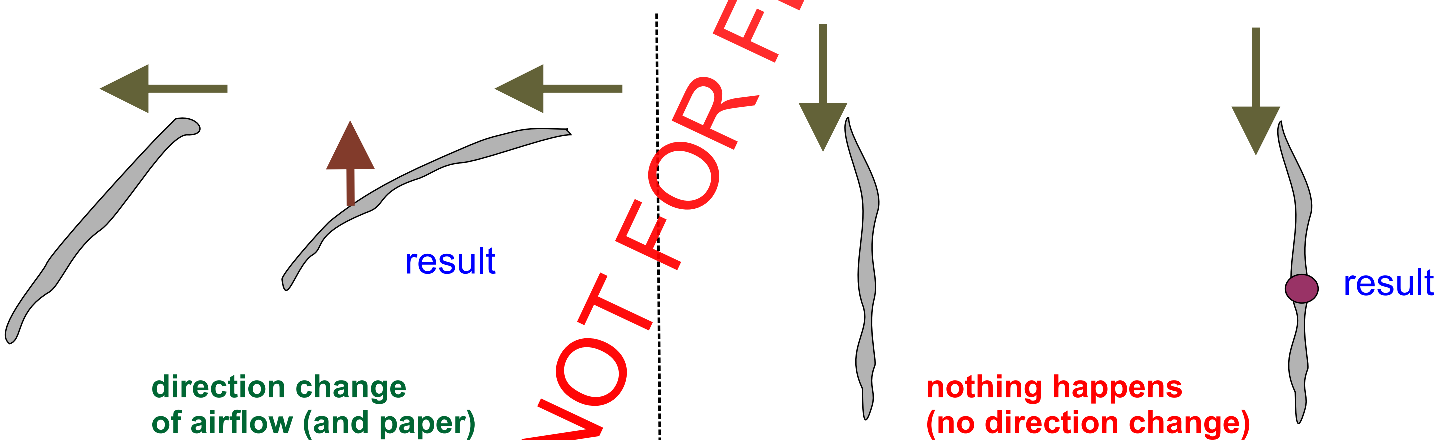
(*changing the direction of airstream has to be caused by a force which is the lift force*)
The direction change of the airstream is caused by a force. The force has to exist and is not generated by another effect (such as Bernoulli or the Downwash).
The main misconception is to **exchange the cause with the effect**, e.g. Downwash is an effect, not the cause of the force.

Newton's Second Law:

In order to change the velocity of a mass (accelerate/deaccelerate) - there must be a force.

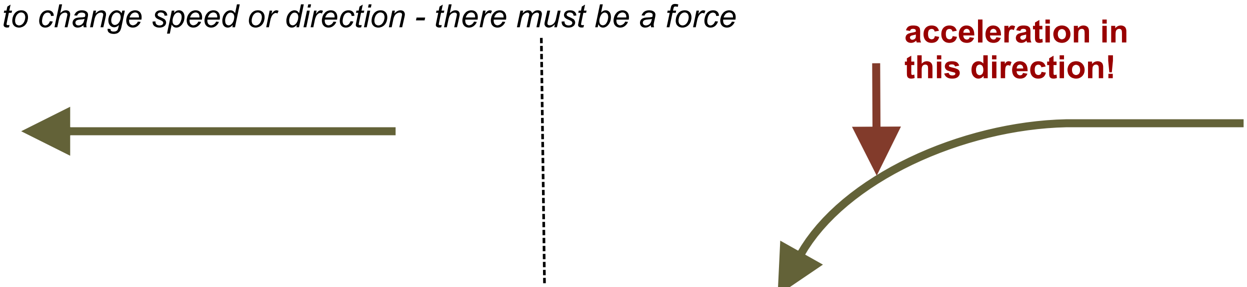
F = m * a

Experiment:
Do this well-known experiment where air is blown over a piece of paper.

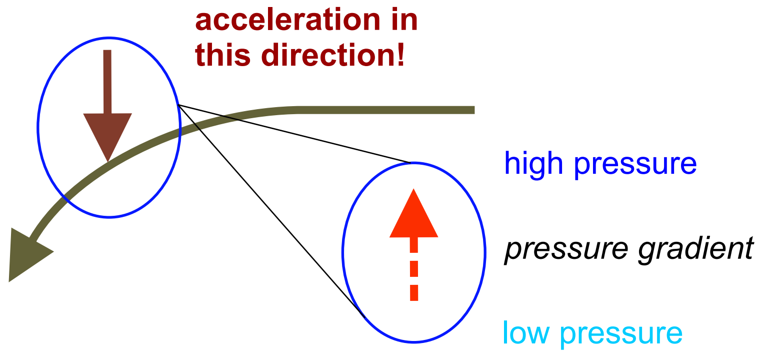


Conclusion:
There must be a change of the airstream direction which matters, not the flow itself.
And changing the direction can only be caused by an existing (net) **force**.

Newton's Second Law:
in order to change speed or direction - there must be a force



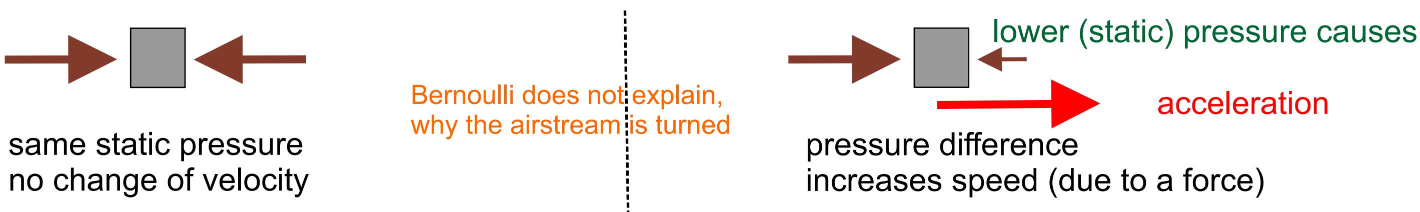
Pressure is a force:
So, there seems to be a (air) pressure (as the force) which causes the direction change (acceleration towards a different axis).
The pressure has to decrease towards the direction change (bending the airflow), so that the (net) force can act to accelerate the airstream towards this new (!) direction.



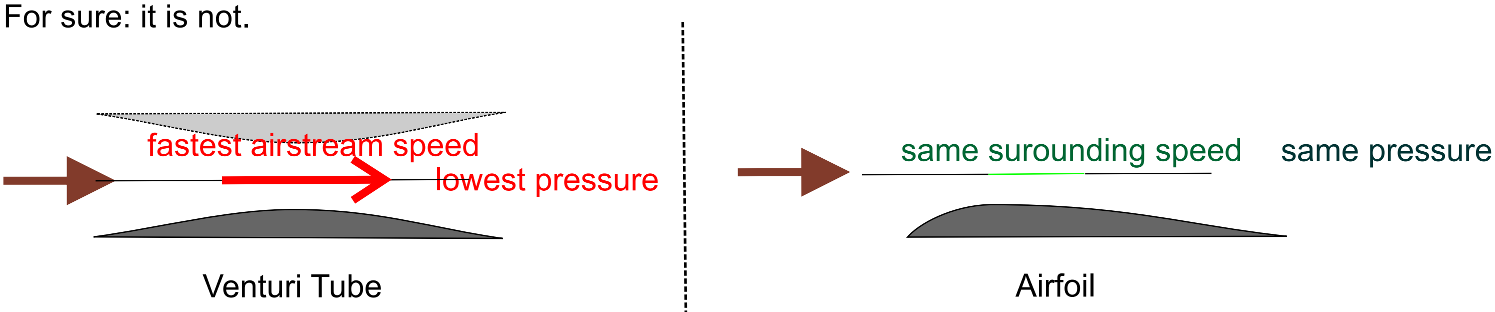
Pressure gradient:
So, there must be a lower pressure so that the airflow will change the direction.
And because, there is a lower pressure on upper side of airfoil, the higher pressure on bottom side will lift the airfoil (wing). There is also a high pressure field on bottom side of the wing.

And Bernoulli?:
WRONG: a faster speed lowers the pressure (cause and effect are exchanged)
CORRECT: due to a force applied - the speed will increase. The airstream entering the lower pressure region is affected by a force which will accelerate the stream (Newton's second law).
Bernoulli is right by: where the speed is higher - the pressure must be lower. But what causes the acceleration? It is still a **force**. So, acceleration does not cause the pressure difference, it is the effect of it (opposite cause and effect): an existing **force is the reason**: not acceleration causes a force.

BTW: Bernoulli is only 'valid' for a directed airstream, not for a stream changing the direction.

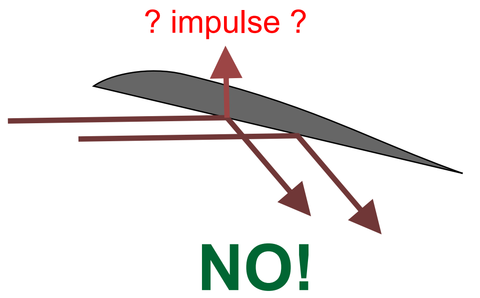


WRONG: airfoil is a '*half Venturi Tube*'
Pretty obvious: in Venturi Tube the highest airstream velocity is right in the center.
So, if airfoil is just a half tube - the airstream far away from surface should be faster as surrounding one.
For sure: it is not.

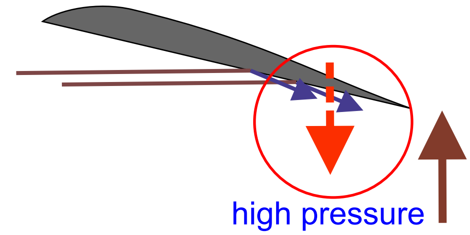


WRONG: bouncing mass and impulse
Are the air molecules really deflected on lower surface and can create so much (*back bouncing*) impulse in order to push our wing up?
Potentially not: the mass of the air molecules is so small, the density so small (otherwise we could not walk in our surrounding air: any step forwards would pull us back - it does not happen).

CORRECT: decelerating the airflow is a force
The airstream decelerates on the bottom side of the airfoil. A deceleration needs again a force (Newton's second law). So, there seems to be a pressure gradient doing so. The airstream enters a region of higher pressure and slows down.
This higher pressure region resides on the bottom side of the airfoil.

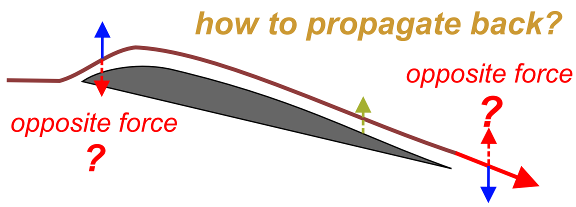


speed and mass of air molecules,
esp. in higher, less dense altitude
cannot cause such a strong lift force

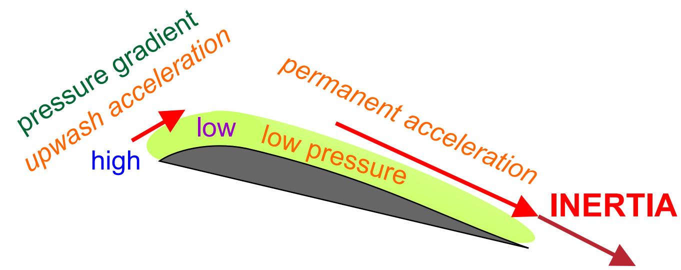


decelerate due to moving against higher pressure
a decelerating higher pressure is a force to lift up

WRONG: downwash creates lift
How can a force propagate back in opposite direction to the wing? (*where is the 'coupling'?*)
And if downwash creates an opposite force upwards - we have also upwash on leading edge - why it does not push the wing down on leading edge?
The airmass does not changes - should these 'opposite forces' not cancel out each other?



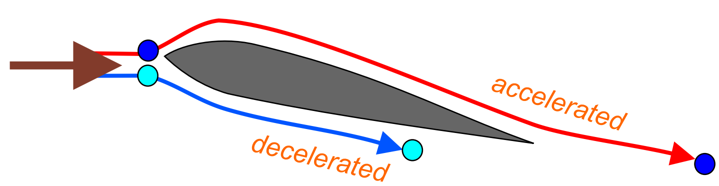
Airflow is ***not a solid*** object! How should a force be propagated back?
And why the same effect should not be there at the leading edge of the wing? (in opposite direction)



Airflow is accelerated (increased velocity) - it keeps going in same direction (Newton's First Law).

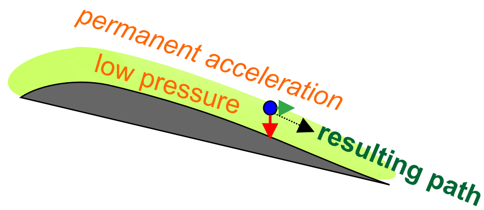
Airflow follows the pressure gradient. It remains accelerated as long there is a (net) force.
It keeps going in *last* direction if a force is not applied anymore (***Inertia***, Newton's First Law).

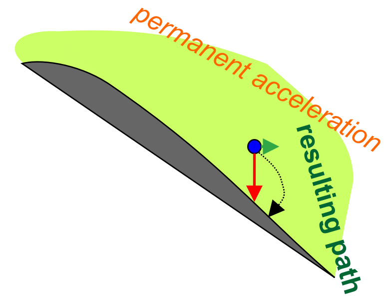
FORGET:
the simplification such as "*Longer Path*" or "*Equal Transit Time*"**!**
The airflow is accelerated above and decelerated below wing surface much more, whereby the velocity and '*arrival time*' of the particles at the trailing edge are never the same again
(they do not have a '*brotherhood*').



A symmetric airfoil has the same path around the airfoil chamber on both sides.
But the speed and time is not the same for particles traveling above vs. below.

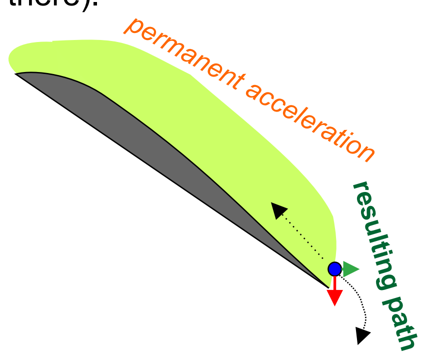
WRONG: airflow separation happens because it *cannot follow curvature*
Why should an air molecule be able to *see* or *feel* the curvature of the solid object where it is forced to move around? Does it have an *intelligence* to realize where the wing surface is? Obviously not.
What causes the airflow (air molecules) to take this path about the curvature of the airfoil?
It is the **pressure gradient field**, the shape of the **pressure regions**, not the shape of the object itself!
The shape of the airfoil (curvature) is designed in such a way that the pressure field(s) move(s) the particles exactly on a path along the object curvature (the pressure field has the 'same' curvature).
If the air particles are accelerated too much - then they are '*pushed*' even more downwards until they hit the wing surface or even have to flow backwards (vortex, vortices).



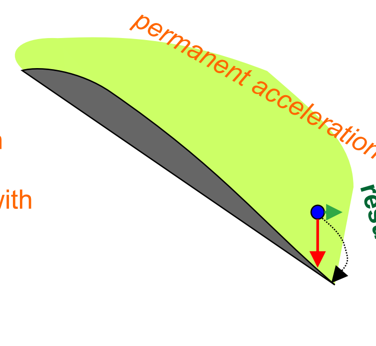


If the pressure gradients getting stronger (due to higher *Angle of Attack* (AoA) and larger pressure difference), the airflow is '*pushed*' more down and towards the wing surface. If the acceleration in the vertical axis is so large then the air molecules have to travel even backwards, deflected by the wing surface (creating a vortex and airflow separation). Bernoulli is correct here: if the pressure is lower, the velocity has to be increased (and it does with the airstream over upper surface of wing).

Where does the airflow separation start?
This vortex generation (*too much deflection downwards*) starts at the point, where the forces have acted **long enough** (*accumulation of movements*). It is a function of factors such as: how strong the force is (pressure difference) as well as how long the molecules have been forced into changed direction by it. So, the airflow separation (and vortex generation) starts at the **trailing edge of the wing** (NOT on the top of the curvature and point of strongest *deflection*: *'not long enough exposed to the force*' even strongest there).



increased pressure difference
(higher AoA) "*sucks*" the downwash
backwards over the wing,
vortecis generated due to contact with
wing surface and interactions



You could imagine:
The downwash is a result of *too much vertical down acceleration*. If you increase the pressure difference (pressure gradients), then the airflow is forced even more downwards
(AoA will do, increase pressure difference).
If this '*downwash effect*' behind the wing starts to travel backwards along the upper surface of the wing, the more airflow is separated. If the acceleration downwards is so strong and it hits the surface - then the airflow can turn even more backwards (towards the wing tip). This creates an opposite force and decelerates the wing velocity dramatically (drag), starts to 'kill' the pressure differences (loss of lift).

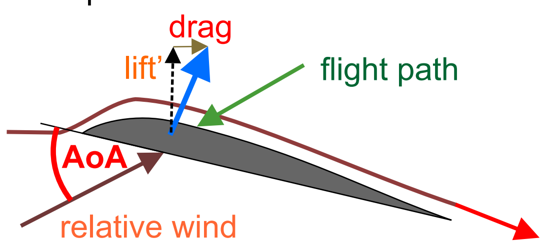
Conclusion:
The airfoil (shape) is not the starting point. Instead. the **airfoil was designed** in a way, that the pressure gradients (pressure field around it) are '*perfect*' for a smooth airflow, so that air molecules will take a path around with minimum drag, largest lift coefficient and do not hit surface (avoid additional drag), etc.
The starting point was the behavior of airflow (fluid mechanics and physics).
We have selected the *best* airfoil for our wing *according* to the airflow (fluid) physics and behavior.
The airflow does not try to *follow at best any of our airfoils*! (it is not a smart intelligence to do so).
We **provide a shape** to the airflow which is most appropriate to it, for the effects we want to get
(less drag, more lift).

But what about Ground Effect?

FORGET:
the '*theory*' of an '*air cushion*' below the wing. Why such a *cushion* is not there when you stall the wing and '*fall downwards the ground*'? Would it stop let falling you down short before hitting the ground?

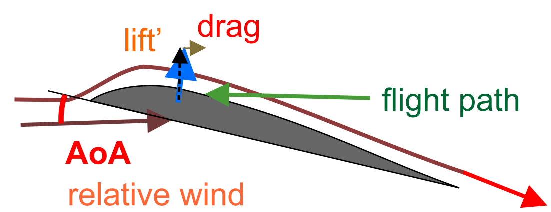
People also say: *the AoA is lowered* (due to changed relative wind) and it results in less drag (but why does it create enough or even more lift with a lower AoA?).
Or the '*downwash is killed*' and therefore less drag ('*ahhhh, less dawnwash eq. less drag - a hint already*'), but if downwash would be the lift (w*hich is not!*) - it should be less lift then - something seems to be wrong (contradictorily) here.

My short answer:
in Ground Effect the drag is reduced (due to less downwash). And air flow separation happens later (due to '*less downwash*'). You can increase AoA even more without to stall the wing (above the ground only). Yes, there is also a reduction of wing tip vortices (more lift, less drag).
Your transition above the ground let's you stay longer airborne and remain flying. If you keep going without any transition or any round out - you would hit the ground exactly as predictable. The transition, round out, is the possibility to increase the AoA even more without to stall - seems to be the answer.
An airplane does not transition *itself* into ground effect, neither it does on a (soft field) take-off.



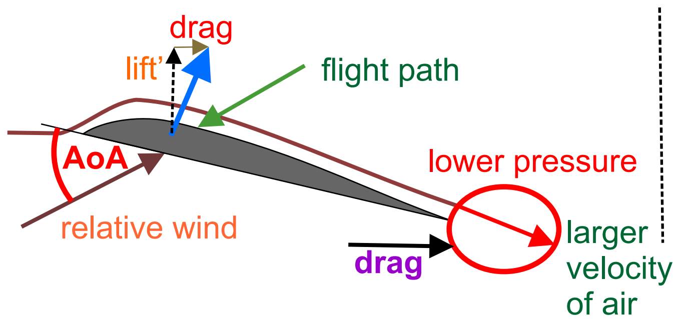
induced drag is not only a **tilted lift vector**, there are other (pressure) distributions (fields) around the wing, e.g. downwash

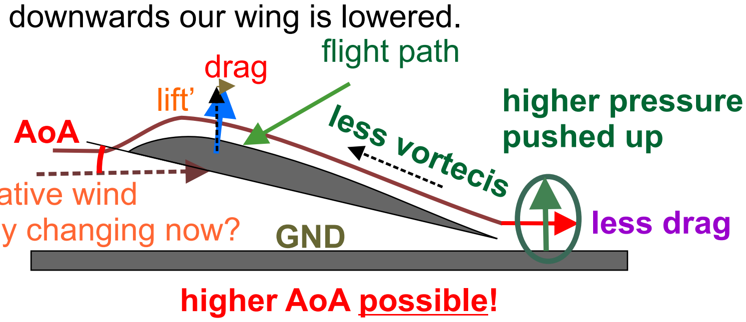
let's forget wing tip vortices which might be reduced by *winglets* (sure, they contribute to drag reduction in ground affect but they are not the major effect)



If AoA is reduced so much - it **would not create enough lift** anymore.
The upright lift vector is not large enough anymore, esp. this vector magnitude is lowered as well (pressure)! Sure, a bit drag is reduced but plane would never accelerate: instead it slows just down the deceleration (we don't increase speed in ground effect! We keep it more constant, so airflow speed increase does not happen and lift must come from something else).

I think, what happens:
If Bernoulli's Law states: "w*here a higher velocity is - there must be a lower pressure*" (which is true), then we should have a lower pressure region even behind the wind trailing edge (airflow still faster as surrounding flow there, in the ***downwash***).
This lower pressure region creates a force from higher pressure region (before wing) to the lower one (behind wing, against the flight direction), which is opposite to flight path (**drag**).
If we lower this pressure difference (lower downwash - then we get less drag.
The higher pressure under the wing is pushed upwards (at the trailing edge) - we lower the pressure difference above the wing and do not accelerate airflow down so much anymore.
And: If we lower pressure difference above the (trailing edge of the) wing - we **can increase AoA even more** w/o to separate airflow because the deflection downwards our wing is lowered.





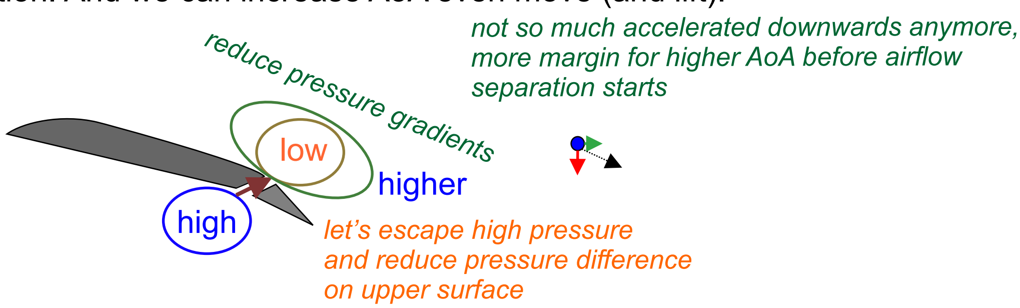
Conclusion:
We can fly in **ground effect** with an **even higher AoA** without to stall the airplane (but we have to transition, pull-up, on landings and take-off, to make use of it).
We can take-off and get airborne with higher AoA at ground but which results in a
stall above ground effect when we keep the same AoA outside ground effect!.

If you see a *ground effect vehicle* - its AoA is higher as '*usual*'.
It is <u>not</u> the higher lift you get from ground effect - it is the <u>possibility</u> to create more lift by increasing the AoA even more in ground effect.

if you stall the plane short before entering ground effect - it will not *recover* in it!

Proof of Concept:
If a *too large* pressure difference hinders us to increase AoA (for more lift) due to creation of vortices, the airflow does not "follow" anymore the contour of airfoil (too much accelerated down) - could we lower the pressure gradients so let the air molecules not to be pushed down too much?
Answer: YES, see the 'Fowler Flaps'.

Let '*escape*' the higher pressure on lower surface to the upper surface, so that we reduce the pressure gradients, the air flow separation. And we can increase AoA even move (and lift).



Besides the increase of wing area - we can now increase AoA (and create more lift) before the separation of airflow will start. *Too much pressure* (force) can be '*bad*' - lowering the pressure difference can create additional margin for other parameters (such as higher AoA).

Conclusion:
Aerodynamics and Lift are complex.

Lift is a force and caused by <u>turning</u> an airflow (a moving fluid)!

All is dependent: a larger velocity is caused by a force (pressure difference, Newton's Second Law), also a higher velocity results in a lower pressure (Bernoulli).
Nevertheless, it seem's to be **Newton's Second Law** explaining most of the effects, even Bernoulli remains valid, but does not cause first of all effects, does not contribute so much or could really explain why we have lift.

Main *Reason of all*? (where does it start?):
The (my) argumentation starts at: "*there must be a force first*". But where is it coming from?
I might argue this way:
There is a relation to convert kinetic engery into potential energy (and vice versa).
So, the velocity of the airsteam (kinetic energy) is converted into a (static energy), represented by the pressure differences.
But this pressure difference (static energy) is converted 'back' into a kinetic energy, such as the acceleration of the airstream.
If such '*transformations*' happens - there must be a force involved (acceleration/deceleration/gravity ...).
If this force is a result or the effect of all these 'energy transformations'? (No idea).
An open question about '*Chicken or Egg first*'.
What was first? Potentially just a very tiny, almost infinite, small imbalance. Cross-wise influences and effects - both parameters are progressing and influencing each other (and over time).
At the end, it seems to be **Newton's Second Law**: ***there must be a force involved*** (pressure difference) in order to explain, what happens. Where the ***origin of this force*** is remains a bit magical (but we do not know either what has caused the '*Big Bang*', maybe a quantum?).

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