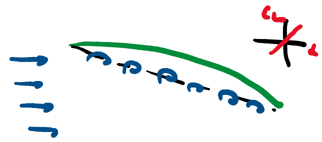
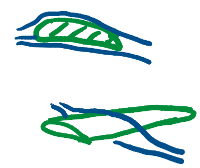
Lecture 13: Airfoils and wings

Monday, October 26, 2020 8:55 AM

LAST TIME: THIN AIRFOIL THEORY → culmination of incomp. + inviscid theory



TODAY: back to basics: PHYSICAL overview of AIRFOILS, WINGS

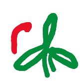


(L) LIFTING SURFACES: a physical intro

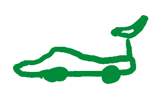
→ Mostly WINGS/AIRCRAFT, also

FANS

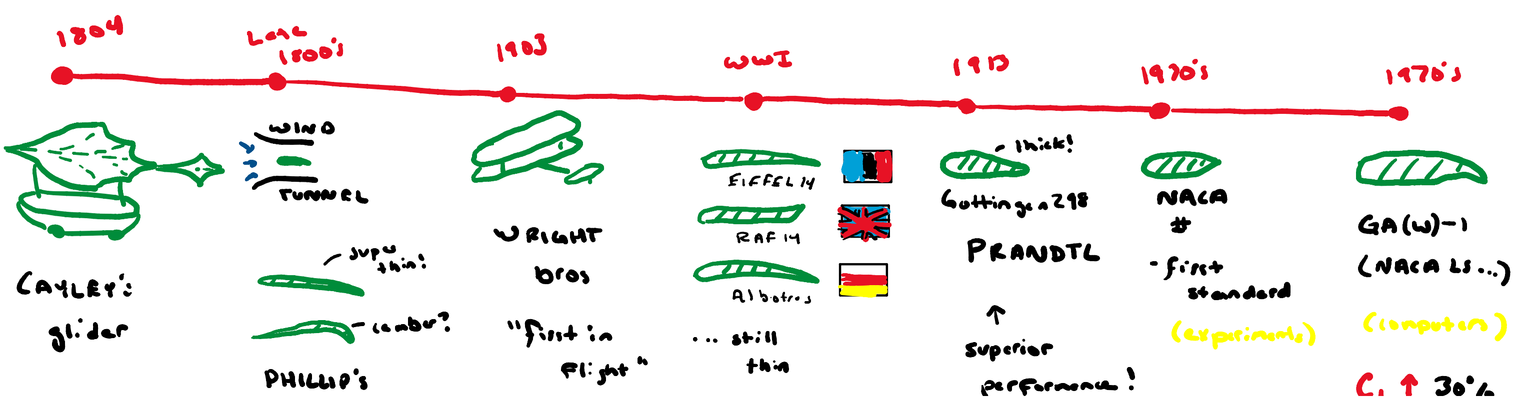
PROPS/TURBINES



SPOILERS



HISTORY (of airfoil shape... CAMBER + THICKNESS)



glider — camber? PHILLIP's experiments | "first in flight" | ... still thin | ↑ superior performance! | (experiments) | (computers) C_L ↑ 30% L/D ↑ 50%

Why so THIN?

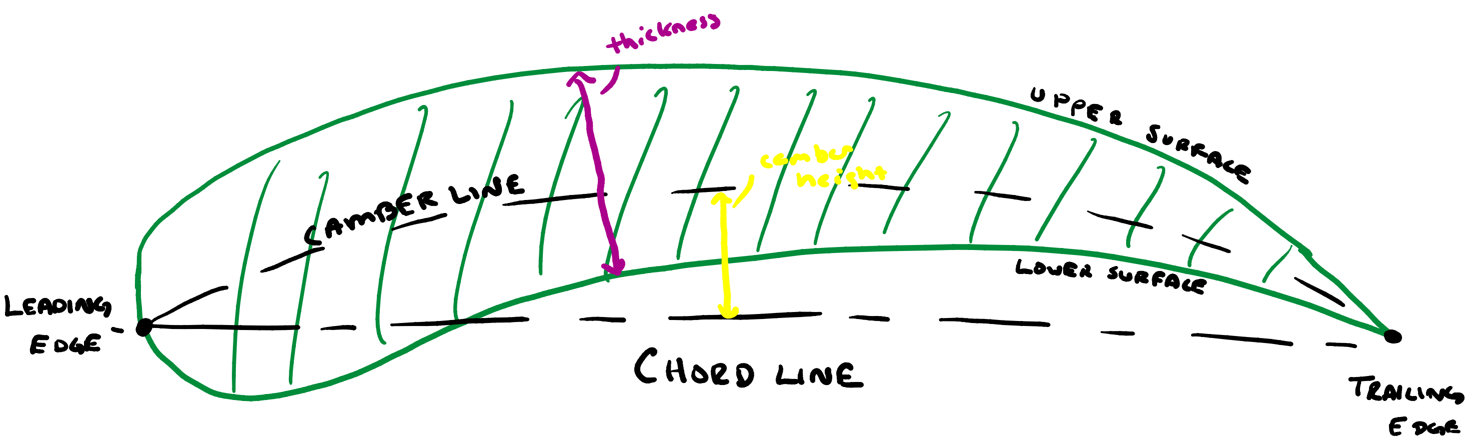
- Tradition (Cayley did it)
- Biomimicry (Birds do it)
- Low Re experiments THICKNESS → DRAG

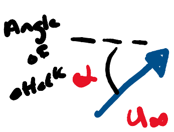
(1) AIRFOILS

BASICS

CHORD: connect LE — TE

CAMBER: halfway between U.S. L.S.

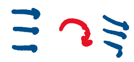


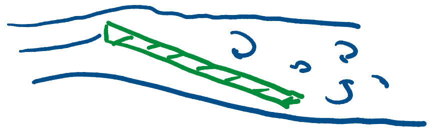


Typically:
1. choose an AIRFOIL family (NACA, CLARK, EPPLER)
2. choose MAX thickness
3. choose MAX camber height

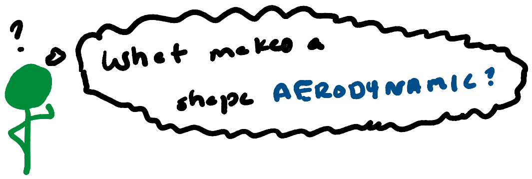
"GOAL" – to TURN (LIFT) air w/out DISTURBING (DRAG) it

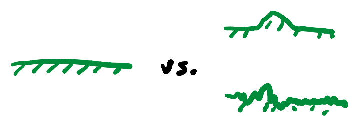
GOAL – to TURN air w/out DISTURBING it

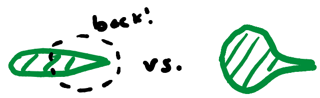




THICKNESS
CAMBER
make this happen!

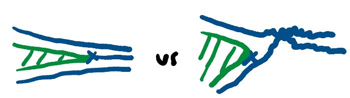


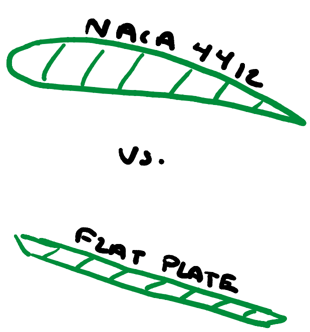
SMOOTH  Lower skin friction drag

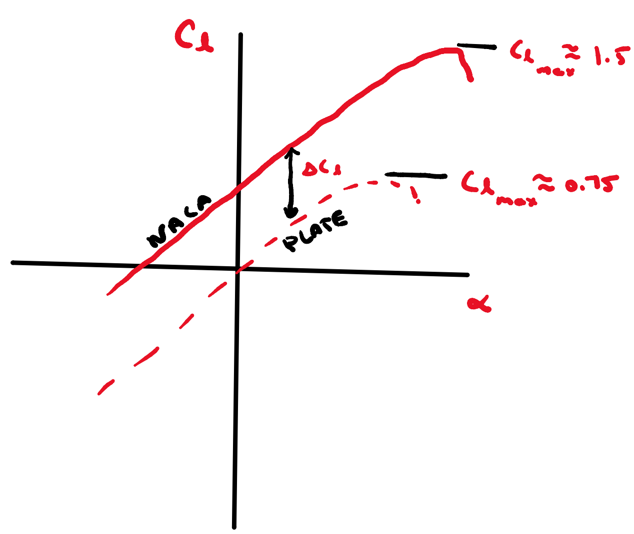
SLENDER 

Avoid changing shape too fast (avoid separation)

ROUND LE  Let flow BEND w/out separation

SHARP TE THIN 
- fixes TE stagnation KUTTA-CONDIT.
- streamlines meet gracefully

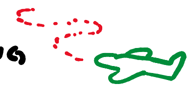




This is just basic shape! What about...

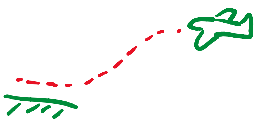
MODIFICATION → changing FORCES / MOMENTS during flight

Throughout flight, NEEDS change

- TAKEOFF / CRUISE / LANDING
- WIND / TURB. 
- MANEUVERING 

> **AIRFOILS** need to:
>
> (1) ACTIVELY change L/D/M
>
> (2) Sometimes need MAX LIFT $C_{l_{max}}$

Consider LANDING → want LOW U (safer, less energy, less beefy gear)

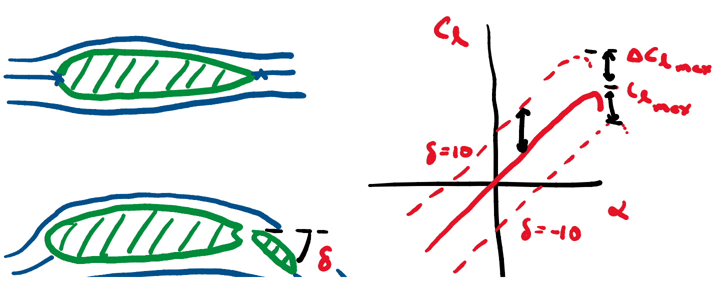


$$L = \frac{1}{2}\rho U^2 S C_L \Rightarrow U = f\left(\sqrt{\frac{1}{C_L}}\right)$$

(L: const. = W; $\frac{1}{2}\rho$, S, c: fixed; U: min this; C_L: max this)

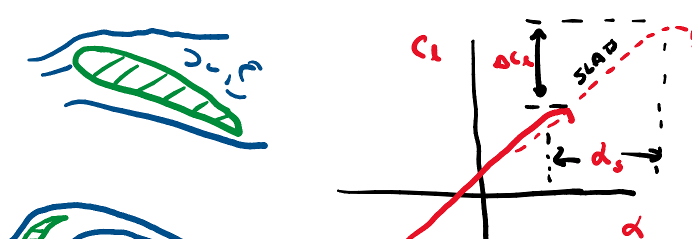
So, we design ways to $C_L \uparrow\downarrow$

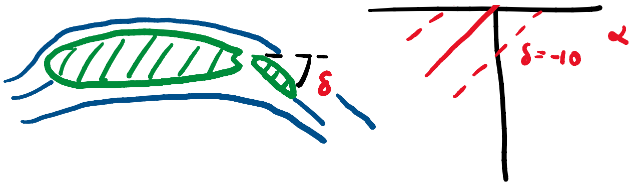
TE FLAPS

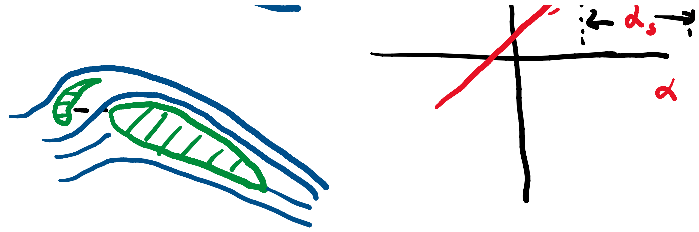


LE SLATS

(sometimes "droops" "flaps")

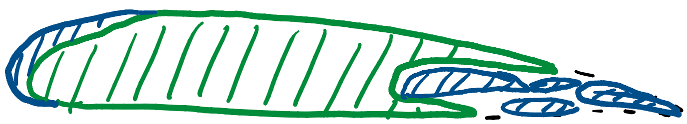




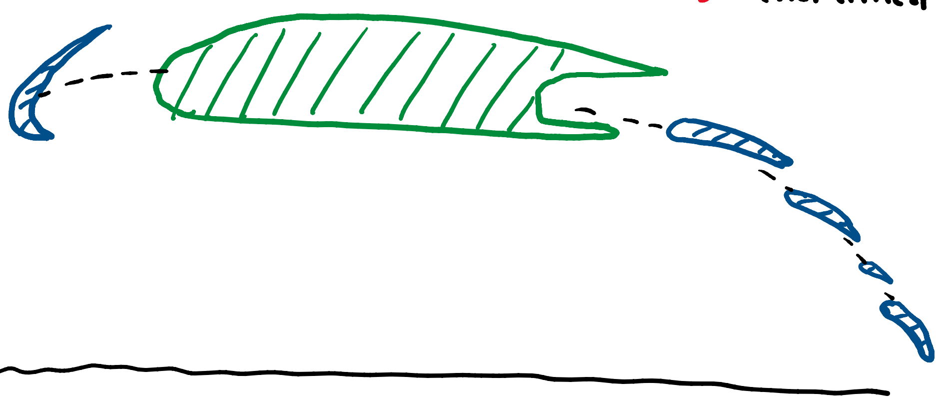


Modern Foils:

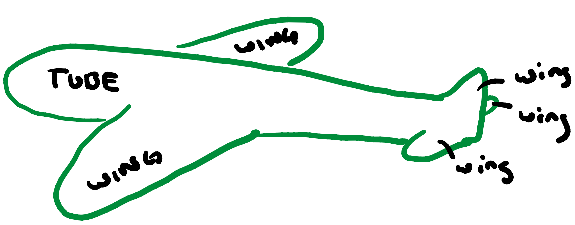
CRUISE $u\uparrow$ $C_L\downarrow$ $C_D\downarrow\downarrow\downarrow$



LANDING $u\downarrow$ $C_L\uparrow$ C_D... (not critical)



(2) WINGS (the 3rd dimension!)



WINGS are about more than AERO

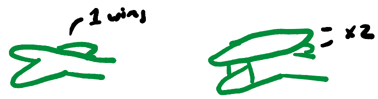
- structure / strength
- weight
- stability / control

NOTE: this overview is <u>cursory</u> ... check out WIKI: "Wing Configuration"

BASICS — Configuration of MAIN wing

WHY?

(OLD) **NUMBER:**



monoplane — biplane

• more lift / fuselage

★ **POSITION:**

Low — med. — shoulder

• stability

(OLD) **SUPPORT:**

cantilevered — braced

• Structure / strength

★ **ASPECT RATIO:**

Low — med. — high

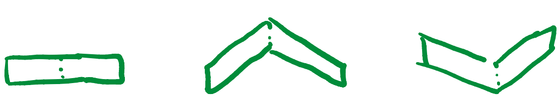
• Efficiency (PRO)
• weight / strength (CON)

★ **CHORD VAR.:**

rect. — tapered — elliptical — delta

• Efficiency (PRO)
• Control loss (CON)

★ **SWEEP:**



straight — swept — forward swept

• design constraint
• stability

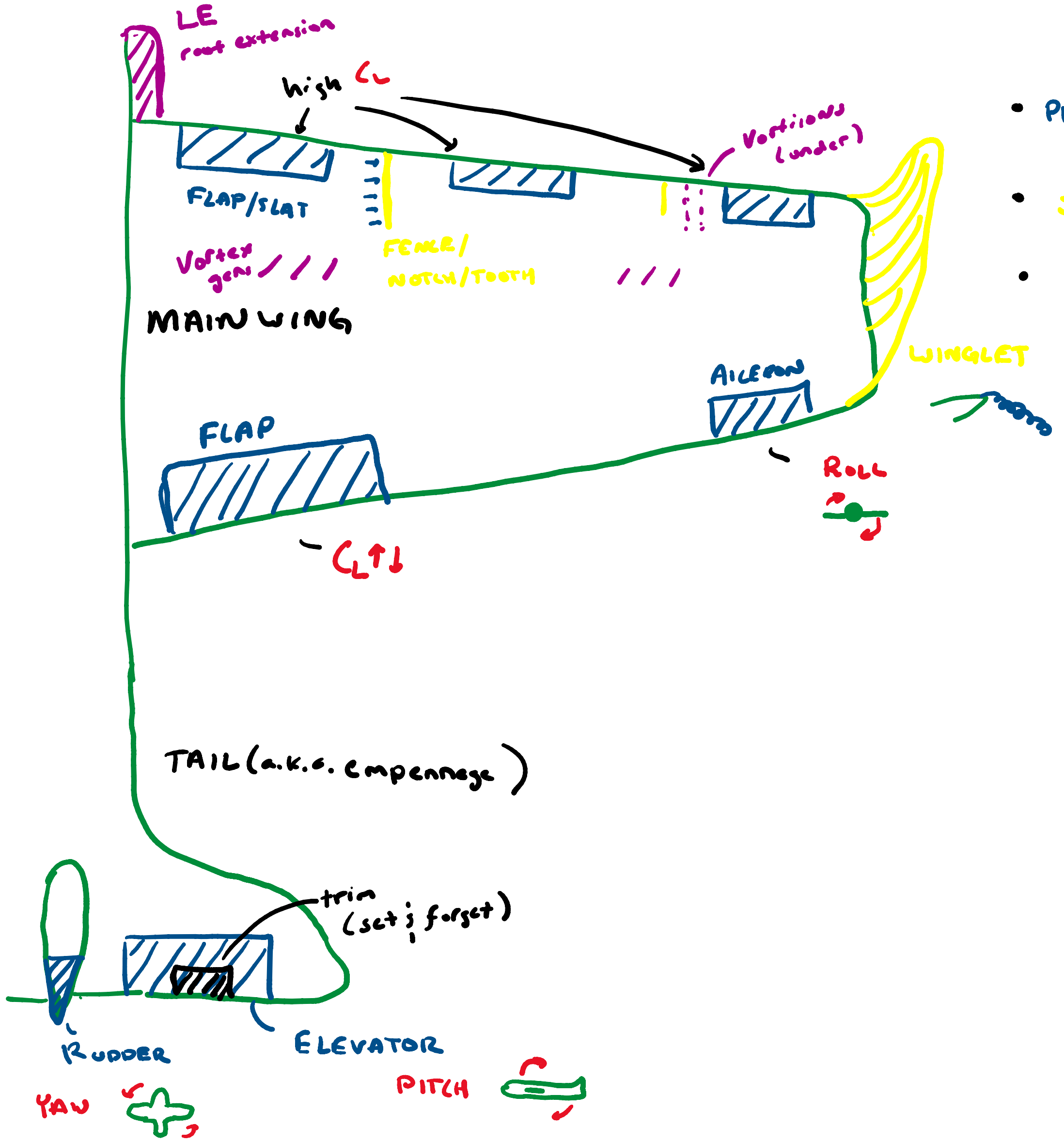
★ **HEDRAL (?):**

dihedral — anhedral

• Stability / control

MODIFICATION

adjusting flight PERFORMANCE / CONTROL



- PRIMARY CONTROL SURFACES
- SPANWISE FLOW CONTROL
- STREAMWISE FLOW CONTROL

2D AIRFOILS ⟹ 3D WINGS

AERODYNAMICS

AERODYNAMICS

STRUCTURE + STRENGTH

CONTROL + STABILITY

STRUCTURE + STRENGTH

CONTROL + STABILITY