THE PHYSICS OF FLIGHT

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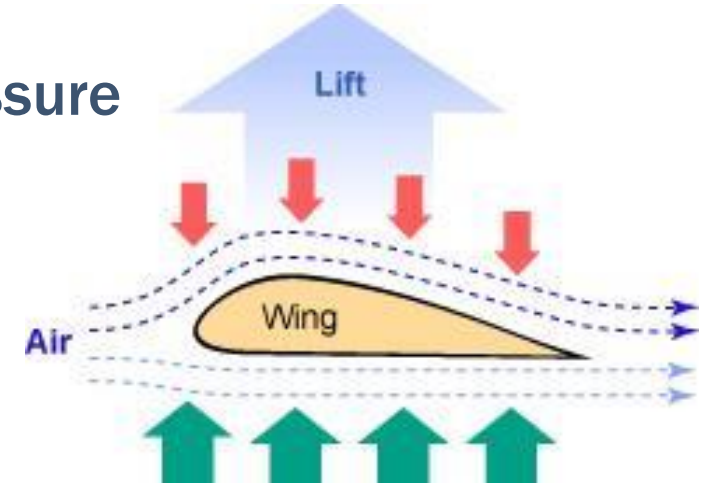
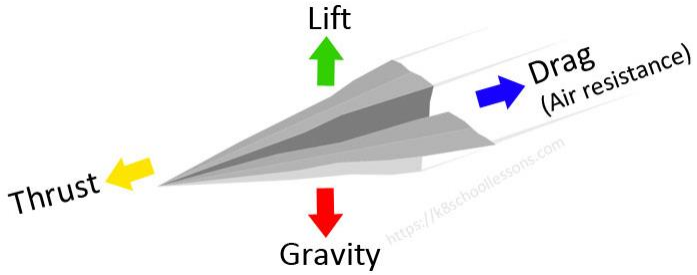
BERNOULLI'S PRINCIPLE

- Upward pressure on a moving wing generates lift
- Triangular wing shape builds pressure
- Disparity in velocity of moving air
  - Air under wings moves more slowly
  - Air above wings moves more quickly
  - Higher air pressure underneath creates lift



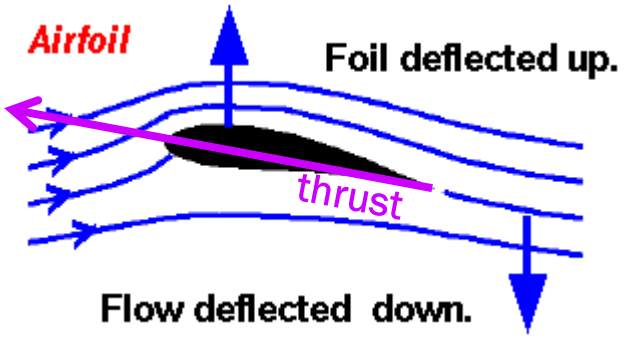
“FORWARD” FORCE: THRUST



- Wings must be in motion
- Motion is enabled by thrust
- Thrust drives flying objects along their trajectory
- Thrust acts as the source of velocity
- There are different ways to generate thrust

NEWTON'S THIRD LAW

- Every action produces an equal and opposite reaction
- A flier's nose and thrust point in the direction of its angle of attack, α
- Outside of cruise phase, α has a y-component along with its x-component
- Therefore, thrust also creates lift



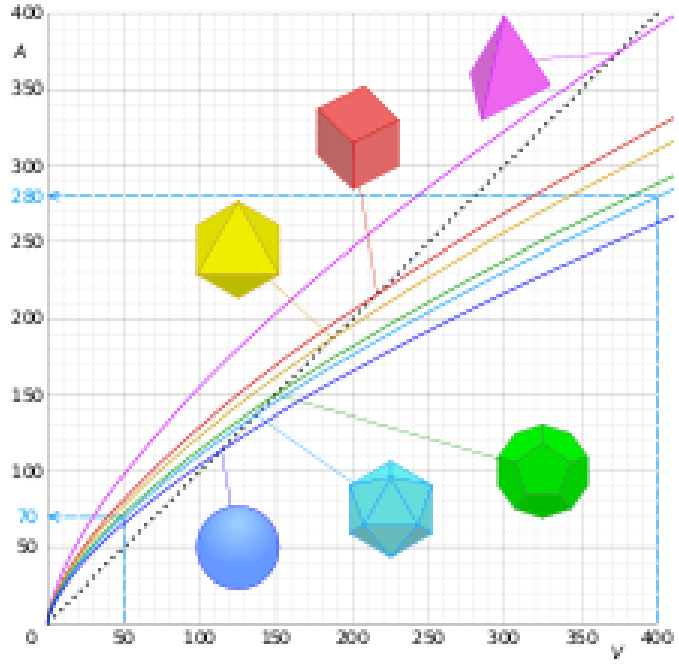
LIFT EQUATION

- $L = \frac{\rho V^2 S C_L}{2}$
  - L is lift, equal to the flier's weight
  - ρ is air density
  - V is flier's velocity
  - S is wing area
  - C_L is lift coefficient


DISCORSI
E
DIMOSTRAZIONI
MATEMATICHE,
intorno à due nuoue scienze
Attenenti alla
MECANICA & i MOVIMENTI LOCALI,
del Signor
GALILEO GALILEI LINCEO,
Filosofo e Matematico primario del Serenissimo
Grand Duca di Toscana.
Con una Appendice del centro di gravità d'alcuni Solidi.
IN LEIDA,
Appresso gli Elsevirii. M. D. C. XXXVIII.

TWO NEW SCIENCES

- Galileo Galilei, 1638, days 1-2
- Square-cube law
  - Assume density is held constant
  - Given a 3D object of side length b:
    - Surface area S increases proportionally to b^2
    - Object's volume W increases relative to b^3



$$S \propto b^2$$

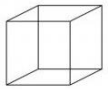
$$W \propto b^3$$

$$\frac{W}{S} \propto \frac{b^3}{b^2} = b$$

$$b > 1 \rightarrow b^3 > b^2$$

$$\therefore \frac{b^3}{b^2} > 1$$

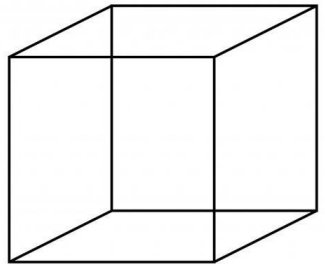
EFFECTS ON FLIGHT



Height	1m
Surface area	$1m^2$
Volume	$1m^3$

$$V = s^3$$
$$SA = 6s^2$$

- Wing area and lift increase proportionally to b^2
- Mass and gravity increase relative to b^3
- Increase in mass outpaces the increase in wingspan
- Mathematically, the costs outweigh the benefits



Height	10m
Surface area	$100m^2$
Volume	$1000m^3$

$$dV = 3s^2\, ds \qquad dSA = 12s\, ds$$

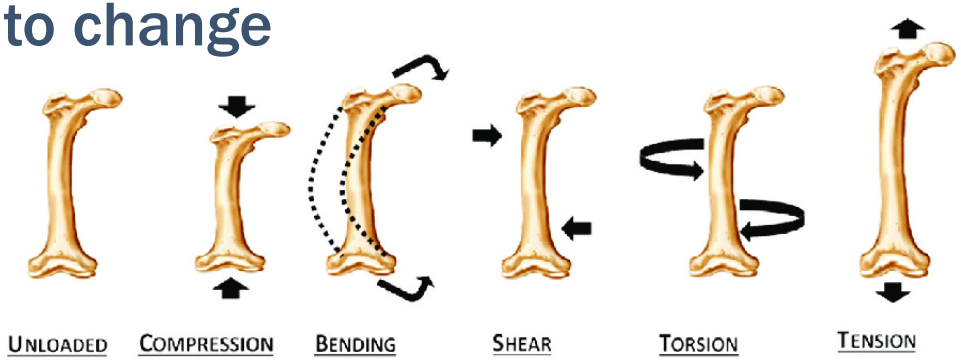
$$\frac{dSA}{12} = s\, ds \qquad dV = 3s \times s\, ds = 3s\, \frac{dSA}{12} = \frac{s\, dSA}{12}$$

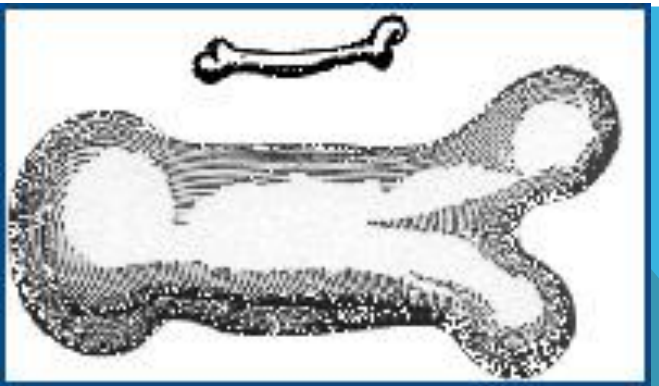
WING LOADING

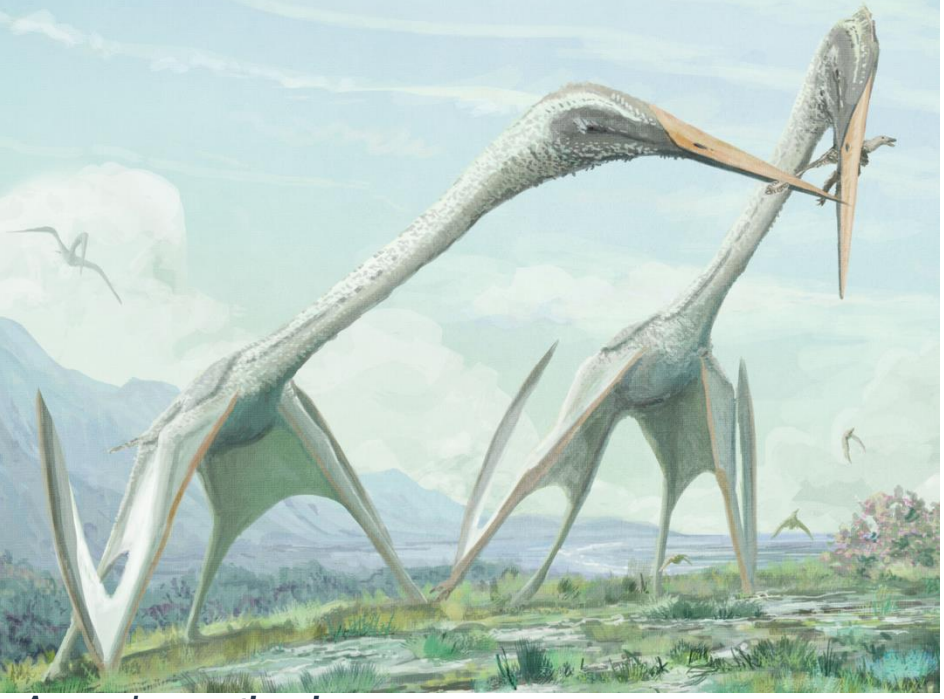
- Isometric increase in size increases wing loading
- Mass divided by wing area, proportional to b
- High wing loading requires more speed for equal lift
- Therefore, a small value of b is optimal
- Smaller size is better for flight

ANATOMY AND BIOMECHANICS

- Isometric scaling does not fortify bone structure
- Strength increases with b^2, mass with b^3
- High scaling factors strain bones too much
- Bone shape would need to change







Arambourgiania

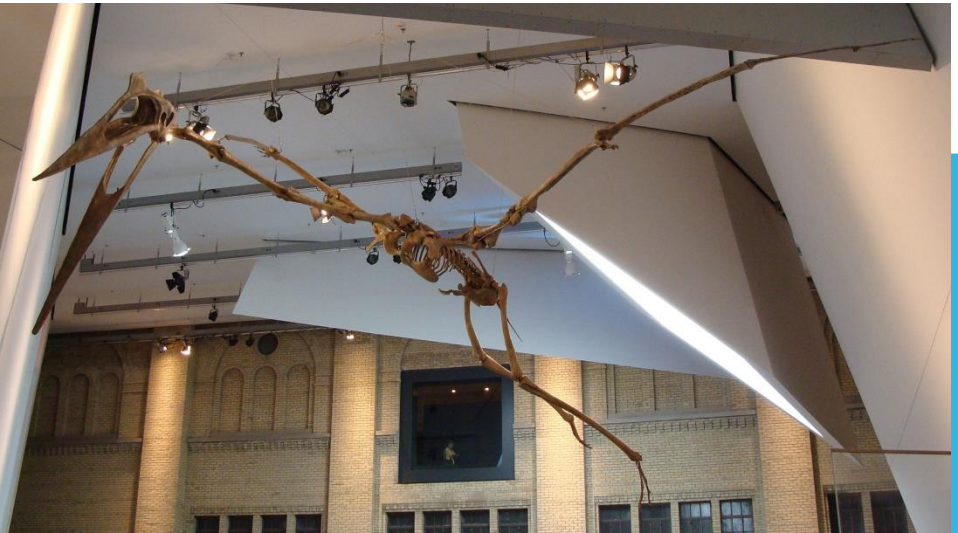
Argentavis Magnificens

Wandering Albatross

RECORD SETTERS

Antonov-225

Quetzalcoatlus



FURTHER RESEARCH AIMS

- Lift coefficient
- Change in velocity with increasing b
- Variable body density
- Different values of ρ
- Other methods of counteracting $\overrightarrow{F_g}$

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