Fluids at Rest

Introduction to Biomechanics
2008/10/22

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Solids vs. Fluids

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	Solid	Fluid	
Defined shape	Yes	No	
Defined volume	Yes	**Liquid**	**Gas**
		Yes	No
Force-deformation curve			
Force vs deformation rate curve			

Example:
Gas — Air, water vapor
Liquid — Water, honey
} Life's media
Solid — Rock

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Which stresses each state of matter resist

	Compression	Tension	Shear
Solid	X	X	X
Liquid	X	X	
Gas	X		

Fluids

Though gas and liquid have similar dynamics, but different statics. (e.g. 10^3 difference in density)

➔ *Air and Water: The Biology and Physics of Life's Media.* By Mark Denny (1993).

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Basic Rules about Gases

1. For ideal gases within a container of rigid wall,

$$pV = nRT$$

p: pressure
V: volume of container
n: number of molecules (moles)
R: a constant = 8.314 J/mole-°K
T: temperature (°K)

2. For a given amount of the same gas,

$$\frac{p_1 V_1}{T_1} = \frac{p_2 V_2}{T_2}$$

... "Boyle's law"

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3. In the absence of specific chemical reactions, the individual gases in a mixture act independently.

$$p_{ALL} = P_1 + P_2 + \ldots + P_n$$

Partial pressure

$$\rho_{ALL} = \rho_1 + \rho_2 + \ldots + \rho_n$$

e.g. $P_{air_sea\ level}$ = 101,000 Pa, O_2: 20.95% air → P_{02} = 21,160 Pa
→ If P_{air} = 1/5 ATM, need pure O_2 to breathe normally (~ @ 12,000 m high)

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4. In the air, the effect of gravity on the density and pressure of a gas can be ignored.

To increase air pressure by 1 ATM → 8400 m

84 m → Expand the air in your lung only by 1%

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5. Underwater, the gravity of water dramatically increase the gas pressure within a container

To increase air pressure by 1 ATM → 10.3 m
So dive down 20 m, your lung ↓ volume by half

10 kPa– limit of muscle work to inhale (~ 1 m down)

Can brontosaur breathe underwater by snorkeling?

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6. Increase the % of a light gas in a mixture

→ ↓ Density of the mixture

→ Cause convection

e.g. water vapor (MW = 18 g/mole)
dry air (MW = 28.6 g/mole)

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Buoyancy

$$F = mg = (\rho - \rho_o)Vg$$

ρ_o: density of the medium

Organisms are made of materials slightly denser than freshwater or sea water

→ How to pelagic (non-bottom-living) animals maintain buoyancy?

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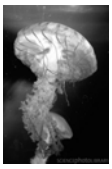
Schmidt-Nielsen (1997) in *Animal Physiology: Adaptation and Environment*—

1. Abandon dense materials

e.g. jellyfishes & nudibranchs (sea slugs)



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2. In body fluid, use ionic solutions of less density

e.g. Cells of some large marine algae

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3. Retain large reserves of fats and oils

e.g. Sharks & deep sea fishes

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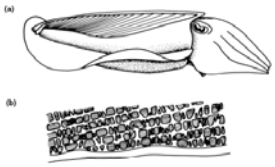
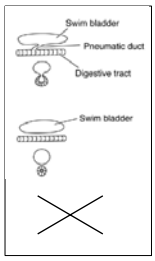
4. Use gas-filled organs

(i) Store gas in rigid structures (nautilus & cuttlefish)



4. Use gas-filled organs

(ii) Bony fishes store gas in flexible swimbladder



E.g. Goldfish, carp
(can gulp air from surface)

E.g. Most fishes, e.g. Perch,
(gas secretion from blood)

E.g. Bottom-living fish
Continuous swimmer (e.g. Mackerel)

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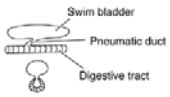
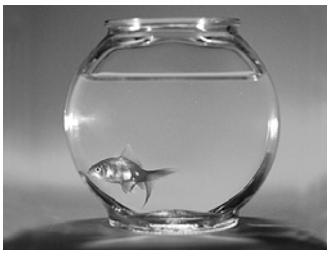
Goldfish





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5. Use lung

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Pressure and solubility

Henry's law:

at a constant temperature, the amount of a given gas dissolved in a given type and volume of liquid is directly proportional to the partial pressure of that gas in equilibrium with that liquid

Implications for organisms:

e.g. Diving (N_2 in blood→ bubbles when ascending)

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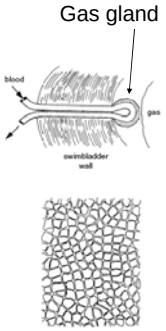
Q1. How does swimbladder extract gas (O_2) from the blood against the [ΔC] & @ 400ATM?

Q2: How is gas retained in swimbladder despite high pressure?



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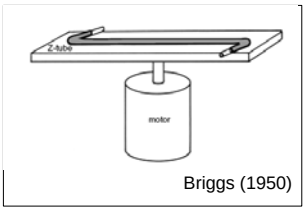
The liquid state

Measuring the internal cohesion of water



Briggs (1950)

The water column ruptures @ 28 MPa (~ 280 ATM)!!

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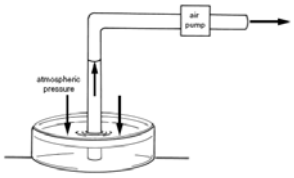
What does an air pump do?

Can it raise water column to 2884 m (280 ATM)?



Only 10.3 m
(Only 1 ATM)

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How about trees?

The tallest living tree
(coast redwood, *Sequoia sempervirens*)

Guinness World Records:
In September 1998, it was 172 m

In a 100 m tall tree

→ 1 MPa internal tensile stress (-10 ATM)

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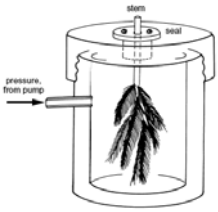
A Scholander bomb→ negative pressure of a tree



Results: -20 ATM

Not only to pull on water, but also to overcome some resistance (e.g. narrow vessels & detach water from soil)

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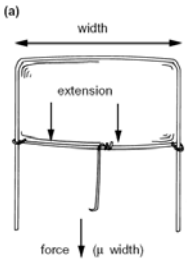
The Air-Water Interface– Surface Tension



http://en.wikipedia.org/wiki/Image:Ggb_in_soap_bubble_1.jpg

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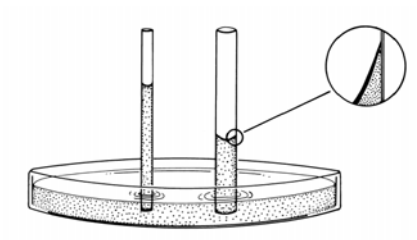
Capillarity



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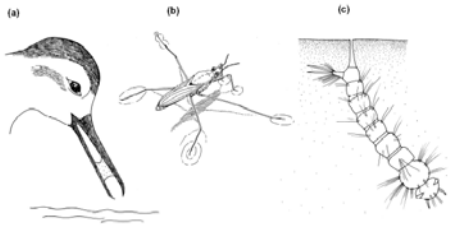

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