What would happen to a giraffe on the Moon?

The role physics plays in the human body

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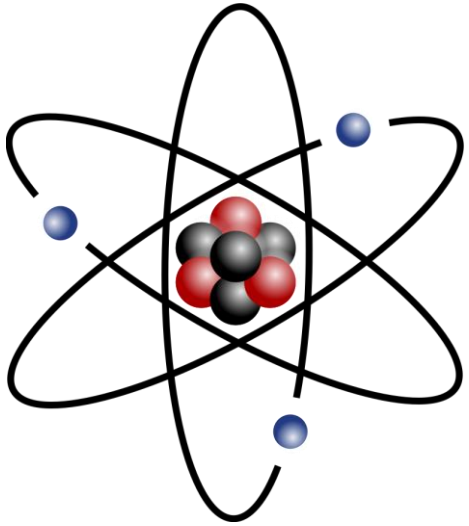
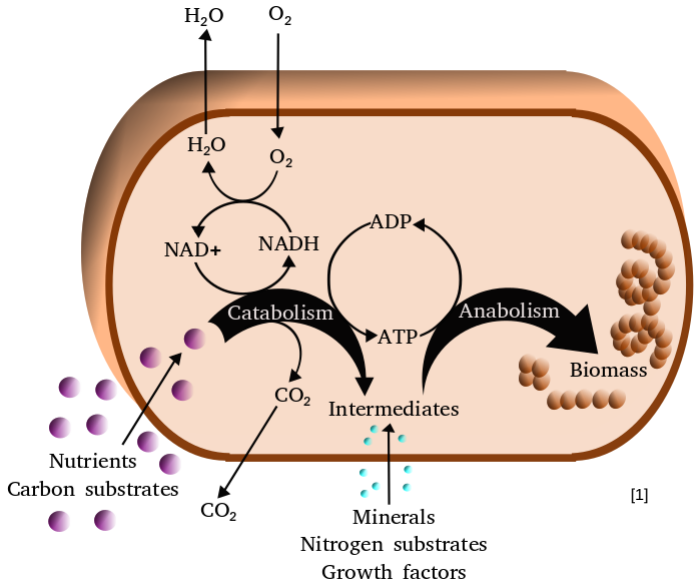
Role of Physics in Human Body





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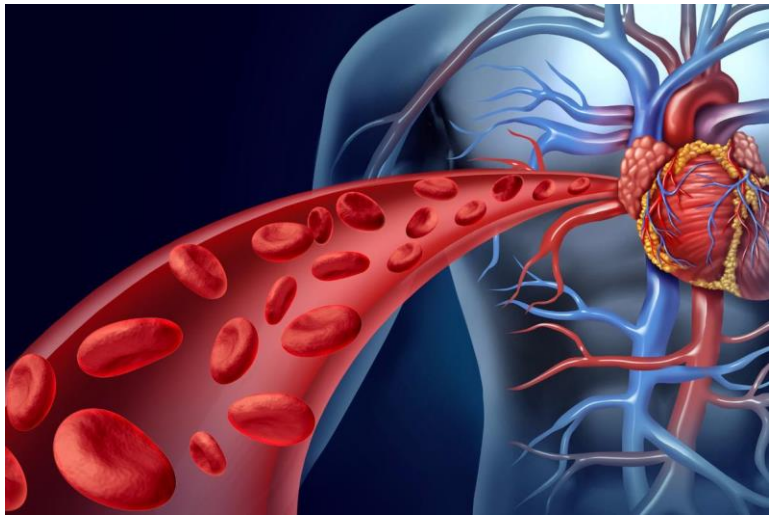

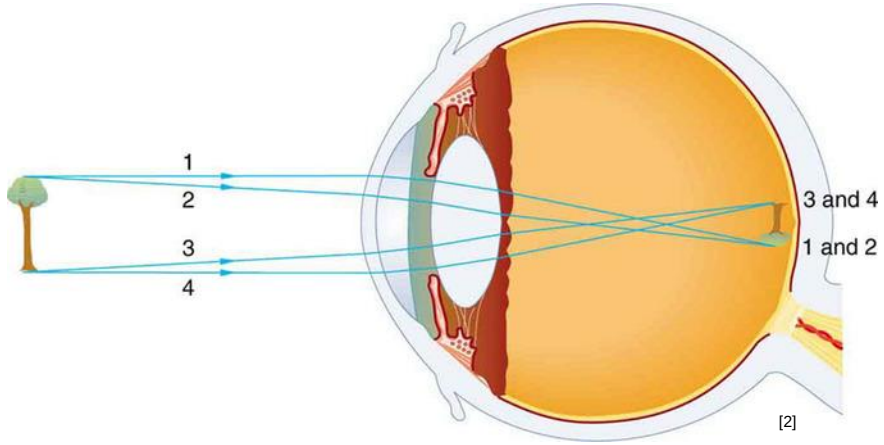

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[1] By Linares-Pastén, J. A. (2018): A simplified view of the cellular metabolism. figshare. Figure. - https://doi.org/10.6084/m9.figshare.7138037.v1, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=76000296

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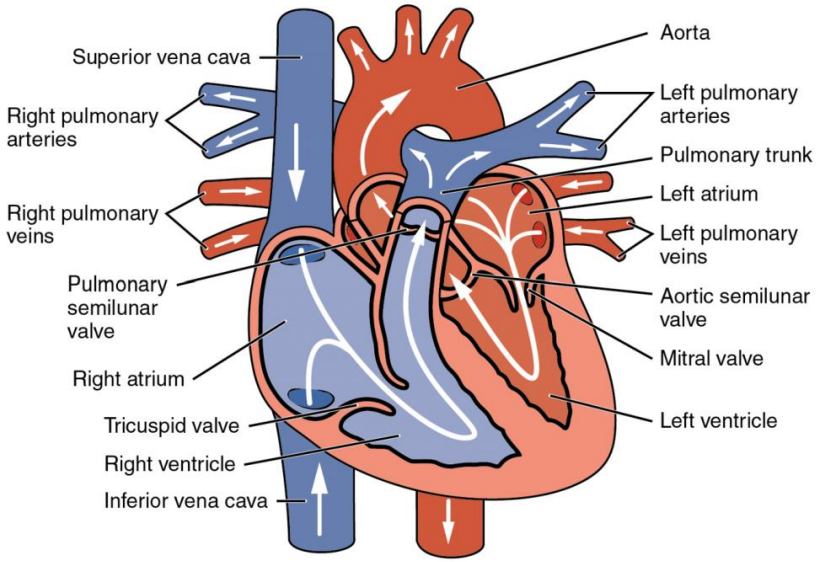
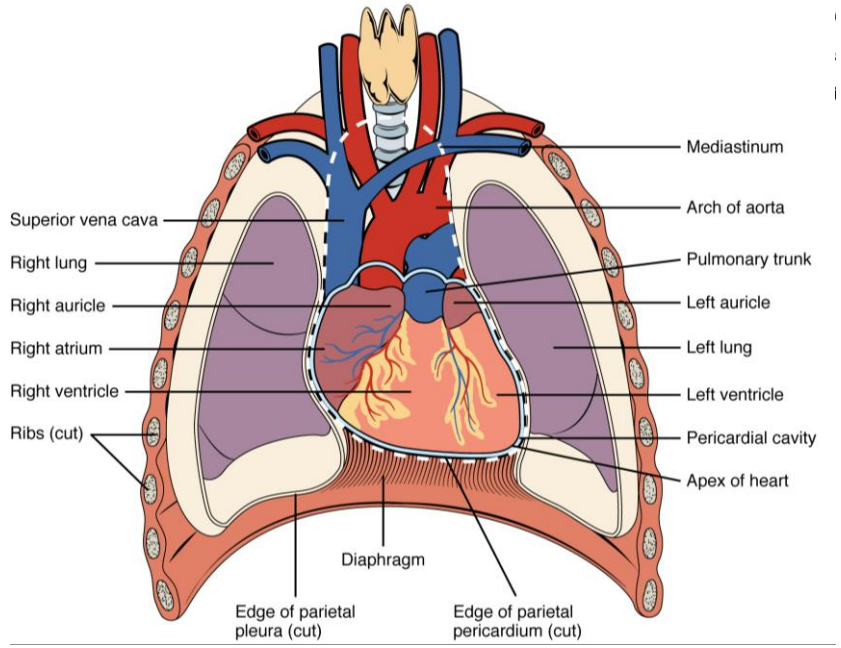
Fluid Flow in the Body

- Two major fluid systems in the body:
  1. Blood in the heart and circulatory system
  2. Air in the lungs and respiratory system

- Other systems include:
  - urine in the renal and urinary systems, and
  - food and digestive juices in the gastrointestinal system
- Fluid motion there controlled by:
  - Fluid flow in vessels
  - Direct transport by motor proteins
  - Diffusion over short distances (up to ~100μm)





Pressure in the Body

- Newton's Second Law of motion:

$$\boldsymbol{F = mg}$$

where $g = 9.81\ m/s^2$, is the acceleration of any freely falling object due to gravity

- A column of a liquid of mass density ρ and height h exerts a pressure $P(Pa)$:

$$\boldsymbol{P = \rho g h}$$

- At sea level on Earth (0°C) the air pressure is 1 atmosphere (1 atm) or 101,325 Pa, which is the pressure exerted by the air column above it. The same pressure is exerted by 760 mm of Hg (mercury) or 1,033 cm of water.

Example 1: Pressure on the Ear

- How far down below sea-level can a person swim before their eardrum will burst?
  - Average eardrum will burst at pressure > 35 kPa.
  - Sea water has a density of 1030 kg/m^3
- What force will be experienced by the ear at that depth?
  - Average eardrum is 1 cm in diameter.
- Note these are all gauge pressures!

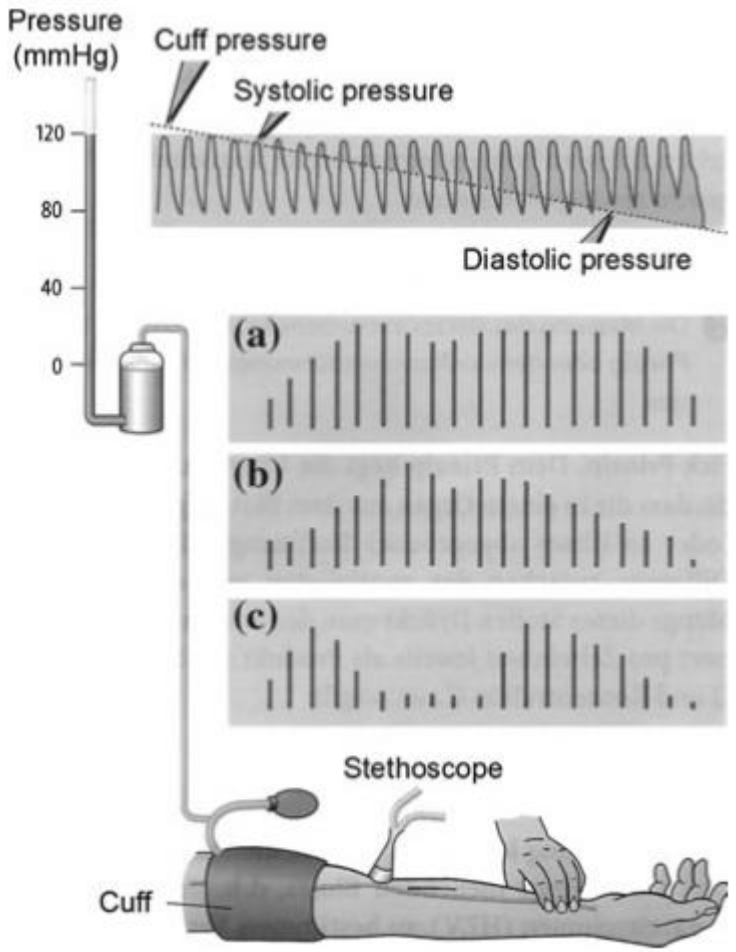
Pressure in the Body

- Blood pressure is commonly reported in mmHg, as in 120/80, which means that the systolic and diastolic pressures are, respectively, 120mmHg and 80mmHg.

- Pressure is often referenced to atmospheric pressure.
  - A blood pressure of 120 mmHg really means an absolute pressure that is 120 mmHg pressure above atmospheric pressure (with 1atm = 760mmHg),

- This is called a **gauge pressure** $\left(P_{gauge} = \rho g h\right)$

$$P_{gauge} = P_{abs} - P_{atm}$$



Measuring Blood Pressure

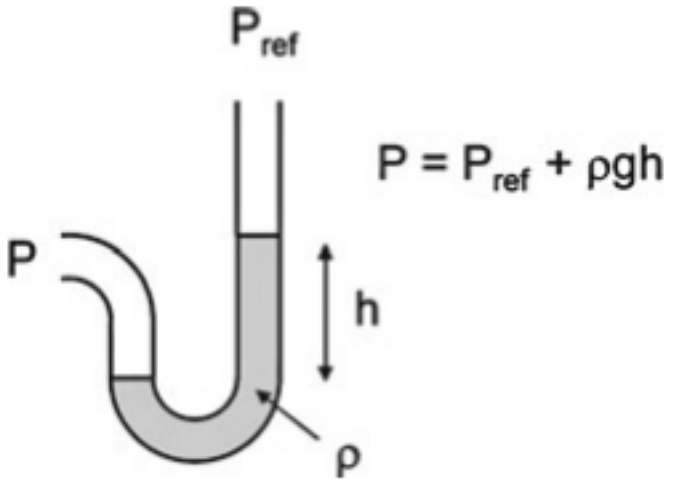
Table 7.1 Typical (gauge) pressures in the body (in mmHg)

Arterial blood pressure	
Maximum (systolic)	100–140
Minimum (diastolic)	60–90
Capillary blood pressure	
Arterial end	30
Venous end	10
Venous blood pressure	
Typical	3–7
Great veins	<1
Middle ear pressure	
Typical	<1
Eardrum rupture threshold	120
Eye pressure	
Humors	20 (12–23)
Glaucoma threshold range	~21–30
Cerebrospinal fluid pressure	
In brain—lying down	5–12
Gastrointestinal	10–12
Skeleton	
Long leg bones, standing	~7,600 (10 atm.)
Urinary bladder pressure	
Voiding pressure	15–30 (20–40 cmH_2O)
Momentary, up to	120 (150 cmH_2O)
Intrathoracic	
Between lung and chest wall	−10

- One way to measure pressure is with a monometer:

$$P = P_{ref} + \rho g h$$

- P = the height of the fluid column plus the reference pressure.



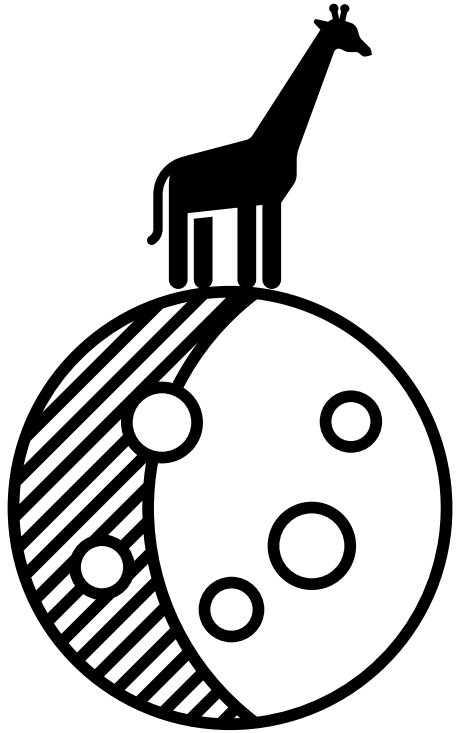
Blood Pressure and Gravity

- A blood pressure of 120/80 generally refers to someone lying down.
- When you stand upright vertically there is an additional pressure ρgh, where h is the height relative to the heart.
- This pressure drop is strongly affected by gravity so this pressure difference in outer space or on other planets would be different.
- One manifestation of this effect of gravity is potential fainting when you stand.

- So how does this affect a giraffe on the moon?

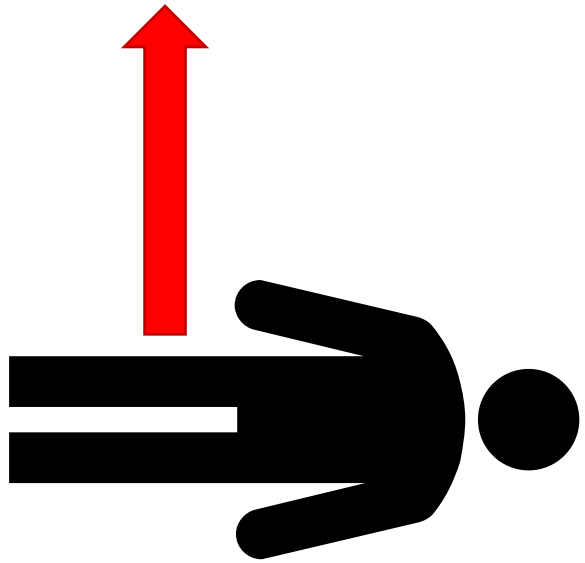
Example 2: Giraffe on the Moon

- How would the pressure in the brain of a giraffe change on the moon?
  - This giraffe's brain is 1.8 meters above its heart.
  - Normal blood pressure at the heart of a giraffe is 220/180
  - $g_{moon} = 1.63\ m/s^2$
  - Blood density is 1060 kg/m^3
  - 1 mmHg = 133.32 Pa

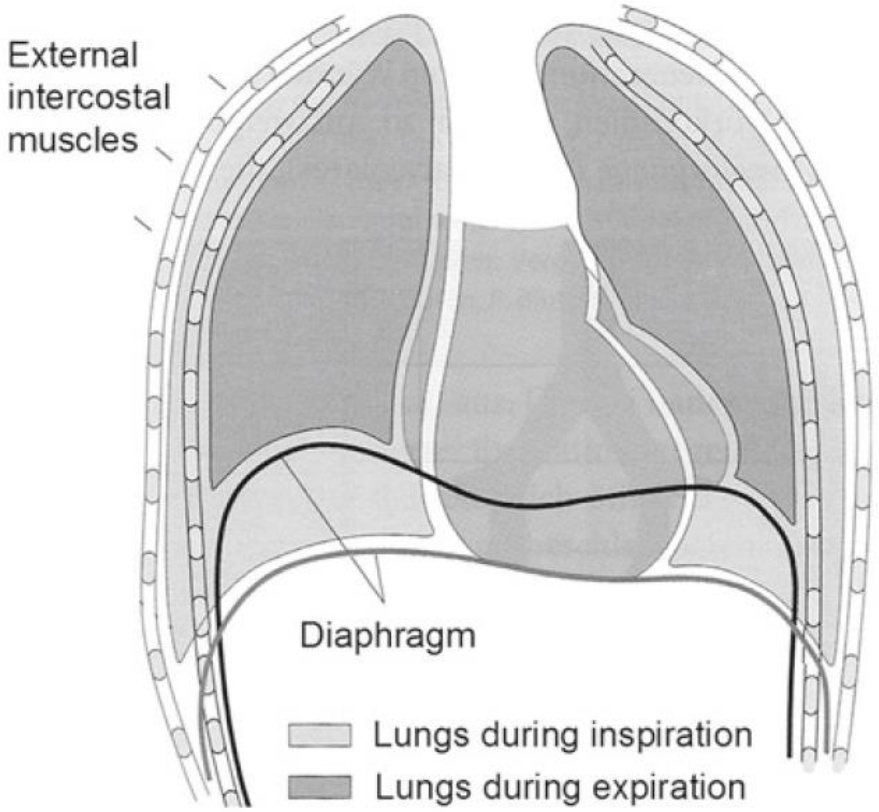


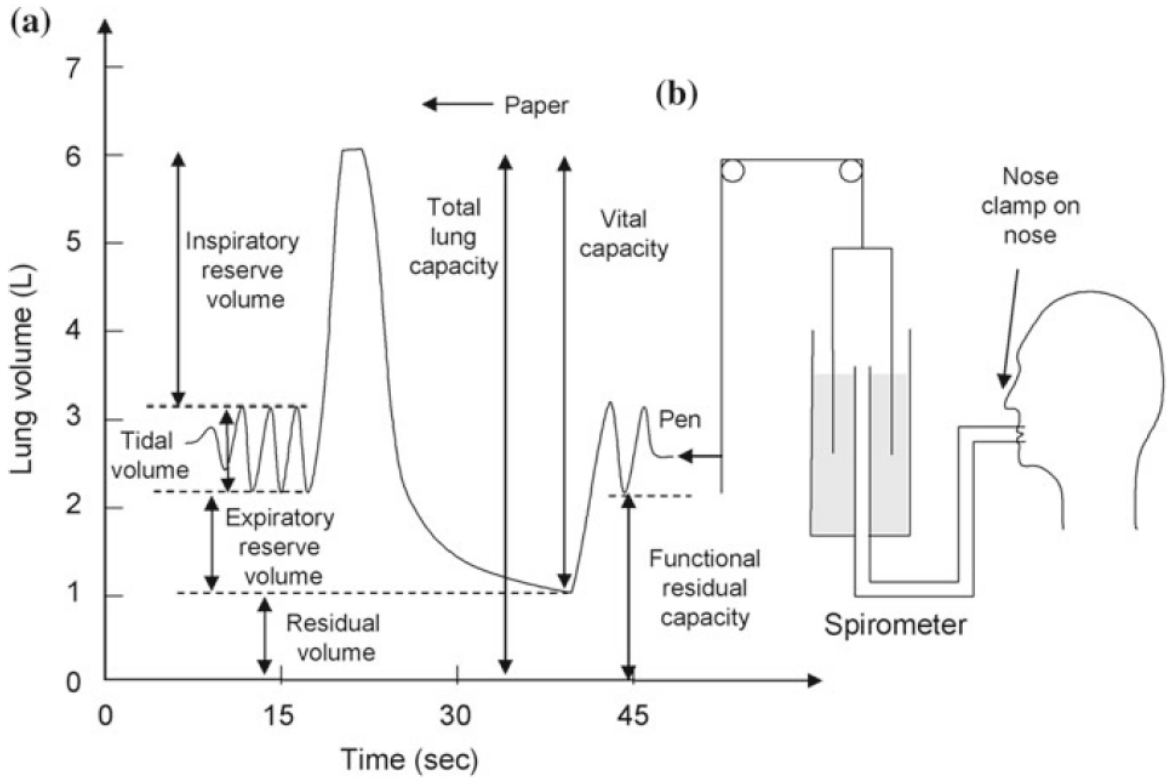
Example 3: Blood pressure in the Aorta

- You are lying down and are injured in such a way that blood from a major artery squirts upward. How high can it spurt?
  - Large arteries have blood pressure of 100 mmHg
  - Blood density is 1060 kg/m^3



Volumes of the Lungs





Example 4: Density changes when breathing

- A 70 kg man has a density of 1010 kg/m^3 after normal exhalation. Does he float in water? Will he float after he inhales 2 L of air?
  - Density of water is 1000 kg/m^3
  - 1000 L = 1 m^3

Thank You

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