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Medical Physics
PHY-311

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Chapter Four

Pressure inside the Body

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4-1 Pressure inside the body

The pressure P under a column of liquid can be calculated from the following:

$$P = \rho\, g\, h \ldots\ldots\ldots\ldots\ldots\ldots\ldots 4-1$$

ρ is the fluid density, g is the gravitational constant, and h is the height of the column

- It is very common to cite the gauge pressure, P_{gauge}, which is the pressure relative to a standard, which is usually atmospheric pressure.

$$P_{gauge} = P_{abs} - 1\ \text{atm}\ldots\ldots\ldots\ldots 4\text{-}2$$

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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

1 atm = 760 mmHg
= 10332.2 mm water
= 760 torr
= 101325 Pa
= 101.3 KPa
= 14.69 psi

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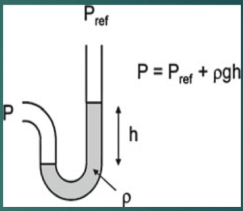
- One way of directly measuring pressure is with a **manometer**.
- The measured pressure is that corresponding to the height of the fluid column plus the reference pressure, so

$$P = P_{ref} + \rho\, g\, h \ldots\ldots\ldots\ldots 4-3$$



- The most common way to measure blood pressure is with a sphygmomanometer (sfig-muh-ma-nah'-mee-ter)

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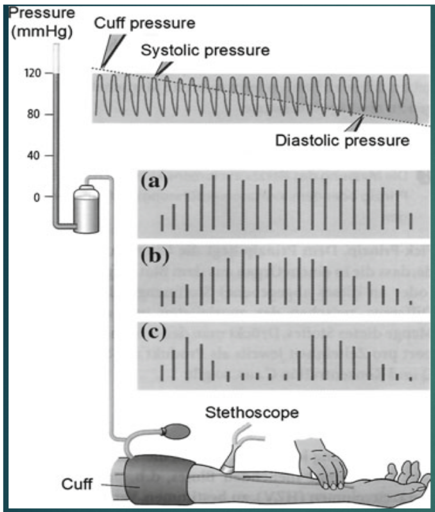
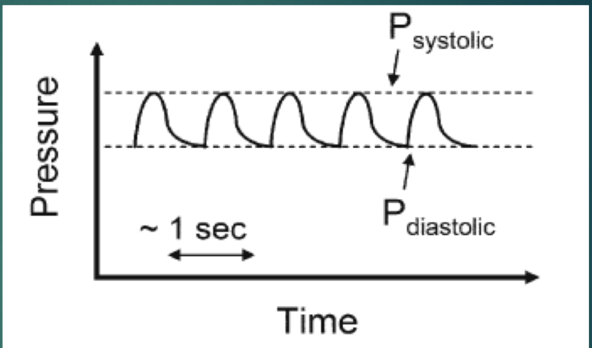
Measuring blood pressure



Measuring blood pressure , listening to Korotkoff sounds (of varying levels during the turbulent flow shown in a–c). (Listening to sounds is called auscultation)



Variation of blood pressure with time, for blood leaving the left heart for the systemic system, with the systolic and diastolic pressures.

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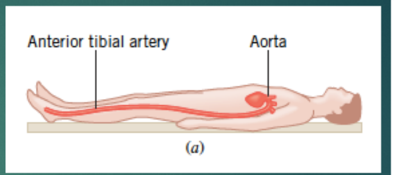
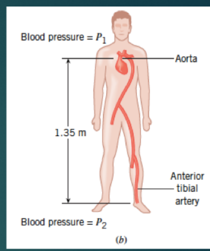
Example) Estimate the amount by which the blood pressure P_2 in the anterior tibial artery at the foot exceeds the blood pressure P_1 in the aorta at the heart when a person is

(a) reclining horizontally (b) standing.

Note: The effects of this flow can be ignored and the blood treated as a static fluid. density of blood 1060 kg/m^3





Solution) a) When the body is horizontal, there is little or no vertical separation between the feet and the heart. Since h = 0 m

$$P_2 - P_1 = 0\ Pa$$

b) When an adult is standing up, the vertical separation between the feet and the heart is about 1.35 m

$P_2 - P_1 = \rho g h = (1060)(9.8)(1.35) = 1.4\times10^4$ Pa

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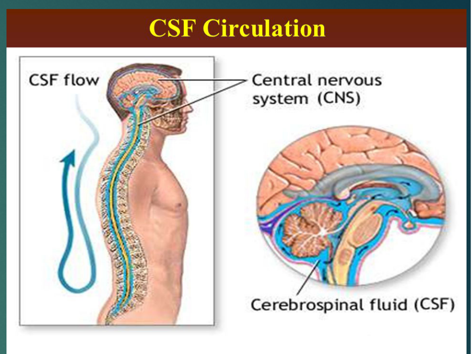
4-3 Pressure inside spinal column and skull

- The brain contains approximately 150 cm^3 of **cerebrospinal fluid (CSF)** in a series of interconnected openings called ventricles.
- There is a 5-12 mmHg pressure in the fluid surrounding the brain and filling the spinal column.
- This cerebrospinal fluid serves many purposes, one of which is to **supply flotation to the brain.**



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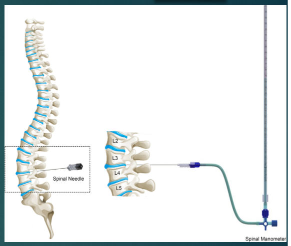
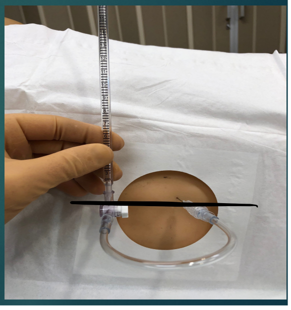
- The buoyant force supplied by the fluid nearly equals the weight of the brain.
- If there is a loss of fluid, the brain rests on the inside of the skull, causing severe headaches, constricted blood flow, and serious damage.
- If at birth this opening is blocked for any reason, the CSF is trapped inside the skull and increased the internal pressure. This condition, called **hydrocephalus** (water head).
- Spinal fluid pressure is measured by means of a needle inserted between vertebrae that transmits the pressure to a suitable measuring device.





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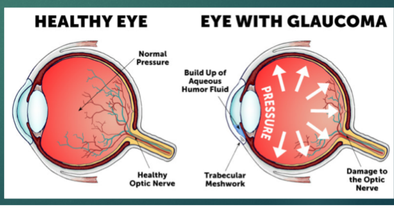
4-4 Eye pressure

- The shape of the eye is maintained by fluid pressure, **called intraocular pressure**, which is normally in the range of **12-24 mmHg**.
- When the circulation of fluid in the eye is blocked, it can lead to a buildup in pressure, a condition called **glaucoma**.
- The net pressure can become as great as 85.0 mmHg, an abnormally large pressure that can permanently damage the optic nerve.



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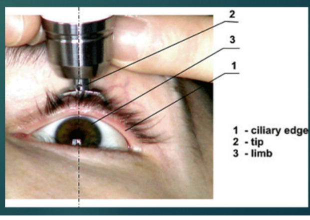
- Suppose the back of the eye has an area of 6 cm^2, and the net pressure is 85.0 mmHg. force is given by $F= P\times A$, then we calculate as follows:

$$F = \rho gh\, A = (85\times10^{-3})(13\times10^{3})(9.8)(6\times10^{-4}) = 6.8N$$

- Most measurements involve exerting a force on the (anesthetized) eye over some area (a pressure) and observing the eye's response.
- If the intraocular pressure is high, the eye will deform less and rebound more vigorously than normal.



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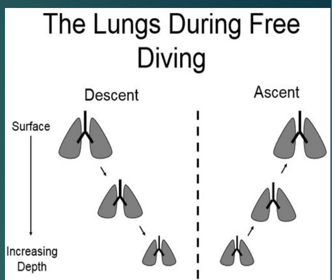
4-5 The pressure in the lung

- **P** **in the lung at any depth** > **P** **in the lung at sea level**, this means that the air in the lung is denser under water and that the partial pressures of all the air components are proportionately higher.
- The higher partial pressure of O_2 causes more O_2 molecules to be transformed into the blood and oxygen poisoning results if the partial pressure of O_2 gets high.



- Breathing air at a depth of (30m) is also dangerous because it may result in excess N_2 in the blood and tissues, there is a possibility of having

1- Nitrogen narcosis 2-The bends or decompression sickness

- *O_2 is attached to RBC, while N_2 is dissolved in the blood and tissues.*

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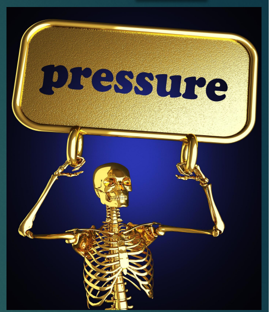
4-6 Pressure in the skeleton

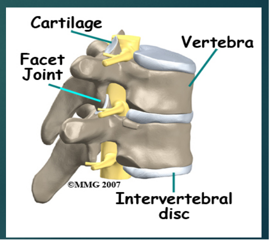
- These pressures are the largest in the body, due both to the **high values of initial force**, and the **small areas to which this force is applied**, such as in the joints.

when a person lifts an object improperly, a force of 5000 N may be created between vertebrae in the spine, and this may be applied to an area as small as 10 cm^2. The pressure created is

$$P = \frac{F}{A} = \frac{5000}{10^{-3}} = 5{\times}10^{6}\ N/m^2$$

- This pressure can damage both the spinal discs (the cartilage between vertebrae), as well as the bony vertebrae themselves.





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4-7 Pressure in the urinary bladder

- This bodily pressure is one of which we are often aware.
- Bladder pressure climbs steadily from **zero** to about **25** mmHg as the bladder fills to its normal capacity of **500 cm^3**.
- This pressure triggers the micturition reflex, which stimulates the feeling of needing to urinate.
- It also causes muscles around the bladder to contract, raising the pressure to over 100 mmHg, accentuating the sensation.

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- **Coughing**, **straining**, **tensing in cold weather**, **wearing tight clothes**, and **experiencing simple nervous tension** all can increase bladder pressure and trigger this reflex.
- Bladder pressure can be measured by a catheter or by inserting a needle through the bladder wall and transmitting the pressure to an appropriate measuring device.
- One hazard of high bladder pressure (sometimes created by an obstruction), is that such pressure can force urine back into the kidneys, causing potentially severe damage.

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