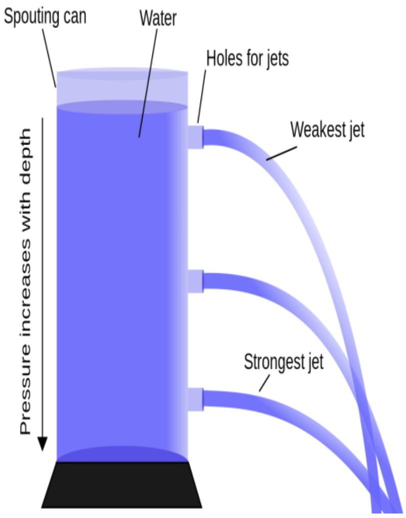
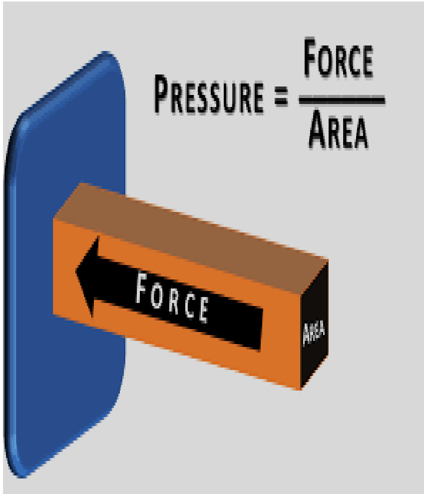
Pressure

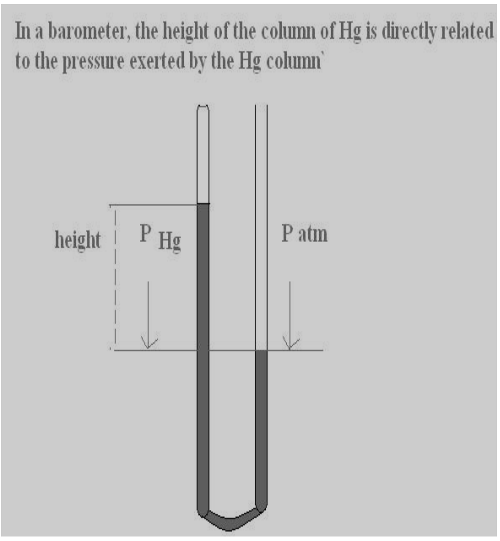
Pressure is defined as the force per unit area in a gas or a liquid. For a solid the quantity force per unit area is referred to as stress.

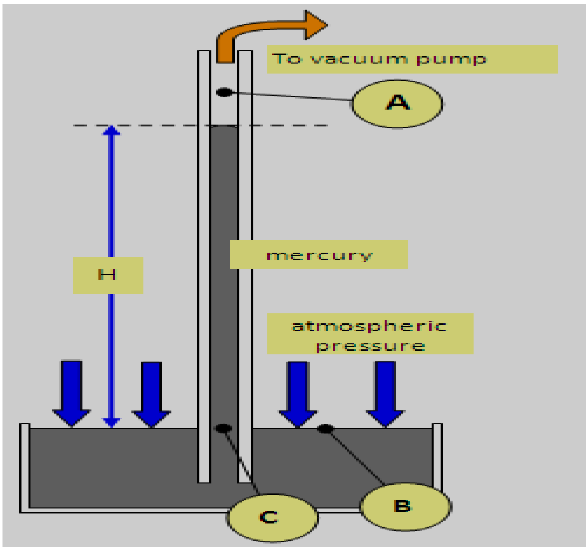




In the metric system the pressure is measured in dynes per square centimeter or newton per square meter; the SI unit for the latter is the **Pascal (Pa)**.None of these units is in commune use in medicine.

The most common method of indicating pressure in medicine is by the height of a column of mercury (Hg).





For example, a peak (systolic) blood pressure reading of 120 mmHg indicates that a column of mercury of this height has a pressure at its base equal to the patient's systolic blood pressure.

The pressure **P** under a column of liquid can be calculated from this formula:

$$P = p \times g \times h$$

Where ***p*** is the density of the liquid, **g** is the acceleration due to gravity, and **h** is the height of the column.

Example: What height of water will produce the same pressure as 120 mmHg?

$$P\ (120\ \text{mmHg}) = pgh = (13.6\ \text{g/cm}^3)\ (980\ \text{cm/sec}^2)\ (12\ \text{cm})$$

$$= 1.6\times10^5\ \text{dyne/cm}^2$$

For water:

$$1.6\times10^5\ \text{dynes/cm}^2 = (1.0\ \text{g/cm}^3)\ (980\ \text{cm/sec}^2)\ (\text{h cm } H_2O)$$

$$h = 163\ \text{cm}H_2O$$

Or

$$P_{Hg} = P_{water}$$

$$(p\ gh)_{Hg} = (p\ gh)_{water}$$

$$p_{Hg} \times h_{Hg} = p_{water} \times h_{water}$$

$$h_{water} = (p_{Hg} \times h_{Hg}) \ /\ p_{water} = (13.6 \times 12)/1 = 163\ \text{cm}H_2O$$

Note:-

1 atmosphere (atm) = 1.01×10^5 N/m^2

1 atmosphere (atm) = 1033 cmH_2O

1 atmosphere (atm) =760 mmHg

1 cmH_2O =0.735 mmHg or 1mmHg = 1.36 cmH_2O

Example: calculate the atmospheric pressure in N/m^2 and in $dyne/cm^2$,where p_{Hg} =13.6 g/cm^3?

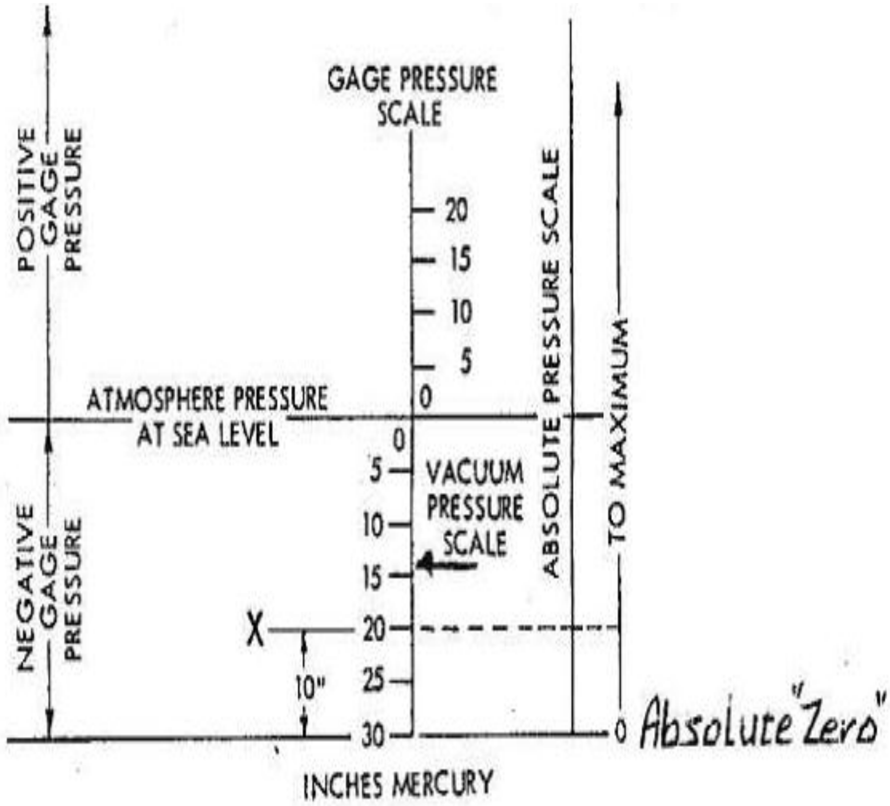
1 atm =760 mm = 76 cm =0.76m

p_{Hg} =13.6 g/cm^3 or 13600 Kg/m^3

The atmospheric pressure in N/m^2 is equal $P = p\ g\ h = 13600\ Kg/m^3 \times 9.8 m/sec^2 \times 0.76m$ $P=101292.8\ N/m^2$	The atmospheric pressure in $dyne/cm^2$ is equal $P = p\ g\ h = 13.6\ g/cm^3 \times 980 cm/sec^2 \times 76cm$ $P=1012928\ dyne/cm^2$

Types of Pressure

- _Absolute Pressure_
- _Atmospheric Pressure_
- _Gauge Pressure_



Absolute pressure

Reference pressure is the pressure which equal zero, which exists in the air-free space of the universe, which is known as absolute pressure.

Atmospheric pressure

Atmospheric pressure is the air pressure which is exerted by the weight of air present in the atmosphere.

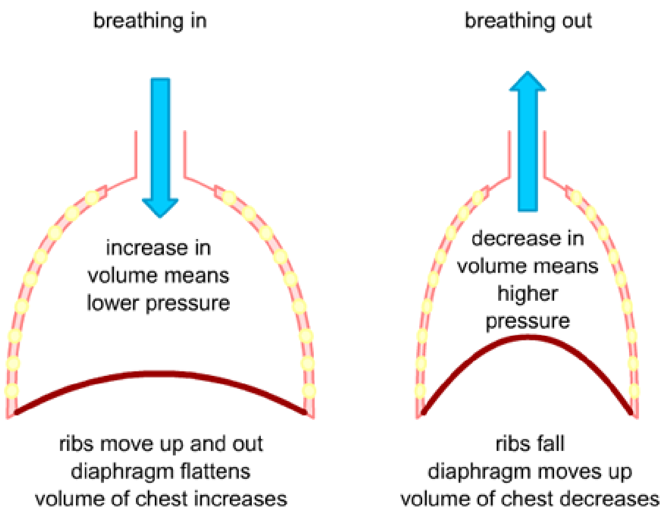
Gauge pressure

Is the pressure relative to atmospheric pressure, Gauge pressure is positive for pressures above atmospheric pressure, and negative for pressures below it.

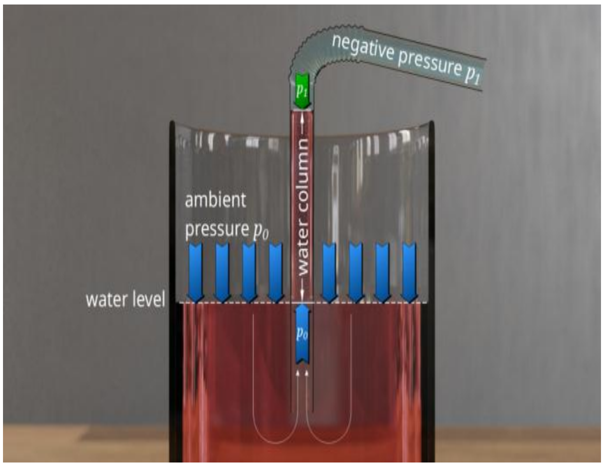
There are a number of places in the body where the pressures are lower than the atmospheric pressure or negative.

***Example* for negative pressures**

1-The lung pressure during inspiration is typically a few centimeters of water negative. In other word, When we breathe in (inspire) the pressure in the lung must be somewhat lower than atmospheric pressure or the air would not flow in.

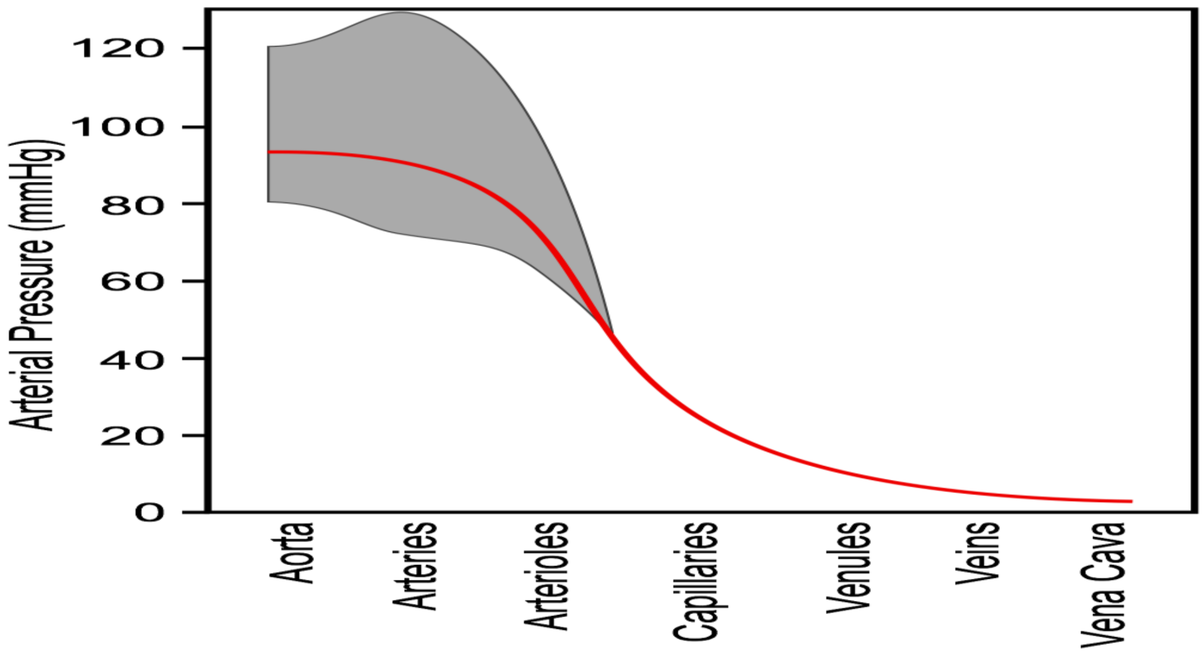


2- A person drinks through a straw the pressure in his mouth must be negative by an amount equal to the height of his mouth above the level of the liquid he is drinking.



Typical pressures in the normal body

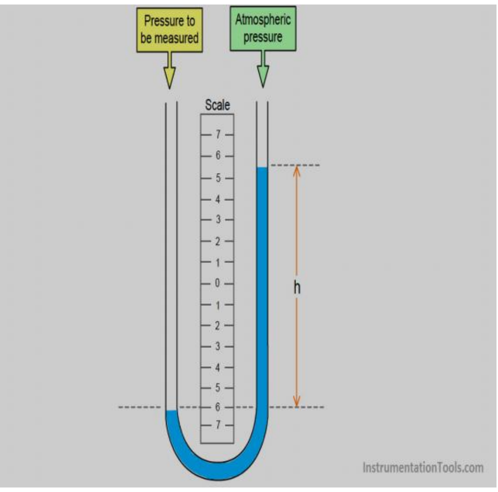
Different parts of the body	Typical pressure (mmHg)
Arterial blood pressure Maximum(systole) Minimum(diastole)	 100-140 60-90
Venous blood pressure	3-7
Great veins	<1
Capillary blood pressure Arterial end Venous end	 30 10
Middle ear pressure	20
Eye pressure-aqueous humor	20
Cerebrospinal fluid pressure in brain	7-15
Gastrointestinal pressure	10-20
Intrathoracic pressure (between lung & chest wall)	~10



Measurement of pressure in the body

The classical method of measuring pressure is to determine the height of a column of liquid that produces a pressure equal to the pressure being measured.

An instrument that measures pressures is called a *manometer*. One type of manometer is a U-shaped tube containing a fluid that is connected to the pressure to be measured. The levels in the arms change until the difference in the levels is equal to the pressure. This type of manometer can measure both positive and negative pressures.



The most common clinical instrument used in measuring pressure is the ***Sphygmomanometer***, which measures blood pressure. Types of pressure gauges are used in Sphygmomanometers:

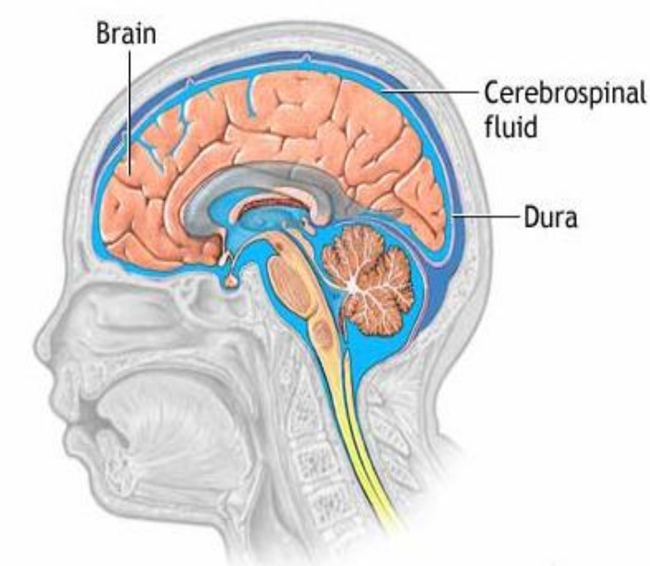
1-*A mercury manometer type*: the pressure is indicated by the height of a column of mercury inside a glass tube.

2-*An aneroid type*: the pressure changes the shape of a sealed flexible container, which causes a needle to move on a dial.

3- Digital type.

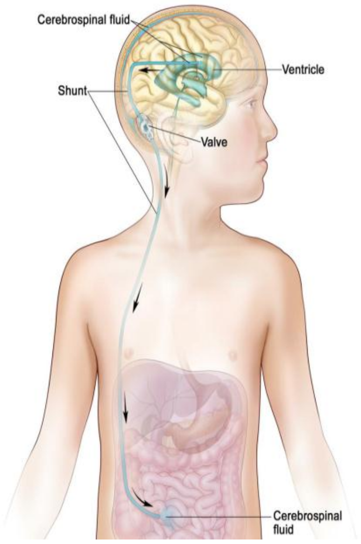
Pressure inside the skull

The brain contains approximately 150 cm^3 of cerebrospinal fluid (CSF) in a series of interconnected openings called ventricles. CSF is generated inside the brain and flows through the ventricles into the spinal column and eventually into the circulatory system. One of the ventricles, the aqueduct, is especially narrow.



If at birth this opening is blocked for any reason, the CSF is trapped inside the skull and increases the internal pressure which called Intracranial pressure (ICP). ICP is measured in millimeters of mercury (mmHg) and, at rest, is normally 7–15 mmHg for a supine adult. The body has various mechanisms by which it keeps the ICP stable, the increased pressure causes the skull to enlarge .This serious condition, called hydrocephalus (water head).

The most common treatment for hydrocephalus is the surgical insertion of a drainage system, called a shunt. It consists of a long, flexible tube with a valve that keeps fluid from the brain flowing in the right direction and at the proper rate.



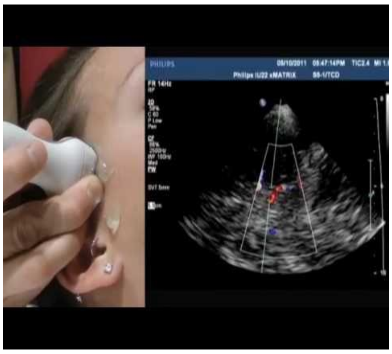
<u>Methods of measurement the CSF pressure</u>

A-Noninvasively method

1-Crude method of detecting hydrocephalus is to measure the circumference of the skull just above the ears. Normal values for newborn infants are from 32-37cm, and a large value may indicate hydrocephalus.

2-Transillumination makes use of the light –scattering properties of the rather clear CSF inside the skull.

3- Ultrasound techniques, transcranial Doppler



4- Electroencephalography (EEG)

5-Magnetic resonance imaging (MRI)

6-Computerized tomography (CT)

B-invasively method

The test measures the pressure in the head directly by using a small pressure-sensitive probe (pressure microsensor) that is inserted through the skull.

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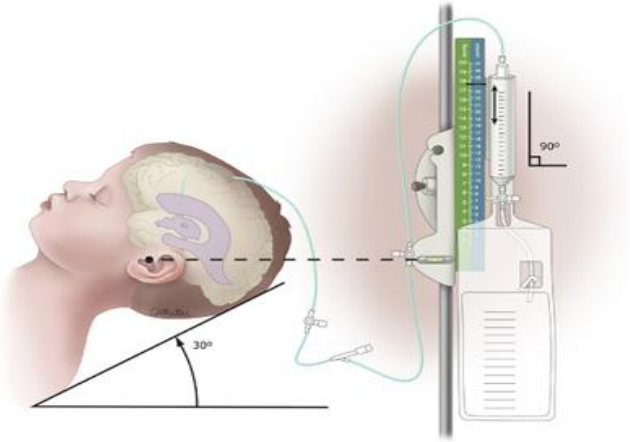
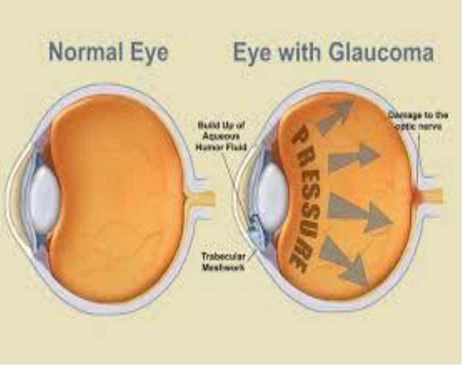


Eye pressure

The clear fluids in the eyeball (the aqueous and vitreous humors) that transmit the light to the retina (the light sensitive part of the eye), are under pressure and maintain the eyeball in a fixed size and shape .The dimensions of the eye are critical to good vision-a change of only 0.1mm in its diameter has a significant effect on the clarity of vision. The pressure in normal eyes ranges from 12-23 mmHg. The fluid in the front part of the eye, the aqueous humor, is mostly water. The eye continuously produces aqueous humor and a drain system allows the surplus to escape. If a partial blockage of this drain system occurs, the pressure increases and the increased pressure can restrict the blood supply to the retina and thus affect the vision. This condition, called ***glaucoma***, produces tunnel vision in moderate cases and blindness in severe cases.

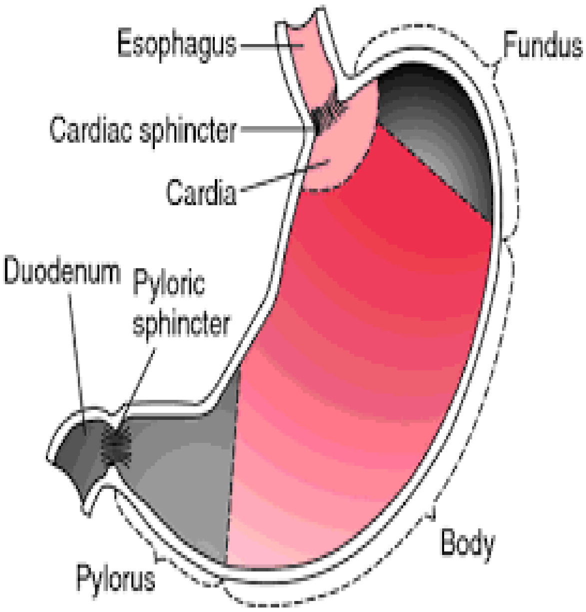


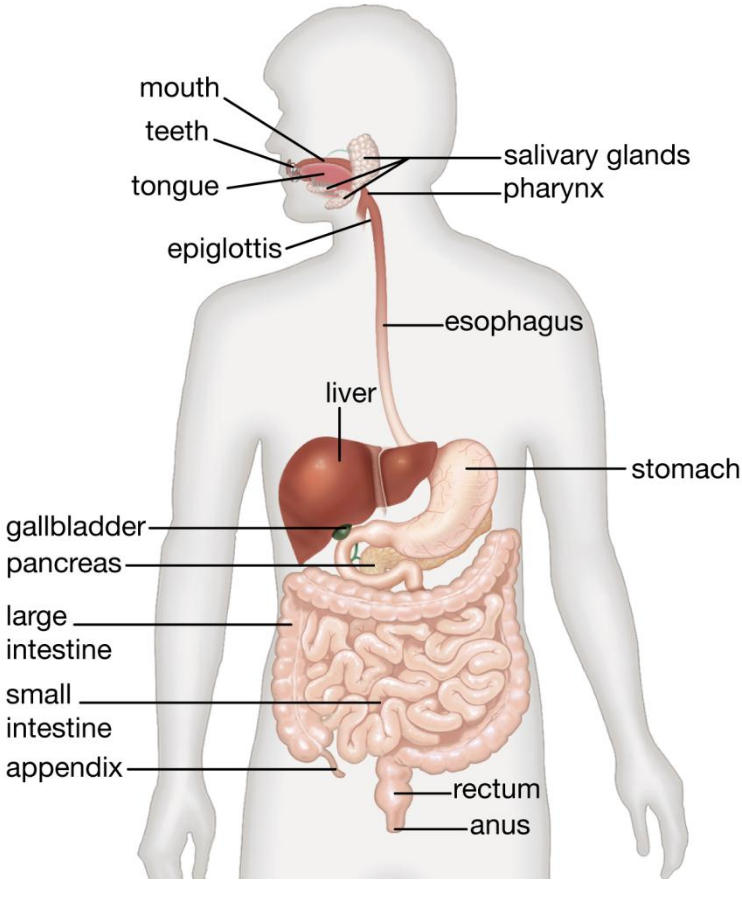
Early physicians estimated the pressure inside the eye by "feel" as they pressed on the eye with their fingertips. Now pressure in the eye is measured with several different instruments, called *tonometers*.

Pressure in the digestive system

The body has an opening through it .This opening, the digestive tract, is rather tortuous; it extends over 6m from the mouth to the anus. Most of the time it is closed at the lower end and has several other restrictions.

The valves are designed to permit unidirectional flow of food. With some effort it is possible to reverse the flow, such as during vomiting. The pressure is greater than atmospheric in most of the gastrointestinal (GI) system. However, in the esophagus, the pressure is coupled to the pressure between the lungs and chest wall (intrathoracic pressure) and is usually less than atmospheric.





During eating the pressure in the stomach increases as the walls of the stomach are stretched. However, since the volume increases with the cube of the radius (R^3) while the tension (stretching force) is proportional to *R*, the increase in pressure is very slow. A more significant increase in pressure is due to air swallowed during eating.

Air trapped in the stomach causes burping or belching. This trapped air is often visible on an X-ray of the chest.

One valve, the pylorus, prevents the flow of food back into the stomach from the small intestine. Occasionally a blockage forms in the small or large intestine and pressure builds up between the blockage and the pylorus; if this pressure becomes great enough to restrict blood flow to the critical organs, it can cause death. Intubation, the passing of a hollow tube through the nose, stomach, and pylorus, is usually used to relieve the pressure. The pressure in the digestive system is coupled to that in the lungs through the flexible diaphragm that separates the two organs systems. When it is necessary or desirable to increase the pressure in the gut, such as during defecation, a person takes a deep breath, closes off the lungs at the glottis(vocal cord),and contracts the abdominal muscles.

Pressure in the urinary bladder

One of the most noticeable internal pressures is the pressure in the bladder due to accumulation of urine. Figure shows the typical pressure-volume curve for the bladder, which stretches as the volume increases. For adult, the typical maximum volume in the bladder before voiding is 500ml.At some pressure (~30 cmH_2O) the micturition (gotta go) reflex occurs.

The resulting sizable muscular contraction in the bladder wall produces a momentary pressure of up to 150 cmH_2O.Normal voiding pressure is fairly low (20 to 40 cmH_2O), but for men who suffer from prostatic obstruction of the urinary passage it may be over 100 cmH_2O.

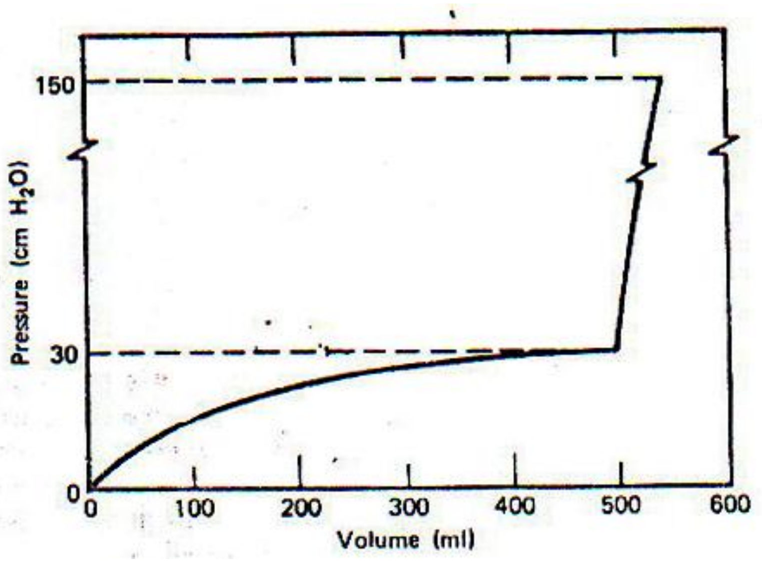
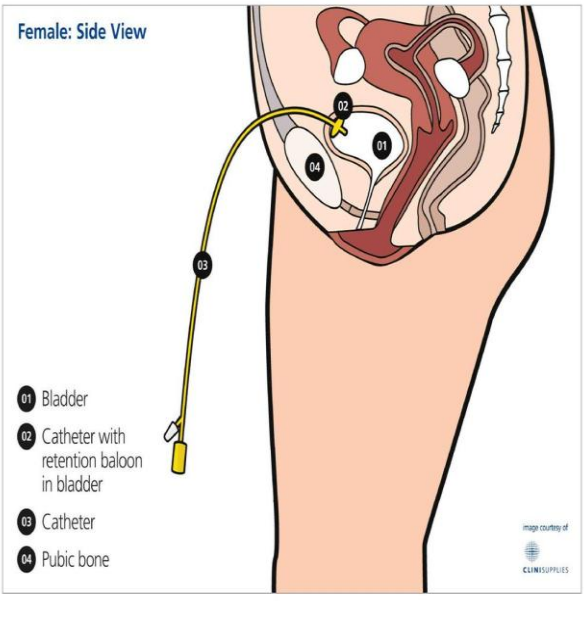


Figure: The typical pressure-volume relationship in the urinary bladder.

<u>*The pressure in the bladder can be measured by:*</u>

1-By passing a catheter with a pressure sensor into the bladder through the urinary passage (urethra).

2-By a needle inserted through the wall of the abdomen directly into the bladder. This technique gives information on the function of the exit valves (sphincters) that cannot be obtained with the catheter technique.



The bladder pressure increases during coughing, straining, and sitting up. During pregnancy, the weight of the fetus over the bladder increases the bladder pressure and causes frequent urination.

Hyperbaric oxygen therapy (HOT)

The body normally lives in an atmosphere that is about one-fifth oxygen and four-fifths nitrogen. In some medical situations it is beneficial to increase the proportion of oxygen in order to provide more oxygen to the tissues. To greatly increase the amount of oxygen, medical engineers have constructed special high pressure (hyperbaric) oxygen chambers. Some are just large enough for a patient, while others are large enough to serve as operating rooms.

Hyperbaric oxygen therapy is used to treat several medical conditions.

1- Gas gangrene :The bacillus that causes gas gangrene cannot survive in the presence of oxygen, almost all gas gangrene patients treated with HOT are cured without the need for amputation

2- Carbon monoxide poisoning: The red blood cell cannot carry oxygen to the tissues because the carbon monoxide fastens to the hemoglobin at the places normally used by oxygen. The presence of even a few carbon monoxide molecules on a red blood cell greatly reduces the ability of the cell to transport oxygen.

Normally the amount of oxygen dissolved in the blood is about 2% of that carried on the red blood cells. With HOT, the partial pressure of oxygen can be increased by a factor of 15, permitting enough oxygen to be dissolved to fill the body's needs.

3-Treatment of cancer: The patient was placed inside a transparent plastic tank, and the radiation was beamed through the walls into the tumor. The theory was that more oxygen would make the poorly oxygenated radiation-resistant cells in the center of the tumor more susceptible to radiation damage.

Figure: A patient receives treatment with Hyperbaric oxygen chamber

Hazard of HOT

1- The oxygen atmosphere makes fire a much greater hazard.
2- Risk of rupture of the tank due to the high pressures used.