five lecture : pressure

DEFINE THE PRESSURE

the pressure is **defined** as : the force per unit area in **gas** or **liquid** . for a **solid** the quantity force per unit area is referred to as stress , the (SI) unit for the latter is the Pascal (pa) . 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) mm Hg indicates that a column of mercury of this height has a pressure at its base equal to the patients systolic blood pressure , and the pressure of column of **liquid** calculated as : $\mathbf{p = \rho g h}$ where the (ρ) is the density , (g) gravity acceleration and (h) is height of column , since the density of mercury is (**13.6** g / cm^3) .there are a number of places in the body where the pressures are lower than atmospheric , or **negative** . For example **when** we breath (inspire) the pressure in the lung must be lower than atmospheric or the air would not flow in , and **when** person drinks through straw . The atmospheric pressure is about (10exp 5 N/M^2) or (**760** mm Hg)

Note : **In** the metric system it is measured in dynes per square centimeter or Newton's per square meter. **And** in the SI unit it is measured in Pascal (Pa) . **But** none of these units is in common use in medicine where the most common method of indicating pressure in medicine is by the height of column of mercury (Hg).

Example : What height of water will produce the same pressure as (120) mm Hg ?

Example : Using the density of air is 1,3 * 10 exp -3 gm/ cm^3 , calculate the pressure difference in dynes per square centimeter and in millimeters of mercury between the bottom and the top of a building 30 m tall (8 stories) ?

What is blood pressure?

Blood pressure is the force of blood moving through your arteries . Arteries are the blood vessels that carry blood from your heart to the rest of your body.

What do blood pressure numbers measure?

Blood pressure is measured with 2 numbers. An example is shown below. Ideally, we should all have a blood pressure below 120 over 80 (120/80). This is the ideal blood pressure for people wishing to have good health. At this level, we have a much lower risk of heart disease or stroke. If your blood pressure is above 120/80mmHg, you will need to lower it.

BLOOD PRESSURE BASICS

The top number measures the force of blood in your arteries when your heart contracts (beats). This is called ***systolic pressure***. The bottom number measures the force of blood in your arteries while your heart is relaxed. This is called ***diastolic pressure***.

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 pressure by this method is called a "manometer" .A common 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. The fluid used is usually mercury , but water or other low density fluids can be used when the pressure to be measured is relatively small. The most common clinical instrument used in measuring pressure is the "Sphygmomanometer", which measures blood pressure . Two types of pressure gauges are used in sphygmomanometer:

1- In a mercury type the pressure is indicated by the height of a column of mercury inside a glass tube.

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

Recently another type used (digital).

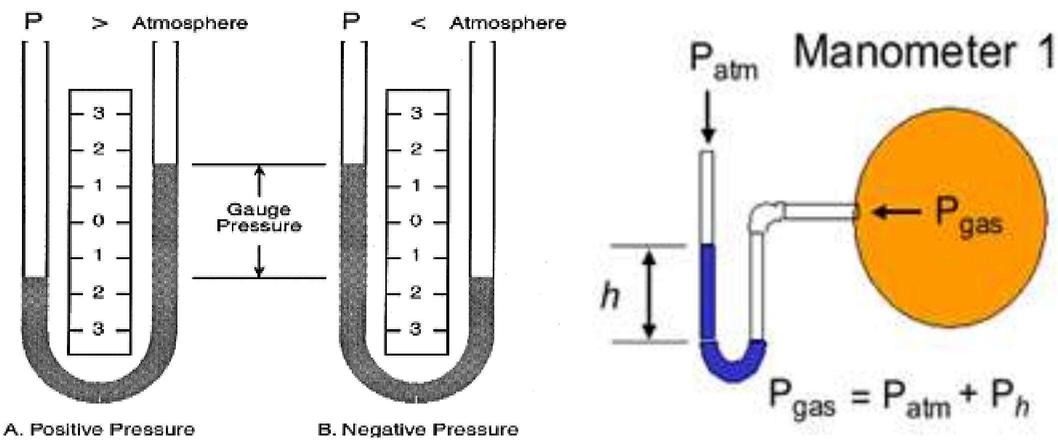


Figure. Gauge pressure is a measurement relative to atmospheric pressure and it varies with the barometric reading. A gauge pressure measurement is positive when the unknown pressure exceeds atmospheric pressure (A), and is negative when the unknown pressure is less than atmospheric pressure (B).

<u>Gauge pressure</u> :is defined as the excess pressure over atmospheric pressure.

Gauge pressure = ρ g h = 1000 x 9.8x10 = 10^5 N/m^2 = 1 atm

Absolute pressure = atmospheric pressure + gauge pressure

=1+ 1= 2 atm

Or In N/m^2

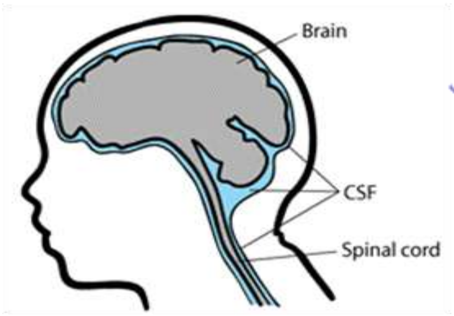
$=10^5 + 10^5 = 2x\ 10^5\ N/m^2$

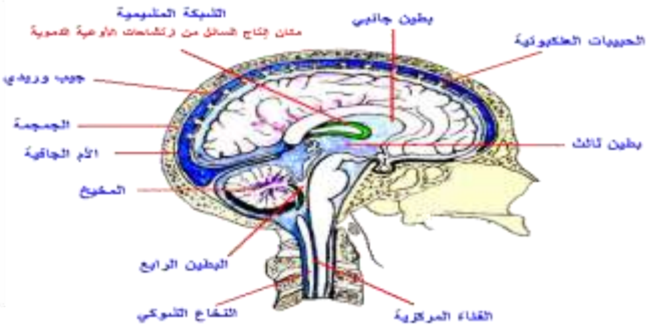
Atmospheric pressure = $\rho_{Hg}\ g\ h_{Hg}$ $=13600x\ 9.8\ x0.76$

$=10^5\ N/m^2$

Pressure inside the skull

The brain contains approximately 150 cm^3 of cerebrospinal fluid (CSF) in a series of interconnected openings called **ventricles cerebrospinal fluid** is generated inside the brain and flows through the ventricles into the spinal column and 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 increase the internal pressure . The increased pressure causes the skull to enlarge .This serious condition , called **hydrocephalus** (water – head) is common problem in infants. However, if the condition is detected soon enough , it can often be corrected by surgically .



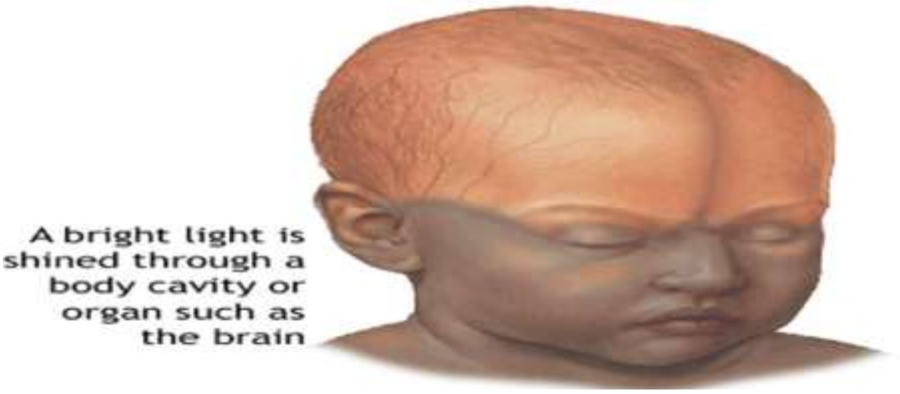


Measuring the CSF pressure

It is not convenient to measure the SCF pressure directly. There are two methods:

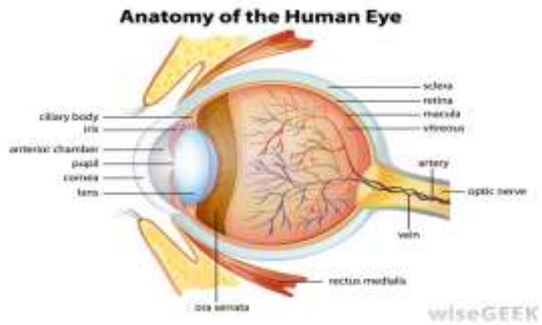
1-Crude method: This method can measure the pressure inside the skull by measuring the circumference of the skull just above the ears. Normal values for newborn infants are from (32-37) cm, and a larger value may indicate hydrocephalus.

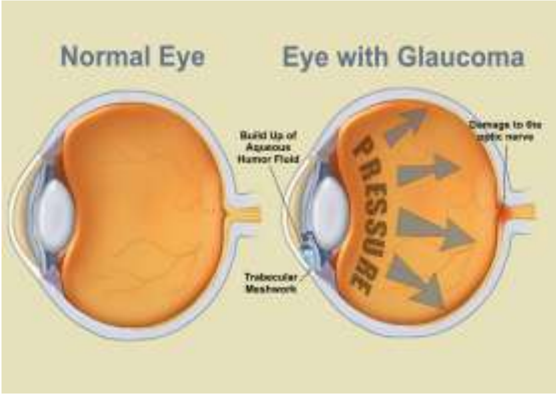
2-Transillumination: is a qualitative method of detection. Make use of the light –scattering properties of the rather clear CSF inside the skull.



EYE PRESSURE

The clear fluids in the eyeball that transmit the light to the retina , 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 0.1 mm in its diameter has a significant effect on the clarity of vision .If you press on your eyelid with your finger you will notice the resiliency of the eye due to the internal pressure . The pressure in normal eyes ranges from 12 to 23 mm Hg . 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" 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 opining , the digestive tract , 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 , However , in the esophagus , the pressure is **coupled** to the pressure between the lungs and chest wall and is usually less than atmospheric . The pressure is sometimes determined by measuring the pressure in the esophagus, **During eating** the pressure in the stomach increases as the walls of the stomach are stretched , 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 is often visible on an x-ray of the chest.

The increased pressure inside the GI system is due to:

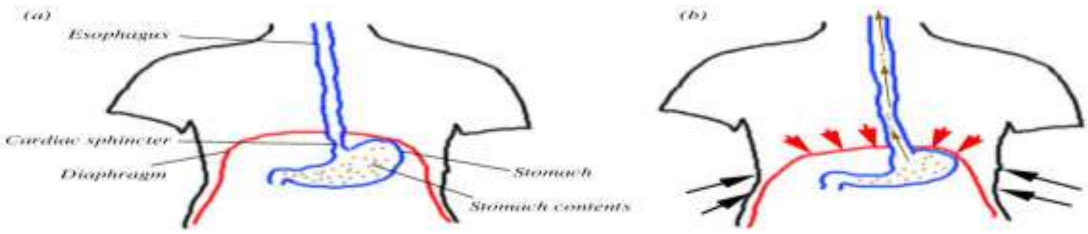
1- Accumulation of food increase the pressure inside stomach layers, the volume is directly proportional with the cube of the radius (R^3) while the tension (stretching force) is proportional to (R) ,$V \alpha R^3$, $T \alpha R$

2- Swallowing the air during eating food . Air trapped in the stomach causes burping and belching.

3- The gas generation due to the bacterial action increases the pressure.

There are external factors increases the pressure inside the stomach and these factors are :

1- Belts **2-** Girdles **3-** Flying **4-** Swimming



PRESSURE IN THE SKELETON

The highest pressures in the body are found in the weight bearing bone (joints). The pressure in the knee joint may be more than 10 atm. P=F/A the surface area of a bone at the joint is greater than its area either above or below the joint. The larger area at the joint distributes the force thus reducing the pressure according to the equation. Bone has adapted in another way to reduce pressure the finger bones are flat rather than cylindrical on the gripping side and the force is spread over a large surface this reducing tissues over the bones according to P=F/A .

When all the weight is on one leg , such as when walking , Since pressure is the force per unit area, for a given force the pressure is reduced as the area is increased . Healthy bone joints are better lubricated than the best man- made bearings. If a conventional lubricant were used in a joint it would be squeezed out and the joint would soon be dry .. The skeletal system joints are the best bearing that any man can make . The lubrication of it is **due to** synovial fluid .**The** large area of the joints , **the** shape of the bones , **and the** lubrication by synovial fluid **is** naturally designed to reduce the pressure on the joints.

Pressure effects while diving

We recall Boyles law : for a fixed quantity of gas at a fixed temperature **the** product of the absolute pressure and volume is constant (pv=

constant) . That is , if the absolute pressure is doubled , the volume is halved . Applications of Boyles law to scuba diving are given in Example :

a-What volume of air at an atmospheric pressure of (1.01 * 10 exp 5 N/M2) is needed to fill a (14.2 liter) 0.5 ft3 scuba tank to a pressure of 1.45 * 10exp 7N/M2(2100 1b/in2) ?

P1v1= p2v2 (1.01*10exp5)(v1) = (1.45*10exp7)(14.2)

V1= 2* 10exp3 liters (72 ft3)

b-Since at sea level a diver uses about 14.2 liters (0.5 ft3) of air per minute during moderate activity , the tank in (a) would last about 144 min . How long would the tank last at a depth of 10m (33 ft) where the pressure is increased by 1 atmosphere , assuming the same volume us rate ?

Since the absolute pressure is twice as great (2 atm) , the tank will last only 72 min . (However , no safety – conscious diver would completely empty his tank during a dive for then he would have to surface without air.)

The middle ear is one air cavity that exists within the body. For comfort the pressure in the middle ear should equal the pressure on the outside of the eardrum . This equalization is produced by air flowing through the Eustachian tube , which is usually closed except during swallowing , chewing , and yawning . When diving , many people have difficulty obtaining pressure equalization and feel pressure on their ears . A Pressure differential of 120 mm Hg across the eardrum , which can occur in about 1.7 m of water, can cause the eardrum to rupture . Rupture can be serious since cold water in the middle ear can affect the vestibular or balance mechanism and cause nausea and dizziness ,

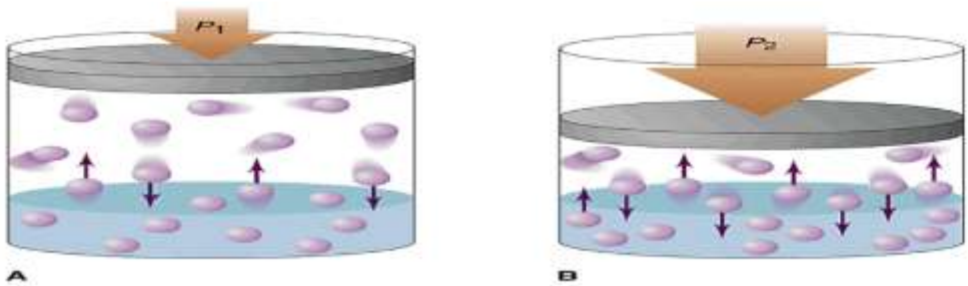
Breathing air at a depth of 30 m is also dangerous, **this** can produce serious problems :

1-Nitrogen narcosis which is an intoxication effect. While oxygen is transported by chemical attachment to red blood cells, nitrogen is dissolved in the blood and tissues. According to **Henrys law** , the amount of gas that will dissolve in a liquid is proportional to the partial pressure of the gas in contact with the liquid. Thus more nitrogen is dissolved in the blood and from there into the tissues as a diver goes deeper

2- Bends "decompression sickness" which is an ascent problem. When the diver ascends , the extra nitrogen in the tissues must be removed via the blood and the lungs . The removal is a slow process , and if the diver ascends too fast , bubbles from in the tissues and joints. The bends(diver paralysis) are quit painful,. Bends occur because of sudden decrease in pressure when the diver ascends.

Henrys law

The amount of gas that will dissolve in a liquid is proportional to the partial pressure of the gas in contact with the liquid.



Q: what is negative pressure?

Q: calculate the pressure in millimeters of mercury equal to a pressure of (20 cm) H_2O?.

Example

Find the pressure of 10 m of water in Dy/cm^2 and N/m^2?

$10 \times 100 = 1000$ cm　　　　1m=100cm

$\therefore\ P = \rho g h = 1\times980\times1000 = 980000 = 9.8\times10^5\ Dy/cm^2$

$P = \rho g h = 1000 \times 9.8 \times 10 = 9.8\times10^4\ N/m^2$

Example

Calculate the systolic pressure in Dy/cm^2 and N/m^2?

In systolic pressure =120 mmHg=12 cmHg = 0.12 m Hg

$\therefore$ $P = \rho_{Hg}\, g\, h_{Hg} = 13.6\times980\times12 = 159936 = 1.6\times10^5$ Dy/cm^2

$P = \rho_{Hg}\, g\, h_{Hg} = 13600\times9.8\times0.12 = 1.6\times10^4$ N/m^2

Question: Calculate the length of water column that can produce the same pressure of a column of mercury of (1mm) length. **(Answer =13.6 mm)**

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

P (120 mm Hg) = ρgh = (13.6 g / cm^2) * (980 cm/sec^2) * (12 cm) =$1.6*10^5$ dyne/cm^2

For water

$1.6*10^5$ (dyne/cm^2) = (1.0 g/cm^3)*(980 cm/sec^2)*(h cm H_2O)

$\therefore$ h = 163 cm H_2O.

Example:- what height of water will be produced the same pressure as 120 mmHg.?

Solution: P= ρ g h= 13.6x980x12 = 1.6x105 dy/cm^2 •

For water P= ρ g h $\longrightarrow$ 1.6x10^5 =1x980xh •

So h= 163 cm H_2o Or P • Hg =PH_2o

(ρ g h)Hg =(ρ g h)H_2o

ρ • Hg hHg = ρH2o hH_2o

h • H_2o = (13.6x12)/1 =163 cmH_2o

Example:- Calculate the atmospheric pressure in N/m^2 ?

Solution :- 1 atm =760 mmHg =76 cmHg •

The atmospheric pressure in N/m^2

is equal

P= ρ g h = 13600kg/m^{3}x9.8m/s^{2}x0.76m = 1.01x10^5 N/m^2

Typical pressure in the normal body

Different parts of the body	Typical pressure(mmHg)
Max.(systole)	100 - 140
Min. (diastole)	60 - 90
Venous blood pressure	3 - 7
Middle ear pressure	less than 1
Eye pressure	20
CSF inside the brain	5 – 12

Question: Calculate the length of water column that can produce the same pressure of a column of mercury of (1mm) length. **(Answer =13.6 mm)**

Negative Pressure

• Any pressure lower than atmospheric pressure. For example: The lung pressure during inspiration is a few centimeter of water negative,a person drink through a straw the pressure in his mouth must be negative.

• There are numbers of places in the body where the pressure is lower than atmospheric pressure or negative .For example when we breath inspire the pressure in the lungs must be lower than the atmospheric pressure .

Hyperbaric oxygen therapy (HOT)

The body normally lives in an atmosphere • that is about one fifth O_2 and four-fifth N_2. In some medical situations it is beneficial to increase the proportion of O_2 in order to provide more O_2 to the tissue.

1-Gas gangrene:

The bacillus causes gas gangrene then it's treated with (HOT). That is due to bacillus cannot survive in the presence of oxygen

2-Carbon monoxide poisoning:

-The red blood cells cannot carry O_2 to the tissues because the carbon monoxide fasters to the hemoglobin at the places normally used by O2.

-Normally the amount of O_2 dissolved in the blood is about 2% of that carried on the red blood cells.

-By using the (HOT) technique, the partial pressure of O_2 can be increased by a factor of 15 , permitting enough O_2 to be dissolved to fill the body's needs

3-Treatment of cancer:

(HOT) with radiation is given to the patient in transparent plastic tank. The theory was that more oxygen would make the poorly oxygenated radiation –resistant cell in the center of the tumor more susceptible to radiation damage.

<u>Homework</u>

Positive pressure is used in blood transfusion .Suppose a container is placed (1) m above a vein with a venous pressure of (2) mm Hg , if the density of the blood is (1.04) g/cm^3 ,what is the net pressure acting to transfer the blood into the vein?

Homework

Atmospheric pressure is due to the weight of the air above us . The density of air is ($1.3 * 10^{-3}$) g/cm^3 .What is the weight in dynes of (1) cm^3 of air ? If this weight were spread over (1) cm^2 what would be the pressure ? What fraction of (1) atm would it be?