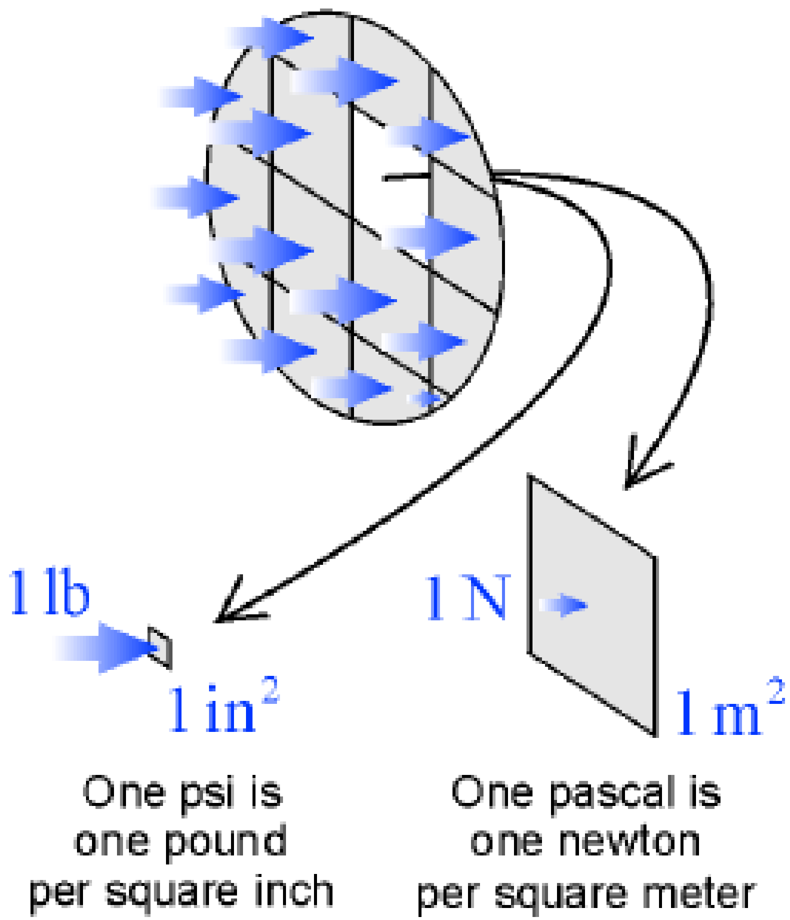
Fluids properties-Pressure

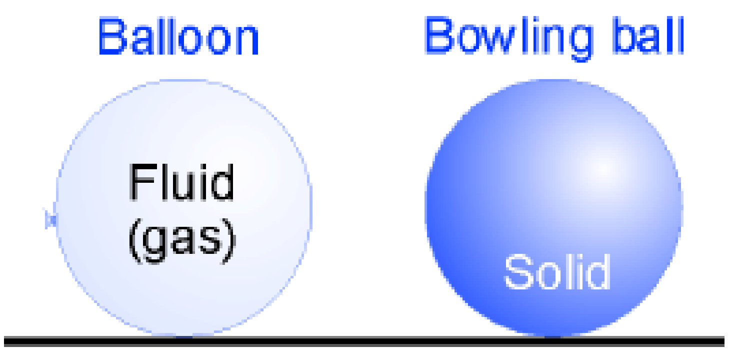
Pressure

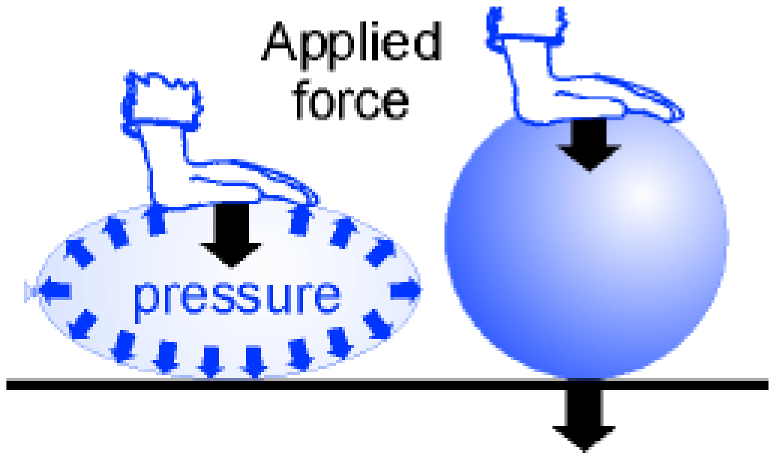
- Forces applied to fluids create pressure instead of stress.
- Pressure is force per unit area, like stress.
- A pressure of 1 N/m^2 means a force of one newton acts on each square meter.



Pressure

- Like stress, pressure is a <u>ratio of force per unit area.</u>
- Unlike stress however, pressure acts in all directions, not just the direction of the applied force.





Pressure and forces

Pressure is defined as the vertical force affecting unit area

$P = F/A$

Pressure measuring unit; Newton per square meter (N/m^2) Pascal ،

(Pa) ،

$P = \rho g h$ where $\rho = 13500\ kg/m^3$

bar = $10^5\ P_a$ Atmospheric pressure is measured with a

barometer

torr = $1.3 \times 10^2\ P_a$

1 atm = 1.013×10^5 Pa=760 mmHg=760 torr

Example-1

Example: a 75 kg mass standing on a metal piece measuring 250 cm^2, calculate the pressure on the metal piece because the person?

$$P = \frac{F}{A} = \frac{mg}{A} = \frac{75x9.8}{0.025(m^2)} = 2.94x10^4\ Pa$$

Example-2

A-standing person weight 500 N on the ice of a frozen pond so that his feet adjacent to the area of ice, what is the pressure on ice?

B. If the ice will fall apart when the pressure of 16,000 Pa, how is the weight of the person required to rupture the ice as the same contact area?

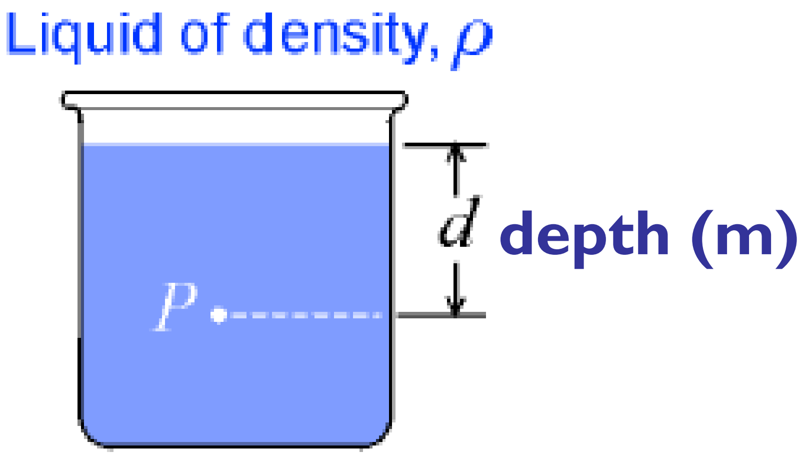
$$P = \frac{F}{A} = \frac{500}{0.05} = 10000\,Pa = 10\,k\,Pa$$ **A**

$$F = PA = 16000 \times 0.05 = 800\,N$$ **B**

-Static fluid pressure:

- The pressure varies depending on the depth, for example as shown in the drawing,

-Pressure on the bottom is



$$\because F = w = mg$$

$$\because m = \rho V = \rho A h$$

$$\therefore F = \rho A h g$$

$$\therefore P = \frac{F}{A} = \rho h g$$

The relationship show increased pressure with increasing depth (***h*** or ***d***) with increasing density of the liquid.

Where V: column size fluid, ρ: fluid density, d: depth

If we calculate the total pressure affecting the bottom area A, we add the atmospheric pressure (because the pot open) to compress the liquid column, that is:

$$P_t = P_a + P$$

$$P_t = P_a + \rho g h$$

it is known that atmospheric pressure at standard conditions is: $P_a \cong 1.013 \times 10^5 \text{ Pa}$

this is the column of mercury pressure height 76 cm

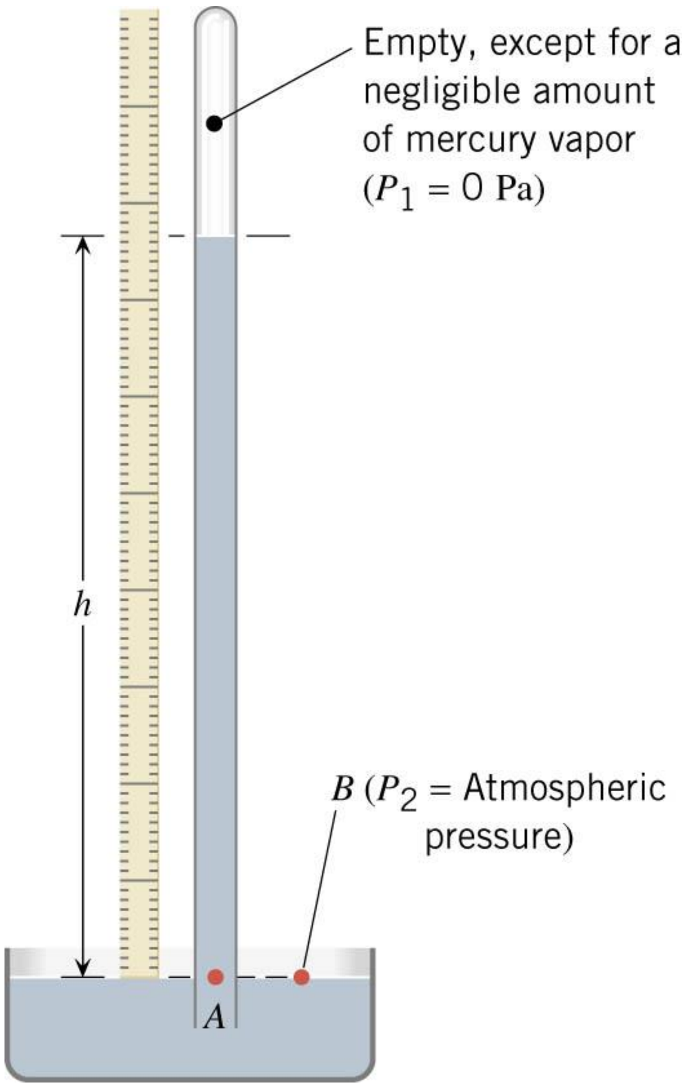
Example-3 : creating a column of mercury pressure height 76 cm .note that the density of mercury

$$P = \rho g h$$

$$= 0.76\,\text{m} \times 13600 \frac{\text{kg}}{\text{m}^3} \times 9.8 \frac{\text{m}}{\text{s}^2}$$

$$\cong 1.01 \times 10^5\,\text{Pa} = 1\text{atm}$$

Pressure Gauges



$$P_2 = P_1 + \rho g h$$

$$\Downarrow$$

$$P_{atm} = \rho g h$$

$$\Downarrow$$

$$h = \frac{P_{atm}}{\rho g} = \frac{\left(1.01\times10^5\ \text{Pa}\right)}{\left(13.6\times10^3\ \text{kg/m}^3\right)\left(9.80\ \text{m/s}^2\right)}$$

$$= 0.760\ \text{m} = 760\ \text{mm}$$

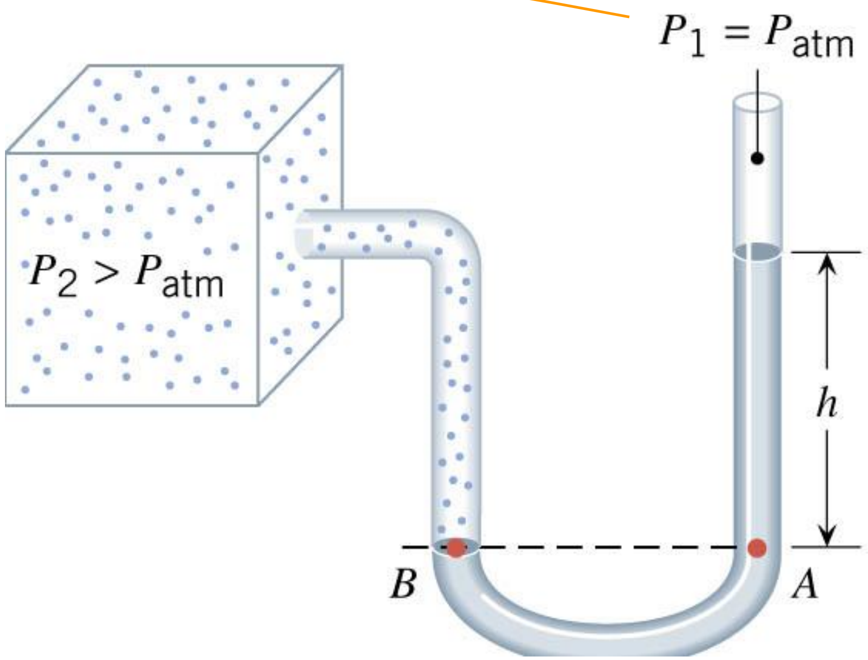
Pressure Gauges

$$P_2 = P_B = P_A$$

$$P_A = P_1 + \rho g h$$

absolute pressure

$$\underbrace{P_2 - P_{atm}}_{\text{gauge pressure}} = \rho g h$$



Example-4

what is the total pressure at the bottom of the pool depth of 2 m and a completely filled with water.

$$P_A = P_1 + \rho gh$$

$$= 1.013 \times 10^5 + 2 \times 1000 \times 9.8$$

$$= 1.013 \times 10^5 + 19600$$

$$= 1209600 \text{ Pa}$$

Medical pressure measurement.

This is a major application for sensor technology.

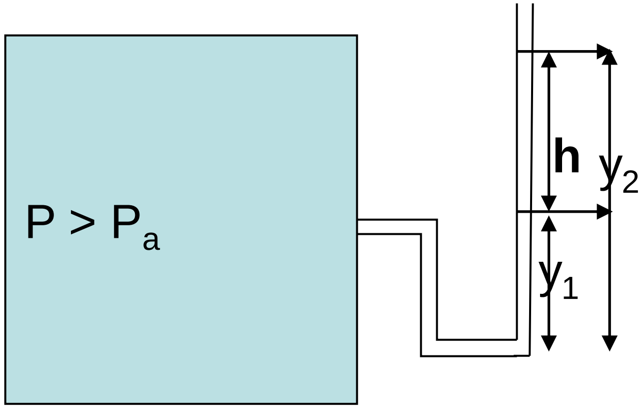
Most common measurement is for blood pressure. More fully:

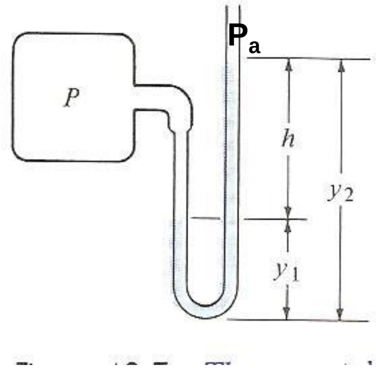
- Arterial blood pressure
- Venous blood pressure
- Central venous pressure
- Inter-cardiac blood pressure
- Pulmonary artery pressure
- Spinal fluid pressure
- Intraventricular brain pressure

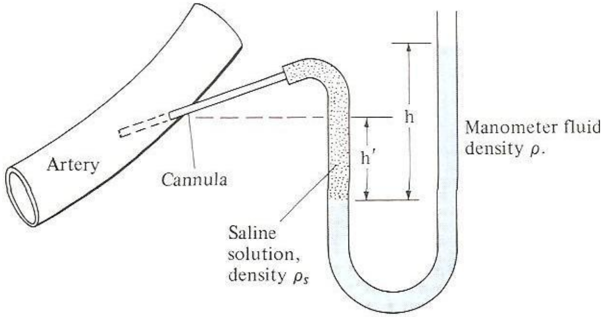
The difference in these measurements is the range of measurement; we can often use the same sensor for different measurements

-Almanomitr: the open-tube manometer

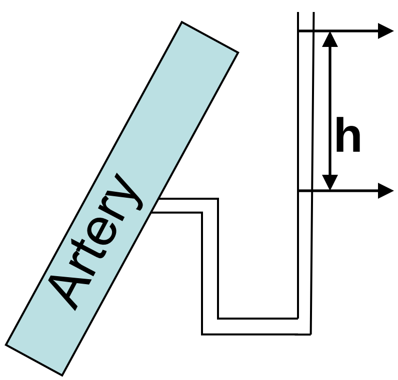
-$P - P_a = \rho g h$







Blood pressure and its measurement methods:



-Direct method: measurement device connected artery and the change in height of the liquid in the tube connected to the pressure in the artery, as showed.

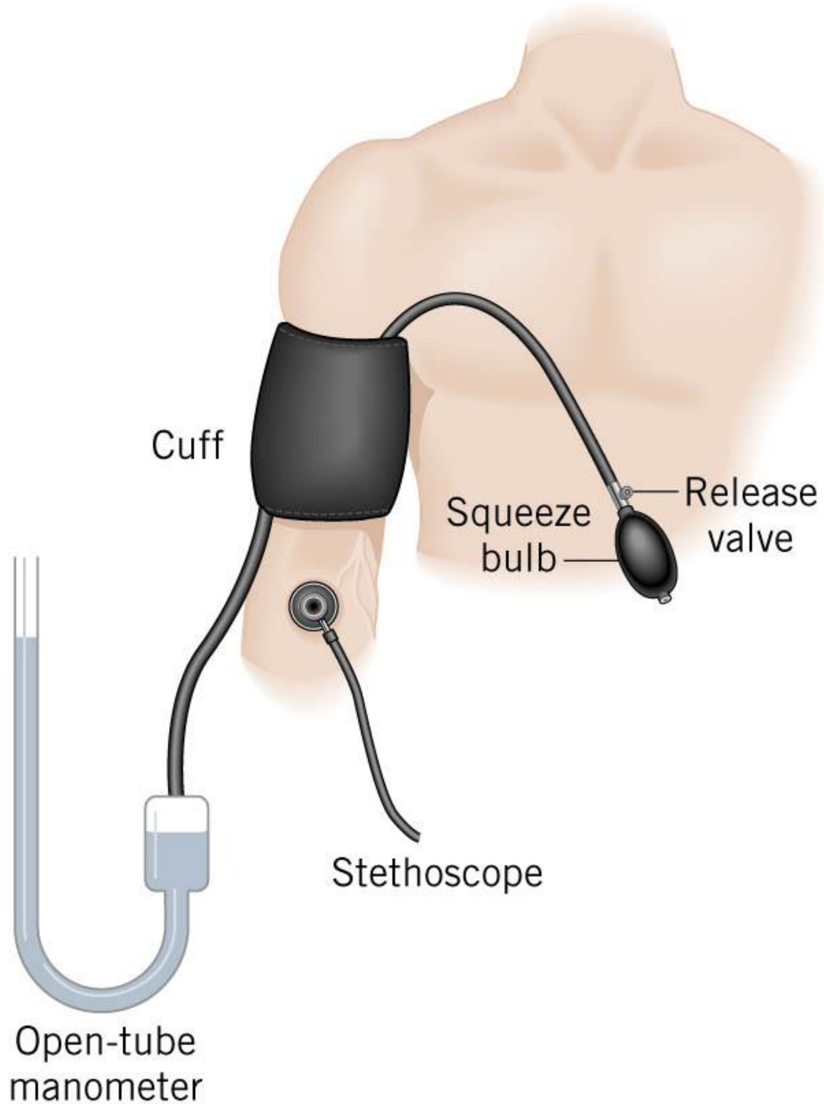
Pressure Gauges Sphygmomanometry (Korotkoff Method)

-Inflatable cuff placed on upper arm and inflated until blood can't flow

- Sound sensor (stethoscope) placed downstream

- Pressure is released
 When can hear blood squirting (Korotkoff sounds), the cuff pressure equals systolic (higher) pressure

 -Hear continuous but turbulent flow when cuff pressure equals diastolic pressure



-Indirect way: using the blood pressure measuring device

Sphygmometer



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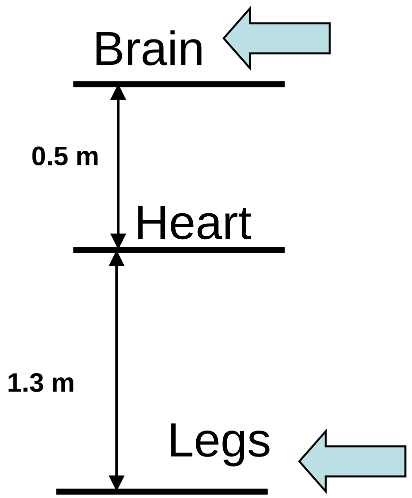
Blood pressure depends on the height, or depth, the pressure in the -vessels vary according to the distance from the Earth, for example; at heart, arterial pressure is 120/80 ≡ 100 mmHg,

horizontal average arterial pressure in the brain and feet is equal,-

in the vertical position:-



$$P = 100(mmHg) - \frac{\rho(blood) * h}{\rho(Hg)}$$

$$= 100 - \frac{1050(kg/m^3) * 0.5(m)}{13600(kg/m^3)} = 60\,mmHg$$

$$P = 100(mmHg) - \frac{\rho(blood) * h}{\rho(Hg)}$$

$$= 100 - \frac{1050(kg/m^3) * 1.3(m)}{13600(kg/m^3)} = 200\,mmHg$$

This may cause the pressure foot ***<u>varicose</u>*** legs if no movement or - .standing too long without animation

-To find the pressure required for a vessel explosion:

$T = R\,P$ -------→ $\Delta P_{max} = |dT/dR|_{max}$

Young's modulus (modulus of elasticity)-Y = stress (F/A), strain(Δ L/L)

$Y = P/(\Delta L/L)$ -------→ $\Delta P_{max} = Y_{max}\, dR/Ro = Y_{max}\, t/Ro = |dT/dR|_{max}$

Where: t wall thickness, and the R0 original RADIUS

Ymax of the arteries is equal to N/m2 7x105 for youth and seniors 1.8 x 105 N/m2 ، R_0=0.35 cm & t=0.07 cm

-Calculate the pressure required to blast the vessel was approximately،

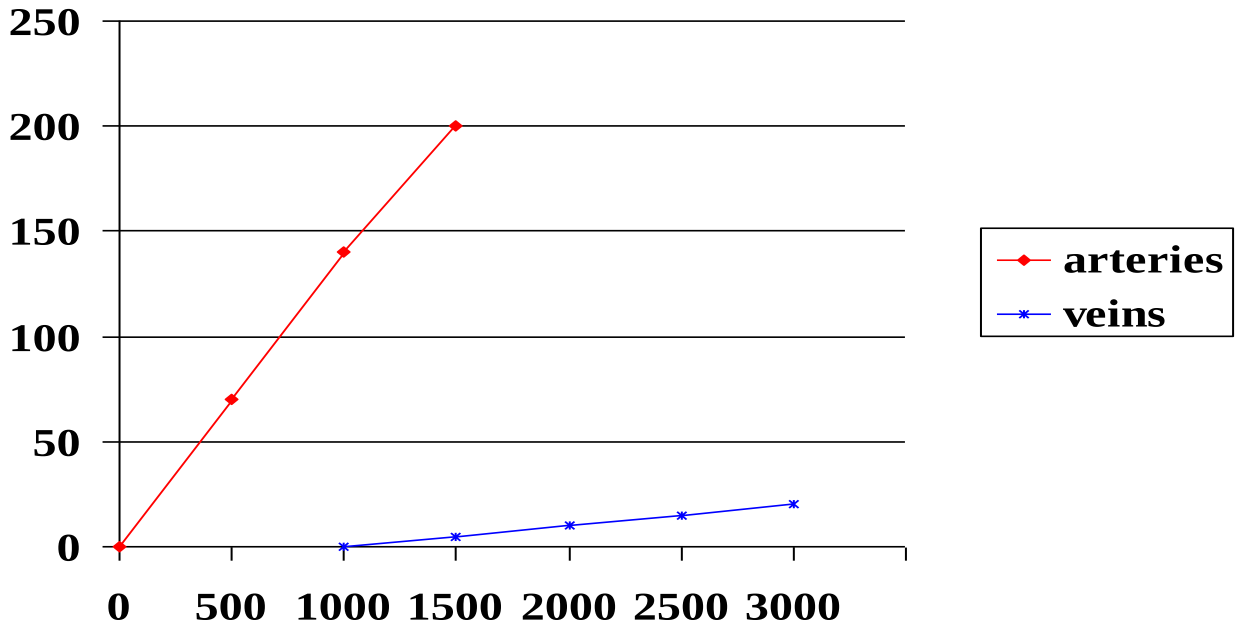
ΔP_{max} = 1.4x105 Pa ≈ 1000 mm Hg

This is equivalent to ten times the normal pressure and understood that the artery to explode if hit by disease leading to stiffen, leading to lower the value of the coefficient of Yong (modulus of elasticity).

Volume-Pressure relationships

- A Δ volume $\propto$ Δ pressure
- In systemic arteries a small Δ volume is associated with a large Δ pressure
- In systemic veins a large Δ volume is associated with a small Δ pressure

Volume-Pressure relationships



Pressure gradient

- Driving force of blood
- difference in pressure between two points
- proportional to flow (Q)
- At a given Q the greater the drop in P (Δ P) in a segment or compartment the greater the resistance to flow.

Resistance

- Parallel circuit
  - $1/R_T = 1/R_1 + 1/R_2 + 1/R_3 + \dots 1/R_N$
  - $R_T <$ smallest individual R
- Series circuit
  - $R_T = R_1 + R_2 + R_3 + \dots R_N$
  - $R_T =$ sum of individual R’s
- The systemic circulation is predominantly a parallel circuit

Advantages of Parallel Circuitry

Independence of local flow control •

increase/decrease flow to tissues –
independently

Minimizes total peripheral resistance •
(TPR)

Oxygen rich blood supply to every tissue •