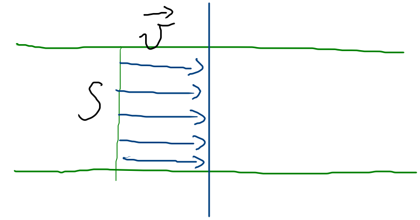
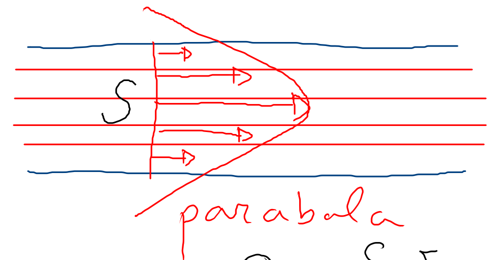
FLUIDI "REALI"

$$Q = S v$$



ideale
- $\eta = 0$
- moto stazionario
- " irrotazionale

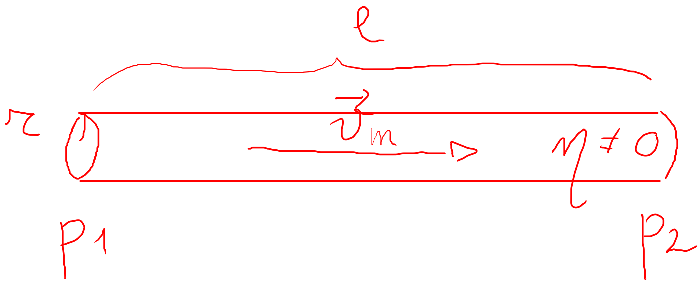
"reale"
- $\eta \neq 0$
- moto stazionario
- moto laminare



$$Q = S v_m$$

↑ velocità media

LEGGE DI POISEUILLE



$p_1 \neq p_2$

$p_1 > p_2$

$$Q = \frac{\pi}{8} \frac{r^4}{\eta} \frac{(p_1 - p_2)}{\ell} \quad \rightarrow \text{FLUIDO NEWTONIANO}$$

$$\frac{(p_1 - p_2)}{\ell} \simeq \frac{|\Delta p|}{\ell} \sim \frac{dp}{dx}$$

$$v_m = \frac{Q}{S} = \frac{Q}{\pi r^2}$$

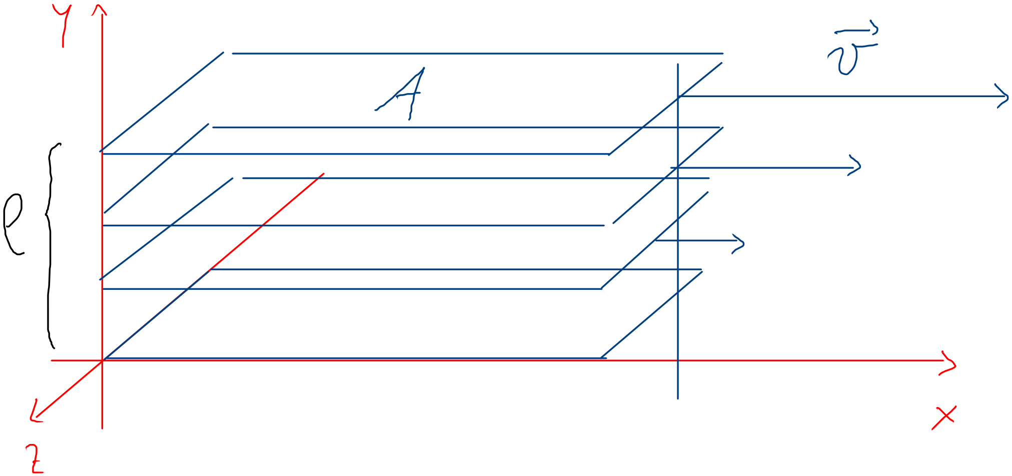
$$v_m < v_c$$

$$v_c = N_R \frac{\eta}{\rho r}$$

N_R → numero di Reynolds

$N_R \sim 1000$

DEFINIZIONE DI VISCOSITÀ

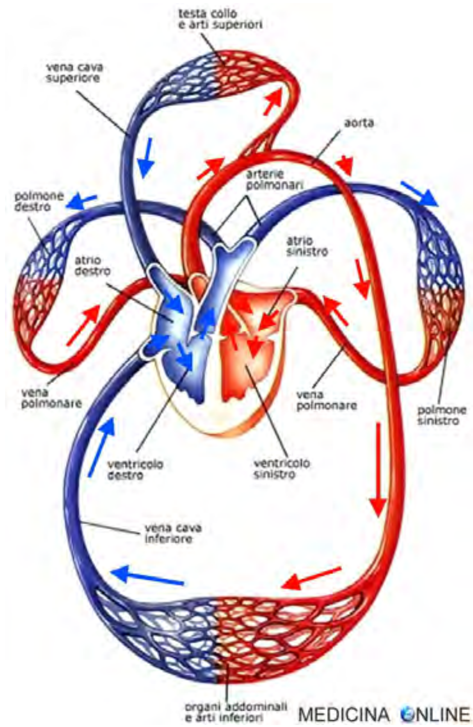


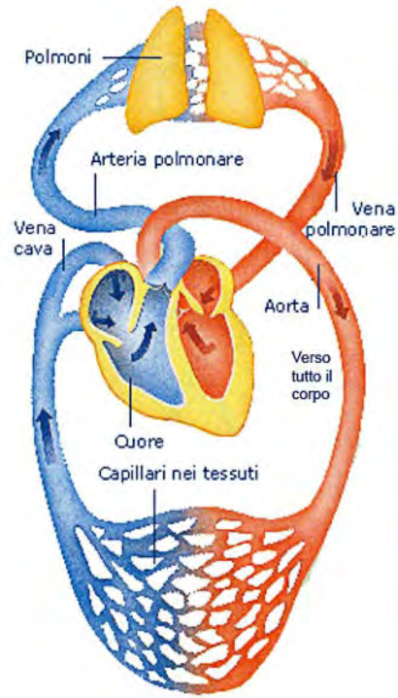
$$\frac{dv}{dy} = \text{cost} = \frac{v}{l}$$

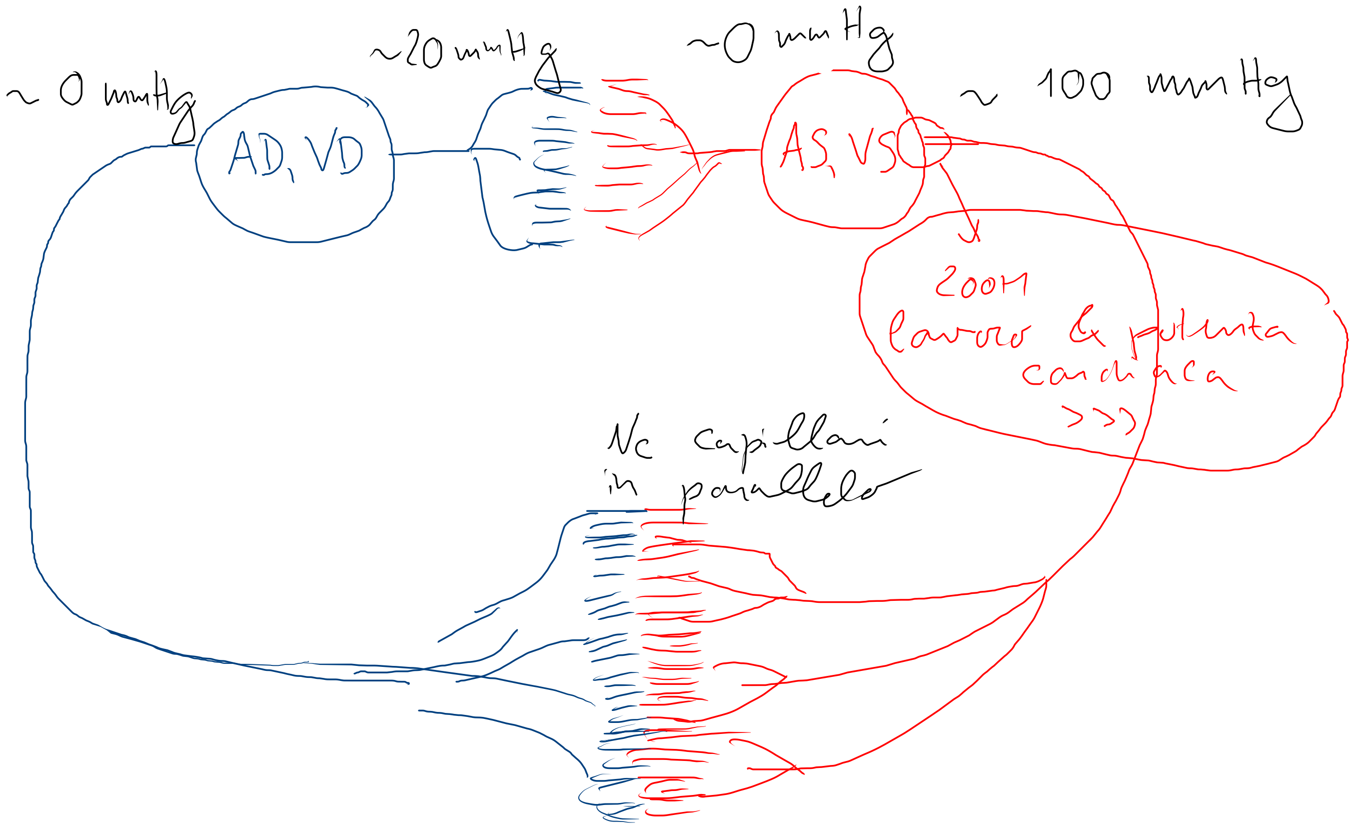
$$F \propto \left(\frac{dv}{dy}\right) A \qquad F = \eta \left(\frac{dv}{dy}\right) A$$

carico di scorrimento: $\frac{F}{A} = \eta \left(\frac{dv}{dy}\right) = \eta \frac{v}{l}$

CIRCOLAZIONE SANGUIGNA





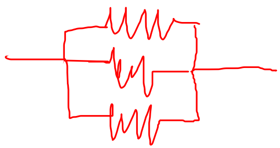

~ 0 mmHg
AD, VD
~20 mmHg
~0 mmHg
AS, VS
~ 100 mmHg
zoom
lavoro & potenza cardiaca
>>>
Nc capillari in parallelo

$$|\Delta p| = \underbrace{\frac{8\eta l}{\pi r^4}}_{R} Q \qquad \Delta V = R I$$

resistenze in serie

$$R_{eq} = R_1 + R_2 + \dots + R_N$$

in parallelo



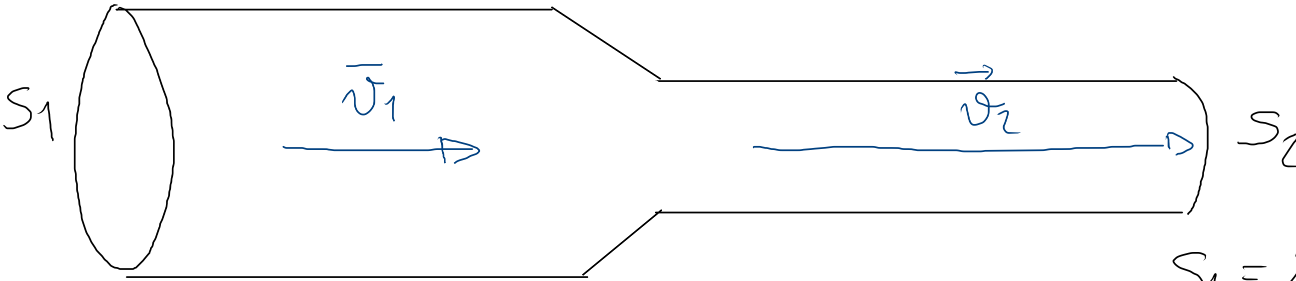
$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \dots + \frac{1}{R_N}$$

N_c capillari $\sim 2 \cdot 10^6$

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \dots + \frac{1}{R_{N_c}} \qquad R_1 = R_2 = \dots = R_{N_c} = R_c$$

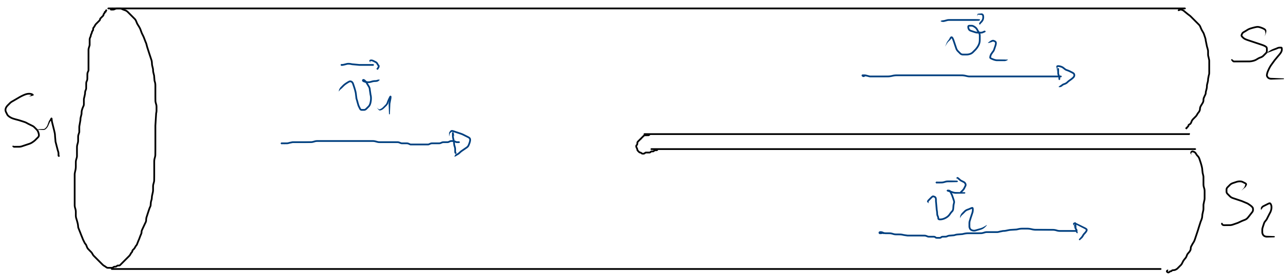
$$= N_c \cdot \frac{1}{R_c}$$

$$R_{eq} = \frac{R_c}{N_c}$$



$$S_1 = 2 S_2$$

$$v_2 = 2 v_1$$



S_1

$$2 \cdot S_2 = S_1$$

$$v_1 = v_2$$

VISCOSITÀ DEL SANGUE

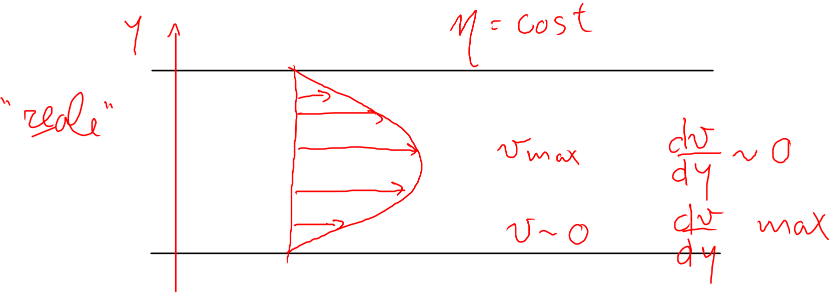
- viscosità $\propto$ ematocrito

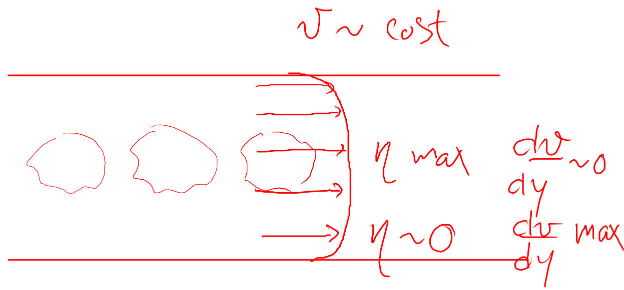
- η_∞ nei vasi grandi

  nei vasi piccoli r

$$\eta(r) = \frac{\eta_\infty}{\left(1 + \frac{d}{r}\right)^2}$$

d diametro eritrociti 6-9 μm





$$\frac{F}{A} = \eta \cdot \left(\frac{dv}{dy}\right)$$ piccolo

LAVORO DEL CUORE
& potenza!

$$V = S \cdot \Delta x$$

$$p = \frac{E}{S}$$

$$F = pS$$

1 contrazione

sx $\mathcal{L} = F \cdot \Delta x = p S \Delta x = p V$ $\qquad p \sim 100$ Torr

dx $\mathcal{L}' = p' V$ $\qquad p' \sim 20$ Torr

$\mathcal{L}_{TOT} = \mathcal{L} + \mathcal{L}' = (p + p') V$ $\qquad V \sim 60\ cm^3$

$\mathcal{L}_{TOT} \sim 1\ J$ $\qquad \mathcal{P} \sim 1\ W$

$$200\ \frac{Kcal}{die}$$

LEGGE DI LAPLACE

$S = 4\pi r^2$

$r \to r + \Delta r$

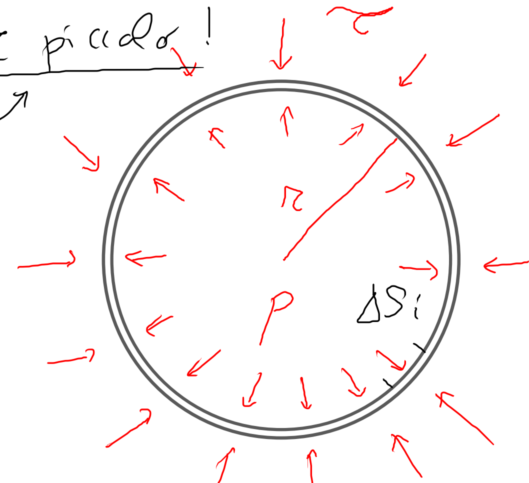
$$\mathcal{L} = \tau \left[4\pi (r + \Delta r)^2 - 4\pi r^2 \right] \cdot 2$$

$$= 2\tau \left[4\pi (\cancel{r^2} + 2r\Delta r + \Delta r^2) - \cancel{4\pi r^2} \right]$$

$$= 8\pi \tau \left[2r\Delta r + \cancel{\Delta r^2} \right]$$

Δr piccolo! → trascurabile

(1) $$= 16\pi \tau r \Delta r$$



$$\mathcal{L}_i = F_i \Delta r = p \cdot \Delta S_i \Delta r$$

$$\mathcal{L} = \sum_i \mathcal{L}_i = \sum_i p \Delta S_i \Delta r$$

$$= p \cdot \Delta r \sum_i \Delta S_i$$

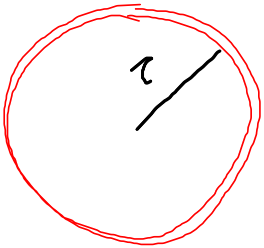
(2) $$= p \cdot \Delta r \, 4\pi r^2$$

(1) = (2)

$$\overset{4}{\cancel{16\pi}} \tau \cancel{r} \cancel{\Delta r} = \cancel{4\pi} r^{\cancel{2}} p \cancel{\Delta r} \rightarrow$$

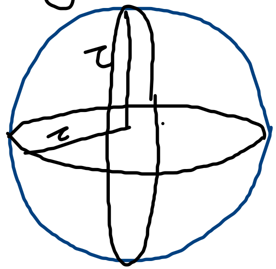
$$p = \frac{4\tau}{r}$$

bolla



$$p = \frac{4\tau}{r}$$

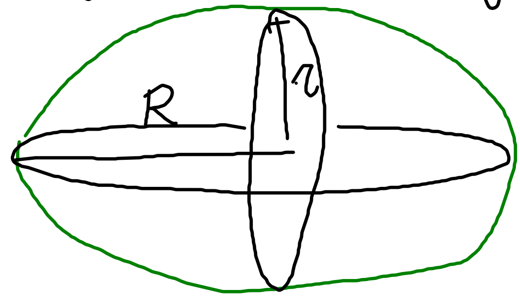
goccia



$$p = \frac{2\tau}{r}$$

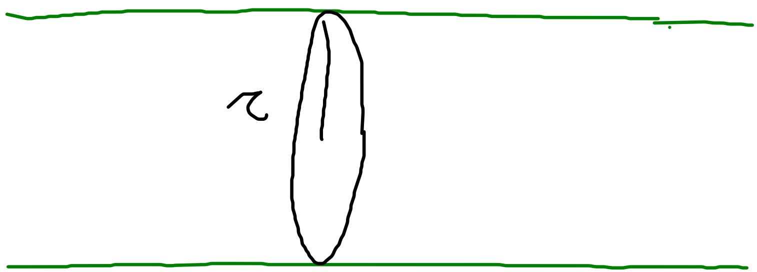
$$p = \frac{\tau}{r} + \frac{\tau}{r}$$

goccia allungata



$$p = \frac{\tau}{r} + \frac{\tau}{R}$$

$R \to \infty$

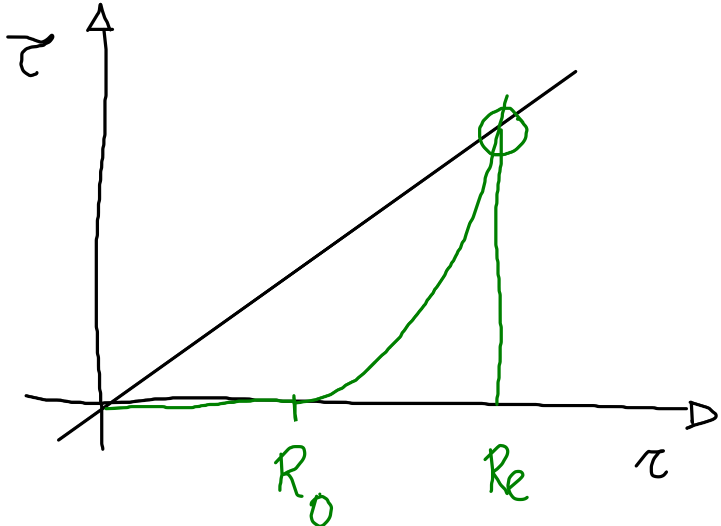


$$p = \frac{\tau}{r}$$

$$p = \frac{\tau}{\tau}$$

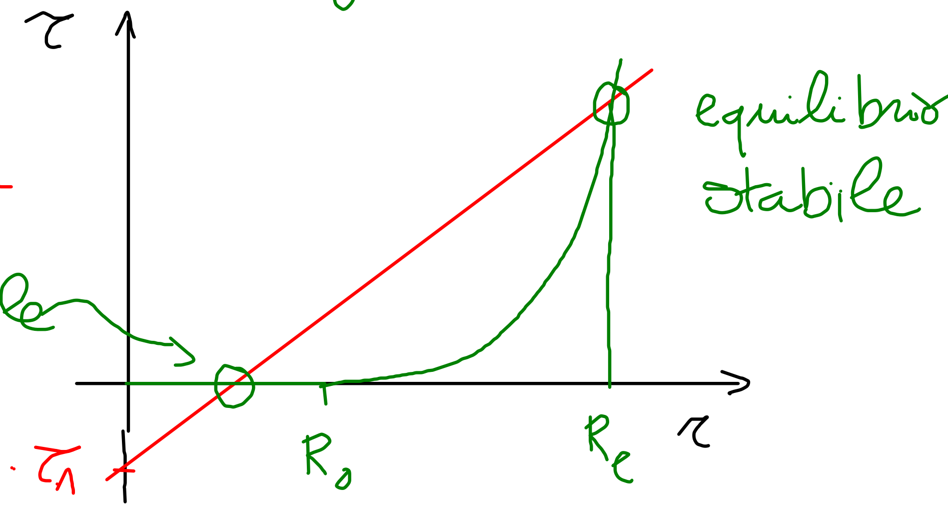
$$\tau = p\tau \quad —$$

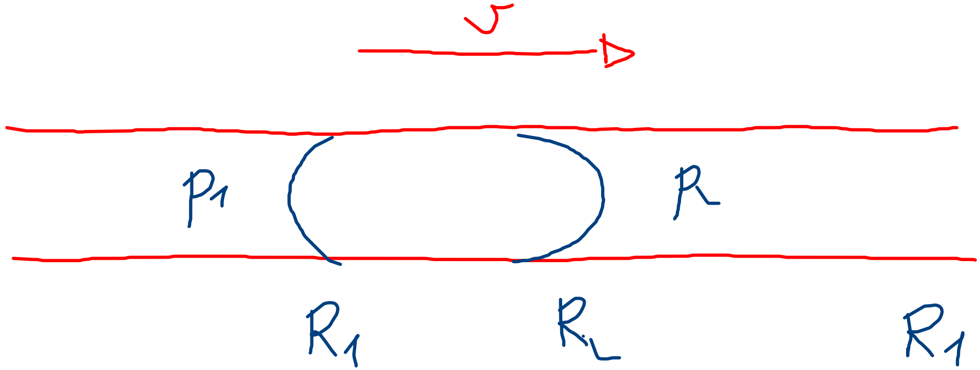
$$\tau = \tau(\tau) \quad —$$



$$\tau + \tau_A = p\tau$$

$$\tau = p\tau - \tau_A \quad —$$





$R_1 > R_2$

$p_1 > p_2$

per avere circolazione

$p_1 < p_2$

$\Rightarrow$ embolia gassosa