PASSION ACADEMIC TEAM

YU - MEDICINE

Cardiovascular System

Sheet# 7

Lec. Date :

Lec. Title : Hemodynamics 1

Written By : Mustafa Tawaha & Wasan Ababneh

If you come by any mistake , please kindly report it to shaghafbatch@gmail.com

emodynamics 1

-**Hemodynamics** : physical factors that manage and regulate blood flow "**Q**" ; Which include :

1-Resistance 2-Velocity
3-laminar and turbulent flow 4-wall tension and compliance

-Blood flow 'Q': quantity (volume) of blood that pass a given point in circulation per time unit

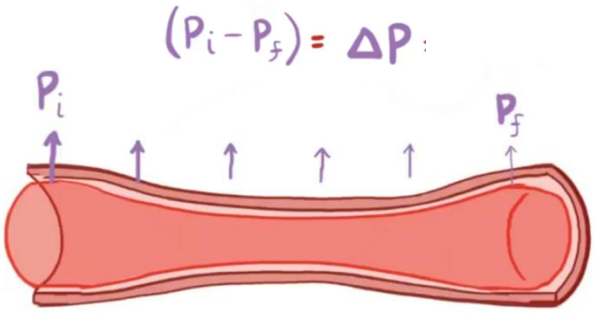
$$\mathbf{Q} = \frac{\boldsymbol{V}}{\boldsymbol{t}}$$

Note: here we used Q for blood flow but in slides F → both are the same

-So, it is measured in ml \ sec or L \ min ,etc….

-Also, we have another equation for 'Q' which have relationship to pressure and resistance

$$\mathbf{Q} = \frac{\boldsymbol{\Delta P}}{\boldsymbol{R}}$$



; ΔP:the difference bet. 2 points in pressure

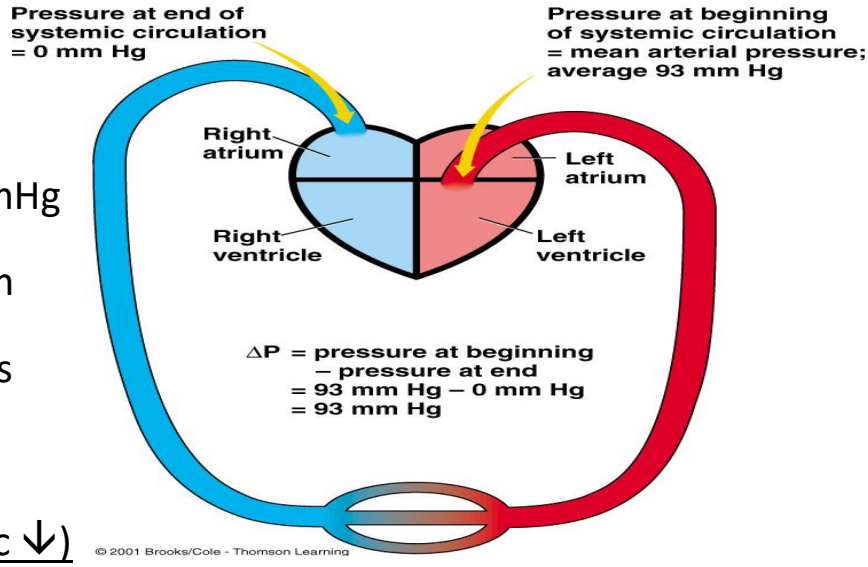
R: resistance

So, blood flow is proportional to pressure of blood (vasoconstriction increase blood flow and vice versa) and inversely proportional to resistance of wall of blood vessels

-This equation can be applied on single vessel or organ or entire circulation :

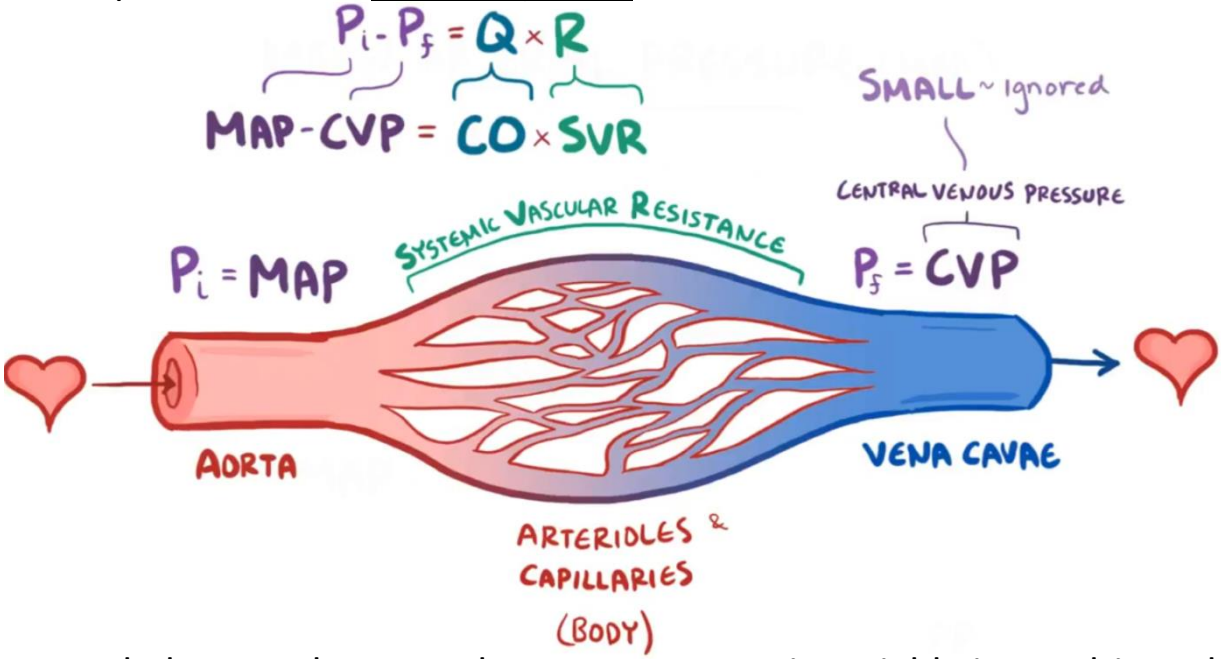
1-if U applied it on an **organ** the *ΔP* will be difference bet. Arterial pressure of the arteries going into the organ and venous pressure of the veins going out of the organ (*ΔP = arterial P – venous P)*

2-if U applied it on the **entire circulation** the *ΔP* will be difference bet. The pressure of aorta(beginning of the circulation) and the pressure of right atrium (end of it)



-The pressure of aorta is mean arterial pressure ”MAP” = 93 mmHg

While the pressure in right atrium =central venous pressure which is ignored(=0) because it is small in comparison to 93 (Look at pic ↓)



-we took the MAP because the press. In aorta is variable in sysoltic and diastolic so I took the ‘average’ which is MAP

MEAN ARTERIAL PRESSURE (MAP)

* AVERAGE PRESSURE

SYSTOLE ~ 1/3 CARDIAC CYCLE

DIASTOLE ~ 2/3 CARDIAC CYCLE

PULSE PRESSURE = SBP − DBP

في عندنا قانونين لنطلع ال MAP

$$MAP = \frac{1}{3}(SBP) + \frac{2}{3}(DBP)$$

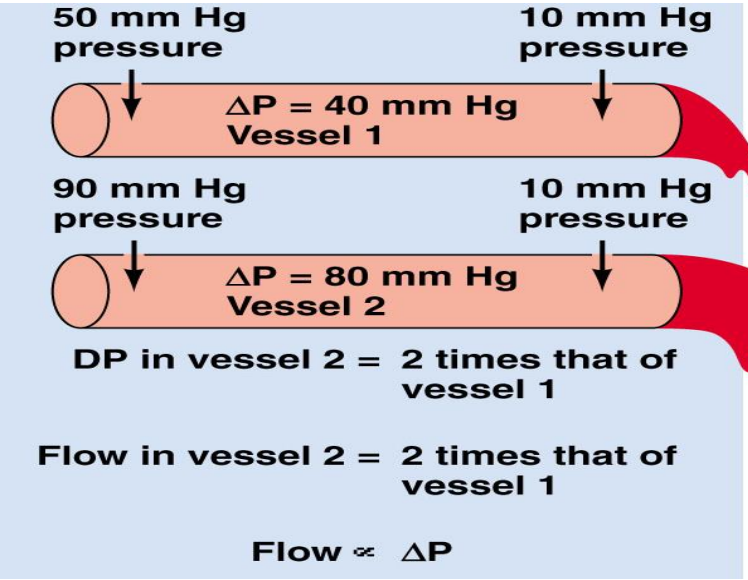
$$-\frac{1}{3}DBP \quad +\frac{1}{3}(DBP)$$

$$\frac{1}{3}(SBP-DBP) + DBP = \frac{1}{3}(PP) + DBP$$

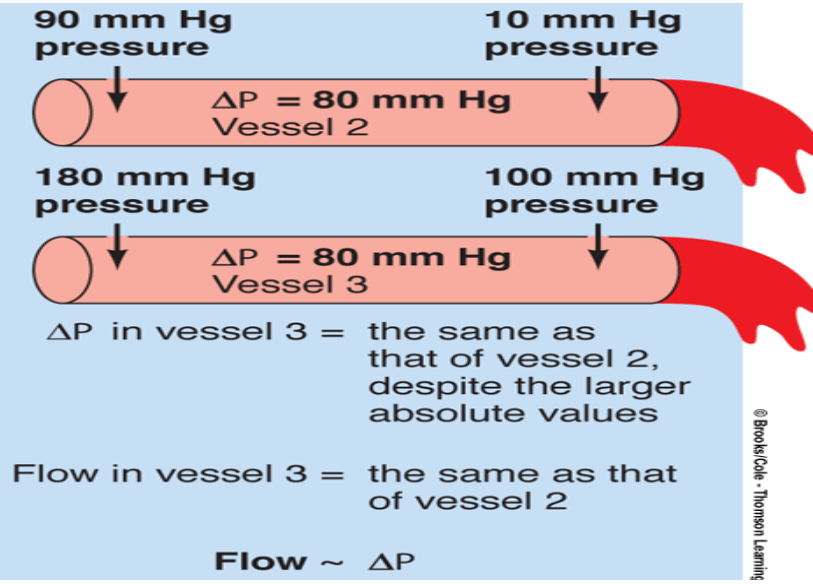
MAP = 1\3 * (120-80) + 80 = 93 mmHg

- طيب ليش ما اخذت الaverage مباشرة الي هو اجمع الاثنين تقسيم 2؟

لانو ببساطة systole بوخذ ثلث فترة الزمنية لل cardiac cycle بينما الDiastole بوخذ ثلثين فا مش منتظمات



1



2

-هذول الرسمتين بتوضحلنا انو الي بهمنا وبلعب دور بالقانون وب blood flow هو ΔP وليس قيمة كل pressure (P1 , P2)

-in 1 , ΔP in vessel 1 is calculated as well as in vessel 2 and we see that ΔP in vessel 2 = the double of ΔP in vessel *1* → Q in vessel 2 = double of Q in vessel 1

-in 2 , ΔP in vessel 3 is equal in vessel 2 → Q in vessel 3 = Q in vessel 2 ;despite of large values in vessel 3 and small in vessel 2

So, blood flow depend in proportional relationship on *ΔP , and not the absolute values of each pressure*

Q : how the pressure gradient in the circulation is established?

-by contraction of the heart import pressure through arteries which is the main driving force for blood flow (يعني القلب هو الي المسؤول عن توليد الضغط بالدروة الدموية

*توليد قيصري ولا طبيعي هه

ΔP **=perfusion pressure**

- طبعا بداية blood circulation بتكون resistance اقل وبتصير تزيد نتيجة زيادة الاحتكاك بين الدم وجدران الاوعية الدموية لهيك بكون الضغط اعلى ما يكون في ال aorta الي هي البداية بضل يقل الضغط اول باول لحد ما يصير تقريبا صفر بنهاية criculation
- طبعا نتيجة الاحتكاك (resistance) الدم راح يفقد جزء من طاقته ليتغلب عليهم وهيك بقل ضغطه وهيك بتكون عندنا ΔP بين البداية والنهاية , يعني لو ما عندنا احتكاك راح يكون الضغط نفسه بكل اجزاء الدورة الدموية بالتالي ما راح يتكون عندنا ΔP يعني Q=0 ← راح يضل الدم محله ما يمشي ويتحرك. وهالنقصان بالضغط بكون اكثر اشي موجود في arterioles لانها تسمى resistance vessels

Q:who is responsible of establishing Resistance?

-Sympathetic vasoconstrictor fibers in smooth Muscles , which cause partial vasoconstriction = Tonic contraction ,and the effect of it is increased in arterioles so that's why it is called "resistance vessels"

So, if contraction increased → The resistance increase and blood flow decrease

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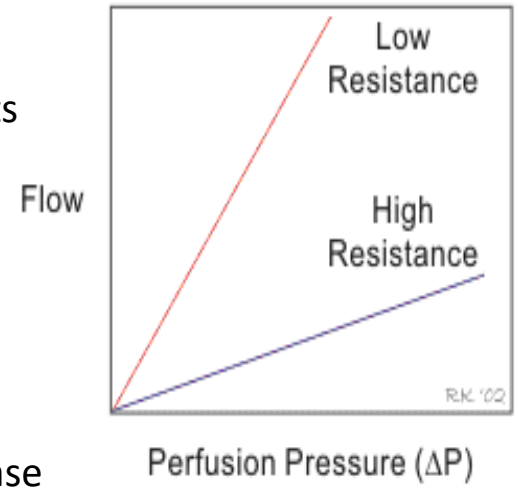
<u>Relationship between blood flow and Resistance:</u>

-Resistance is the opposition of blood flow hinderants of blood flow through the vessel.

-according to the figure → , ΔP is shifted to right and downward when resistance increase and vice versa.



-So, according to **Q**= $\frac{\boldsymbol{\Delta P}}{\boldsymbol{R}}$ and the figure → any increase in resistance perfusion pressure ,the perfusion pressure must increase (By either increasing pressure at beginning of vessel "P1"or decreasing it at the end"P2") <u>in order to maintain the same blood flow "Q"</u>

-but usually there is increasing in P1 by increasing contractility of heart

-In conclusion, where the vessel offer more resistance this mean the heart must work harder to maintain the same blood flow which we see

*يعني باختصار,زيادة الR تعني نقصان Q مع ثبات $P\Delta$

in pathological cases like aortic stenosis which cause L. ventricle hypertrophy due to overload of working

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-**Resistance** depends on many factors:

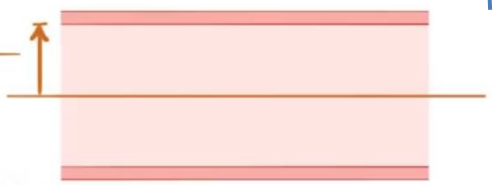
$$R = \frac{8\eta L}{\pi r^4}$$

1) * VISCOSITY ~ "THICKNESS"
   - ↑R ∝ ↑η

2) * BLOOD VESSEL LENGTH
   - ↑R ∝ ↑L

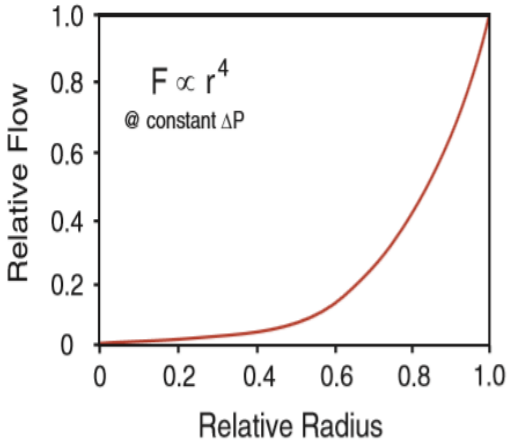
3) * BLOOD VESSEL RADIUS
   - ↑↑R ∝ $\frac{1}{(\downarrow r)^4}$

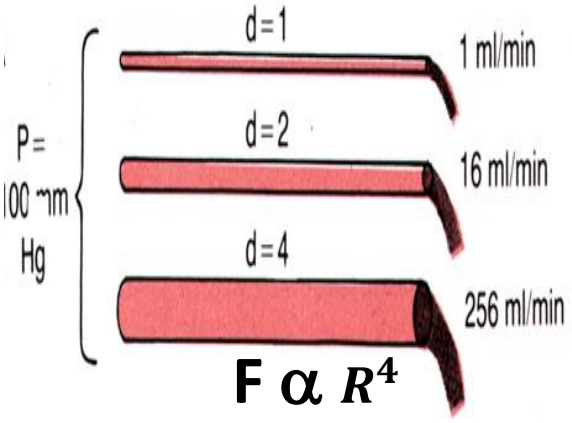
ARTERIOLES
- VASOCONSTRICT ~ ↑↑R
- VASODILATE ~ ↓↓R

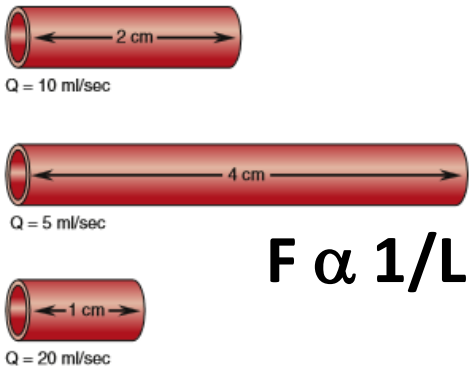


-So, R is proportional to viscosity and Length and inversely proportional to Radius which is the most important factor because any change in it will lead to a big change in R because Radius is to the power of 4 + we can control through vasoconstriction and dilation

-In SUMMARY, viscosity and length is **inversely proportional** to Blood flow 'Q' while Radius is **proportional** to 'Q' or 'F'







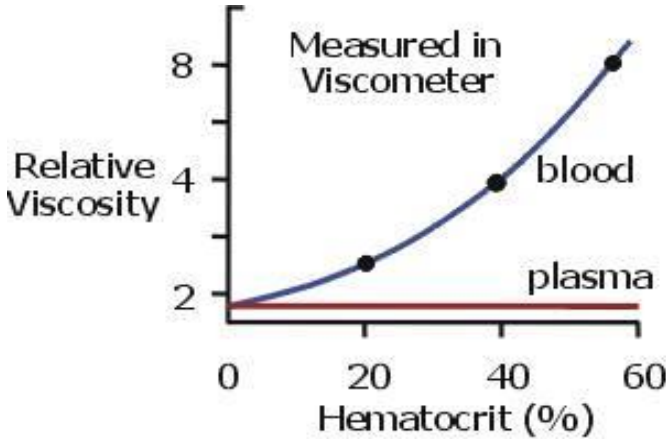
R = ΔP/Q:

- **entire systemic vasculature=1 PRU**
- **entire pulmonary vasculature= 0.14 PRU**

peripheral resistance unit

-viscosity is mostly determined by circulating Resistance pieces :
proteins in plasma and **hematocrit**: percentage of RBC in blood

↑ circulating R pieces , ↑ viscosity



*Plasma of blood is more viscose than plasma of water because it contains proteins in it. ~~~but the blood is more viscose than plasma

-↑surface area of blood vessel in contact with blood α↑ Resistance →↓ F

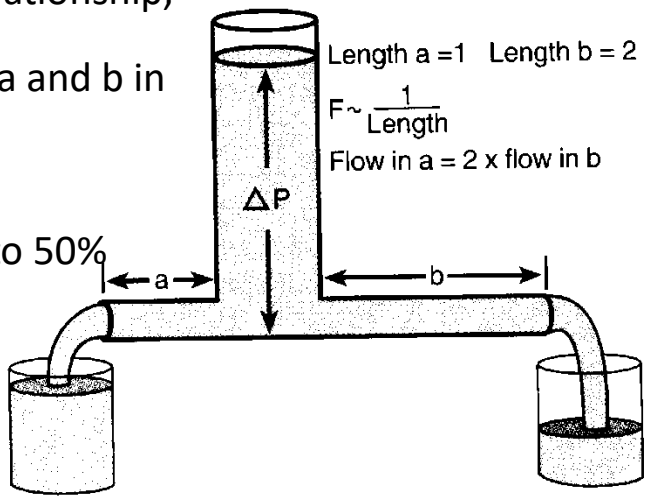
-بالتالي في aorta هذه ال surface area بتكون قليلة بينما في ال arterioles بتكون اكبر بكثير

Relationship between Blood flow and Length

-we can't change the length in normal people so it's not so important but it may change in obese people so they will have more resistance therefore less blood flow .

-we repeat what we say previously about relationship, see the figure → and make comparison bet. a and b in length and their blood flow

-if we double the length, blood flow reduce to 50%



Relationship between Blood flow and Radius

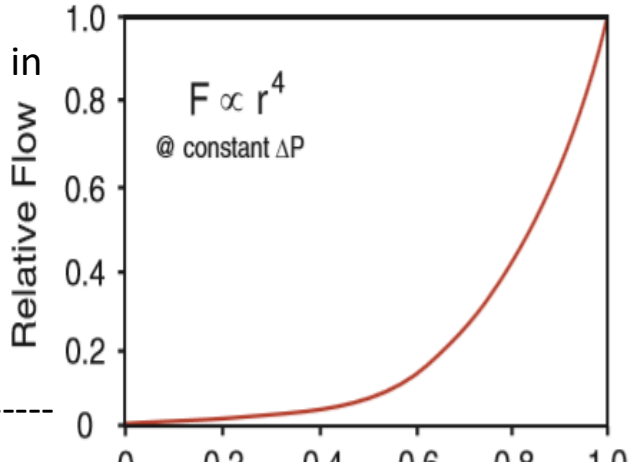
-again, repeating what we said previously

-it is very important factor and we can change it In normal people through vasoconstrictors and Vasodilators

-Also, as we say in the figure ,any little change in Radius will lead to huge change in blood flow

-if we double the radius→ blood flow will Increase 16 times !!

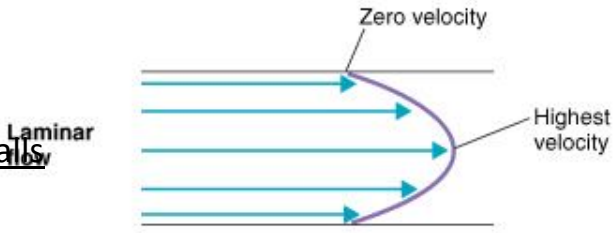
$E \alpha 1/L$



Laminar vs. Turbulent Flow

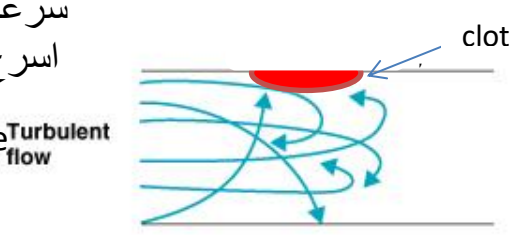
-Laminar flow is parabolic, highest velocity in center (least resistance), lowest velocity adjacent to vessel walls Due to friction(Resistance) to vessel wall equal approximately zero

-حركة الدم بتكون ع شكل طبقات الطبقة القريبة من الجدار اقل سرعة وكل ما تحركنا من الجدار للوسط بتزيد السرعة لحتى تكون اسرع ما يكون بالوسط تماماً



Quiet sound

-Turbulent flow is disoriented, no longer Parabolic due to clot that change the smooth regular surface of vessel , kinetic energy wasted ,thus more pressure required (more work on heart) to drive blood flow



Noisy sound

-وبنتج عنه صوت مسموع عكس laminar و هالمبدأ بنستخدمه لما نيجي نقيس الضغط

-A big example on it is the measurement of blood pressure :

To measure blood pressure, the cuff is placed around the bare and stretched out upper arm, and inflated until no blood can flow through the brachial artery. Then the air is slowly let out of the cuff.

As soon as the air pressure in the cuff falls below the systolic blood pressure in the brachial artery, blood will start to flow through the arm once again. This creates a pounding sound (turbulent flow) when the arteries close again and the walls of the vessels hit each other after a heart beat. The sound can be heard by placing the stethoscope close to the elbow. Right when you start to hear this pounding for the first time you can read your systolic blood pressure off the pressure meter.

The pounding sound stops when the air pressure(laminar flow) in the cuff falls below the diastolic blood pressure in the brachial artery. Then the blood vessels remain open. Right when the pounding stops, you can read the diastolic blood pressure off the pressure meter.

سوالف كلنا بنعرفها

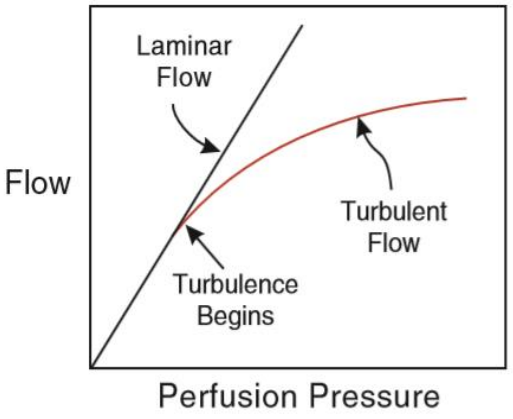
-another example is stenosis in valves lead to turbulent → will hear noisy irregular sounds

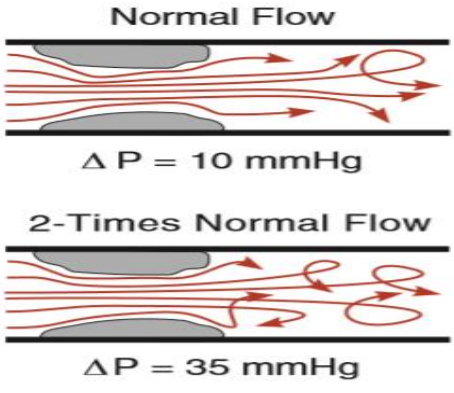
-we have factors that determine turbulence

FACTORS PREDICTING TURBULENCE

* DENSITY ~ ρ
* VISCOSITY ~ η
  e.g. $\eta_{HONEY} > \eta_{WATER}$
* VELOCITY ~ v
* DIAMETER ~ d
* REYNOLDS NUMBER ~ Re

$$Re = \frac{\rho d v}{\eta}$$





Directly proportional to the:

– density of blood (ρ, i.e. rho) **– diameter of the vessel (d) in cm**

– velocity of blood flow (V) in cm/sec; and is

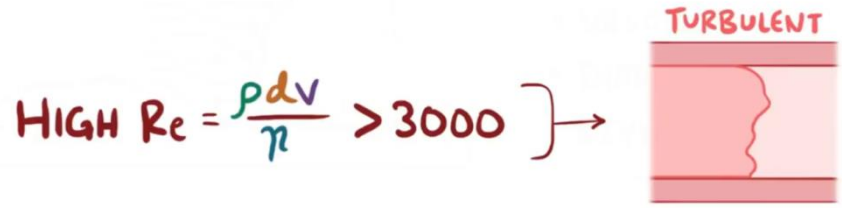
Indirectly proportional to:

– viscosity of the blood (η, i.e. eta).

-if Reynold number :

1

2



3 between 2000-3000 there is increasing likelihood that blood flow will be turbulent

Q:what happen in anemia ? does it lead to turbulent or laminar flow?

A(from osmosis) :in anemia

1- **there is low hematocrit → low viscosity 'η'→increase Re**
2- **often they have increase in Cardiac Output → increase blood velocity 'V' → increase Re**

→TURBLENT FLOW

Series And Parallel Resistance

-it is important to note that poiseuille's equation (relationship bet. Q with radius,Length,pressure and viscosity) → → →

Q	Flow rate
P	Pressure
r	Radius
η	Fluid viscosity
l	Length of tubing

Is applied on single vessel not for entire circulation

For example : if we say an arteriole in kidney has vasoconstriction

To half then resistance will increase 16 folds but the overall

$$Q = \frac{\pi \Pr^4}{8\eta l}$$

Renal Resistance change would be very very negligible because there

Are many other resistance vessels didn't change in resistance

What is Series arrangment of R ?

-it applies on blood vessel arrangment within organ

-look at the figure down,we see in series R that total R is the **the sum of the individual resistances (R artery+R arteriole + …)and all within an organ**

-so if we take an orgn we see first arteries going into it then bifurcate to arterioles then capillaries(capillaries are parallel) but in total there is a series for these vessels

-Total flow is the same at each level, but pressure decreases progressively due to increase resistance(friction)

-النقصان في الضغط مهم جدا لضمان الحفاظ على نفس الblood flow عبرseries

لانه بؤدي لحدوث فرق بالضغط بين البداية والنهاية وبالتالي $P\Delta$ ثابته

-so reduction in pressure is compensated increasing in R in order to keep blood flow the same in all levels

-total R is larger than any Rn

SERIES RESISTANCES

$$R_{total} = R_1 + R_2 + R_3 + R_4 + R_5$$

-we have branches from aorta that supply all organs in the body and these arteries branched from aorta are in parallel arrangment and in parallel arrangment the total Resistance is reciporcal for individual R

As shown down in the figure

-total R is smaller than the smallest Rn

***every circulation arrangment of R is Parallel except portal system Is series**

-Benefits of parallel arrangment:

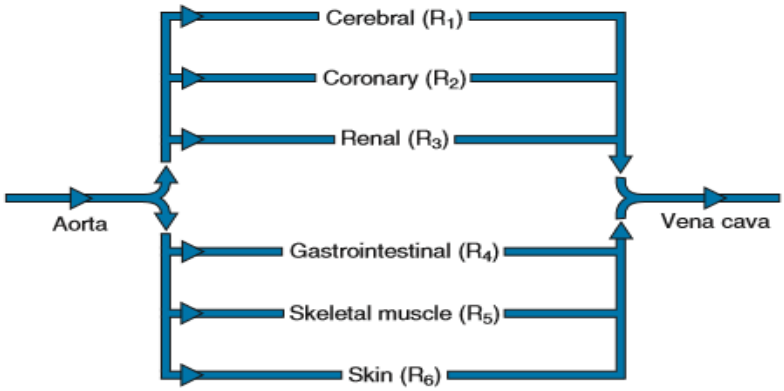
1 -total R decrease :total R is smaller than the smallest Rn

2-NO lost of pressure for branched artieries from aorta:same P for all

3-if there is adjusment in any branch it will not affect the other branches.UNLIKE the series arrangment that will affect the rest

4-any addition to any R.the total R will decrease rather than increase which is very gd

$$\frac{1}{R_{total}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4} + \frac{1}{R_5} + \frac{1}{R_6}$$



- **Flow to each organ is a fraction of the total blood flow**