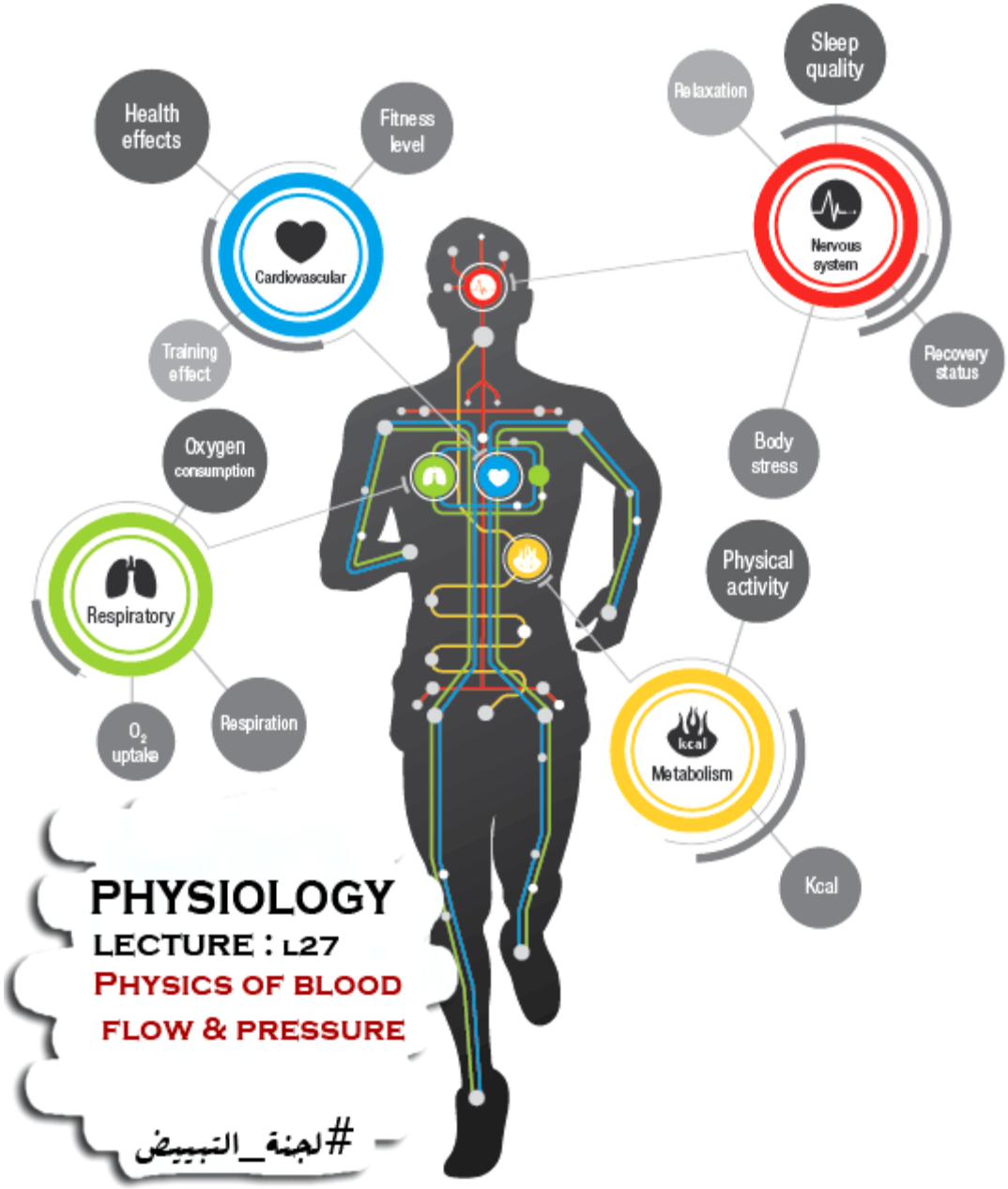


- **Sunday – 7/4/2019**
- **Cardiovascular system**

- إعداد : يوسف الطراونة ، صلاح سائد ، منذر القطاونة ، فراس أحمد .
لجنة _ التبييض

PHYSICS OF BLOOD FLOW & PRESSURE :

- All **blood vessels** are lined with a *thin* layer of endothelium, a type of epithelium which is supported by a basement membrane :
  - Called the *tunica intima* (or *tunica interna*) .
  - Only layer of capillary walls .

- The walls of most **arteries** and **veins** have layers of smooth muscle and/or elastic connective tissue called the *tunica media* and fibrous connective tissue called the *tunica externa*, surrounding the endothelium .

-The thickness of the *tunica media and externa***vary indifferent** vessels depending on their function or the amount of internal (blood) pressure that they encounter .

- The *Tunica Media* for **arteries** contains elastic fibers and smooth muscle fibers .
- **Capillaries**doesn't have a *Tunica Media*.
- **Viens** have a *Tunica Media* but thinner than the **arteries** .

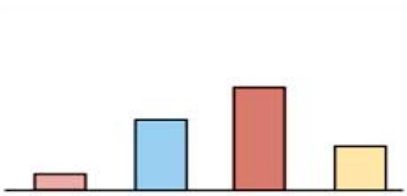
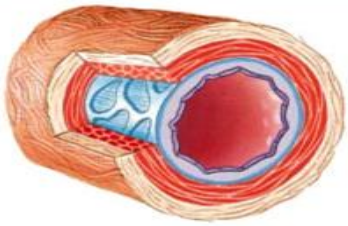
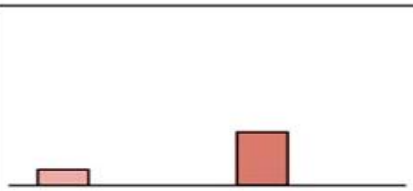
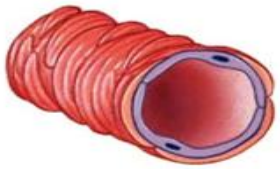
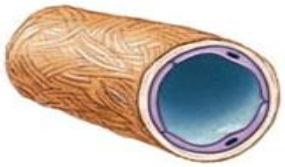
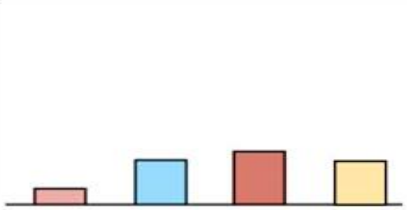
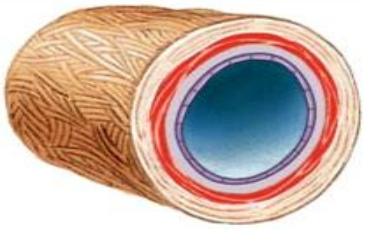
- Most blood vessels contain vascular smooth muscle arranged in **circular** layers which is partially contracted at all times creating a condition known as **muscle tone** .

- Additional contraction of the smooth muscle results in **vasoconstriction** which narrows the diameter of the vessel lumen .
  - Most of the vasoconstriction is controlled by **arteries** due to their *Tunica Media*contents it makes the **resistance** in blood vessels because their *tunica media*contains a higher amount of smooth muscle cells .

- Relaxation of the smooth muscle results in **vasodilation** which widens the diameter of the vessel lumen .

- **Neurotransmitters**, hormones and paracrine signals influence vascular smooth **muscle tone** which in turn will affect blood pressure and blood flow throughout the cardiovascular system .

- The *Tunica Media* for arteries contains elastic fibers and smooth muscle fibers.

	Mean diameter	Mean wall thickness	Endothelium / Elastic tissue / Smooth muscle / Fibrous tissue	
Artery	4.0 mm	1.0 mm		
Arteriole	30.0 µm	6.0 µm		
Capillary	8.0 µm	0.5 µm		
Venule	20.0 µm	1.0 µm		
Vein	5.0 mm	0.5 mm		

Ohm's Law:

$$F = \frac{\Delta P}{R}$$

Where :

F(CO) = Blood flow .

ΔP = Pressure difference (P_1-P_2).

R = Resistance .

Poiseuille's Law:

$$F = \frac{\pi \Delta P r^4}{8\,\eta l}$$

Where :

F = Blood flow .

ΔP = Pressure difference (P_1-P_2).

r = Radius .

η = **Viscosity** .

l = Length of vessel .

BLOOD RESESTANCE :

- In a normal human, **length** of the system is fixed (so we *ignore* it), so blood **viscosity** and **radius** of the blood vessels have the largest effects on **resistance** .

Ohm's Law & Poiseuille's Law :

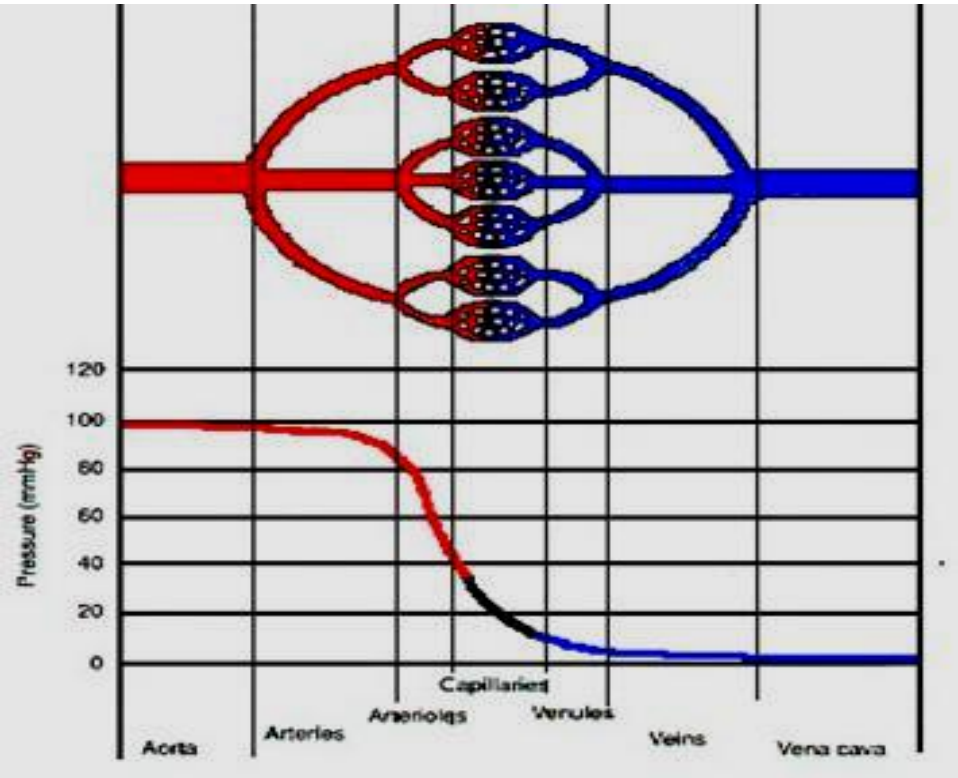
$$F = \frac{\Delta P}{R} \quad \& \quad F = \frac{\pi \Delta P r^4}{8\,\eta l} :$$

$$\frac{\Delta P}{R} = \frac{\pi \Delta P r^4}{8\,\eta l} \longrightarrow R = \frac{8\,\eta l}{\pi r^4}$$

1. **Total peripheral resistance (TPR) and blood pressure :**

- We Know that if the **resistance***increases* ,the pressure will *increase* so, the blood vessels with the highest pressure will have the greatest resistance.

- An example is the **aorta** it has the highest pressure so it will have the **greatest resistance**,another example is the **vena cava** it has the lowest pressure so it will have the lowest resistance .



2. "Conductance" of blood in a vessel and Its relation to resistance :

- **Conductance** =**Compliance** : which is the change of volume in a blood vessel divided on the change of pressure in that blood vessel so, when more blood volume is found in a vessel we say it's highly distensible so this will *increase* the conductance or the compliance of the blood vessel Compliance in **veins** is much higher than **arteries**; because **arteries** have a greater resistance due to their High smooth muscle cell content. also**veins** have a wider Lumen compared to **arteries** which in turn *increases* the vascular compliance in the **veins**.

- **Conductance** (C_L) is a measure of the blood flow through a vessel for a given pressure difference .

$$C = \frac{\Delta V}{\Delta P}$$ Where :ΔV = Change of volume &ΔP = Change of pressure .

- This is generally expressed in terms of milliliters per second per millimeter of mercury pressure, but it can also be expressed in terms of liters per second per millimeter of mercury or in any other units of blood flow and pressure.

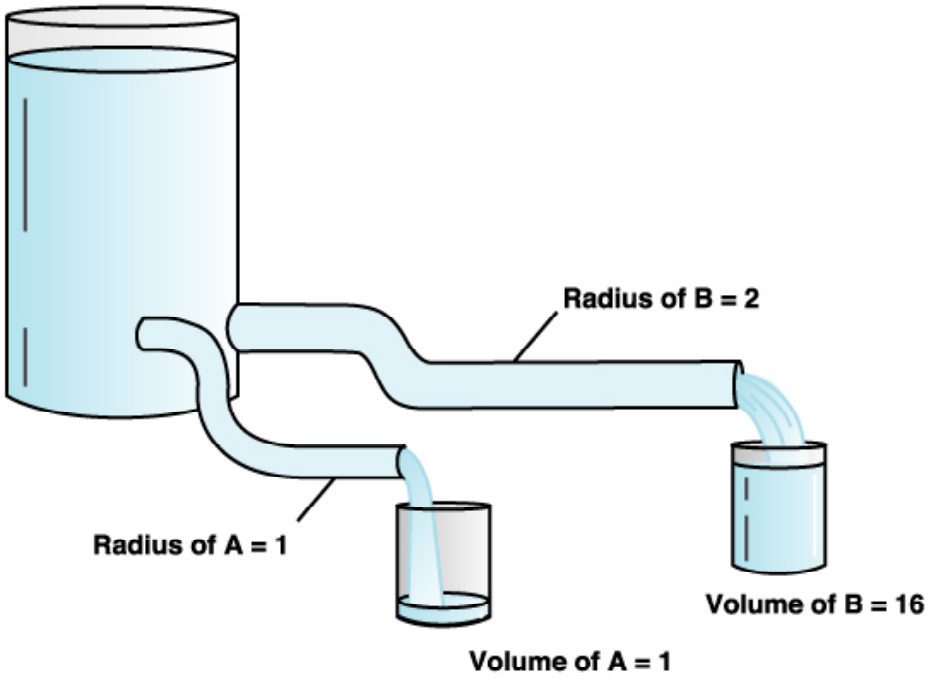
- It is evident that conductance is the exact reciprocal of resistance in accord with the following equation:

$$\boldsymbol{Conductance = 1/Resistance}$$

- The vascular **compliance** is proportional to the vascular distensibility and vascular volume of any given segment of the circulation. The **compliance** of a systemic **vein** is **24** times that of its corresponding **artery** because it is about **8** times as distensible and it has a volume about 3 times as great.

3. Effect of radius on resistance and blood flow :

- **Viscosity** is higher in blood due to its protein contents .
- **Protein** is an osmotically active molecule so, if we raised its *concentration* the osmolarity will *increase* and the **viscosity** will *increase* too *
- If we have **water** in our bodies instead of **blood** the pressure will be lower **.**



Resistance ~ $\frac{1}{\text{radius}^4}$	
Tube A	Tube B
R ~ $\frac{1}{1^4}$	R ~ $\frac{1}{2^4}$
R ~ 1	R ~ $\frac{1}{16}$

Flow ~ $\frac{1}{\text{resistance}}$	
Tube A	Tube B
Flow ~ $\frac{1}{1}$	Flow ~ $\frac{1}{\frac{1}{16}}$
Flow ~ 1	Flow ~ 16

- imagine that we have to tubes (A,B)

Radius of Tube A = 1 mmRadius of Tube B = 2 mm

By applying the equation of the resistance :

the Resistance of (tube A = 1),(tube B = 1/16)

By applying the equation of the flow:

tube A will have lower flowof blood than Tube B

so ,any few increase in the radius will cause a big difference in the resistance and in the flow of blood

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4. Effect of Viscosity on resistance and blood flow :

- The viscosity of normal blood is about three times as great as the viscosity of water .

$R = \frac{8\,\eta l}{\pi r^4}$ → - Increasing viscosity increase the resistance & thus decrease the rate of blood flow .

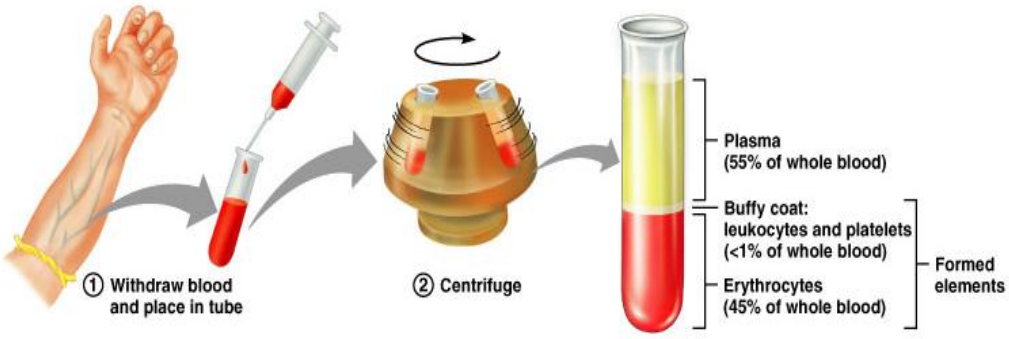
In which case the blood is more viscous polycythemia or anemia ?

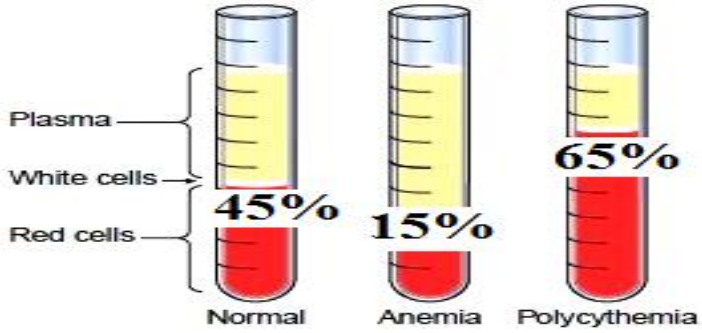
The viscosity in polycythemia is higher

because,the number of red blood cells or hematocrit is higher & the plasma volume is lower ----> so this will increase the viscosity of blood to a high degree .

*but if the plasma volume gets higher or the number if **RBCs** gets lower (lower hematocrit) .. (anemia) →the viscosity of blood will be lower because the percentage of water in plasma is almost 90% and it will decrease the viscosity of the blood .

- Viscosity of blood increase as hematocrit and osmolarity increase :





- **Hematocrit** or packed cell volume (PCV) is a routine examination which we take a blood sample from a person then we put it into a centrifuge so after centrifugation the blood *will be separated* into plasma and cells .

-This test is used to compare the percentage of volume for the **RBC's** compared to the percentage of volume for the plasma.

- So, in normal conditions the (PCV) for blood will be **45%** .

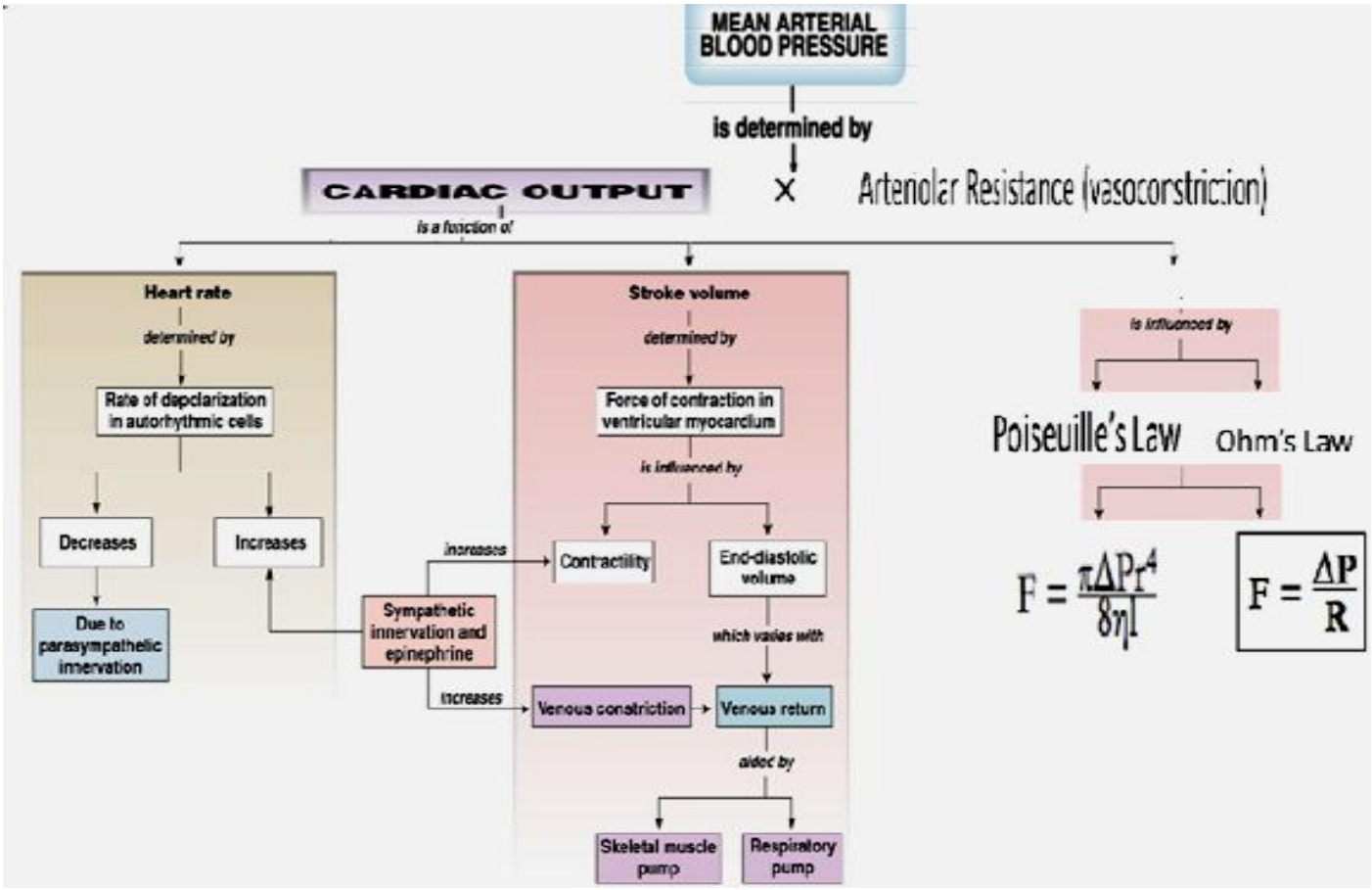
- If the percentage is lower this would indicate a *decreased* amount of **RBC's** like in **anemia** .

- Is that percentage is **higher** this would indicate an increased amount of **RBC's** like in **polycythemia**.

-1ry **polycythemia** is normally in persons who live at high altitudes due to increased blood reduction in the oxygen levels in the body.

* 2ry**polycythemia** is a disease which is caused due to a problem in the kidneys or in the respiratory system.

Summary of blood pressure and flow regulation :



Important question:

2 persons are in the resting state

-The first one's heart rate = 40-60 bpm

-The second one's heart rate = 60 -100 bpm

Identify the athletic person and the sedentary person between them? why?

→ The first one is an athletic person (lower heart rate)

The second one is sedentary person (higher heart rate)

Because, athlete's resting heart rate may be considered low when compared to the general population. Because prolonged exercise:

1- strengthens the heart muscle

2- The myocardium isthicker .
This allows it to pump a greater amount of blood with each heartbeat

3- Increase force of contraction→ the stroke volume increase → turn will increase the cardiac output of the person so the athlete will not need a high heart rate to give the high cardiac output that he has already so at rest the athletic person will have the lower heart rate than the sedentary .