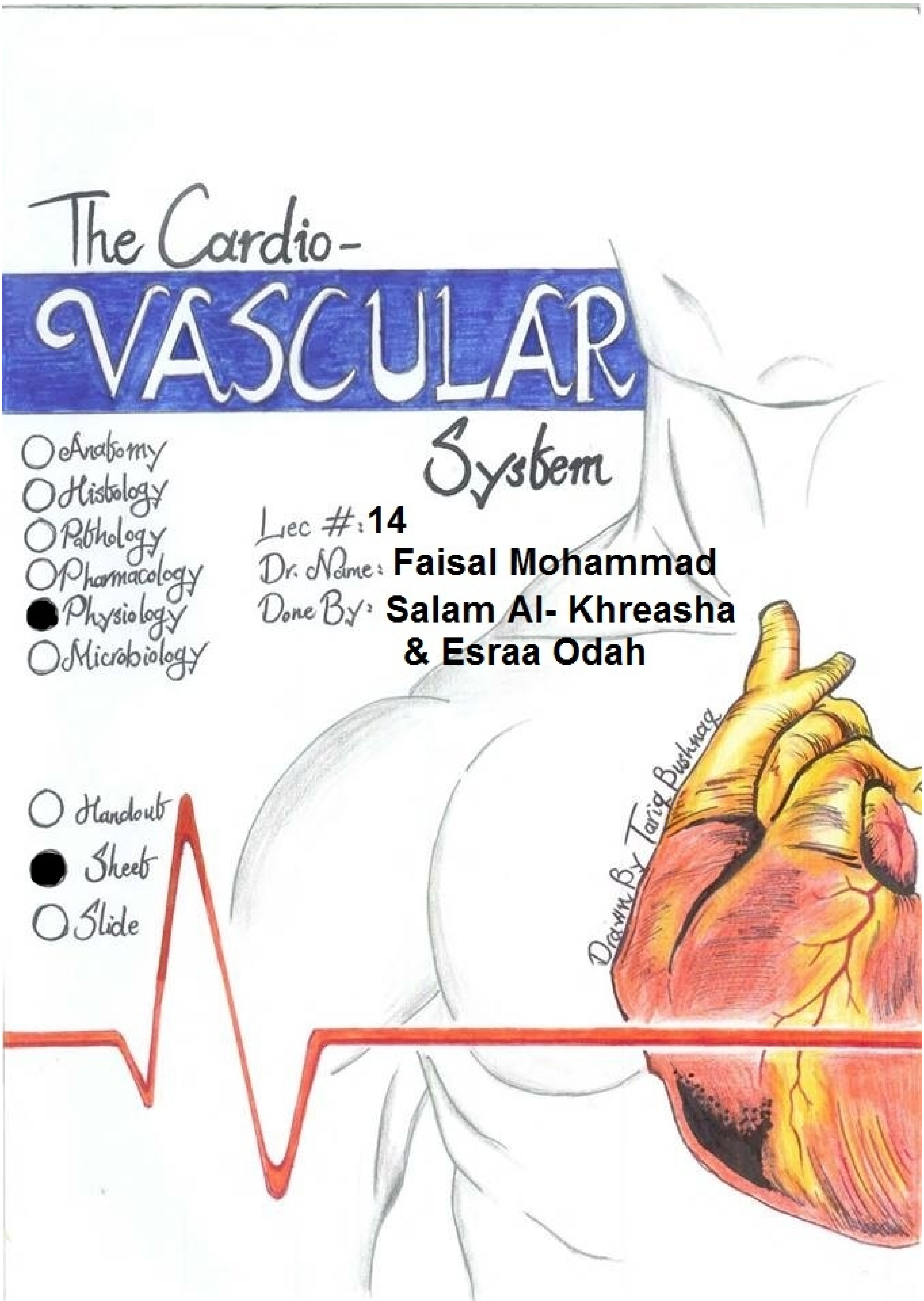
The Cardio-
VASCULAR
System
Anatomy
Histology
Pathology
Pharmacology
Physiology
Microbiology
Lec #: 14
Dr. Name: Faisal Mohammad
Done By: Salam Al- Khreasha
& Esraa Odah
Handout
Sheet
Slide
Drawn By Tariq Bushnaq

The Cardio-VASCULAR System

- ○ Anatomy
- ○ Histology
- ○ Pathology
- ○ Pharmacology
- ● Physiology
- ○ Microbiology

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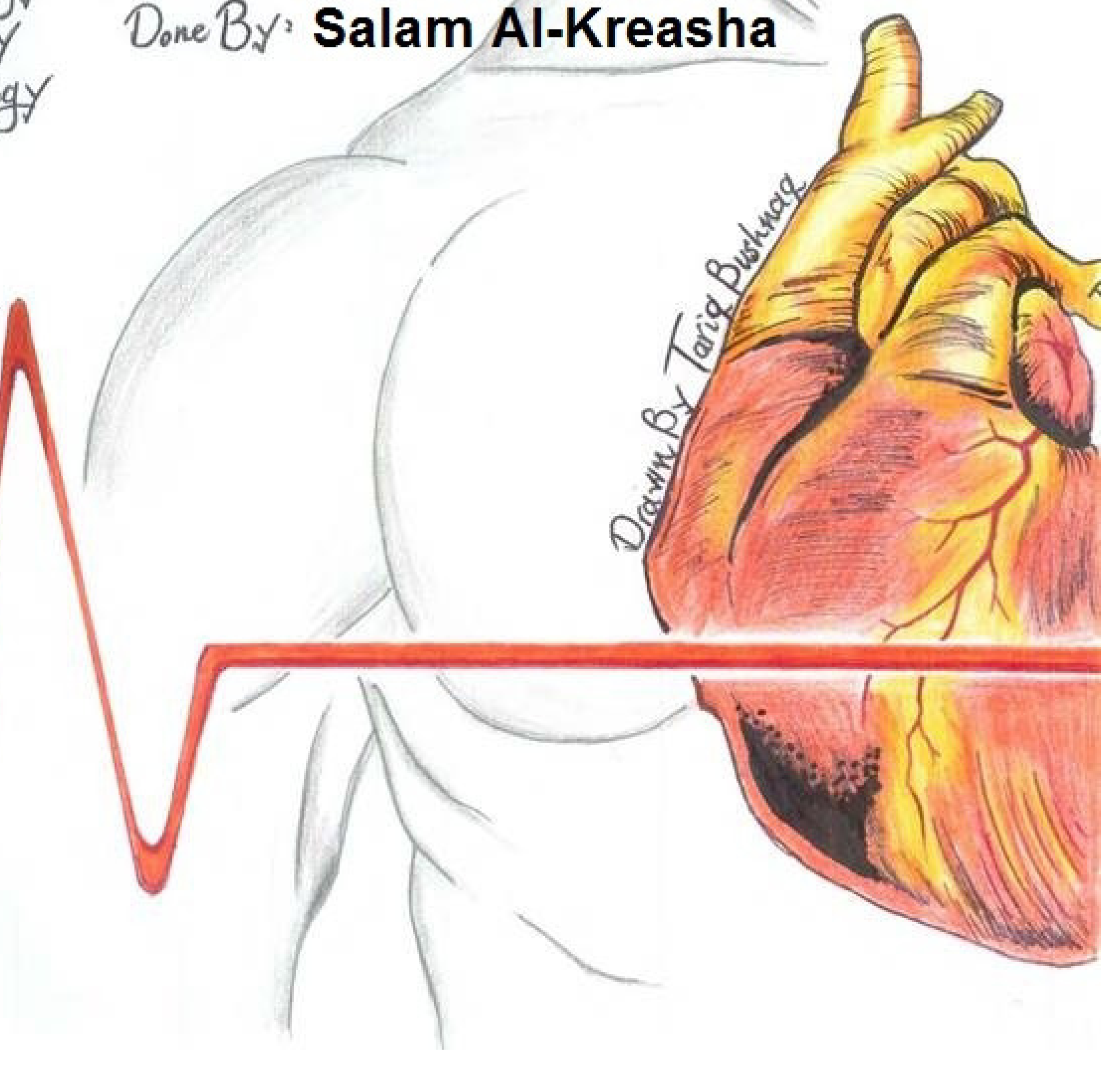


Hemodynamic CVS

This sheet was written according to sec1-

The objectives that we will talk about :

point out the physical characteristics of the circulation:

distribution of blood volume

total cross sectional area

velocity

blood pressure

List the determinants of blood flow

Define and calculate blood flow, resistance ,and pressure.

Define and calculate conductance.

Apply Poiseulle's law.

Hemodynamic : physical characteristics of the circulation (blood volume, cross sectional area ,velocity , blood pressure) we will talk about each one of them and its effect on blood flow , through this lecture .

First we have two type of circulation on our bodies:

1- **Systemic circulation**

2- **Pulmonary circulation (special circulation that we will talk about later in this system (**

Systemic circulation

BLOOD FLOW THROUGH BODY TISSUES IS INVOLVED IN:

Delivery of O2 and removal of CO2 from tissue cells.

Gas exchange in lungs.

Absorption of nutrients from GIT.

Urine formation in kidneys) very high blood flow (

So how the blood move from the heart to these tissue and do it's job ?

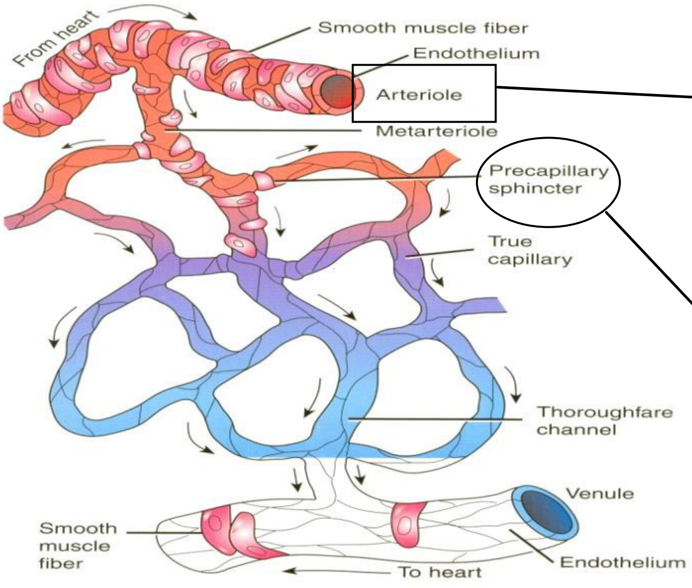
By vessels which has a lot of types in our bodies .

When we start from the heart :

Aorta → large artery → medium artery → small artery arteriole capillary → venule → vains → S.V.C& I.V.C →

The last type of arterial vessels that have smooth muscle cells in its wall so it can respond to vasoconstriction or vasodilatation .

It doesn't have any smooth muscle cells in its wall so there is nothing called capillary vasoconstriction or capillary vasodilatation .



(a) Details of a capillary network

The last type of arterial vessels that have smooth muscle cells in its wall so it can respond to vasoconstriction or vasodilatation .

It doesn't have any smooth muscle cells in its wall so there is nothing called capillary vasoconstriction or capillary vasodilatation.

Note from the previous lecture** :

The O_2 concentration in any arterial vessel it's the same because there is no exchange of O_2 or blood until the capillaries.

Why the exchange of gases and nutrients occur only in capillaries?

(you will know the answer when you finish another few papers)

Now

When we want to study the changes in the systemic circulation we should take each segment in the system (artery, arteriole , capillary ,venule , vein) as one unit .

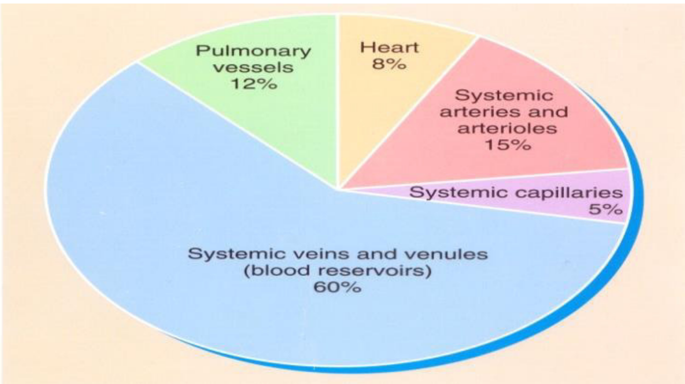
e.g. all artery in the systemic circulation consider as one unit and the blood flow in all artery should equal the cardiac output .

also the blood flow in the capillaries should be equal to the CO, and this also go with aorta, arterioles ,venules and veins.

So we need to put in our mind that the blood flow in each systemic type of vessels equal to the cardiac output .

So we need to put in our mind that the blood flow in each systemic type of vessels equal to the cardiac output .

Blood Volume Distribution



As you see in this picture:

-This picture shows the changes in blood volume in the circulation well see changes in thw pressure below-

3/2-of our blood volume is in the Veins- they are also known as" capacitant vessels , - "so mainly the mean systemic filling pressure affected by any change in the veins, if the volume in the vein increase the pressure (mean systemic filling pressure) will increase .

-Also ,venoconstriction or venodilatation will affect the mean systemic filling pressure more than vasoconstriction or vasodilatation because the veins have 2/3(60%) of our blood in comparison with arteries which have only 15% of our blood volume.

Read these slides :

The Circulatory System is Composed of the Systemic and Cardiopulmonary Circulation .

Systemic Circulation

Serves all tissues except the lungs

Contains 84% of blood volume,Also called **the *peripheral circulation***

Pulmonary Circulation

Serves the lungs

Lungs contain 9% of blood volume and heart 7%

Blood Reservoir Function of Veins

-60% of blood is in veins

-Under various physiological conditions, blood is transferred from the veins into arterial system to maintain arterial pressure.

So if we want to increase the cardiac output we should increase the venous return ,and by that the mean arterial pressure will increase .

**Now , how the venous return will increase ??

The venous return will increase if more blood runs from the veins to arteries .

-The spleen, liver, large abdominal veins, and the venous plexus also serve as reservoirs.

-Spleen also serves as a special reservoir for red blood cells(in case of hemorrhage the spleen can compensate the blood loss by constriction and release blood to the circulation)

Basic Theory of Circulatory Function

***Blood flow* to tissues is controlled in relation to tissue needs**(the blood flow to tissue its always given as minimal because we can't give the tissue all blood required once)

-*Cardiac output* is mainly controlled by local tissue flow.

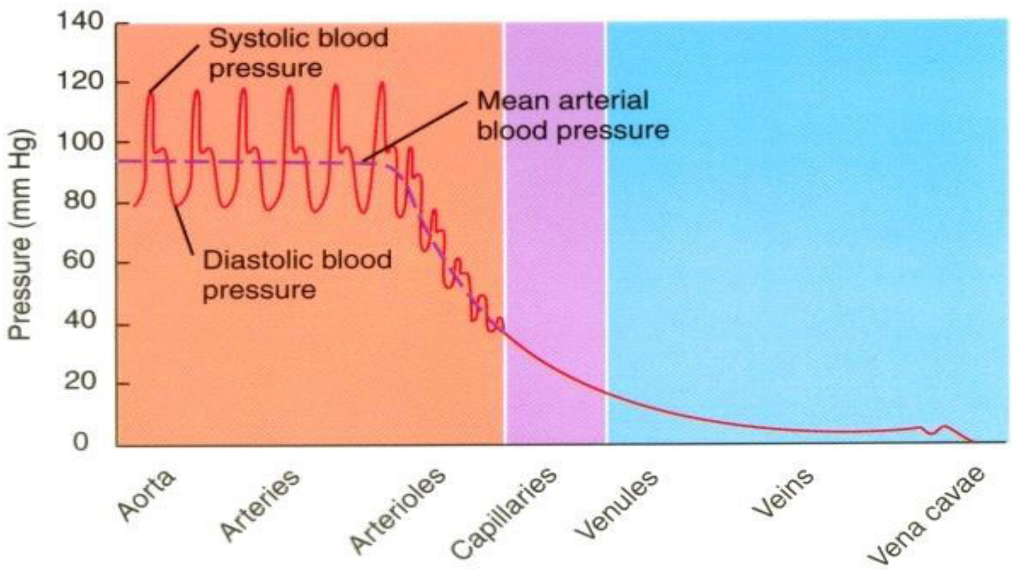
-*Arterial pressure* is controlled independent of either local blood flow control or cardiac output control.

*Mean arterial pressure = CO * R*

Let us start talking about changes and their effect on blood flow through systemic circulation :

1) **Pressure changes**
2) **Cross sectional area and velocity**

1) Pressure Changes through the circulation

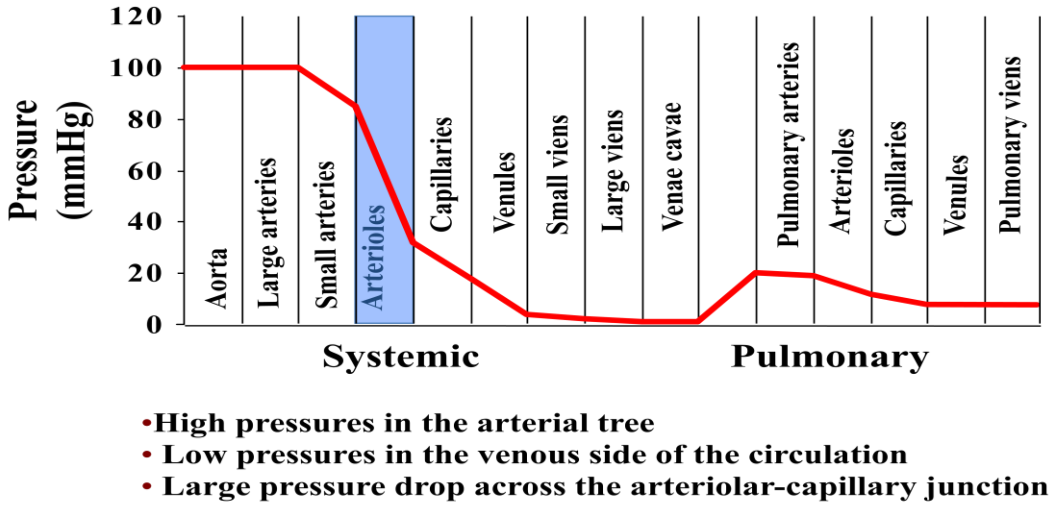


<u>**From the previous picture we can conclude that :**</u>

A. **Aorta :** the pressure in the aorta varies from 120(systolic blood pressure) to 80(diastolic blood pressure) .

B. **Arteries :** the pressure will drop slightly(small drop), the best site to measures the pulse is the arteries because the resistance is low and the blood flow is very high (the pulsation to occur should have blood flow before it ; the pulsation move through the vessel wall) .

-The pressure responsible for the blood movement is the mean arterial pressure not the systolic or the diastolic .



Mean arterial pressure = 1/3 * systolic pressure +2/3*diastolic pressure .

MAp = 1/3*120+2/3*80

MAp = 40+53.33

MAp = 93.33

MAp ~100 in the diagram above .

Note :- when we take the cardiac cycle time, sytole = 0.3 sec and diastole = 0.5 sec, thus diastolic pressure contributes more in MAP .

C. **Arterioles (resistance vessels)** : the MAP will drop from 85 to 35 the p=50 is very high so the resistance will be very high .

D. **Veins (competence vessels) :** the pressure is very low so the blood flow is very high .

Note :
As we see there is a very high pressure drop from the aorta to the vena cava , so the blood will move under the effect of pressure gradient .

2) Changes in Cross Sectional Area and Velocity:

Flow:- Rate of fluid movement which equals the cardiac output, and we know that CO is the same in any segment in systemic circulation → Then the Flow is fixed .

Flow (through a vessel)= cross sectional area (A) × velocity (V)

A is ***inversely*** proportionate to **V** on the imposition of constant F (Flow) and since the flow is constant in the circulation then A is inversely proportionate to V .

Note that :- The cross-sectional area is to the whole segment, Millions of capillaries → larger cross-sectional area than the Aorta .

	cm
Aorta	**2.5**
Small Arterioles	**20**
Arterioles	**40**
Capillaries	**2500**
Venules	**250**
Small Veins	**80**
Venae Cavae	**8**

In the aorta the cross sectional area = 2.5cm so the velocity is very high , and then it drops down till it reaches the **capillaries** with the **least velocity**

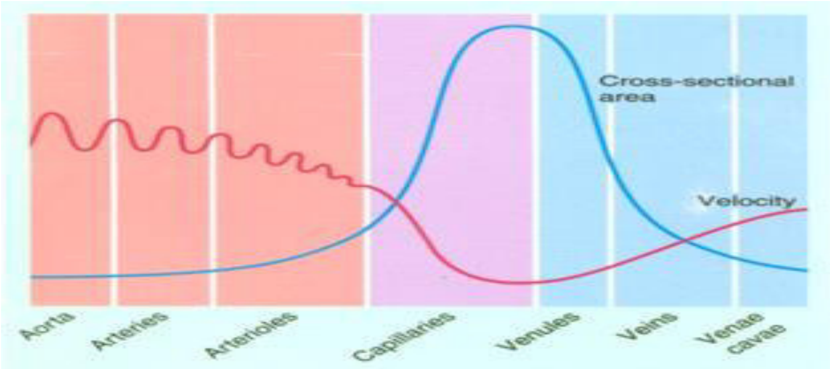
>> this is perfect for the capillaries for **two reasons** :-

1- large cross-sectional area → larger surface area (Relation between them is below) → better exchange in the capillaries .

2- large cross-sectional area → decrease in blood velocity, which gives more time to the exchange to occur .

-After the capillaries the velocity increases in the venules and then more in the veins (drop in cross sectional area with maintaining the same flow)

-but The velocity in the vena cavae is less than the aorta because we have one aorta and two vena cavae (and we take them as one unit so they have a larger Cross-sectional area) .



*the Capillaries Have the Largest Total Cross-sectional Area of the Circulation

*Velocity of Blood Flow is Greatest in the Aorta

$$\textit{Velocity} \text{ of Blood Flow} = \frac{\text{Blood Flow}}{\text{Cross sectional area}}$$

Aorta >Arterioles> Small veins >Capillaries

معلومةطايرة :

The surface area of all capillaries around 700m^2 which is very high *note surface area is different than cross sectional area

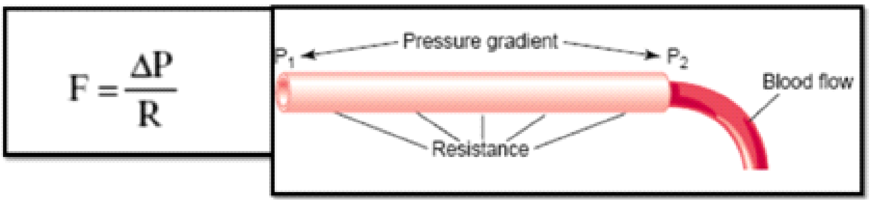
Surface area = cross sectional area * radial

Blood flow :

Again blood flow or ‘‘F‘‘ = Blood flow means simply the quantity of blood that passes a given point in the circulation in a given period of time (mL/Sec).

In the systemic circulation ,Overall flow in the circulation of an adult is 5 liters/min which is the cardiac output.

(F) = cardiac output (CO)= ΔP/R



the pressure gradient ΔP = (difference between mean arterial blood pressure and atrial pressure which is around zero) = mean systemic arterial B.P, so cardiac output means systemic arterial blood pressure over the total peripheral resistance .

1-Pressure gradient produced by heart pumping moves blood in the system from the arterial to the venous side, 5 L/min

2-Fluid pressure expands cardiac chambers and blood vessels.

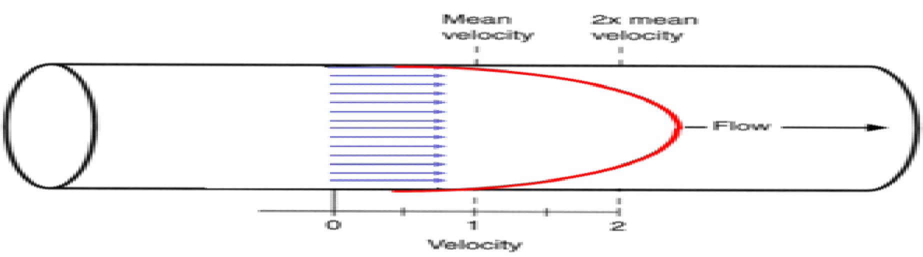
Blood flow types :

1-**laminar flow (stream line):** Blood usually flows in streamlines with each layer of blood remaining the same distance from the wall, this type of flow is called laminar flow.

(**the effective flow**)

the flow here is **parabolic**: The fluid nearest the vessel wall flows the slowest, and fluid in the center of the tube moves the most rapidly

this produces laminae (layers) with uniform speed at certain distance from the wall.



>>If the flow rate is increased then the trend for turbulence will increase.

2-**Turbulent flow**: (Eddy"دوامة "current)the blood flow goes everywhere, **not an effective flow** .

مثل دوامة المويه بس تسوي لويه :P

<u>When the flow becomes Turbulent, there is an equation concerning it:</u>

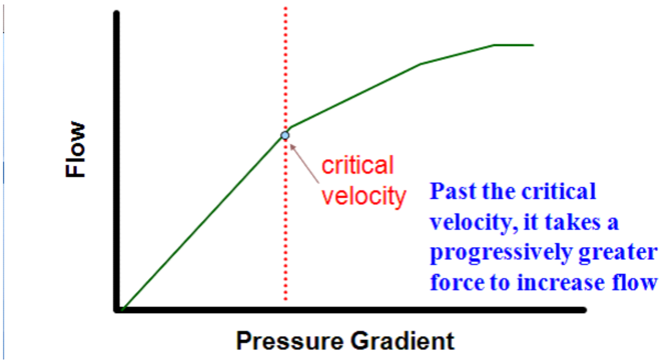
$$\text{Reynold's No (Re)} = \frac{v \;.\; d \;.\; \rho}{\eta}$$

v : velocity, d : diameter, ρ(rho) : density, η(eta) : viscosity of fluid.

** Keep in mind ***turbulence of blood around closed valves is what produces the sounds of Heart .***

1-if the (Re) number more than 1000 the flow is turbulent.

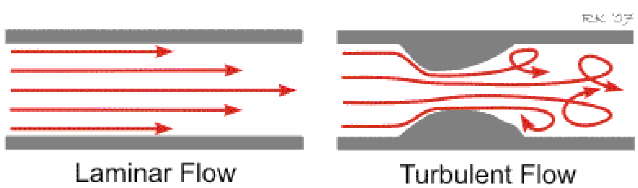
<u>*Critical velocity</u>: where the blood flow above it become turbulent and below it normal.



2- If this number is less than 400, the flow is stream line (laminar).

3-If this number is between 400 and 1000 , the flow might be laminar or turbulent → depending on the situation, What makes the flow turbulent ?

1-Constriction: look at this figure :-



2-sharp turns in circulation >>angulation of vessel like axillary artery

3-rapid velocity predispose to turbulent flow, slow flow mainly stream line(laminar)

4- from Ryenold's equation : increase in the diameter, velocity, or the density increase turbulence, while velocity decrease it .

5-rough surface in the circulation

Again turbulence flow is not affective (the blood does not flow)

And that's predispose to the formation of thrombosis that's why when you have atherosclerosis (vessel wall become atheromatous goes to the lumen so the lumen radius decreases producing constriction, the flow is becoming turbulent, this eventually form thrombus, thrombus may lead to embolus , embolus in arterial system might cause CDA, coronary myocardial infarction .

Thrombus in vein >> pulmonary embolism

- ***Laminar flow is silent, whereas turbulent flow tend to cause murmurs***

As we said above the turbulence movement of blood around the closed valves **normally** gives us the first heart sound and the second heart sound, now if there is any abnormality in the structure of the heart that will lead to produce abnormal heart sounds .

If the additional abnormal sounds popped off between S1 and S2

then it's **Systolic murmur,** whereas if it appeared between S2 and S1 then it's **Diastolic murmur** .

* Pericardial murmurs are more properly described as "**Rubs**" rather than murmurs .

1-Systolic Murmur: A murmur that occurs when the heart muscle contracts is called a systolic murmur occur between s1 and s2

Systolic murmurs can indicate: Aortic stenosis, Mitral valve prolapse or regurgitation

2-Diastolic murmur: A murmur that can be detected when the heart muscle relaxes between beats is called a diastolic murmur.

Diastolic murmurs can indicate: Mitral or tricuspid stenosis, Aortic or pulmonary regurgitation .

Bruit, or "**vascular murmur**" :- is the abnormal sound generated by turbulent flow of blood in the ***vessels*** (**Not in the heart**) due to either an area of partial obstruction; or a localized high rate of blood flow through an unobstructed artery .

Murmurs or bruits are important in diagnosing vessels stenosis, vessel , vessel shunts, and cardiac valvular lesions .

رح نوخذهم بالتفصيل بال introductory course

" ē-brū **" -: Bruit** of **Pronunciation**

" بروي " زي ما بتقرأ

Clinical significance of turbulence:

>>Normally : at the branching of vessels and at roots of aorta and pulmonary arteries

>>Pathologically:

1-Constriction of arteries by atherosclerotic plaque.

2-In severe anemia :why turbulence occur in anemia ?!

Because the Viscosity is decreased leading to an increase in velocity

3-Stenotic and incompetent cardiac valves> gives us murmur.

murmur 7l8i mn hal sheet -_-

The peripheral resistance:

It is the resistance to blood flow through a vessel caused by friction between the moving fluid and the vascular wall.

Mainly caused by **Arterioles** that's why arterioles called **major resistance vessels.**

Most of the resistance to blood flow occurs in arterioles (50%) and capillaries (25%) so it is called peripheral.

Hemodynamic laws:

The doctor reads from slids:

- Ohm's law: $F = \Delta P/R$
  - F = Flow, ΔP = Change in Pressure, R = Resistance

$$CO = \frac{MAP - Rt.AtrialP}{TPR}$$

CO = cardiac output, MAP = mean arterial pressure, TPR = total peripheral resistance. Since Rt. Atrial pressure = 0 then

$$CO = \frac{MAP}{TPR}$$

Poiseuille's law

$F = \pi \Delta P r^4 / 8\eta L$
F = flow,
ΔP = change in pressure
r = radius of the vessel
η (eta) = viscosity
L = length of the vessel
Then Resistance, $R = 8\eta L / \pi r^4$

If we want to know what's the effect of certain variable we fix all the variables and change one that we want to see it's effect.

1- pressure:
first we changed the pressure gradient (ΔP): we found that the flow (F) is **directly proportional** to the pressure gradient (ΔP)
increase in gradient>>increase in flow, decrease in gradient >> decrease in flow.

2-length of vessel:
we changed the length of the tube: we found that the length is **inversely proportional** to the
flow.

increase in the length>>decrease in flow, decrease in length>>increase in flow.

but in our circulation we can't change the length of the tube(it is the **least changeable factor), except in few cases , such as: growing child So this means it's the least important one to change.

3 - viscosity:
we changed the viscosity: we found that the flow is inversely proportional to viscosity
Increase in viscosity>>decrease in flow, decrease in viscosity>> increase in flow.

-Remember **severe anemia** above :-)

4-radius :
We changed the radius : we found that the flow is **directly proportional to the 4th power of radius.**

If we had a vessel with 1 mm diameter>> here the flow is going to be 1ml/min, but if you double the diameter to 2mm>> the flow is going to increase to 16ml/min and so on :

Diameter	Flow
mm1	ml/min1
mm2	ml/min16
mm3	ml/min81
mm4	ml/min256

⇒ So the increase in flow is proportional to the fourth power of radius (r4)

While decrease it to ½ mm will give you 1/16 ml/min flow, 1/3mm >> 1/81…

>>Then the Flow is proportional to ΔPr4/L (all variables that we discussed above)

To convert this relation to equation we need constant which = π/8

>>F= constant *ΔPr4/ηL

Poiseuille's law>> $$F = \frac{\pi \Delta P r^4}{8 \eta L}$$

Then Hagen derived the same law mathematically

F = flow, P = change in pressure, r = radius of the vesselΔ

eta) = viscosity L=length of the vessel)η

F= P/FΔP/R >> R=Δ

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

-Resistance is mainly affected by radius (r4); double the radius will decrease the resistance too much and decrease the radius for half its value will increase the resistance.

-blood flow to the tissue: we **don't change the pressure** (it **should remain constant**), but when we want to increase or decrease the flow to the tissues, we are causing vasoconstriction or vasodilation.

Vasoconstriction= increase the resistance and decreases the flow.

Vasodilation= increase the diameter decrease the resistance and increase the flow.

هسا إذا وصلتوا لهون و فقدتوا البوصلة ومش فاهمين الدكتور شو بدو بالظبط بعد كل هالحكي، اللي فوق شرح الدكتور ***مجبورين نكتبوا***

بدي أحاول اشرح الفكرة المهمة **البسيطة جدا** وأحاول اوصللكم الفكرة :-

هسا حسب القانون "التدفق" في الدم بيتأثر ***بأربع شغلات*** اللي مذكورين فوق

هسا بالوضع الطبيعي ثلاثة منهم ما بنقدر نلعب فيهم

الأشي الوحيد اللي بنقدر نلعب فيه هوا ***Radius***

Ie , diameter of the vessels

صار

Vasoconstriction → decrease in diameter→ decrease in blood flow

Vasodilation→increase in diameter → increase in blood flow .

وهدول طبعاً حسب ما متذكرين

بأثر عليهم ال metabolic rate and tissue demand

وآخر علاقة اللي بعديها حبوا يربطوا **المقاومة** ببقية العناصر بالمعادلة فالأخ Hagen طلع هالعلاقة ووضح تأثر ثلاثة من المتغيرات الأربع على المتغير الرابع وهوا المقاومة وبعيد مرة ثانية المتغير اللي عنجد بتغير هوا Diameter والباقي بالوضع الطبيعي ثابت .

** **But keep in mind** that **diameter** is **directly proportionate** to

to the blood flow, whereas **Cross-sectional area** is **inversely proportionate** (Don't mix them) :-) .

Parallel and Serial Resistance Sites in the Circulation:

When vessel resistance is **<u>in series</u>**; the **total resistance is higher than the highest of them.**

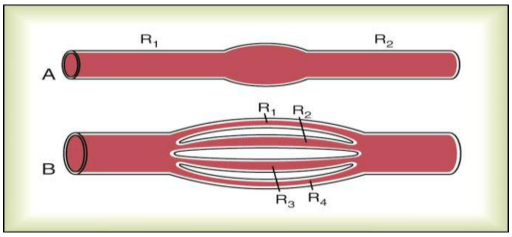
$$R_{total} = R_1 + R_2 + R_3 + R_4 \ldots$$

And when vessels are **parallel**; the **resistance is lower than the lowest of them.**

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

Serial resistance →

Parallel resistance →



-The resistance is affected by the radius, and is affected by the viscosity

What are the factors that changes the viscosity??

1-hematocrit: the number of RBC.

2-Plasma proteins.

3-diameter of the blood vessel

4-temperature

1 + 2 are considered the **<u>main</u>** determinants of **blood viscosity .**

The end

We dedicate this sheet to each other

And to our awesome friend **Ghiada khresat ♥**

and to the great patch "**Doctor 2013**"

ناس **احسن**

Corrected By :- **F** u **A** d **Z** a **Y** e **D**