PASSION ACADEMIC TEAM

YU - MEDICINE

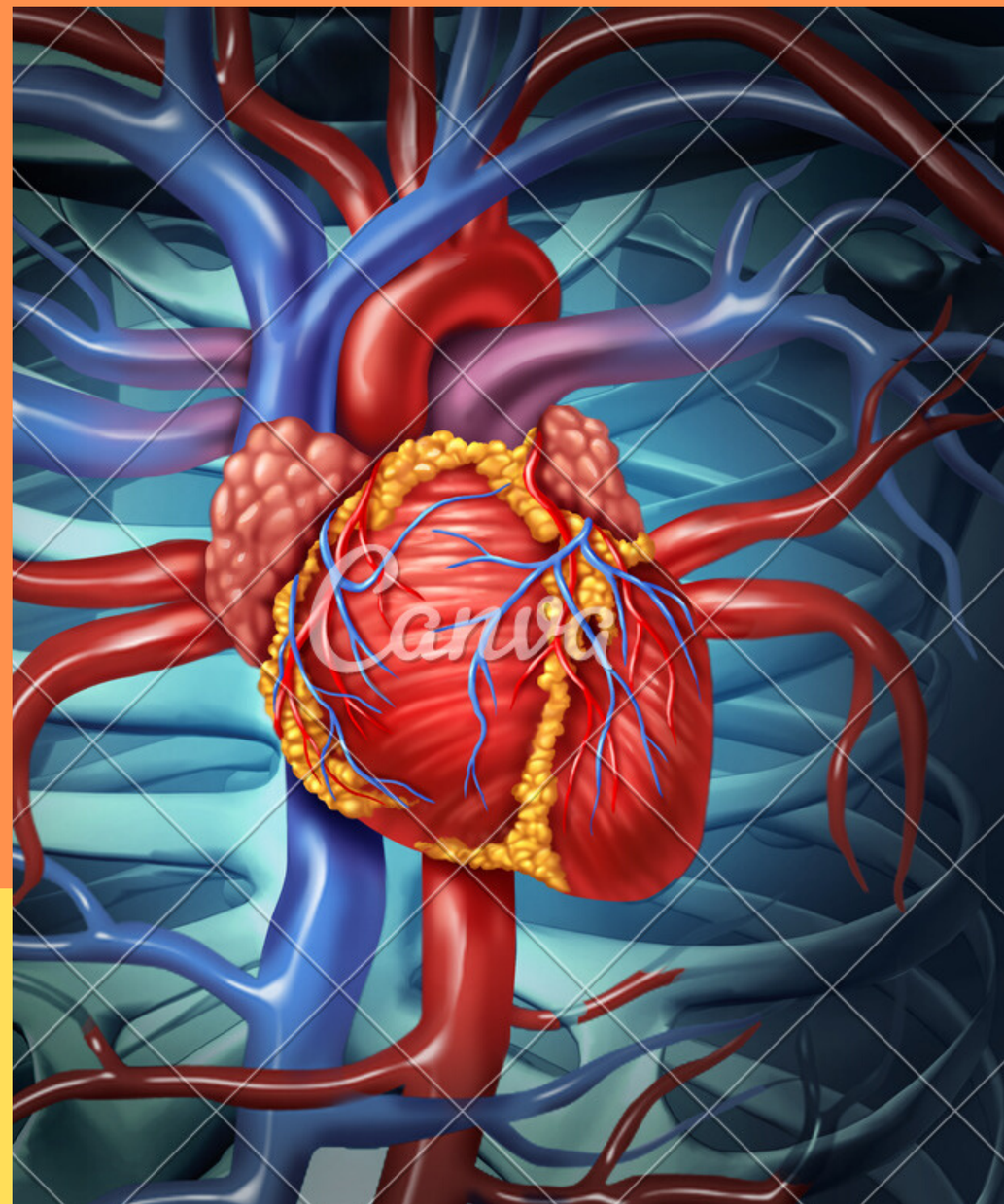
Cardiovascular System

Sheet# 9

Lec. Date :

Lec. Title : Hemodynamics II

Written By : Assem A Khatatbeh & Amira Otoum



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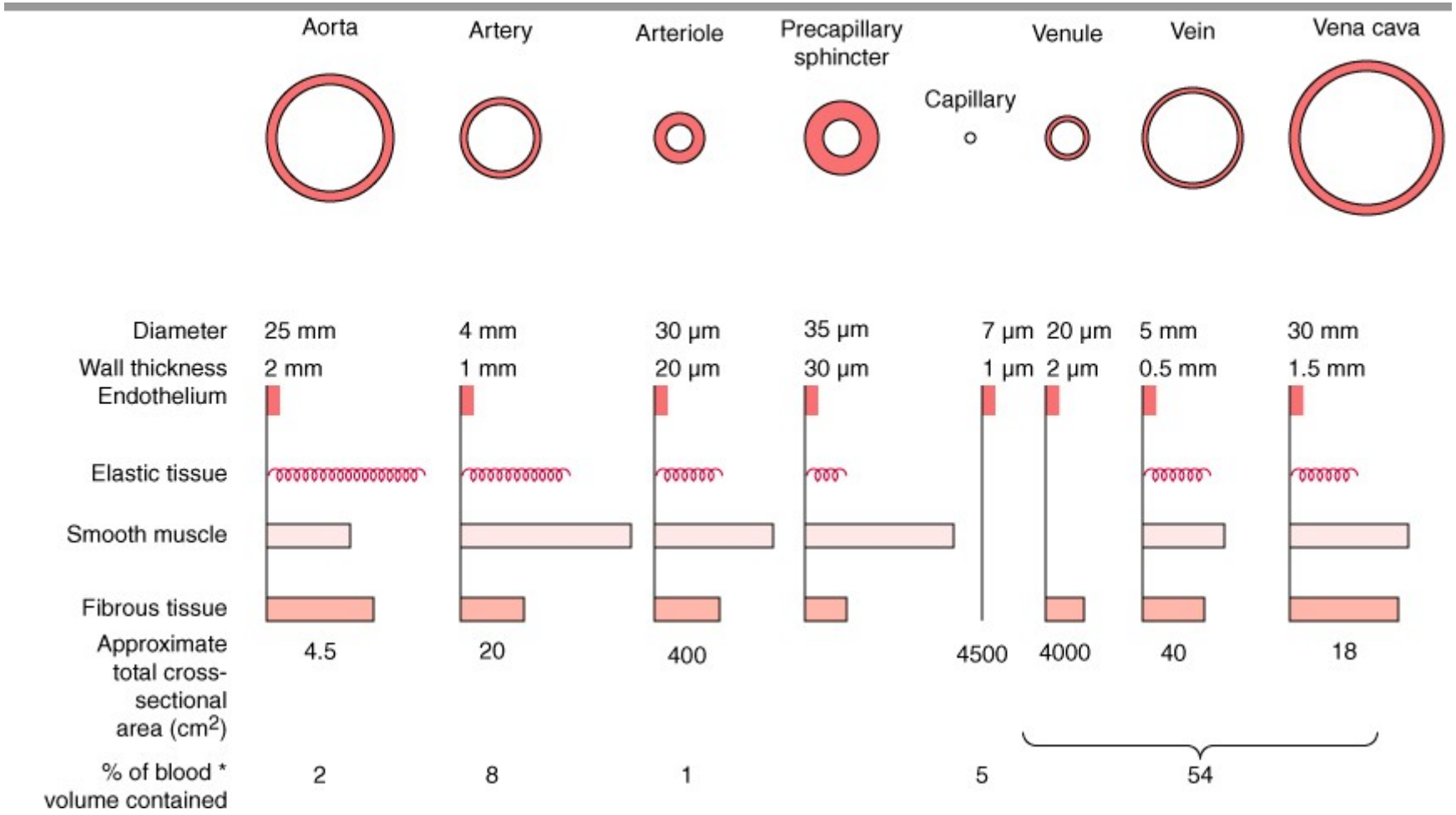
HEMODYNAMICS (PRESSURE, FLOW, AND RESISTANCE)

Types and Characteristics of Blood Vessels



Types and characteristics of a blood vessels:

[] blood vessels are route through which blood is carried from the heart to tissues and from tissues back to the heart.

[] ينتقل الدم الغني بالاكسجين عن طريق الشريان الى الانسجه والدم منزوع الاكسجين من الانسجه الى القلب عن طريق الأورده

[] الاوعيه الدمويه تمتاز بخصائص معينه تميزها عن الاوعيه الدمويه الاخرى و هذه الخاصيه تجعل الوعاء الدموي ذا قدره على اداء وظيفه معينه لا يستطيع الوعاء الدموي الاخر القيام بها.

[] diameter of the blood vessels declines as result of the branching and as we can see the diameter decreases from 25 mm in the Aorta to a minimum of 7 µm in the capillaries.

[] نتيجة ال branching ال Aorta رح يتحول إلى arteries , وال arteries إلى Arterioles ثم إلى capillaries, وكل ما صار branching رح يقل ال diameter.

وحسب الرسمة كان في ال aorta = 25 mm وفي ال capillaries وصل ل 7 micrometer, ولكن بعد ال capillaries بصير عندي margin of the vessels وتلتحم مع بعضها البعض, عشان هيك ال lumen برجع بزداد.

[] ال capillaries تلتحم وتعطي venules وبالتالي ما صار عندي branching, صار merging وبالتالي ال diameter قاعد بزيد من ال capillary صعودا إلى ال vena cava

[] branching will not decrease diameter only, in other way it will increase the number of vessels

[] so due to branching, the number of the blood vessels increase, so the capillary has the largest number, so the total cross-sectional area of the capillary is the highest which is 4500 cm^2

[] the vessels also change histologically → the Aorta is a predominantly elastic vessel (has more elastic tissue then muscular and elastic tissue).

[] if you look to arteries and arterioles you will see that peripheral arteries become more muscular until the arterioles muscular tissue predimate.

[] when we are moving away from aorta, we will see that muscular tissue is more and elastic tissue is less and we will see that muscular tissue is the pre-dominant in arterioles, and this muscular tissue makes arterioles have considerable resistance.

[] and to that reason we call arterioles resistance vessels.

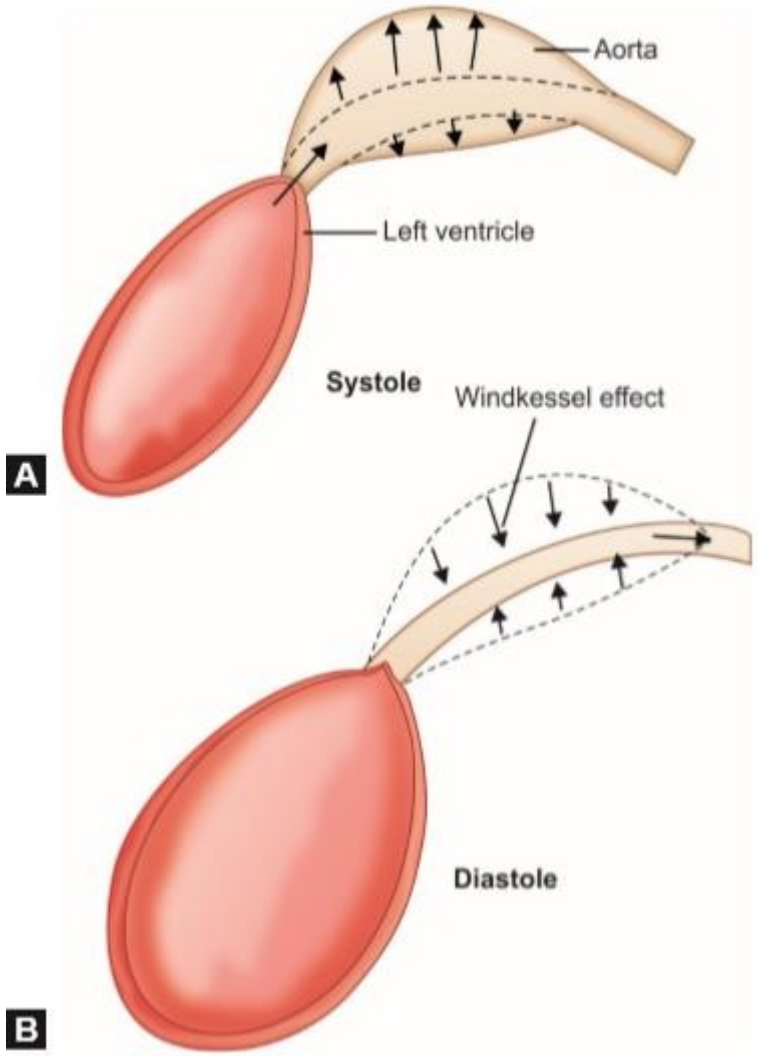
[] all blood vessels are lined by a single layer of endothelial cells (simple squamous endothelial tissue).

[] in capillaries we have only endothelial cells so that's why capillaries are thin blood vessels, so it is the place where exchange of Materials between capillaries and interstitial fluid.

[] endothelial cells collectively actually they constitute a remarkable organ, this organ release a substances that affect the diameter of a blood vessels, that also affect the growth, that also has an importance of repairing the blood vessels after injury, and also they are able to form a new blood vessels that carry blood to growing tissue.

Arteries

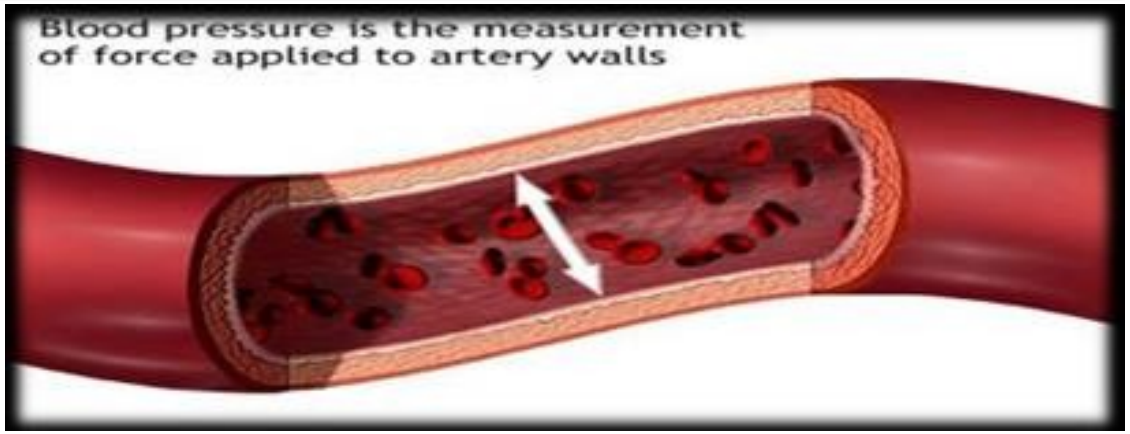
Arteries are specialized:
(1)to serve as rapid-passageways for blood
(2)to act as a pressure reservoir

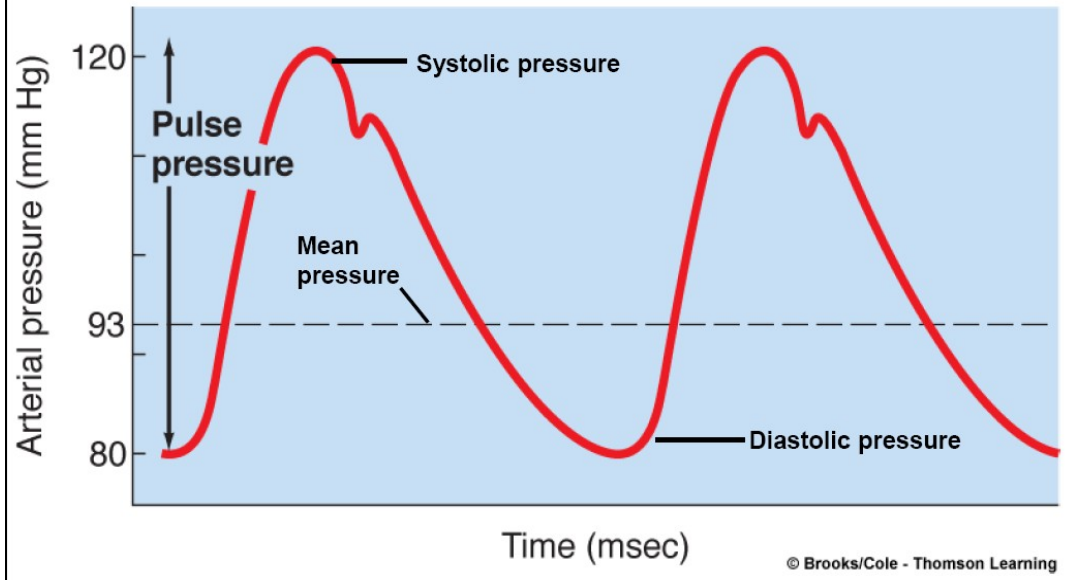


Arterial blood pressure

- Arterial blood pressure is defined as the lateral force exerted the blood on wall of arteries. depends on the volume of blood contained within the vessel and the compliance of the vessel walls.
- Arterial blood pressure is expressed in four different terms:
  1. Systolic blood pressure
  2. Diastolic blood pressure
  3. Pulse pressure
  4. Mean arterial blood pressure (MAP)

  MAP = DP + 1/3 PP.





[] arteries like aorta and large artery, they are specialized (have specific function) to serve as a :

1) rapid passage way for blood transportation from the heart to the tissue
2) And specialized to act as a reservoir, attributed to have a large radius so little resistance to blood flow serve as rapid passage way for transportation.
3) they act as a pressure reservoir and this attributed to the elasticity of the arteries and aorta.

[] if there is distension in aorta during heart contraction, during systolethis will produce energy part of this energy is released from the heart during it's contraction and it is reserved as potential energy in the wall of the Aorta so stretching will occur.

[] this stretching is a potential energy reserved in walls of Aorta.

[] during diastole the stretched elastic wall of the Alberta recoil back, so potential energy which is stored in the wall is released into the blood causes the blood to flow during diastole this effect called **Windkessel effect.**

[] this effect is produced because of elasticity in the large artery wall, and these vessels have elastic tissue more than any tissue.

[] pressure is force exerted by the blood against the vessel wall and it depends on the volume of a blood contained in the vessel and it also depends on the vessel compliance, when I have more volume I have more pressure.

[] when I have more compliance I have less pressure but if compliance is decreased for example like what happens in atherosclerosis the pressure will be high.

[] the arterial blood pressure can be reviewed by four different terms:

1) Pulse pressure: (SP – DP) – (PP)
2) Diastolic pressure
3) Systolic pressure
4) Mean arterial blood pressure: which is the average pressure driving the blood forward to the tissue during cardiac cycle which equals 93 (DP + 1/3 PP)

PP = (SP – DP) *

[] when we spoke about mechanisms that regulate blood pressure we were talking about mean arterial blood pressure.

[] systolic pressure is the maximum pressure exerted in the arteries when the blood is ejected during systole = 120
[] diastolic pressure is the maximum pressure within the arteries during heart relaxation = 80

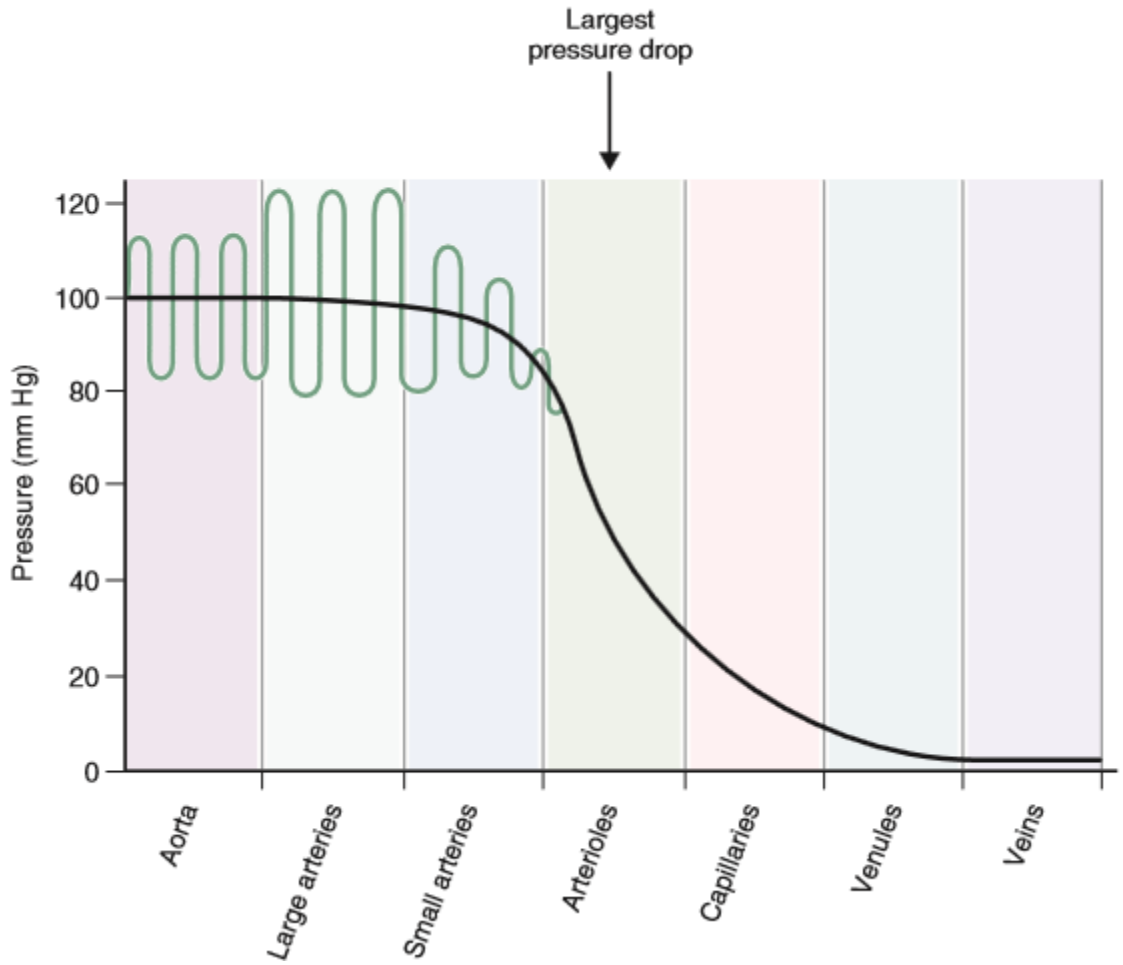
[] PP: is the difference between these two pressures, when you pulpate your artery specially artery close to the surface of the skin, when you feel it with your finger what you feel is the difference between the systolic and diastolic pressure and this is the pulse.
[] but you don't feel actually anything during diastole, you just feel the surge of pressure during systole, so when your pressure is 120/80 so your pulse is 40.

[] minimum value and maximum value is pulsatile.

Mean pressure changes within the systemic vasculature

- The amount of pressure lost in a particular segment is proportional to the resistance of that segment.

- There is a small pressure drop in the major arteries (low-resistance segment);
- the largest drop is across the arterioles (highest resistance segment),



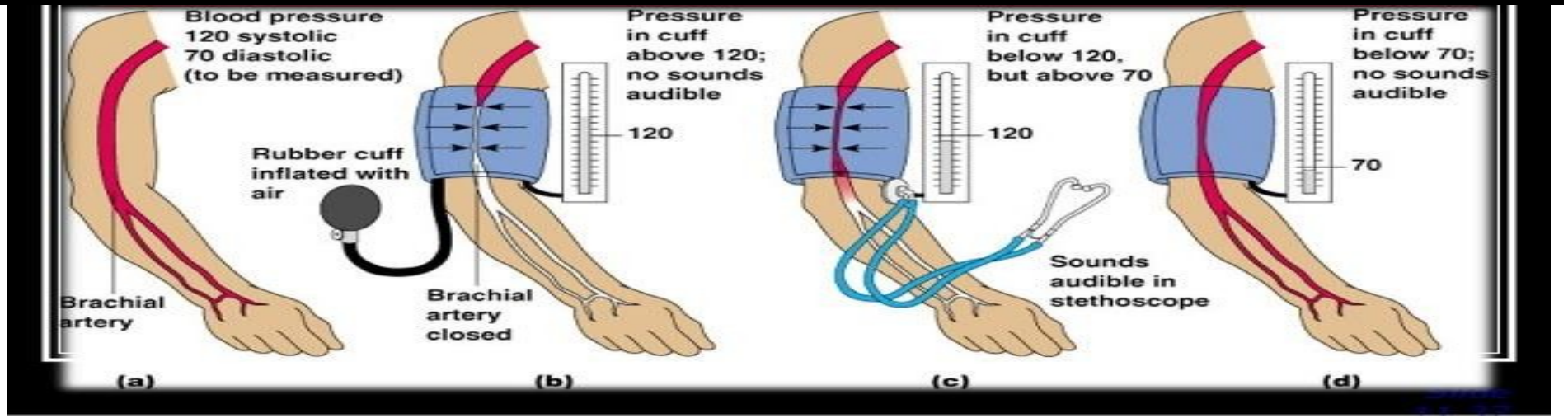
[] to see the fluctuation and Pulsatile fashion of blood pressure we see that the pressure is it fluctuate.
[] arterial blood pressure fluctuate between a peak systole pressure 120 mmHg and a low diastolic pressure of 80mmHg during the cardiac cycle.

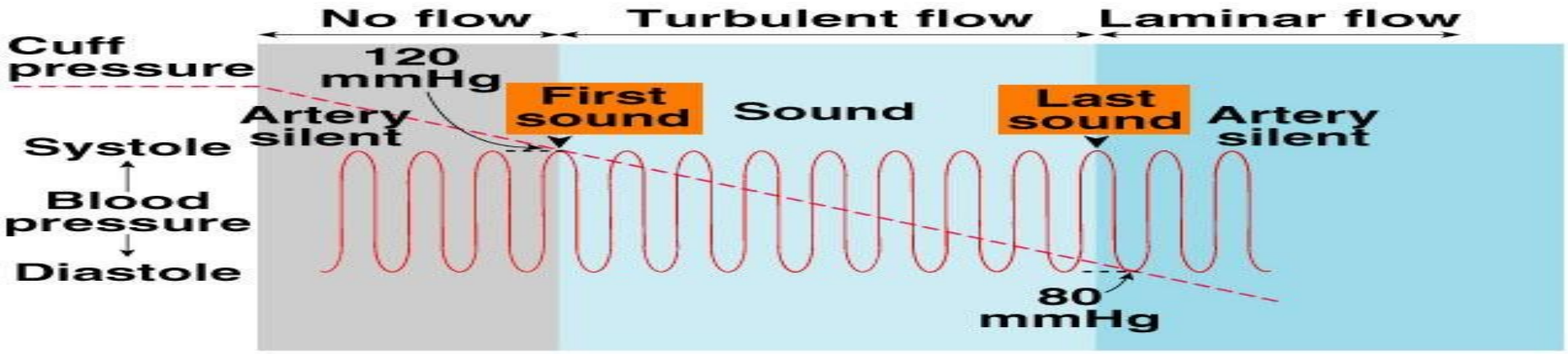
[] when we move from aorta to large arteries then to small arteries, we will enter the arterioles we will notice that systolic to diastolic swings fluctuation in the pressure is converted to non pulsatile fashion.

[] يعني التمرجح ما بين ال systolic + diastolic وال fluctuation اختفت في منطقة ال arterioles

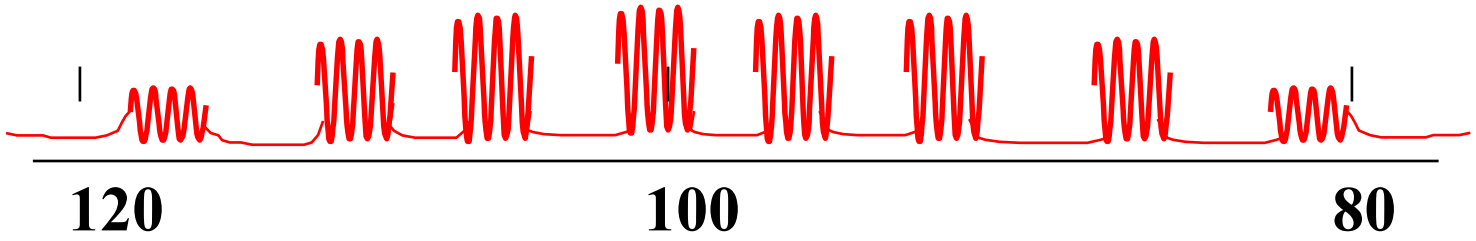
[] the fluctuation almost it is Nill in the vein.

Measurement of Blood Pressure





Korotkoff Sounds



[] measurement of the blood pressure is osciltatory method → that means we examine the blood pressure by listening.

[] we have a cuff, at the beginning we generate a pressure in the cuff, that will be higher by (20 to 30 mmHg) above the normal systolic pressure.

[] means, the normal systolic is 120, so I rise the pressure in the cuff to 150.

[] pressure in cuff is lowered progressively by period of time, the brachial artery is dilated for sound by placing stethoscope on it.

[] يعني ولدنا ضغط في ال cuff اعلى من الضغط في الشريان (brachial artery)وهو المكان المعتاد لقياس الضغط ,صار في عندي collapseوصار تسكير للشريان وما في عندي blood flowبعدين ببلش انزل الضغط تدريجيا وخلال هذه الفتره بنكون نسمع عن طريق السماعه جريان الدم عبر الشريان ,في البدايه ما راح نسمع اشي ولكن لما يكون الضغط في ال cuffمساوي لضغط الشريان بفتح الشريان ولكن مش فتحه كامله ف بصير جريان للدم ولكن بسرعه عاليه ف بنسمع الصوت وفي الواقع رح نسمع اصوات يعني هذا الصوت يلي بنسمعه للوهله الاولى هذا الصوت رح يمر بتغيرات في الجودة والشدة.

[] the sound of blood flow by the stethoscope Will be by five pieces we will get sound these sounds are different by their intensity and quality, the most importance sounds are:

1) appearance of the sound → as soon as I hear the sound for the first time and this sound is recorded as systolic pressure.

2) disappearance of sound → and in this moment we are recording the diastolic pressure.

[] five different sounds are called korokoff sounds.

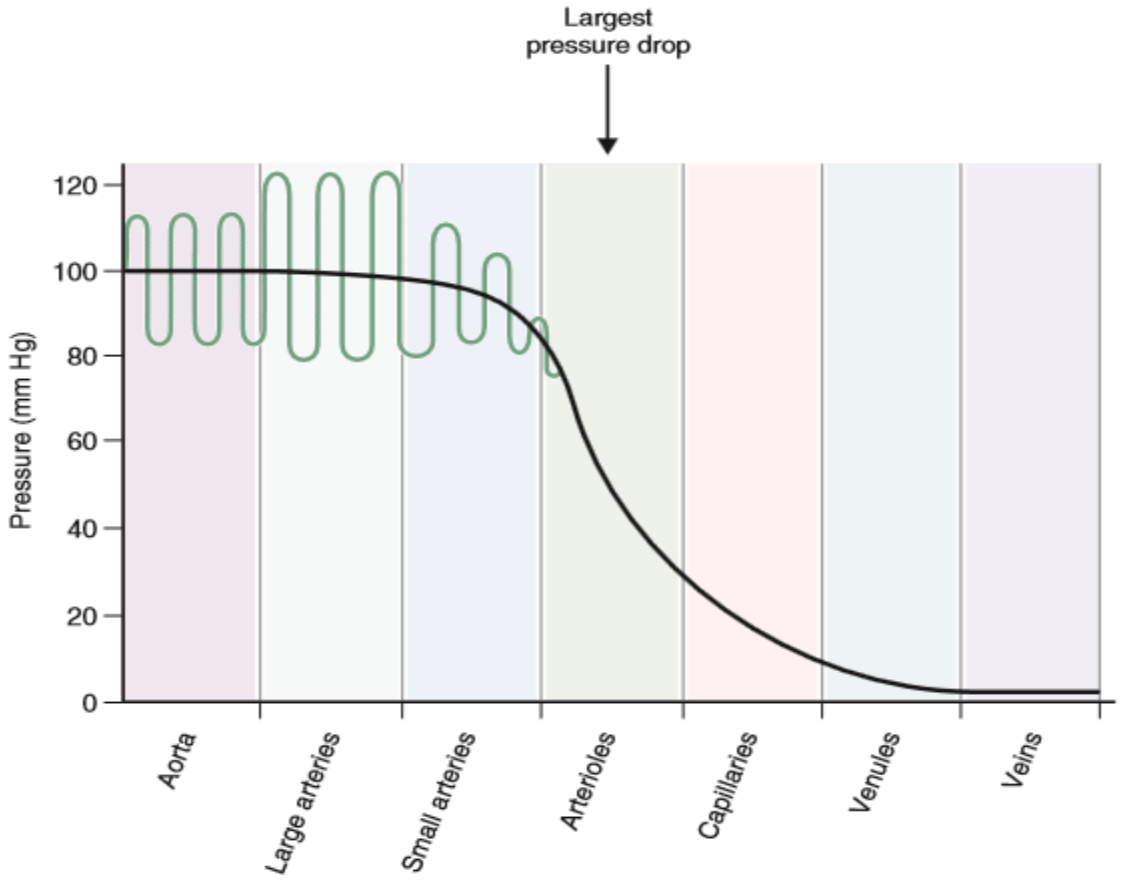
[] if someone put the stethoscope on brachial artery without the cuff he will never hear a sound.

[] when I put the cuff and I decreased it's pressure and it's a pressure then was equal to the pressure of the brachial artery then there will be movement of the blood in a high velocity and this movement caused a sound, because the blood flow turned from laminar into turbulent.

[] laminar movement is movement of blood as layers which is silent.
[] turbulent movement is caused by many factors but in this case the cause is that brachial artery is narrowed, it is not opening completely and because blood is moving in high velocity.

Arteriolar

- Arterioles are the main resistance vessels
- Most of the resistance to blood flow occurs in arterioles (50%) and capillaries (25%).



[] *arterioles The main resistance vessels in the circulation because their radius is small and their wall has layer of smooth muscles (هذه تنقبض وتنبسط), so they offer considerable resistance to the blood flow

[] * capillaries have a smaller radius then arterioles, but the resistance offer by arterioles is 50% while that offered by capillaries is 25% why?! لإنه لما بتحكي عن resistance إحنا بنوخذ الvessels كلهاcollective to others فالcapillary كلهاdont offers much resistance to flow as arterioles do ----> simply because there are many vessels extensively branched(higher surface area) so offer less R to blood flow.

[] *نلاحظ أنّarterioles بسبب هذا ال(R) - - -> causing a marked drop in MABP* لوبدنا نتطلع على الرسمه بس ع الMAP بح نلاحظ انو كانت فيه انخفاض بسيط جدا ولكن إجمالا ثابته ما فيه اختلاف ولكن نلاحظ(significant, sharp, huge. pre drops in arteries) يعني الsmall arteries up to small arteries* وفيها ثبات 100 وهذا capillariesويستمر الضغط بالانخفاض عبر ال 50 % يعني تقريبا 37الى 60فينخفض تقريبا من الانخفاض مهم جدا نتيجة هذا الانخفاض نتيجة الresistance يلي وجهها الدم في الarterioles صار عندي pregradiantوهذ very important for circulation ومنخفضهو عالي في بداية circulationBlood flow في الequal هوMAP كثير مهمه بالتالي الresistance بالتالي هاي الdriving خصوصا في الarterioles. في نهايتها بسبب الR

Arteriolar

The radius (and, accordingly, the resistances) of arterioles supplying individual organs can be adjusted independently to accomplish two functions:

(1) to variably distribute the cardiac output among the systemic organs, depending on the body's momentary needs, and

(2) to help regulate arterial blood pressure.

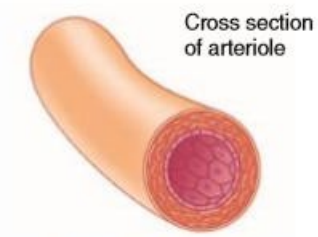
Mechanisms involved in adjusting arteriolar resistance:

Vasoconstriction and Vasodilation:

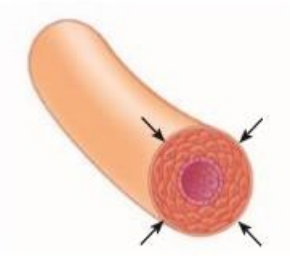
Vasoconstriction is the term refers to narrowing of a vessel. In contrast, the term vasodilation refers to enlargement of the radius of a vessel as a result of its smooth muscle layer relaxing

Vascular Tone

a state of partial constriction, which establishes a baseline of arteriolar resistance

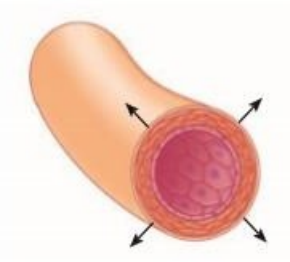


(b) Normal arteriolar tone



Major causes:
Local control:
↑ Oxygen (O_2) and other local chemical changes indicative of decreased need for blood flow
Extrinsic control:
↑ Sympathetic stimulation

(c) Vasoconstriction (increased contraction of circular smooth muscle in the arteriolar wall, which leads to increased resistance and decreased flow through the vessel)



Major causes:
Local control:
↓ O_2 and other local chemical changes indicative of increased need for blood flow
Extrinsic control:
↓ Sympathetic stimulation

Factors affecting total peripheral resistance

- The primary determinant of total peripheral resistance is the adjustable arteriolar radius.

- Two major categories of factors influence arteriolar radius:

  (1) local (intrinsic) control, which is primarily important in matching blood flow through a tissue with the tissue's metabolic needs and is mediated by local factors acting on the arteriolar smooth muscle, these include:

  - vasodilator metabolites produced in metabolically active tissues.
  - Autoregulation
  - vasoregulatory substances produced by endothelial cells
  - circulating vasoactive hormones

  (2) extrinsic control, which is important in regulating blood pressure and is mediated primarily by sympathetic influence on arteriolar smooth muscle.

arterioles : the radius of it can be adjusted by many mechanism - - - - - - > ونتيجة هذا التحكم ب ال radius ال arterioles - - - - - >
accomplish two functions* أصلا صغير وفي عندي طبقه من العضلات الملساء الموجودة في جدار ال radius تبعها لإنه ال radius لأنه من السهولة تغير ب ال
arterioles ونتيجه انقباض وانبساط هذه العضلات بصير تغيير في ال radius وهذا أهميته:*Two important functions...

1) distribution of Co among the spstemic organs depending on their needs
2) regulations of arterial blood pre(vasodilation, vasocomstriction)* ال Mechanism التي تستخدم حتى تعمل adjustment the radius

بنقدر نقسمهم إلى قسمين:

[] vasoconstriction or vasodilation happen by a lot of mechanisms:

1) intrinsic and extrinsic neural mechanism → and it is important to regulate blood pressure, it is important to determine the blood flow distribution of Cardiac output depending on tissue need (activity)

Intrinsic could be vasoactive substance that can dilate or constrict the artery, and this released from the cell surrounding the blood vessel or from the endothelium that lies the blood vessel .

As we said endothelium is an organ that release substance has a rule in repair of the vessel and produce important substances for growing of the vessel.

Sometimes vessel local mechanism can be a few circulating hormone, which produce hormones that are mostly extrinsic.

[] Mechanical stretch (myogenic) is the third local mechanism and it is important in regulating blood pressure and flow.

2) Vascular tone: factors are responsible for vascular tone is a partial contraction of the blood vessel:

A. arterioles smooth muscles have considerable myogenic activity, these smooth muscles are able to show self induced contractile activity, they can excite their self because single unit smooth muscle is self excitable so they don't need nervous stimulation for contraction, they create continuous action potential.

B. we have sympathetic fibers supplying most arterioles continuously

[] arterioles always get sympathetic stimulation, so vascular tone is resulted

[] first mechanism that regulate the radius of the arterioles and control the blood flow is the mechanisms that called metabolic theory.

[] metabolic theory autoregulation, because it is intrinsic mechanism, specifically local mechanism.

[] when the metabolic rate is increased blood flow will increase so the greater the metabolic activity of the tissue the greater the production of the metabolite which causes vasodilation so more blood flow, this is what we call metabolic theory.

[] when the blood flow increase, washing away the metabolite that makes vasodilation and return the blood flow to the normal.

[] and when I have decreasing in the blood flow, like when pressure is decreased or any other reason this will cause to accumulation of metabolite, or if the metabolism it's self increases it will increase the metabolite.

[] when I have decreasing in the blood flow there will not be washing of the metabolite so it will accumulate and makes vasodilation in the arteries, and then decrease the resistance, which will increase the flow and when the flow is increased it will cause washing to the vasodilator substance so everything will return to normal, and this called metabolic theory.

[] metabolites that make vasodilation is too much as example reduction in PO2 makes vasodilation.

[] and also decreasing in the PH and increasing in P CO2 make vasodilation, and in osmolarity they make vasodilation and make relaxation in arterioles, and not only in it but in peripherally sphincters, the capillary branch from arteriole has at the beginning of it too.

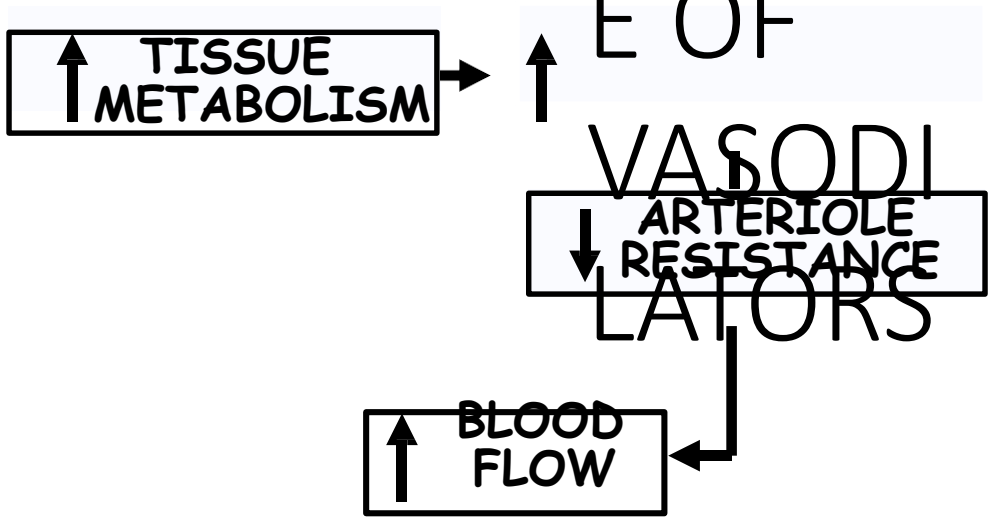
[] at the beginning what we call meta arteriole there is what we call peripherally sphincters and these in addition to meta arterioles has no nervous stimulation, so vasodilation and construction in the muscles that make is a result from local factor and result from external factor like nervous or harmonic stimulation.

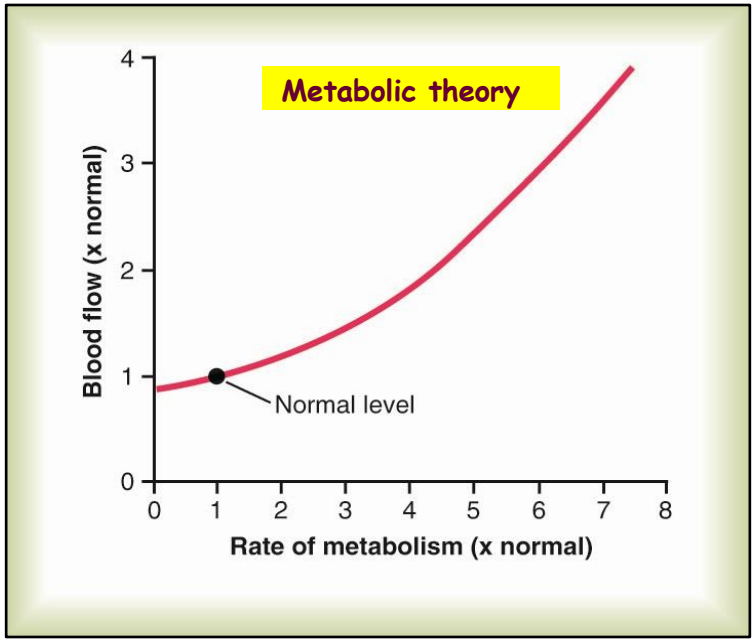
[] and also the substance that accumulate and work as vasodilator is the potassium and lactate which are vasodilators, especially in skeletal muscle cell, and histamine makes vasodilation too specially at tissues that has been injured or damaged.

[] adenosine increases permeability of capillary and this is a result from ATP, and this is very strong vasodilator specially in cardiac muscle (not skeletal muscle) and can also work as inhibitor of nor epinephrine release, so less vasoconstriction.

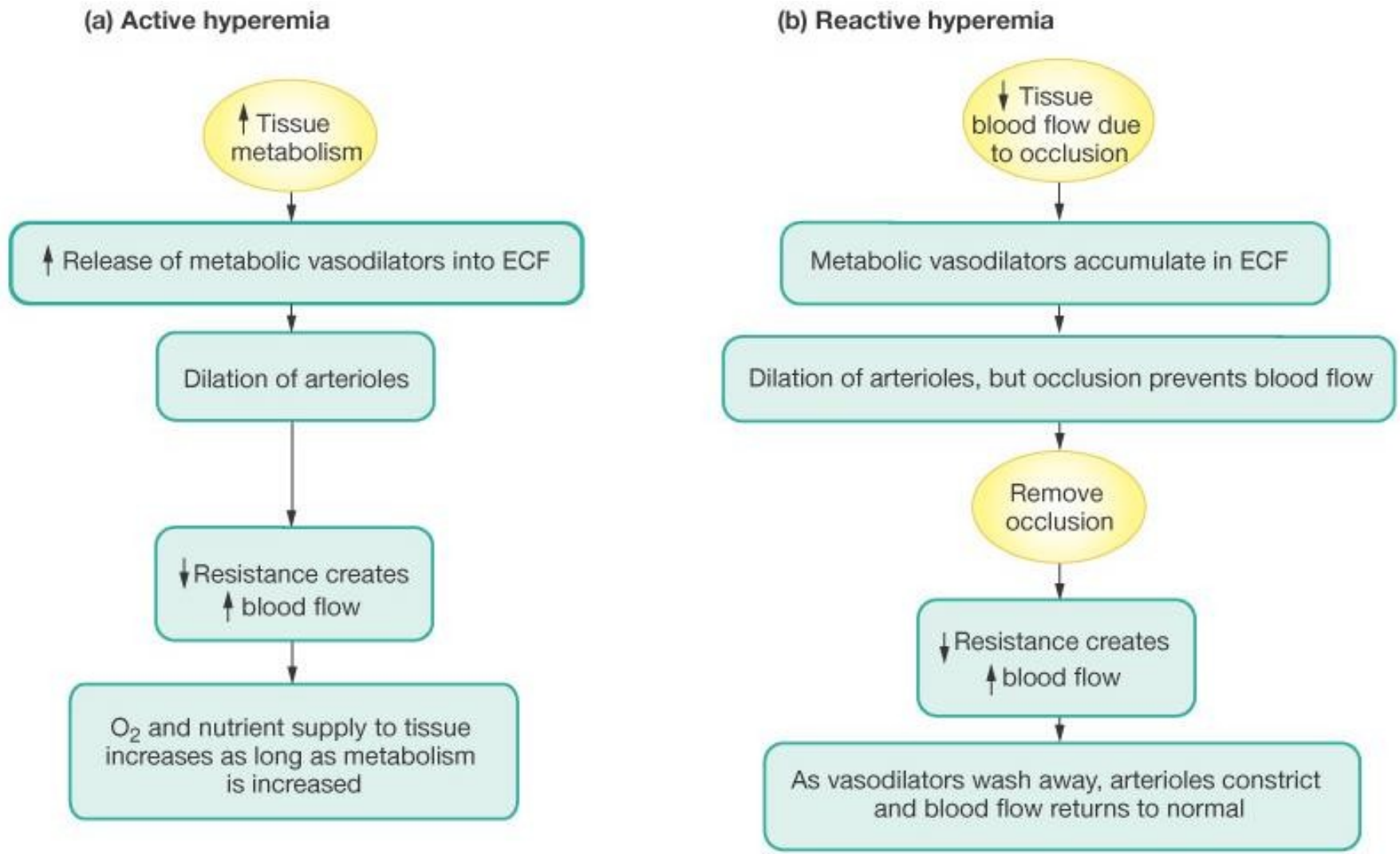
Vasodilator Metabolites

RELEASE OF VASODILATORS





Vasodilator Metabolites



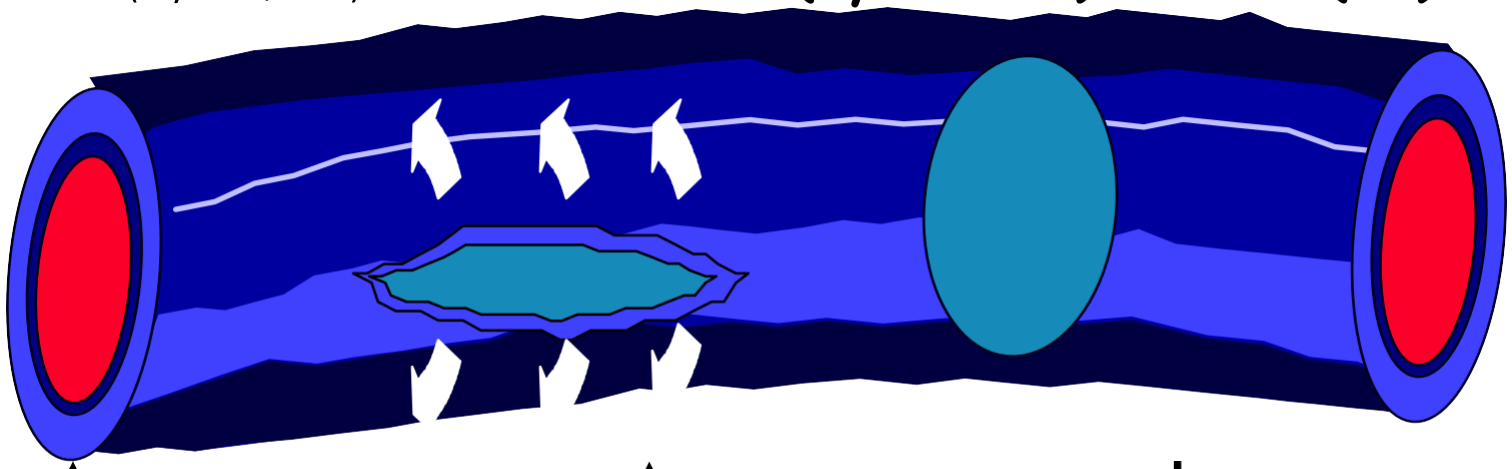
في أمثله على ال local vasodilator Metabolite فعندي
1)active hyperemia: vasodilation that accurse when the metabolic ratio increase
(metabolic ratio) ، هذا لما يزداد بصير accumulation of vasodilator substances و هذه تتراكم لما يقل ال blood flow
فبتعمل vasodilation ل local arterioles مو اي arterioles و انما ال local
هذا يساعد ال tissue --> to receive additional blood flow يلي هو بحاجتها (O2+neutrient)
لأنه هاي local change مثلا الموجود في العضلات الهيكليه هذا بصير فيها مو اي مكان اخر لأنّ هذه ال Metabolite تكونت عند النسيج يلي صار فيه active
صار زياده في ال Metabolism

*relative hyperemia: is a phenomenon by which the local blood flow to the organ is controlled after a period of ischemia.
يعني بكون عندي occlusion ف after vascular occlusion صار تكسير في vessels معين و أثناء هذا التكسير ما فيه عندي blood flow لكن عندي عمليات Metabolism فصار تراكم ال vasodilator metabolite و لكن فيش blood flow حتى يقيمها فبتضل تتراكم ال metabolite فلما اتخلص من هذا occlusion و يرجع ال blood flow لطبيعته رح ترجع بشكل كبير جدا لأن تراكم هذا الvasodilators بعمل vasodilation فلما يصير ازالة لل occlusion رح يكون ال blood flow عالي جدا و رح يضل عالي الى ان يتم ازالة ال metabolite يلي تراكمت خلال ال occlusion هذي اسمها relative hyperemia.

Autoregulation

Myogenic mechanism

TENSION (dynes/cm) = PRESSURE (dynes/cm²) X RADIUS (cm)



↑ PRESSURE → ↑ TENSION → ↓ RADIUS

(to maintain tension constant) ↑

↓ PRESSURE → ↓ TENSION → ↑ RADIUS

(to maintain tension constant) ↑

Autoregulation meachanism (myogenic mechanism)
Many tissues have the ability to maintain relatively constant blood flow during fluectuation in perfusion pressure
لما بصير عندي تغيير في الperfusion pre يلي هو لو الdriving pre من 80ل160 يعني نقصانا او زياده في بعض الانسجه لديها المقدره على ان تحافظ على almost constant relative وهذه المقدره على تنظيم الblood flow في ضوء تفسير ال perfusion pre من 80الى160 تسمى autoregulation
Physiological basis of this machanism is not well setteled(. However, one faetorcould
ممكن يفسر الاليه وههو عباره عن myogenic response theory
Its an internsic mechanism used by some tissue to have relatively constant blood flow, this mechanism regulate blood flow by vasoconstriction of the arterioles when perfusion pre increases and vasodilation of the arterioles when the perfusion pre decrease
اذا صار عندي زياده في ال perfusinopre رح يصير. Vasoconstrietion زياده في ال resistance نقصان في ال radius نقصان في ال flow
واذا صار نقصان في perfusion pre بصير فيه vasodilation وهذا مهم للحفاظ على ال relatively constant blood flow
كيف؟؟
اذا صار زياده بال perfusion pre يلي هو. Driving pre
رح يصير flow كثير للنسيج وهذا بعمله damage فال response التي تحدث انه اذا زاد perfusion pre
بصير vasoconstriction بالتالي less flow يعني ال flow بتضل طبيعيه حتى لو صار vasoconstriction
ولكن الperfusion عالي فهذول بعملوا compensation لبعض انو ال perfusion عالي فزادت ال resistance والزياده في ال resistance تمنع ال perfusion pre من زياده ال flow عن الحد الطبيعي.

Substances Secreted by the Endothelium

(i) Prostaglandins and thromboxane A2.

(ii) **Endothelium-derived relaxing factor.**

(iii) **Endothelins (ET).**

Circulating Hormones that Affect Vascular Smooth Muscle

- Hormones in the circulation that have general effects on the blood flow include vasoconstrictors and vasodilators.
  - **The principal vasoconstrictors are:**
    - **norepinephrine and epinephrine**
    - **vasopressin, and**
    - **angiotensin II**
  - **The principal vasodilators are:**
    - **vasoactive intestinal peptide (VIP)**
    - **kinins, and**
    - **natriuretic peptides.**

[] endothelium derived relaxing factor
Local regulation of blood flowوهي blood flow هاي المواد تعمل على تنظيم ال
Vasoconshiction or dilationبتعمل
Vasoconstriction وفي عندي مجموعه من الهرمونات بعضها بعمل
Vasodilator وبعضها

short term blood flow regulating mechanism عباره عن local chnges هذه ال

:long term blood regulationاما ال

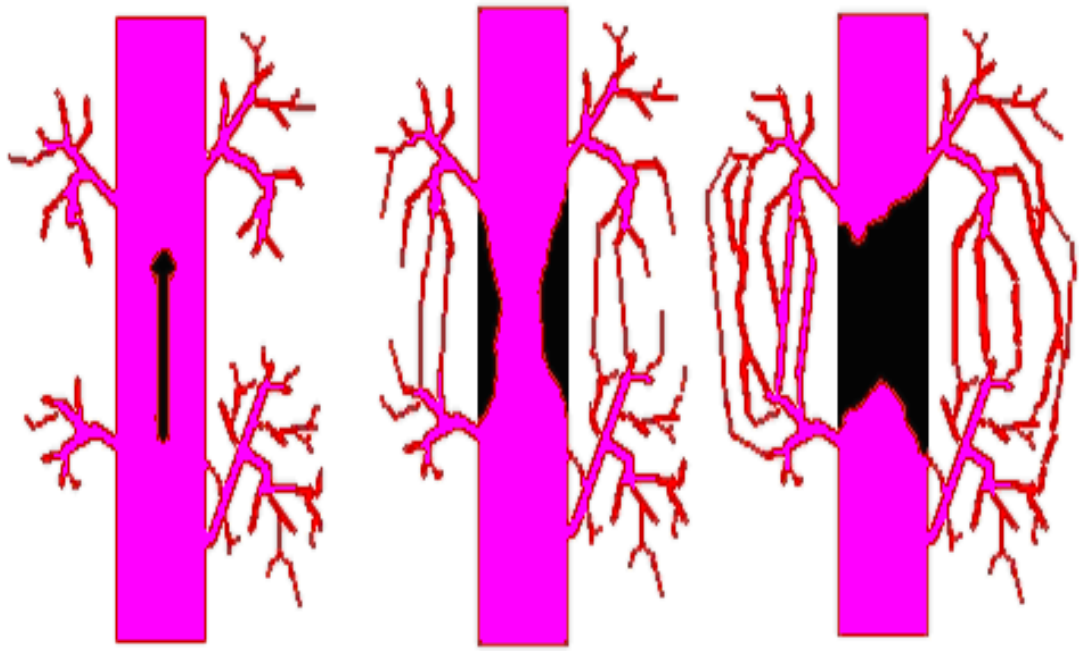
[] this develops over a period of days to months to match the metabolic need of tissue EX: is the development of collateral vessels after thrombosis to one of the coronary arteries or a blocked veins which leads to increase blood flow to this tissues الي block بسبب ال flowاحترقت من ال
[] collateral is a new vessels develop around a new vessels and allow the affected tissue to be at least partially supplied with the blood

[] the growth of new vessels called angiogenesis
3 factors that stimulat angiogenesis :
1)VEGF
2)FGF
3)angiogenin
tissue او من tumer هذه يتم استخلاصها يا من
((that are rapidly growing واحنا هون تحكمنا بال blood flow وعملنا على زيادته

MECHANISM INVOLVED IN LONG-TERM BLOOD FLOW REGULATION

- Long-term blood flow regulation is required by:
  - Ischaemic tissues,
  - Tissues that are growing rapidly and
  - Tissues that become chronically hyperactive.

- The long-term blood flow regulation is brought by an increase in the physiological size of the vessels in a tissue and in certain circumstances even by an increase in the number of blood vessels (angiogenesis).
- Angiogenic factors:
  - Vascular endothelial growth factor,
  - Fibroblast growth factor and
  - Angiogenin.



Development of collateral circulation to compensate for vessels occluded by atherosclerosis

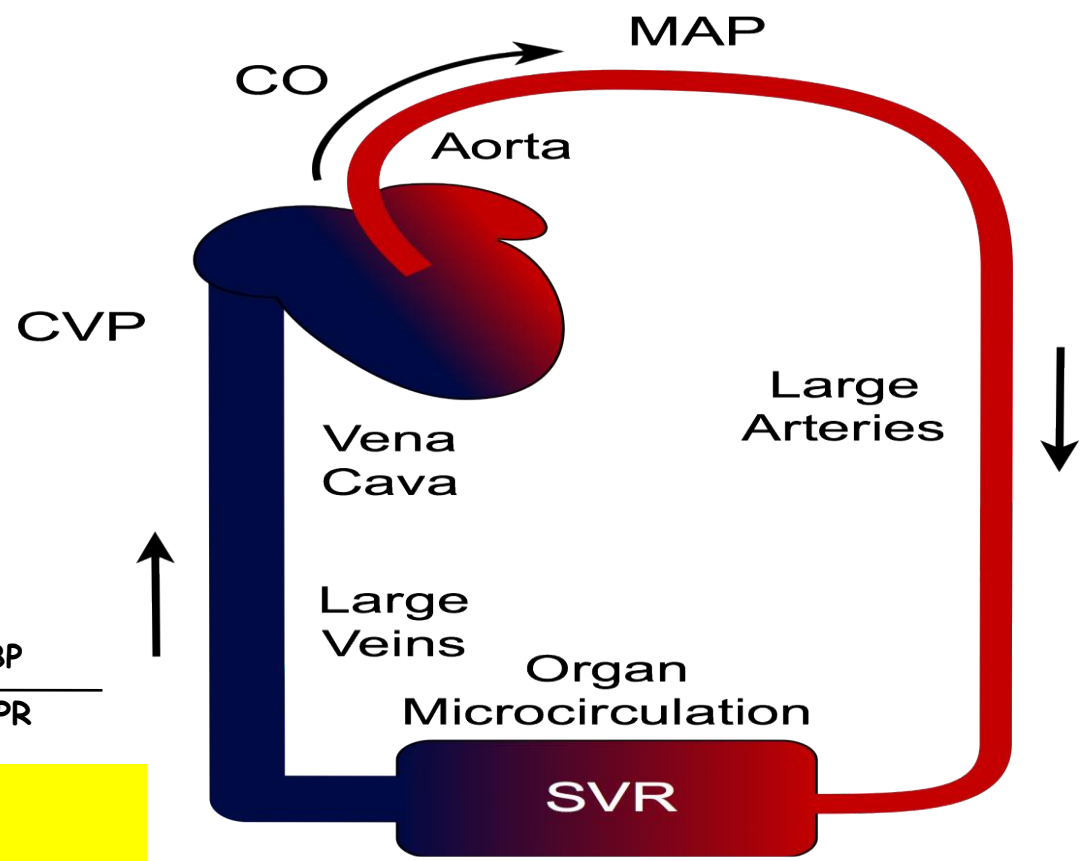
Extrinsic sympathetic control of arteriolar radius is important in regulating blood pressure.

- Extrinsic control of arteriolar radius includes:
  - Neural influences
  - Hormonal influences
- the effects of the sympathetic nervous system being the most important.

$$Q = \frac{MABP - RAP}{TPR}$$

Since Rt. Atrial pressure = 0 then $Q = \frac{MABP}{TPR}$

MABP= cardiac output (Q) × total peripheral resistance (TPR)

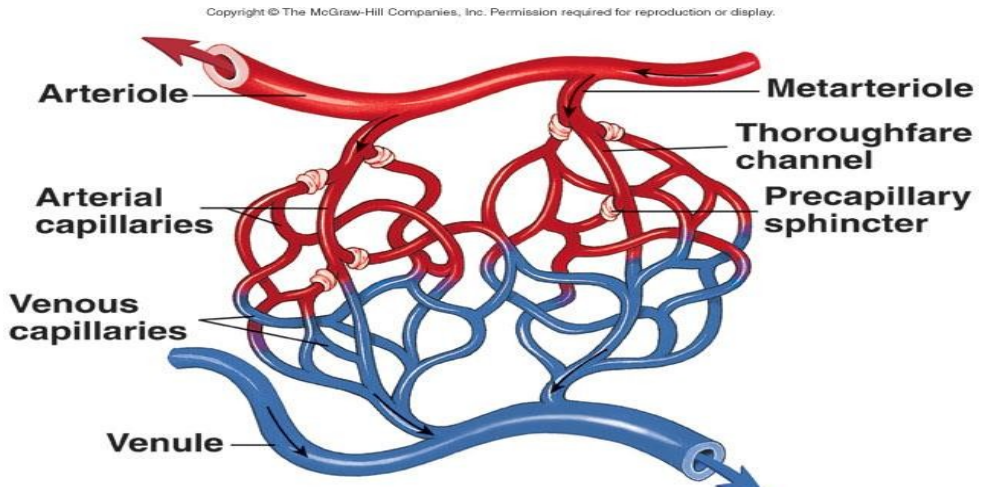


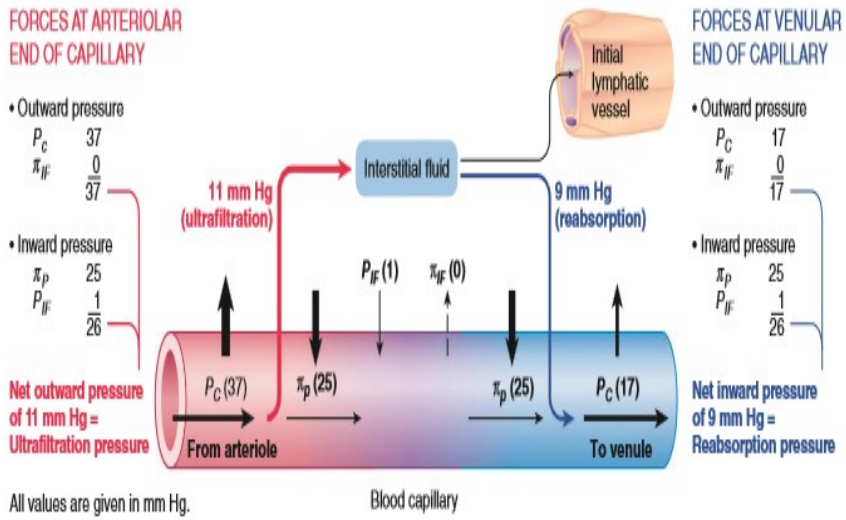
[]حكينا إنه الRadius تبع الArteriole بصيرله (Vasoconstriction+Vasodilation)
أيضا عن طريق
extrinsic sympathetic innervation
ولكن هذا في الغالب له دور مهم في تنظيم ضغط الدم BP وليس تدفق الدم Blood Flow لهيك ما رح نحكي ع هذا السلايد

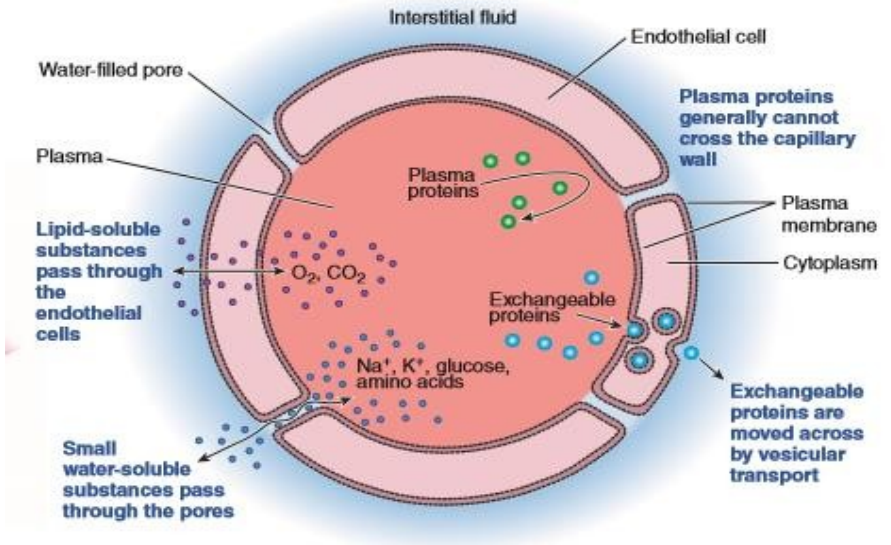
والسلايد يلي بعده ببين بعض ال factors التي تتحكم بضغط الدم BP وهذا حكينا عنه

Capillary Network

- Blood flows from arterioles through metarterioles, then through capillary network
- smooth muscle in arterioles, metarterioles, precapillary sphincters regulates blood flow







[] **Capillary Network**
Is the terminal portion of the arteriole but sometimes the terminal portion before it forms the capillary we call it *Metarterioles* then they will drain into the capillaries, but on the upstream side on the opening of capillaries we have Sphincters (which are Smooth Muscles) Called *Precapillary sphincter, it controls the flow of blood to capillaries, if it's open there will be flow and if it's closed no flow to capillaries will occur.*

[] The precapillary sphincter and Metarteriole have *no Nervous OR Hormonal Stimulation, they dilate or constrict because of Local changes.*
[] we said that Capillaries are extensively branched and because of that they have the highest total cross sectional area. The surface area of capillaries together equals 4500 *cm^2.*

[] And since the capillaries have the largest cross sectional area the velocity of blood flow will be the slowest, because we have Inverse proportion between cross sectional area and the velocity, and this makes the capillary the best site for exchange.

***Three Properties** for the capillary give it the ability to make exchange with interstitial fluid:

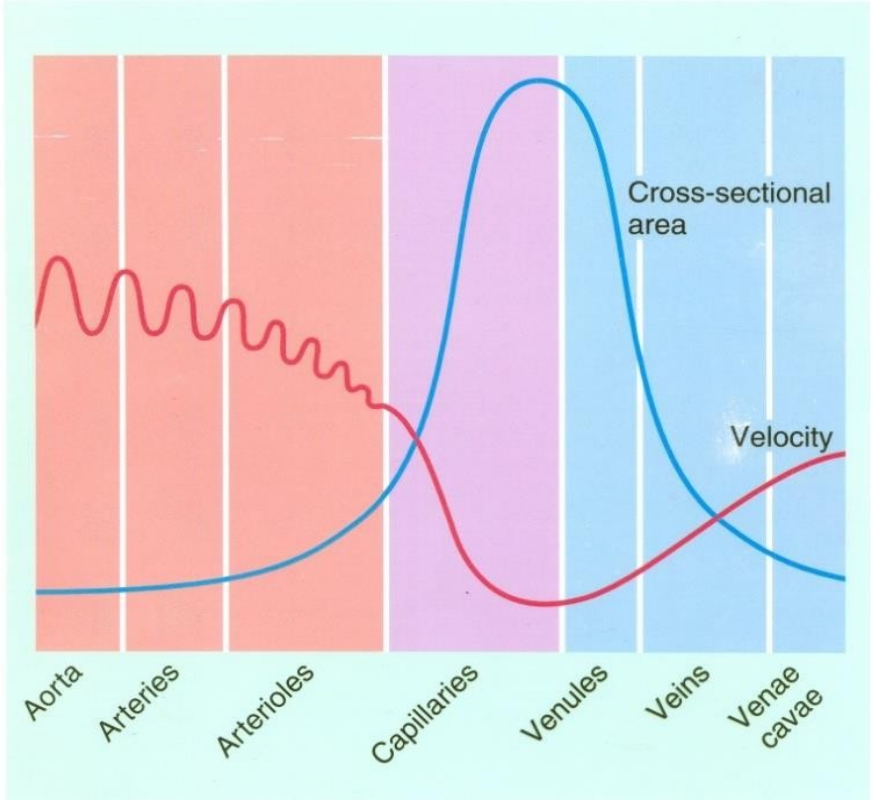
1) they have the largest total cross sectional area so the velocity of the blood is the lowest in capillaries which give the blood a chance to do exchange with the interstitial fluid.
2) capillaries have very thin wall (single endothelial layer).
هاي الخصائص بتخليها مكان مناسب للexchange وهذا يحدث
بـ Mechanisms مختلفه

حسب الرسمه عاليمين من تحت:

Some substances cross capillary wall by vesicular transportation (means to be transported into capillaries from outside or from inside to outside these substances need vesicles to be transported we called it vesicular transportation and this type of transportation involved exocytosis and endocytosis)
(لانه بدخل عبر الخلايا فendoمن جهه وexoمن جهه اخرى)
Relatively little materials transported by vesicle transportation.(هذه الطريقه لا تستخدم كثيراً)
The most common mechanism to exchange salt and fluid by the junction between endothelial cells
 # sinusoid : large junction between endothelial cells found in the liver and endocrine glands especially anteriorpitutry gland (not all endocrine gland)

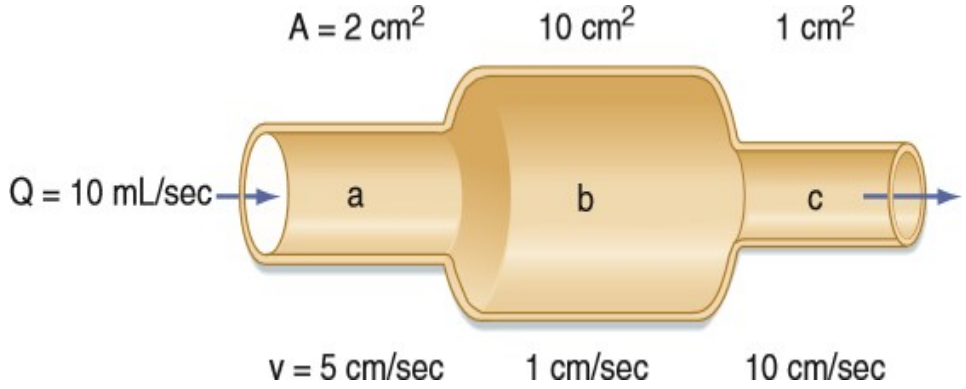
*** in endocrine tissue, small intestine and the kidney the transportation happens in capillaries called fenestrated capillaries → endothelial cells contain fenestrations so substances exchange throw these fenestrations → (substances which exchange here are about 600 in diameter)**
*** in skeletal muscle , cardiac muscle , there is no fenestration but there is small passages between endothelial cells (substances here up to 10 nm)**

Slow Velocity of Flow Through Capillaries



- Aorta= 2.5cm^2
- Small Arterioles= 20cm^2
- Arterioles= 40cm^2
- Capillaries= 2500cm^2
- Venules= 250cm^2
- Small Veins= 80cm^2
- Venae Cavae= 8cm^2

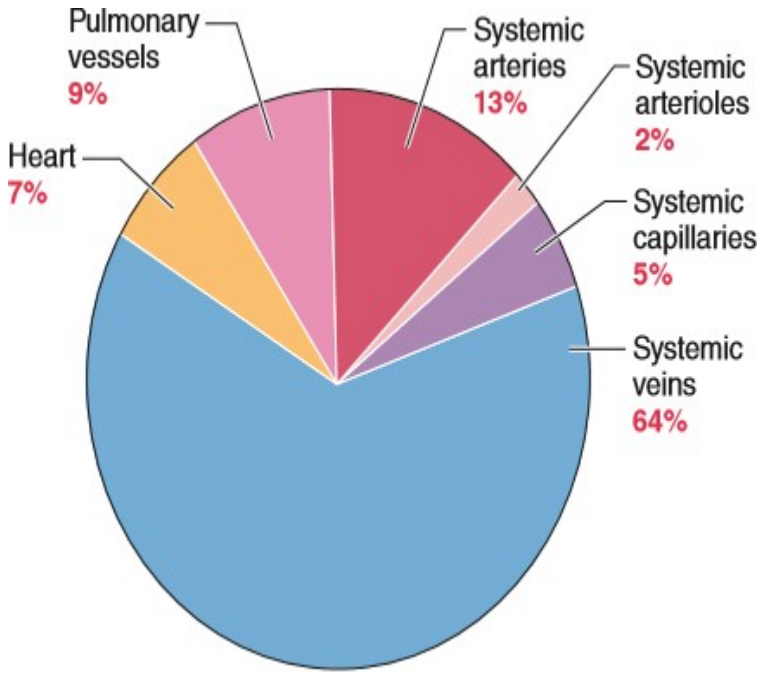
$$v = Q/A$$



veins

Functions of Veins:

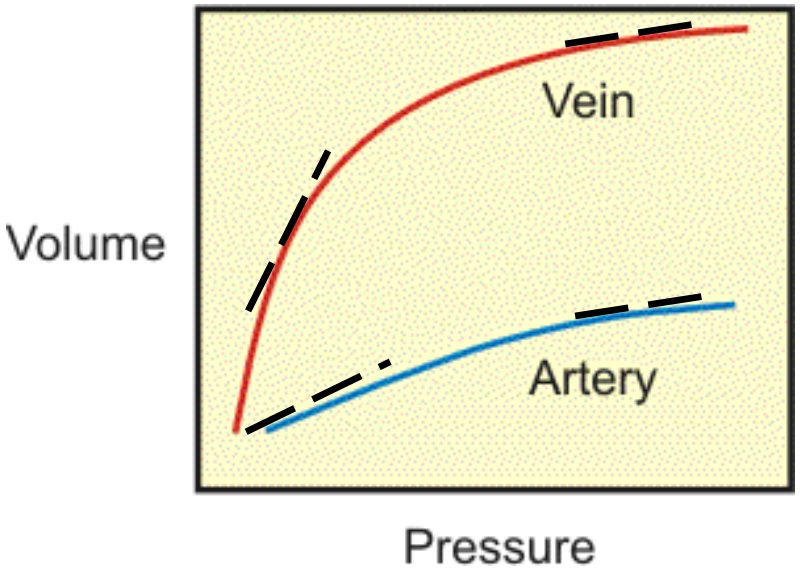
1. **Venous system transports deoxygenated blood from tissues to the heart. From heart, blood is pumped into the lungs where carbon dioxide is removed from it.**
2. **Veins are capacitance vessels as they can accommodate a large volume of blood. They act as reservoir of blood. In fact, more than 60% of the total blood is present in the venous compartment.**



Compliance of blood vessels

- At low pressures, veins have a greater compliance than arteries, Therefore, veins can accommodate a large changes in blood volume with only a small change in pressure.

- At high pressures, compliance is similar in veins and arteries (but volume is much greater in veins)
- This characteristic makes veins suitable for use as arterial by-pass grafts.



WALL TENSION

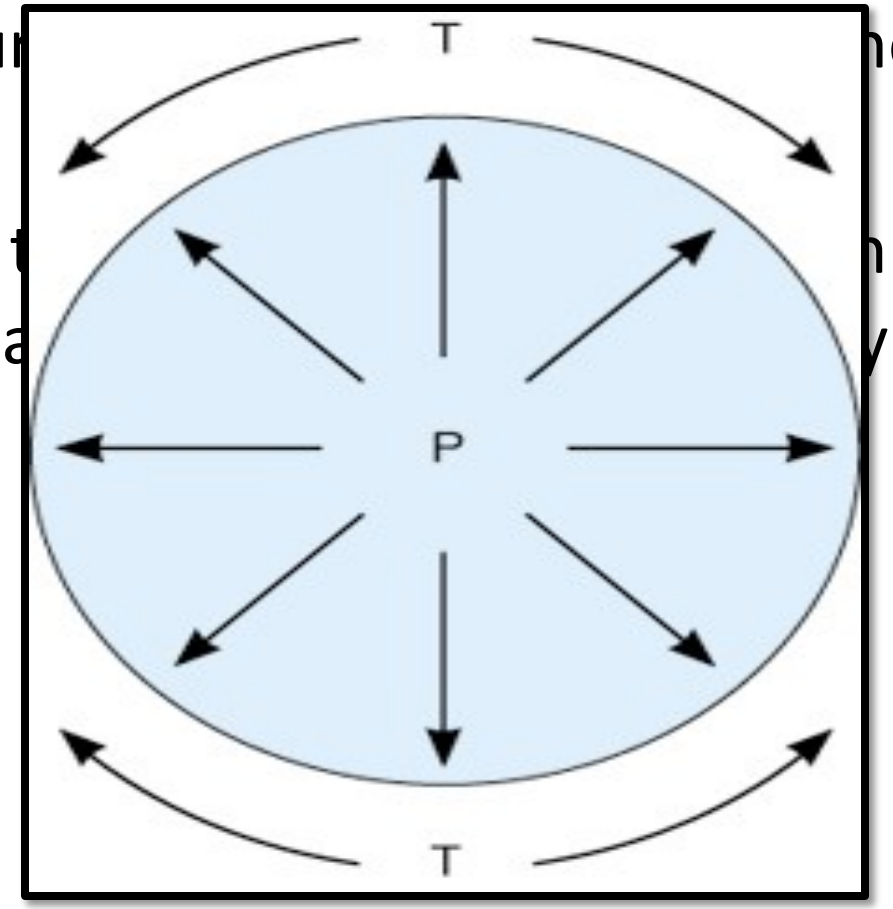
the relationship between the distending pressure (P), the tension

- (T) in the wall of a structu ned by the l of Laplace
  - It states that the wall t n is equal to product of distending (P) a y the thickne of the wall (w):

$$T = \frac{Pr}{W}$$

- **In thin-walled structures, wall thickness is negligible**

$$P = \frac{T}{r} \quad \text{or} \quad T = P \times r$$



WALL TENSION

- This implies that large arteries must have thicker walls than small arteries in order to withstand the level of tension (Aneurysm).
- Arteries must have thicker walls than veins because they carry much higher blood pressure.