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LOOKING FOR MORE MEMBERS !

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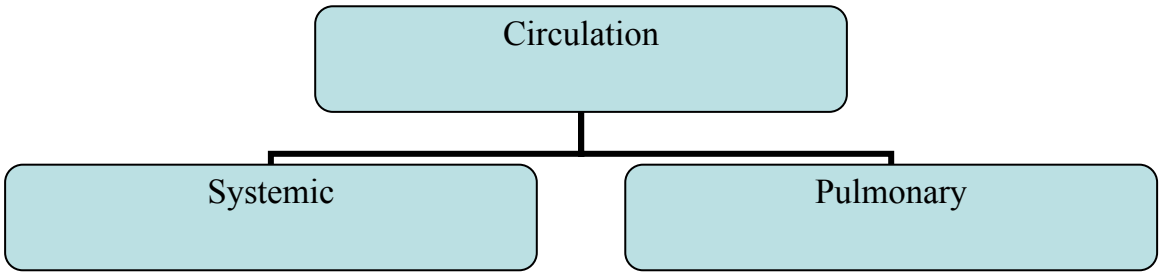
,,,, WITH REGARDS

PSL TEAM (A) 427

IMPORTANT NOTICE

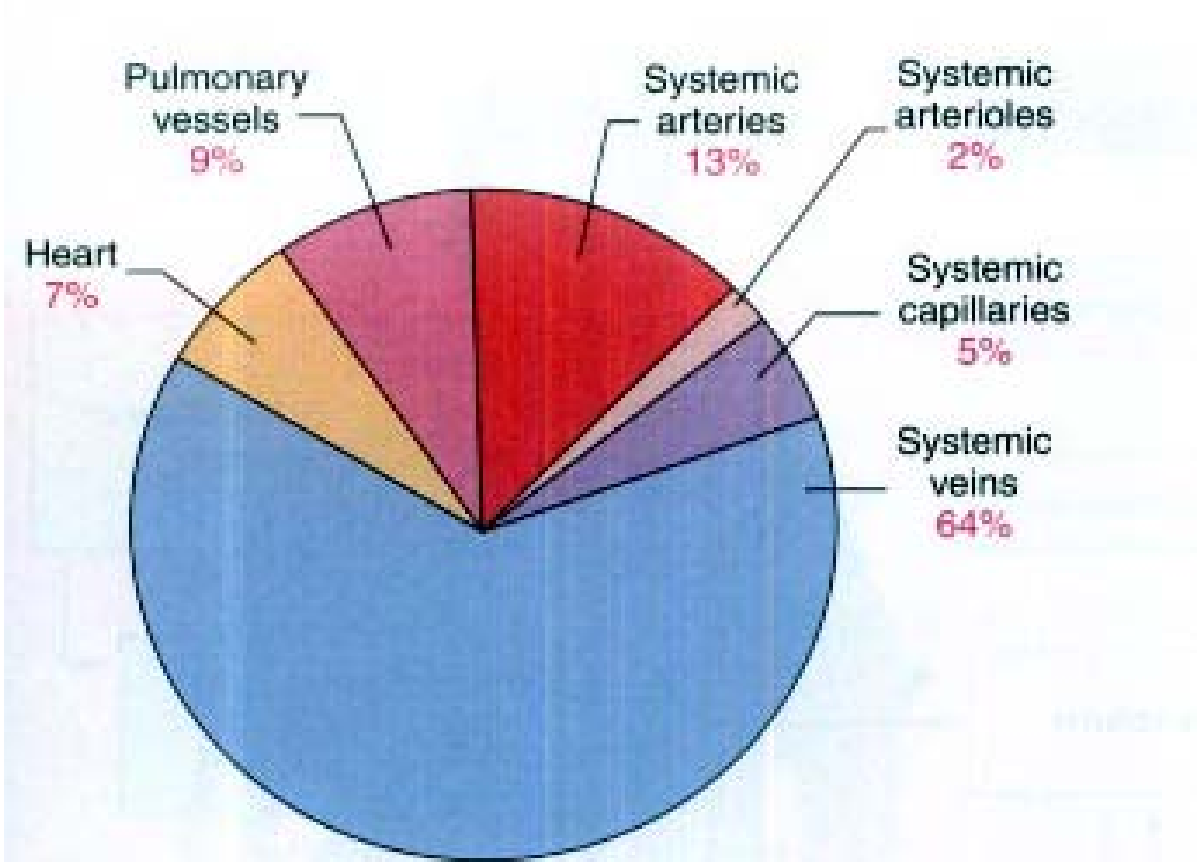
THESE NOTES ARE ONLY A **HELP** FOR STUDYING PHYSIOLOGY OF CIRCULATION AND IT **SHOULD BE REFERED TO OTHER RESOURCES FOR THE EXAM PUPROSE.**

CIRCULATION



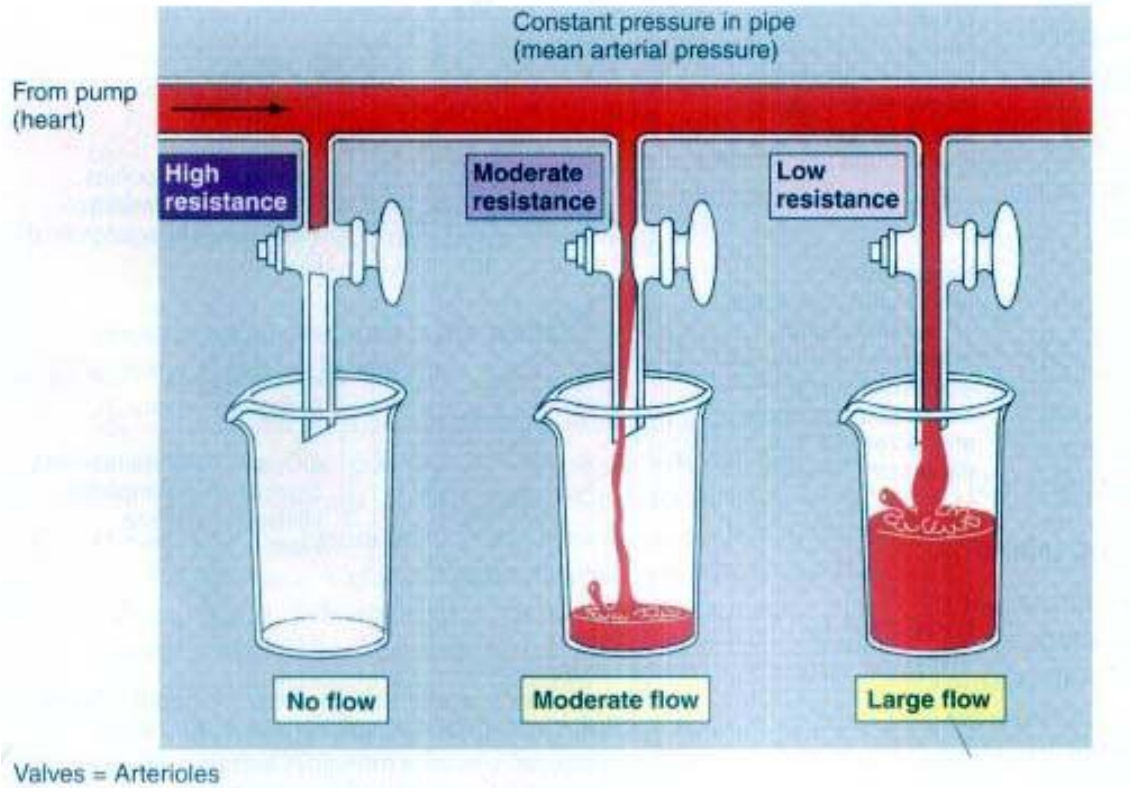
Blood circulation (Systemic) provides tissues with requirement (nutrient, O_2, hormones, electrolytes) and removes CO_2 & wastes.

Where is blood usually found?



- We found that the **systemic veins** contain **most the blood**

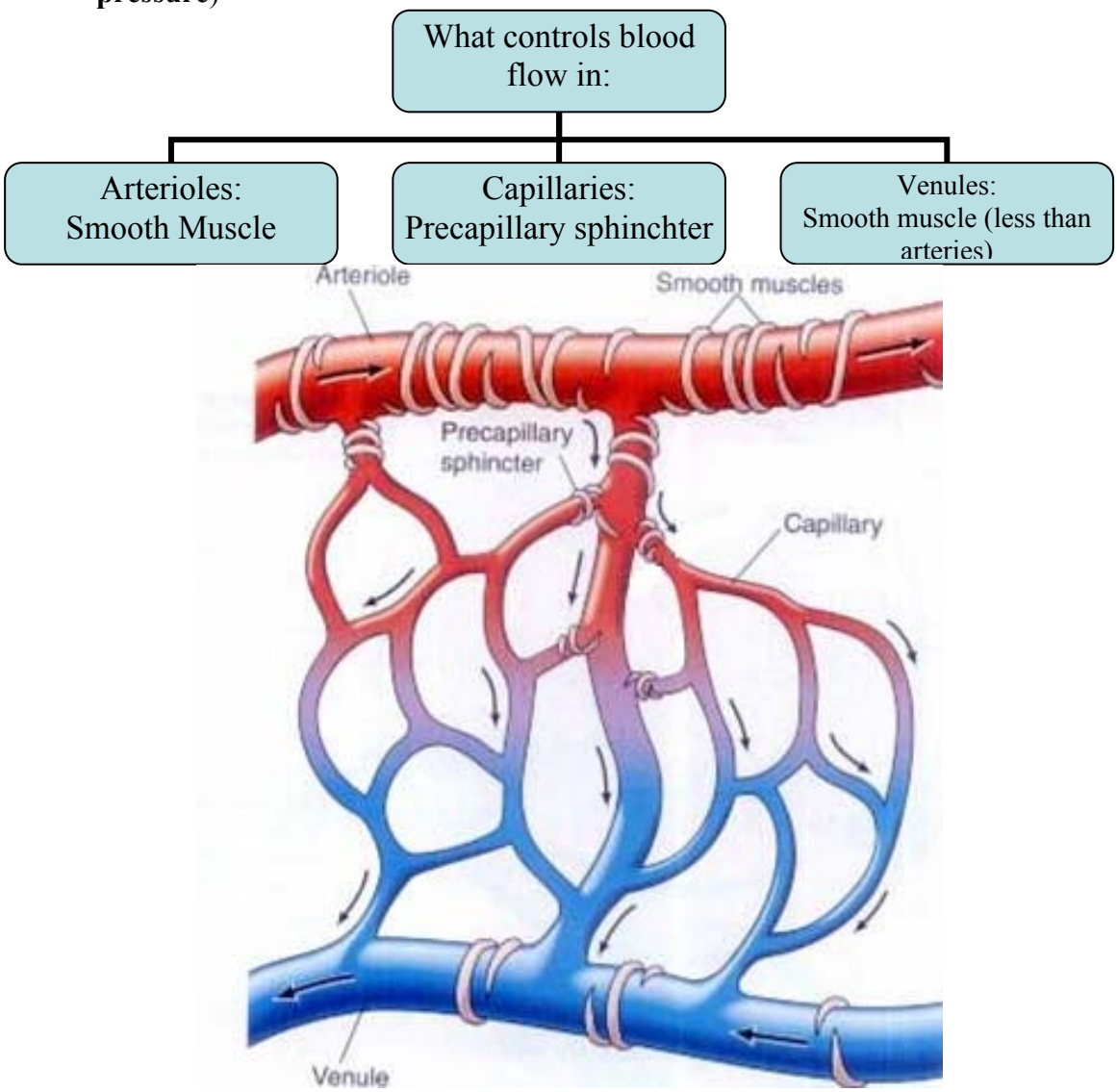
- If there is **constriction** in small arteries & **arterioles** there will be a ↓**blood flow**. They are called: resistance blood vessels.



- **Capillaries are called exchange vessels:**
  - They are the **most important** part of the circulation **because exchanging of materials** takes place there.
  - **Thin** wall (one layer of endothelial cells & no smooth muscle)
  - **Diameter** is very **small**
  - Many **pores** to allow movement of small molecular substances (exchange takes place rapidly).
  - Very **large surface are** (the largest), because every cell needs its own exchange of nutrients. (Total surface area of capillaries: 500,000 – 700,000m^2).
  - There are ≈ 10 billion capillaries.

- **Venules & Veins: Capacitance (سعة) vessels:**
  - **Less thick.**
  - **Greater Diameter.**
  - **Largest amount** of **blood**.
  - In case of loss of blood (e.g. hemorrhage) it squeezes to push blood to the right atrium to compensate the loss.
  - Less smooth muscle in thinner walls.
  - It is usually under **low pressure**.

- The pressure is **decreasing** when the blood flows **from the left ventricle** to aorta➔ arteries ➔ capillaries ➔ venules ➔ veins➔ (**right atrium having the least pressure**)



Vasomotor tone:-

- **Only sympathetic innervations** play a role in the **vasomotor** (vaso=vessel) tone:
  - Normal sympathetic supply ➔ Normal Diameter.
  - ↑ sympathetic supply ➔ Vasoconstriction (↓diameter)
  - ↓sympathetic supply ➔ Vasodilatation (↑ diameter)

Factors affecting arteriole diameter:

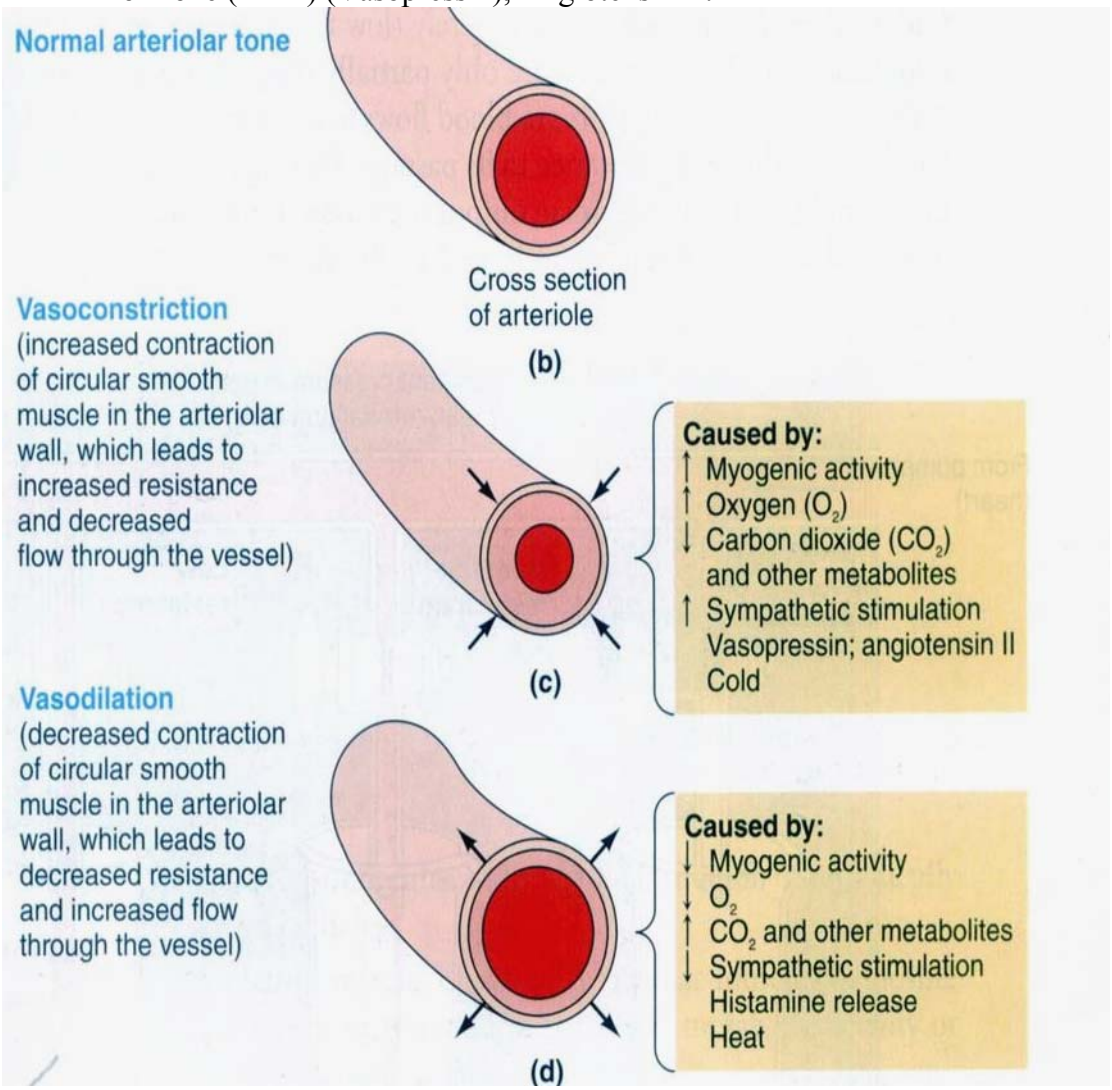
Vasodilation

- $\downarrow O_2$, $\uparrow CO_2$, $\uparrow H^+$
- ↑Adenosine,

- ↑heat
- ↑Endothelial Derived Releasing Factor (EDRF) e.g. Nitric Oxide (NO).
- ↓ympathetic stimulation (below normal)
- Myogenic Activity
- **Hormonal Factors (not local)** e.g. histamine, Bradykinin

vasoconstriction:-

- ↑O_2 , ↓CO_2 , ↓H^+
- ↓Adenosine
- Cold
- ↓EDRF e.g ↓NO
- ↑ympathetic stimulation
- **Hormonal Factors (not local)** e.g. Norepinephrine, epinephrine, AntiDieuretic Hormone (ADH) (Vasopressin), Angiotensin II.

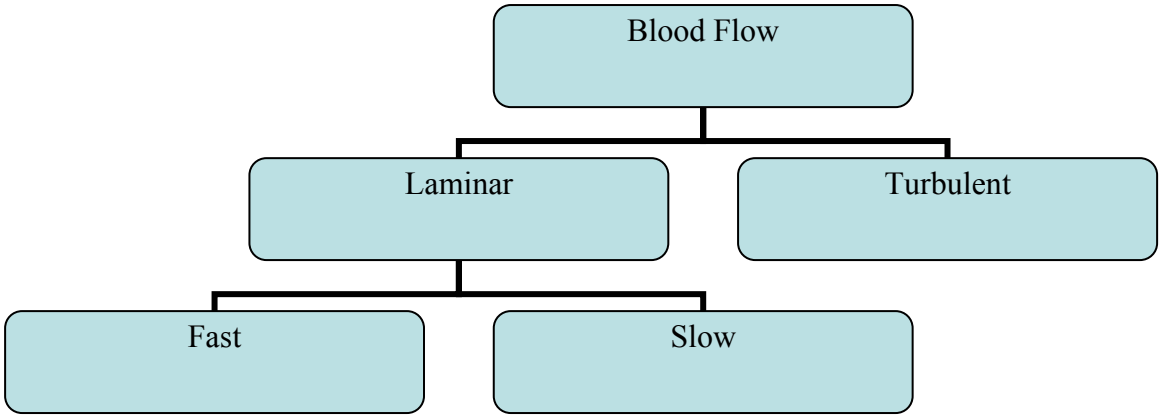


Flow lows:

Ohm's Law: $Q = \frac{\Delta P}{R}$	Q: Blood Flow ΔP: pressure Difference R: Resistance (**inversely proportional to flow)**.
$R = \frac{L \times \eta}{r^4}$	R: Resistance L; Length η: viscosity (depends mainly on plasma proteins & blood cells) r: radius
(From the 2 above equations we get:) $Q = \frac{\Delta P \times r^4}{L \times \eta}$	**The physiological importance of the equations:** $Q \propto r^4$ $R \propto \frac{1}{r^4}$ (The main determinant (محدد) of blood flow is the **radius**, which is proportional by its 4^{th} power).

- Blood **flow** in **capillaries** is **intermittent (متقطع)** flow

Types of blood flow:



Laminar Flow:

- **Steady**
- **No Sound**
- **Normal** Blood flow
- **Less energy** required
- Normal velocity
- **Streamline** flow

Slow flow:

- There is **resistance**.
- There is **friction** between RBCs and the wall of the vessel.

Fast flow:

- **Less resistance**
- **RBCs** are located in the **center** leading to **less friction** between RBCs and the walls.

Turbulent Flow:

- Happens when anything **blocks** the way of the RBCs.
- Blood goes in **different directions** (mixing of blood flow).
- There are sounds heard called **murmers** or **Korotkoff sounds**[1].
- **Less velocity.**
- More **energy loss.**
- Slow blood flow.
- Occurs by narrowing of arteries wall e.g. obstruction of blood vessels when we measure B.P.

What happens during…

Constriction of vessel:

- ↑B.P., ↓velocity, ↑ resistance

Relaxation:

- ↑ Blood flow, ↑ velocity, ↓resistance

↑ in Hematocrit (RBC Count):

- ↑ viscosity ➔ More B.P. required to push blood ➔ ↑ resistance, ↓velocity, ↓O_2 Delivery

So hematocrit is a determinant of the B.P. & viscosity.

BLOOD PRESSURE (B.P.)

Definition: It is pressure exerted by blood against the vessel wall.

Systolic B.P.

- **Definition:** the **highest** pressure recorded in the arteries during **systole**.
- **At rest:** 120 mmHg in young age, **in old age** ↑B.P. (may reach 140)
- **↑Activity:** systolic B.P. ↑.
- **Range:** 100-140 mmHg
- **Systolic Hypertension:** caused by ↑ H.R. & ↑ contractility of the heart.

Diastolic B.P.

- **Definition:** The **lowest** pressure recorded in the arteries during **diastole**.

[1]Blood flow through partially open blood vessel causing turbulent blood flow and that will produce a sound called **Korotkoff** sound

- **At rest:** 80 mmHg.
- **Range:** 60-90 mmHg
- ↑**Activity:** diastolic B.P. ↓.
- **Diastolic Hypertension:** caused by ↑ T.P.R. [1]

Pulse Pressure

- **Definition:** Systolic Pressure (S.P.) - Diastolic Pressure (D.P.)
- e.g. 120-80=40mmHg.
- If stroke volume ↑, pulse pressure ↑.
- If the compliance[2] ↑, pulse pressure ↓.
- In some cases the pulse pressure is not felt but the heart is contracting. This indicates bad contractility of the heart.

Mean B.P.

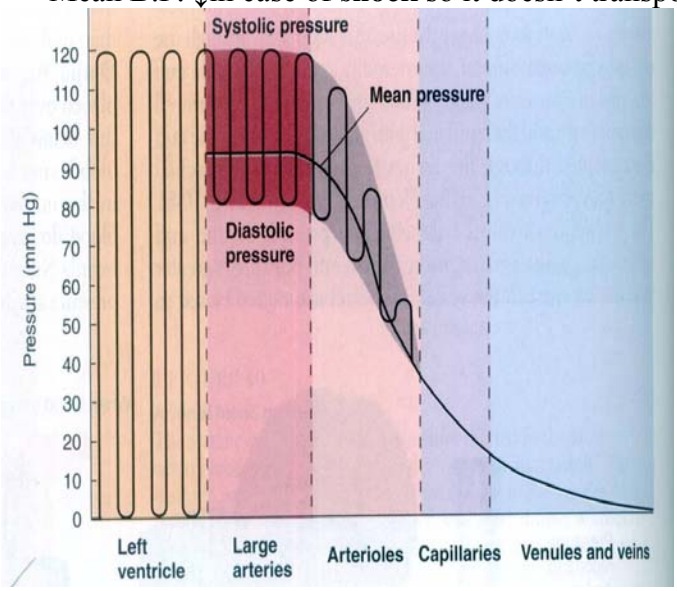
- **Definition:** It is the **average pressure** which **forces the blood to the tissues**. It is **the most important B.P.**.

$$\text{Diastolic B.P.} + \frac{\text{Systolic Pressure (S.P.)} - \text{Diastolic Pressure (D.P.)}}{3}$$

$$= \text{Diastolic B.P.} + \frac{\text{Pulse Pressure}}{3} \quad \text{E.g. } 80 + \frac{40}{3} = 93\text{mmHg}$$

(divided by 3 because diastole is 3 times longer than systole, the number should be nearer to the diastole than the systole).

- **Mean B.P**. is directly **proportional** to **Cardiac Output** & **Total Peripheral Resistance**
- Mean B.P. ↓in case of **shock** so it doesn't transport blood to tissues.



[1] To know more about TPR look at Linda Physiology, 3rd Ed, P.151
[2] Compliance = distensible = قابل للتوسع

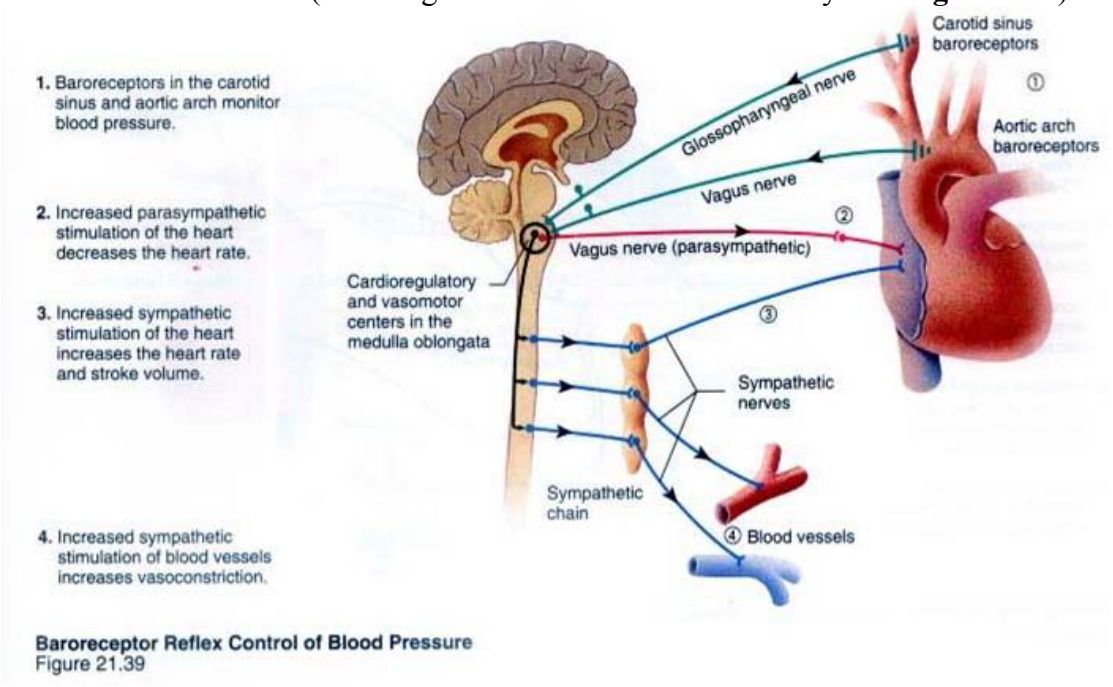
Vasomotor Center:

- The center that controls H.R. & circulation.
- It is found in the medulla of the brain.
- It keeps the vasomotor tone (blood vessels are partially contracted) by sending impulses continuously to sympathetic system.
- It does the action of:
  - Excitation of sympathetic ➔ Constriction of blood vessels
  - Inhibition of sympathetic ➔ Dilatation
- Vasomotor center regulates the B.P. in ms (**rapid control**)
- **Cardioregulatory center:**
  - ↑ heart rate ➔ sympathetic
  - ↓heart rate ➔ parasympathetic

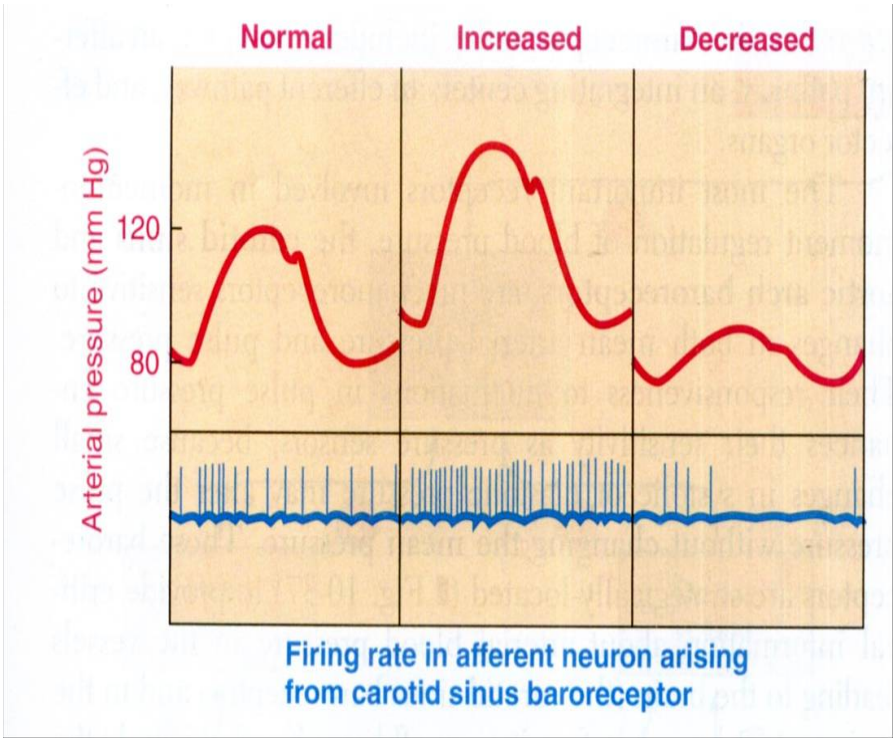
Rapid B.P. Control Mechanism

1. Baroreceptor (pressure receptor):

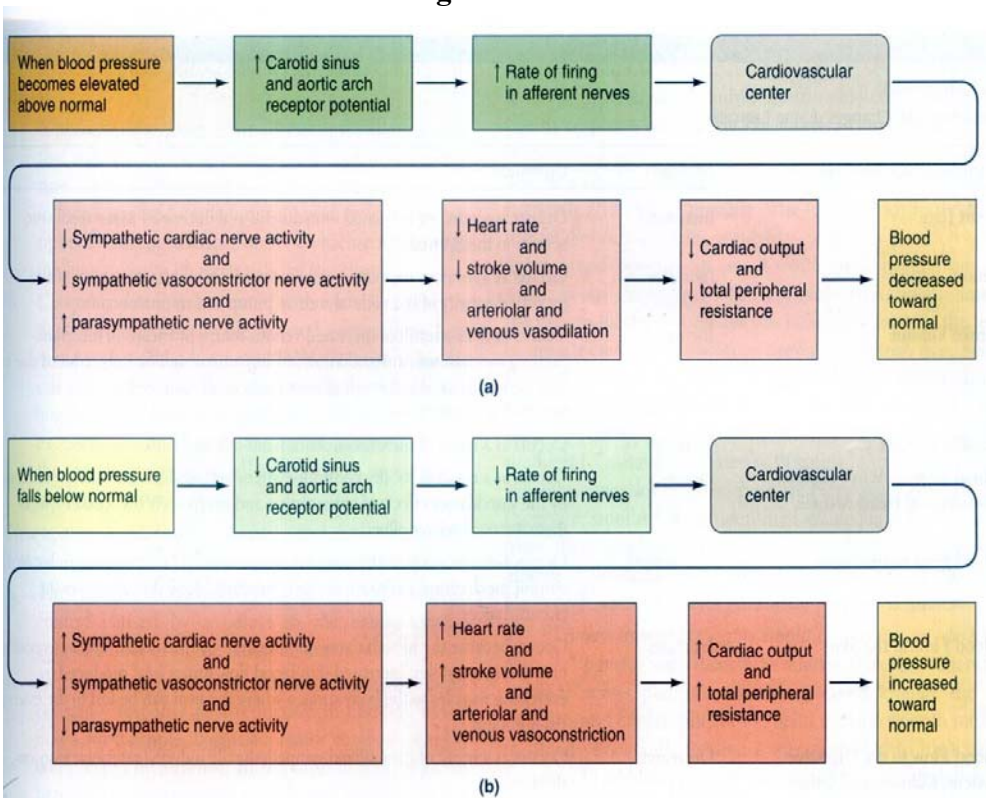
- Are **sensitive** to any change in B.P.
- Are mainly found in:
  - **Carotid sinus** (angle of the jaw) where the carotid artery bifurcates. (sends signals to the vasomotor center via the **Glossopharyngeal nerve**).
  - **Aortic arch** (sends signals to the vasomotor center by the **Vagus** nerve).



Baroreceptor Reflex Control of Blood Pressure
Figure 21.39



- When there is ↑ **in B.P**. the barorecptor will send **signals to vasomotor** center to ↓**H.R.** and **dilate the blood vessels**.
- **Increased signals** from barorecptor causes:
  - **Inhibition** of the vasomotor (**sympathetic**)
  - **Stimulation** of the **Vagus** nerve



2. Low Pressure Receptor (stretch receptor)

- Found in **atria**, large **veins**, and **pulmonary circulation**.
- Stimulated by ↑ **blood volume** causing stretching
- Effects of low pressure receptor stimulation
    1. ↑ **afferent** blood flow to the **kidney** ➔ ↑ GFR[1] ➔ ↑ urine output.
    2. ↓**secretion** of **ADH** hormone.
    3. ↓**aldosterone** secretion.
    4. ↑ atrial natriuretic peptide hormone (**ANP**) secreted by the atria
- **Effects** of low pressure receptor:-
    1. ↑ urine output (↓**water** in blood).
    2. ↑ Na^+ excretion by the kidneys (↓**Na^+** in blood).

3. CNS effects

Any **stress** condition ➔ stimulation to **sympathetic** system ➔ ↑ **H.R.** ➔ ↑**constriction** of blood vessel ➔ ↑ **B.P.**

4. Chemoreceptor:-

↓B.P. (<80 mm Hg) ➔ ↓O_2 ➔ chemoreceptor stimulated ➔ ↑ B.P. ➔ ↑ O_2

- It is **not as sensitive** as the barorecptor.
- Found in the **same places as the barorecptor**.
- They are called **carotid & aortic bodies**.

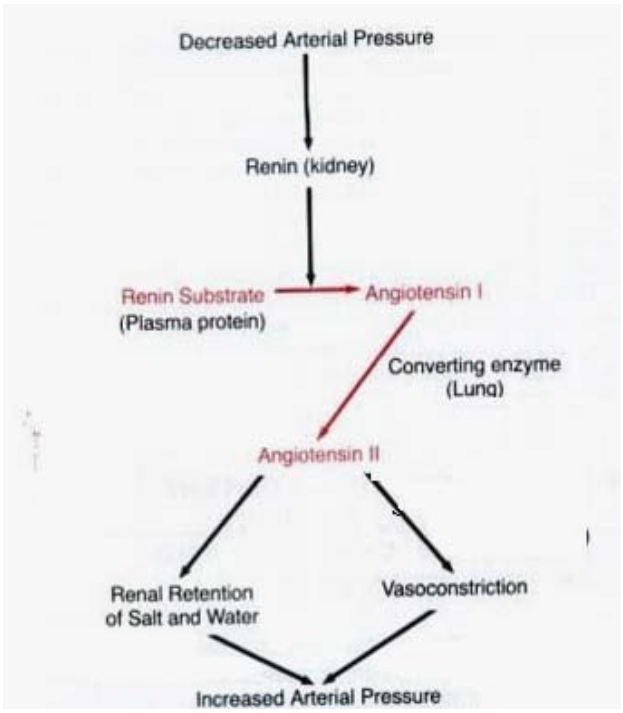
Long Term Regulation of B.P.

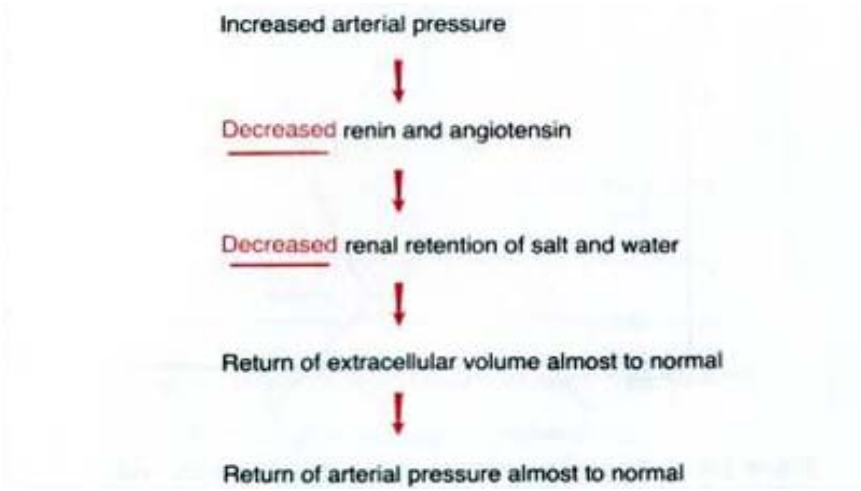
It is used in long term and ***NOT*** rapidly, used when the baroreceptors (short term receptors) get used to the high B.P. so it does not affect the B.P.

Sequence of events

- In case of Hypotension:
    - Angiotensiongen changes to Angiotensin I by **renin** from kidney.
    - Angiotensin I is changed to Angiotensin II by **converting enzymes** from lungs, which will cause:
        - Vasoconstriction ➔ ↑B.P.
        - ↑Aldosterone (which will ↑ sodium and water reabsorption) ➔ ↑B.P.
- In case of hypertension:
    - ↓Renin secretion by the kidneys ➔ ↓angiotensin II
      ➔ ↓aldosterone, ↓ADH secretion, ↑ ANP hormone secretion
      ➔ Na^+ excretion with urine (control of ↑ B.P. by urine output),
      ↓Blood volume ➔ ↓B.P.

[1] GFR stands for Glomerular Filtration Rate. It is the rate of filtration of the kidney.





High B.P. Complications:

- **Left heart failure** ➔ pulmonary edema
- **Renal failure**
- **Stroke** in brain (brain bleeding & clotting) ➔ paralysis.
- **Impairment** of vision.

MICROCIRCULATION

- (micro) because it is **not seen by naked eye**, it should be seen by the microscope.
- The **most important** part of the circulation.

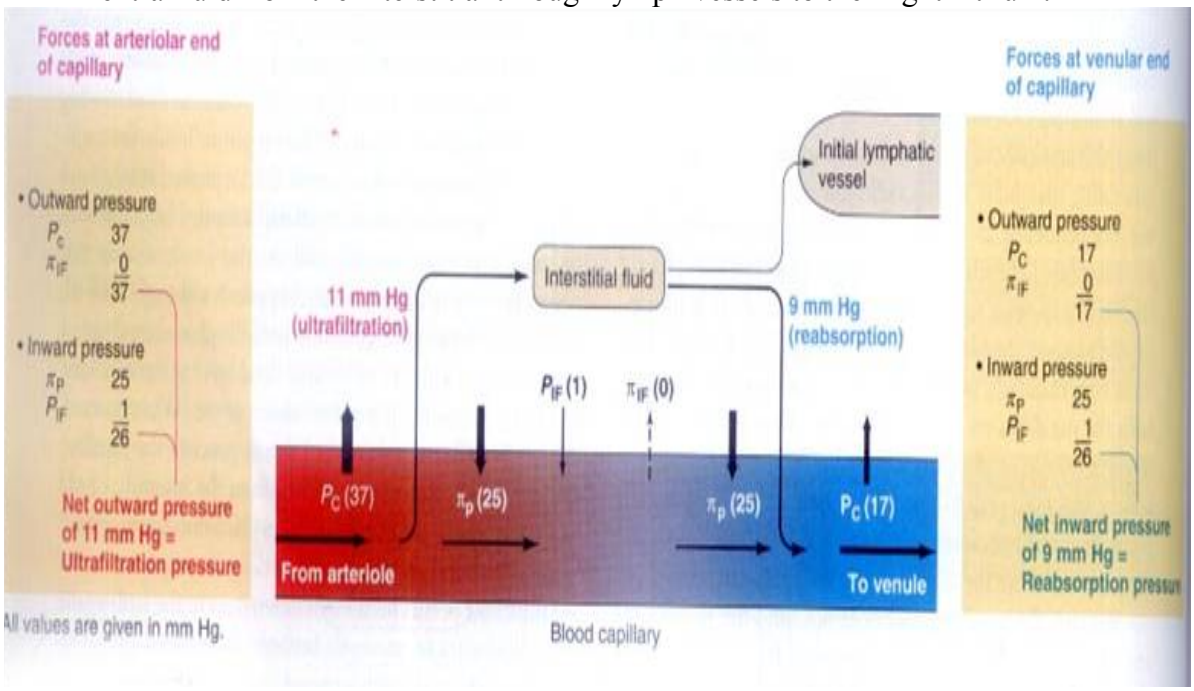
- Starts when the small arterioles enter the tissues and ends when the small venules leaves the tissue.
- Site of exchange of nutrients, electrolytes, and wastes
- Flow is slow to allow exchanging.
- It involves capillaries, arterioles, and venules.
- Very **large surface area** (the largest) in the capillaries, because every cell needs its own exchange of nutrients. (Total surface area of capillaries: 500,000 – 700,000 m^2).

Main Forces in Blood for Fluid Filtration&Reabsorption:

1. **Hydrostatic pressure (filtration pressure):** it makes water leave the capillaries to the interstitial space:
   - When blood enters the arteriole, the B.P. is 37 mmHg (hydrostatic pressure).
   - Filtration will take place in the **arterial** end of the capillaries.
   - Filtration = 37 – 25 – 1 = 11 mmHg
2. **Plasma Colloid Osmotic Pressure (oncotic pressure):** it causes suction pressure or reabsorption pressure (includes inhibition of filtration).
   - When blood leaves through venules, the B.P. is 17 (oncotic pressure is **constant** and ≈ 25mmHg).
   - Reabsorption will take place in the venous end of the capillaries.
   - Interstitial pressure is 1 mmHg & this pressure is hydrostatic pressure **back** to the capillaries.

Role of lymphatics

Lymphatics have an important role in filtration & reabsorption because it takes the extra fluid from the interstitial through lymph vessels to the Right Atrium.



Edema

- Edema is **excessive fluid** that accumulates in the **interstitial space**.
- When there is **high hydrostatic** or **low oncotic pressure**, edema occurs.

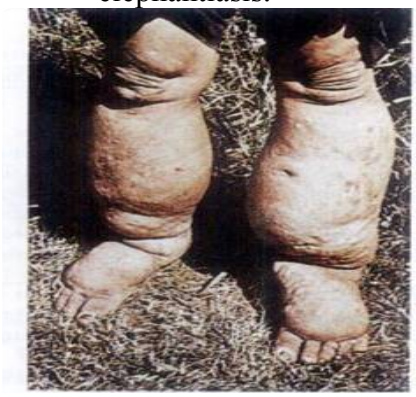
Causes of Edema

- **Retention** (احتفاظ) of salt & water by the kidneys.
- ↑ **venous pressure** ➔ ↑ hydrostatic pressure ➔ Heart failure:
    - If in R.V. ➔ edema in lower limbs & congestion of the liver.
    - If in L.V. ➔ pulmonary edema.

And the ↑ in the venous pressure is caused by:

- Block of veins.
- Standing for a long period because of gravity ➔ ↓venous return ➔ ↑pressure in venules ➔ ↑ filtration ➔ edema in ankle & feet.
- Paralysis (muscle pump fails ➔ edema).
- Immobilization (not moving ➔ edema).

- **Dilatation** of the **arterioles** cause:
    - Failure of the sympathetic nervous system ➔ loss of vasomotor tone.
    - Vasodilator drug (e.g. drugs used for ↓B.P.)
- ↓**plasma proteins** ➔ ↓oncotic pressure . It is caused by:
    - Nephrotic Syndrome: Kidney Disease (nephrosis) ➔ protein excreted in urine (normally no protein in urine).
    - Malnutrtion: not taking protein. (may be due to not eating proteins or to bad absorption of amino acids in the intestines).
    - Liver disease: Liver is the main organ that synthesizes protein (albumin). Liver disease ➔ ↓plasma proteins ➔ edema.
- Increase **capillaries' permeability** ➔ loss of proteins from blood to the interstitial space ➔ ↓oncotic pressure ➔ edema. It is caused by:
    - Burn or Injury.
    - Allergic reaction ➔ ↑ histamine ➔dilatation of capillaries ➔ loss of protein ➔ ↓oncotic pressure ➔ edema.
- **Lymphatic obstruction** ➔ fluid accumulates in interstitial space ➔ edema. It may be caused by:
    - Flaviasis due to nematode (a type of worms that blocks lymphatics) ➔ elephantiasis.



SHOCK

(This part is NOT included in the 2nd physiology quiz on Sat.19/12/1428H)

- It is **sudden drop in B.P. & C.O**. leading to **decreased tissue perfusion** (tissue blood flow).
- Shocked person may be conscious ,unconscious, semiconcious or in coma (غيبوبة).

Symptoms & signs;-

- Very **rapid thready** (ضعيف وسريع) **pulse**.
- ↑ H.R., ↓pulse, ↓contractility.
- **Skin** is **cold** (due to vasoconstriction on the skin), and **wet** (vasodilatation of blood vessels to sweat gland), and undergoes **cyanosis**[1].
- **↓B.P.**
- **↓C.O.**
- **↑ Respiratory rate,**
- **Oliguria**[2]
- **Thirst**.

Causes of shock;

- **Hypovolumic shock** ➔ ↓C.O., ↓B.P. It may be caused by:
  - **Hemorrhage** نزيف (**loss of whole blood**). This is the most common cause.
  - Vomiting, diarrhea, sweat (**loss of plasma**).
- **Cardiogenic** shock (e.g. myocardial infaction).
- **Vasogenic** shock: ↑ widespread (منتشر) **vasodilatation** of blood vessels because:
  - **Septic** shock (**bacterial** infection).
  - **Anaphylactic** shock: secretion of **histamine** due to **allergic** reaction.
- **Neurogenic** shock:
  - Due to **failure of sympathetic** nervous system ➔ loss **of vasomotor tone** ➔ **vasodilatation** ➔ **↓B.P & ↓C.O.**

Stages of shock:

- Non-progressive (**compensated**) stage.
- **Progressive** shock.
- **Irreversible** shock.

[1] Blueness of the skin, and its cause is excessive amounts of deoxygenated hemoglobin in the skin blood vessels

[2] Diminished urine output below the level of intake of water and solutes.

Compensatory mechanism in shock[1]:

a. (The below three mechanisms happen in the first 30 seconds)

1.Baroreceptor:

- barorecptor stimulated ➔ ↑ sympathetic stimulation ➔:
  - ➔↑ vasoconstriction of the arterioles ➔ ↑ TPR ➔ B.P.
  - ➔ venoconstriction ➔ ↑ venous return.

➔ ↑ C.O.

2.Central N.S

Ischemic response. If there are **↓O_2 & ↓blood flow** ➔ another **sympathetic stimulation**. (Last trial depending on sympathetic).

3. Reverse stress relaxation of the circulation system

Blood vessel will contract to contain the small amount of the blood to maintain B.P.

b. Hormonal Mechanism (time of occurrence: 10 min – 1 hour)

1. ↑ **renin** secretion by the kidney (its action is explained above).
2. ↑ **ADH** secretion by posterior pituitary gland. (retention of water &salt ➔ ↑ blood volume ➔ ↑ B.P.

c. Factors ↑ blood volume (time of occurrence: 1hour – 48 hours)

1. ↑ **absorption of water** from the G.I.T.
2. ↑ **reabsorption** of fluid from the interstitial space to the capillaries.
3. ↑ **water intake**, ↑ salt desire (شهوة).

If there is **↓of mean B.P. to 70 mmHg** the **circulation of the heart & brain will not be affected** because thy have minimum sympathetic effect and also excellent autoregulation.

Progressive shock

The situation gets much worse تدهور, and from its effects:

1. **Cardiac depression** because of ↓O_2.
2. **Vasogenic** failure (loss of vasomotor tone).
3. ↑ **intravascular coagulation** (small blood vessels will be blocked because of clots)
4. ↑ **capillary permeability** because of secretion of histamine ➔ vasodilator ➔ ↑interstitial fluid ➔ may cause edema ➔ ↓Blood Volume.
5. **Organs Failure**: Liver, Kidney.

Introduction to treatment,,

- If there is **loss of plasma fluid ➔ transfusing plasma expander**.
- If there is **loss of whole blood ➔ whole blood transfusion**.

[1] If there is 10% loss of blood there is no effect on the body because it will compensate. If there is 35-45% loss of blood the C.O. & B.P. are zero (irreversible shock)