Arterial Blood Pressure & Its Regulation

Black: in male / female slides
Red : important
Pink: in female slides only
Blue: in male slides only
Green: notes
Gray: extra information

Editing File

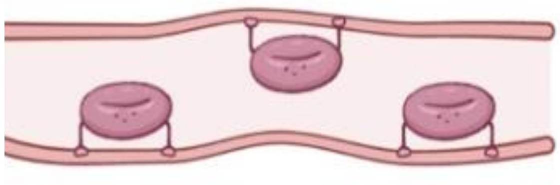
Objectives

- ❖ Concept & definition of blood pressure.
- ❖ Normal values of systolic & diastolic blood pressure.
- ❖ Physiological variations in arterial blood pressure.
- ❖ Pulse & Mean arterial pressures. Factors affecting & determining blood pressure.
- ❖ Relationships between blood pressure, Cardiac Output, & Total Peripheral Resistance.
- ❖ Recognize short, intermediate & long-term regulatory mechanisms of ABP.
- ❖ Recognize different neural & hormonal mechanisms that regulates ABP.
- ❖ Baroreceptors regulatory mechanism of ABP.
- ❖ Chemoreceptors regulatory mechanism of ABP.
- ❖ Role of Kidney in long-term regulation of ABP.

Part 1:
Blood Pressure

Blood Pressure

Introduction:



- **Blood pressure:** the lateral pressure force exerted by the blood flow on the arterial wall against any unit area of the vessel wall. (P=F/A, remember?)
- The force of blood flow is created by the pumping force of the heart.
- Arterial blood pressure (BP) is one of the most important vital signs.
- It is important to keep normal levels of blood pressure for proper blood flow to the body's organs & tissues. (ΔP=QxR)
- Arteries are **pulsatile.** (because their wall is made of thick smooth muscle, it's not fixed)
- **Standard units of BP:** mmHg and sometimes cmH_2O (1mmHg = 1.36 cmH_2O)
  1 ml of mercury pressure= 1.36 centimeters of water pressure because the specific gravity of mercury is 13.6 times that of water, and 1 centimeter is 10 times as great as 1 millimeter.

120 mmHg

Systolic blood pressure (Top Number)

- Arterial pressure recorded during maximum ventricular contraction (maximum contraction of the heart.)

- The **maximum force** exerted by the blood flow against any unit area of the vessel wall **while** the heart is **maximally** contracting (Systole).

80 mmHg

Diastolic blood pressure (Bottom Number)

- Arterial pressure recorded during maximum ventricular relaxation (maximum relaxation of the heart.)

- The **minimum force** exerted by the blood flow against any unit area of the vessel wall **while** the heart is **maximally relaxing** (Diastole).

Normal Arterial Blood Pressure Levels:

Normal Levels are 90–120 mmHg/60–80 mmHg (systolic/diastolic). (It doesn't have a specific value cuz the arteries pulsatile)

- Both numbers are important to determine the state of the heart health
- Greater numbers than the ideal range indicate that the heart is working too hard to pump blood to the rest of the body. Ideal is less than 120/80. At aorta, it's 120/80.

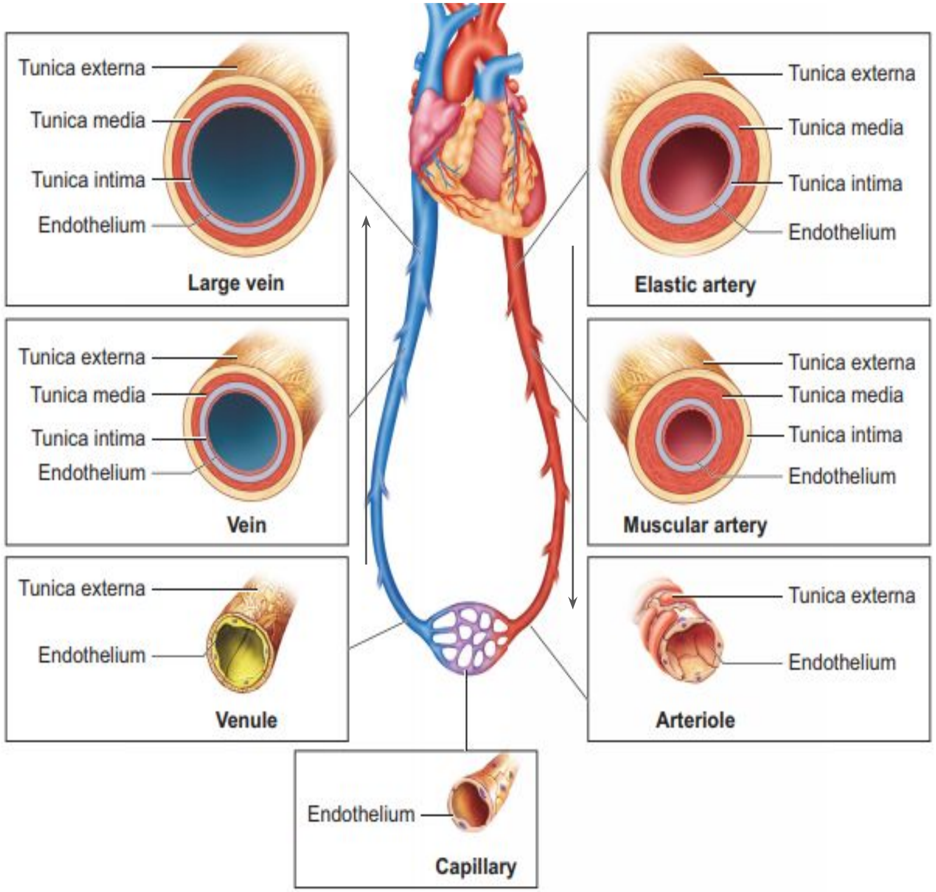
.Types of Blood Pressure

"Depending on the nature of the blood vessels "

- Arterial Blood Pressure.
- Venous Blood Pressure.
- Capillary Blood Pressure.

Pressure Changes Throughout Systemic Circulation

- Blood flows down a **pressure gradient** (the higher the pressure gradient the faster is the flow).
- Pressure is **highest** at the heart (driving Pressure), and **decreases** over distance.
- Pressure decreases more than 90% from aorta to vena cava.
- **Greatest drop** in pressure occurs in arterioles (greatest resistance vessels) which regulate blood flow through tissues.
- No large fluctuations of pressure in capillaries & veins.
- BP averages 120 mmHg in aorta & drops to 2mmHg in Right Atrium.



Videos recommended by doctor:
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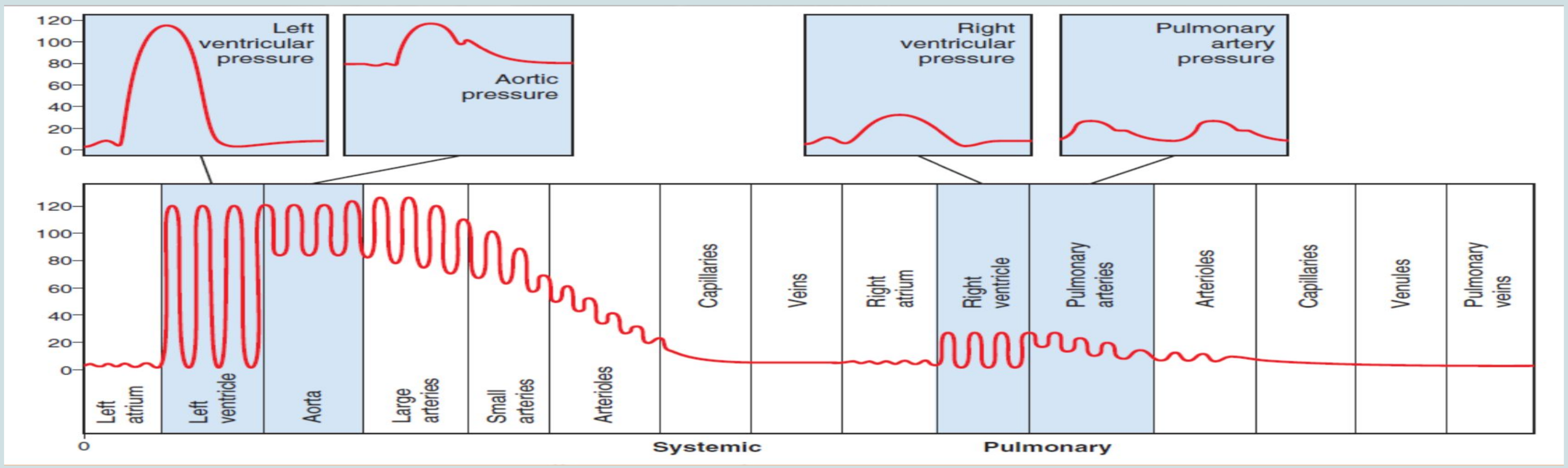
Note:
vaso = arterioles
veno = venules

Blood Pressure Changes



From Guyton

Note at the far right side of the **Figure** the respective pressures in the different parts of the pulmonary circulation. In the pulmonary arteries, the pressure is pulsatile, just as in the aorta, but the pressure is far less: pulmonary artery systolic pressure averages about 25 mm Hg and diastolic pressure averages about 8 mm Hg, with a mean pulmonary arterial pressure of only 16 mm Hg. The mean pulmonary capillary pressure averages only 7 mm Hg. Yet, the total blood flow through the lungs each minute is the same as through the systemic circulation.the low pressures of the pulmonary system are in accord with the needs of the lungs because all that is required is to expose the blood in the pulmonary capillaries to oxygen and other gases in the pulmonary alveoli.

Explanation:

LV BP = 120/2
AORTIC BP=120/80

ليه هذا الاختلاف ؟
لان عند أعلى قيمة للانقباض aortic valve يفتح ويصير الـ LV و aorta

= one chamber = 120

لكن عند أعلى قيمة للانبساط يقفل valve الضغط داخل الـ LV ينزل الى مايوصل 2
لكن بال aorta مايقدر ينزل اكثر من 80 لان الدم رايح لل systemic circulation it's not a closed chamber

Pulse and Mean Arterial Pressures

- Arterial pressure is pulsatile, so a single value is used to represent the overall driving pressure. This is called the **Mean Arterial pressure (MAP)**. Pulsatile means it have muscle thickness makes it palpable; that's why the ABP fluctuates.
- Mean arterial pressure is a better indicator of perfusion to the vital organs than systolic blood pressure.
- It's responsible for driving blood into the tissues throughout the cardiac cycle.

Mean Arterial Blood Pressure=

Diastolic Pressure + ⅓(Pulse Pressure)

Pulse Pressure =Systolic-Diastolic

OR

⅓Systolic BP + ⅔Diastolic BP

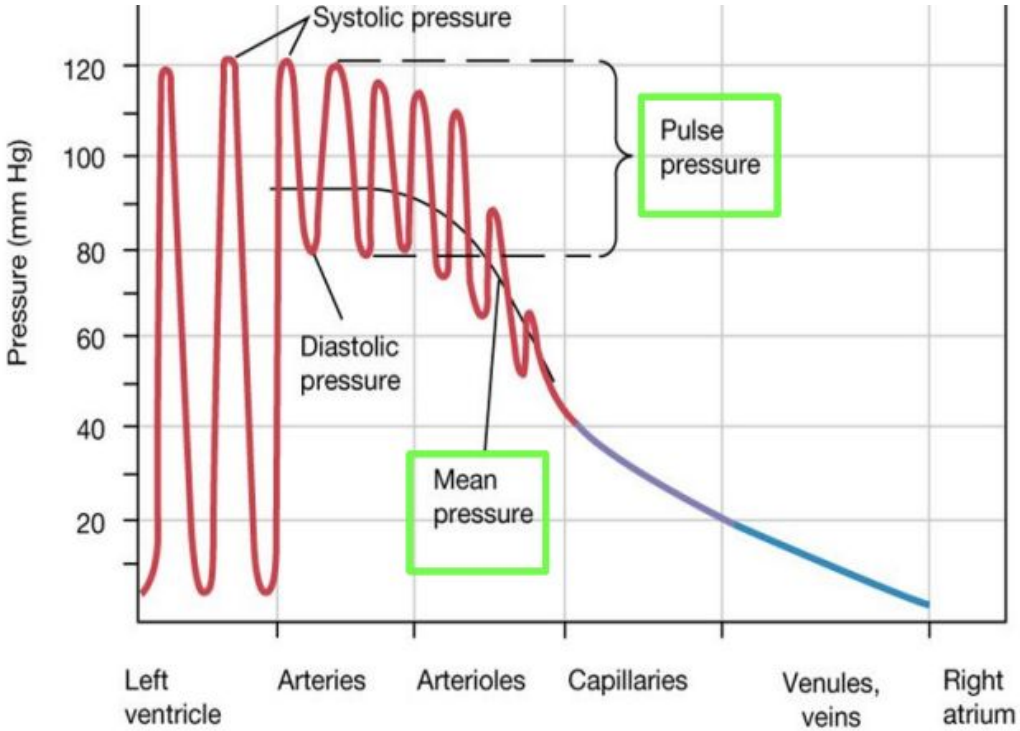
Example

If a patient's blood pressure is 83/50 mmHg, his MAP would be 61 mm Hg.

MAP = 1/3 (SBP - DBP) + DBP
= 1/3 (83-50) + 50
= 1/3 (33) + 50
= 11 + 50
= 61 mm Hg

Another way:

MAP = SBP + 2 (DBP)/3
MAP= 83 +2 (50) /3
MAP = 83 +100/3
MAP = 61



Range & Variations In Arterial BP Levels

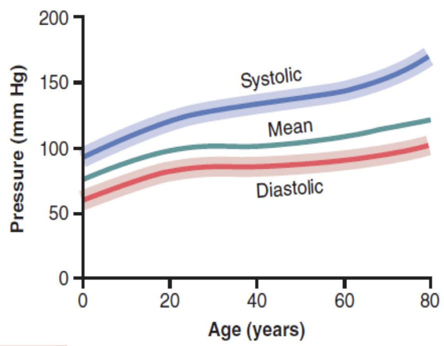
Blood Pressure Category	Systolic		Diastolic
Normal	<120	and	<80
Elevated (prehypertension)	120-129	**and**	<80
High Blood Pressure (Hypertension) Stage 1	130-139	**or**	80-89
High Blood Pressure (Hypertension) Stage 2	140 or Higher	or	90 or Higher
Hypertensive Crisis (consult your doctor immediately)	Higher than 180	and/or	Higher than 120

Value	Old Guidelines	New Guidelines
<120	normal	normal
120-129	high normal	elevated blood pressure
130-139	high normal	stage 1 hypertension
140 or Higher	hypertension	stage 2 hypertension

Physiological Factors Affecting Arterial Blood Pressure

Sex Male > Female But equal at menopause up to age of 40 years males have higher arterial Age: values than women, becoming lower than women after age 50	**Age** BP ↑ with Age (diabetes, atherosclerosis..)	**Body Mass Index** BP ↑ with body size	**Race** Dietary factors, stress	**Pregnancy** BP ↑ due to ↑ metabolism	**Sleep** BP ↓ due to ↓ venous return

Exercise BP ↑ due to ↑ venous return	**Emotions** BP ↑ due to Neuronal & hormonal factors	**Hormones** EPI, NE and Thyroid H ↑ BP	**Gravity** BP ↑ in lower limbs than upper limbs	**Temperature** BP↓ with heat due to vasodilation &↑ with cold due to vasoconstriction



nd Hall, pp 183 Changes in systolic, diastolic, and mean arterial pressures with age. The shaded areas show the approximate normal ranges.

From Guyton

A slight extra increase in systolic pressure usually occurs beyond the age of 60 years. his increase results from decreasing distensibility, or "hardening," of the arteries, which is often a result of atherosclerosis. The final effect is a higher systolic pressure with considerable increase in pulse pressure, as previously explained.

Note that the mean pressure (solid green line) at all ages is nearer to the diastolic pressure than to the systolic pressure. However, at very high heart rates, diastole comprises a smaller fraction of the cardiac cycle and the mean arterial pressure is more closely approximated as the average of systolic and diastolic pressures.

Factors Determining Arterial Blood Pressure (MAP)

Only in female slide Except the definition of CO

Blood Pressure = Cardiac Output x Peripheral Resistance

team 436: If one of these factors are missing then there will be NO blood pressure.

1. Cardiac Output (Flow)

The amount of blood pumped by each ventricle in 1 minute.average: 4900-5000

Determined by :

1-stroke volume

2-heart rate

CO = Stroke volume(SV) x Heart rate(HR)

Note that Any increase in the (SV)or (HR)will increase the CO which will eventually increase the arterial blood pressure

2. Peripheral Resistance

Depends on:

1- size of the blood vessel (r)

2- blood viscosity/thickness (η)

3- length of blood vessels (L) remains constant so we can ignore it

Note that any increase in Peripheral Resistance will eventually increase the arterial blood pressure

3. Blood Volume

Depends on:

1- Fluid intake

2- Fluid loss

Note that any increase the Blood volume will eventually increase the arterial blood pressure

Final Note : أي تغيير في العوامل الي تؤثر على العوامل المؤثرة على ضغط الدم راح يأثر على ضغط الدم we will discuss that in the next slides

Regulation of Cardiac Output

Only in female slide Except the definition of SV

Cardiac Output= Stroke Volume x Heart Rate

CO is regulated by:
i) Regulation of stroke volume (SV)
ii) Regulation of Heart Rate

i) Regulation of Stroke Volume (SV)

Stroke Volume = EDV – ESV

Stroke volume : The Amount of blood ejected from each ventricle with each contraction. 70-80 ml/beat.

Stroke volume (SV) is regulated by 3 variables:

1.End Diastolic Volume (EDV):
Affected by the preload (venous return).

2. End Systolic Volume (ESV):
a) Contractility (strength of contraction):
Affected by Starling's law & sympathetic innervation.
b) Total peripheral resistance (afterload).

End diastolic volume ≠ preload
preload (VR) is **all** the blood returning to the heart.
End diastolic volume is the amount of blood that fully fills the ventricle up.

1. Factors Affecting End-Diastolic Volume

End-diastolic pressure is affected by the preload (venous return) which is affected by:
1. Blood volume.
2. Pressure gradient
3. Gravity.
4. Veno-constriction: caused by sympathetic nervous system.
5. Presence of valves in the large veins.
6. Skeletal muscles pump.
7. Respiratory activity (breathing).

2. Factors Affecting End-Systolic Volume

a) Cardiac contractility:
Intrinsically affected by: end diastolic volume (EDV) & Frank Starling's law of the heart.
Extrinsically affected by sympathetic stimulation, hormones and drugs.

↑↑ contractility → ↑↑ SV → ↓↓ ESV
↓↓ contractility → ↓↓ SV → ↑↑ ESV

(Starling's Law: the more the cardiac muscle is stretched, the stronger the contraction)

b) Total Peripheral Resistance (Afterload=MAP):
In response to all regulatory mechanisms

↑↑ resistance (Vasoconstriction)→ ↓↓ Flow → ↓↓ SV → ↑↑ ESV
↓↓ resistance (Vasodilatation) → ↑↑ Flow → ↑↑ SV → ↓↓ ESV

Only in female slide Except the definition of HR

Regulation of Cardiac Output

Cardiac Output= Stroke Volume x Heart Rate

CO is regulated by:
i) Regulation of stroke volume (SV)
ii) **Regulation of Heart Rate**

ii) Regulation of Heart Rate

Heart rate: The number of contractions of the ventricles each minute.
Normal heart rate (HR) = 60-100 beats/min
If > 100 beats/min → Tachycardia
If < 60 beats/min → Bradycardia

Heart Rate is regulated by:

1. **Autonomic Nervous System**
2. **Hormones/Drugs**

1. Autonomic Nervous System

Sympathetic nerves → increase HR
Parasympathetic nerves (vagus nerve)→slow HR.

HR is regulated by autonomic nervous system through **cardiac control centers** in medulla oblongata in the brain stem:
1- Cardiac-accelerator Center (Vasomotor center)
Sympathetic nerve fibers
Function :

1. increase HR
2. increase cardiac contractility (ventricular contractility not atrial since ventricles are the actual pumps).
3. vasoconstriction
4. adrenal medulla release of adrenaline and noradrenaline

2- Cardiac-inhibitory Center
Parasympathetic nerve fibers
Function:

1. Decrease HR (ONLY one function)

**note that they never function at the same time; one is stimulated and the other is inhibited (not blocked).

2. Hormones/Drugs

Epinephrine & thyroxine→ increase HR.
Decrease blood calcium→ decreases HR.

Sympathetic, drugs, and parasympathetic affect **HR**

Only sympathetic and drugs affect **contractility**
(parasympathetic has no effect on contractility)

Regulation of Cardiac Output

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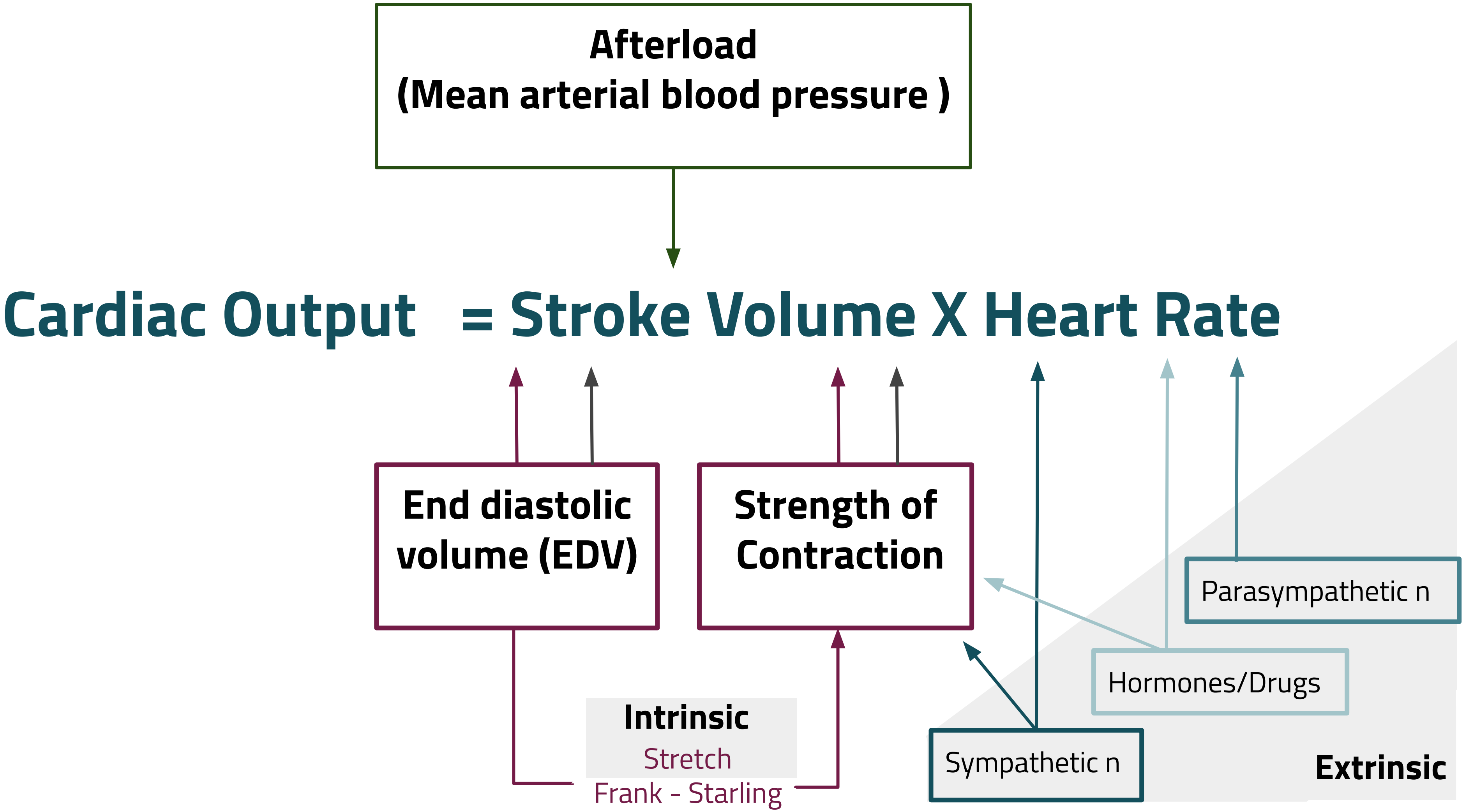

Starling's law of the heart – the more the cardiac muscle is stretched, the stronger the contraction

(we will discuss resistance here)

Blood Flow

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From guytone : the blood flow to body according to tissue's needs, tissue needs more blood flow when they are active. Most tissues "autoregulate" their own blood flow 'permits blood flow from one tissue to be regulated independently of flow to another tissue' .

Blood flow(Q) is the amount of blood moving through a vessel in a given time period.

Generally is equal to the Cardiac output (CO=Q).

Blood flow has 2 equations:

1.

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

2. Poiseuille's Law:

$$Q = \frac{(Pi-Po)\pi r^4}{8\eta L}$$

Flow and Poiseuille's Law

Fluid Flow (Q) through cylindrical tubes.

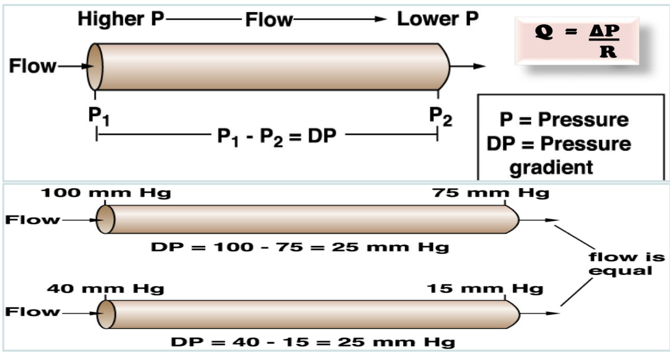
Flow ↓ when resistance ↑.
Flow **resistance** ↓ when vessel diameter ↑.

(Pi-Po)=ΔP: difference in pressure (direct relationship) **R:** Resistance. **r:** radius (direct). **η:** Viscosity (inverse). **L:** Length (inverse).

Pressure Difference

Pressure difference: the driving pressure in a vascular system (i.e. driving pressure/pressure gradient).
Pressure difference is directly proportional to the flow

Blood flows down a pressure gradient
Absolute value of pressure is not important to flow, but the difference in pressure (DP or gradient) is important to determining flow.



From guytone : pressure between the two ends of the vessel that provides the driving force for flow

pressure gradient is much lower in pulmonary circulation than that in the systemic circulation but the blood flow is the same .

Resistance

Resistance: tendency of vascular system to oppose flow.

Resistance is Inversely proportional to the flow (Flow = 1/R)

According to Poiseuille's Law **R = 8ηL/πr4**,
so **Resistance is influenced by:**

1. Radius of the tube (**r**)
2. Viscosity of the blood (**η**)
3. Length of the tube (**L**)

In a normal human, length of the vascular system is fixed, so blood viscosity & radius of the blood vessels have the largest effects on the resistance.

*Effect of Radius (r) & Pressure on Flow

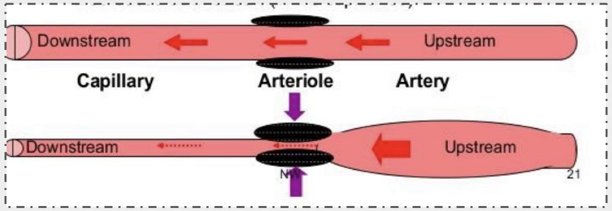
*Only in female slide

Radius with flow

Directly proportional to flow.

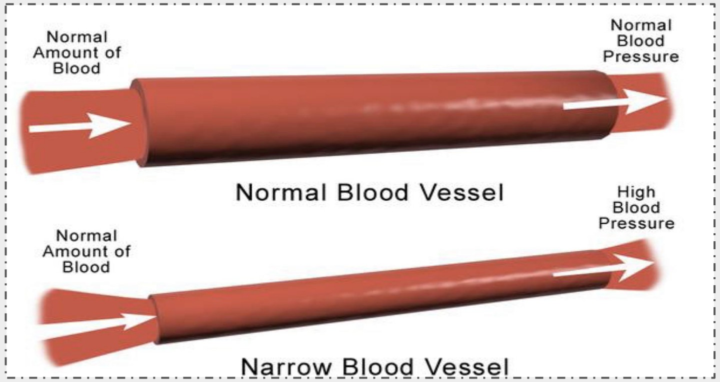
Vascular tone - effects

- ❖ Increased tone in a segment of blood vessel e.g increased arteriolar tone.
- ❖ Decreased radius of arteriole.
- ❖ Greatly increased blood across the arteriole
- ❖ The effect on blood volume
  - Increased upstream (in artery).
  - Decreased downstream (in capillaries).



Radius with pressure

Inversely proportional to pressure

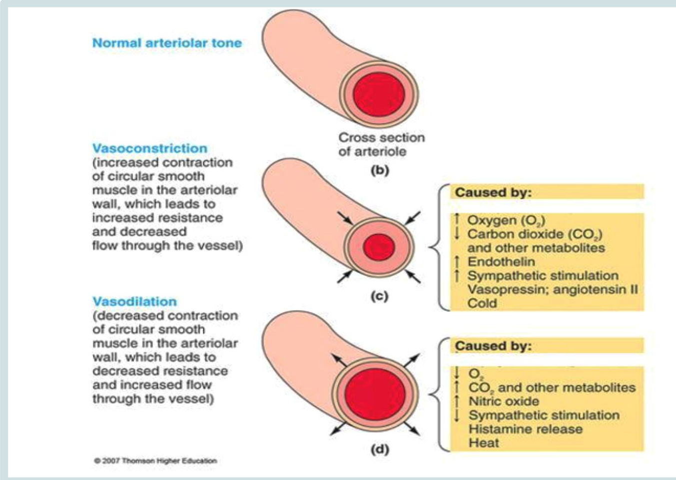


Factors Affecting Vessel Diameter: Radius (r)

Vasodilator Agents	
CO2 & other metabolites	Histamine
Nitric Oxide (NO)	Prostacyclin (PGI2)
Atrial Natriuretic Peptide (ANP)	

Radius of vessel ⬆️ = blood flow ⬆️ & the peripheral resistance and the pressure decreased

Vasoconstrictor Agents	
Oxygen (O2)	Endothelin-1
Vasopressin (also called ADH)	Thromboxane A2
Angiotensin II	Norepinephrine
Cold	



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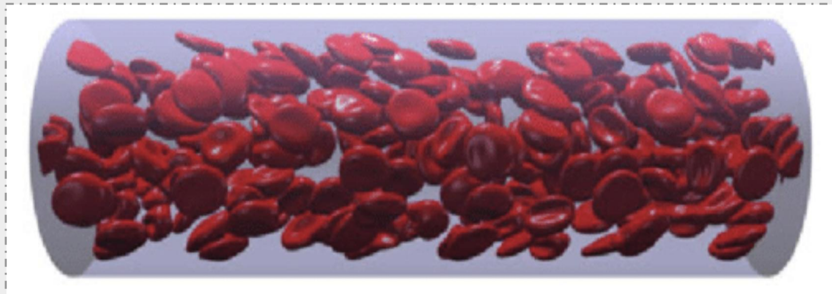
Effect of Viscosity & Length on Flow

Effect of Viscosity (η) on flow

- Blood viscosity is the thickness & stickiness of the blood.
- Human blood is five times more viscous than distilled water.
- It is an important factor that determines the resistance of blood to flow.
- Viscosity of the whole blood is mainly due to cells, & that of plasma is due to plasma proteins.
- **Viscosity is inversely proportional to the flow.**

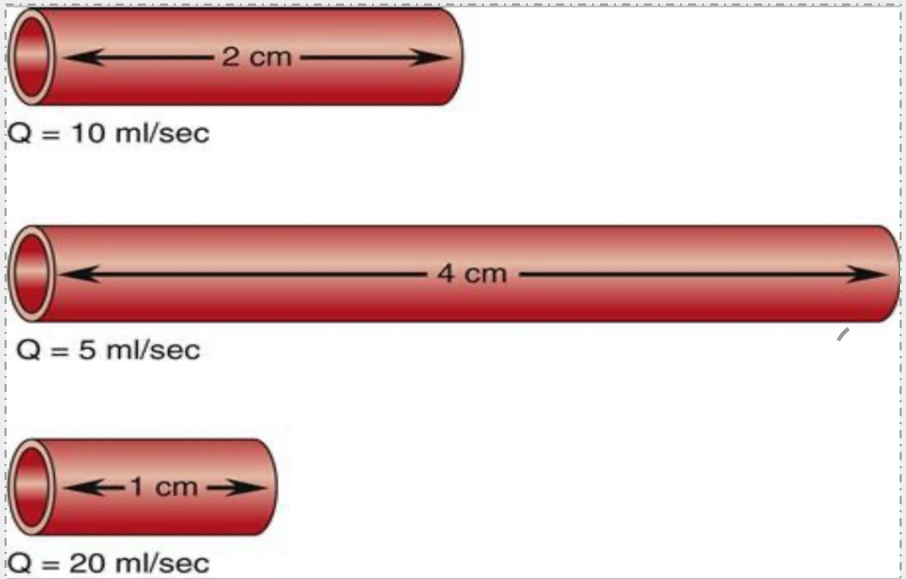


viscosity increases as plasma decreases as a result of sweating,diarrhea,vomiting.

Effect of Length (L) on flow

- **Length is inversely proportional to the flow.**

N.B. In a normal human, length of the vascular system is **fixed** (cannot change).



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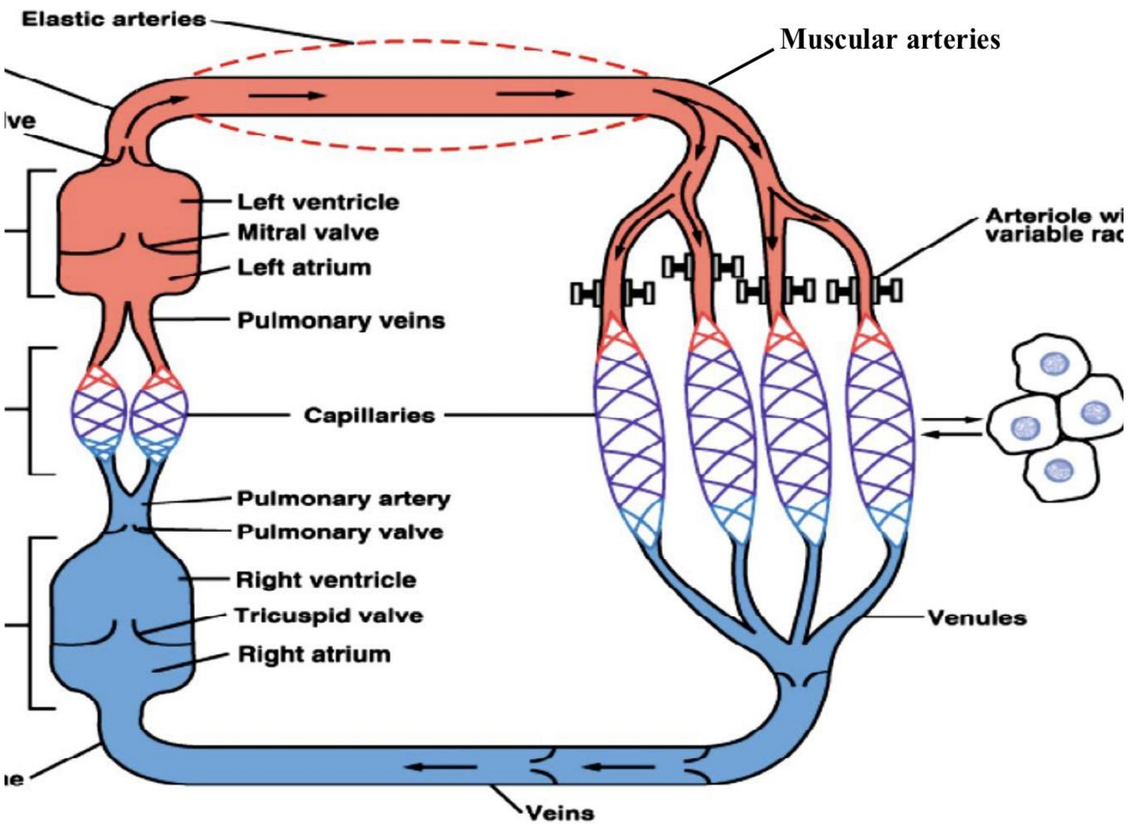
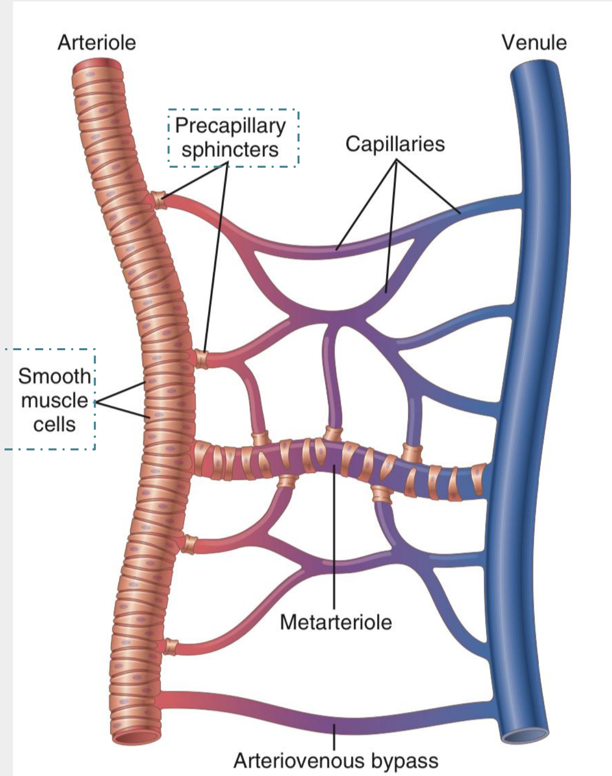
Vascular system possesses different mechanisms for promoting continuous flow of blood to the capillaries

Elastic recoil | Smooth-m regulation of Diameter | Sphincter | Valves

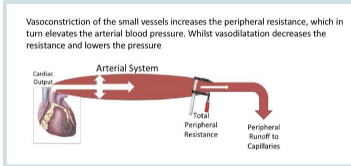




Extra picture for clarification

Explanation:
With these factors we can ensure continued blood flow which may need adjustments like increase the blood flow or decrease it which's done by ex: vasodilator agents

Total Peripheral Resistance (TPR)

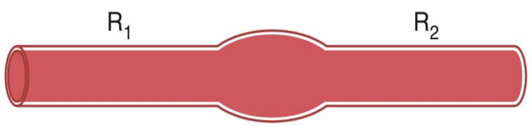
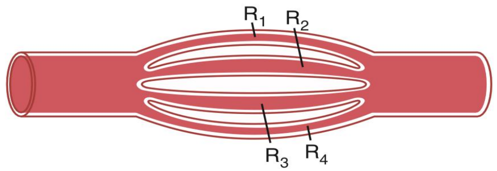


Affecting factors: $R = \frac{\Delta P}{Q}$

Systemic Circulation	Pulmonary Circulation
TPR= $\frac{\text{Aortic Pressure - RAP}}{\text{Flow (Q)}}$	**PulR=** $\frac{\text{Pulmonary Pressure - LAP}}{\text{Flow (Q)}}$
TPR= $\frac{\text{120 - 2 mmHg}}{\text{83.3 ml/sec (5 L/min)}}$	**PulR=** $\frac{\text{15 - 3 mmHg}}{\text{83.3 ml/sec (5 L/min)}}$
TPR= 1.2,1.41 (PRU's)	**PulR= 0.12 , 0.14 (PRU's)**
RAP= Right Atrial Pressure PRU= Peripheral Resistance Units	LAP= Left Atrial Pressure Pul R= Pulmonary Resistance

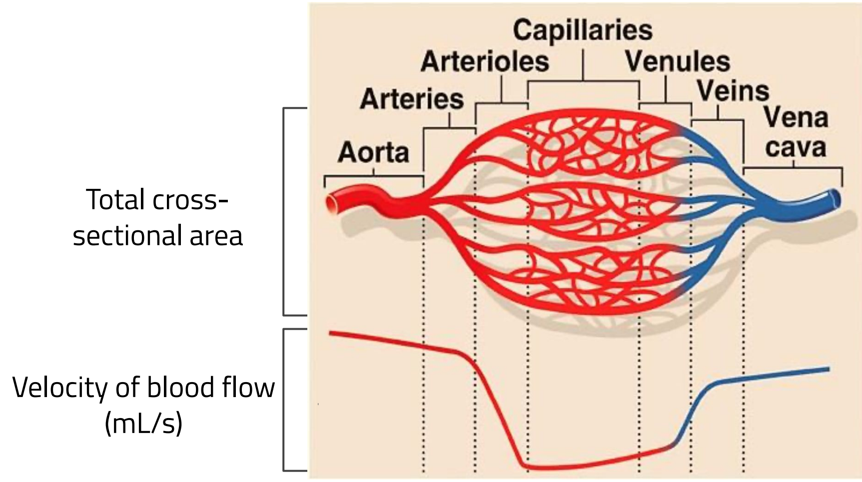
Basically, resistance of the systemic circulation is MUCH higher than that of the pulmonary circulation. This is because the systemic circulation has a larger pressure difference so it has a larger resistance.

Resistance to Flow in Cardiovascular System "Basic Concepts"

Series Resistance	Parallel Resistance
$R_{Total} = R_1 + R_2 + R_3$	$\frac{1}{R_{Total}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$
	
Higher Resistance (Arterioles)	**Lower Resistance (Capillaries)**

Cross- Sectional Area

- **As diameter of vessels ↓:**
  - total cross-sectional area↑ & velocity of blood flow ↓
- The velocity of blood flow within each segment of the circulatory system is inversely proportional to the total cross-sectional area of the segment. Because the aorta has the smallest total cross-sectional area of all circulatory segments, it has the highest velocity of blood flow.
- The diameter of a single capillary is quite small, the number of capillaries supplied by a single arteriole is so great that the total cross- sectional area available for the flow of blood is increased. Hence, the pressure of the blood as it enters the capillaries decreases.



Girl's dr : delete this slide Because it is confusing

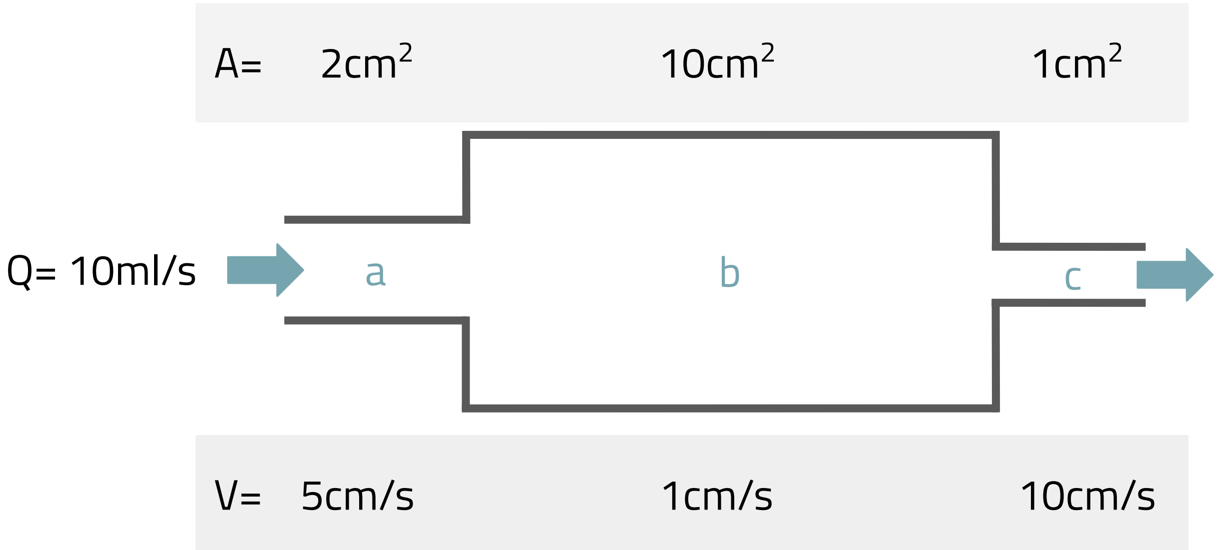
Velocity

$$V = \frac{Q}{A}$$

V= Velocity;

Q= Flow;

A= Cross Sectional Area



Recall that when the flow rate at one point is equal to another, the velocity and area at both points will be equal.
Q1=Q2 -> A1V1=A2V2

Compliance of Blood vessels

- Compliance = Distensibility.

- Compliance is the volume of blood that the vessel can hold at a given pressure.

- Venous system has a large compliance & acts as a blood reservoir (high volume & low pressure)

- **Venous** system has the **highest compliance**, while the arterial system has a low compliance..
- Elasticity of blood vessels: Changes in the elasticity of large vessels affects ABP.In atherosclerosis, decrease in arterial compliance ("hardening of the arteries"). This makes arteries like a tube, during systole, blood is ejected into the arteries, they don't distend as normal and pressure increases significantly PP.

Compliance

Only in female slide

$$C = \frac{V}{P}$$

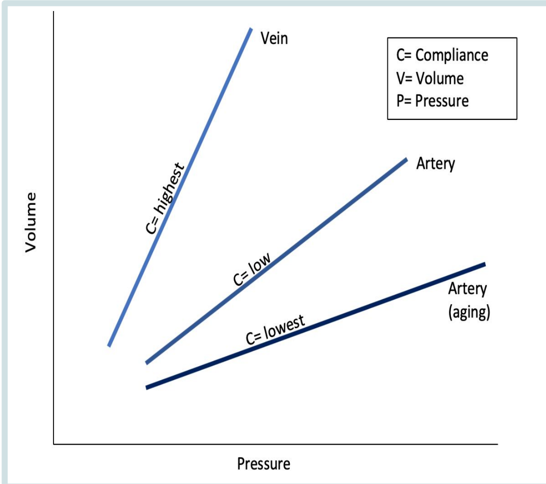
V= volume;

C= compliance;

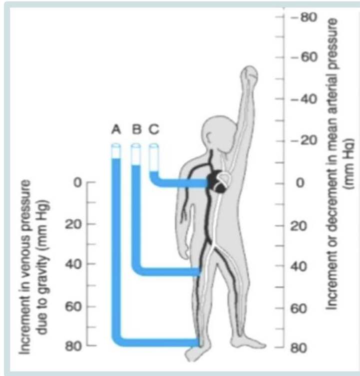
P= pressure

From this figure you can know that
Veins : have the highest volume value with lowest pressure value this is the cause of the **highest compliance** in the **venous system** .

Veins of systemic circulation and the pulmonary circulation have the same compliance, in contrast arteries of the systemic circulation have less compliance compared to arteries of pulmonary circulation

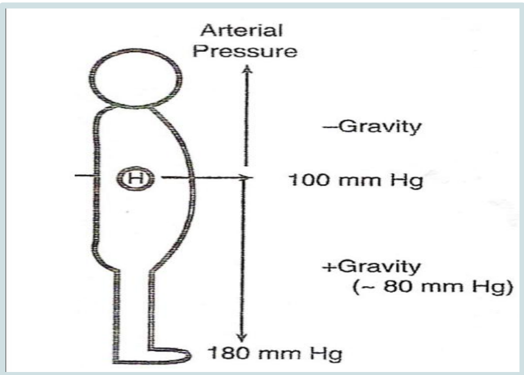


Effect of Gravity on Blood Pressure



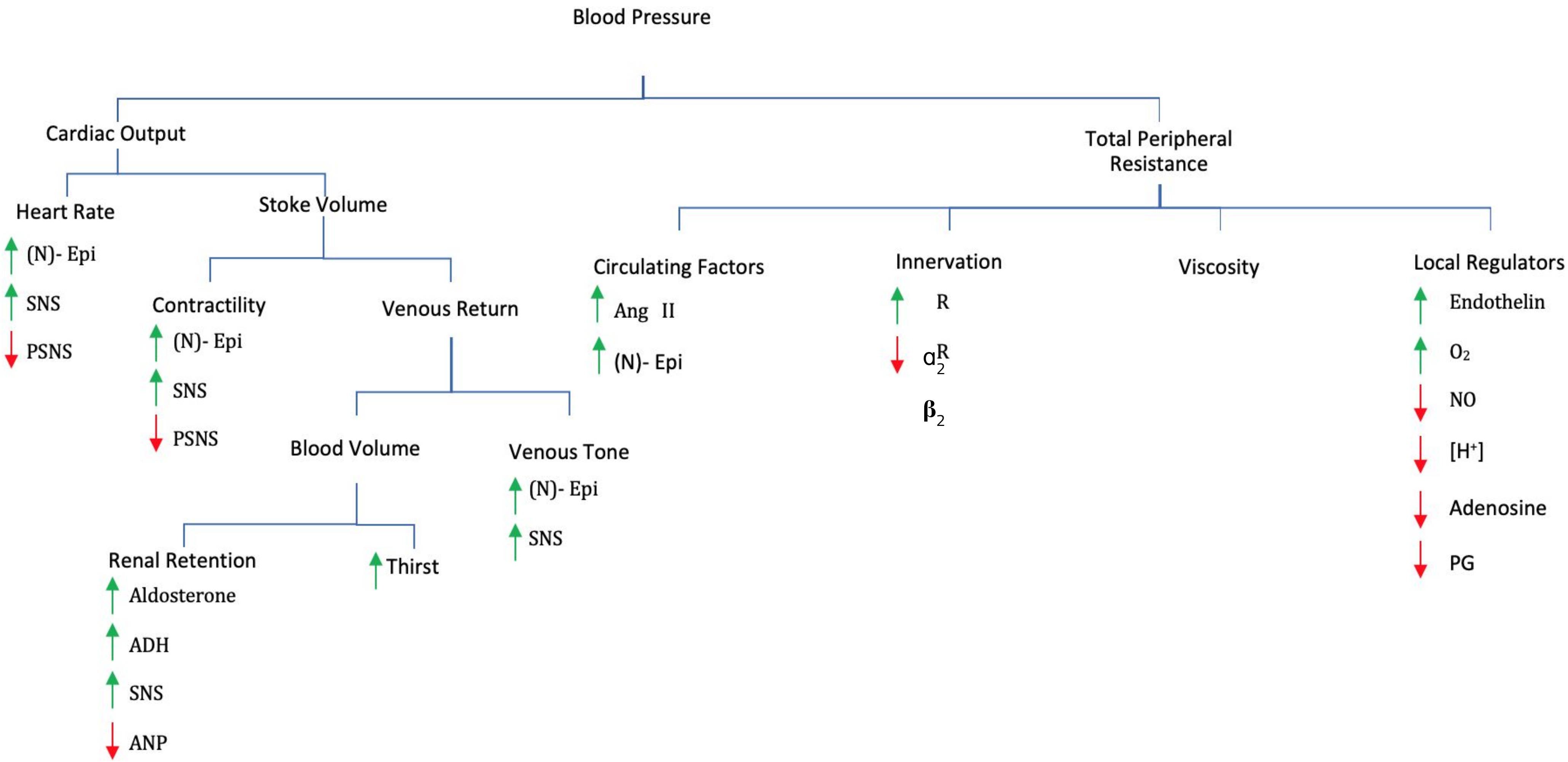
- The pressure in any vessel below the level of the heart is increased.
- Decreased in any vessel above the level of the heart due to the effect of Gravity.
- Gravitational effect = 0.77 mmHg/cm at the density of normal blood.
- In an adult human in the upright position, if mean MAP at heart level = 100 mmHg, the MAP in an artery at the head (50 cm above heart) = 100- [0.77X 50] = 62 mmHg.

Do you miss the Respiratory Block? yeah me too..



Above heart level
50cm = 100 – [0.77 X 50] = 62 mm of Hg
1cm = 0.77 mm of Hg
Below heart level
105cm = 100 + [0.77 X 105] = 180 mm of Hg

Summary: Physiological Factors Affecting Arterial Blood Pressure



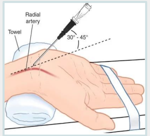
When BP increase everything in this chart takes effect

Found only in male slides

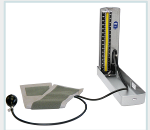
Measurement of Blood Pressure

Methods:

1- Direct (Arterial Catheter)



2- Indirect (Stethoscope & Blood pressure cuff)



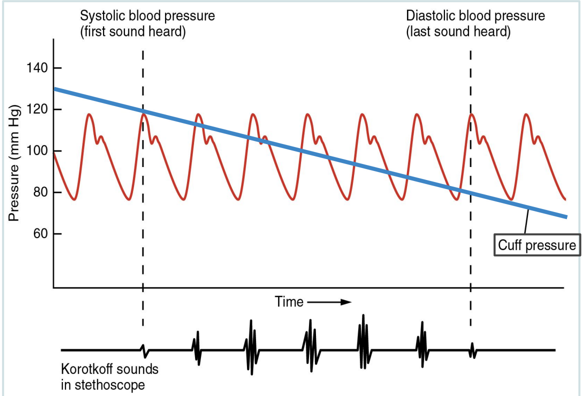
Sphygmomanometers

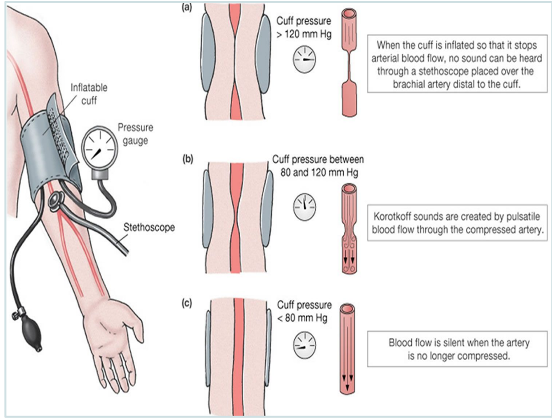
Types:
- Mercury sphygmomanometer
- Aneroid equipment
- Automatic equipment

Cuff sizes:
- **Small** (Children and small adults(Average)
- **Large** (Overweight and large adults)

BP is measured by listening for **Korotkoff sounds produced** by turbulent flow in arteries:

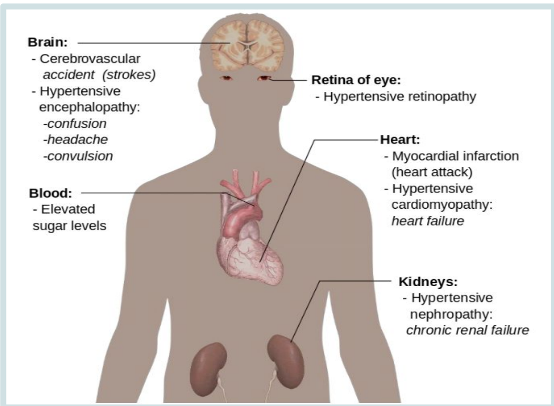
- Systolic pressure: 1st sound
- Diastolic pressure: last sound





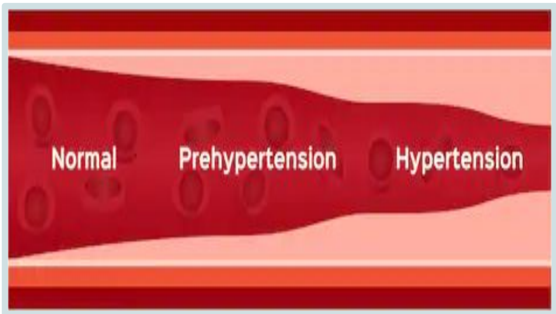
Causes of Hypertension

- Excess body weight
- Diabetes
- Dietary factors
- Smoking
- Family history



Clinical Features of Hypertension

- May be asymptomatic
- Headache
- Dizziness - Confusion
- Shortness of breath
- Nausea - Vomiting
- Chest discomfort
- Visual disturbance
- Sleepiness



Part 2: Regulation

Congratulations! You're more than halfway done. :)

Regulation of Arterial Blood Pressure

❖ Maintaining BP is important to ensure a steady blood flow (perfusion) to the tissues.

❖ Inability to regulate blood pressure can contribute to diseases.

❖ In order to regulate the blood pressure, determining factors should be regulated:
- **Cardiac Output (CO)**
- **Peripheral Resistance (PR)**
- **Blood Volume**

Mechanisms Regulating Mean Arterial Blood Pressure

1 Neurally-Mediated **Fast Response (short-term)**
- Concerned in regulating **CO** and **PR**
- 1-Baroreceptors Reflex (excitatory + inhibitory)
- 2-Chemoreceptors Reflex (excitatory)
- 3-CNS ischemic response (excitatory) so FAST
- **Other vasomotor reflexes:**
  - ❖ Atrial Stretch ReceptorReflex (Inhibitory)
  - ❖ Thermo-receptors (excitatory + inhibitory)
  - ❖ Pulmonary Receptors (excitatory)

2 **Intermediate**
- Angiotensin Vasoconstriction System(excitatory)
- ADH Vasoconstriction System
- Fluid Shift Mechanism. (excitatory + inhibitory)
- Stress-Relaxation Mechanism (Inhibitory)

3 **Long-term (slow response)** (endocrine mechanism)
- Aldosterone System(excitatory)
- Vasopressin (or ADH)(excitatory)
- Natriuretic peptide(Inhibitory)
- Erythropoietin(excitatory)

From guytone: Local tissue blood flow control can be divided into two phases: (1) acute control and (2) long-term control. Acute control occurs within seconds to minutes via constriction or dilation while the Long-term control occurs over a period of days, weeks, or even months and, in general, provides even better control.

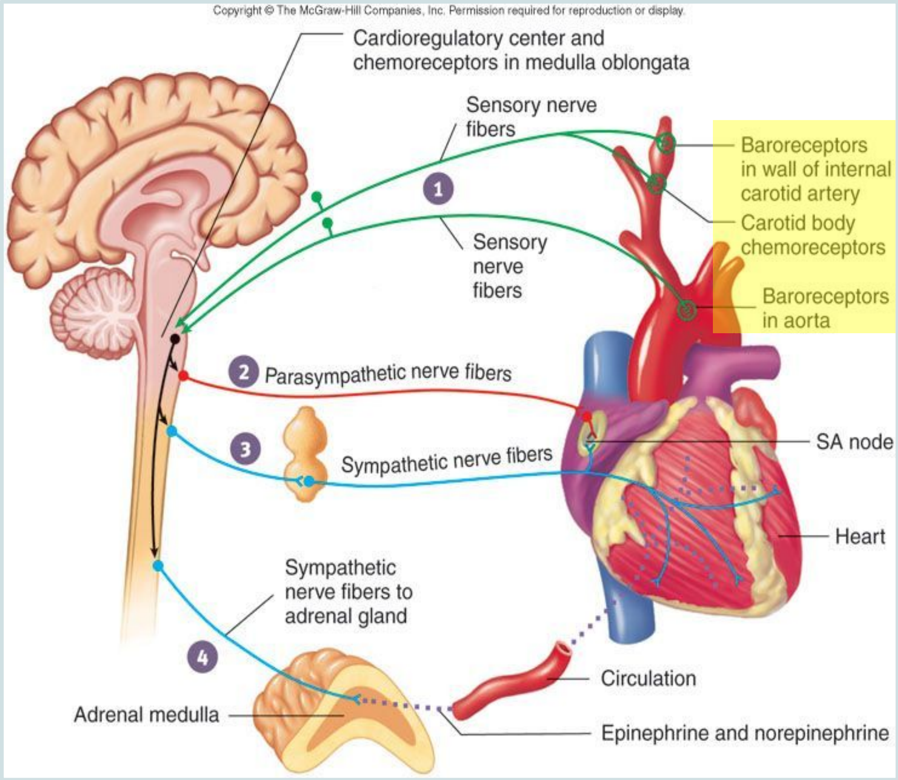
Rapidly Acting Control Mechanisms

- Fast Response (Acts within sec/min)
- (Short-Term)
- Concerned in regulating **Cardiac Output** & **Peripheral Resistance**
- **Neurally-Mediated** Regulation of ABP.
- It is made up of reflex mechanisms that act through autonomic nervous system (Centers in Medulla Oblongata).
  - Vasomotor Center (VMC) → Sympathetic nervous system.
  - Cardiac Inhibitory Center (CIC) → Parasympathetic nervous system

When homeostasis is disturbed (by physical stress, chemical changes, or increased tissue activity) an inadequate local BP and blood flow lead to autoregulation which decrease the local resistance and increase the blood flow. When autoregulation is ineffective, stimulation of either responses can happen to restore homeostasis:

1. Receptors of the **neural** mechanisms (sensitive to changes in systemic BP or chemistry) → activate cardiovascular centers leading to short term elevation of BP by sympathetic stimulation of heart and peripheral vasoconstriction.

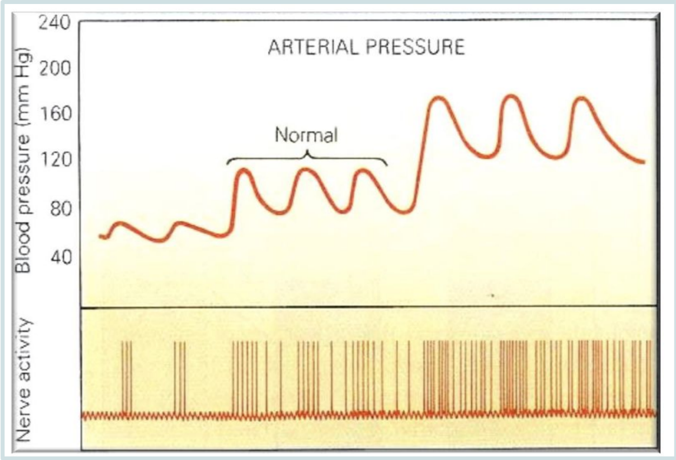
2. **endocrine** mechanisms and responses occur —> long-term increase in blood volume and BP.



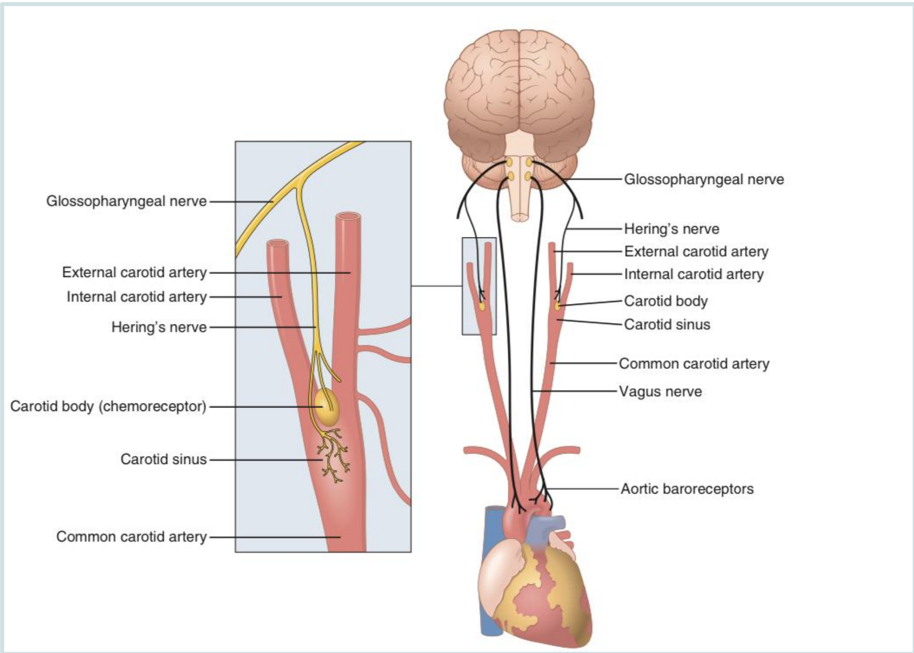
Rapidly Acting : 1-The Baroreceptors reflex

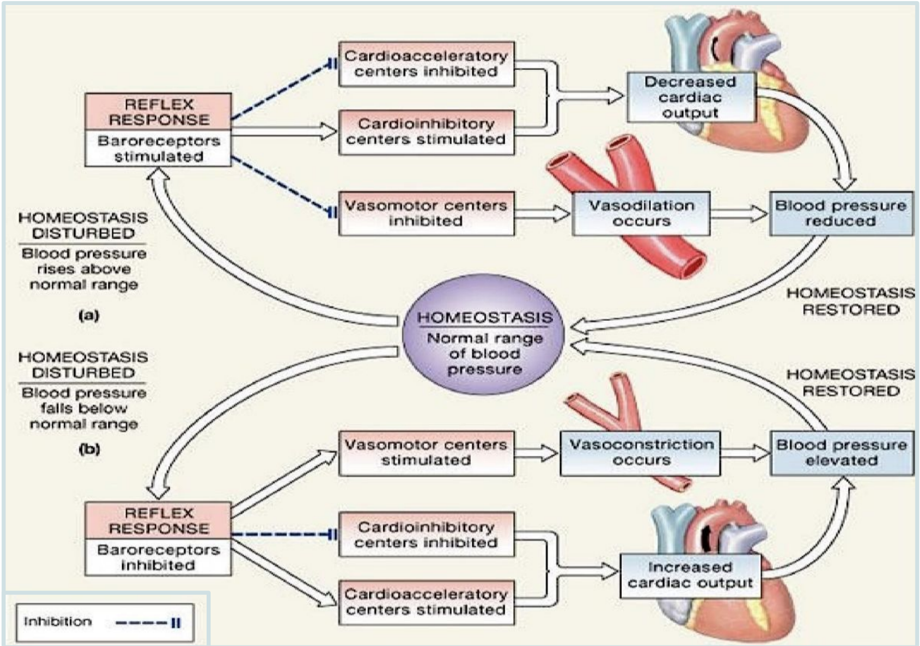
Baro = pressure or stretch

- They are mechano-stretch receptors.
- **Located in the wall of carotid sinus** both sides of the neck **& aortic arch.**
  Receptors in the aorta and carotid sinus send impulses through the vagus nerve and the glossopharyngeal nerve respectively to the medulla to activate or inhibit the sympathetic and parasympathetic activity.
- Fast & neurally mediated
- Provide powerful moment-to-moment control of arterial blood pressure.
- Stimulated in response to blood pressure changes
  (rapid changes)



This figure just to show the normal values for **Arterial pressure**





Rapidly Acting : 1-The Baroreceptors reflex

- Changes in MAP are detected by baroreceptors (pressure receptors) in the carotid and aortic arteries.
- These receptors provide information to the cardiovascular centres in the medulla oblongata about the degree of stretch with pressure changes.
- At normal arterial pressure, the baroreceptors are active.
- **Increased** blood pressure **increases their rate of activity**, while **decreased** pressure **decreases the rate of firing (activity).**
- They play an important role in **maintaining** relatively **constant blood flow** to **vital organs** such as brain **during rapid changes in pressure** such as standing up after lying down. That is why they are called “pressure buffers”.

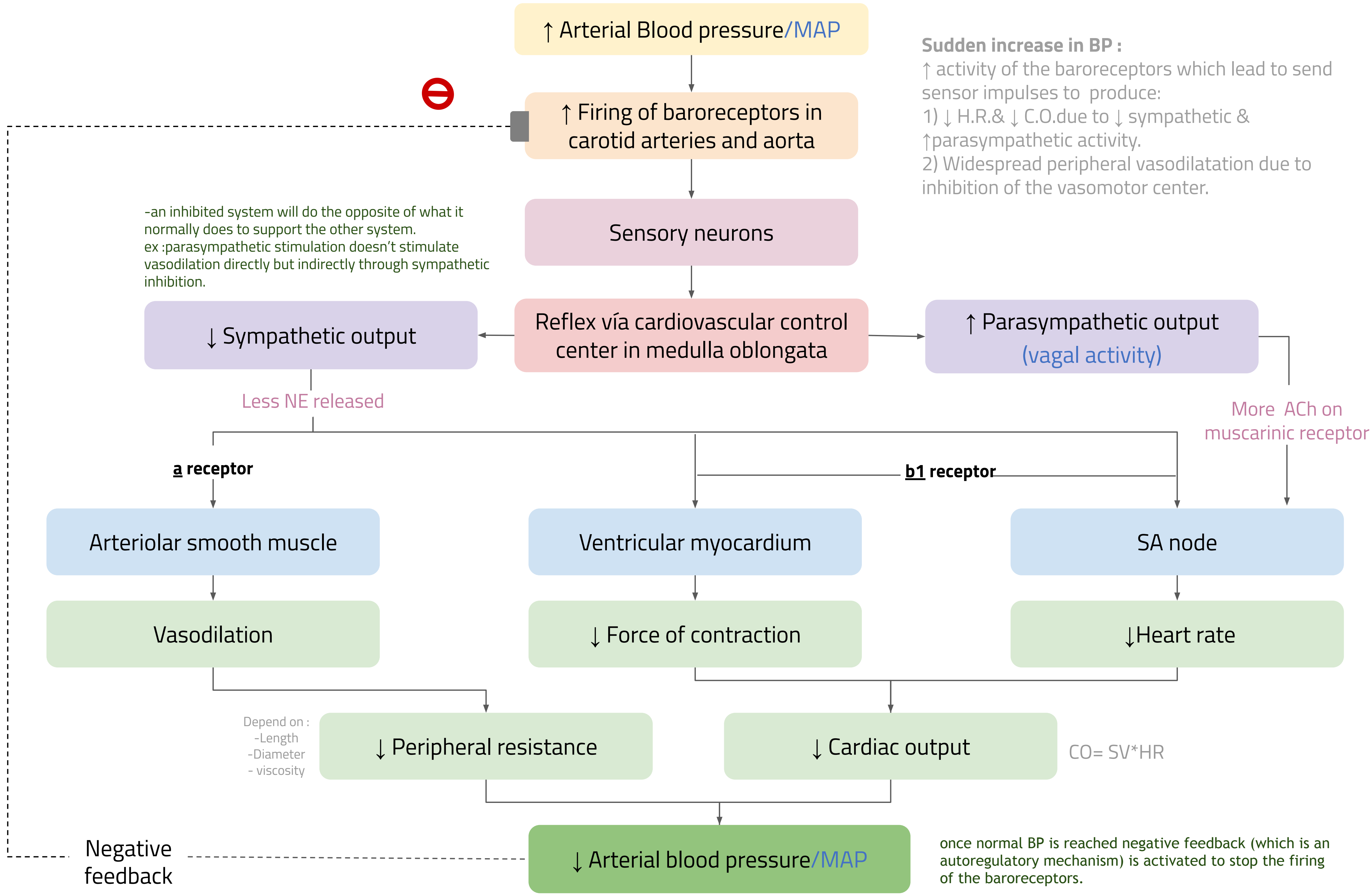
Arterial Baroreceptor Reflex Role In Hemorrhage

Hemorrhage
↓
↓Blood volume
↓
↓Venous pressure
↓
↓ Venous Return
↓
↓Atrial pressure
↓
↓ Ventricular end-diastolic volume
↓
↓ Stroke volume
↓
↓ Cardiac output
↓
↓ Atrial blood pressure

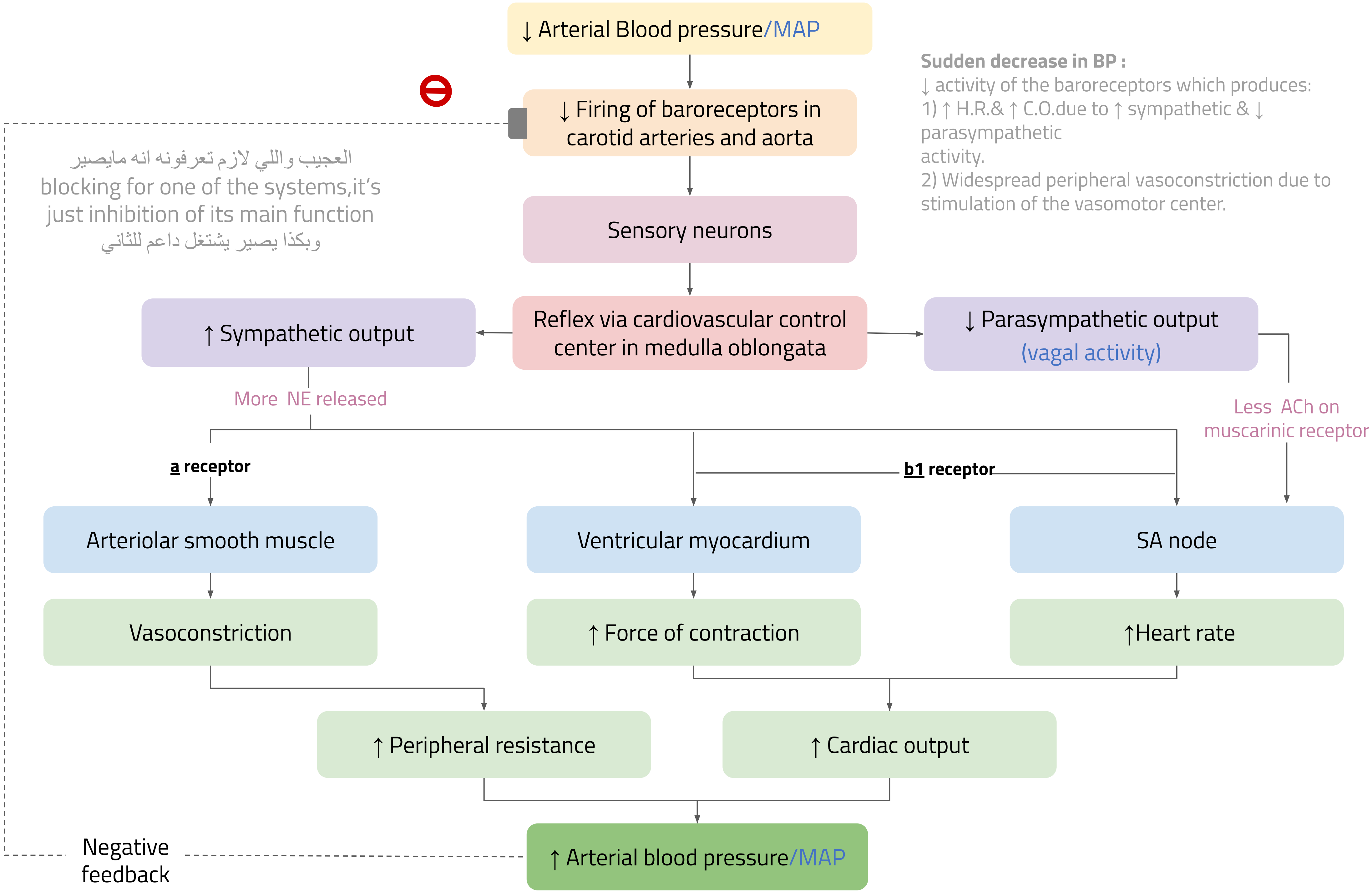
Baroreceptor Reflex Mechanism During Changes in Body Posture

- Baroreceptors are important in maintaining MAP constant during changes in body posture. When change of posture from supine to erect, there is a drop in the MAP in the head and upper part of the body.
- Immediately on standing, arterial pressure in the head & upper part of the body tends to fall (bc of pooling of blood in the lower limbs by gravity) ... ? cause loss of consciousness.
- Falling pressure at the baroreceptors elicits an immediate reflex, resulting in strong sympathetic discharge throughout the body.
- This minimizes the decrease in pressure in the head & upper body.
- **The baroreceptor reflex → Inhibited → strong sympathetic impulses → vasoconstriction. This minimizes the drop in MAP**

Key:
Stimulus - Receptor - Afferent pathway - Integrating center - Efferent pathway - Effector - Tissue response - Systemic response

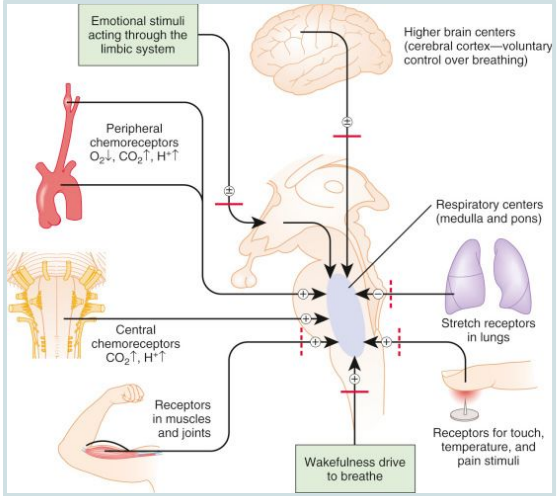


Key:
Stimulus - Receptor - Afferent pathway - Integrating center - Efferent pathway - Effector - Tissue response - Systemic response



Rapidly Acting : 2- Chemoreceptors Reflex

- Closely associated with the baroreceptor pressure control system.
  يرتبط بشكل كبير مع الbaroreceptor system والي كان يقيس ضغط الدم في الArch of aorta و ال carotids ويرسلها للدماغ للمحافظة على توازن الضغط .
- Chemoreceptor reflex operates in much same way as the baroreceptor reflex, **EXCEPT** that chemoreceptors are chemo-sensitive cells instead of stretch receptors.
- Chemoreceptors have high blood flow (1200 ml/min/g tissue), which make it easy for
- these cells to **detect changes in O2, CO2, & H+**.(لما يقل تدفق الدم راح يحس ان فيه خلل)
- Reduced blood flow (due to reduced MAP) stimulates the **chemoreceptors** through **oxygen lack**, **increased hydrogen** ions or **carbon dioxide**.
- Chemoreceptors are stimulated when the MAP is lower than 60 mmHg.
- Their response is **excitatory**, NOT inhibitory; mainly through activation of sympathetic nervous system.
- They reduce blood flow to unessential areas and protect vital tissues like brain and heart.



Found in females' slides

Types of Respiratory Chemoreceptors

Central Chemoreceptors

- Sensory receptors located in the medulla itself.
- Very sensitive to CO2 excess (↑) & (↓) pH in medulla.
-only activated in extreme hypotension.

Peripheral (arterial) Chemoreceptors:

- Sensory receptors located in carotid & aortic bodies.
-Sensitive to O2 lack (↓), CO2 (↑or↓), & pH (↑or↓)
- Chemoreceptors' stimulation excite nerve fibers, along with baroreceptor fibers.

Rapidly Acting : 2- Chemoreceptors Reflex

Found in females slides

Peripheral chemoreceptors Reflex

Chemoreceptor reflexes usually act to increase BP

Briefly : BP decreased due to hypoxia leading to stimulating the chemoreceptors to send sensory impulses through glossopharyngeal nerve to VMC stimulate sympathetic system and through Vagus nerve to CIC to inhibit the parasympathetic system

- Haemorrhage
- ↓ BP
- Hypoxia
- + Peripheral Chemoreceptors
- ++ Vasomotor Center (VMC)
- = Cardioinhibitory Center (CIC)
- + Sympathetic nerve fibers
- = Parasympathetic nerve fibers
- + Adrenal medulla
- Vasoconstriction & ↑Total peripheral resistance (TPR)
- ↑ Cardiac Output (CO)
- ↑ Heart Rate (HR)

Note that : **=** means no change, **+** means increases

Rapidly Acting : 3- CNS Ischemic Response

"Last Ditch Stand" Pressure Control Mechanism

through the stimulation of central chemoreceptors.

1. It is **not** one of the **normal** regulatory mechanisms of ABP. It operates principally as an **emergency pressure control** system to prevent further decrease in arterial pressure whenever blood flow to the brain.

2. It's one of the most powerful activators of the sympathetic vasomotor (vasoconstrictor system) nervous control areas in medulla oblongata.

3. It acts rapidly and very powerfully.

4. It acts whenever blood flow to the brain ↓ dangerously close to the lethal level (MAP < 20mmHg) → cerebral ischemia of vasomotor center → strong excitation of vasomotor center due to accumulation of local CO_2 & lactic acid, in order to prevent further decrease in arterial pressure (MAP) → strong vasoconstriction of blood vessels including the kidney arterioles.

-peripheral chemoreceptors→ stimulated when MAP less than 60 mmHg.
-central chemoreceptors→ stimulated when MAP less than 20 mmHg.

Rapidly Acting : Other Vasomotor Reflexes

1) Atrial stretch (volume receptor) receptor reflex:(weaker reflex than chemoreceptors' & baroreceptors' reflex)

Receptors in large veins close to heart, walls of the atria (response of blood volume).

↑ Venous Return (increase blood volume) → ++ stretch atria & activate atrial stretch receptors → sensory afferent nerves to medulla → inhibiting the cardiovascular center → reflex decrease in blood volume & ↓ ABP through:

(a) sympathetic drive to kidney:

- → dilate afferent arterioles → ↑ glomerular capillary hydrostatic pressure →↑ GFR →↓ blood volume (towards normal).
- ↓ renin secretion (Renin is an enzyme which activates angiotensinogen in blood). Inhibition of renin secretion → inhibit RAAS → inhibit aldosterone production →↓ Blood volume (towards normal)

-on a note unrelated to kidneys ,sympathetic system is also inhibited to try to accommodate more blood in blood vessels by vasodilation.

(b) ↓ ADH secretion

- ↓ blood volume (towards normal).

(c) ↑ Atrial Natriuretic Peptide (ANP)

- causes loss of blood volume.

GFR = Glomerular filtration rate

2) Thermo-receptors: (in skin/hypothalamus)

- Exposure to heat → vasodilatation.
  -(team 438: Allows fluid to exit and absorb the heat).
- Exposure to cold → vasoconstriction.
  -(team 438 : Allows the heat to be trapped in the system).

3) Pulmonary receptors:

- Lung inflation → vasoconstriction → فيساعد في رجعة الدم الى القلب

Intermediate Mechanisms Regulating ABP

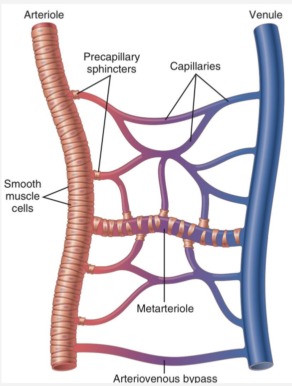
- Activated within 30 min to several hrs
- During this time, the nervous mechanisms usually become less & less effective.

1. Renin-angiotensin vasoconstriction mechanism (system).

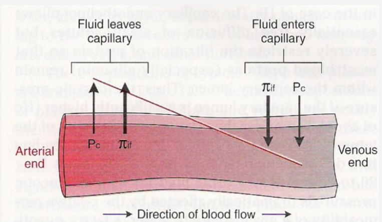
2. ADH vasoconstriction mechanism (system)

3. Fluid(Capillary)-Shift mechanism (explained in capillary circulation lecture)

- Movement of fluid from interstitial spaces into capillaries in response to ↓ BP to maintain blood volume (filtration<absorption).
- Conversely, when capillary pressure ↑ too high, fluid is lost out of circulation into the tissues, reducing blood volume as well as all pressures throughout circulation (filtration>absorption).



Arterial end→ filtration.
venous end→ absorption.



4. Stress-relaxation of the vasculature

- Adjustment of blood **vessel smooth muscle** to **respond to changes in blood volume.**
- When pressure in blood vessels becomes too high, they become stretched & keep on stretching more & more for minutes or hours; resulting in fall of pressure in the vessels toward normal.
- This continuing stretch of the vessels can serve as an intermediate-term pressure "buffer."

Long- Term (Slow Response) Regulation

- **Hormonally** mediated.
- Takes few hours to being showing significant response.
- Concerned in **regulating blood volume**.

Mainly Renal (Acts if BP is too low):

1. Renin-Angiotensin-Aldosterone System

Explained in the next slide.

2. Vasopressin/Anti-Diuretic hormone (ADH)

- Hypovolemia & dehydration stimulates Hypothalamic **Osmoreceptors**. It will send signals to posterior pituitary to release the ADH.
- ADH will be released from posterior pituitary gland:
  - Promotes water reabsorption at kidney tubules leading to↑blood volume.
  - Causes **vasoconstriction**, in order to ↑ ABP.
- Thirst stimulation.
- Usually, when secreted aldosterone is secreted.

Others:

3. Low-pressure volume receptors: Atrial Natriuretic Peptide Mechanism (weaker effect than RAAS & ADH)

- ANP is a hormone released from cardiac muscle cells (wall of right atrium) as a response to an increase in ABP in order to decrease the blood volume.
- Simulates an ↑ in urinary production, causing a ↓ in blood volume & blood pressure.

4. Erythropoietin(EPO)

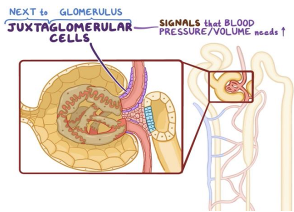
- Secreted by the kidneys when blood volume is too low.
- Leads to RBCs formation → ↑ blood volume.

-ADH is a hormone synthesized by the hypothalamus and stored in the posterior pituitary gland.

Renin-Angiotensin Aldosterone System

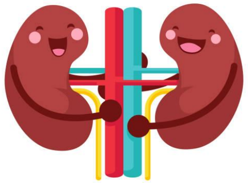
↓ Renal blood flow and/or ↓Na+

sensed by



++ Juxtaglomerular apparatus of kidneys (considered volume receptors)

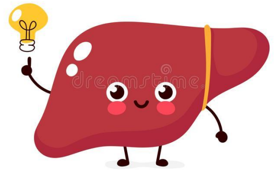
which releases



This is also an Intermediate Mechanism

Renin
(hormone-like substance)

hormone-like substance means it's a substance released directly into the blood.

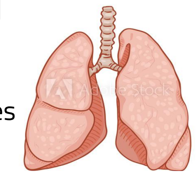


This is also an Intermediate Mechanism

Angiotensinogen (Plasma protein)
453 amino acid long

Angiotensin I
10 amino acid long

Angiotensin converting enzymes (ACEs)



Angiotensin II (powerful vasoconstrictor + Thirst stimulation)

Adrenal Cortex

Corticosterone

Aldosterone

(Na+& Water retention) At kidney tubules

Hypothalamus

Thirst and drinking

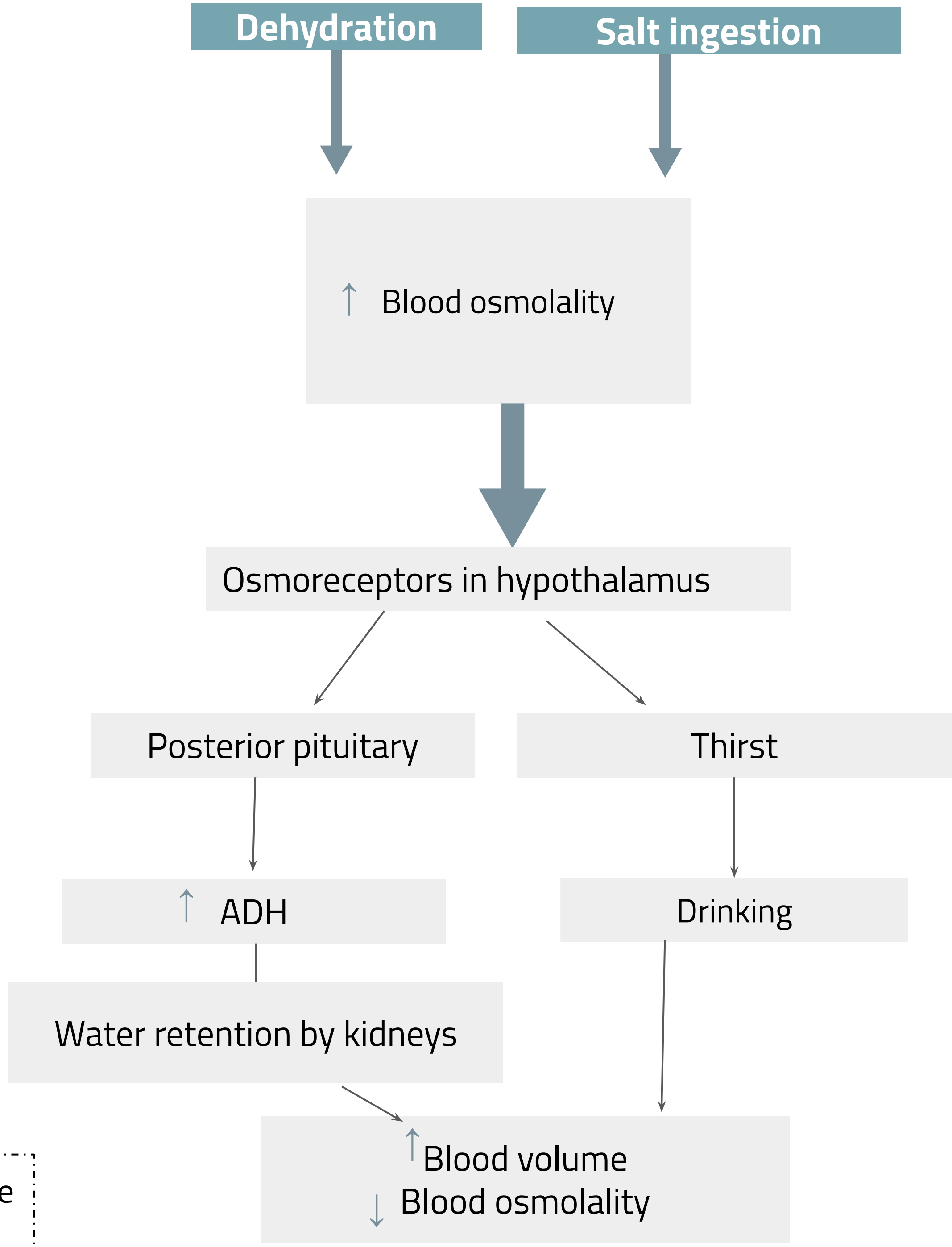
Angiotensin III
(powerful vasoconstrictor)

Result: Elevated blood pressure

Found only in male slides

Renal Body fluid control mechanism

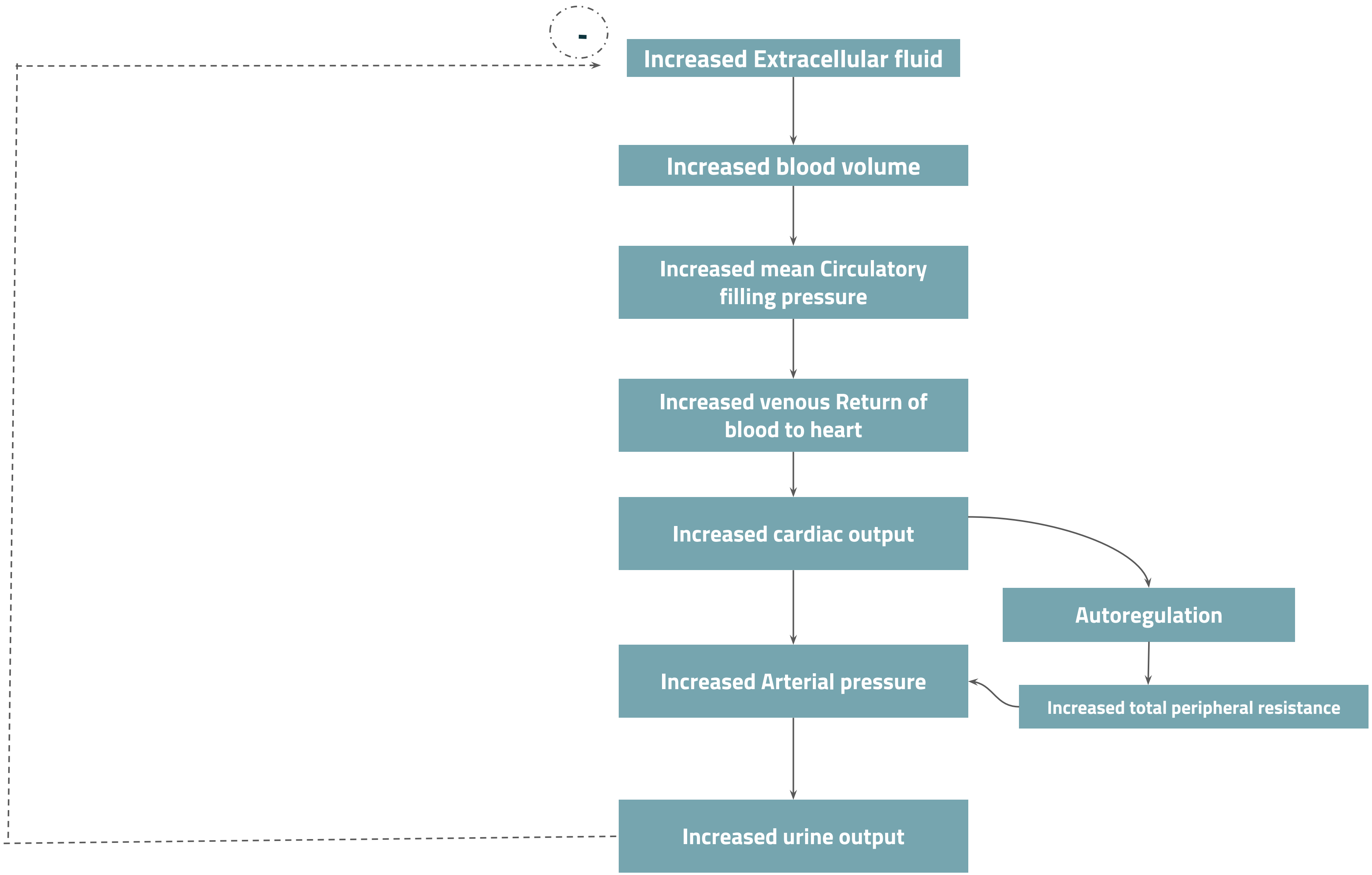
Stimuli



Negative feedback response

Renal Body fluid control mechanism

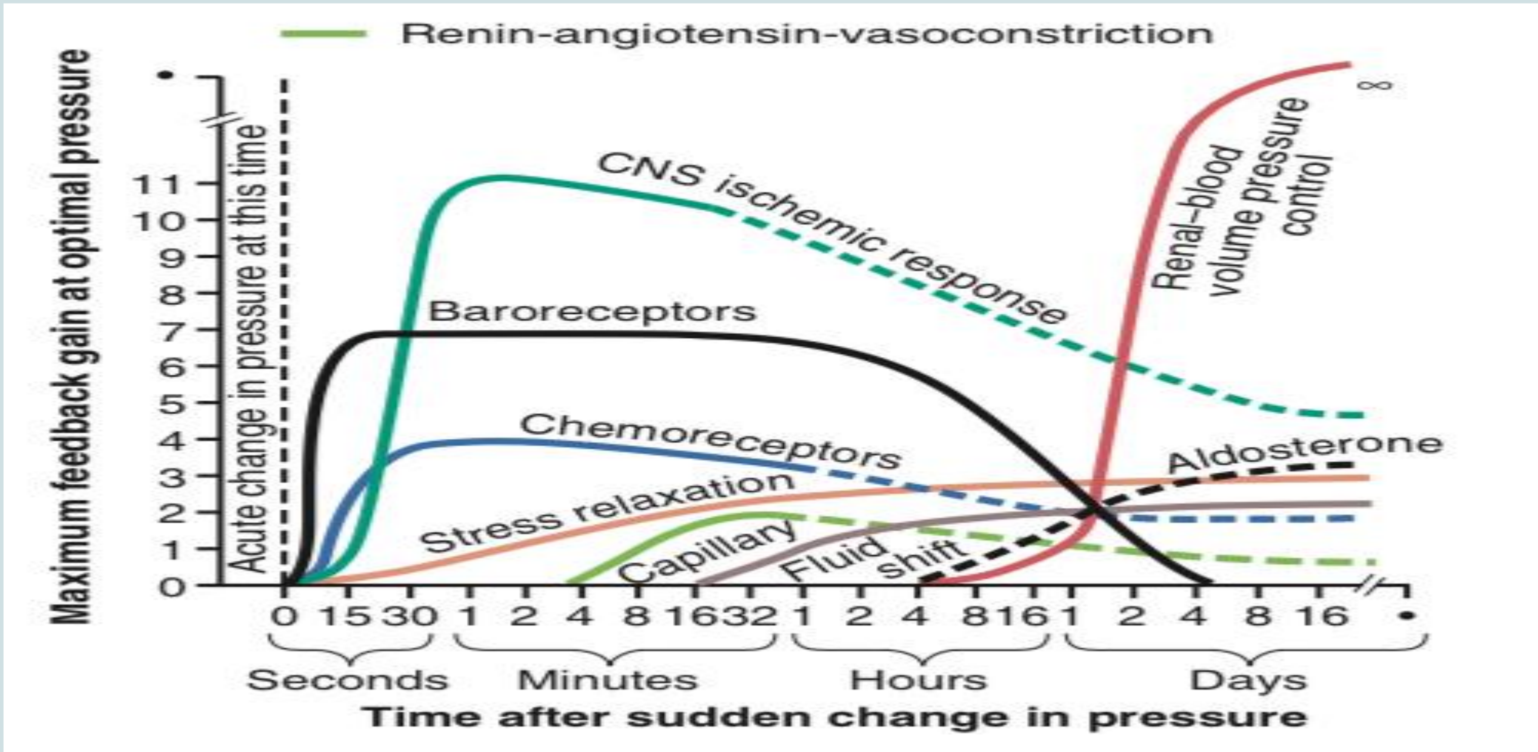
Found only in male slides
Another way.



From Guyton:
Sequential steps by which increased extracellular fluid volume increases the arterial pressure. Note especially that increased cardiac output has both a direct effect to increase arterial pressure and an indirect effect by first increasing the total peripheral resistance.

Found in females slides

Control mechanisms at different time intervals after onset of a disturbance to the arterial pressure:



From Guyton:
Approximate potency of various arterial pressure control mechanisms at different time intervals after the onset of a disturbance to the arterial pressure. Note especially the infinite gain (∞) of the renal body fluid pressure control mechanism that occurs after a few weeks' time.

Quiz:

1-what's the normal systolic pressure range?
A) 120-129
B) 140-159
C) <120
D) >120

2-what are the types of blood pressure?
A) venous only
B) Arterial only
C) Capillaries only
D) All

3-Which of the following indicates hypertensive crisis?
A) BP of 180/120 mmHg
B) BP of 160/100 mmHg
C) BP of 150/99 mmHg
D) BP of 140/99 mmHg

4-Length is directly proportional to the flow
A) True
B) False

5-What is the velocity when the flow (Q) is 10m/s and the Cross-Sectional area is 2cm^2?
A) 1cm/s
B) 2cm/s
C) 5cm/s
D) 10cm/s

6-Which of the following is a vasodilator?
A)Norepinephrine
B)Angiotensin II
C)Vasopressin
D)Nitric Oxide (NO)

7- Bp is measured
A) Directly (stethoscope)
B) Directly (Arterial catheter)
C) Indirectly (stethoscope)
D) Indirectly (Arterial catheter)

8- which of the following is not a factor for regulating blood pressure?
A) blood flow
B) cardiac output
C) peripheral resistance
D) blood volume

Answer Key: 1C - 2D - 3A - 4B - 5C
6D - 7B -8A

Quiz:

9- **what happens to MAP when an abrupt change in posture happens?**
A) rises
B) drops
C) constant
D) zero

10- Which of the following hormones is released in response to a decrease in blood volume?
A) Atrial Natriuretic Peptide (ANP) hormone
B) Renin
C) Angiotensin II
D) Erythropoietin

11- ADH will be released from:
A) Liver
B) CNS
C) thyroid gland
D) posterior pituitary gland

12- Movement of fluid from interstitial spaces into capillaries in response to:
A) Normal BP
B) Increase in BP
C) Decrease in BP
D) None

13- Which one of the following decrease blood volume:
A) Renin angiotensin aldosterone
B) EPO
C) ADH
D) ANP

14- Central Chemoreceptors are Sensory receptors located in the:
A) medulla
B) pons
C) cerebellum
D) carotid & aortic bodies.

15- An emergency pressure control system to prevent further decrease in arterial pressure:
A) Renal Body fluid control mechanism
B) ADH vasoconstriction system
C) Capillary Fluid Shift mechanism
D) CNS Ischemic Response

16- Chemoreceptors are stimulated when the MAP is lower than:
A) 40 mmHg
B) 50 mmHg
C) 60 mmHg
D) 70 mmHg

17- Thermo-receptors exposure to heat that will lead to:
A) vasodilatation
B) vasoconstriction

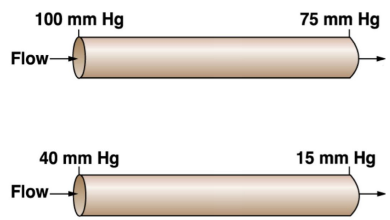
Answer Key: 9B - 10D - 11D - 12C
13D - 14A - 15D - 16C -17A

Quiz:

1- what's the normal arterial blood pressure range?

2-enumerate factors that affecting arterial BP?

3-How does the flow differ in these two vessels?



4- BP in arteries is measured by :

5- why does the venous system have a higher compliance?

A1: 90 – 120 mmHg systolic. 60 – 80 mmHg diastolic.

A2: 1-pregnancy 2-exercise 3-race

A3: They have the same blood flow because they have the same pressure difference
100-75= 25mm Hg
40-15= 25mm Hg

A4: listening for Korotkoff sounds produced by turbulent flow

A5: because it has high volume & low pressure

Quiz:

6-Mechanism of action of ADH?

7-Mechanism of action of Fluid-Shift?

8-where are the baroreceptors located?

9-what are the Peripheral (arterial) chemoreceptors ?

10-Maintaining BP is important, why ?

A6:slide 16

A7:slide 19

A8: Carotid baroreceptors are located in the carotid sinus, both sides of the neck.Aortic baroreceptors are located in the aortic arch

A9: slide 11

A10: slide 3

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