Al-Mustaqbal University College

Pharmacy Department / Second Stage

PHYSIOLOGY

CARDIOVASCULAR SYSTEM, L2

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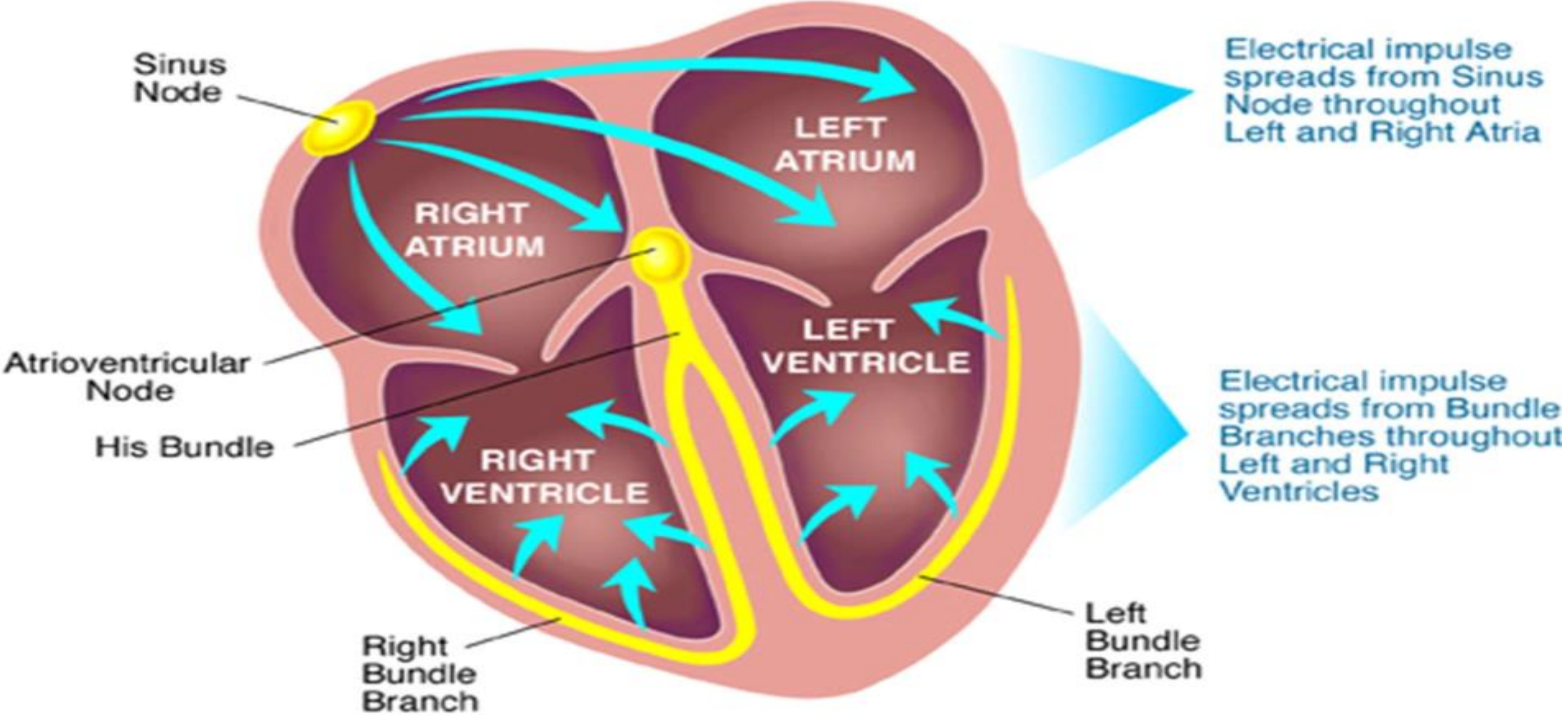
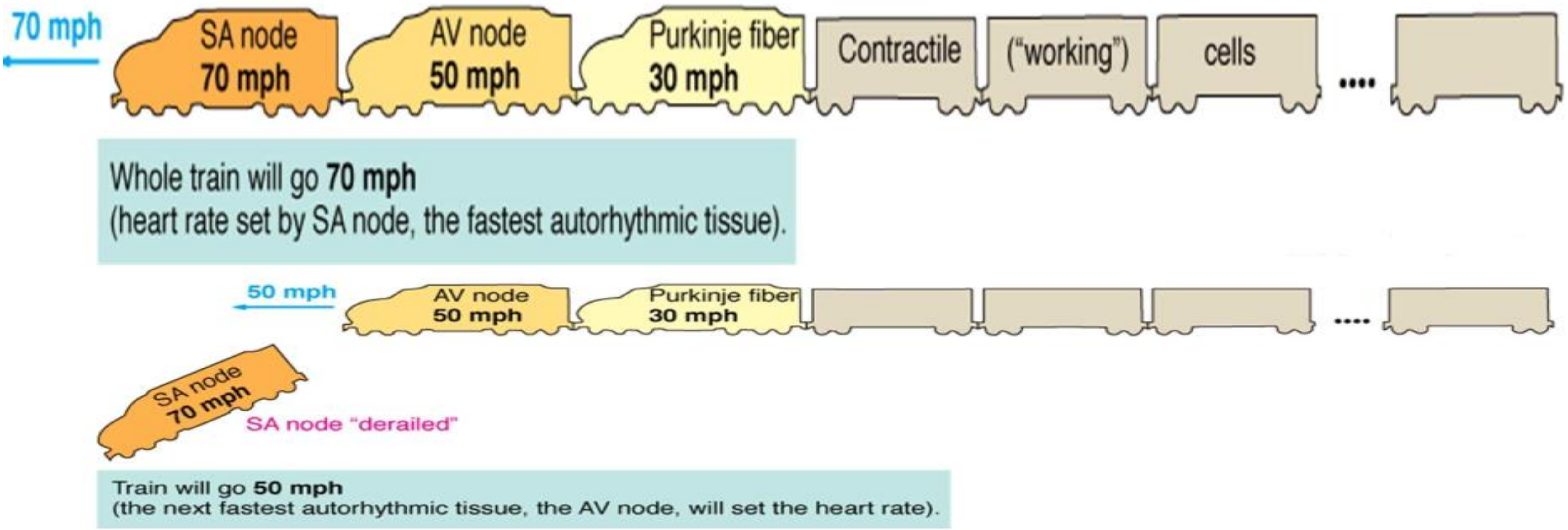
Conductive System of the Heart





- Non-SA nodal tissues are *latent pacemakers* that can take over (at a slower rate), should the normal pacemaker (SA node) fail
- If SAN is damaged or its signal is blocked, the AVN takes over setting with pace (40-60/min)
- If AVN is next damaged, the bundles set the rate (20 – 40/min)

Primary cardiac cell characteristics

Characteristic	Location	Function
Automaticity	SA node, AV junction, Purkinje network fibers	Electrical
Excitability	All cardiac cells	Electrical
Conductivity	All cardiac cells	Electrical
Contractility	Myocardial muscle cells	Mechanical

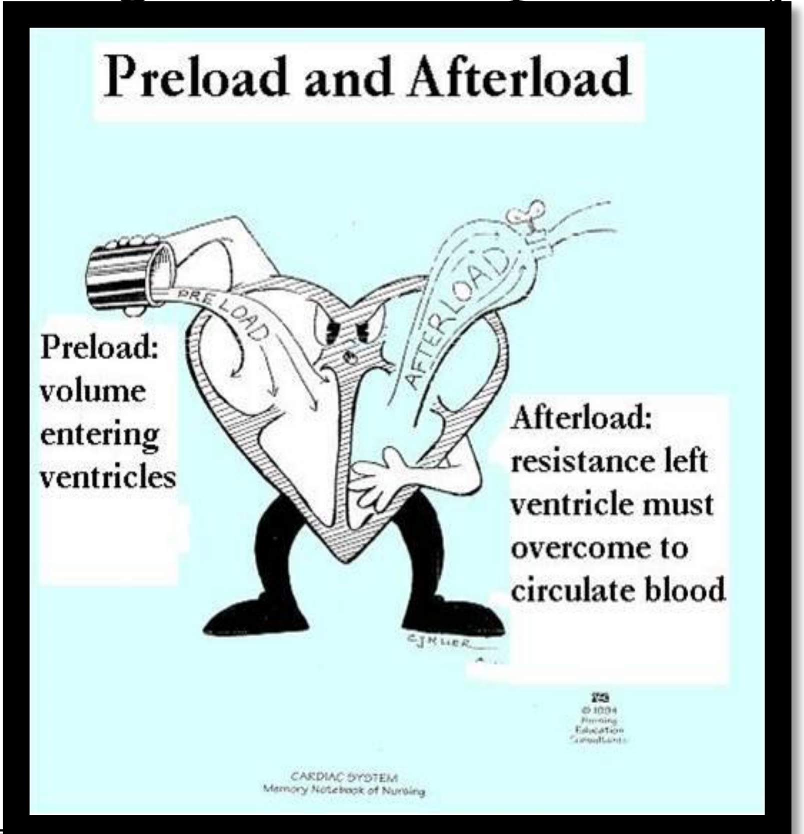
Frank-Starling's law of the heart:

1) **The length-tension relationship in muscles: the force of myocardial contraction is directly proportional to the initial length of the cardiac muscle fibers i.e. the returned blood to heart will distend the ventricles so the ventricles will produce more powerful contraction to pump the returned blood.**
2) **The relationship of preload (VR) and force of contraction.**
3) **The relationship of Ventricular EDV and stroke volume**

The Frank-Starling Principle states that the greater the volume of blood entering the heart during diastole, the greater the volume of blood ejected during systole

Summary
(Regulation of Stroke Volume)

- End-diastolic volume (EDV): SV is directly proportional to preload; an increase in EDV results in an increase in stroke volume (Frank-Starling law).
- The total peripheral resistance: SV is inversely proportional to TPR (afterload); it is the aortic impedance; higher peripheral resistance; higher arterial pressure that reduce the stroke volume.
- Sympathetic input (Inotropy): Strength of contraction varies directly with EDV; myocardial contractility is directly proportional with SV.



The Electrocardiogram (ECG)

- The body is a good conductor of electricity because tissue fluids have a high concentration of ions that move (creating a current) in response to potential differences.
- Potential differences generated by the heart are conducted to the body surface, where they can be recorded by surface electrodes placed on the skin.
- **The recording thus obtained is called an electrocardiogram (ECG or EKG);** the recording device is called an *electrocardiograph.*
- Each cardiac cycle produces three distinct ECG waves, designated P, QRS, and T.

1. **Atrial depolarization** creates the **P wave**
2. **Ventricle depolarization creates the QRS** and thus to **contraction of the ventricles.**
3. **The plateau phase** of the cardiac action potential is related to **the S-T segment** of the ECG .
4. Finally**, repolarization of the ventricles** produces the **T wave**

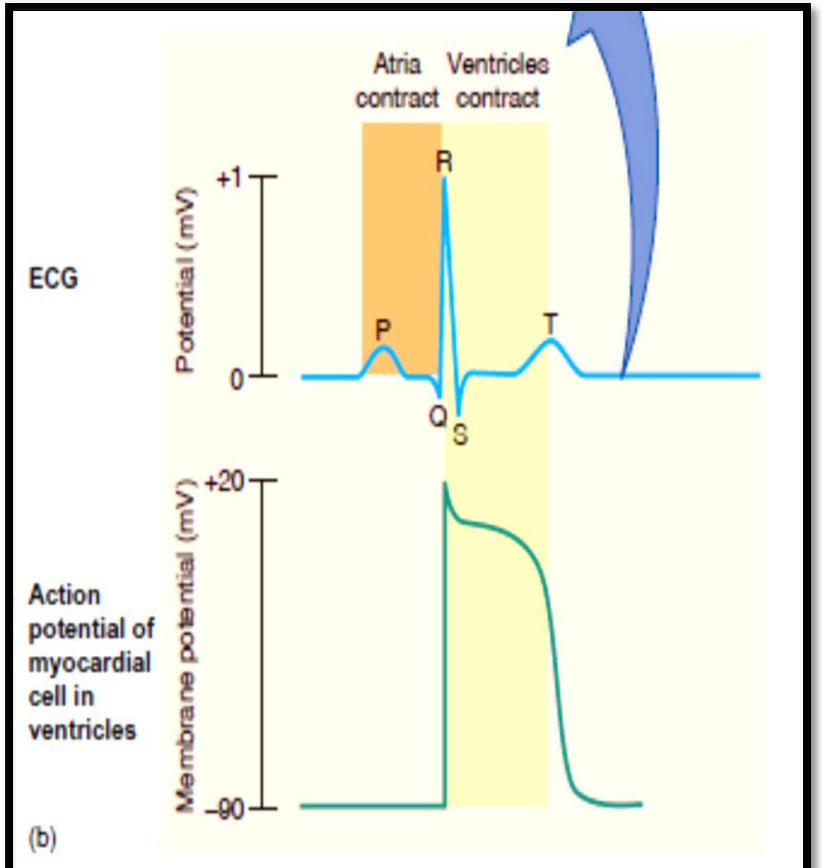
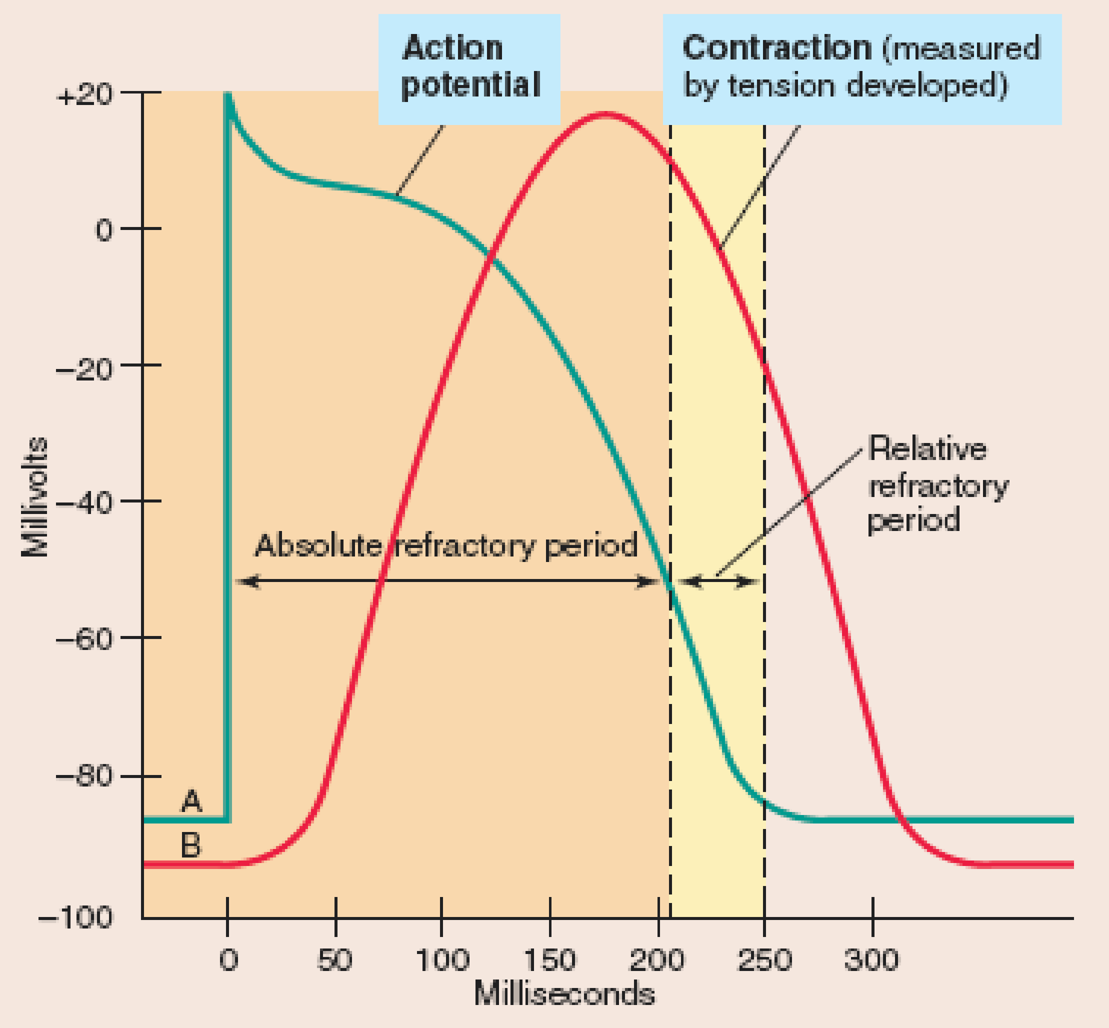


Figure 13.22 **The ECG and cardiac cycle.** (*a*) The electrocardiogram (ECG) waves and intervals. (*b*) The correlation of the myocardial action potentials, ECG waves, and contraction of the atria and ventricles.

Refractory period:

- **Absolute refractory period (ARP):** it is the interval during which no action potential can be produced, regardless of the stimulus intensity. It lasts the upstroke plus plateau and initial repolarization till mid-repolarization at about -50 to -60 mV. This period prevents waves summation and tetanus.

- **Relative refractory period (RRP):** it is the interval during which a second action potential can be produced but at higher stimulus intensity. It lasts from the end of ARP (midrepolarization) and ends shortly before complete repolarization



Heart Sounds

- Closing of the AV and semilunar valves produces sounds that can be heard by listening through a stethoscope placed on the chest. These sounds are often verbalized as "lub-dub." The "lub," or **first sound, S1,** is produced by **closing of the AV valves** during isovolumetric contraction of the ventricles

- The "dub," or **second sound, S2,** is produced by **closing of the semilunar valves** when the pressure in the ventricles falls below the pressure in the arteries. The first sound is thus heard when the ventricles contract at ***systole*,** and the second sound is heard when the ventricles relax at the beginning of ***diastole.***

- **Murmurs** are abnormal heart sounds produced by abnormal patterns of blood flow in the heart. Many murmurs are caused by defective heart valves. Defective heart valves may be congenital, or they may occur as a result of rheumatic endocarditis , e.g, mitral stenosis (mitral valve becomes thickened and calcified).

Flow Within The Cardiovascular System

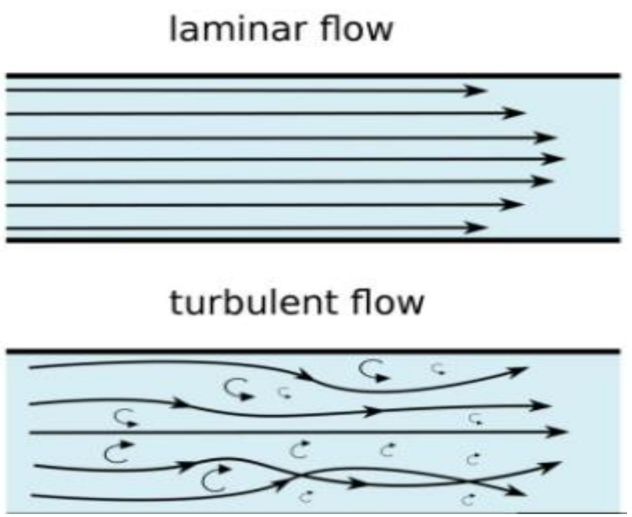
The cardiovascular system is a closed network of vessels connected to the heart. It enables blood, oxygen and other nutrients to flow around the body.

There are two ways in which blood flows within our vessels:

1. laminar : In most straight blood vessels Velocity (rate of blood flow) is highest in the center of the vessel and decreases closer to the vessel wall. This decreasing velocity gradient is due to increasing resistance closer to the vessel wall.

2.**turbulent** : when blood vessels branch off or become constricted . Sometimes, turbulent flow can be heard (known as a ‘**bruit**’) over arteries with atherosclerotic plaques.

Flow = Pressure / Resistance



Pressure

Liquids flow down their concentration gradients from areas of high pressure to areas of lower pressure. In practice, this means blood will flow from the arterial end of a vessel to the venous end. This pressure gradient is primarily created by the pumping action of the heart.

Resistance

Resistance is the force that opposes the flow of blood. Different blood vessels throughout the body have varying levels of resistance to blood flow.

For example, our veins have very little resistance due to their ability to distend; this enables a vein's resistance to fall in response to increasing pressure and thus keeps flow constant.

Resistance is determined by Poiseuille's Law:

$$R = 8\eta l / \pi r^4$$

Where: R : resistance, η : Viscosity, l : Length, r : Radius

Starling Forces

Fluid movement between the capillaries and tissues is controlled by four forces:

Blood hydrostatic pressure: the pressure exerted by blood in the capillaries against the capillary wall. This pressure forces fluid out of the capillary.

Blood colloid osmotic (oncotic) pressure: the pressure exerted by proteins in the blood, mostly by albumin in the capillaries. This pressure is attempting to pull fluid into the blood. Proteins in the plasma are normally too large to diffuse into the interstitium, however, in certain scenarios, such as in inflammation, these proteins can.

Interstitial hydrostatic pressure: the pressure of the fluid in the interstitium. This pressure forces fluid back into the capillary.

Interstitial colloid osmotic (oncotic) pressure: the pressure of the proteins in the interstitium. This pressure pulls fluid out of the capillary.

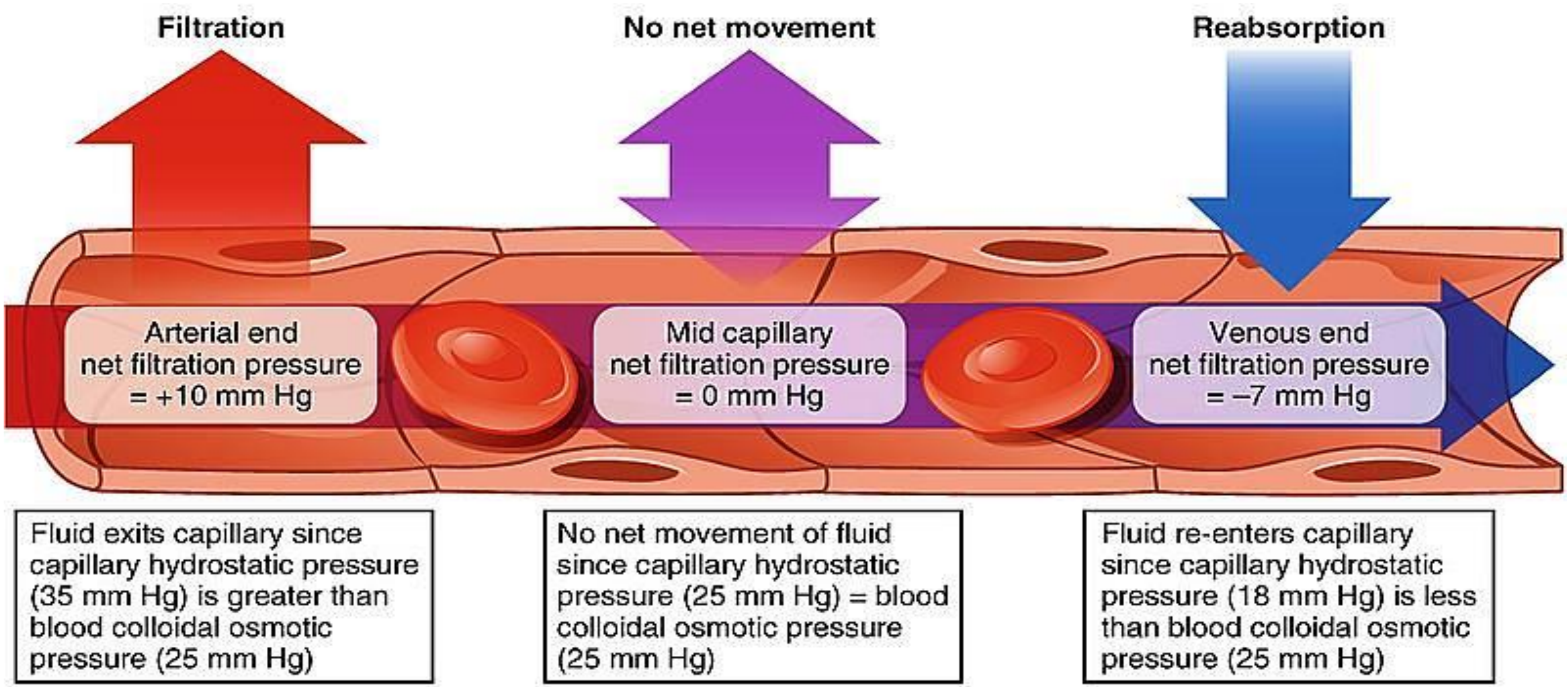


Diagram showing the Starling forces that take place over a capillary bed

Arterial blood pressure (BP)

- BP is the pressure exerted by the blood on the arterial walls during systole and diastole.
- Systolic BP normally averages 120 mmHg in young adult males (range 90 -140 mmHg).
- >140 = systolic hypertension.
- The diastolic BP normally averages 80 mmHg (range 60 - 90 mmHg).
- > 90 = diastolic hypertension.
- The BP is often reported as the systolic over the diastolic (e.g. 120/80).
- < 90 systolic BP = hypotension.

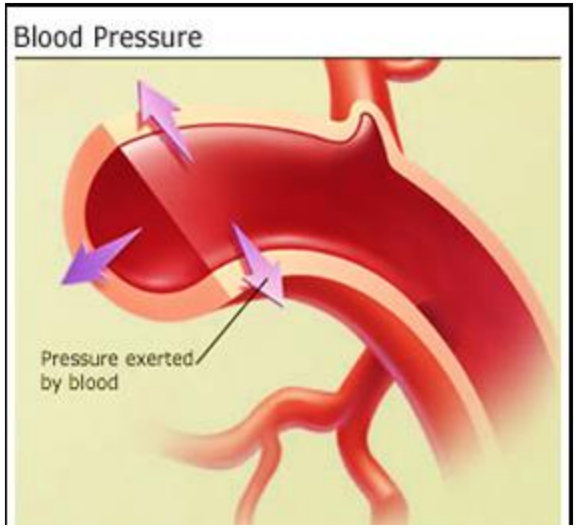
- Pulse pressure (Pp): The difference between systolic and diastolic BP (normally averages 40 mmHg). systolic BP – diastolic BP

  120 – 80 = 40 mmHg.

- Mean arterial blood pressure (Tissue perfusion pressure)

  Diastolic BP + 1/3 Pp.

  80 + 13 = 93 mmHg.



- The Normal Blood Pressure is 120/80 mmHg

Systolic Blood Pressure

- When the left Ventricle of the heart ejects the blood into the aorta the maximal aortic pressure exerted by the ejection of blood is termed as Systolic Blood Pressure
- The Normal Systolic Pressure is 120mmHg.

Diastolic Blood Pressure

- As the left ventricle is relaxing and refilling, the pressure in the aorta falls. The lowest pressure in the aorta, which occurs just before the ventricle ejects blood into the aorta, is termed the diastolic pressure
- The Normal Diastolic Pressure is 80mmHg.

Importance (function) of the arterial blood pressure:

- It maintains tissue perfusion (i.e. blood flow)
- It produces the capillary hydrostatic pressure (interstitial fluid).

Diastolic blood pressure:

- It maintains blood flow to the tissues during ventricular diastole (continuous, not intermittent).
- It is essential for the normal coronary blood flow.

Factors that determine the blood pressure:

1- Stroke volume (SV) & Cardiac output (CO).

2- Total peripheral resistance (PR).

3- Elasticity of the aorta and large arteries (Compliance of Blood Vessels) .

4- Blood volume and circulatory capacity.

Stroke Volume & Cardiac Output

Stroke Volume (SV) is the amount of Blood ejected from the ventricles in one contraction of heart muscles measure in milliliters

Cardiac output (CO) is the measurement of blood flow from the heart through the ventricles, and is usually measured in litres per minute.

CO= SV X HR (Heart Rate)

Any factors like sympathetic Nervous stimulation, Hormonal Influence & Increased Calcium ions in blood can increase the Arterial BP by increasing the Cardiac Output

And factors that causing parasympathetic Stimulation, Electrolyte Imbalance & Acidosis decrease the Blood Pressure by decreasing the Cardiac Output.

Cardiac output & blood pressure

- The arterial BP is directly proportionate to the CO.

$$CO = SV \times HR.$$

With a constant HR, an increase in the SV raises systolic pressure with no significant change in diastolic pressure.

Total peripheral resistance & Blood pressure

- PR is the sum of all the vascular resistances.
- The PR is essential for maintenance of the arterial B.P. particularly the diastolic BP.
- It is produced mainly in the arterioles.
- It is determined by 3 factors:

(a) The radius (or diameter) of the vessel.

(b) Blood viscosity.

(c) The length of the vessel.

Vessel Length & Diameter

The length of the Vessel is directly proportional to its Blood Pressure

The greater the pressure there is decreased blood flow

When the blood vessel is long there is Increased surface area that Increases the BP & decreases blood flow,

Likewise if the vessel is shortened there is decrease in pressure and Increase in Blood flow

The contractility state of the smooth muscles of the blood vessel is the primary determinant of blood vessel diameter & is inversely proportional to pressure & directly proportional to blood flow

In increased diameter (Vasodilation) there is less blood contacting the vessel wall, thus lower friction, subsequently increasing Blood flow & decrease in Pressure

In decreased diameter (Vasoconstriction) more of the blood contacts the vessel wall, subsequently decreasing Blood flow & Increase in Pressure.

Blood Viscosity

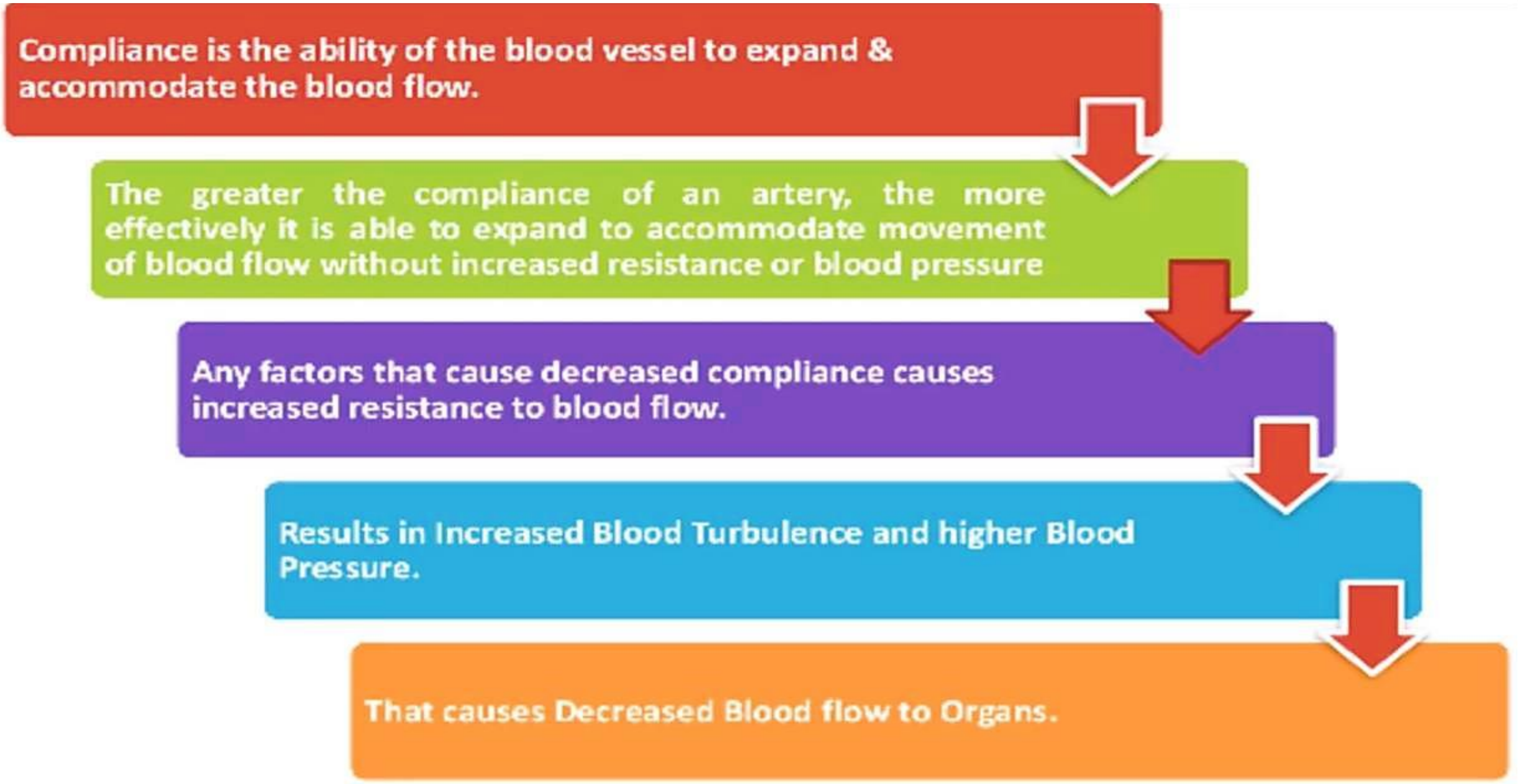
Blood Viscosity is the thickness of the blood that affects the ability of blood flow

The viscosity of blood is directly proportional to blood pressure & inversely proportional to Blood flow

Any condition that causes Increased viscosity will also increase BP and decrease blood flow

Conversely, any condition that causes decreased blood viscosity will decrease BP and increase Blood flow.

Compliance of Blood Vessels



Blood Volume & Capacity

There exists an obvious relationship between the blood volume & Blood Pressure

As the blood volume increases, the Blood pressure &blood flow also Increases

On the other hand when the blood volume decreases, the blood pressure and flow also decreases

In low blood volume, called Hypovolemia the regulatory mechanisms of the body effectively maintain the blood pressure until 10-20% loss in blood volume later will require a volume replacement

In excess Fluid Volume, Hypervolemia leads to Increased Sodium & water Retention that results in Congestion of fluid within the Blood Vessels causing Increased Blood Pressure.

Regulation of Blood Pressure

Baroreceptors & Neuronal Regulation

Renin-Angiotensin Aldosterone System (RAAS)

Anti-Diuretic Hormone

Atrial Natriuretic Peptide

Prostaglandins

Barorecepters

- Changes in blood pressure are detected by baroreceptors. These are located in the arch of the aorta and the carotid sinus. Baroreceptors regulate blood pressure only for short term because the mechanism of triggering baroreceptors takes place only when an adequate blood pressure is restored.

Sympathetic Stimulation	**Decreased arterial pressure is detected by baroreceptors, which then trigger a sympathetic response. This stimulates an increase in heart rate and cardiac contractility leading to an increased blood pressure.**
Para Sympathetic Stimulation	**Increased arterial pressure stretches the wall of the blood vessel, triggering the baroreceptors. These baroreceptors stimulate the autonomic Nervous System to reduce the heart rate and cardiac contractility via the efferent parasympathetic fibres (vagus nerve) thus reducing blood pressure.**

PHYSIOLOGICAL FACTORS AFFECTING ARTERIAL BLOOD PRESSURE

- **Sex:** Male > Female …(equal at menopause)
- **Age:** (↑) Old age: Atherosclerosis
- **Emotions:** BP (↑) due to neural & hormonal factors.
- **Exercise:** (↑) BP due to ↑ venous return.
- **Hormones:** Some hormones like adrenaline, noradrenaline & thyroid (↑) BP.
- **Gravity:** BP is higher in lower limbs than upper limbs.
- **Stress:** (↑) stress
- **Sleep:** BP (↓) due to ↓ venous return. BP (↑)
- **Pregnancy:** due to ↑ in metabolism.
- **Temperature:** BP (↓) with heat due to vasodilatation
  (↑) with cold due to vasoconstriction

Obesity (↑)

Diurnal Variation	Blood Pressure rapidly rises on wakening in the early morning, reaches a plateau during the morning, falls slightly in the early afternoon and rises again in the early evening.
Fever	Fever can Increased the blood pressure due to dehydration that Increases the workload of the heart & Kidneys which in turn Increases BP
Fluid Intake	Excess Fluid Intake can Increase the congestion within the blood vessels and therefore Increases the BP

Hereditary	Person with a family history of Increased BP is also at risk of developing Increased BP.
Medications	Drugs like NSAIDs & decongestants can Increase BP by causing vasoconstriction of the arteries. Drugs like Anti-hypertensives can decrease the BP.
Diet	Diet high in Sodium & Vitamin-D can cause Increased BP by Increasing the Blood volume & Peripheral Vascular Resistance Diet high in Potassium can decrease BP by causing relaxation of smooth muscles of blood vessels.
Climate	Blood pressure generally is higher in the winter and lower in the summer. In low temperatures blood vessels constrict — which increases blood pressure because more pressure is needed to force blood through your narrowed veins and arteries.

Emotional States	In emotional States like Stress & Anxiety, cortisol is released that increases the heart rate & BP.
Exercise	Exercise lowers blood pressure by reducing blood vessel stiffness and increasing the blood flow.
Life Style	Sedentary lifestyle & urbanization can result in overweight that can lead to Increased Blood pressure due to formation of fatty deposits on the walls of the arteries that decreases the diameter of the blood vessels causing Increased BP.
Habits	Habits like smoking, alcohol & drug Abuse can cause vasoconstriction which can lead to Increased BP.

Measurement of Blood Pressure

Two methods:

Direct : Arterial catheter

Indirect : Stethoscope and blood pressure cuff (Sphygmomanometer) :

Types:

Mercury sphygmomanometer **Aneroid equipment** **Automatic equipment**

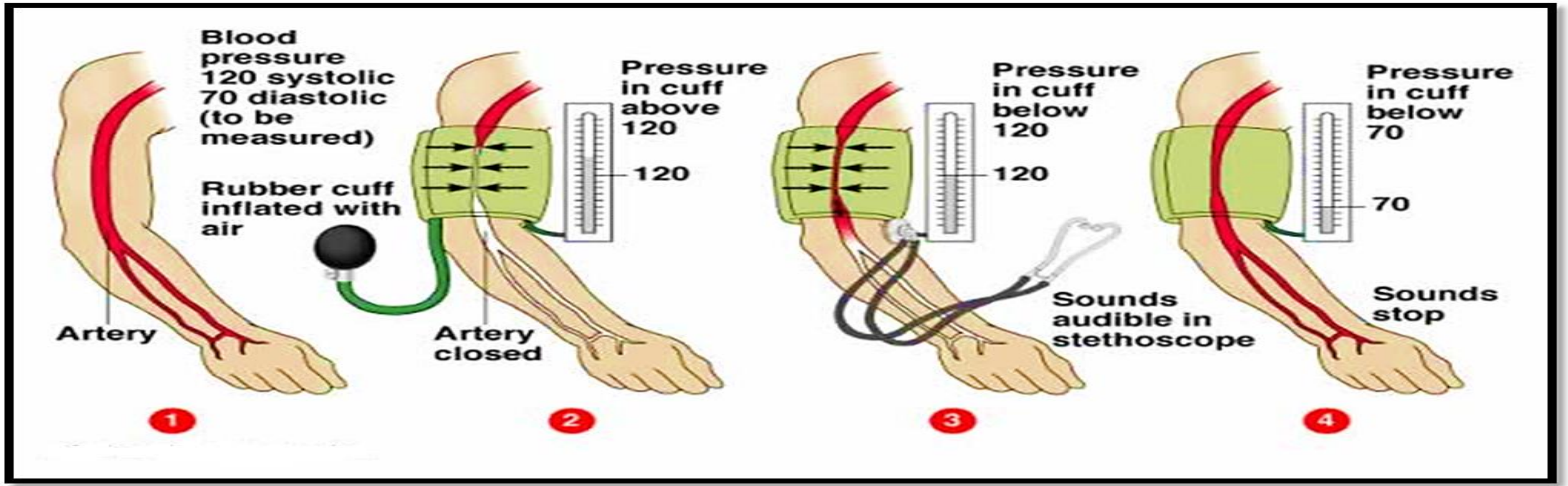
Measurement of Blood Pressure

- Bp cuff is inflated occluding brachial artery.

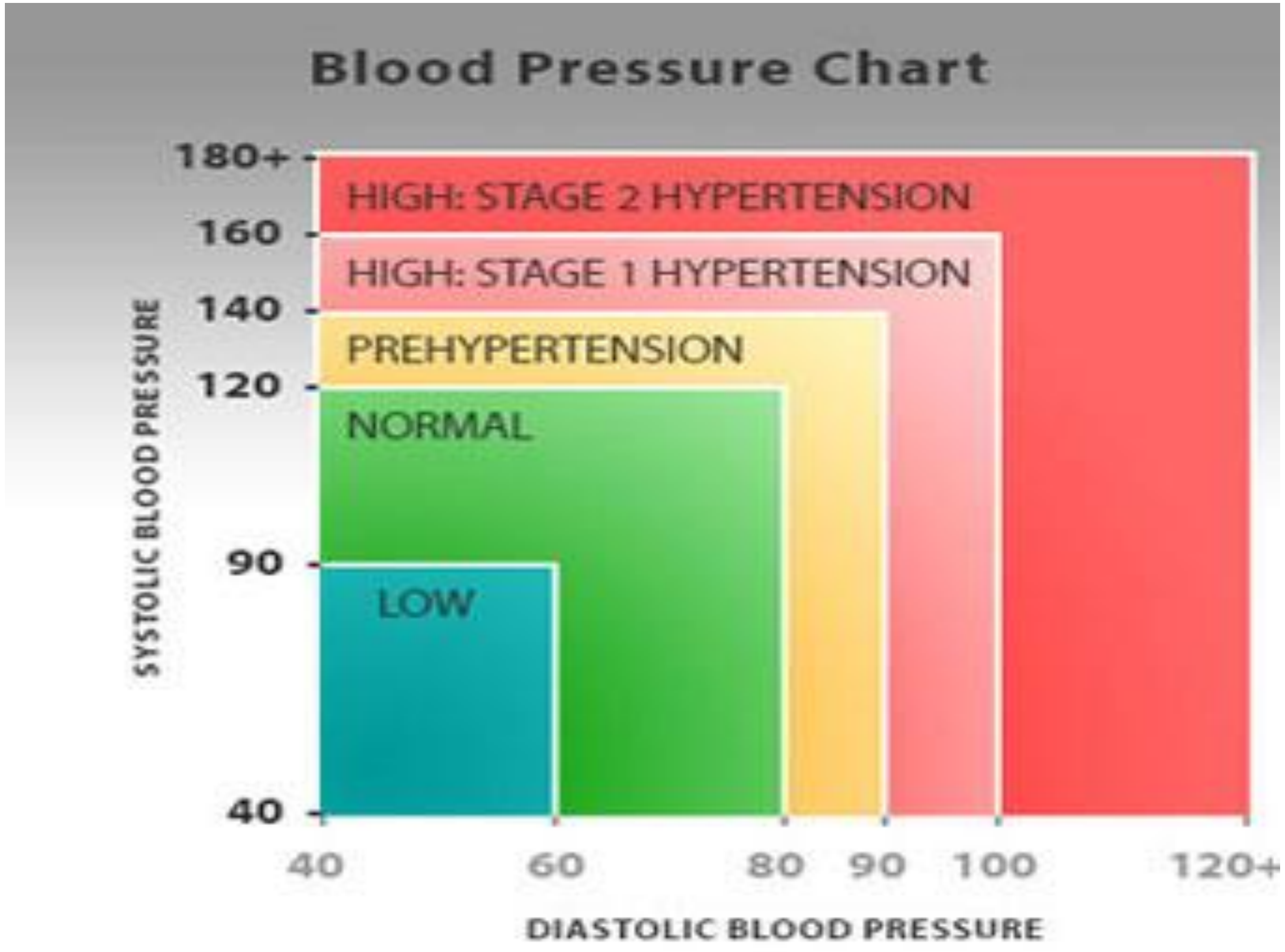
- As cuff pressure is lowered, blood flows when systolic pressure is above cuff pressure, producing first Korotkoff sounds.

- Sounds are heard until cuff pressure equals diastolic pressure (Korotkoff sound disappear).

- Cuff constricts artery creating turbulent flow & noise as blood passes constriction during systole (1st Korotkoff sound) & partially blocked during diastole (muffled sound) because cuff pressure = diastolic pressure).



ARTERIAL BLOOD PRESSURE



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