Cardiovascular physiology

HEART RATE

Normal heart rate is 72/minute. It ranges = 60 & 80 per minute.

TACHYCARDIA

is the increase in the heart rate above 100/minute.

Physiological conditions when tachycardia occurs are:

1. Childhood
2. Exercise 3. Pregnancy

4. Emotional conditions such as anxiety.

Pathological conditions when tachycardia occurs are:

1. Fever

2. Anemia
3. Hypoxia4. Hyperthyroidism
5. Hypersecretion of catecholamines
6. Cardiomyopathy
7. Valvular heart diseases.

BRADYCARDIA

is the decrease in the heart rate below 60/minute. Physiological conditions when bradycardia occurs are:

1. Sleep
2. Athletic heart.

Pathological conditions when bradycardia occurs are:

1. Hypothermia
2. Hypothyroidism
3. Heart attack
4. Congenital heart disease
5. Degenerative process of aging
6. Obstructive jaundice
7. Increased intracranial pressure.

REGULATION OF HEART RATE

Heart rate is maintained within normal range constantly. It is subjected for variation during normal physiological conditions such as exercise, emotion, etc.- the altered heart rate is quickly brought back to normal-- is regulated by nervous mechanism which consists of three components:

I. Vasomotor center
II. Motor (efferent) nerve fibers to the heart
III. Sensory (afferent) nerve fibers from the heart.

MOTOR (EFFERENT) NERVE FIBERS TO HEART

Heart receives efferent nerves from both the divisions of autonomic nervous system.

Parasympathetic fibers arise from the medulla oblongata and pass through vagus nerve. The sympathetic fibers arise from upper thoracic (T1 to T4) segments of spinal cord.

SENSORY (AFFERENT) NERVE FIBERS FROM HEART

The afferent (sensory) nerve fibers from the heart pass through the inferior cervical sympathetic nerve. These nerve fibers carry sensations of stretch and pain from the heart to the brain via spinal cord.

Nerve supply to heart

The parasympathetic nerve fibers supplying heart arise from the dorsal nucleus of vagus The preganglionic parasympathetic nerve fibers from dorsal nucleus of vagus reach the heart and terminate on postganglionic neurons. The postganglionic fibers from these neurons innervate heart muscle.

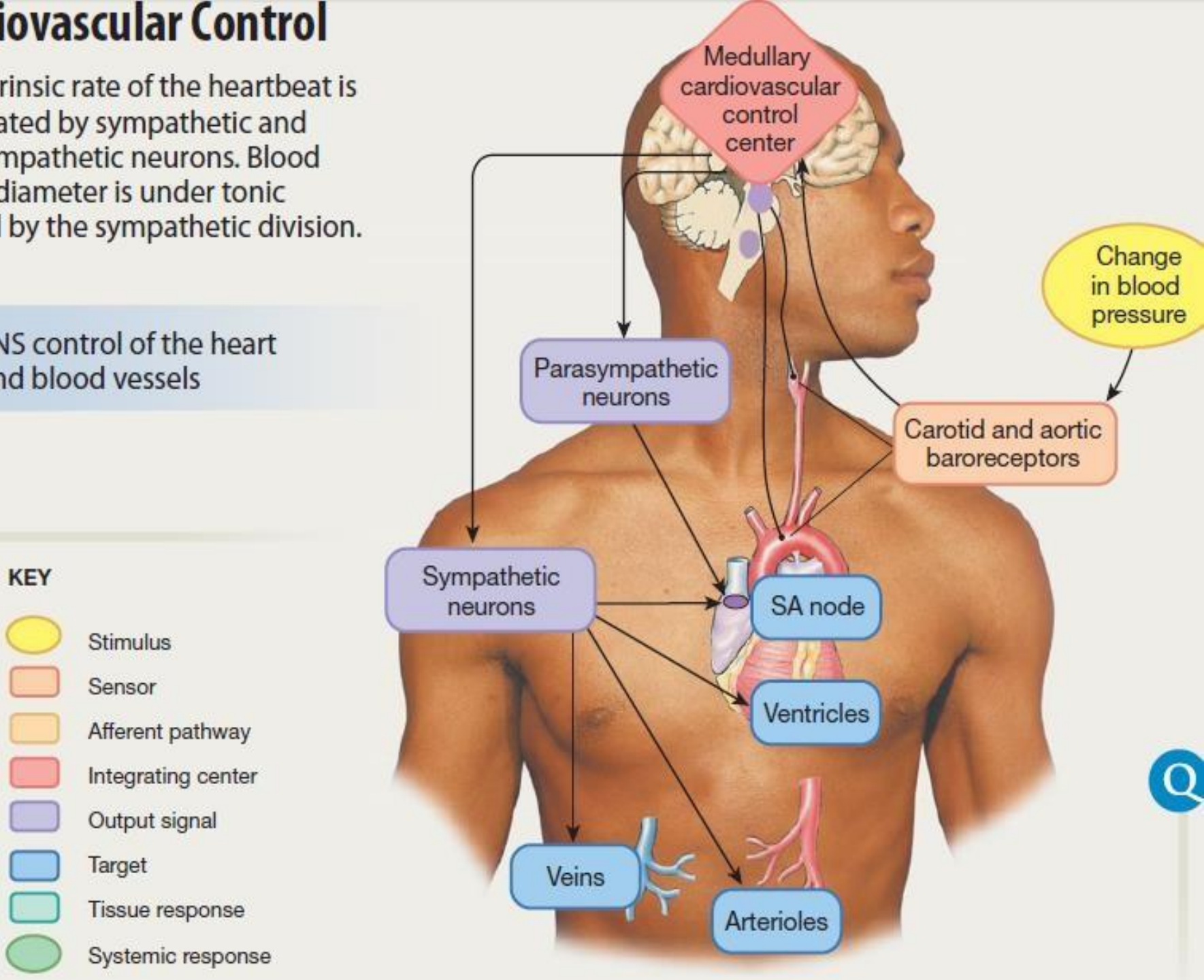
Most of the fibers from right vagus terminate in SA node. Remaining supply the atrial muscles and AV node.

Most of the fibers from left vagus supply AV node and some supply the atrial muscle and SA node. Ventricles do not receive the vagus nerve supply.

Cardiovascular Control

The intrinsic rate of the heartbeat is modulated by sympathetic and parasympathetic neurons. Blood vessel diameter is under tonic control by the sympathetic division.

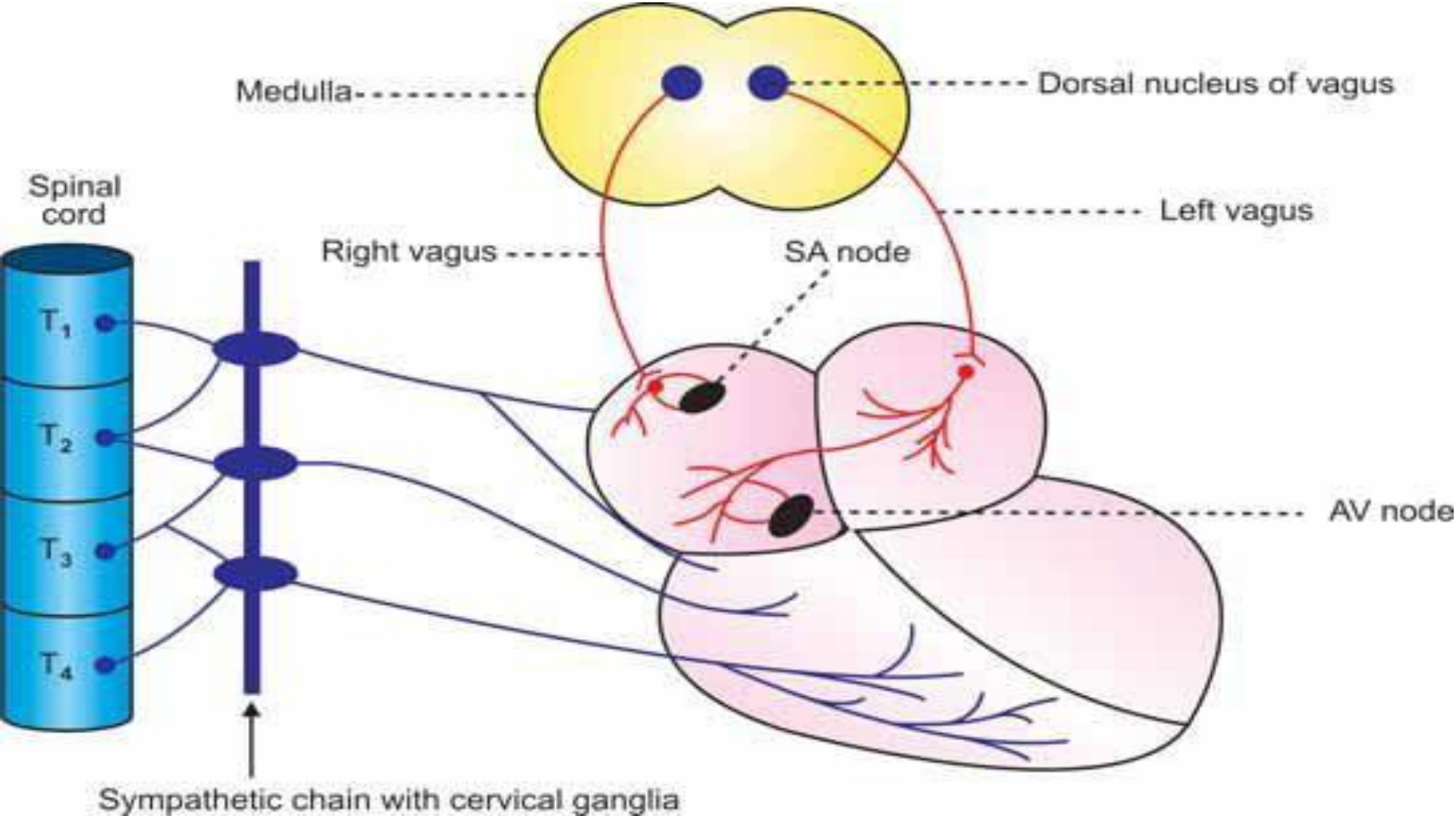
(a) CNS control of the heart and blood vessels



SYMPATHETIC NERVE FIBERS

The preganglionic fibers of the Sympathetic nerves to heart arise from lateral grey horns of the first 4 thoracic (T1 to T4) segments of the spinal cord.

The sympathetic nerves are cardioaccelerator in function and carry cardioaccelerator impulses from vasoconstrictor area to the heart.



FACTORS AFFECTING VASOMOTOR CENTER –

The vasomotor center regulates the cardiac activity by receiving impulses from different sources in the body. After -, the vasodilator area alters the vagal tone and modulates the activities of the heart. The various sources from which the impulses reach vasomotor center are:

1. IMPULSES FROM HIGHER CENTERS(Cerebral Cortex, Hypothalamus)
2. IMPULSES FROM RESPIRATORY CENTERS
3. IMPULSES FROM BARORECEPTORS – MAREY'S REFLEX

The baroreceptors or pressoreceptors are the receptors, which give response to change in blood pressure. two types, carotid baroreceptors and aortic baroreceptors

The baroreceptors regulate the heart rate through a reflex called Marey's reflex. The stimulus for this reflex is increase in blood pressure.

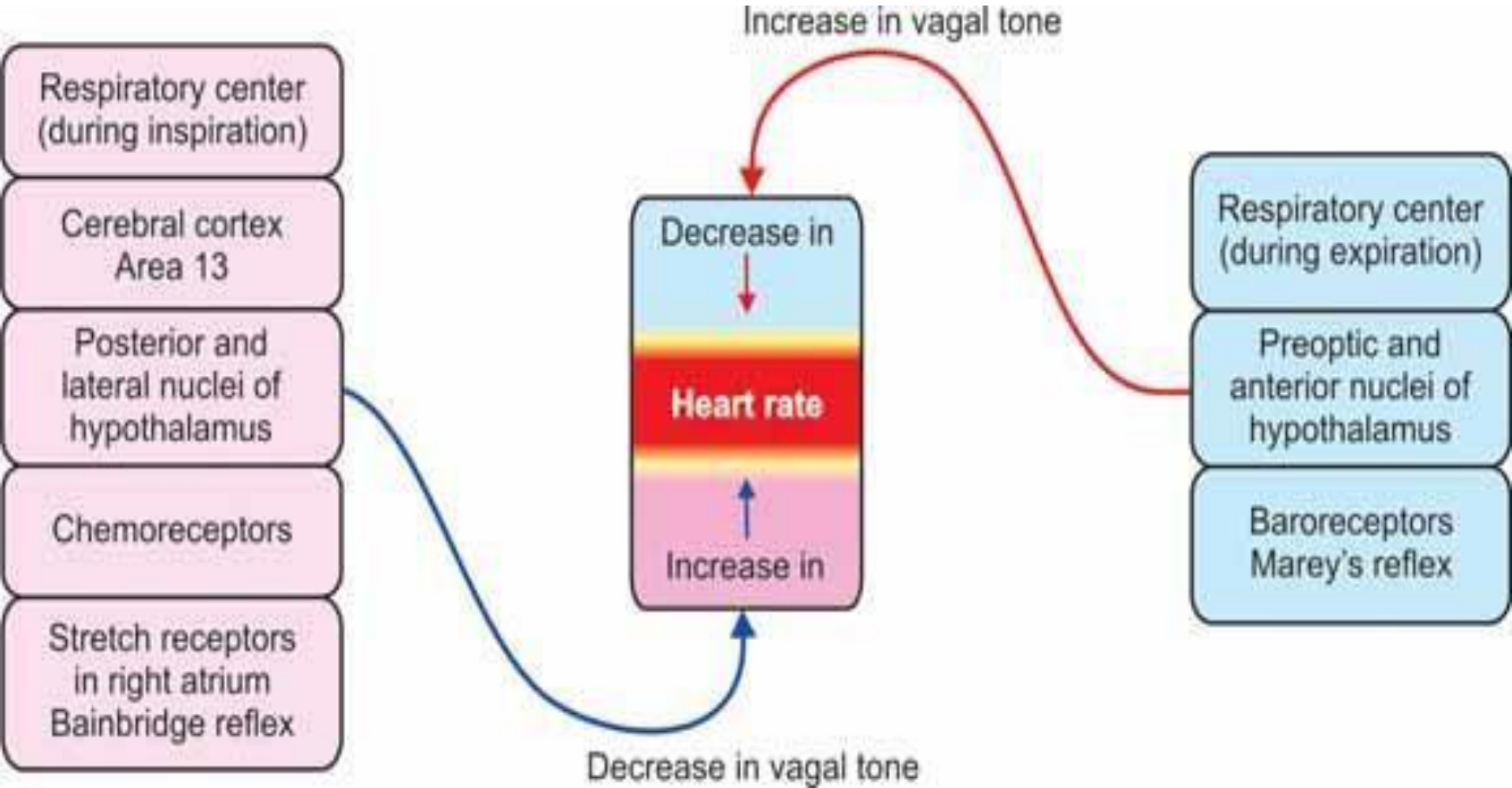
4. IMPULSES FROM CHEMORECEPTORS

are receptors giving response to change in chemical constituents of blood, particularly oxygen, carbon dioxide and hydrogen ion concentration.

Peripheral chemoreceptors are situated in the carotid body and aortic body adjacent to baroreceptors.

5. IMPULSES FROM RIGHT ATRIUM – BAINBRIDGE REFLEX
6. IMPULSES FROM OTHER AFFERENT NERVES

Factors regulating vagal tone and heart rate



Arterial blood pressure

is the lateral pressure exerted by the column of blood on the wall of arteries. is expressed in four different terms: 1. Systolic blood pressure

2. Diastolic blood pressure

3. Pulse pressure

4. Mean arterial blood pressure.

Systolic blood pressure (systolic pressure) is the maximum pressure exerted in the arteries during systole of the heart- is 120 mm Hg. It ranges = 110 & 140 mm Hg.

Diastolic blood pressure (diastolic pressure) is the minimum pressure in the arteries during diastole of the heart. The normal-is 80 mm Hg. varies between 60 & 80 mm Hg.

Pulse pressure is the difference between systolic pressure and diastolic pressure. Normally, it is 40 mm Hg (120 to 80).

PHYSIOLOGICAL VARIATIONS

Age

2. Sex

In females, up to period of menopause, arterial pressure is about 5 mm Hg less than inmales of same age. After, the pressure in females becomes equal to that in males of same age.

3. Body Built--The pressure is more in obese persons than in lean persons.

4. Diurnal Variation

In early morning, the pressure is slightly low. It gradually increases and reaches the maximum at noon. It becomes low in evening.

5. After Meals

The arterial blood pressure is increased for few hours after meals due to increase in cardiac output. 6. During Sleep

Usually, the pressure is reduced up to 15 to 20 mm Hg during deep sleep. However, it increases slightly during sleep associated with dreams.

7. Emotional Conditions

During excitement or anxiety, the blood pressure is increased due to release of adrenaline.

8. After Exercise

After moderate exercise, systolic pressure increases by 20 to 30 mm Hg above the basal level due to increase in force of contraction and stroke volume. Normally, diastolic pressure is not affected by moderate exercise. It is because the diastolic pressure depends upon peripheral resistance, which is not altered by moderate exercise.

After severe muscular exercise, the systolic pressure rises by 40 to 50 mm Hg above the basal level. But, the diastolic pressure reduces because the peripheral resistance decreases in severe muscular exercise.

DETERMINANTS OF ARTERIAL BLOOD PRESSURE – FACTORS MAINTAINING ARTERIAL BLOOD PRESSURE

Some factors are necessary for maintenance of normal blood pressure, which are called local factors, mechanical factors or determinants of blood pressure. These factors are divided into 2 types:

I. **Central factors** -pertaining to the heart:(Cardiac output& Heart rate). II**. Peripheral factors--** pertaining to blood and blood vessels: 1. Peripheral resistance

2. Blood volume

3. Venous return

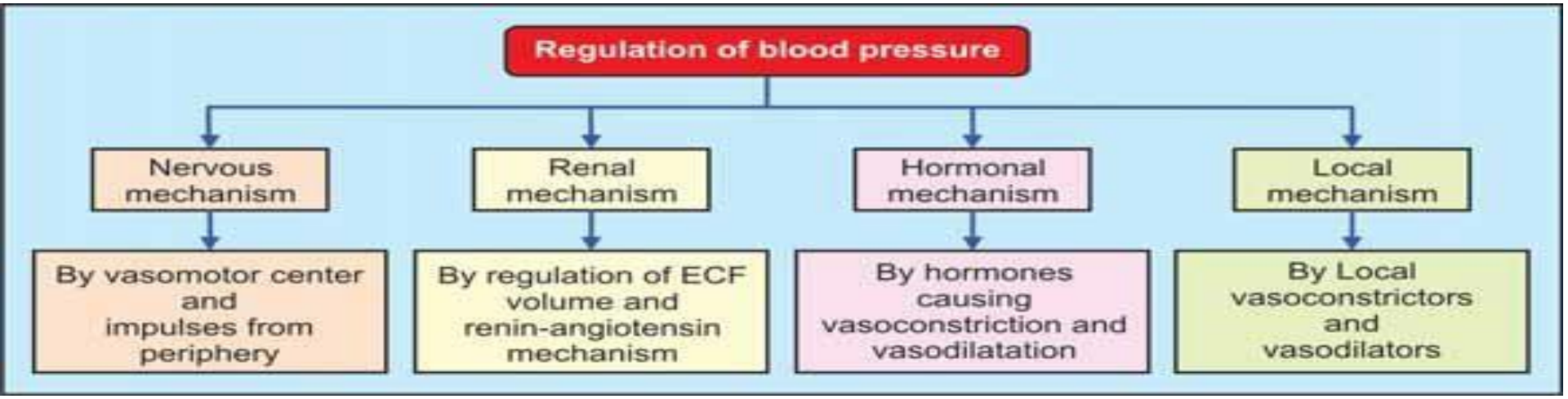
4. Elasticity of blood vessels

5. Velocity of blood flow 6. Diameter of blood vessels

7. Viscosity of blood.

REGULATION OF ARTERIAL BLOOD PRESSURE

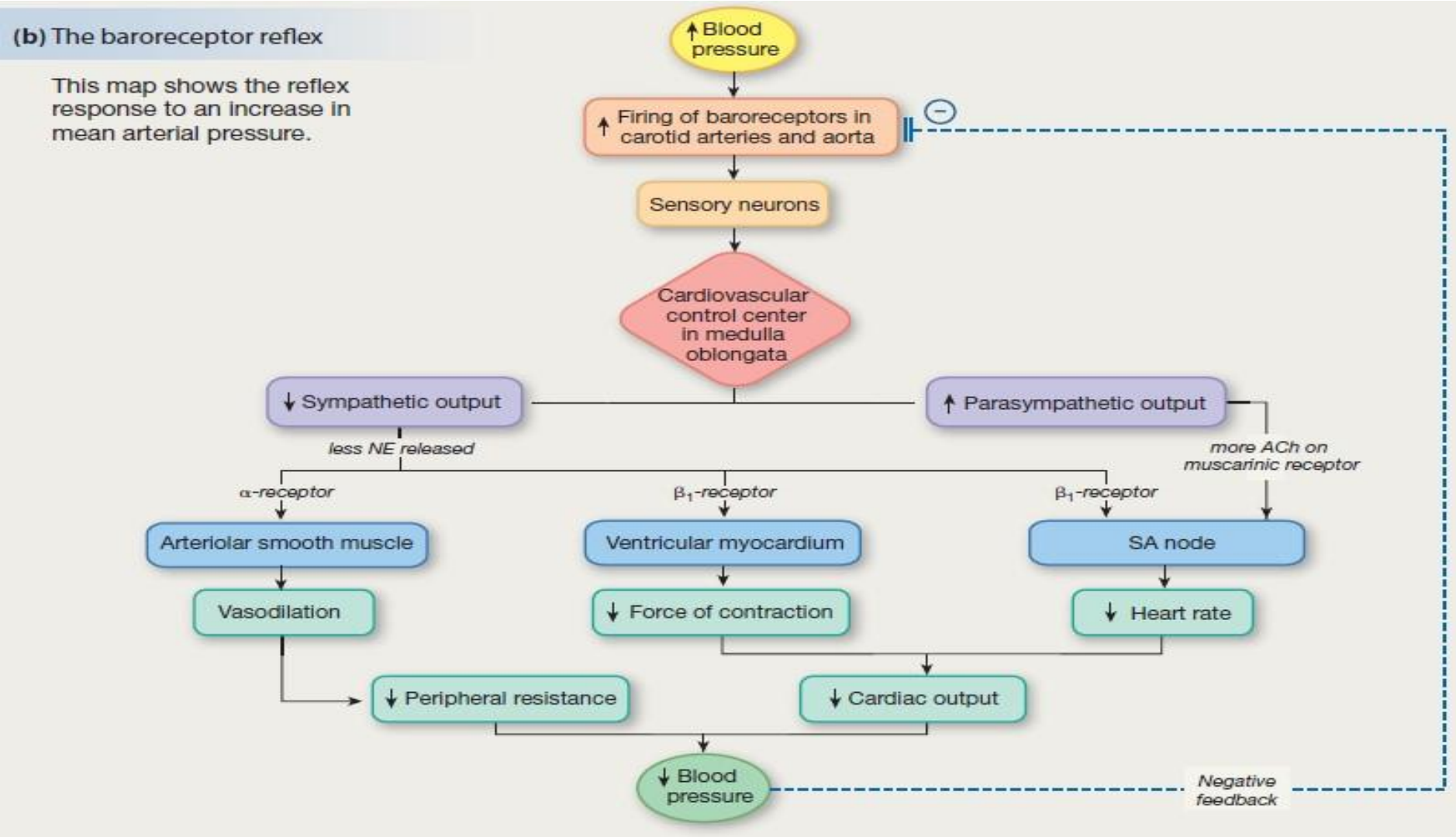
Body has 4 regulatory mechanisms.



The nervous regulation is rapid among all the mechanisms involved in regulation of ABP. When BP alters, nervous system brings the pressure back to normal within few minutes. Although nervous mechanism is quick in action, it operates only for a short period & then it adapts to the new pressure, through the vasomotor system.

The vasomotor center regulates ABP by causing vasoconstriction or vasodilatation, its actions depend upon the impulses it receives from other structures such as baroreceptors, chemoreceptors, higher centers and respiratory centers. --baroreceptors and chemoreceptors play a major role in the short-term regulation of blood pressure. = called short-term regulation.

Regulation of blood pressure by baroreceptor mechanism

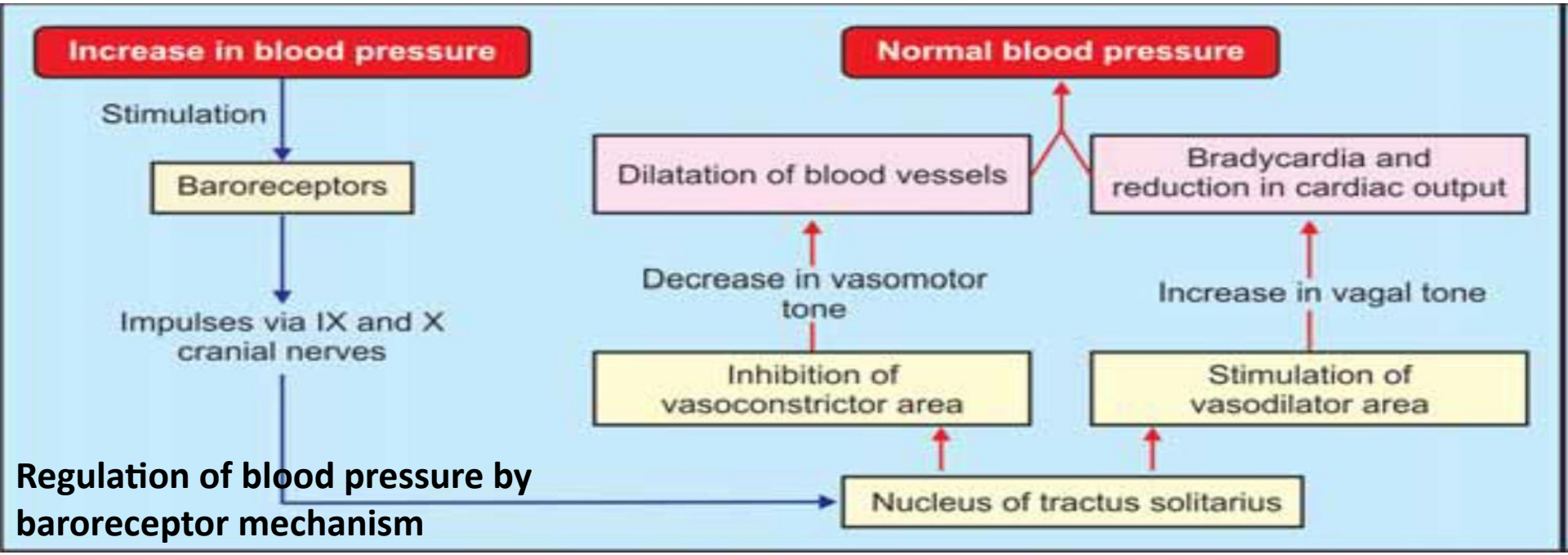


Regulation of blood pressure by baroreceptor mechanism

2. Chemoreceptor Mechanism

Whenever blood pressure decreases, the blood flow decreases resulting in decreased oxygen content and excess of carbon dioxide and hydrogen ion.

These factors stimulate the chemoreceptors, which send impulses to stimulate the vasoconstrictor center. The blood pressure rises and blood flow increases.



Regulation of blood pressure by baroreceptor mechanism

Sinoaortic mechanism

Mechanism of action of baroreceptors and chemoreceptors in carotid and aortic region. The nerves from the baroreceptors and chemoreceptors are called buffer nerves because these nerves regulate the heart rate, blood pressure and respiration.

RENAL MECHANISM FOR REGULATION OF B P – LONG-TERM REGULATION

kidneys play an important role in the long term regulation of ABP. by 2 ways:

1. By regulation of ECF volume
2. Through renin-angiotensin mechanism.

BY REGULATION OF EXTRACELLULAR FLUID VOLUME

When the BP increases, kidneys excrete large amounts of water & salt, particularly sodium by means of pressure diuresis & pressure natriuresis. Pressure diuresis is the excretion of large quantity of water in urine because of increased BP (Even a slight increase in BP doubles the water excretion).

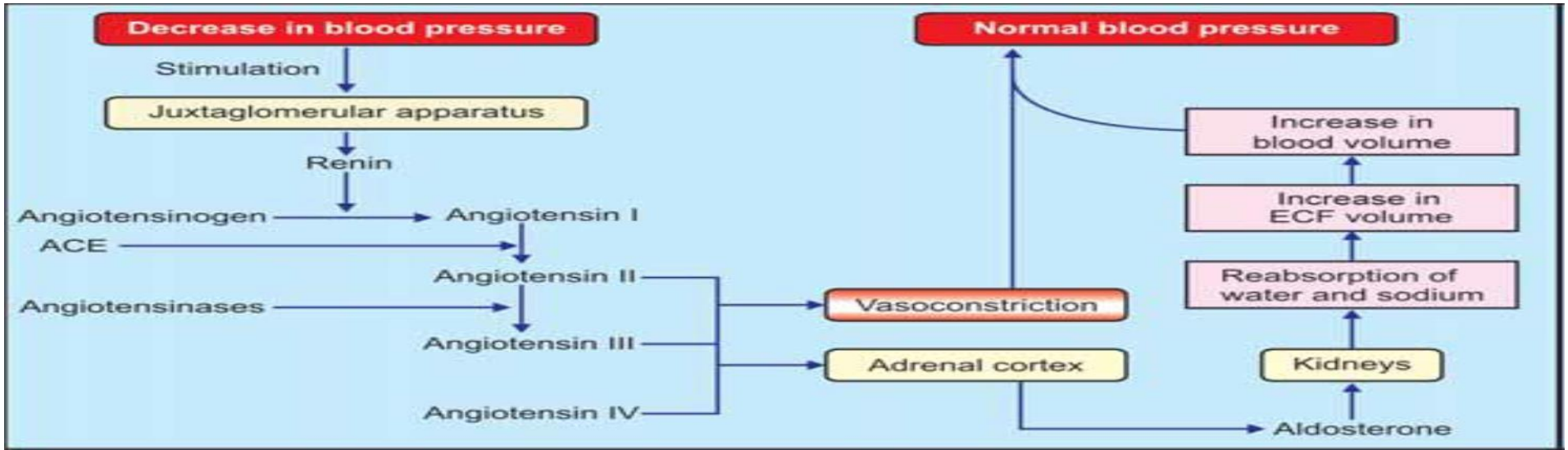
Pressure natriuresis is the excretion of large quantity of sodium in urine. Because of diuresis & natriuresis, there is decrease in the ECF volume &blood volume, which in turn brings the ABP back to normal level.

When blood pressure decreases, the reabsorption of water from renal tubules is increased. This in turn, increases ECF volume, blood volume & cardiac output resulting in restoration of BP.

Regulation of blood pressure by renin-angiotensin mechanism(Actions of Angiotensin II)

When BP & ECF volume decrease, renin secretion from kidneys increased. It converts angiotensinogen into angiotensin I, This converted into angiotensin II by ACE, acts in 2 ways to restore the BP:

i. It causes constriction of arterioles in body so that the peripheral resistance is increased, & BP rises. In addition, angiotensin II causes constriction of afferent arterioles in kidneys so that the glomerular filtration reduces. This results in retention of water & salts. This increases ECF volume to normal level. This in turn increases the BP to normal level.



ii. Simultaneously, angiotensin II stimulates the adrenal cortex to secrete aldosterone. This hormone increases reabsorption of sodium from renal tubules, is followed by water reabsorption resulting in increased ECF volume & blood volume. It increases the BP to normal level.

HORMONAL MECHANISM FOR REGULATION Of BP

Hormones which **Increase** the Blood Pressure

1. Adrenaline
2. Noradrenaline
3. Thyroxine
4. Aldosterone
5. Vasopressin
6. Angiotensin
7. Serotonin.

Hormones which **Decrease** the Blood Pressure

1. Vasoactive intestinal polypeptide (VIP)
2. Bradykinin
3. Prostaglandin
4. Histamine

5. Acetylcholine
6. Atrial natriuretic peptide
7. Brain natriuretic peptide
8. C-type natriuretic peptide.

LOCAL MECHANISM FOR REGULATION OF BP

some local substances also regulate the BP.-- by vasoconstriction or vasodilatation.

LOCAL VASOCONSTRICTORS

The local vasoconstrictor substances are of vascular endothelial origin= known as endothelins (ET). Endothelins are produced by stretching of blood vessels. These peptides act by activating phospholipase, which activates the prostacyclin & thromboxane A2. These two substances cause constriction of blood vessels & increase in blood pressure.

LOCAL VASODILATORS

The local vasodilators are of two types:

1. Vasodilators of metabolic origin such as carbon dioxide, lactate, hydrogen ions & adenosine
2. Vasodilators of endothelial origin such as nitric oxide (NO).

HYPERTENSION

the persistent high blood pressure. Clinically, systolic pressure remains elevated above 150 mm Hg & diastolic pressure remains elevated above 90 mm Hg, it is considered as hypertension. If there is increase only in systolic pressure, it is called systolic hypertension.

Types of Hypertension

1. Primary hypertension or essential hypertension

Primary hypertension is the elevated blood pressure in the absence of any underlying disease- called essential hypertension.

The arterial blood pressure is increased because of increased peripheral resistance, which occurs due to some unknown cause.

2**. Secondary hypertension**

is the high blood pressure due to some underlying disorders. The different forms of secondary hypertension are:

- i. Cardiovascular hypertension that is produced due to the cardiovascular disorders such as atherosclerosis(hardening of blood vessels by fat deposition) and coarctation (narrowing) of aorta
- ii. Endocrine hypertension which is due to hyperactivity of some endocrine glands such as pheochromocytoma, hyperaldosteronism and Cushing's syndrome
- iii. Renal hypertension that is caused by renal diseases like glomerulonephritis and stenosis of renal arteries
- iv. Neurogenic hypertension which is developed by nervous disorders such as increased intracranial pressure and lesion in tractus solitarius
- v. Hypertension during pregnancy which is due to toxemia of pregnancy.

HYPOTENSION

is the low BP. When the systolic pressure is less than 90 mm Hg, considered as hypotension. Types **1. Primary hypotension**

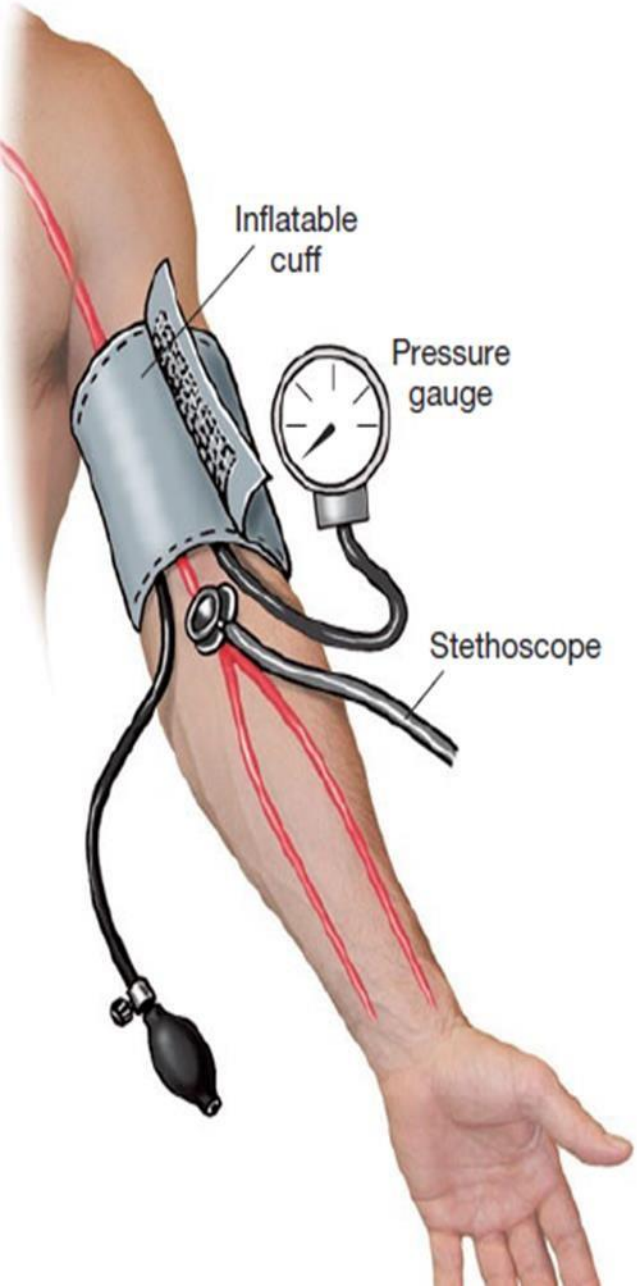
is the low BP that develops in the absence of any underlying disease & develops due to some unknown cause. It is also called essential hypotension. Frequent fatigue and weakness are the common symptoms of this condition. However, the persons with primary hypotension are not easily susceptible to heart or renal disorders.

2. Secondary hypotension

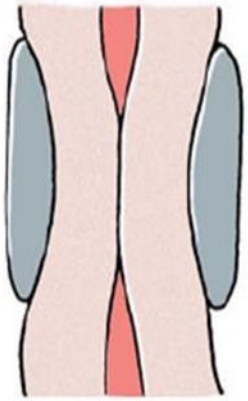
occurs due to some underlying diseases. The diseases which cause hypotension are:

- ❑ i. Myocardial infarction
- ❑ ii. Hypoactivity of pituitary gland
- ❑ iii. Hypoactivity of adrenal glands ❑ iv. Tuberculosis
- ❑ v. Nervous disorders.

Arterial blood pressure is measured with a sphygmomanometer (an inflatable cuff plus a pressure gauge) and a stethoscope. The inflation pressure shown is for a person whose blood pressure is 120/80.



(a)



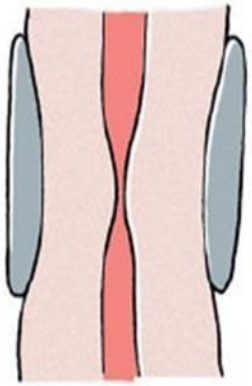
Cuff pressure > 120 mm Hg





When the cuff is inflated so that it stops arterial blood flow, no sound can be heard through a stethoscope placed over the brachial artery distal to the cuff.

(b)



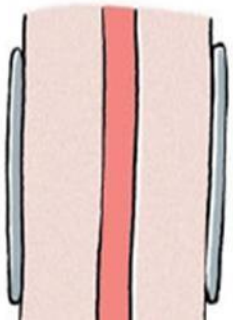
Cuff pressure between 80 and 120 mm Hg





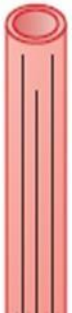
Korotkoff sounds are created by pulsatile blood flow through the compressed artery.

(c)



Cuff pressure < 80 mm Hg





Blood flow is silent when the artery is no longer compressed.