MEDICAL UNIVERSITY – PLEVEN
FACULTY OF MEDICINE
DISTANCE LEARNING CENTER

Lecture № 8

Circulation. Dynamics of blood pressure, flow and resistance. Microcirculation. Veins and their functions

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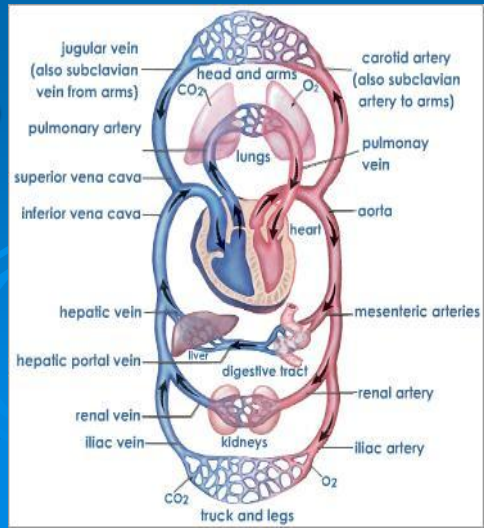
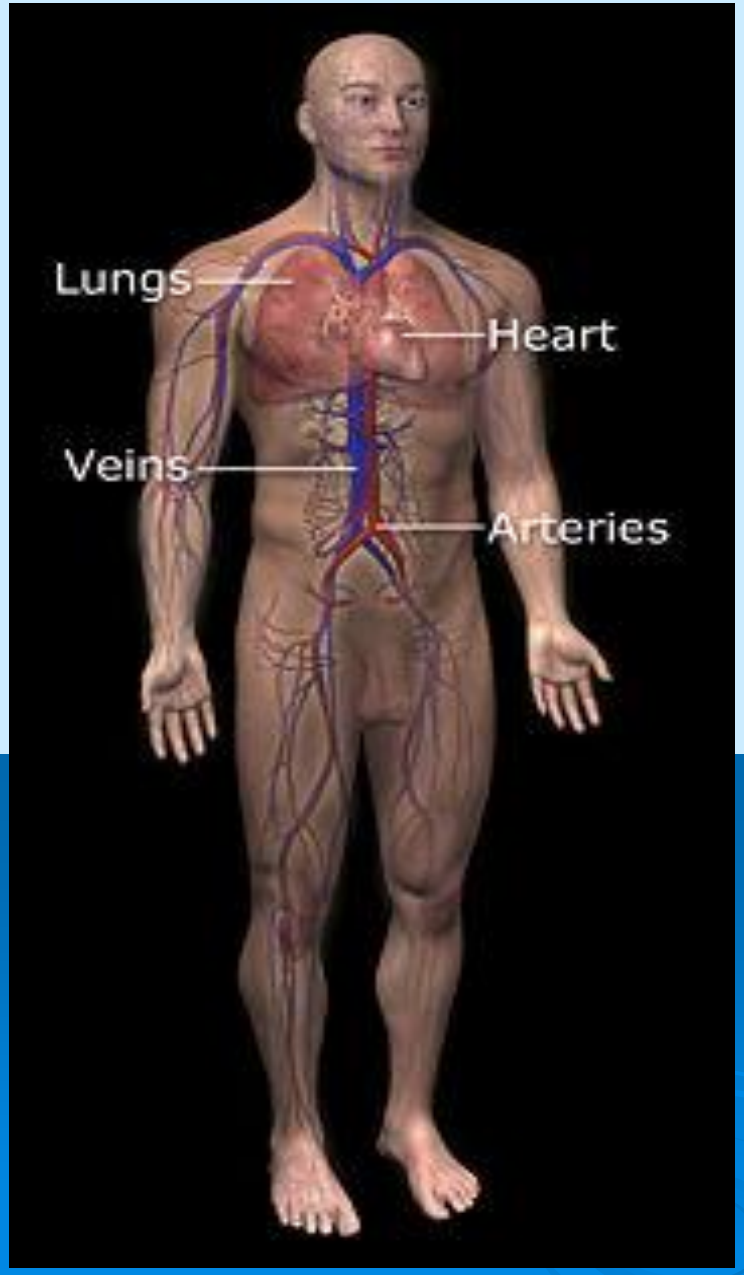
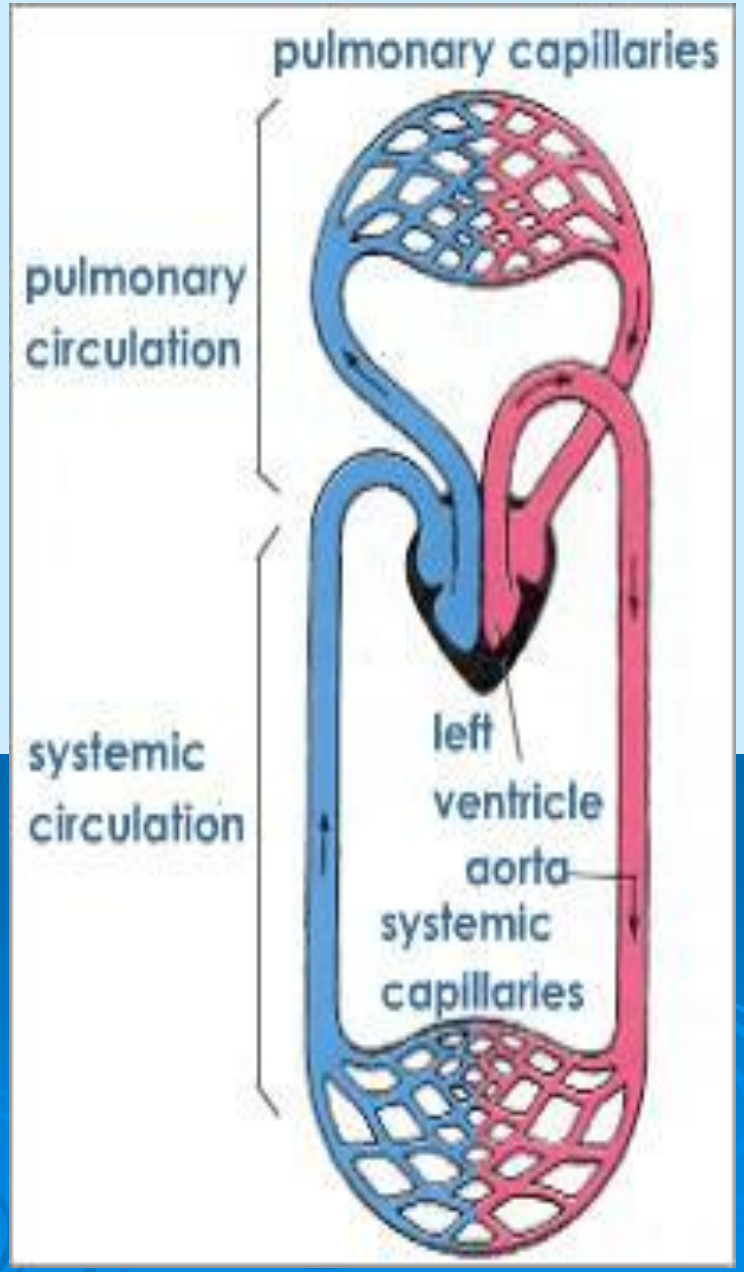


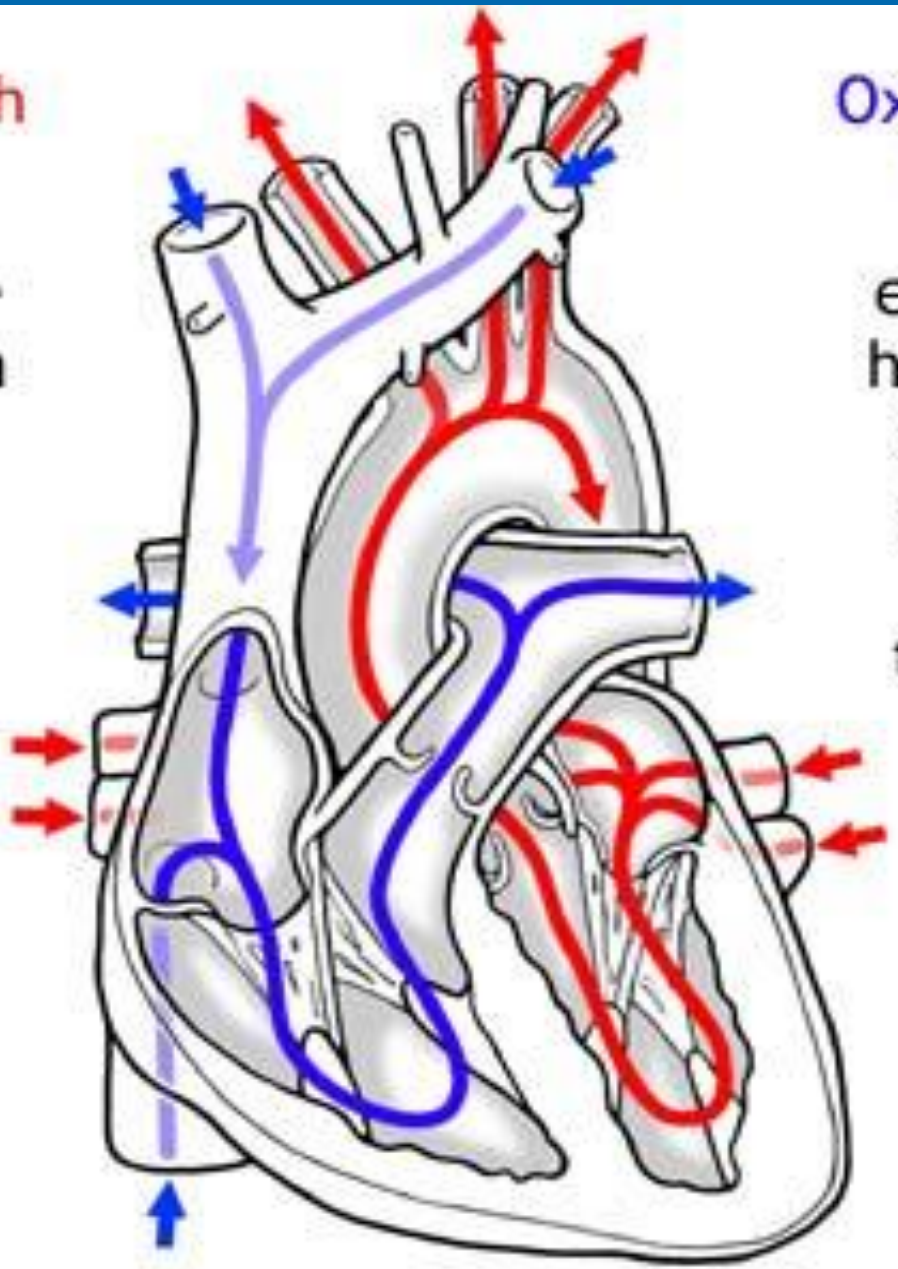
Physical characteristics of the circulation





Oxygen-rich blood

enters the heart from the lungs and goes out to the body



Oxygen-poor blood

enters the heart from the body and goes out to the lungs

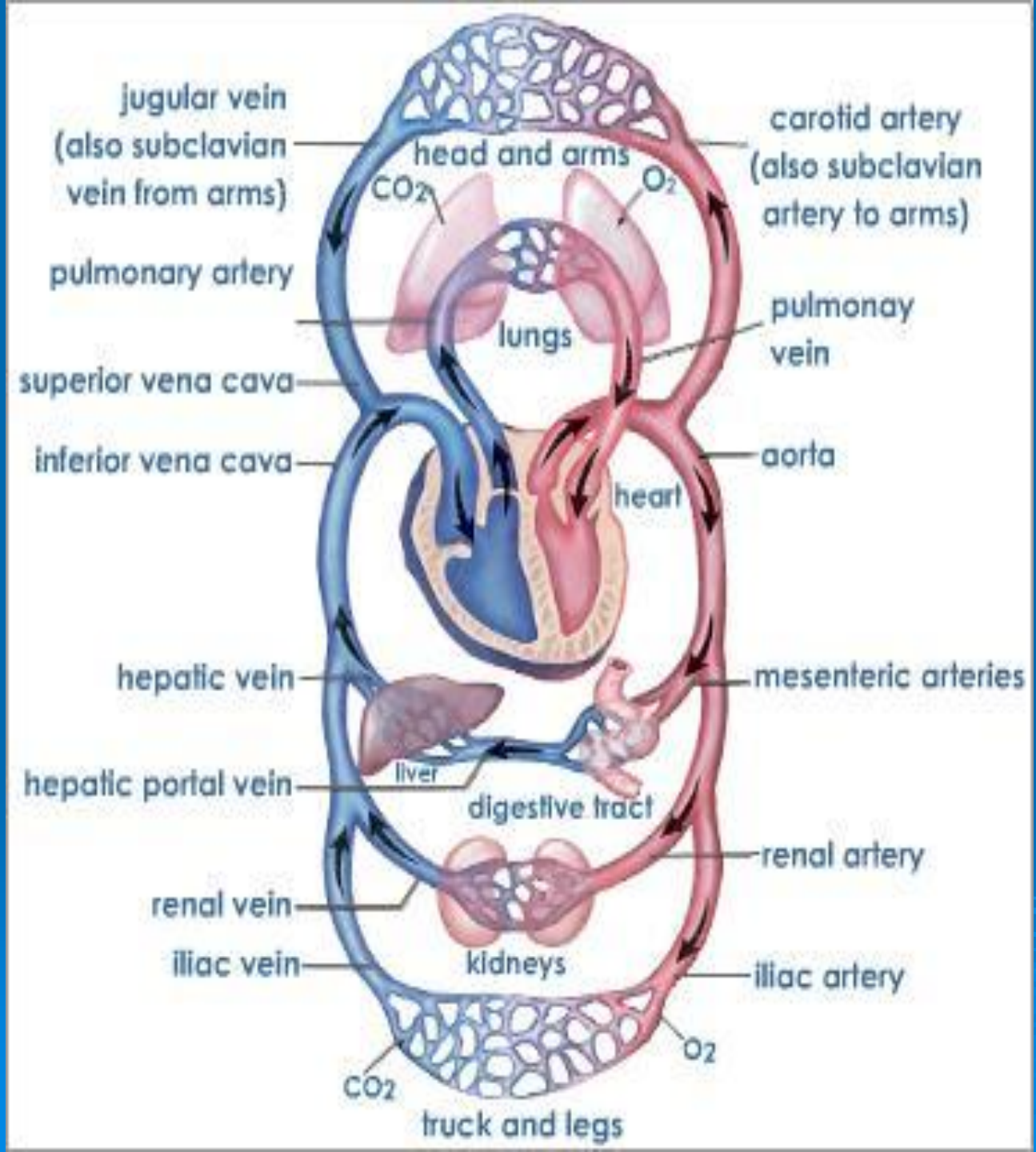
Basic Theory of Circulatory Function

- 1. The rate of blood flow to each tissue of the body is almost always precisely controlled in relation to the tissue need.
- 2. The cardiac output is controlled mainly by the sum of all the local tissue flows.
- 3. In general the arterial pressure is controlled independently of either local blood flow control or cardiac output control.

Circulatory system

There are various kinds of blood vessels:

- Arteries
  - Aorta (the largest artery, carries blood out of the heart)
  - Branches of the aorta, such as the carotid artery, the subclavian artery, the celiac trunk, the mesenteric arteries, the renal artery and the iliac artery.
- Arterioles
- Capillaries (the smallest blood vessels)
- Venules
- Veins
  - Large collecting vessels, such as the subclavian vein, the jugular vein, the renal vein and the iliac vein.
  - Venae cavae (the 2 largest veins, carry blood into the heart)


jugular vein
(also subclavian
vein from arms)
head and arms
carotid artery
(also subclavian
artery to arms)
CO_2
O_2
pulmonary artery
lungs
pulmonay
vein
superior vena cava
inferior vena cava
aorta
heart
hepatic vein
mesenteric arteries
liver
hepatic portal vein
digestive tract
renal artery
renal vein
kidneys
iliac vein
iliac artery
O_2
CO_2
truck and legs

Distribution of the blood in systemic circulation

- Heart - 5%;
- Brain – 15% ;
- Muscles – 20%;
- Kidney -20%
- Splanchnichus area -25%;
- Skin - 15%

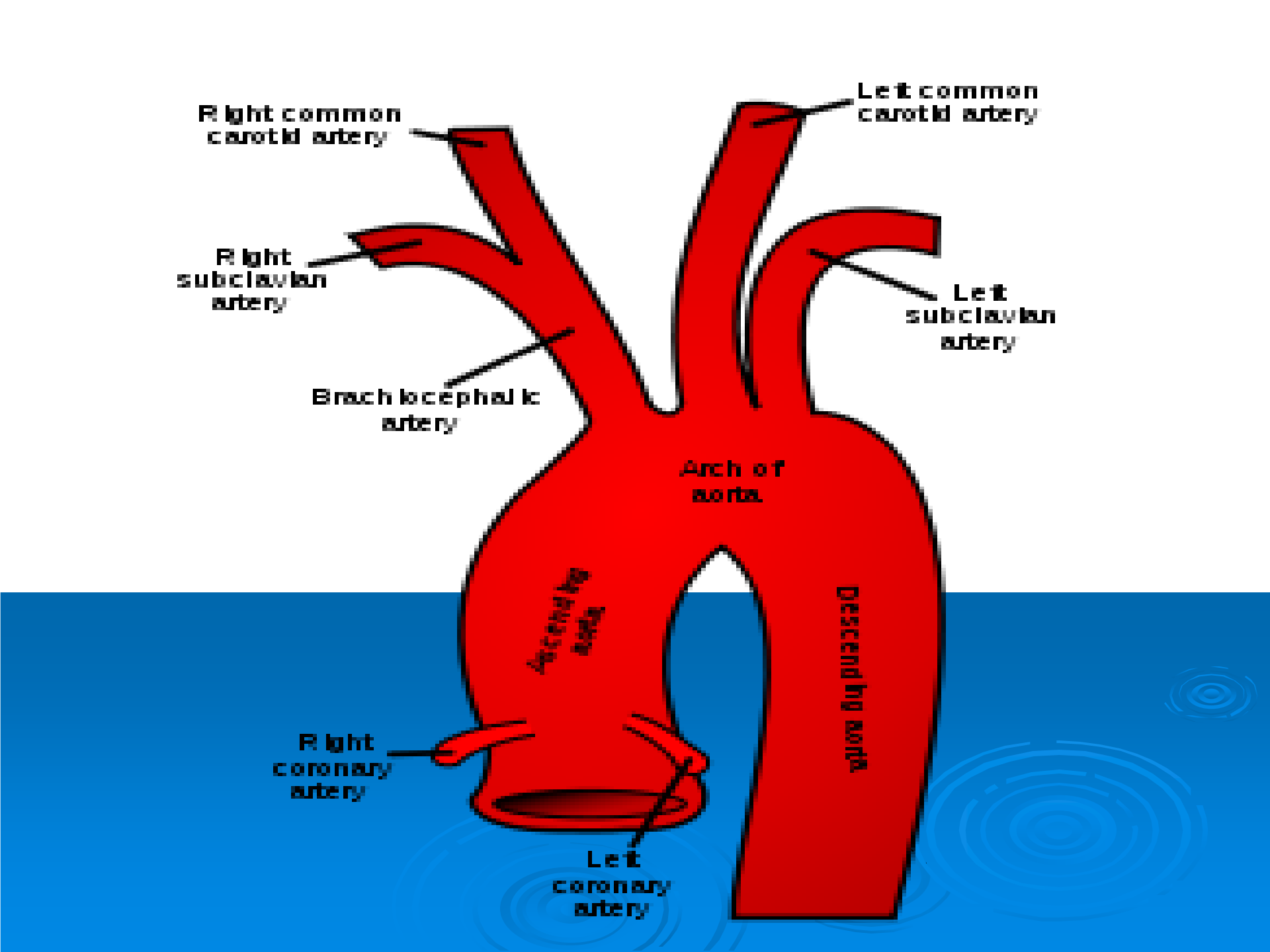
Classification of the vessels

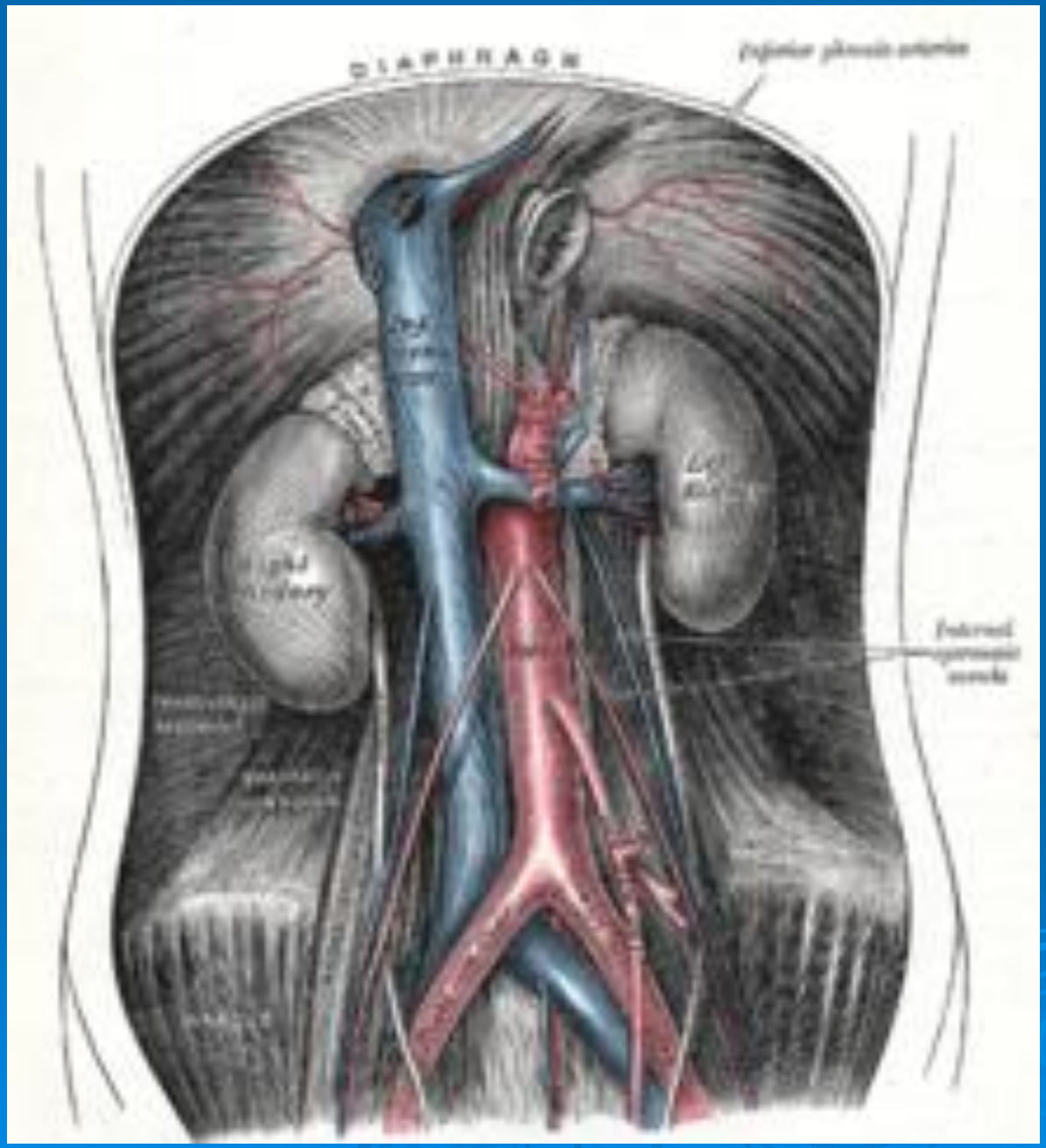
1. Depending on functions:
- Modulation of the tone
- Resistance of the blood flow
- Exchange of the gases and the substances
- Reservoir of the blood

2. Depending on pressure:
- System of low BP
- System of high BP

Circulatory system

- The aorta is usually divided into five segments/sections/ :
- Ascending aorta — the section between the heart and the arch of aorta
- Arch of aorta — the peak part that looks somewhat like an inverted "U"
- Descending aorta — the section from the arch of aorta to the point where it divides into the common iliac arteries
  - Thoracic aorta — the half of the descending aorta above the diaphragm
  - Abdominal aorta — the half of the descending aorta below the diaphragm


Right common carotid artery
Left common carotid artery
Right subclavian artery
Left subclavian artery
Brachiocephalic artery
Arch of aorta
Ascending aorta
Descending aorta
Right coronary artery
Left coronary artery


DIAPHRAGM

Circulatory system

Types of arteries:

- Systemic arteries deliver blood to the arterioles, and then to the capillaries, where nutrients and gasses are exchanged.

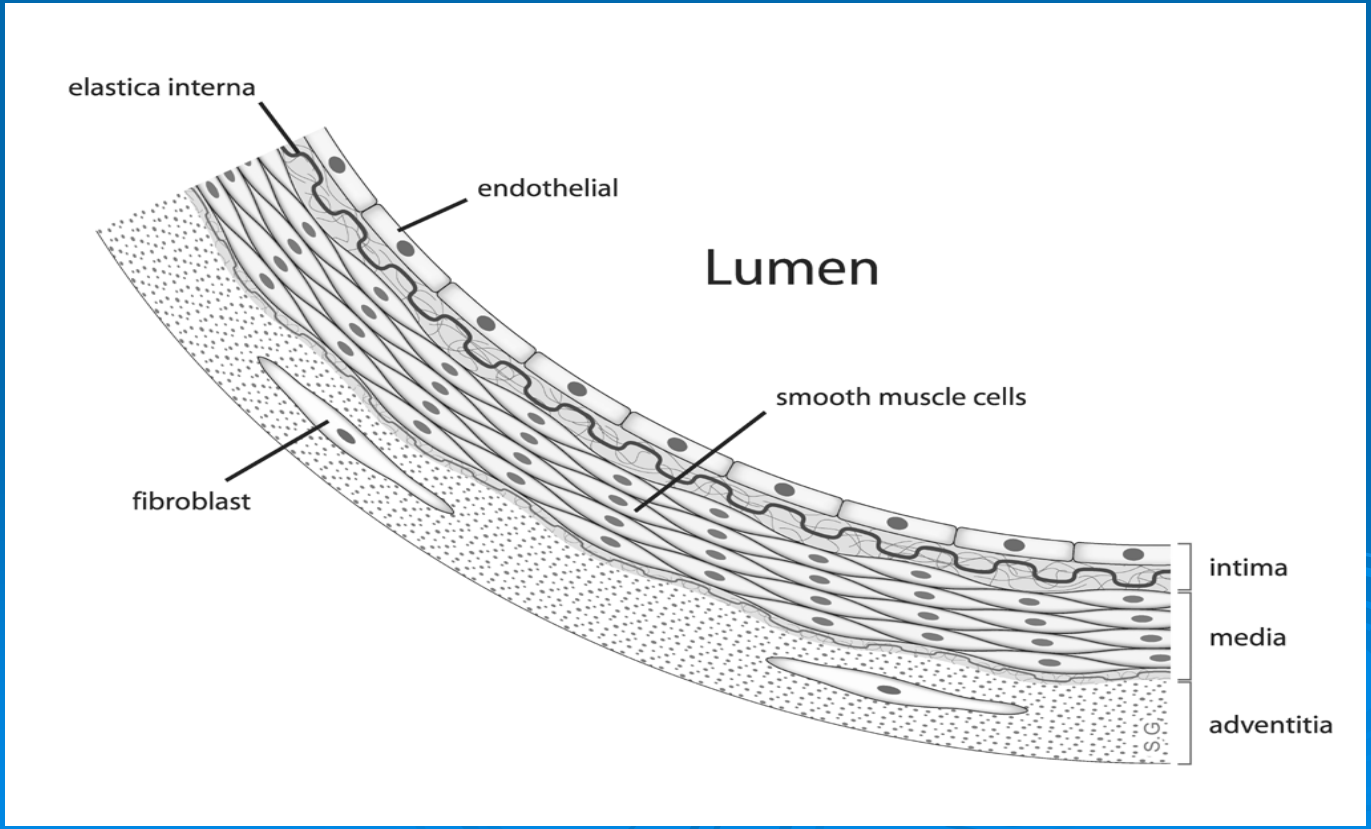
- The pulmonary arteries carry deoxygenated blood that has just returned from the body to the lungs, where carbon dioxide is exchanged for oxygen.

Circulatory system

Vessel Cross-Sectional Area (cm^2)

- Aorta = 2.5
- Small arteries = 20
- Arterioles = 40
- Capillaries = 2500
- Venules = 250
- Small veins = 80
- Venae cavae = 8

The outermost layer is known as the *tunica externa* formerly known as "tunica adventitia" and is composed of connective tissue. Inside this layer is the *tunica media*, or *media*, which is made up of smooth muscle cells and elastic tissue. The innermost layer, which is in direct contact with the flow of blood is the *tunica intima*, commonly called the *intima*. This layer is made up of mainly endothelial cells. The hollow internal cavity in which the blood flows is called the lumen.



Functions of endothelium

- covers the vessels inside
- secretion of the substances for control of the vessel tone
- secretion of the substances for control of the vessel growth
- control on the coagulation of the blood
- control on the transport processes trough the vessel walls

Circulatory system

- An **arteriole** is a small diameter blood vessel that extends and branches out from an artery and leads to capillaries.

- Arterioles have thin muscular walls (usually only one to two layers of smooth muscle) and are the primary site of *vascular resistance*.

Circulatory system

- This means blood pressure in the arteries supplying the body is a result of the interaction between
- the cardiac output (the volume of blood the heart is pumping per minute) and
- the *vascular resistance*, usually termed total peripheral resistance by physicians and researchers.

Dynamics of blood pressure, flow and resistance

- $Q = \Delta P / R$
- $R = 8l\eta / \pi r^4$
- $Q = \Delta P \pi r^4 / 8l\eta$
- $\Delta P = Q8l\eta / \pi r^4$

Blood pressure (BP)

- **Systolic BP** normal value: **100-140** mmHg

SBP depends on cardiac output (av. 5,25 l/min)

cardiac output = stroke volume x heart rate

- Stroke volume depends on:
  - venous return and
  - dystensibility of arterial vessels and
  - myocardial contractility
- Heart rate depends on:
  - the tone of sympathicus

Blood pressure (BP)

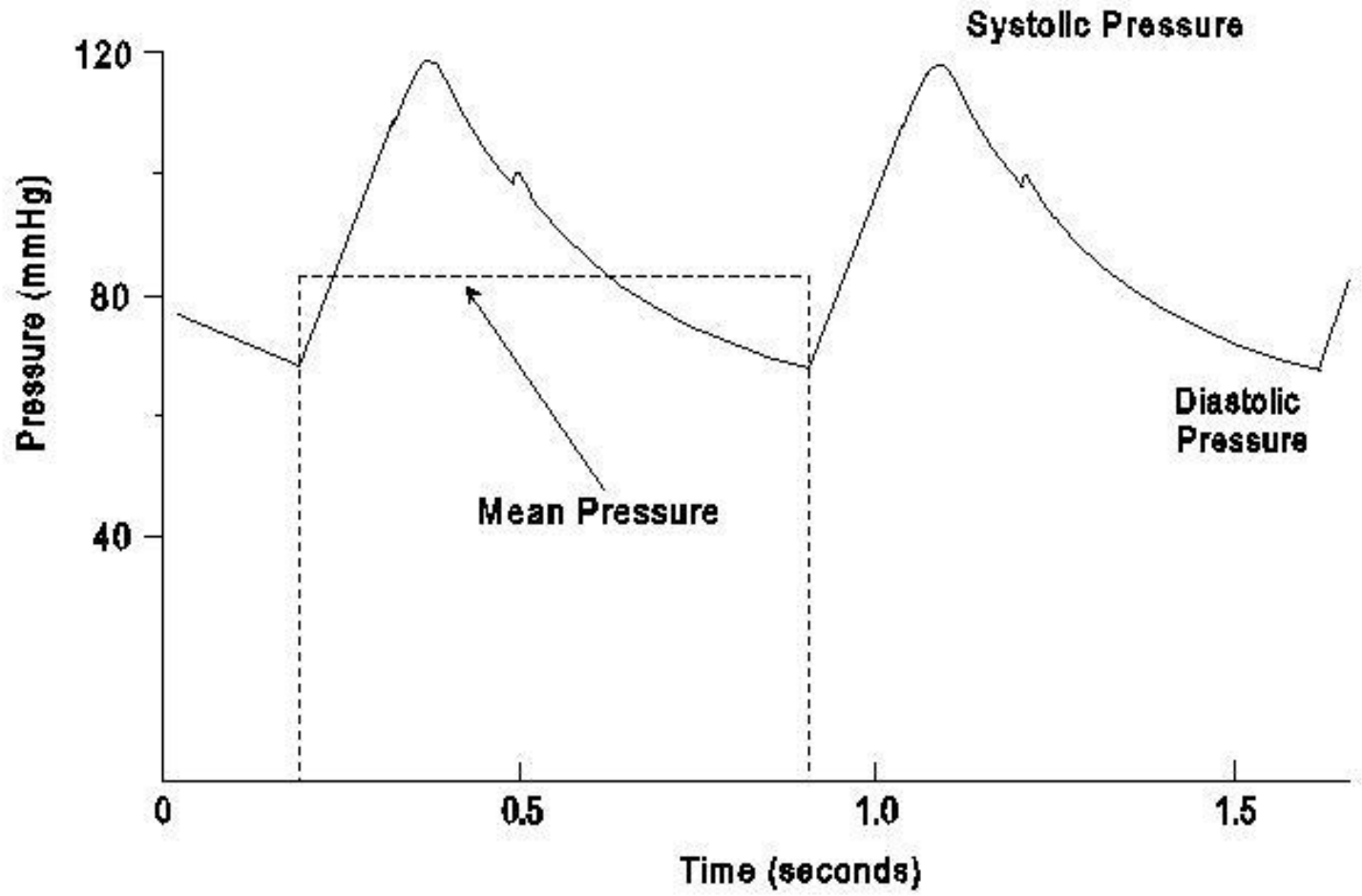
- Diastolic BP normal value: 60-90 mmHg

Depends on: peripheral resistance

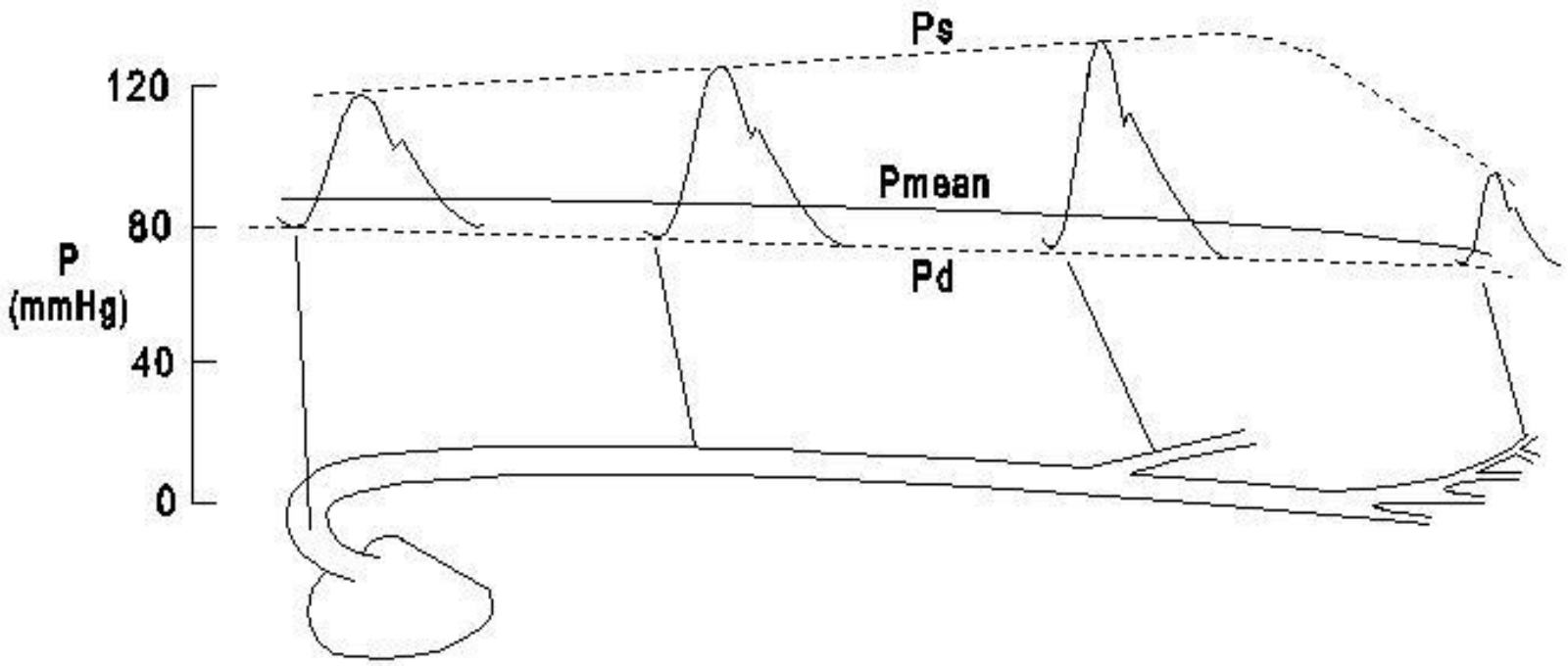
- Pulse pressure = SBP – DBP

- Mean BP = DBP + 1/3 PP

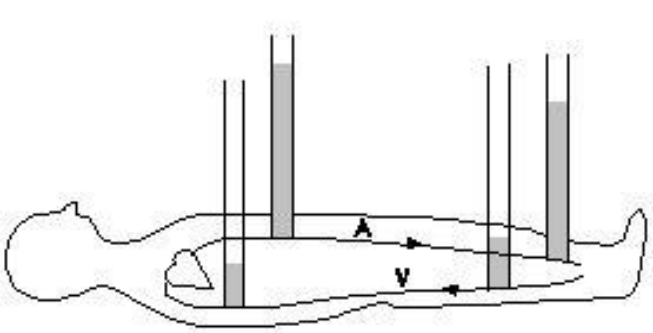
Mean Arterial Pressure



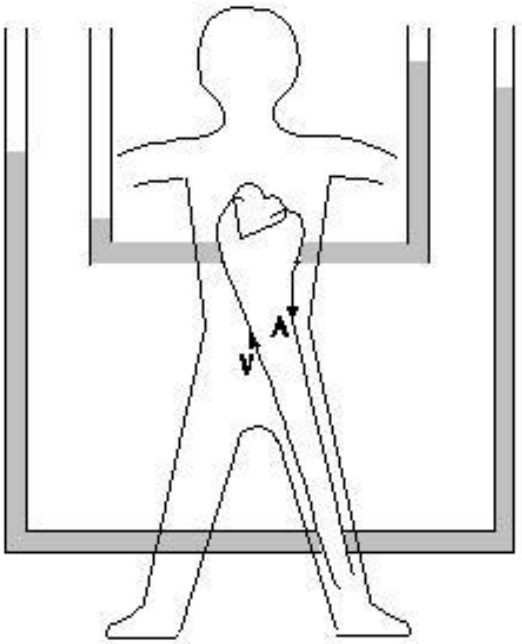
Pressure Change along the Arterial Tree



Effect of Gravity on Cardiovascular Pressures



Supine Position



Standing Position

The vessel tone

- **Local control**

1. Miogenic autoregulation
2. Local humoral factors: CO_2, H^+, O_2, adenosin, lactate
3. Endothelial control: NO; endothelins

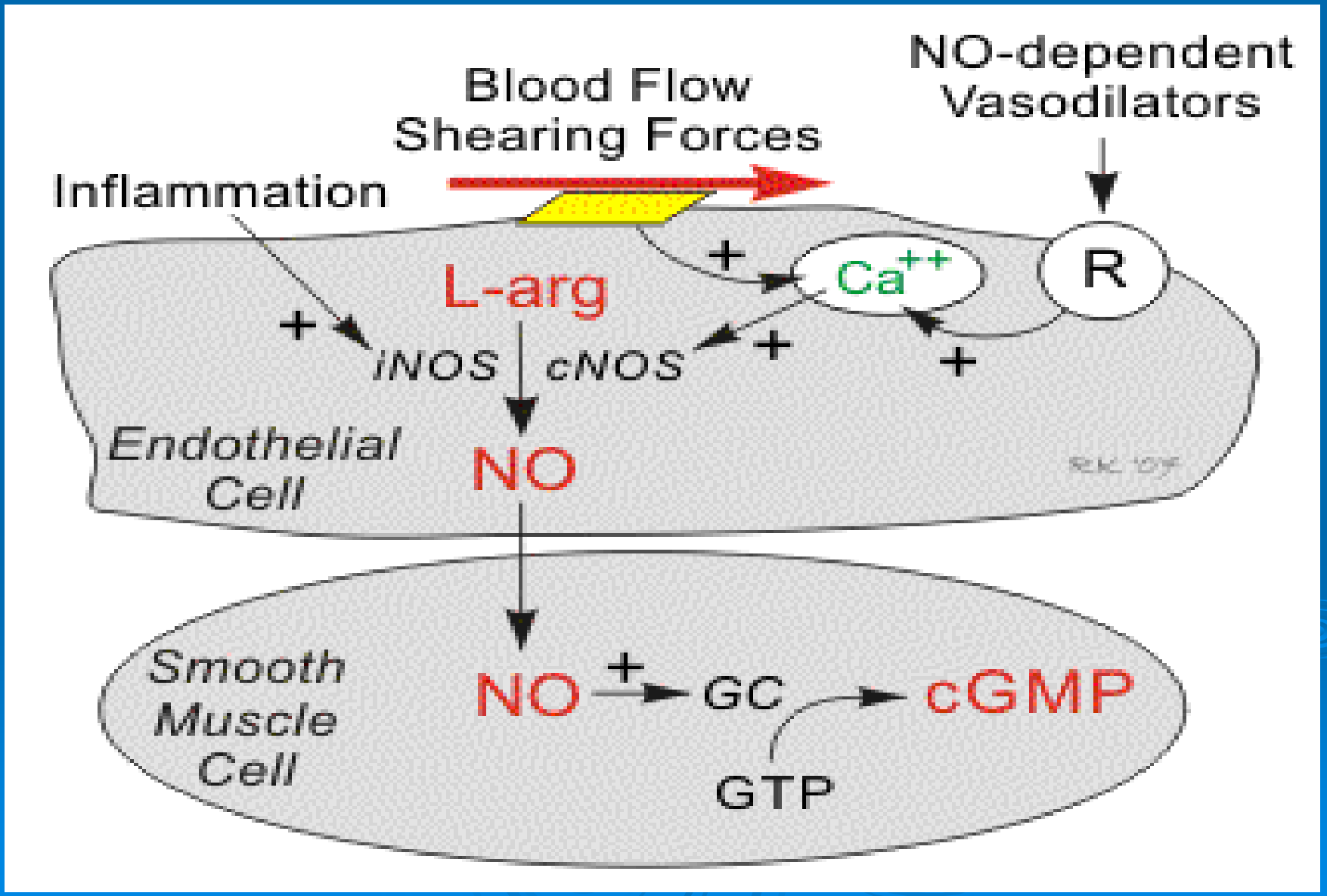
The vessel tone - Endothelial control

- NO is produced from the amino acid **L-arginine** by the enzymatic action of nitric oxide synthase (NOS). Co-factors for eNOS include oxygen, NADPH, tetrahydrobiopterin and flavin adenine nucleotides.
- Under normal, basal conditions in blood vessels, NO is continually being produced by eNOS. The activity of eNOS is calcium and calmodulin dependent. There are two basic pathways for the stimulation of eNOS, both of which involve release of calcium ions from subsarcolemmal storage sites.

The vessel tone - Endothelial control

- First, shearing forces acting on the vascular endothelium generated by blood flow causes a release of calcium and subsequent eNOS activation. Therefore, increases in blood flow stimulate NO formation (**flow-dependent NO formation**).
- Second, endothelial receptors for a variety of ligands (for acetylcholine, bradykinin, substance-P, adenosine, and many others vasoactive substances) stimulate calcium release and subsequent NO production (**receptor-stimulated NO formation**).

The vessel tone - Endothelial control



The vessel tone - Endothelial control

- In the late 1970s, Dr. Robert Furchgott observed that acetylcholine released a substance that produced vascular relaxation, but only when the endothelium was intact. This observation opened this field of research and eventually ***led to his receiving a Nobel prize.***
- Initially, Furchgott called this substance **endothelium-derived relaxing factor,** but by the mid-1980 he and others identified this substance as being NO.
- *The Nobel Prize in Physiology or Medicine 1998 was awarded jointly to Robert F. Furchgott, Louis J. Ignarro and Ferid Murad "for their discoveries concerning nitric oxide as a signalling molecule in the cardiovascular system".*

The vessel tone - Endothelial control

- Vascular actions of NO include the following:

- Direct vasodilation (flow dependent and receptor mediated)
- Indirect vasodilation by inhibiting vasoconstrictor influences (e.g., inhibits angiotensin II and sympathetic vasoconstriction)
- Anti-thrombotic effect - inhibits platelet adhesion to the vascular endothelium
- Anti-inflammatory effect - inhibits leukocyte adhesion to vascular endothelium; scavenges superoxide anion
- Anti-proliferative effect - inhibits smooth muscle hyperplasia

The vessel tone - Endothelial control

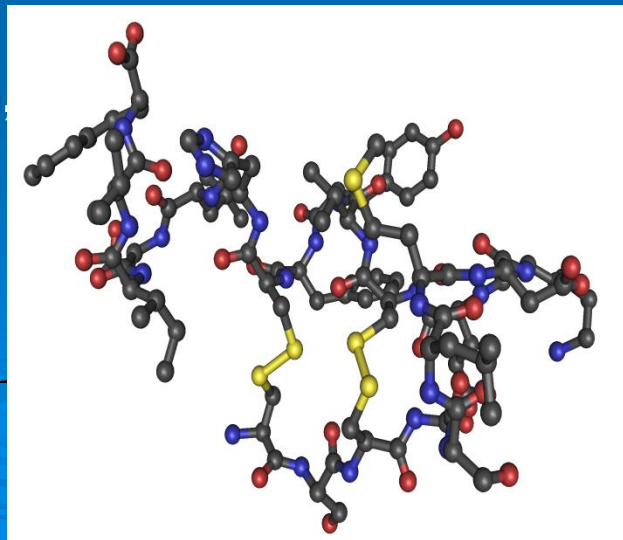
- Because of the above actions of NO, when its production is impaired or its bioavailability is reduced, the following can result:
- Vasoconstriction (e.g., coronary vasospasm, elevated systemic vascular resistance, hypertension)
- Thrombosis due to platelet aggregation and adhesion to vascular endothelium
- Inflammation due to upregulation of leukocyte and endothelial adhesion molecules
- Vascular hypertrophy and stenosis
- Diseases or Conditions Associated with Abnormal NO Production and Bioavailability: Hypertension, Obesity, Dyslipidemias, Diabetes (both type I and II), Heart failure, Atherosclerosis, Aging

The vessel tone - Endothelial control

- **Endothelins** are proteins that constrict blood vessels and raise blood pressure. They are normally kept in balance by other mechanisms, but when they are over-expressed, they contribute to high blood pressure (hypertension) and heart disease.

- Endothelins are 21-amino acid vasoconstricting peptides produced primarily in the endothelium having a key role in vascular homeostasis.

Among the strongest vasoconstrictors known, endothelins are implicated in vascular diseases of several organ systems, including the heart, general circulation and brain.



The vessel tone

- **Humoral control**

- Vasodilatators: bradykinine, hystamine, prostaglandins, ATP, Atrial natriuretic peptide

- Vasoconstrictors: epinephrine, norepinephrine, angiotensine II, vasopressin,serotonine

The vessel tone

- **Nervous control:**

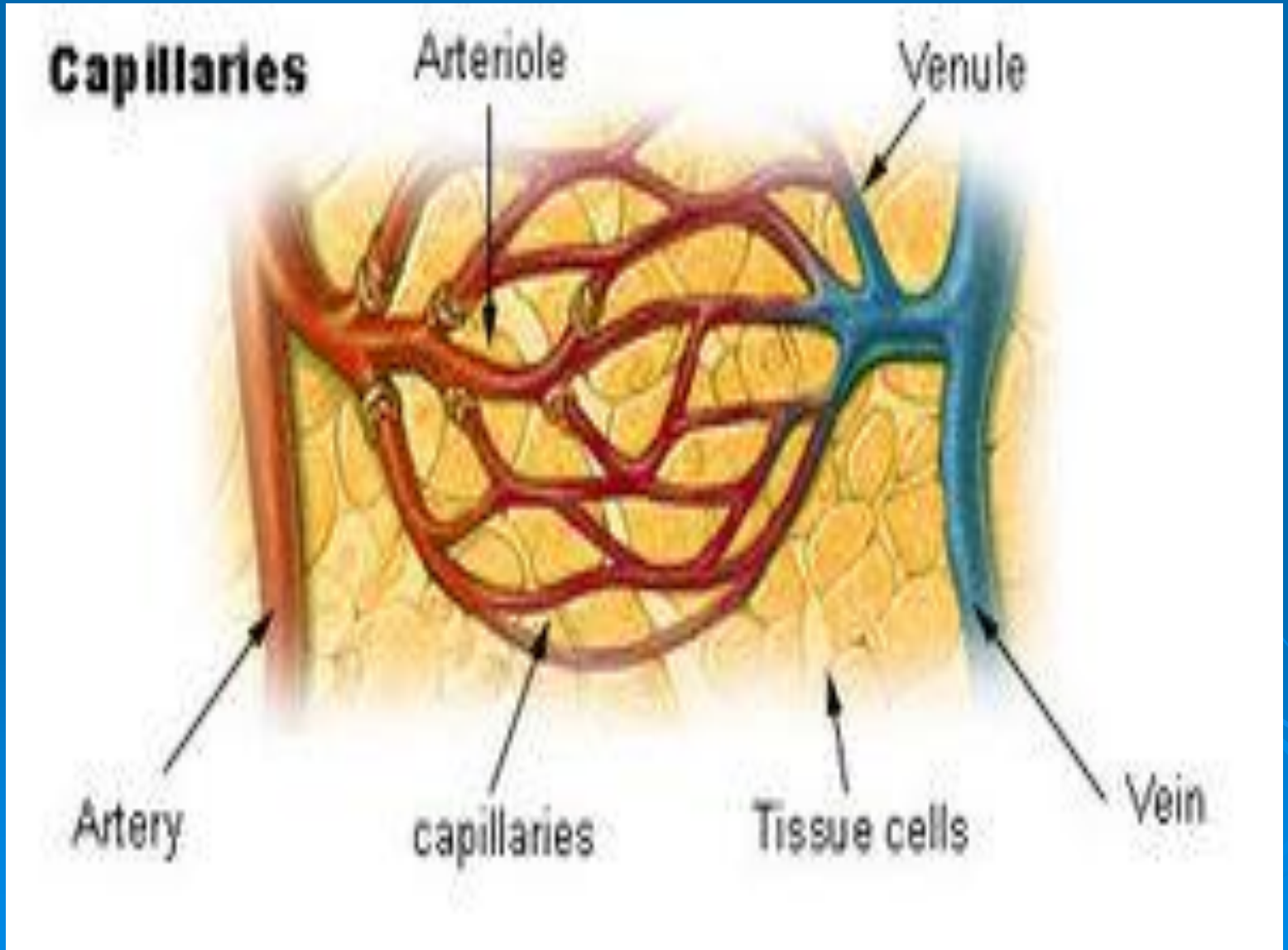
1. Sympathicus gives tonic impulses at the rest with F=1-3/s

2. Parasympaticus performs vasodilatation on the vessels of: pia mater, salivary glands end external genitalia

Microcirculation

- Microsircullatory unit consist of: arteriole, meta arteriole, precapillary sphincter, capillaries, venule
- Permeability of capillaries is different in different areas of organism (the lowest permeability in the brain)
- Mechanisms of transport: diffusion, osmosis, filtration

Microcirculatory unit



Arteriole:

HP=+32mmHg

KOP=-25mmHg

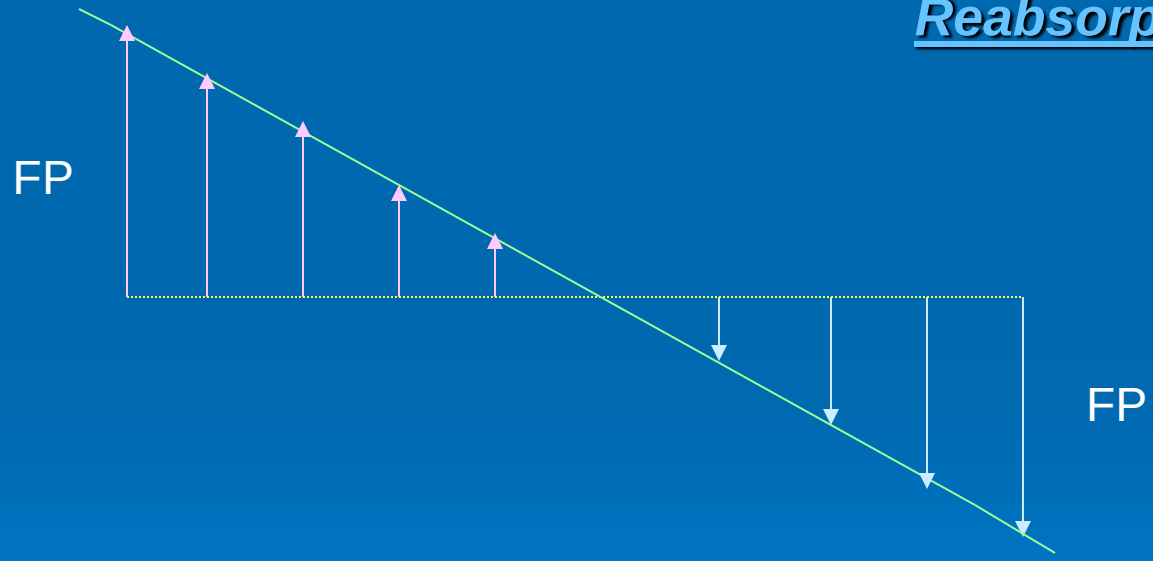
Filtration **FP= +7 mmHg**

Venule:

HP=+15mmHg

KOP= - 25mmHg

Reabsorption **FP= -10 mmHg**



Veins and their functions

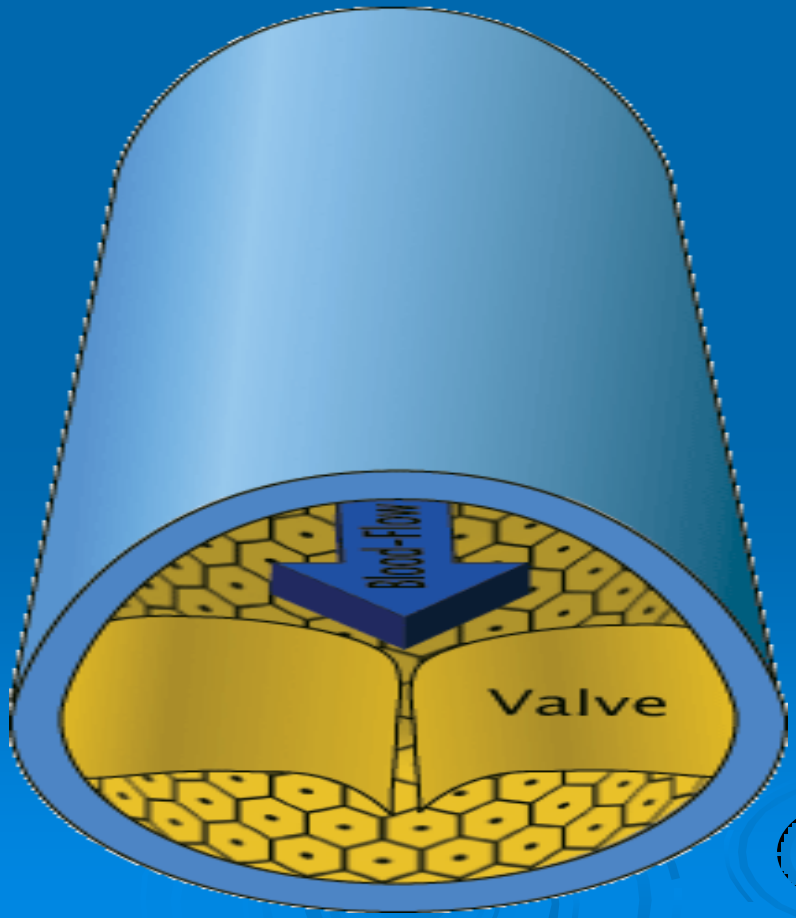
- 1.Veins are the reservoir of blood
- 2.Veins function to return deoxygenated blood to the heart, and are essentially tubes that collapse when their lumen are not filled with blood.

Veins and their functions

- The thick, outer-most layer of a vein is comprised of collagen, wrapped in bands of **smooth muscle** while the interior is lined with endothelial cells.
- Most veins have one-way flaps called venous valves that prevent blood from backflowing and pooling in the lower extremities due to the effects of gravity. The precise location of veins is much more variable from person to person than that of arteries.

The mechanisms of venous blood flow:

1.The presence of the *venous valves*



The mechanisms of venous blood flow:

- 2.The contractions of the *skeletal muscles* of the legs
- 3. The contraction of *lig. Inguinalae* during the movements
- 4. The contractions of the *diaphragm* during the inspirium

The venous pressure

1. **in laying position** VP is 5 mm Hg lower than the pressure of capillaries
2. **in standing position**:

- VP of the arm = +6 , + 8 mm Hg
- VP of the leg = +40, + 90 mm Hg
- CVP = +2, +4 mm Hg

Thanks for your attention!