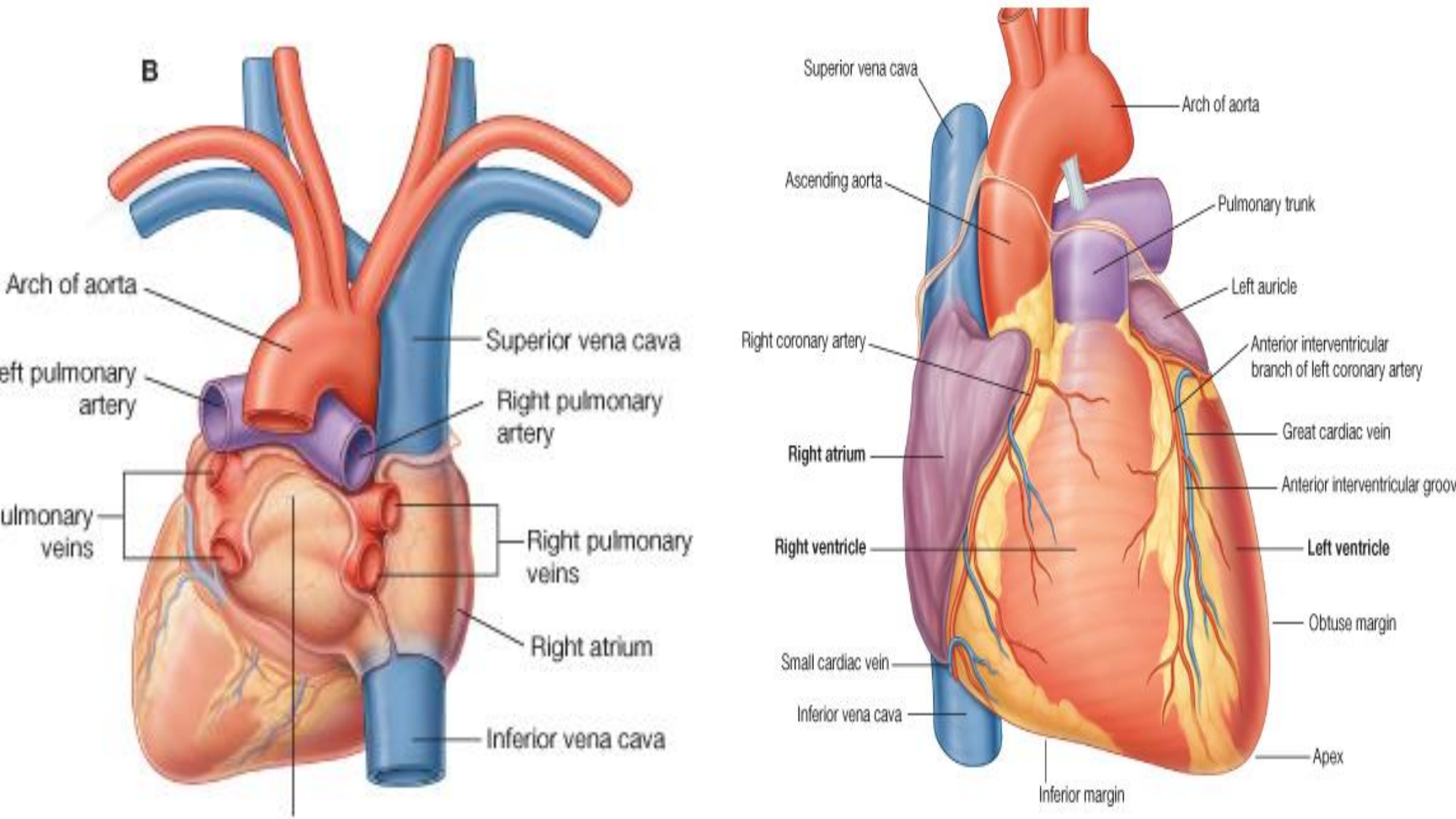
CARDIOVASCULAR SYSTEM

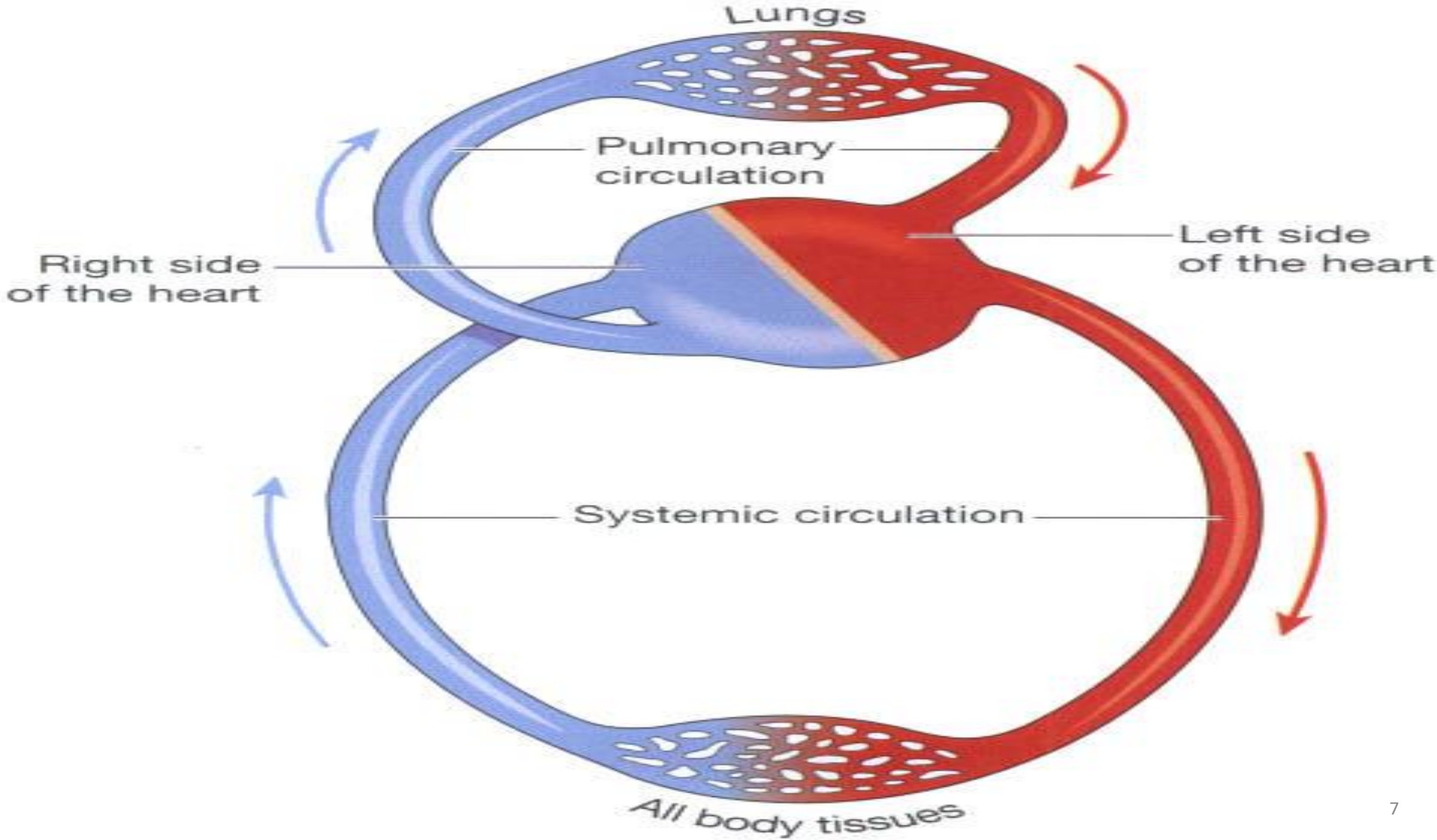
introduction

- The cardiovascular system (CVS) is divided into two parts:
  - ✓ The heart (pump)
  - ✓ The blood vessels (pipes)
- The heart pumps blood into two systems of blood vessels namely;
  - ✓ The pulmonary circulation
  - ✓ The systemic circulation

- Right side of the heart pumps blood to the lungs (**the pulmonary circulation)** where gas exchange occurs.
- Left side of the heart pumps blood into the **systemic circulation**; supplies rest of the body.


B
Arch of aorta
Superior vena cava
eft pulmonary artery
Right pulmonary artery
ulmonary veins
Right pulmonary veins
Right atrium
Inferior vena cava
Superior vena cava
Arch of aorta
Ascending aorta
Pulmonary trunk
Left auricle
Right coronary artery
Anterior interventricular branch of left coronary artery
Great cardiac vein
Right atrium
Anterior interventricular groov
Right ventricle
Left ventricle
Obtuse margin
Small cardiac vein
Inferior vena cava
Apex
Inferior margin

Relationship between pulmonary and systemic circulations


Lungs
Pulmonary circulation
Left side of the heart
Right side of the heart
Systemic circulation
All body tissues

Assignment

1. Draw a diagram showing the relationship between pulmonary and systemic circulations

BLOOD VESSELS

Blood vessels vary in **structure, size** and **fuction**

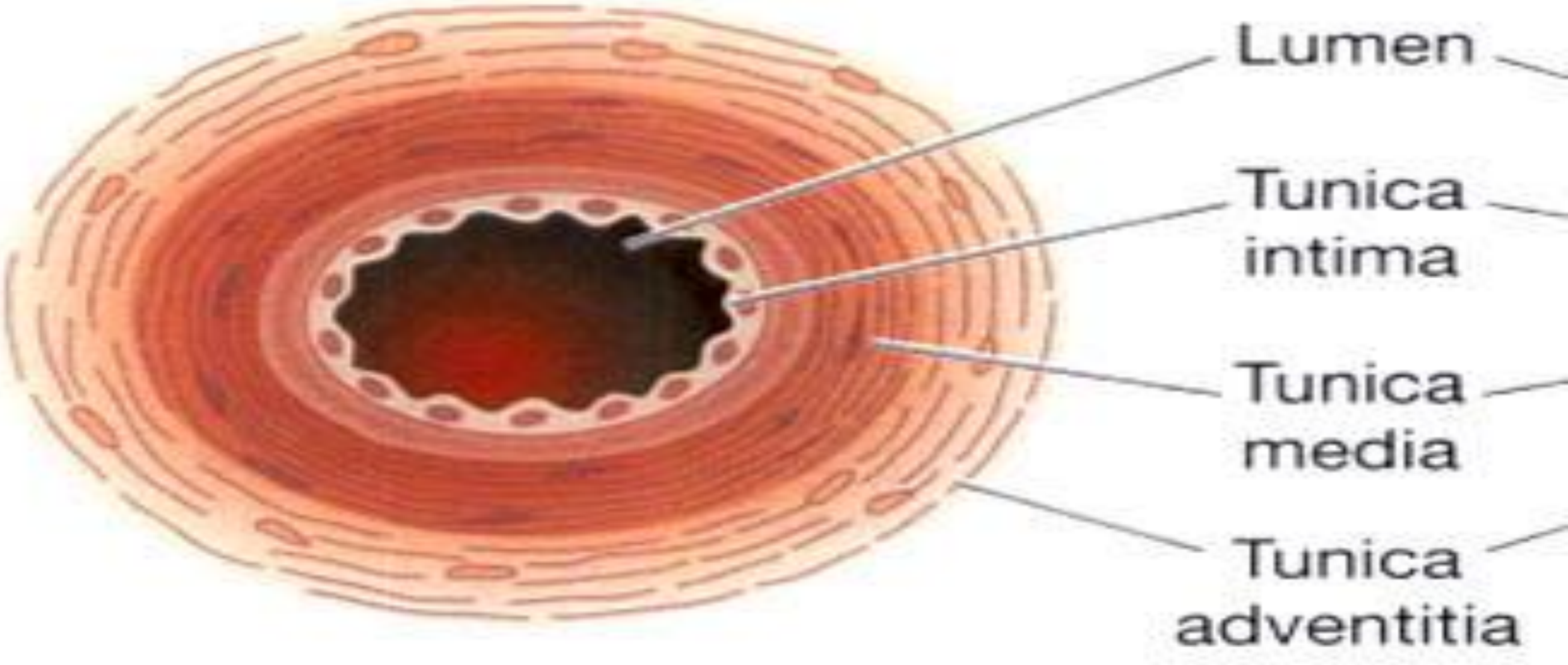
- **Types:**
- **Arteries**
- **Arterioles**
- **Capillaries**
- **Venules**
- **Veins**

ARTERIES AND ARTERIOLES

- Blood vessels that transport blood away from the heart.
- Vary considerably in size
- Walls consist of 3 layers of tissue

- **tunica adventitia** or outer layer of fibrous tissue
- **tunica media** or middle layer of smooth muscle and elastic tissue
- **tunica intima/**inner lining of squamous epithelium- *endothelium*.

- Amount of muscular and elastic tissue varies in the arteries depending upon their size.
  - Large arteries (elastic arteries); **tunica media** consists of **more elastic tissue** and **less smooth muscle.**
  - Arterioles (smallest arteries); **tunica media** consists almost entirely of **smooth muscle**.
- Arteries have **thicker walls** than veins; enables them to withstand high pressure of arterial blood.



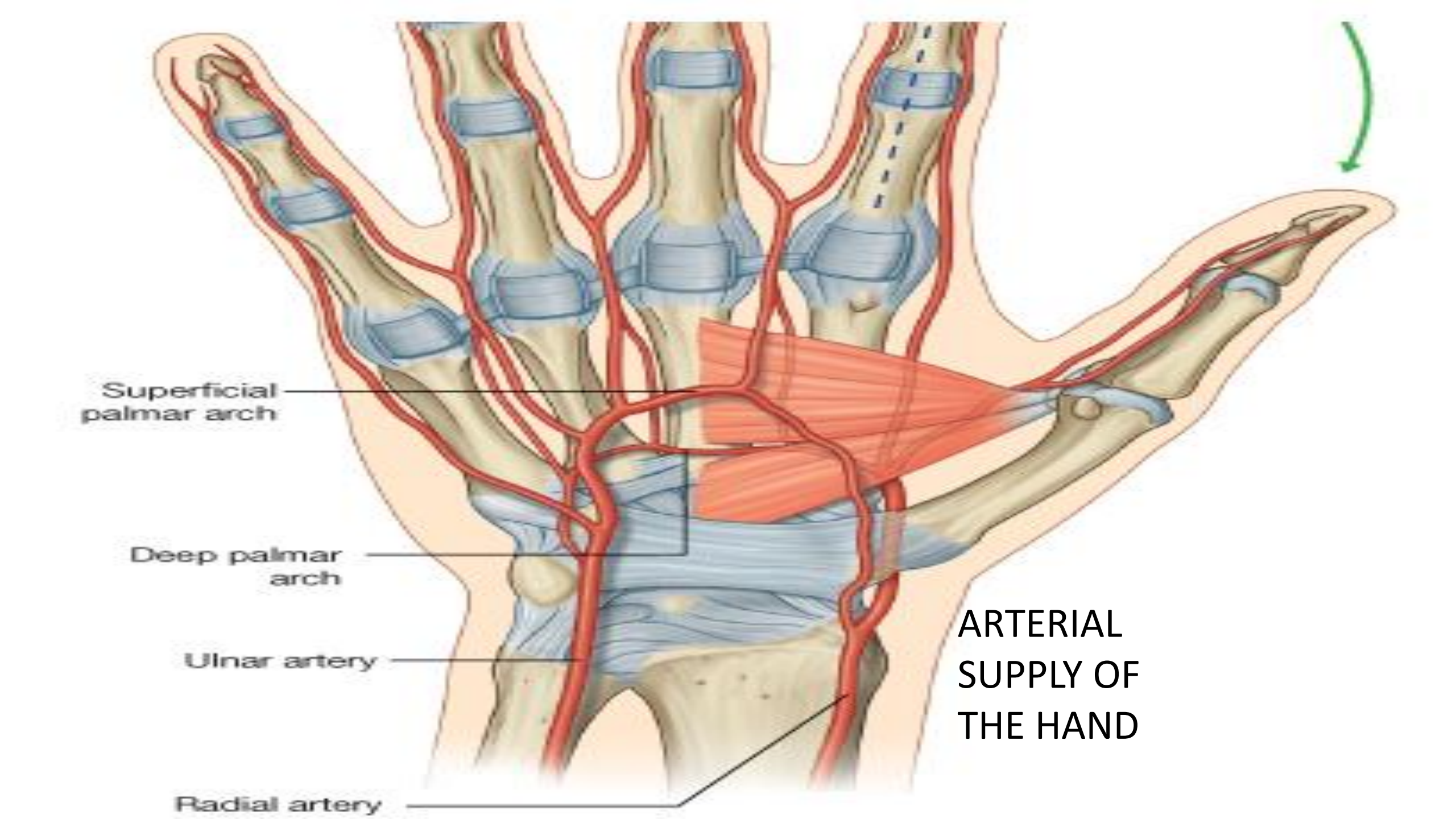
Artery

- The tiny arteries are known as arterioles and since they cannot stretch, they offer resistance which determine systemic blood pressure. Are therefore known as *resistance vessels.*

ANASTOMOSES

- **Def:** arteries that form a link between main arteries supplying an area, e.g. the arterial supply to the palms of the hand and soles of the feet, the brain, the joints and, to a limited extent, the heart muscle.

- If one artery supplying the area is occluded anastomotic arteries provide a **collateral circulation**.
- This provides an adequate blood supply when the occlusion occurs gradually, giving the anastomotic arteries time to dilate.



ARTERIAL SUPPLY OF THE HAND

END-ARTERIES

- **Def:** arteries with no anastomoses or those beyond the most distal anastomosis, e.g. the branches from the circulus arteriosus **(circle of Willis)** in the brain or the central artery to the retina of the eye.
- When an end-artery is occluded the tissues it supplies die because there is no alternative blood supply.

CAPILLARIES

- **Def:** minute vessels formed from break up of smallest arterioles.
- Walls consist of a single layer of endothelial cells through which water and other small-molecule substances can pass.
- Form a vast network of tiny vessels which link smallest arterioles to smallest venules.

- Diameter; approximately **7 µm.**
- **Capillary bed**: site of exchange of substances between blood & tissue fluid.
- Blood entry into the capillary bed is guarded by ***precapillary sphincters*** that direct blood flow

SINUSOIDS

- Capillaries that are wider and leakier than normal capillaries
- Have extremely thin walls separating blood from the neighboring cells.

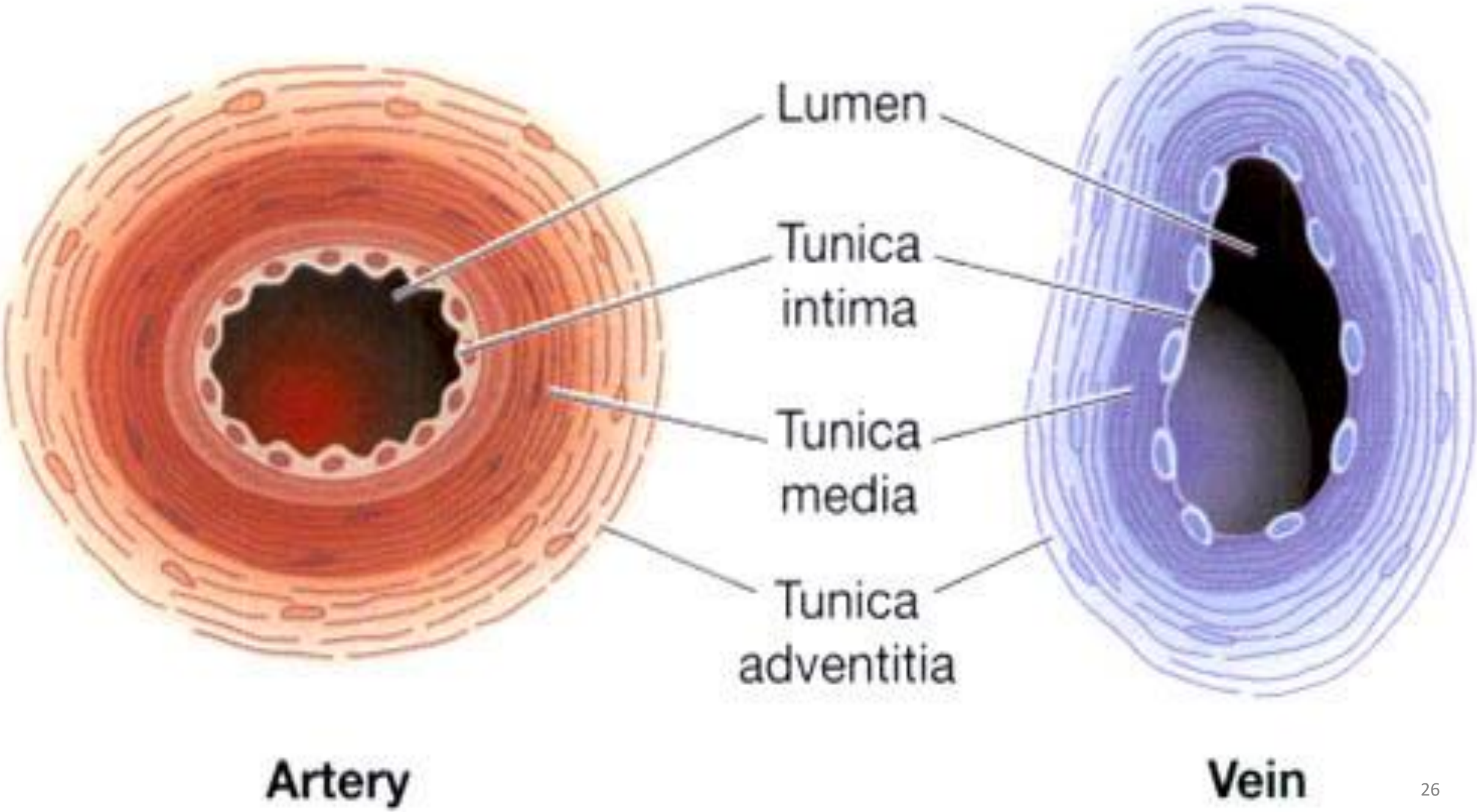
- Found in :
  - ✓ bone marrow,
  - ✓ endocrine glands,
  - ✓ spleen
  - ✓ liver.
- Because of their larger lumen, BP in sinusoids is lower than in capillaries and there is a slower rate of blood flow.

VEINS AND VENULES

- **Veins**: blood vessels that return blood at low pressure to the heart.
- **Venules**: smallest veins
- Walls of the veins are thinner (because there is less muscle and elastic tissue in the tunica media than those of arteries) but have the same three layers of tissue.

- When cut, the veins collapse while the thicker-walled arteries remain open.
- When an artery is cut blood spurts at high pressure while a slower, steady flow of blood escapes from a vein.
- Veins are called **capacitance vessels** coz they are distensible and there4 have the capacity to hold a large proportion of blood

Structure of an artery and a vein

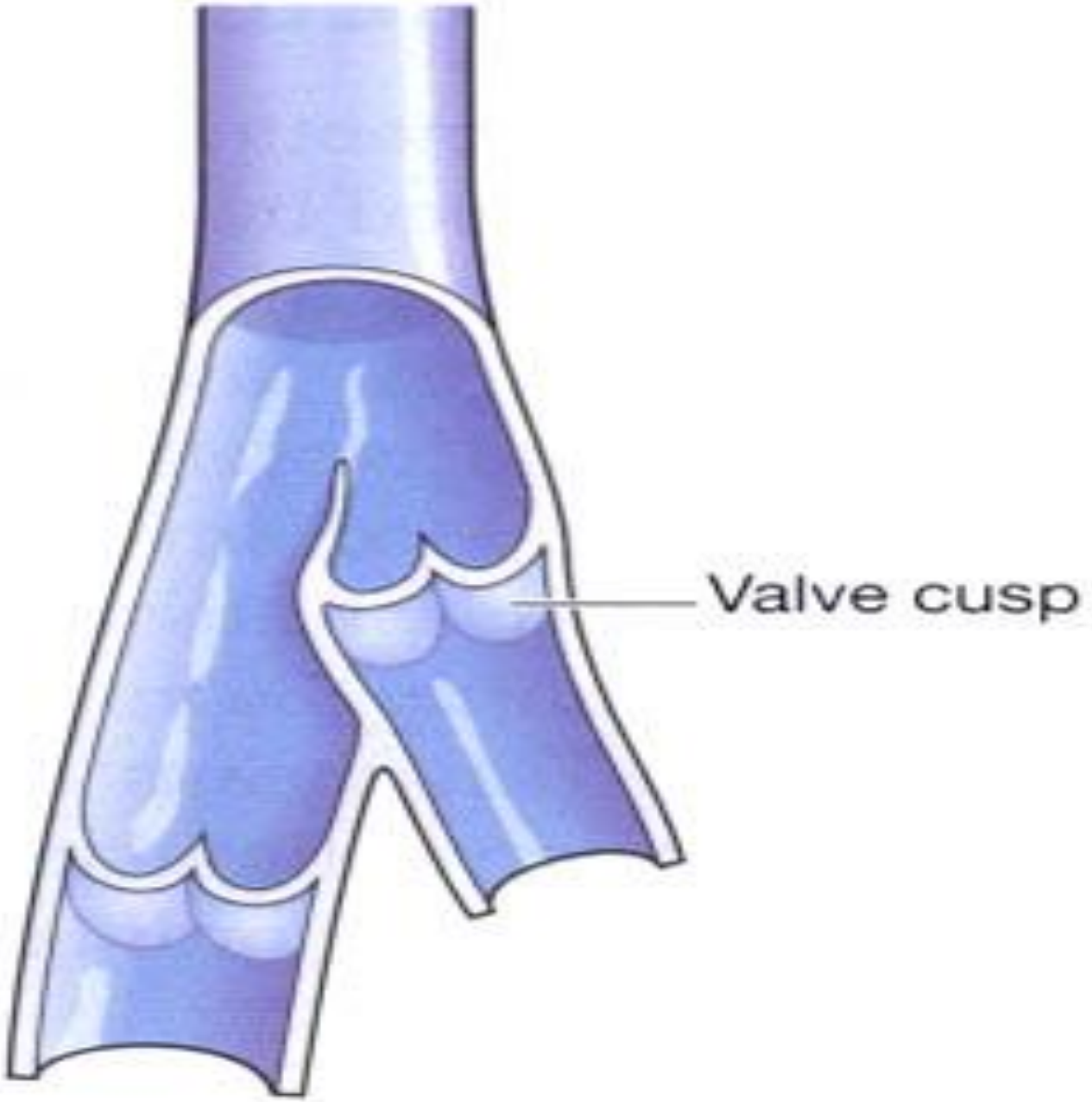

Lumen
Tunica intima
Tunica media
Tunica adventitia
Artery
Vein

Valves

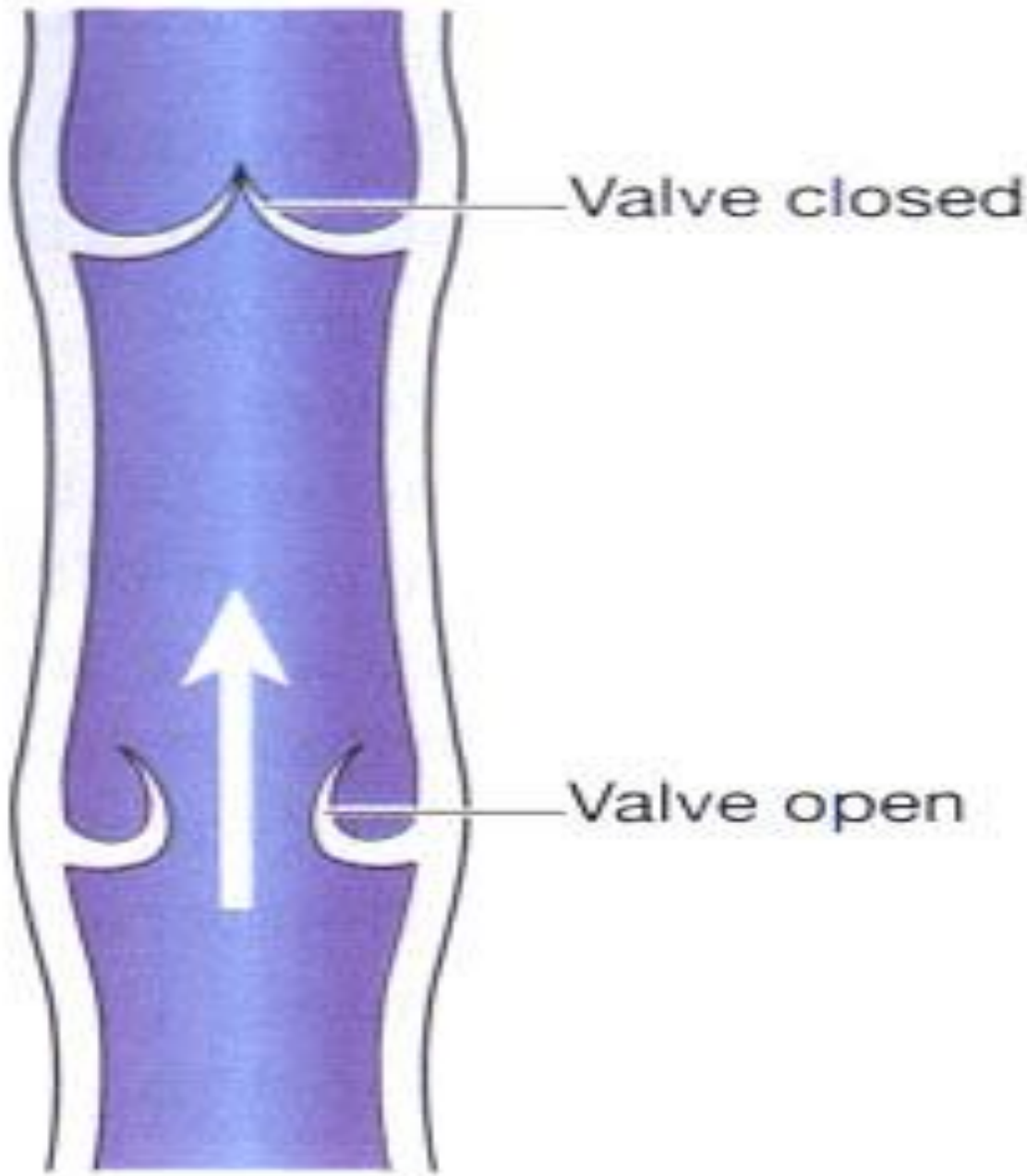
- Present in some veins
- Prevent backflow of blood, ensuring that it flows towards the heart.
- Formed by a fold of **tunica intima** strengthened by connective tissue.

- Cusps are **semilunar** in shape with the concavity towards the heart.
- Are abundant in limb veins, especially the lower limbs where blood must travel a considerable distance against gravity when the individual is standing.
- Absent in very small and very large veins in the thorax and abdomen.

The interior of a vein; valves and cusps

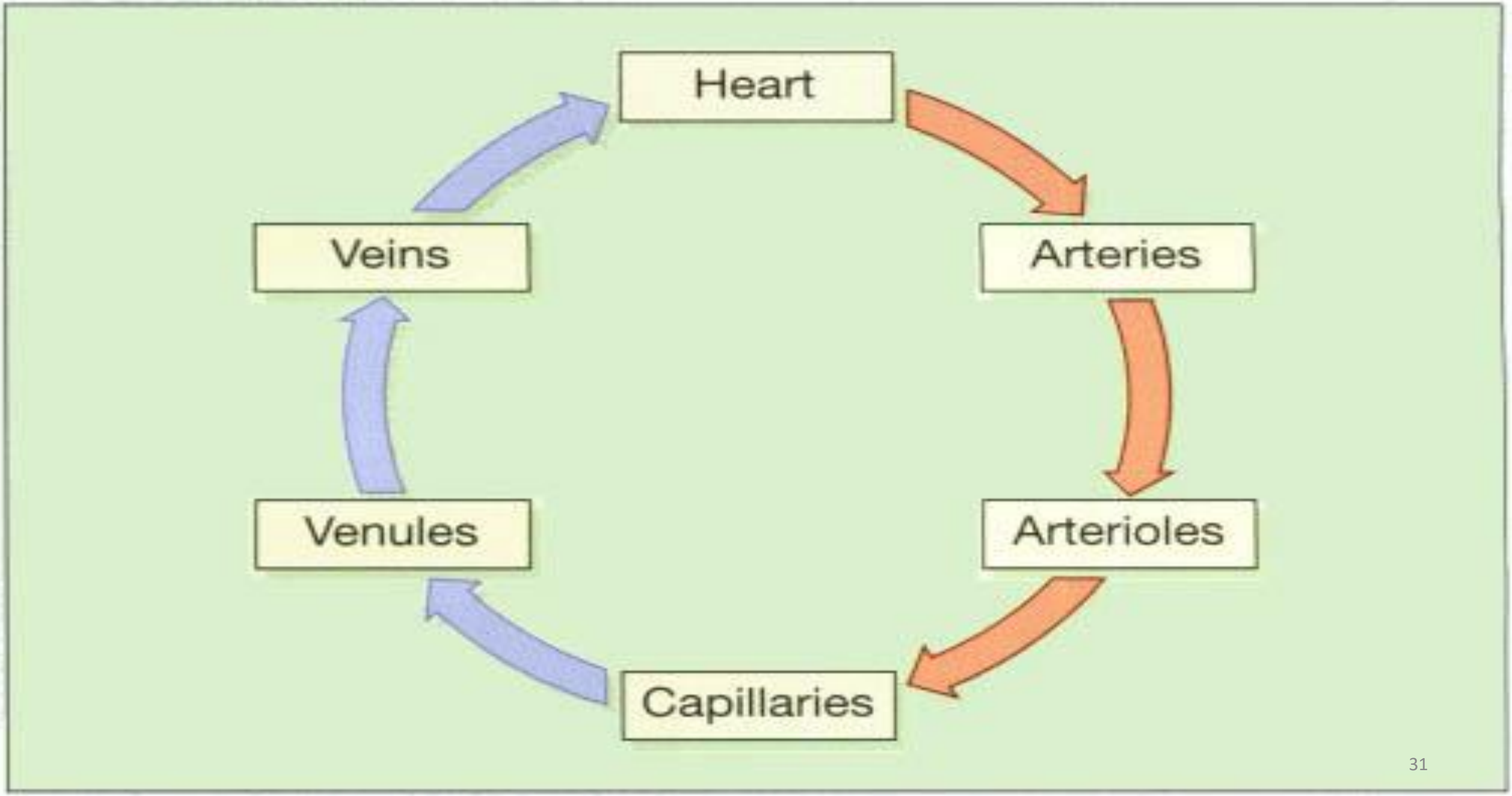


A



B

Relationship between the vascular network



Assignment

1. draw the cross-sectional structure of a vein and an artery

NB:

- Outer layers of tissue of thick-walled blood vessels receive their blood supply via a network of blood vessels called **vasa vasorum**.
- Vessels with thin walls and the endothelium of the others receive oxygen and nutrients by diffusion from the blood passing through them.

Control of blood vessels diameter

- All blood vessels except capillaries have smooth muscle fibres in the tunica media which are supplied by nerves of autonomic nervous system (ANS).
- The nerves arise from the **vasomotor centre** in the medulla oblongata and they change the diameter of the lumen of blood vessels, controlling the volume of blood they contain.

- **Medium-sized** and **small arteries** have more **muscle** than **elastic tissue** in their walls.

- Thus, small arteries & arterioles respond to nerve stimulation whereas the diameter of large arteries varies according to the amount of blood they contain.

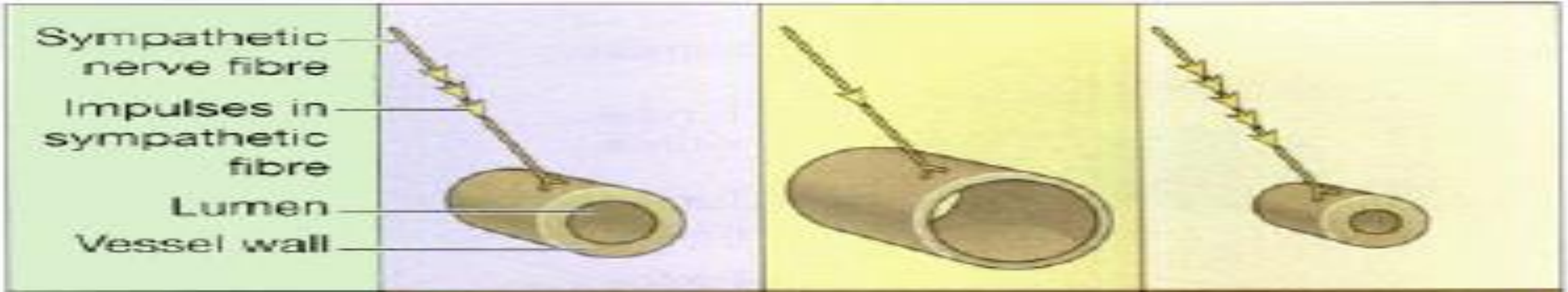
Vasodilatation & vasoconstriction

- Sympathetic nerves supply the smooth muscle of tunica media of blood vessels.
- Diameter of vessel lumen and tone of smooth muscle is determined by degree of sympathetic nerve stimulation.
- No parasympathetic nerve supply to most blood vessels.

- Decreased nerve stimulation causes smooth muscle to relax, thinning the vessel wall and enlarging the lumen **(vasodilatation)** and results in increased blood flow under less resistance. This increases the diameter while decreasing the pressure within blood vessels.
- When nervous activity is increased, smooth muscle of tunica media contracts and thickens **(vasoconstriction).** This decreases the diameter while increasing pressure within blood vessels

- Arterioles provide ***peripheral resistance(PR)*** (a major factor in BP regulation) to blood flow and thus called **resistance vessels**.
- Resistance to flow of fluids along a tube is determined by 3 factors:

- Tube diameter;
- Tube length;
- Viscosity of fluid involved.



	Resting situation	Vasodilatation	Vasoconstriction
Sympathetic stimulation	Moderate	Decreased	Increased
Smooth muscle	Moderate tone	Relaxed	Contracted
Thickness of vessel wall	Moderate	Thinner	Thicker
Diameter of lumen	Moderate	Increased	Decreased
Peripheral resistance in arterioles	Moderate	Decreased	Increased

Figure 5.5 The relationship between sympathetic stimulation and blood vessel diameter.

Autoregulation/Local regulation of Blood Flow

- Accumulation of metabolites in local tissues also influences the degree of dilatation of arterioles.
- This mechanism ensures that local blood flow is increased or decreased in response to tissue need.

- Main mechanisms involved in autoregulation includes:

- Release of metabolic waste products e.g. CO_2 and lactic acid
- Tissue temperature
- Hypoxia
- Release of vasodilator chemicals e.g. Nitric oxide
- Activity of vasoconstrictor substances e.g angiotensin 2 and epinephrine

Capillary exchange

Internal respiration

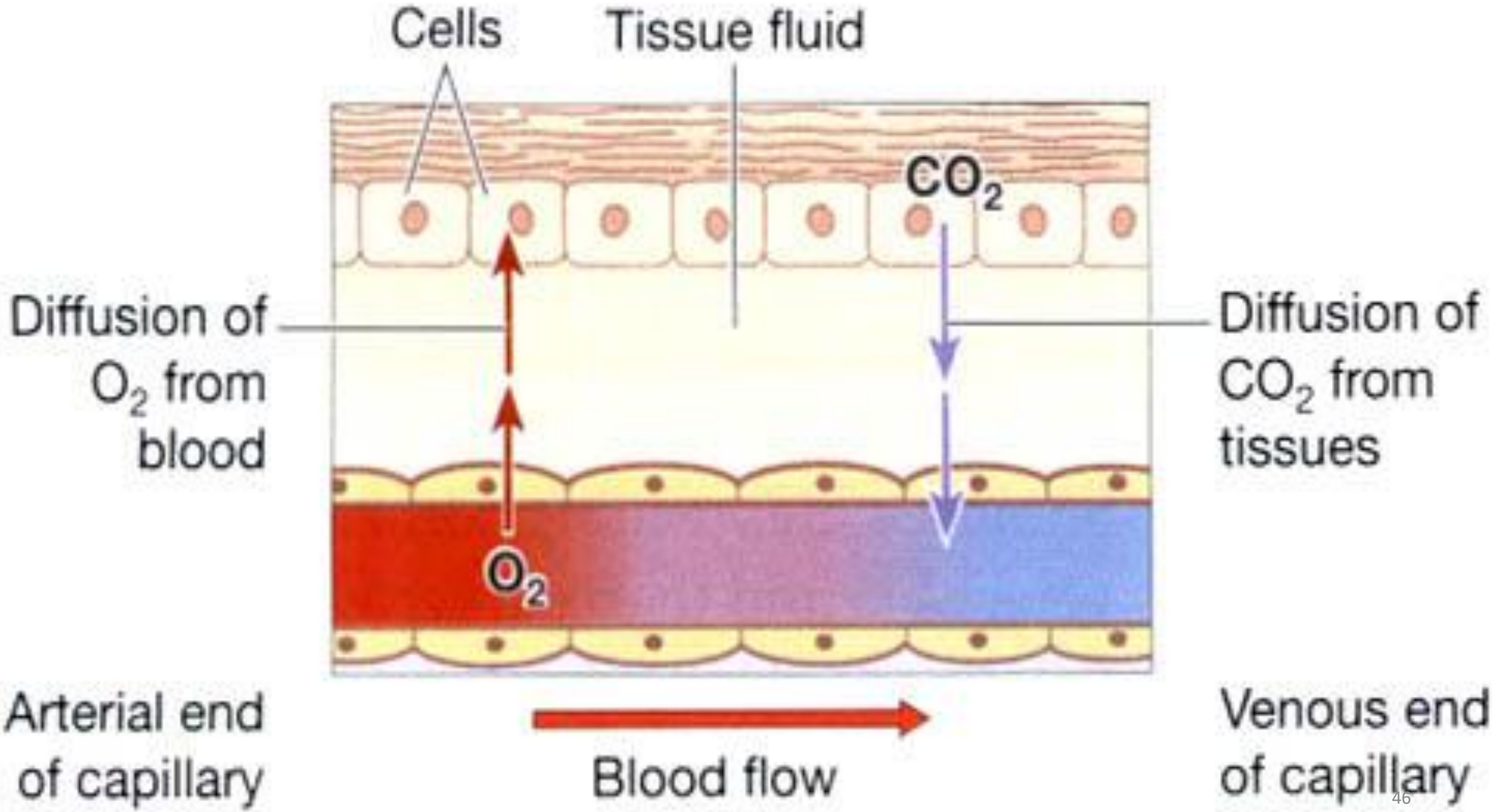
- **Def:** Exchange of gases between capillary blood and local body cells.
- Exchange in tissues takes place between blood at arterial end of capillaries & tissue fluid and then between the tissue fluid and the cells through diffusion.
- Oxygen is carried in the form of oxyhaemoglobin

- Oxyhaemoglobin is an unstable compound and breaks up (dissociates) easily to liberate oxygen which diffuse down its concentration gradient.
- Factors that increase dissociation include
  - Hypoxia
  - raised temperature and
  - Low pH
- In active tissues there is an increased production of CO_2 and heat which leads to an increased availability of oxygen.

- CO_2 diffuses into blood down the concentration gradient towards the venous end of capillary.
- Blood transports CO_2 to lungs for excretion by 3 mechanisms:

- dissolved in water of blood plasma — 7%
- in chemical combination with sodium in the form of sodium bicarbonate — 70%
- remainder in combination with Hb — 23%.

Exchange of gases in internal respiration


Cells
Tissue fluid
CO_2
Diffusion of O_2 from blood
Diffusion of CO_2 from tissues
O_2
Arterial end of capillary
Blood flow
Venous end of capillary

CELL NUTRITION

- Nutrients required by the cells of the body are transported in the blood plasma.
- Mechanism of the transfer of water and other substances from the blood capillaries depends mainly upon diffusion, osmosis & active transport.

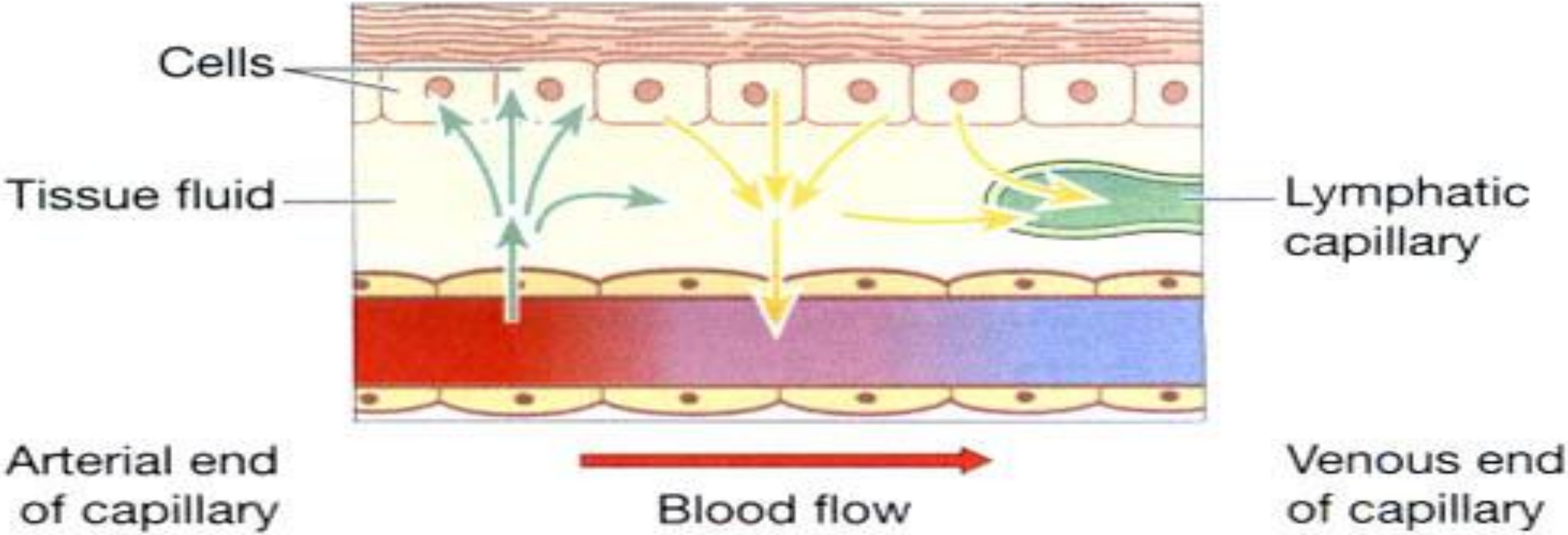
a) Diffusion

- Capillary walls consist of a single layer of epithelial cells that constitutes a semi-permeable membrane which allows substances with small molecules to pass through into tissue fluid, and retains large molecules in the blood.
- Diffusible substances include dissolved oxygen and CO_2, glucose, amino acids, fatty acids, glycerol, vitamins, mineral salts and water.

b) Osmosis

- Osmotic pressure across a semi-permeable membrane draws water from a dilute to a more concentrated solution in an attempt to establish a state of equilibrium.

Diffusion of nutrients and waste products btn capillaries and cells

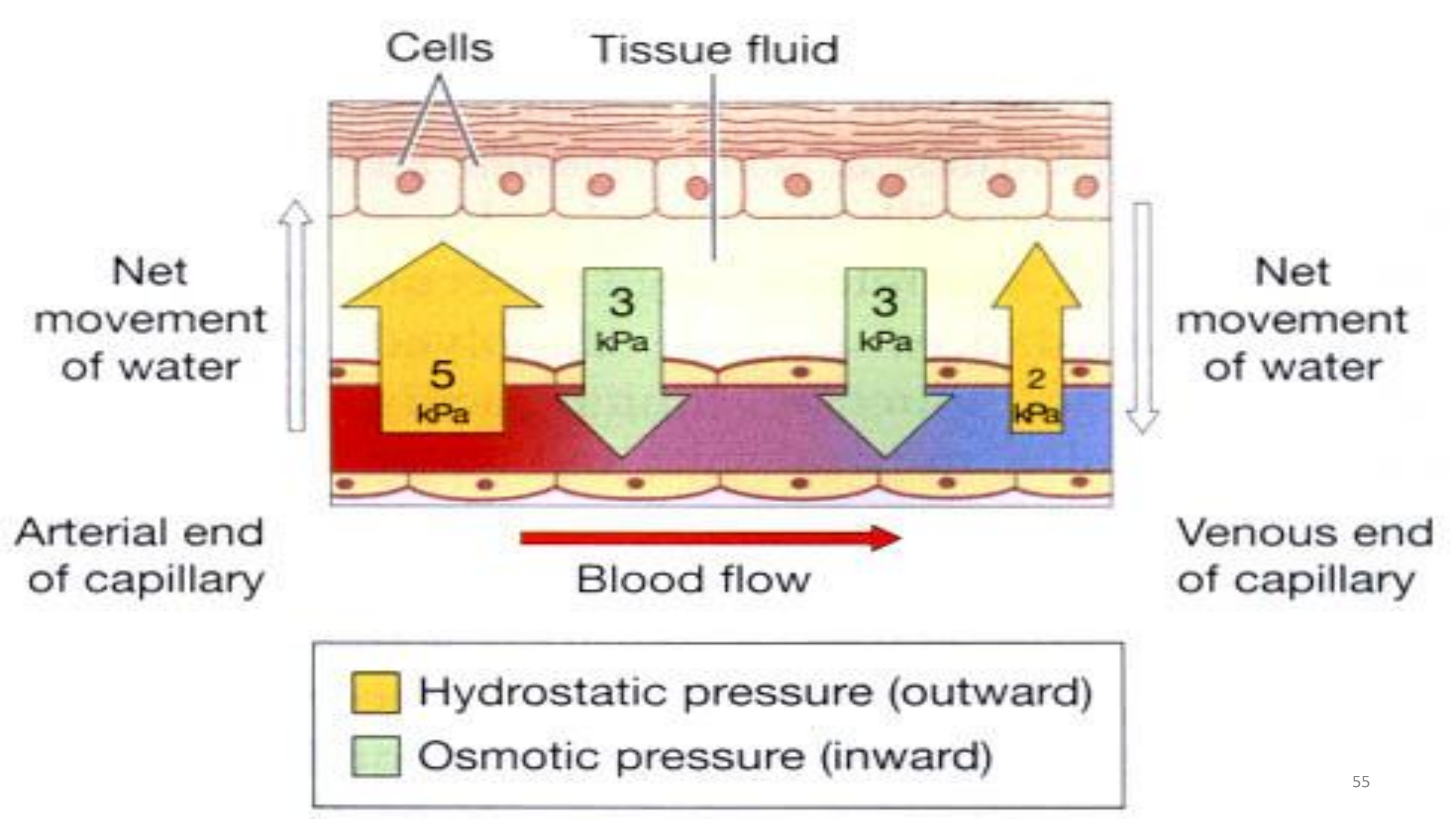

Cells
Tissue fluid
Lymphatic capillary
Arterial end of capillary
Blood flow
Venous end of capillary
Movement of nutrients including oxygen
Movement of excess fluid and wastes, including carbon dioxide

Capillary fluid dynamics

- At arterial end capillary BP, i.e. **hydrostatic pressure**, is about 35 mmHg (5 kPa).
- Causes forward movement of blood and forces some water and solutes of small enough molecular size to pass out of capillaries into tissue spaces.
- O**smotic pressure** in capillaries is about 25 mmHg (3.3 kPa).
- Draws water into capillaries.

- Net **outward pressure** of 10 mmHg is the difference between hydrostatic & osmotic pressures.
- At venous end of capillaries hydrostatic pressure is reduced to about 15 mmHg (2 kPa) and the osmotic pressure remains the same, at 25 mmHg (3.3 kPa). Thus, net force moving water and solvents into capillaries is again the difference between the two pressures, i.e. 10 mmHg.

- As blood flows slowly through the large network of capillaries from arterial to the venous end, there is constant change.
- Not all water and cell waste products return to the blood capillaries.
- Excess is drained away from tissue spaces in the minute lymph capillaries which originate as blind-end tubes with walls similar to, but more permeable than, those of blood capillaries .
- Extra tissue fluid and some cell waste materials enter the lymph capillaries and are eventually returned to the bloodstream.


Cells
Tissue fluid
Net movement of water
Net movement of water
5 kPa
3 kPa
3 kPa
2 kPa
Arterial end of capillary
Venous end of capillary
Blood flow
Hydrostatic pressure (outward)
Osmotic pressure (inward)