VASCULAR SYSTEM

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It consists of two systems as blood and lymph circulation.

The blood circulation system is a closed system. (Heart-artery-capillary-vein)

Elastic artery (Large)

Muscular artery(Medium)

Small arteries and arterioles

Capillaries

Small ven-musculer venul-postcapillary venule

Medium vein

Large vein

VESSELS

A-Tunica Intima

B-Tunica Media

C-Tunica Adventitia

Wall of Vessel
from inside to outside:

A-Tunica Intima (interna):

i) Endothelium: It consists of a single-layer flat epithelium.

ii) Subendothel: It is a typical loose connective tissue and contains abundant longitudinal collagen and elastic fibers.

iii) Membrane elastic interna: Thick intermittent elastic membrane.

B-Tunica Media (Middle layer): It is the thickest layer. According to the type of vessel, elastic fiber or smooth muscle dominates the structure. In this layer, connective tissue fibers and smooth muscle fibers are circularly arranged.

C-Tunica Adventisya (Externa): The outer layer is made of connective tissue. Collagen and elastic fibers are longitudinally arranged.

ARTERIES

According to their structure characteristics:

1. Muscular (distributing) arteries
2. Small arteries ve arterioles.
3. Elastic (conducting) arteries,

ELASTİC (conducting, large) ARTERİES

- These arteries that receive blood directly from the heart - the aorta and the pulmonary artery.
- Their diameter is larger than 7 mm.

A- Tunica Intima: The intima layer is thicker than the muscular artery.

i) Endotel:

- The cells are flat and elongated in shape and are joined by a tight junction (zonulae occuludentes) and gap junction during formation of the epithelial sheet.

- The endothelial organelles contain von Willebrand factor and P-selectin.

ii) Subendothel:

- It has longitudinally arranged collagen and elastic fibers and smooth muscle cells. It plays an important role in the rhythmic contraction and relaxation of the artery.
- The tunica intima consists of an internal elastic membrane.

B) Tunica media:

- The fundamental unit of the large artery is the elastic lamella, which consists of concentric musculoelastic layers (the elastic lamella).
- Each elastic lamella forms together with interlamellar fibres and cells a lamellar unit.

- The elastic lamellae, consisting of elastic fibers, collagens (predominately type III), proteoglycans, and glycoaminoglycans.
- Both fibre types are produced by the smooth muscle cells.
- Smooth muscle cells and collagen fibres are found between the layers of elastic fibres
- The external elastic lamina is difficult to discern from other layers of elastic fibres in the tunica media.

C) T.Adventisya:

- The tunica adventitia appears thinner than the tunica media and contains collagen fibres and the cell types typically present in connective tissue.
- It consists of fibroblasts, macrophages, vasa vasorum and nervi vascularis.

- Elastic arteries receive their own blood supply by the vasa vasorum unlike smaller blood vessels, which are supplied by diffusion.

MUSCULAR (medium, distributing) ARTERIES

- Their diameter is greater than 2.5 mm. (i.e. Coronary, femoral vs.)
- The tunica intima is thinner than in elastic arteries.
- The internal elastic lamina forms a well defined layer.
- The prominent presence of membrane elastica interna / externa is the main feature of the muscular artery.

MUSCULAR (medium,distributing) ARTERIES

Tunica Intima:

- The endothelium is similar to that of elastic artery.
- Subendotelial layer is a thin layer of connective tissue containing collagen and elastic fibers, smooth muscle cells and a few fibroblasts.
- The internal elastic lamina is a fenesrated sheet of elastin that forms a prominent

- The internal elastic lamina is well marked and is always seen as a refracter wavy band in paraffin sections.

Tunica Mediya:

- It is the thickest layer.
- It is caracterized by a thick muscular layer with 20-40 layers of smooth muscle fibers, which are arranged circulary or spirally.
- In the larger muscular artery, elastic fibers (laminae) are still prominenet between the layers of smooth muscle fibers.
- The outer border of the media is marked by the external elastic lamina, which is a less conscipious fenestrated layer of elastin.
- The muscle cells are surrounded by basal laminae and communicate with each other by gap junctions.

MUSCULAR (medium,distributing) ARTERIES

Tunica Adventitia:

- It consists of loose connective tissue containing vasa vasorum, nerve fibres,adipose cells, fibroblasts, collagen and elastic fibers.

SMALL ARTERIES

- It is between 2.5 mm - 30 µm in the vessel in small arteries.
- Tunika intima is adjacent to the endothelium.
- The membrane elastica interna is thin.
- Tunika media consists of 4-10 rows of smooth muscle layers.
- There is no membrana elastica externa.
- Tunica adventitia layer is very thin. Contains loose connective tissue and elastic fiber.

ARTERIOLE

- Tunica intima consists of endothelium and thin subendothelium or no subendothelium.
- The arterioles are defined as the smooth muscle layer becomes 2-3 or single layers.
- Larger arterioles: 50-100µm.
- Terminal arterioles < 50µm.
- A thin fenesrated membrana elastica interna is absent in small arterioles but present in larger arterioles.
- Arterioles do not have an external elastic lamina (Membrana elastica externa).
- Tunica adventitia is scant and continous with surrounding connective tissue.

METARTERIOLE

- A type of vessel has structural characteristics of both an arteriole and a capillary.
- Each metarteriole arises from a terminal arteriole and branches to supply blood to a capillary bed that may consist of 10–100 capillaries
- Slightly larger than the typical capillary.
- The smooth muscle layer is not continuous.

The precapillary sphincters, circular smooth muscle cells that surround the capillary at its origin with the metarteriole

In a capillary bed, arterioles give rise to metarterioles. Precapillary sphincters located at the junction of a metarteriole with a capillary regulate blood flow. A thoroughfare channel connects the metarteriole to a venule. An arteriovenous anastomosis, which directly connects the arteriole with the venule, is shown at the bottom.

TABLE 11–1 Characteristics of Various Types of Arteries

Artery	Tunica Intima	Tunica Media	Tunica Adventitia
Elastic artery (*conducting*) (e.g., aorta)	Endothelium with Weibel-Palade bodies, basal lamina, subendothelial layer, incomplete internal elastic lamina	40 to 70 fenestrated elastic membranes; smooth muscle cells interspersed between elastic membranes; thin external elastic lamina; vasa vasorum in outer half	Thin layer of fibroelastic connective tissue, vasa vasorum, lymphatic vessels, nerve fibers
Muscular artery (*distributing*) (e.g., femoral artery)	Endothelium with Weibel-Palade bodies, basal lamina, subendothelial layer, thick internal elastic lamina	Up to 40 layers of smooth muscle cells; thick external elastic lamina	Thin layer of fibroelastic connective tissue; vasa vasorum not very prominent; lymphatic vessels, nerve fibers
Arteriole	Endothelium with Weibel-Palade bodies; basal lamina, subendothelial layer not very prominent; some elastic fibers instead of a defined internal elastic lamina	One or two layers of smooth muscle cells	Loose connective tissue, nerve fibers
Metarteriole	Endothelium, basal lamina	Smooth muscle cells form precapillary sphincter	Sparse, loose connective tissue

CAPILLARIES

- A capillary is a microscopic channel
- Exchange of gases and other substances occurs in the capillaries between the blood and the surrounding cells and their tissue fluid
- The diameter of a capillary lumen ranges from 5–10 micrometers
- The wall of a capillary consists of the endothelial layer surrounded by a basement membrane

- **Pericytes** are adventitial cells located within the basement membrane of capillary and postcapillary venules.

- **Pericytes** are defined topographically as contractile cells specifically located surrounding the endothelial cells and supporting blood vessel integrity

Capillaries connect arteriole to venule.

There are three major types of capillaries, which differ according to their degree of "leakiness:"

1. Continuous
2. Fenestrated
3. Sinusoid

1-Continuous Capillaries:

- The most common type of capillary, the continuous capillary, is found in almost all vascularized tissues.
- They are lined by a complete simple squamous endothelium and a basal lamina.
- Endothelial cells are linked by tight junctions.
- Pericytes can ocur between the endothelium and the basal lamina.

2-Fenestrated Capillaries

- Fenestrated capillaries have pores or fenestrae, with or without diaphrams.
- With diaphragms fenestrated capillaries: İntestines, endocrine glands and around kidney tubules
- Without diaphragms fenestrated capillaries: Renal glomerulus
- These capillaries are more permeable than continuous capillaries.
- It is important to note that the endothelial basement membrane is still continuous across the fenestrations and thus continues to provide a barrier to diffusion of cells and plasma proteins

3-Sinusoidal Capillaries

(sinusoids, or discontinuous capillaries)

They have endothelial linings with multiple fenestrations (openings), that are around 30 to 40 nm in diameter.

These have no diaphragm and either a discontinuous or non-existent basal lamina and large irregularly shaped vessels

- Sinusoidal capillaries are mainly found in the liver, between epithelial cells and hepatocytes.
- Sinusoidal capillaries can also be found in the lymph nodes, bone marrow, spleen and some of the glands of the endocrine system.

VEINS

- The walls of veins are thinner than the walls of arteries, while their diameter is larger.
- In contrast to arteries, the layering in the wall of veins is not very distinct.
- The tunica intima is very thin. Only the largest veins contain an appreciable amount of subendothelial connective tissue.

VEINS

- Internal and external elastic laminae are absent or very thin.
- The tunica media appears thinner than the tunica adventitia, and the two layers tend to blend into each other.
- The walls of veins in the lower parts of the body are typically thicker than those of the upper parts of the body.
- the walls of veins which are embedded in tissues that may provide some structural support are thinner than the walls of unsupported veins.

Veins consist of three layers like arteries.

1. The venous tunica intima is composed of a traditional continuous endothelium which rests on a thin collagenous meshwork.
2. The venous tunica intima is composed of a traditional continuous endothelium which rests on a thin collagenous meshwork.
3. The venous tunica adventitia is generally the most prominent layer of these vessels and is composed of collagenous tissue which blends into that of the surrounding tissue.

- These three layers are not separated from each other by sharp borders.
- According to the arteries, all layers show loose arrangement. Therefore, it tends to contract when it is not filled with blood.

Veins

4 types according to the size and characteristics of T. media

1. **Venules**

a) **Postcapillary - pericytic**

b) **Muscular venules**

2. **Small veins**

3. **Medium veins**

4. **Large veins**

LARGE VEINS

- Diameter: ≥ 10 mm
(subclavian, portal veins, venae cavae…)
- Tunica intima
- endothelium + basal lamina
- thin subendothelial layer (some smooth muscle cells)
- Tunica Media
- much thinner than in medium-sized arteries
- some layers of circular smooth muscle
- collagen elastic fibers and fibroblasts
- longitudinally oriented smooth muscle cells may be present beneath adventitia
- T. Adventitia
- thickest layer
- collagen fibers and network of elastin fibers
- longitudinally oriented smooth muscle bundles

https://images.slideplayer.com/22/6381682/slides/slide_17.jpg

MEDIUM VEINS

- Diameter: 1-10 mm
- Most deep veins accompanying arteries in this category (radial, tibial, popliteal veins …)
- valves are characteristic
- Tunica intima
- - endothelium + basal lamina
- - thin subendothelial layer (occasional smooth muscle cells)
- - in some cases discontinous internal elastic membrane
- Tunica media
- - much thinner than in medium-sized arteries
- - some layers of circular smooth muscle
- - collagen and elastic fibers
- - longitudinally oriented smooth muscle
- cells may be present beneath adventitia
- Tunica adventitia
- - thicker than tunica media
- - collagen fibers and network of elastin fibers

https://skat.ihmc.us/rid=1NG0K3PCD-24C4ZT0-8W1/Resources%20for%20Histology%20of%20Blood%20Vessels

SMALL VEINS

- (100 μm-1000 μm diameter)
- thin media - only a few layers of smooth muscle cells
- much thicker adventitia - collagen and occasionally some longitudinal smooth muscle fibers

Venules

- Smallest Veins
- Capillaries drain into **post-capillary venules** (**10–40 µm** in diameter)
- Post-capillary venules drain into **large muscular venules** (**40–100 µm** in diameter)
- Important sites or exchange of metabolites

Venules

- Wall is thin
- Large collapsed lumen
- **T intima**: endothelium
- **T media**: 1-2 layers of smooth muscle fibers
- **T adventitia**: thick and composed of connective tissue rich in collagen fibres

VENULES

Muscular venule

- 0.1 mm in diameter
- There is no pericyte under the endothelium
- Tunica media contains 1-2 layers of smooth muscle
- Thin tunica adventitia

POSTCAPILLARY VENULE

Venules are tubes of endothelium.
Small venules (pericytic) (up to 40-50 μm diameter)
- surrounded by pericytes (contractile cells)
- with long, branching processes that are involved in the control of blood flow
- More porous than capillaries, thus Exchange fluid with surrounding tissues

- The endothelial cytoplasm contains histamine and seratonin, which are vasoactive substances.
- Especially in inflammatory and allergic events, the passage of leukocytes and blood fluid to tissue is provided here.

TABLE 11–2 Characteristics of Veins

Type	Tunica Intima	Tunica Media	Tunica Adventitia
Large veins	Endothelium; basal lamina, valves in some; subendothelial connective tissue	Connective tissue; smooth muscle cells	Smooth muscle cells oriented in longitudinal bundles; cardiac muscle cells near their entry into the heart; collagen layers with fibroblasts
Medium and small veins	Endothelium, basal lamina; valves in some; subendothelial connective tissue	Reticular and elastic fibers, some smooth muscle cells	Collagen layers with fibroblasts
Venules	Endothelium, basal lamina (pericytes, postcapillary venules)	Sparse connective tissue and a few smooth muscle cells	Some collagen and a few fibroblasts

Valves of Vein

- Valves are only found in small to medium-sized veins.
- One or two bands of tissue in the lumen of the vein.
- Each band is formed by two apposing layers of tunica intima.

Valves are absent in

- Very small veins;
- Veins within the cranial cavity & vertebral canal
- Venae cavae; SVC & IVC
- In some other veins

Special Vessels

- Other variations in the structure of blood vessels occur in certain organs in response to special functional and anatomical conditions. Some examples of special vessels include:

- **Cerebral arteries and veins:** These arteries are rather thin-walled for their caliber, with a well-developed internal elastica and virtually no elastic fibers in the rest of the vascular wall. The veins have a thin wall devoid of smooth muscle cells.
- **Pulmonary arteries and veins:** These arteries have thin walls as a result of a significant reduction in both muscular and elastic elements, while the veins have a well-developed media of smooth muscle cells.
- **Umbilical vessels:** These arteries have two layers of smooth muscle cells without a prominent internal elastica or adventitia. The vein has a thick muscular wall with two to three muscle layers.
- **Portal systems:** A portal system is one in which two capillary networks are connected in series by an arteriole or venule. In the kidney, an arterial portal system is present at the level of the glomeruli. A venous portal system exists in the liver

Portal System

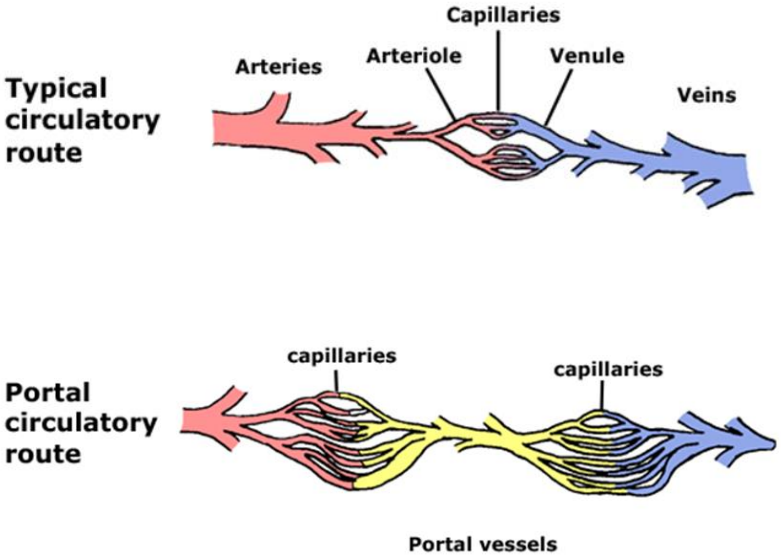
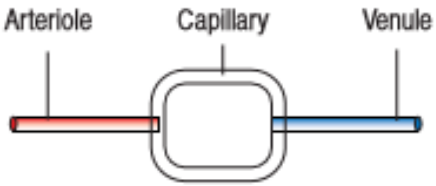


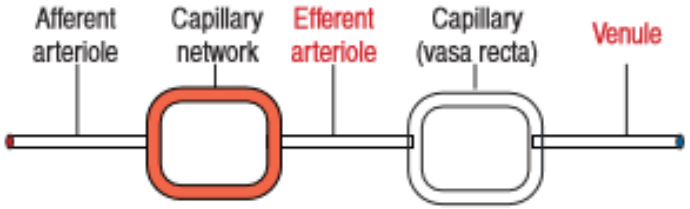
Figure 12-13. Glomerulus and portal systems

Typical arrangement

In general, a capillary network is interposed between an arteriole and a venule.

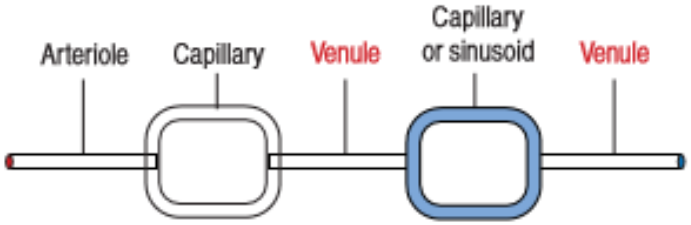


Arterial portal system



In the kidneys, an arteriole is interposed between two capillary networks. An afferent arteriole gives rise to a mass of capillaries, the **glomerulus**. These capillaries coalesce to form an efferent arteriole, which gives rise to capillary networks (peritubular capillary network and the vasa recta) surrounding the nephrons.

Venous portal system



In the liver and hypophysis, venules feed into an extensive capillary or sinusoid network draining into a venule. This distribution is called the **venous portal system**.

Anastomosis

- **Point where 2 blood vessels merge**
- **Arteriovenous shunt**
  - **artery flows directly into vein**
- **Venous anastomosis**
  - **most common, blockage less serious**
  - **alternate drainage of organs**
- **Arterial anastomosis**
  - **collateral circulation (coronary)**

Arteriovenous Anastomosis

Arteriovenous anastomosis (shunt) is the communication between an arteriol and a venule.

- They have a thick muscular coat and average diamater of 20 µm.
- There is no elastic tissue.
- The smooth muscle cells are also developed.
- They regulate blood pressure
- They regulate the secretions of epiteloid cells.

Specialized Sensory Structures in Arteries

1. Carotid sinuses (baroreceptor)

They are located within the walls of the internal carotid arteries just above the bifurcationof the common carotid arteries

T. Adventitia is relatively thicker and endowed with N. Glossopharengeus.

Function: Carotid sinus acts as a baroreceptor or pressure receptor and regulates pressure.

2. Carotid body (chemoreseptor)

- It is a small, oval reddish-Brown sturucture situated behind the bifurcation.
- **Function:** It is acts as a chemoreceptor and responds to changes in the oxygen and carbondioxide and Ph content of the blood.

The carotid body is made up of two types of cells, called glomus cells:

- **glomus type I cells are peripheral chemoreceptors,**
- **Glomus type II cells are sustentacular supportive cells.**
- **Glomus type I cells are derived from the neural crest.**

- Glomus type I cells are derived from the neural crest. They release a variety of neurotransmitters, including acetylcholine, ATP, and dopamine that trigger EPSPs in synapsed neurons leading to the respiratory center. They are innervated by axons of the glossopharyngeal nerve which collectively are called the carotid sinus nerve.

- Glomus type II cells resemble glial cells, express the glial marker S100 and act as supporting cells.

AORTIC BODIES

- İn walls of aorta
- Their function and structure are the same as those of carotid bodies.

GLOMUS

(Complex Arteriovenous Anastomosis)

- They are seen in skin of hands and feet especially thr digital pads and nail beds.
- Vessels are twisted and surrounded by capsules
- Smooth muscle cells have epiteloid appearance.

Paraganglion

Paraganglion (pl. paraganglia) is a group of non-neuronal cells derived of the neural crest.

They are essentially of two types:

1. **Chromaffin or sympathetic paraganglia made of chromaffin cells**
2. **Nonchromaffin or parasympathetic ganglia made of glomus cells. They are neuroendocrine cells. Nonchromaffin paraganglia include carotid bodies and aortic bodies**

The lymphatic vessels (lymph vessels or lymphatics)

- **They are thin-walled vessels (tubes) structured like blood vessels, that carry lymph.**
- **It is made up of a large network of lymphatic vessels, lymphatic or lymphoid organs, and lymphoid tissues**

Unlike the circulatory system, the lymphatic system is not a closed system.

- While watching with arteries and veins all over the body, SSS, bone marrow, thymus, tooth pulp, placenta, inner ear, epidermis, cartilage and bone are not found.

Lymph Capillaries

The lymphatic vessels begin with the 'blind-ended' lymphatic capillaries between the interstitial tissues & cardiovascular system

- The smallest lymphatic vessels are lymphatic capillaries which join together to form larger lymphatic vessels.
- Lymph is a transudate from blood and contains the same protein as in plasma, but in larger amount

- The structure is basically similar to that of blood capillaries but has the greater permeability
- There is an inner lining of endothelium
- Basal lamina is absent or poorly developed
- Pericytes or connective tissue are not present around the capillary

Larger Lymph Vessels

- The structure is similar to that of veins
- Tunica intima, Tunica media and Tunica adventitia can be distinguished
- Elastic fibres are prominent and seen in all three layers
- Media and adventitia contains smooth muscles, arranged circularly
- no permeability: continuous basal lamina, tight junction between endothelial cells, smooth muscle cells - valves! prevent backflow

Numerous valves, similar to those in veins, are present in small and large lymphatic vessels and give lymph vessels a beaded appearance

Sources

1. Colour Textbook of Histology, Leslie. P.Gardner, James L. Hiatt. 3. edition.

2. Histology and Cell Biology: An Introduction to Pathology. Abraham L. Kierszenbaum Laura L. Tres. Fourth edition.

3. Histology A text and Atlas. Michael H. Ross, Lynn J.Romrell, Gordon I Kaye. Third edition.