

Cardiovascular system 2nd stage Histology

Dr. Muntadhir M. Cani

The Circulatory System:

The circulatory system includes both the blood and lymphatic vascular systems.

The **blood vascular system** is composed of the following structures:

§ The **heart**, an organ whose function is to pump the blood.

§ The **arteries**, a series of efferent vessels that become smaller as they branch, and whose function is to carry the blood, with its nutrients and oxygen, to the tissues.

Types: **large elastic arteries** (stabilize the blood flow), **muscular arteries** (medium-sized and small arteries), **arterioles** (diameter 50 - 300 μm)

§ The **capillaries**, the smallest blood vessels (diameter 5 – 10 μm), constituting a complex network of thin tubules that branch profusely in almost every organ and through whose walls the interchange between blood and tissues takes place.

Types of capillaries:

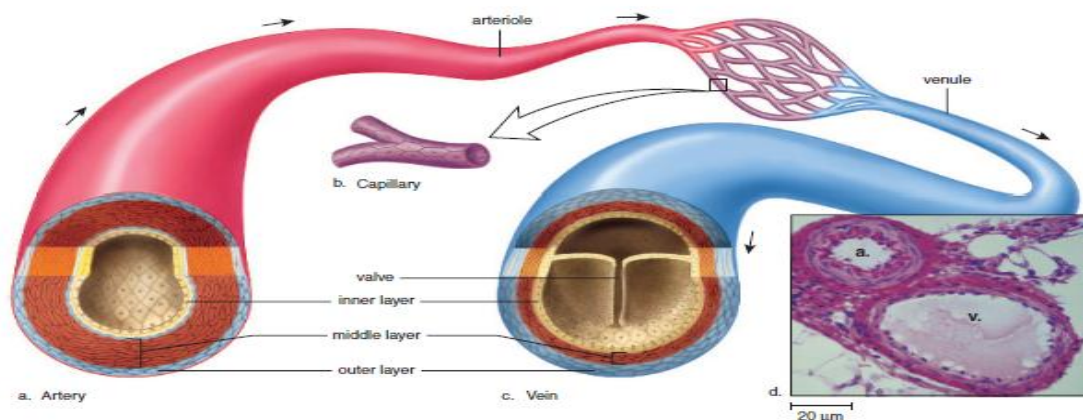
Continuous, somatic

Fenestrated, visceral

Sinusoidal, discontinuous

§ The **veins**, which result from the convergence of capillaries into a system of larger channels that continue enlarging as they approach the heart, toward which they convey the blood to be pumped again.

Types: **venules**, **common type of veins** (thin-walled veins), **muscular veins** (inferior vena cava)



ENDOTHELIUM

Mesenchymal origin, flat polygonal cells (10 μm wide, 20-30 μm long)

Participate in the structural and functional integrity of the vascular wall.

Blood Vessels

All blood vessels within the cardiovascular system, with the exception of capillaries, follow the same histological organization.

The walls of arteries, arterioles, veins, and venules all have three layers, or tunics.

- The innermost layer is the **tunica intima**, which consists of an endothelial tube of longitudinally arranged, simple, squamous epithelial cells termed *endothelial cells*.

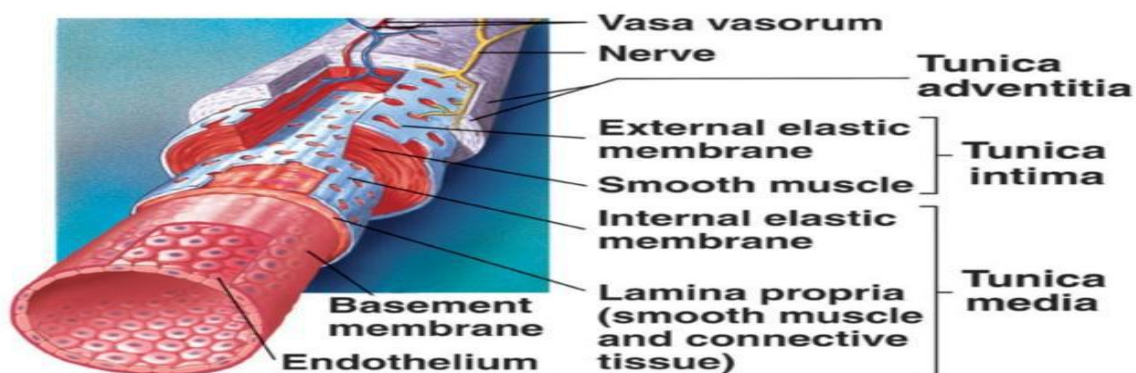
_ A sheet of elastic tissue, termed the *internal elastic membrane (internal elastic lamina)*, forms the boundary between the tunica intima and the second layer of the vessel, the tunica media.

_ The thin, squamous endothelial cells are separated from the internal elastic membrane by a layer of loose connective tissue termed the *sub endothelial connective tissue*. The sub endothelial connective tissue contains a few fibrocytes, occasional smooth muscle cells, and thin collagen fibers.

- The **tunica media** is composed of multiple concentric layers of circularly arranged smooth muscle cells.

An external elastic membrane (*external elastic lamina*) serves as the boundary between the tunica media and the outermost layer of the vessel, the tunica adventitia.

- The **tunica adventitia** consists of fibrocytes, longitudinal bundles of collagen fibers, and a loose network of thin elastic fibers.



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Types of BV

Large or elastic arteries - Medium sized or muscular arteries

- Small arteries – Arteriole
- Capillaries - Postcapillary venules
- Muscular venules - Small veins
- Medium sized veins - Large veins
- Atypical veins

Elastic or Large Arteries - Includes aorta, pulmonary arteries, and their main branched. - They serve as conductor tubes

1- Tunica intima * It is relatively thick. * Endothelium lining and its basal lamina.

* The cells are joined together by tight, and gap junctions.

* The endothelial cells contain cytoplasmic rod-like bodies called Weibel -Palade Bodies.

* These bodies are electron dense structures contain coagulating factor 8 (Von-Willebrand) that are secreted mainly by arterial endothelium into blood stream.

* Sub endothelial layer; CT contain collagen, elastic fibers, and smooth muscle fibers; and occasionally macrophages.

* Internal elastic membrane not well developed.

2- Tunica Media

* It the thickest layer of the wall.

* Formed of multiple layers of smooth muscle fibers separated by elastic lamellae.

* Elastic lamellae are formed of fenestrated sheets arranged in concentric layers, their number and thickness related directly to the age and blood pressure.

* Smooth muscle fibers arranged in layers in between the elastic lamellae. They secrete collagen, elastic fibers, and proteoglycans

3- Tunica adventitia

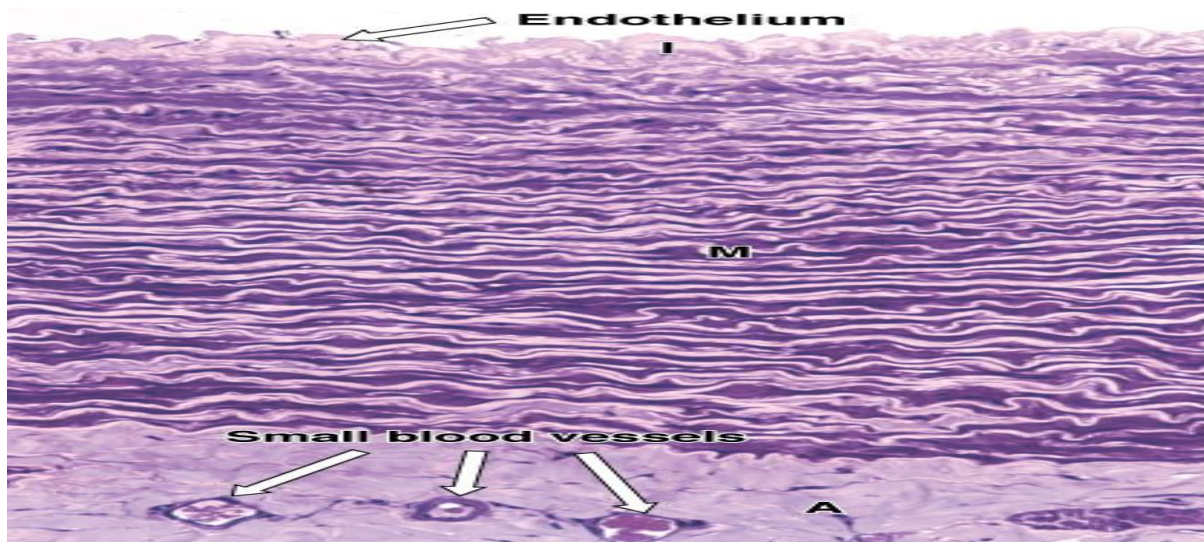
- It is formed of loose network of elastic and collage fibers.

- It contain Fibroblasts, macrophages, blood vessels (vasa vasorum), and nerves (nervi vascularis).

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- **Endothelial cells** play an important role in blood homeostasis.
 - Anti-thrombogenic function
 - Barrier function - selective permeability
 - Secretion of the vasoactive factors (endothelins, prostacyclin)
 - Synthesis of components of basal lamina (laminin, type IV collagen, heparin sulfate PG)
- Participate in the structural and functional integrity of the vascular wall, a process called endothelial activation.
- Maintenance of selective permeability barrier
 - Simple diffusion: O₂, CO₂, lipid soluble molecules.
 - Trans-cellular pathways ..endocytosis - Small pinocytotic vesicles.....
 - Receptor mediated endocytosis
 - Modulation of blood flow and vascular resistance by secreting vasoconstrictors and vasodilators substances.
 - Modified LDL are endocytosed by macrophages to form foam cells, which are characteristic feature in the formation of atherosclerotic plaques.



The several elastic laminae contribute to the important function of making blood flow more uniform. During ventricular contraction (**systole**), the elastic laminae of large arteries are stretched, reducing the force of the pressure somewhat. During ventricular relaxation (**diastole**), ventricular pressure drops to a low level, but the elastic rebound of large arteries helps to maintain arterial pressure. As a consequence, arterial pressure and blood velocity decrease and become less variable as the distance from the heart increases.

Large vessels usually have **vasa vasorum** ("vessels of the vessel"), which consist of arterioles, capillaries, and venules in the tunica adventitia and the outer part of the media. The vasa vasorum provide metabolites to cells of those layers, since in larger vessels the wall is too thick to be nourished solely by diffusion from the blood in the lumen. Luminal blood alone does provide nutrients and oxygen for cells of the tunica intima. Since they carry deoxygenated blood, large veins typically have more vasa vasorum than arteries.

Muscular, Medium Sized Arteries or Distributing Artery

- Tunica Intima: relatively thin, with well prominent Internal Elastic Membrane.

* Endothelium:

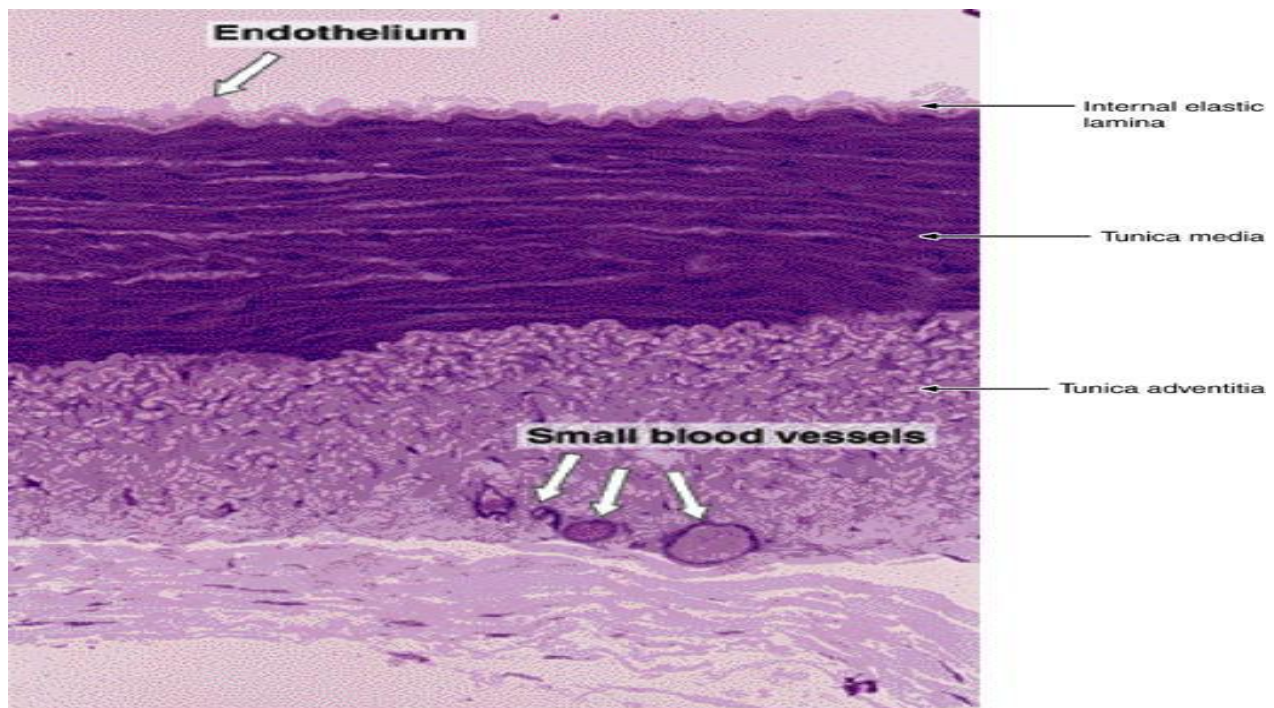
*Sub-endothelium: Somewhat thicker, few smooth muscle fibers may be present.

*Internal elastic lamina: Very prominent, Forms a thick fenestrated band of closely interwoven elastic fibers.

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- Have more smooth muscle fibers and less elastic fiber in the tunica media
- Tunica Media: Formed mainly of smooth muscle fibers, and few collagen and elastic fibers several layers (up to 40).
- Tunica Adventitia: Formed of CT, collagen and elastic fibers, blood vessels, and nerves.
- Separated from tunica media by well prominent External Elastic Membrane.



Small arteries & arterioles

Arterioles: T. Intima: Only Endothelium, T. media: 1 or 2 layers, T. Adventitia: Thin.

Small arteries:

T. intima: Endothelium-Very thin Sub – endothelium, T. media: up to 8 layers,

T. Adventitia: Thin

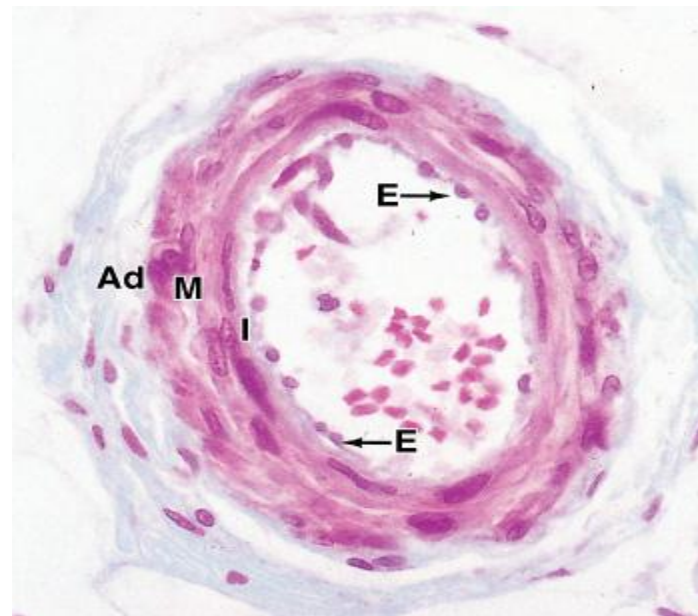
- They are differentiated from each other by the number of smooth muscle fibers layers in tunica media.

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- Internal Elastic Membrane is well defined in small arteries, but could or could not be present in arterioles.

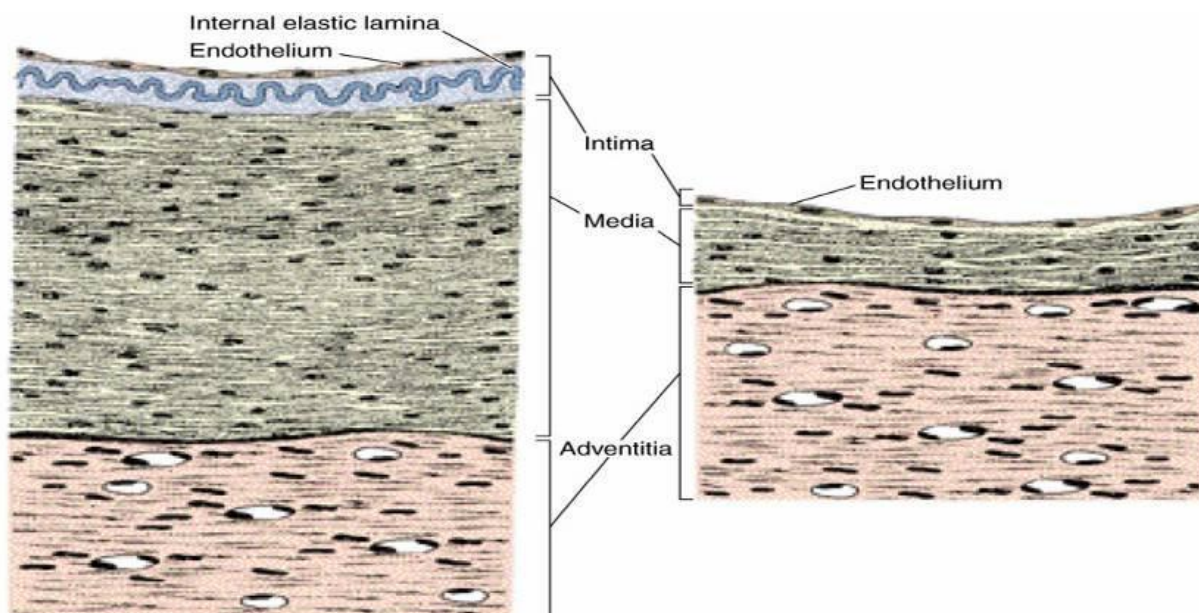
The smallest arteries branch as **arterioles**, which have one or two smooth muscle layers and indicate the beginning of an organ's **microvasculature** where exchanges between blood and tissue fluid occur. Arterioles are generally less than 0.5 mm in diameter, with lumens approximately as wide as the wall is thick, the sub endothelial layer is very thin, the elastic laminae are absent and the media is generally composed of circularly arranged smooth muscle cells. In both small arteries and arterioles, the tunica adventitia is very thin and inconspicuous.



COMPARISON OF MEDIUM SIZE ARTERY & VEIN

Diagram comparing the structure of a muscular artery (left) and accompanying vein (right).

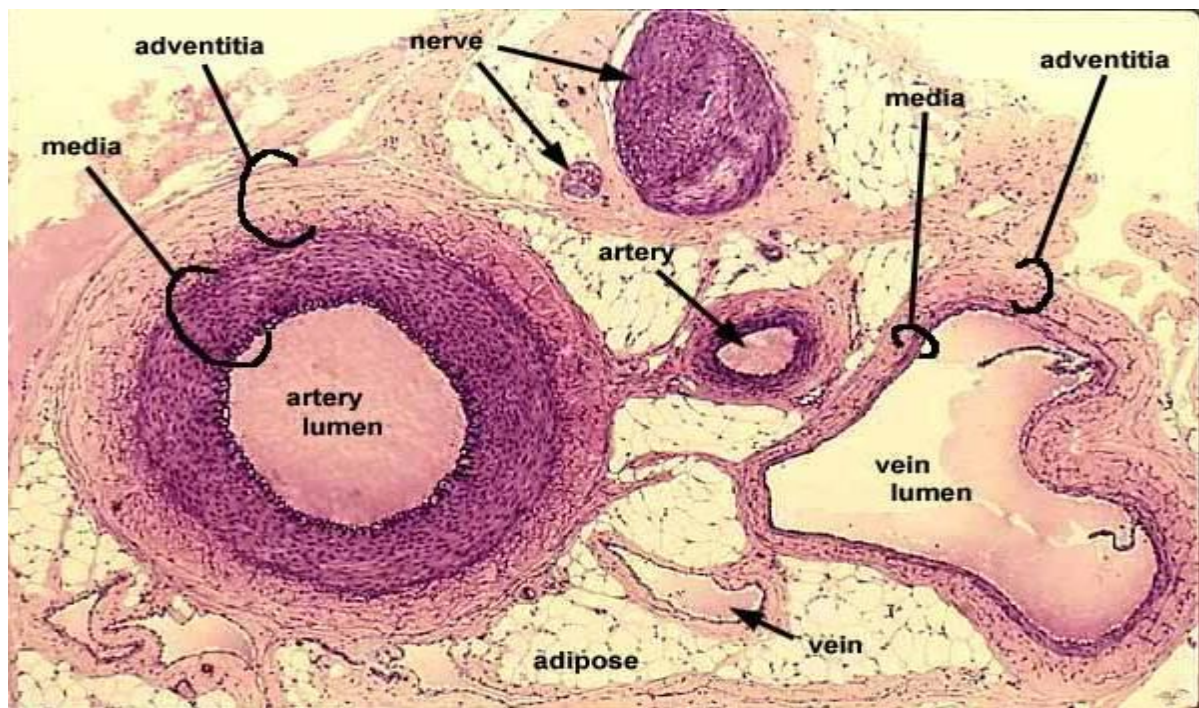
Note that the tunica intima and tunica media are highly developed in the artery but not in the vein



Capillaries

Capillaries permit different levels of metabolic exchange between blood and surrounding tissues. They are composed of a single layer of **endothelial cells** rolled up in the form of a tube. The average diameter of capillaries varies from 5 to 10µm and their individual length is usually not more than 50µm. Altogether capillaries comprise over 90% of all blood vessels in the body, with a total length of nearly 96,000 km. The velocity of blood in the aorta averages 320 mm/s, but in capillaries blood flows only about 0.3 mm/s. Because of their thin walls and slow blood flow, capillaries are a favorable place for the exchange of water, solutes, and macromolecules between blood and tissues.

Endothelial cells are functionally diverse according to the vessel they line. The capillaries are often referred to as exchange vessels, since it is at these sites that O₂,



CO₂, substrates, and metabolites are transferred from blood to the tissues and from the tissues to blood.

In general, endothelial cells are polygonal and elongated in the direction of blood flow. The nucleus causes that part of the cell to bulge into the capillary lumen. The cytoplasm contains a small Golgi apparatus, mitochondria, free ribosomes, and

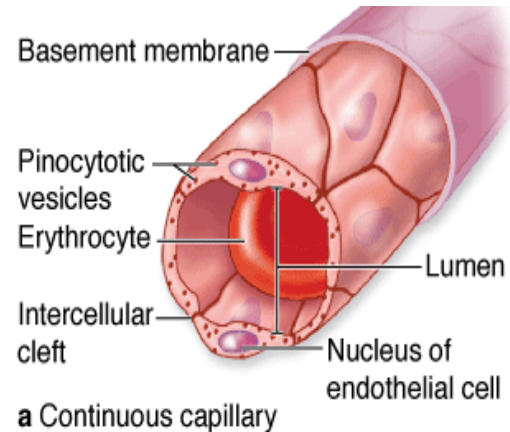
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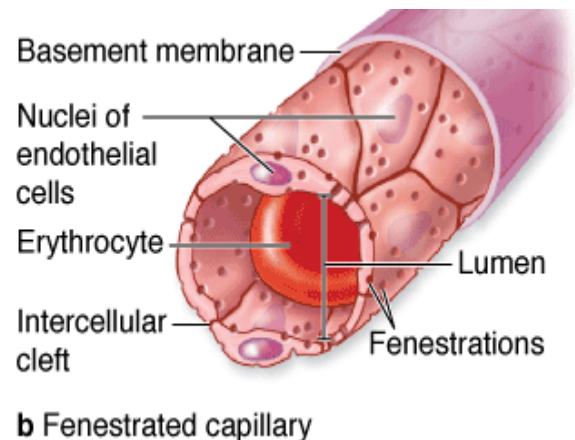
sparse cisternae of RER. Junctions of the tight zonula occludentes type are present between most endothelial cells.

Capillaries can be grouped into three types, depending on the continuity of the endothelial cells and the external lamina.

1. The **continuous**, or tight, **capillary** allows regulated exchange of material and is characterized by the distinct continuity of the endothelial cells in its wall. This is the most common type of capillary and is found in all kinds of muscle tissue, connective tissue, exocrine glands, and nervous tissue. In some places, but not in the nervous system, numerous pinocytotic vesicles are present on both endothelial cell surfaces. Vesicles also appear as isolated vesicles in the cytoplasm of these cells and are responsible for transcytosis of macromolecules in both directions across the endothelial cytoplasm.



2. The **fenestrated capillary** allows more extensive molecular exchange across the endothelium and is characterized by the presence of small circular fenestrae (L, *fenestra*, perforation) through the very thin squamous endothelial cells. Each fenestra is usually covered by a very thin diaphragm containing heparan proteoglycans but no lipid bilayer. The basal lamina of the fenestrated capillaries is continuous, covering the fenestrae. Fenestrated capillaries are found in tissues where rapid interchange of substances occurs between the tissues and the blood, as in the kidney, the intestine, the choroid plexus and the endocrine glands.



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3. The **sinusoid** or **discontinuous capillary** permits maximal exchange of macromolecules as well as cells between tissues and blood and has the following

characteristics: endothelial cells have large fenestrae without diaphragms; the cells form a discontinuous layer and are separated from one another by wide spaces; the basal lamina is also discontinuous.

Sinusoids are irregularly shaped and have diameters as large as 30–40µm, much greater than those of other capillaries, properties which further slow blood flow at this site. Sinusoidal capillaries are found in the liver, spleen, some endocrine organs, and bone marrow.

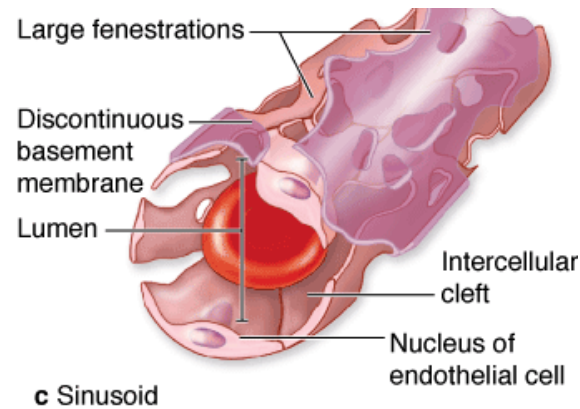


Table 8-1: Summary of Histological Characteristics of Capillaries and Arteries

Blood Vessels	Tunica Intima	Tunica Media	Tunica Adventitia
Capillary	Single layer of endothelial cells and underlying subendothelial layer of loose (areolar) connective tissue	None present	None present
Arterioles	Endothelial cells and underlying connective tissue. Small arterioles lack an internal elastic membrane; larger arterioles may have a very delicate internal elastic membrane.	Only 1 to 2 layers of smooth muscle	Dense, irregular connective tissue composed of longitudinally and circumferentially arranged collagen and elastin fibers
Muscular artery	Endothelial cells on underlying connective tissue; internal elastic membrane present	Smooth muscle and some elastin and collagen; external elastic membrane present	Composed of longitudinally and circumferentially arranged collagen and elastin
Elastic artery	Relatively thick layer with endothelium on underlying connective tissue; internal elastic membrane present but not distinct because of numerous layers of elastic tissue within tunica media	Thick layer of smooth muscle with fenestrated layers of elastin; external elastic membrane present but not distinct because of numerous layers of elastic tissue within tunica media	Thin layer composed of collagen longitudinally arranged; often interspersed with elastic fibers

Veins

- The tunics of veins are not well developed as those of arteries.
- Veins have thinner wall than arteries.
- The lumen of vein is large and collapsed.
- Some veins contain valves, especially those of the lower limbs.

Classification of veins

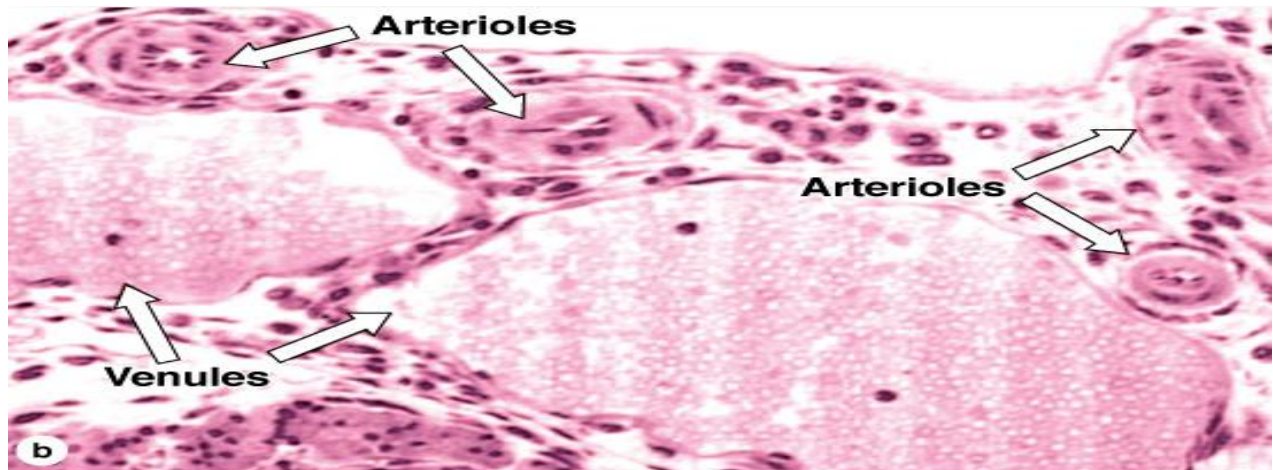
- Small veins or venules: * Postcapillary venules. * Muscular venules.
- Medium sized veins.
- Large veins.

Postcapillary venules

- They receive blood from capillaries.
- Diameter ~ 0.2 mm
- Formed of endothelial lining cells, basal lamina, and pericytes.
- There is no tunica media.
- The endothelial cells are the site of action of vaso-active agents like histamine, and serotonin.
- The postcapillary venules in lymph nodes are called high endothelial venules
- postcapillary venules are the primary site at which white blood cells leave the circulation at sites of infection or tissue damage. These venules converge into larger **collecting venules** which have more contractile cells. With greater size the venules become surrounded by recognizable tunica media with two or three smooth muscle layers and are called **muscular venules**.

Muscular venules

- Located distal to postcapillary venules.
- Their diameter ~ 1mm.
- Have one or two layers of smooth muscle fibers in their tunica media, and thin



tunica adventitia.

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Medium sized veins

- Tunica Intima:

- * Endothelial cells and basal lamina
- * Sub endothelial CT tissue, with some smooth muscle fibers.
- * Sometimes, a thin internal elastic membrane found in some veins.

- Tunica media:

- * Thinner than tunica adventitia.
- * Many layers of smooth fibers, with collagen and elastic fibers in between.
- * Longitudinal arranged smooth muscles fibers.

-Tunica Adventitia:

- * Thicker than tunica media * Contain collagen fibers, and a network of elastic fibers.

Large veins

The big venous trunks paired with elastic arteries close to the heart are large veins.

- Diameter more than 1cm.
- Tunica intima :(**well-developed**) no clear boundary between it and tunica media
- Tunica media: is relatively thin.
- Tunica adventitia: the thickest layer.
- * Longitudinal smooth muscle fibers, collagen, and elastic fibers.
- * Both the media and adventitia contain elastic fibers, but elastic laminae like those of arteries are not present.

Most veins have valves, but these are most prominent in large veins. Valves consist of paired semilunar folds of the tunica intima projecting across part of the lumen, the valves, which are especially numerous in veins of the legs, help keep the flow of venous blood directed toward the heart.

Atypical veins

- In several locations veins with special structure are present such as;
- * Venous channels in the cranial cavity, venous or dural sinuses.
- *Veins of the retina, placenta, and trabeculae of spleen

Table 8-2: Summary of the Histology of the Cardiovascular System: Veins

Blood Vessel	Tunica Intima	Tunica Media	Tunica Adventitia
Venules	Endothelial cells on layer of areolar connective tissue	1 to 2 layers of smooth muscle	Relatively thick layer compared with tunica intima or media
Veins: medium diameter	Layer composed of endothelium resting on subendothelial layer of thin collagen bundles interspersed with elastin. Internal elastic membrane present	Smooth muscle interspersed with elastic fibers that are often arranged longitudinally; external elastic membrane present but not prominent	Forms bulk of wall; composed of collagen and elastin and some longitudinally arranged smooth muscle fibers
Veins: large diameter	Similar to that of medium-diameter veins.	Poorly developed layer; collagen and some elastic fibers interspersed between smooth muscle	Relatively thick layer; bundles of irregularly arranged collagen and elastic fibers interspersed with longitudinally arranged smooth muscle

Heart

The heart is a muscular organ that contracts rhythmically, pumping the blood through the circulatory system. The right and left ventricles pump blood to the lungs and the rest of the body respectively; right and left atria receive blood from the body and the pulmonary veins respectively. The walls of all four heart chambers consist of three major layers or tunics: the **internal endocardium**; the **middle myocardium**; and the **external epicardium**.

Cardiac muscle is limited to the heart. The second form of striated muscle, it exhibits a banding pattern that is quite similar to that seen in skeletal muscle. Cardiac muscle is commonly called a *functional syncytium*, in that excitation of one cardiac muscle cell quickly causes the excitation of all adjacent cells. This is due to the specialized junctions, termed *intercalated discs*, which are found between cardiac muscle cells.

Cardiac muscle, like skeletal muscle, is striated; as a result, these two tissues are often **misidentified**.

Differences between skeletal and cardiac muscle:

- Cardiac muscle cells are considerably smaller than skeletal muscle fibers. The exception to this **rule** is Purkinje fibers.

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- Cardiac muscle cells branch frequently and therefore demonstrate a greater size variation when viewed in cross section.
- Cardiac muscle cells (except for Purkinje fibers) have a single, centrally located nucleus.
- Cardiac muscle cells possess specialized cell junctions called *intercalated discs*, which are visible in longitudinal sections of cardiac muscle.

The endocardium consists of a single layer of squamous endothelial cells on a thin layer of loose connective tissue containing elastic and collagen fibers as well as some smooth muscle cells. Connecting this sub endothelial layer to the myocardium is additional connective tissue (often called the subendocardial layer) containing veins, nerves, and branches of the impulse-conducting system of the heart.

Major histological features of the heart.

Longitudinal view of human heart showing the two **atria** and two **ventricles**. The ventricular walls are thicker than those of the atria, principally because of the much thicker myocardium. The **valves** are basically flaps of connective tissue anchored in the heart's dense **fibrous skeleton** region. Other parts of the fibrous skeleton are the chordae tendinae, cords of dense connective tissue extending from the valves and attached to papillary muscles that help prevent valves from turning inside-out during ventricular contraction. All these parts of the fibrous skeleton are covered by endothelium. **conducting system**, which initiates the electrical impulse for heart's contraction (heartbeat) and spreads it through the ventricular myocardium. Both the sinoatrial (SA) node (pacemaker), in the posterior wall of the right atrium, and the atrioventricular (AV) node in the floor of the right atrium consist of myocardial tissue. The AV node is continuous with specialized bundles of cardiac muscle fibers, the **AV bundle** (of His) which run along the interventricular septum to the apex of the heart, where they branch further as **conducting (Purkinje) fibers** which extend into myocardium of both ventricles.

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Impulse conducting system

- SAN
- AVN
- Bundle of Hiss
- Rt bundle branch
- Lt bundle branch
- Purkinje fibers

Receptors within the cardio-vascular system

- Baro-receptors: High pressure receptors, sense arterial blood pressure (carotid sinus, aortic arch)
- Volume receptors: Low pressure receptors, sense cardiac distention).
- Chemo-receptors: pH and blood gases (carotid and aortic bodies).

