HISTOLOGY 2024-2025

The circulatory system (part I/II)

This system comprises both the blood and lymphatic vascular system. The blood vascular system consists of the heart, arteries, veins, and capillaries. This system transports oxygen and nutrients to tissues, carries carbon dioxide and waste products from the tissues, and circulates hormones from the site of synthesis to their target cells.

The heart: an organ whose function is to pump the blood.

The arteries: efferent vessels that become smaller as they branch, and whose function is to carry the blood with its nutrition and O2 to the tissues.

The capillaries: are the smallest blood vessels that form a network of thin tubules that anastomose profusely, through whose wall the interchange between blood and tissue takes place.

The veins: which result from convergence of capillaries they become larger as they approach the heart.

The lymphatic vascular system begins in the lymphatic capillaries as close-ended tubules that anastomose to form vessels of steadily large in size, these vessels terminated in the blood vascular system.

The internal surface of all components of the blood and lymphatic systems is lined by a simple squamous epithelium called endothelium. As the interface between blood and the organs, cardiovascular endothelial cells have crucial physio logic and medical importance. Not only must endothelial cells maintain a selectively permeable, antithrombogenic (inhibitory to clot formation) barrier, they also determine when and where white blood cells leave the circulation for the interstitial space of tissues and secrete a variety of paracrine factors for vessel dilation, constriction, and growth of adjacent cells.

Innervation: Most blood vessels that contain smooth muscle in their walls are supplied with a profuse network of unmyelinated sympathetic nerve fibers (vasomotor nerves). Whose neurotransmitter is norepinephrine, discharge of norepinephrine from these nerves results in vasoconstriction. Arteries in skeletal muscles also receive a cholinergic vasodilator nerve supply.

Afferent (sensory) nerve endings in arteries include the baroreceptors (stretch receptors) in the carotid sinus and the arch of the aorta as well as chemoreceptors of the carotid and aortic bodies.

The circulatory system is divided into macrovasculature (vessels more than 0.1 mm in diameter) and microvasculature (vessels less than 0.1 mm in diameter can be seen only by light microscope. The microvasculature is particularly important because of its participation in the interchange between the circulatory system and the surrounding tissues in both normal and inflammatory processes.

Tissue component of the vascular wall:

The vascular wall is composed of three basic tissues: the endothelium, the muscular tissue and the connective tissue. The amount and the arrangement of these tissues are influenced by the mechanical factors (represented by blood pressure) and the metabolic factors (which reflect the local needs of the tissues).

The structural element of capillaries and postcapillary venules are the endothelium, basal lamina and pericytes.

Endothelium: Is a semipermeable barrier which monitors the extensive bidirectional exchange of small molecules and restrict the transport of large molecules.

Vascular smooth muscles: Smooth muscle tissue is present in all vessels except capillaries and post-capillary venules. Smooth muscle cells are arranged in helical layers in the tunica media of the blood vessels. Each smooth muscle is surrounded by basal lamina and they are connected by gap junction.

Vascular connective tissue: The collagen fibers are found between smooth muscle fibers, in adventetia. The elastic fibers guarantee the resilient shrinkage of the expanded vessels. They are organized in parallel lamellae regularly distributed between muscle cells. The ground substance forms a heterogenous gel in the extracellular space of the vessel wall.

Structural plan of blood vessels:

Blood vessels are usually composed of the following layers (tunics):

Tunica intima: The intima consists of one layer of endothelial cells supported by subendothelial layer of loose connective tissue. In arteries, the intima is separated from media by an internal elastic lamina, this lamina has gaps (fenestrae) that allow the diffusion of substances to nourish cells deep in the vessel wall.

Tunica media: This tunic consists primarily from concentric layers of helically arranged smooth muscle cells. Among these cells are variable amount of elastic, reticular fibers, proteoglycan and glycoprotein, smooth muscle cells are the cellular source of this extracellular matrix. In arteries, the media has thinner external elastic lamina separate it from tunica adventitia.

Tunica adventitia: This tunica consists from collagen and elastic fibers. It gradually becomes continuous with the connective tissue through which the vessel run.

Vaso vasorum: (vessels of the vessels) which are arteriole, capillary and venules in the adventitia and outer part of T. media. Vaso vasorum provide metabolites to the adventitia and media since in large vessels the layers are too thick to be nourished solely by diffusion from the blood in the lumen. Vaso vasorum are more frequent in veins than arteries.

Large elastic arteries (conducting arteries):

Elastic arteries include the aorta and its large branches. They are >10 mm in diameter. They have yellowish color due to accumulation of elastin. The intima is thicker than the corresponding tunic of muscular artery. An internal elastic lamina, although present may not be seen easily. The media consist of elastic fibers and series of helically arranged of elastic laminae whose number increase with age (40 in newborn and 70 in the adult), among these laminae are smooth muscle fibers, reticular fibers, proteoglycan and glycoprotein, T.adventitia is under developed. The numerous elastic laminae of these arteries contribute to their important function of making the blood flow more uniform. During ventricular contraction (systole) blood is moved through the arteries forcefully and the elastin is stretched, distending the wall within the limit set by the wall's collagen. When the ventricles relax (diastole) ventricular pressure drops to a low level, but the elastin rebounds passively, helping to maintain arterial pressure.

Medium (muscular) sized artery (distributing arteries):

They are 1-10 mm in diameter. These vessels control the affluence of blood to the organs by contracting and relaxing the smooth muscles of T.media. The intima has subendothelial layer which is thicker than that of arterioles, the internal elastic lamina is more prominent. The T. media may contain up to 40 layers of smooth muscle cells intermingled with elastic laminae, reticular fibers and proteoglycans. The external elastic lamina which is the last component of the media is present only in large muscular arteries. Lastly the adventitia consists of connective tissue.

Arterioles:

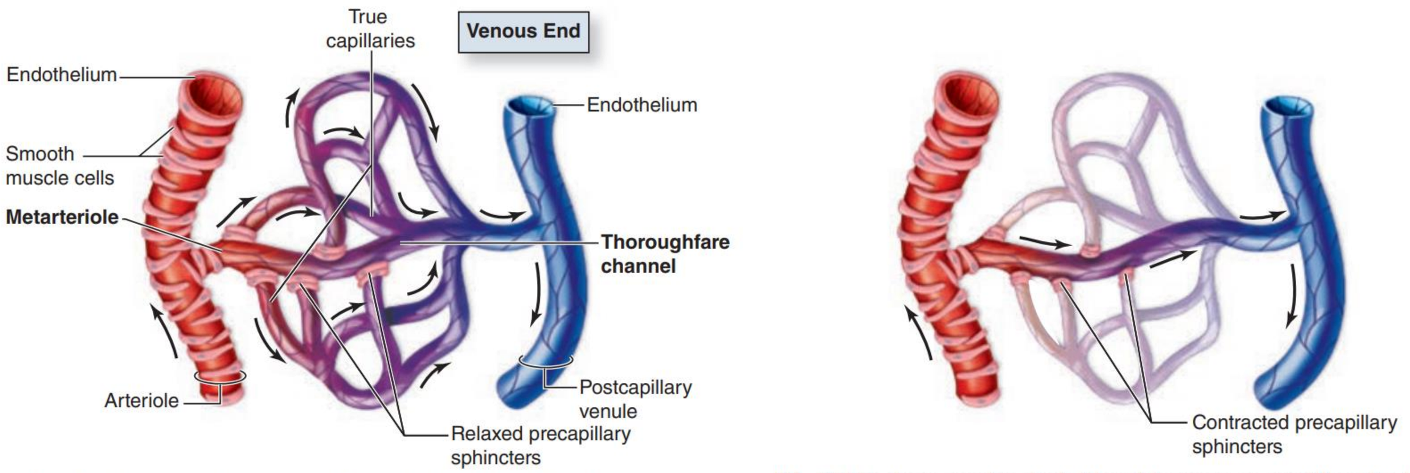
Arterioles are generally less than 0.1 mm in diameter and have narrow lumen and considered the beginning of microvasculature. The subendothelial layer is very thin, the internal elastic lamina is absent in small arterioles, the media composed from 1-2 circularly arranged layers of smooth muscles, it show no external lamina. Above the arterioles are small arteries which have large lumen and more developed T. media, but in both these two vessel the T. adventitia is very thin. Arterioles almost always branch to form anastomosing networks of capillaries that surround the parenchymal cells of the organ. At the ends of arterioles the smooth muscle fibers act as sphincters and produce periodic blood flow into capillaries. Muscle tone normally keeps arterioles partially closed, resisting blood flow, which makes these vessels the major determinants of systemic blood pressure.

Capillary beds

Capillaries are the smallest blood vessels in the body, with a diameter of 4-10 µm which allows transit of blood cells only one at a time, and their individual length is usually not more than 50 µm. These minute vessels make up over 90% of the body's vasculature, with a total length of more than 100,000 km and a total surface area of 5000 m^2. They are composed of a single layer of endothelial cells and basal lamina (which is produced by endothelial cells) with occasional cells called **pericytes.** Endothelial cells are polygonal and elongated in the direction of blood flow, the nucleus make the cell to bulge into the lumen. Its cytoplasm contains few organelles such a small Golgi complex, few cisternae of RER, mitochondria, and free ribosomes.

Capillaries permit and regulate metabolic exchange between blood and tissue cells. These smallest blood vessels always function in networks called **capillary beds**, whose size and overall shape conforms to that of the structure supplied.

Capillary beds are supplied by one or more terminal arteriole branches called **metarterioles**, which are continuous with **thoroughfare channels** connected with the **postcapillary venules**. Capillaries branch from the metarterioles, which are encircled by scattered smooth muscle cells, and converge into the thoroughfare channels, which lack muscle. The metarteriole muscle cells act as **precapillary sphincters** that control blood flow into the capillaries. These sphincters contract and relax cyclically, with 5-10 cycles per minute, causing blood to pass through capillaries in a pulsatile manner. In some tissues there are arteriovenous anastomosis that enable the arteriole to empty directly into the venules (was no capillaries), so when the vessels of AV anastomosis contract all blood pass into the capillary network. These interconnections are abundant in skeletal muscles, and in the skin of the hand (finger tips) and feet, lips, and nose. The capillary circulation is controlled by NEURAL and HORMONAL control. *The richness of capillary network is related to the metabolic activity of that organ. Because the capillaries have thin wall and slow blood flow 0.3 mm/sec therefore; they are the best place for the exchange of water, solutes, metabolites, etc…



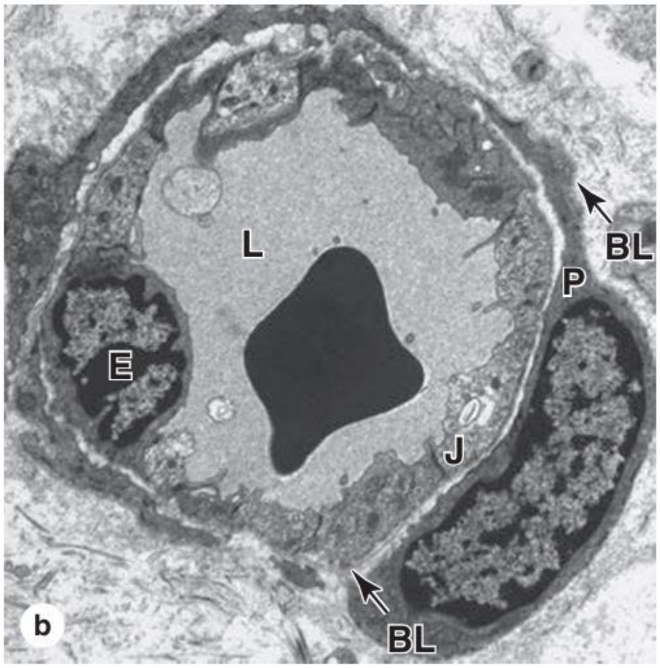
(a) Sphincters relaxed; capillary bed well perfused

(b) Sphincters contracted; blood bypasses capillary bed

Pericytes are mesenchymal cells found at various locations along capillaries and postcapillary venules, they have a long cytoplasmic processes partly surrounding the endothelial layer. Their main functions are:

1. Secret many components of extracellular matrix (ECM) to form their own basal lamina.
2. Having networks of myosin, actin and tropomyosin makes pericytes able to dilate and constrict capillaries help regulate blood flow.
3. Maintain endothelial blood-brain barrier in CNS.
4. After injury, pericytes proliferate and differentiate into other cells to form new blood vessels and connective tissue cells.
5. In many other organs pericytes form a population of mesenchymal stem cells important for regeneration of other tissues.

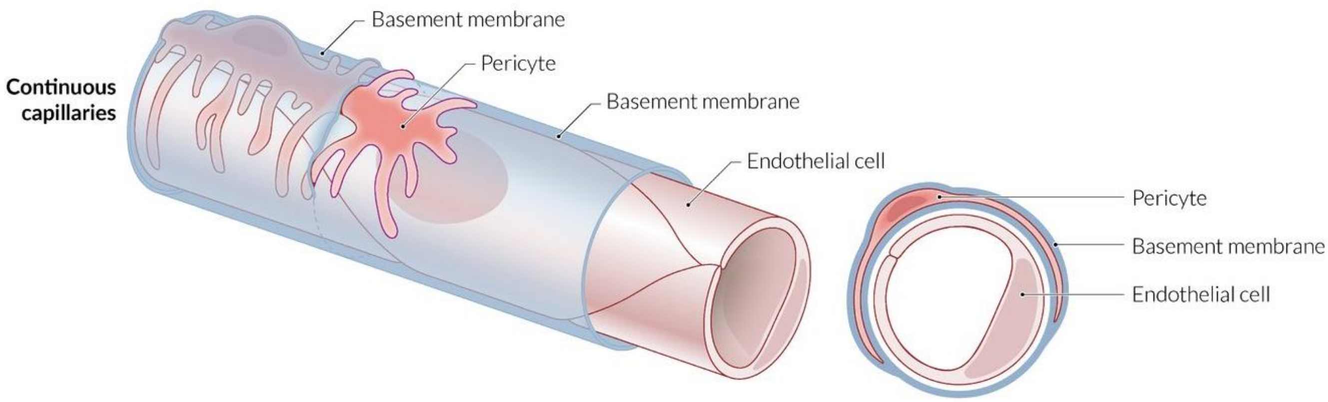
TEM of a capillary cut transversely, showing the nucleus of one thin capillary endothelial cell (E). Endothelial cells form the capillary lumen (L), are covered by a basal lamina (BL), and are bound tightly together with junctional complexes (J). One pericyte (P) is shown, surrounded by its own basal lamina (BL) and with cytoplasmic extensions which surround the endothelial cells.



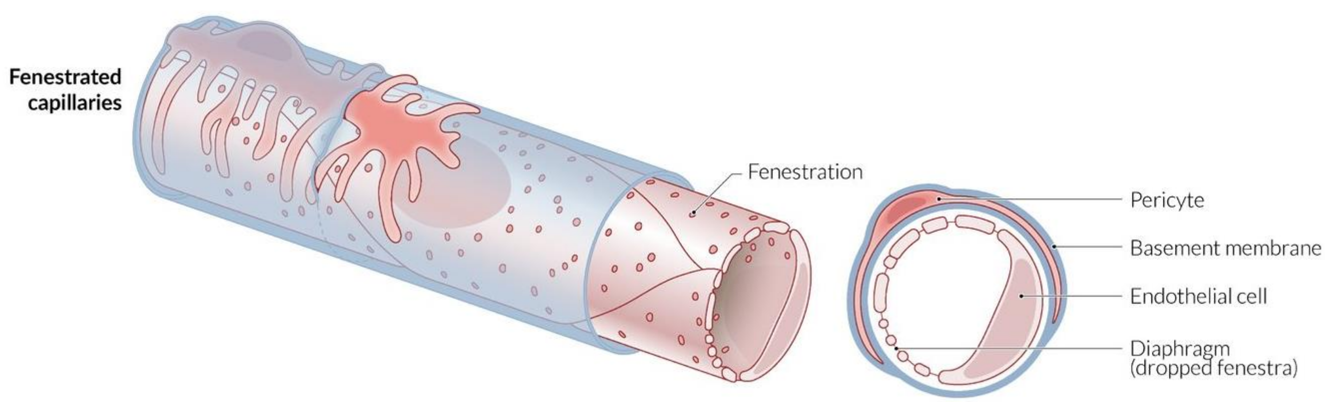
Types of capillaries

Major structural variations in capillaries occur in organs with various functions that permit very different levels of metabolic exchange. Capillaries are generally grouped into three histologic types, depending on the continuity of the endothelial cells and their basement membrane:

1. **Continuous (somatic) capillaries**
They are found in muscle, connective tissue, lungs, exocrine glands and nervous tissue. They have many tight occluding junctions between slightly overlapping endothelial cells with no fenestrae in their walls. In some tissues other than the nervous system they have pinocytic vesicles that may participate in transport of molecules across the endothelial cells.



2. **Fenestrated (visceral) capillaries**
They are found in organs with rapid interchange of substances between tissues and the blood, such as the kidneys, intestine, choroid plexus, gallbladder and endocrine glands. They are characterized by the presence of several opening in the endothelium called fenestrae (80- 100nm in diameter). Each fenestrae is obliterated by a diaphragm that is thinner than the cell membrane, which do not have the tri-laminar structure of a unit membrane. The basal lamina of this type of capillaries is continuous.



3. Discontinuous (sinusoidal) capillaries

They permit maximal exchange of macromolecules as well as allow easier movement of cells between tissues and blood. The endothelium here has large perforations without diaphragms and irregular intercellular clefts, forming a discontinuous layer with spaces between and through the cells. They also have discontinuous basement membranes and have much larger diameters of 30-40 µm, which slows blood flow. They are found in liver, spleen, bone marrow and some endocrine glands (adrenal gland).