The circulatory system

The circulatory system pumps and directs blood cells and substances carried in blood to all tissues of the body. It includes both the blood and lymphatic vascular systems, and in an adult the total length of its vessels is estimated at between 100,000 and 150,000 kilometers. The blood vascular system or cardiovascular system consists of the following structures:

■ The heart: propels blood through the system.

■ Arteries: a series of vessels efferent from the heart that become smaller as they branch into the various organs, carry blood to the tissues.

■ Capillaries: the smallest vessels, are the sites of O 2 , CO 2 , nutrient, and waste product exchange between blood and tissues. Together with the smallest arterial and venous branches carrying blood to and from them, capillaries in almost every organ form a complex network of thin, anastomosing tubules called the microvasculature or microvascular bed.

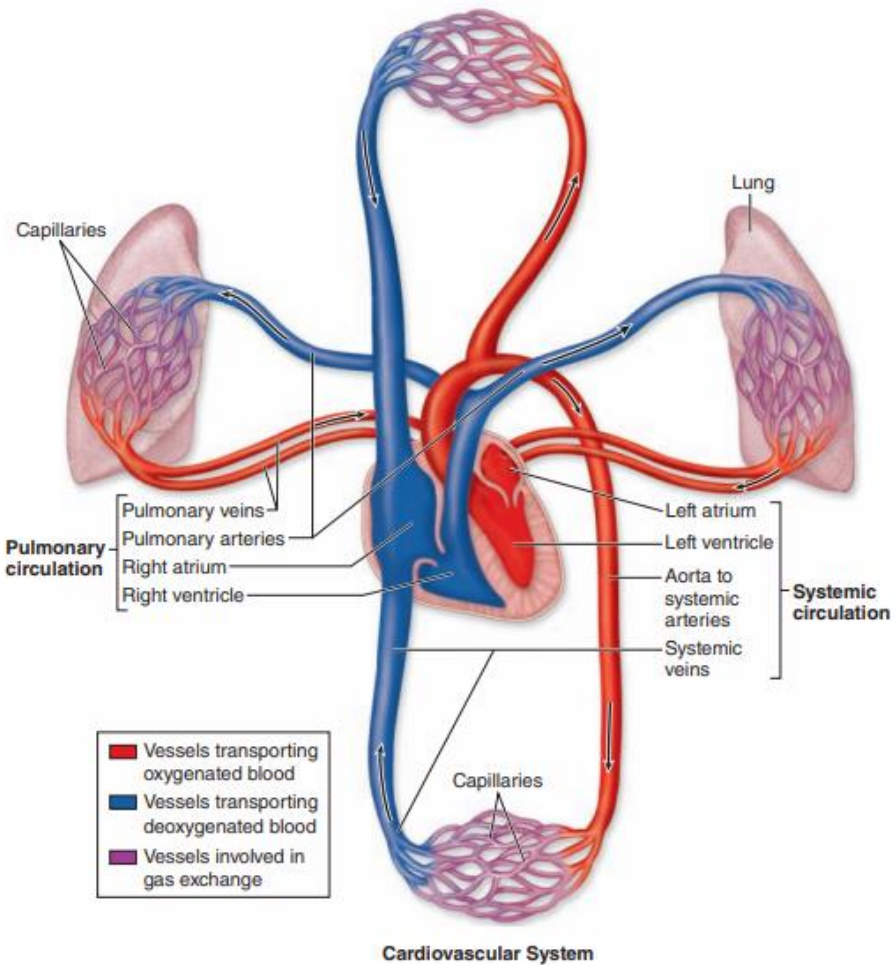


Figure 1: The system consisting of the heart, arteries, veins, and microvascular beds is organized as the pulmonary circulation and the systemic circulation

■ Veins result from the convergence of venules into a system of larger channels that continue enlarging as they approach the heart, toward which they carry the blood to be pumped again.

Two major divisions of arteries, microvasculature, and veins make up: **the pulmonary circulation**, where blood is oxygenated in the lungs, and **the systemic circulation,** where blood brings nutrients and removes wastes in tissues throughout the body.

■ The lymphatic vascular system, begins with the lymphatic capillaries, which are thin-walled, closed-ended tubules carrying lymph, that merge to form vessels of steadily increasing size. The largest lymph vessels connect with the blood vascular system and empty into the large veins near the heart. This returns fluid from tissue spaces all over the body to the blood.

The internal surface of all components of the blood and lymphatic systems is lined by a single layer of a **squamous epithelium**, called **endothelium**.

As the interface between blood and the organs, cardiovascular endothelial cells have crucial physiologic 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**.

 HEART

Cardiac muscle in the four chambers of the heart wall contracts rhythmically, pumping the blood through the circulatory system. The right and left ventricles propel blood to the pulmonary and systemic circulation, 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**: the internal endocardium; the middle myocardium; and the external epicardium.

■ **The endocardium** consists of a very thin inner layer of endothelium and supporting connective tissue, a middle myoelastic layer of smooth muscle fibers and connective tissue, and a deep layer of connective tissue called the subendocardial layer that merges with the myocardium Branches of the heart's impulse-conducting system, consisting of modified cardiac muscle fibers, are also located in the subendocardial layer

■ The thickest layer, **the myocardium**, consists mainly of cardiac muscle with its fibers arranged spirally around each heart chamber. Because strong force is required to pump blood through the systemic and pulmonary circulations, the myocardium is

much thicker in the walls of the ventricles, particularly the left, than in the atrial walls.

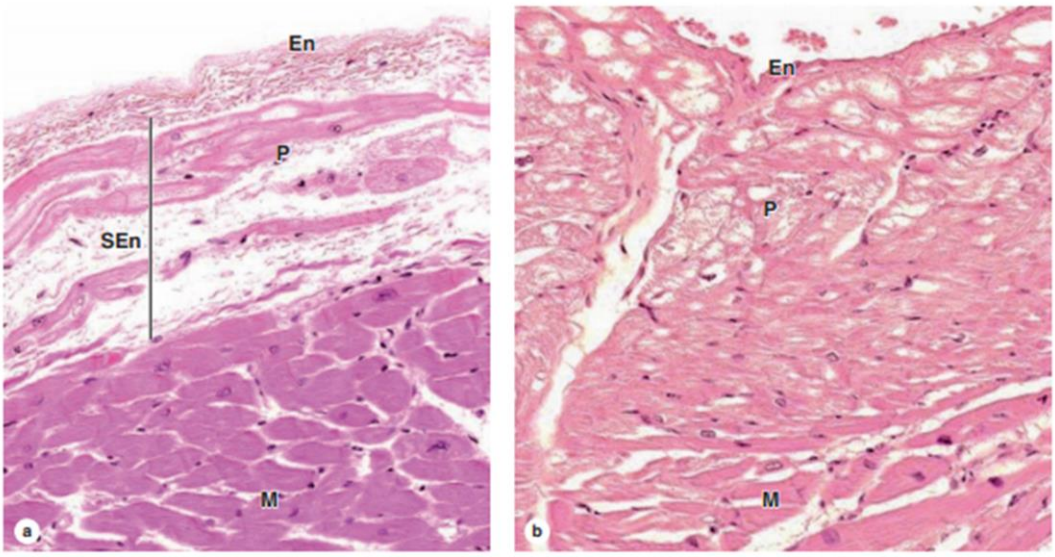


Figure 2: Endocardium, myocardium, and fibers of the subendocardial conducting network

■ **The epicardium** is a simple squamous mesothelium supported by a layer of loose connective tissue containing blood vessels and nerves. The epicardium corresponds to the visceral layer of the pericardium, the membrane surrounding the heart. Where the large vessels enter and leave the heart, the epicardium is reflected back as the parietal layer lining the pericardium. During heart movements, underlying structures are cushioned by deposits of adipose tissue in the epicardium and friction within the pericardium is prevented by lubricant fluid produced by both layers of serous mesothelial cells.

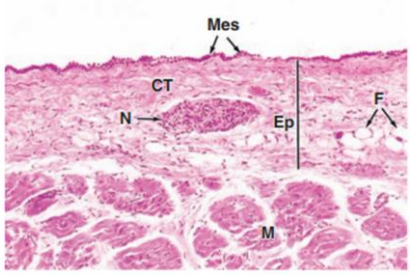


Figure3: Epicardium or visceral pericardium.

Within these major layers the heart contains other structures important for its overall function of moving blood. Dense fibrous connective tissue of the cardiac skeleton forms part of the interventricular and interatrial septa, surrounds all valves of the heart, and extends into the valve cusps and the chordae tendineae to which they are attached. These regions of dense irregular connective tissue perform the following functions:

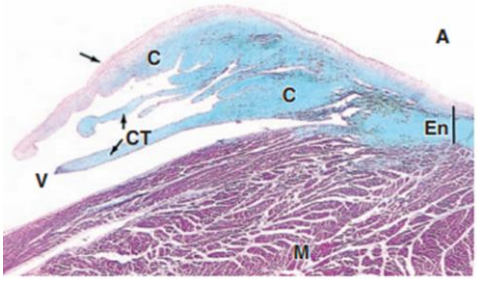


Figure 4: Valve leaflet and cardiac skeleton.

■ Anchoring and supporting the heart valves

■ Providing firm points of insertion for cardiac muscle

■ Helping coordinate the heartbeat by acting as electrical insulation between atria and ventricles Within the subendocardial layer and adjacent myocardium, modified cardiac muscle cells make up the impulse conducting system of the heart, which generates and propagates waves of depolarization that spread through the myocardium to stimulate rhythmic contractions.

This system consists of two nodes of specialized myocardial tissue in the right atrium: **the sinoatrial (SA) node** (or pacemaker) and **the atrioventricular (AV) node**, followed by the **AV bundle** (of His) and the **subendocardial conducting network**. Located in the right atrial wall near the superior vena cava, the SA node is a 6-7 mm^3 mass of cardiac muscle cells with smaller size, fewer myofibrils, and fewer typical intercalated disks than the neighboring muscle fibers. Impulses initiated by these cells move along the myocardial fibers of both atria, stimulating their contraction. When the impulses reach the slightly smaller AV node, located in the floor of the right atrium near the AV valve and composed of cells similar to those of the SA node, they stimulate depolarization of those cells. Conducting muscle fibers from the AV node form the AV bundle, pass through an opening in the cardiac skeleton into the interventricular septum, and bifurcate into the wall of each ventricle. At the apex of the heart, the bundles branch further into a subendocardial conducting network of myofibers, usually called **Purkinje fibers**. These are pale-staining fibers, larger than the adjacent contractile muscle fibers, with sparse, peripheral myofibrils and much glycogen. Purkinje fibers mingle distally with contractile fibers of both ventricles and trigger waves of contraction through both ventricles simultaneously.

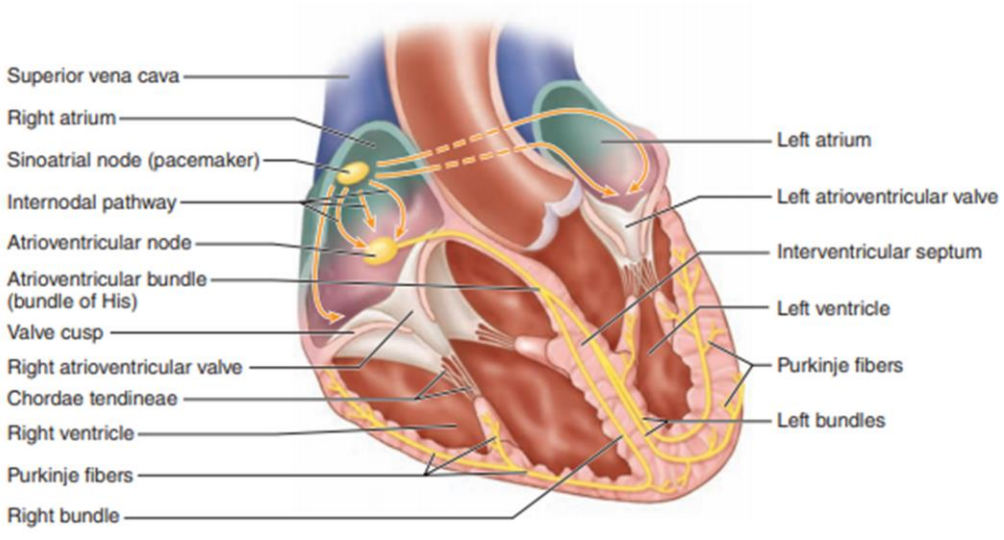


Figure 5: important feature of the heart

Both parasympathetic and sympathetic neural components innervate the heart. Ganglionic nerve cells and nerve fibers are present in the regions close to the SA and AV nodes, where they affect heart rate and rhythm, such as during physical exercise and emotional stress. Stimulation of the parasympathetic division (vagus nerve) slows

the heartbeat, whereas stimulation of the sympathetic nerve accelerates activity of the pacemaker. Between fibers of the myocardium are afferent free nerve endings that register pain, such as the discomfort called angina pectoris that occurs when partially occluded coronary arteries cause local oxygen deprivation

TISSUES OF THE VASCULAR WALL

Walls of all blood vessels except capillaries contain **smooth muscle** and **connective tissue** in addition to the **endothelial lining**. The amount and arrangement of these tissues in vessels are influenced by mechanical factors, primarily blood pressure, and metabolic factors reflecting the local needs of tissues.

The endothelium is a specialized epithelium that acts as a semipermeable barrier between two internal compartments: the blood plasma and the interstitial tissue fluid. Vascular endothelial cells are **squamous, polygonal, and elongated with the long axis in the direction of blood flow**. Endothelium with its basal lamina is highly differentiated to mediate and actively monitor the bidirectional exchange of molecules by simple and active diffusion, receptor mediated endocytosis, transcytosis, Besides their key role in metabolite exchanges between blood and tissues, endothelial cells have several other functions:

■ The endothelium presents a nonthrombogenic surface on which blood will not clot and actively secretes agents that control local clot formation (such as heparin, tissue plasminogen activator, and von Willebrand factor).

■ The cells regulate local vascular tone and blood flow by secreting various factors that stimulate smooth muscle contraction (such as endothelin 1 and angiotensinconverting enzyme (ACE) or relaxation (including nitric oxide [NO] and prostacyclin).

■ Endothelium has several roles in inflammation and local immune responses. In venules endothelial cells induce specific white blood cells to stop and undergo transendothelial migration at sites of injury or infection. Under those conditions P-selectin is expressed rapidly on the luminal surface when unique elongated granules, called Weibel-Palade bodies, fuse with the cell membrane. Endothelial cells also secrete various factors called interleukins that affect the activity of local white blood cells during inflammation.

■ Under various conditions endothelial cells secrete various growth factors, including proteins promoting proliferation of specific white blood cell lineages and cells that make up the vascular wall. Growth factors such as **vascular endothelial growth** factor (VEGF) stimulate formation of the vascular system from embryonic mesenchyme (vasculogenesis), help maintain the vasculature in adults, and promote capillary sprouting and outgrowth from small existing vessels (angiogenesis) during normal growth, during tissue repair and regeneration, and in tumors and other

pathological conditions. In both processes other growth factors, called angiopoietins, stimulate endothelial cells to recruit smooth muscle cells and fibroblasts to form the other tissues of the vascular wall.

Smooth muscle fibers occur in the walls of all vessels larger than capillaries and are arranged helically in layers. In **arterioles and small arteries**, the smooth muscle cells are connected by many more gap junctions and permit vasoconstriction and vasodilation which are of key importance in regulating the overall blood pressure.

Connective tissue components are present in vascular walls in variable amounts and proportions based on local functional requirements. Collagen fibers are found in the subendothelial layer, between the smooth muscle layers, and in the outer covering. Elastic fibers provide the resiliency required for the vascular wall to expand under pressure. Elastin is a major component in large arteries where it forms parallel lamellae, regularly distributed between the muscle layers. Variations in the amount and composition of ground substance components such as proteoglycans and hyaluronate also contribute to the physical and metabolic properties of the wall in different vessels, especially affecting their permeability.

The walls of all blood vessels larger than the microvasculature have many components in common and similar organization. Branching of the vessels helps produce reductions in their size which are accompanied by gradual changes in the composition of the vascular wall. Transitions such as those from "small arteries" to "arterioles" are not clear-cut. However, all of these larger vessels have walls with three concentric layers, or tunics (L. tunica, coat),

■ **The innermost tunica intima** consists of the endothelium and a thin subendothelial layer of loose connective tissue sometimes containing smooth muscle fibers. In arteries and large veins, the intima includes a prominent limiting layer, **the internal elastic lamina**, composed of elastin, with holes allowing better diffusion of substances from blood deeper into the wall.

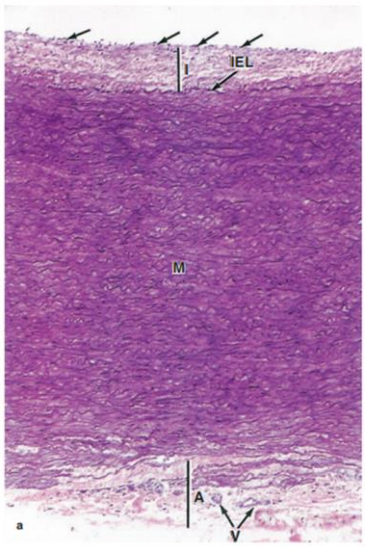
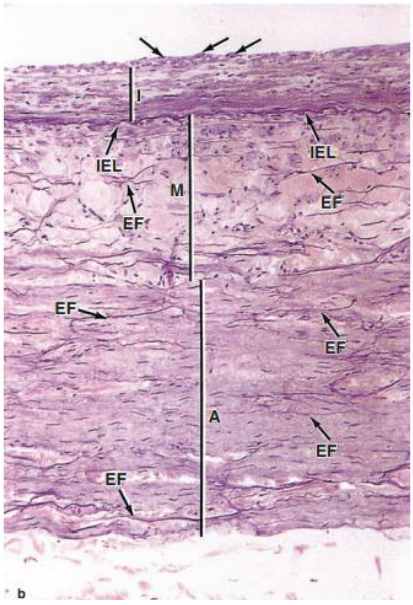


Figure 5A & B: Tunics of the vascular wall

■ **The tunica media**, the middle layer, consists chiefly of concentric layers of helically arranged smooth muscle cells. Interposed among the muscle fibers are variable amounts of elastic fibers and elastic lamellae, reticular fibers, and proteoglycans, **all of which are produced by the smooth muscle cells**. In arteries, the media may have **a thin external elastic lamina**, separating it from the outermost tunic.



■ **The outer adventitia**, or tunica externa, consists principally of type I collagen and elastic fibers. The adventitia is continuous with and bound to the stromal connective tissue of the organ through which the blood vessel runs. Just as the heart wall is supplied with its own coronary vasculature for nutrients and O2, large vessels usually have **vasa vasorum** ("vessels of the vessel"): arterioles, capillaries, and venules in the adventitia and outer part of the media. The vasa vasorum are required to provide metabolites to cells in those tunics in larger vessels because the wall is too thick to be nourished solely by diffusion from the blood in the lumen. Luminal blood alone does provide the needs of cells in the intima. Because they carry deoxygenated blood, large veins commonly have more vasa vasorum than arteries. The adventitia of larger vessels also contains a network of unmyelinated autonomic nerve fibers, the vasomotor nerves, which release the vasoconstrictor norepinephrine. The density of this innervation is greater in arteries than in veins.

VASCULATURE

Large blood vessels and those of the microvasculature branch frequently and undergo gradual transitions into structures with different histologic features and functions.

Elastic Arteries

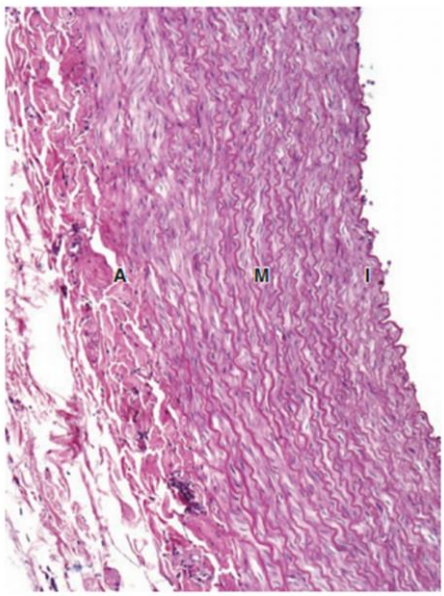


Figure 6: elastic artery

Elastic arteries are **the aorta, the pulmonary artery**, and **their largest branches**; these large vessels are also called conducting arteries because their major role is to carry blood to smaller arteries.

The **most prominent feature** of elastic arteries is the thick media in which elastic lamellae, each about 10 μm thick, alternate with layers of smooth muscle fibers. The adult aorta has about 50 elastic lamellae (more if the individual is hypertensive). The intima is well developed, with many smooth muscle cells in the subendothelial connective tissue, and often shows folds in cross section as a result of the loss of blood pressure and contraction of the vessel at death. The internal elastic lamina is not easily discerned because it is similar to the elastic laminae of the next layer. The

adventitia is much thinner than the media. The numerous elastic laminae of these arteries contribute to their important function of making 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. The aortic and pulmonary valves prevent backflow of blood into the heart, so the rebound continues the blood flow away from the heart. Arterial blood pressure and blood velocity decrease and become less variable as the distance from the heart increases.

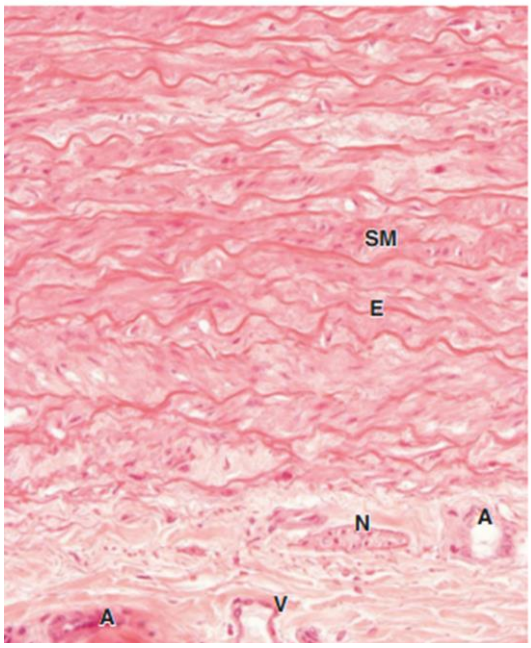


Figure 7: Vasa vasorum.

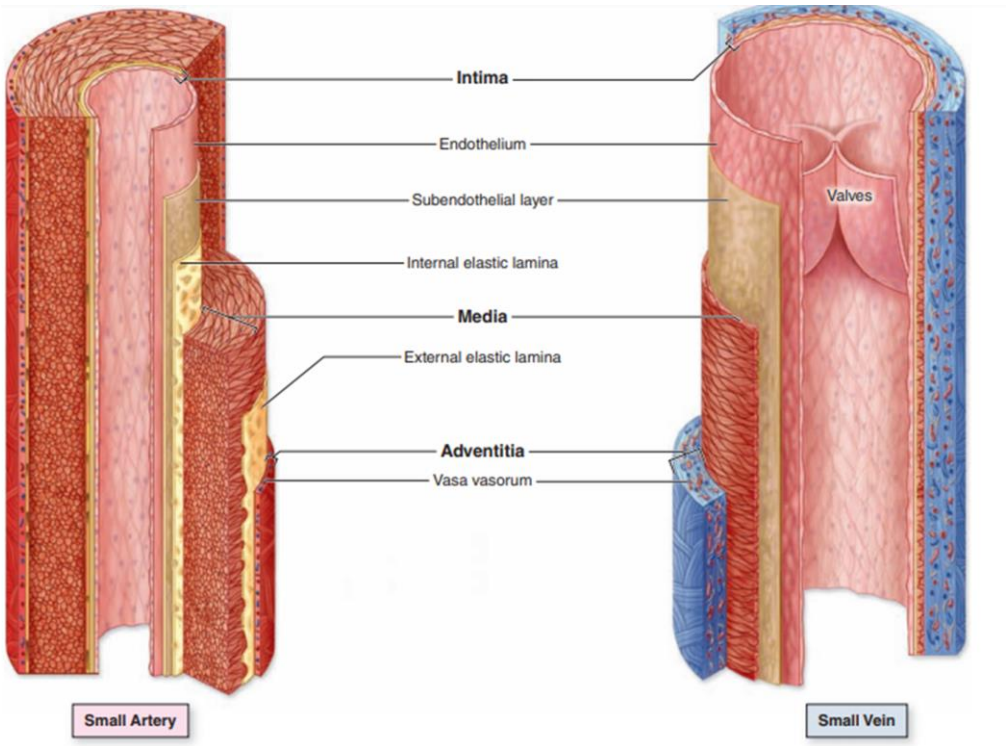


Figure 8: Walls of arteries and veins.

Arterial Sensory Structures

Carotid sinuses are slight dilations of the bilateral internal carotid arteries where they branch from the (elastic) common carotid arteries; they act as important **baroreceptors** monitoring arterial blood pressure. At these sinuses the media is thinner, allowing greater distension when blood pressure rises, and the adventitia contains many sensory nerve endings from cranial nerve IX, **the glossopharyngeal nerve.** The brain's vasomotor centers process these afferent impulses and adjust vasoconstriction, maintaining normal blood pressure. Functionally similar baroreceptors are also present in the aortic arch.

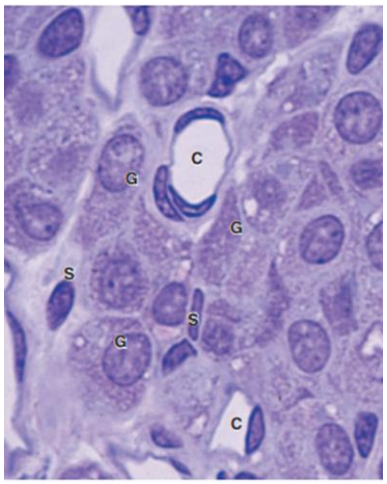
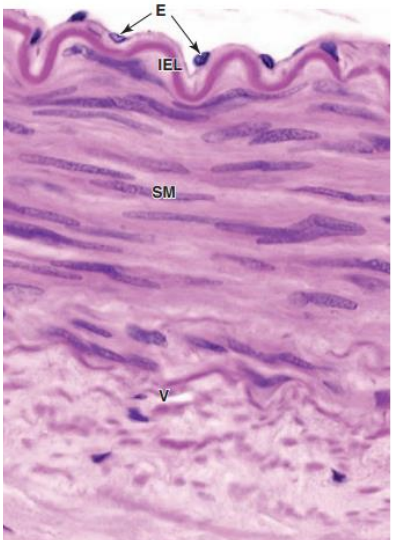


Figure 9: Cells and capillaries in a glomus body.

Histologically more complex chemoreceptors that monitor blood levels of CO2 and O2, as well as its hydrogen ion concentration (pH), are found in the carotid bodies and aortic bodies, located in the walls of the carotid sinuses and aortic arch, respectively. These structures are parts of the autonomic nervous system called **paraganglia** with rich capillary networks. The capillaries are closely surrounded by numerous, large, **neural crest-derived glomus (type I)** cells filled with dense-core vesicles containing dopamine, acetylcholine, and other neurotransmitters, which are supported by **smaller satellite (type II) cells**. Appropriate ion channels in the glomus cell membranes respond to stimuli in the arterial blood, primarily hypoxia (low O2), hypercapnia (excess CO2), or acidosis, by activating release of neurotransmitters. Sensory fibers branching from the glossopharyngeal nerve form synapses with the glomus cells and signal brain centers to initiate cardiovascular and respiratory adjustments that correct the condition.

Muscular Arteries



The muscular arteries distribute blood to the organs and help regulate blood pressure by contracting or relaxing the smooth muscle in the media. The intima has a very thin subendothelial layer and a prominent internal elastic lamina. The media may contain up to 40 layers of large smooth muscle cells interspersed with a variable number of elastic lamellae (depending on the size of the vessel). An external elastic lamina, the last component of the media, is present only in the larger muscular arteries. The adventitia consists of connective tissue. Lymphatic capillaries, vasa vasorum, and nerves

are also found in the adventitia, and these structures may penetrate to the outer part of the media.

Arterioles

Muscular arteries branch repeatedly into smaller and smaller arteries, until reaching a size with three or four medial layers of smooth muscle. The smallest arteries branch as arterioles, which have only one or two smooth muscle layers; these indicate the beginning of an organ's microvasculature where exchanges between blood and tissue fluid occur. **Arterioles** are generally less than 0.1 mm in diameter, with lumens approximately as wide as the wall is thick. The subendothelial layer is very thin, elastic laminae are absent, and the media consists of the circularly arranged smooth muscle cells. In both small arteries and arterioles, the adventitia is very thin and inconspicuous. Arterioles almost always branch to form anastomosing networks or beds of capillaries that surround the parenchymal cells of the organ. Smooth muscle fibers act as sphincters closing arterioles and producing periodic blood flow into capillaries. Acting as "resistance vessels," muscle tone usually keeps arterioles partially closed and makes these vessels the major determinants of systemic blood pressure. In certain tissues and organs arterioles deviate from this simple path to accommodate various specialized functions. For example, thermoregulation by the skin involves arterioles that can bypass capillary networks and connect directly to venules. The media and adventitia are thicker in these arteriovenous shunts (or arteriovenous anastomoses) and richly innervated by sympathetic and parasympathetic nerve fibers. The autonomic fibers control the degree of vasoconstriction at the shunts, regulating blood flow through the capillary beds. High

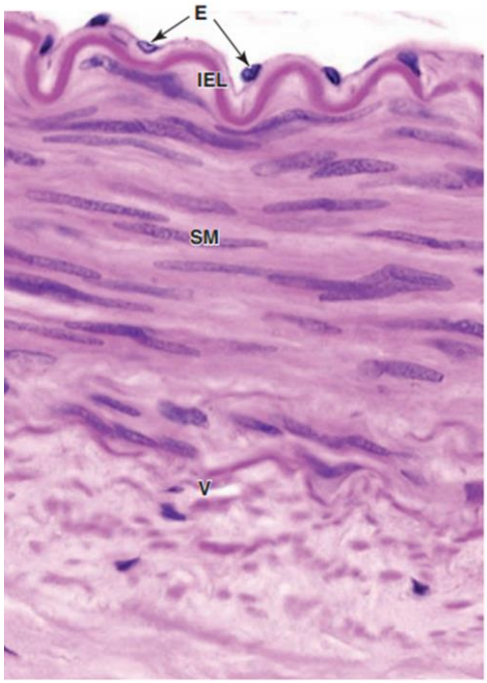
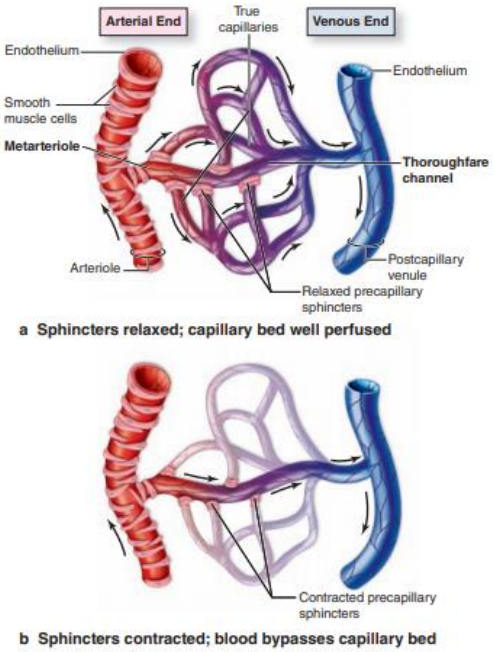


Figure 11A & B: Microvasculature



capillary blood flow in the skin allows more heat dissipation from the body, while reduced capillary blood flow conserves heat—important functions when the environmental temperature is hot or cold, respectively. Another important alternative microvascular pathway is a venous portal system, in which blood flows through two successive capillary beds separated by a portal vein. This arrangement allows for hormones or nutrients picked up by the blood in the first capillary network to be delivered most efficiently to cells around the second capillary bed before the blood is returned to the heart for general distribution. The best examples are the hepatic portal system of the liver and the hypothalamic-hypophyseal portal system in the anterior pituitary gland, both of which have major physiologic importance.

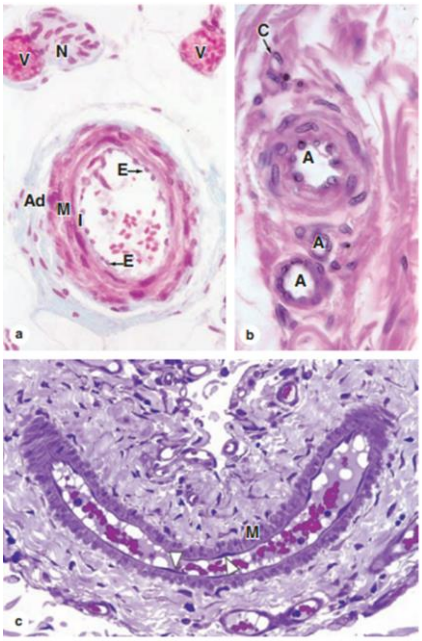


Figure 12: Arterioles

Capillary Beds

Capillaries permit and regulate metabolic exchange between blood and surrounding tissues. These smallest blood vessels always function in groups called capillary beds, whose size and overall shape conforms to that of the structure supplied. The richness of the capillary network is related to the metabolic activity of the tissues. Tissues with high metabolic rates, such as the kidney, liver, and cardiac and skeletal muscle, have an abundant capillary network; the opposite is true of tissues with low metabolic rates, such as smooth muscle and dense connective tissue. Capillary beds are supplied preferentially by one or more terminal arteriole branches called metarterioles, which are continuous with thoroughfare channels connected with the postcapillary venules. True capillaries branch from the metarterioles, which are encircled by scattered smooth muscle cells, and converge into the thoroughfare channels, which lack muscle. At the beginning of each true capillary, muscle fibers act as precapillary sphincters that contract or relax to control the entry of blood. These sphincters contract and relax cyclically, with 5 to 10 cycles per minute, causing blood to pass through capillaries in a pulsatile manner. When the sphincters are closed, blood flows directly from the metarterioles and thoroughfare channels into postcapillary venules. Capillaries are composed of a single layer of endothelial cells rolled up as a tube. The average diameter of capillaries varies from 4 to 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 approximately 5000 m2. Because of the cyclical opening and closing of the sphincters, most capillaries are essentially empty at any given time, with only about 5% (~300 mL in an adult) of the total blood volume moving through these structures. Their thin walls, extensive surface area, and slow, pulsatile blood flow optimize capillaries for the exchange of water and solutes between blood and tissues. capillary cells have many features specialized for molecular transfer by mechanisms ranging from simple diffusion to transcytosis. The basal lamina helps determine which macromolecules interact with the endothelial cells. The average thickness of the cells is only 0.25 μm and a distinctive feature is often the nucleus curved to accommodate the very small tubular structure. The cytoplasm contains mitochondria and most other organelles, along with a typically large population of membrane vesicles. Along with the basal lamina, junctional complexes between the cells maintain the tubular structure, with variable numbers of tight junctions having an important role in capillary permeability. 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 the external lamina.

■ **Continuous capillaries** have many tight, well-developed occluding junctions between slightly overlapping endothelial cells, which provide for continuity along the endothelium and well-regulated metabolic exchange across the cells. This is the most common type of capillary and is found in muscle, connective tissue, lungs, exocrine glands, and nervous tissue. Ultrastructural studies show numerous vesicles indicating transcytosis of macromolecules in both directions across the endothelial cell cytoplasm.

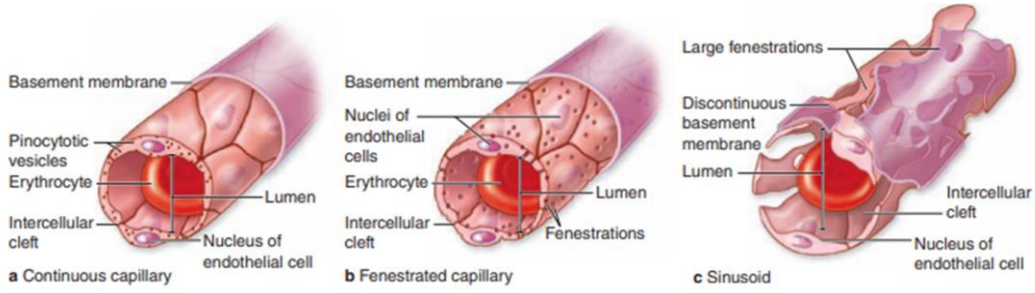


Figure 13: types of capillaries

■ Fenestrated capillaries have a sieve like structure that allows more extensive molecular exchange across the endothelium. The endothelial cells are penetrated by numerous small circular openings or fenestrations (L. fenestra, perforation), approximately 80 nm in diameter. Some fenestrations are covered by very thin diaphragms of proteoglycans; others may represent membrane invaginations during transcytosis that temporarily involve both sides of the very thin cells. The basal lamina is continuous and covers the fenestrations. Fenestrated capillaries are found in

organs with rapid interchange of substances between tissues and the blood, such as the kidneys, intestine, choroid plexus, and endocrine glands.

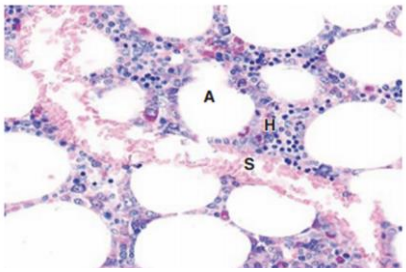


Figure 14: sinusoid capillaries

■ Discontinuous capillaries, commonly called sinusoids, permit maximal exchange of macromolecules as well as allow easier movement of cells between tissues and blood. Individual endothelial cells here have large perforations without diaphragms; collectively they form a discontinuous layer, with wide, irregular spaces between the cells. Sinusoids also differ from other capillaries by having highly discontinuous basal laminae and much larger diameters, often 30 to 40 µm, which slows blood flow. Sinusoidal capillaries are found in the liver, spleen, some endocrine organs, and bone marrow. At various locations along continuous capillaries and postcapillary venules are **mesenchymal cells called pericytes**, with long cytoplasmic processes partly surrounding the endothelial layer. Pericytes produce their own basal lamina, which may fuse with that of the endothelial cells. Well-developed networks of myosin, actin, and tropomyosin in pericytes indicate these cells' primary contractile function to facilitate flow of blood cells. After tissue injuries, pericytes proliferate and differentiate to form smooth muscle and other cells in new vessels as the microvasculature is reestablished.

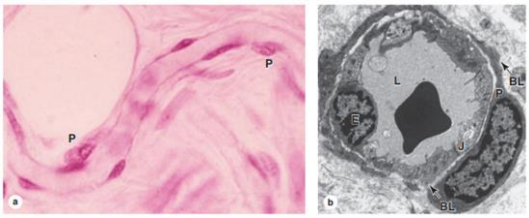


Figure 15: Capillary with pericytes.

Venules

The transition from capillaries to venules occurs gradually. The immediate postcapillary venules are similar structurally to capillaries with pericytes, but range in diameter from 15 to 20 µm.

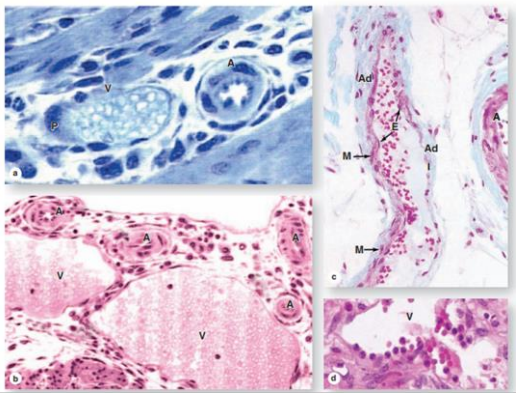


Figure 16: venules

postcapillary venules are the primary site at which white blood cells adhere to endothelium and leave the circulation at sites of infection or tissue damage. Postcapillary venules converge into larger collecting venules that have more contractile cells. With even greater size, the venules become surrounded by a recognizable tunica media with two or three smooth muscle layers and are called muscular venules. A characteristic feature of all

venules is the large diameter of the lumen compared to the overall thinness of the wall.

Veins

Veins carry blood back to the heart from microvasculature all over the body. Blood entering veins is under very low pressure and moves toward the heart by contraction of smooth muscle fibers in the media and by external compressions from surrounding muscles and other organs.

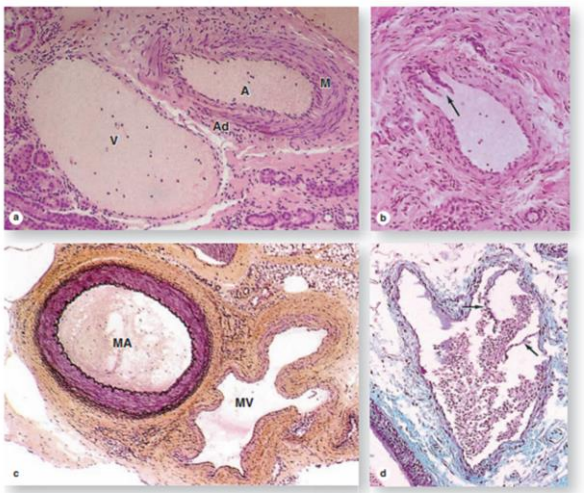


Figure 17: Veins

Valves project from the tunica intima to prevent backflow of blood. Most veins are small or medium veins, with diameters of 10 mm or less. Such veins are usually located close and parallel to corresponding muscular arteries. The intima usually has a thin subendothelial layer, and the media consists of small bundles of smooth muscle cells intermixed with reticular fibers and a delicate network of elastic fibers. The collagenous adventitial layer is well developed. The big venous trunks, paired with elastic arteries close to the heart, are the large veins. Large veins have a well-developed intima, but the media is relatively thin, with alternating layers of smooth muscle and connective tissue. The adventitial layer is thicker than the media in large veins and frequently contains longitudinal bundles of smooth muscle. Both the media and adventitia contain elastic fibers, but internal and external elastic laminae like those of arteries are not present. Medium and large veins have valves consisting of paired folds of the intima projecting across the lumen. They are rich in elastic fibers and are lined on both sides by endothelium. The valves, which are especially numerous in veins of the legs, help keep the flow of venous blood directed toward the heart.

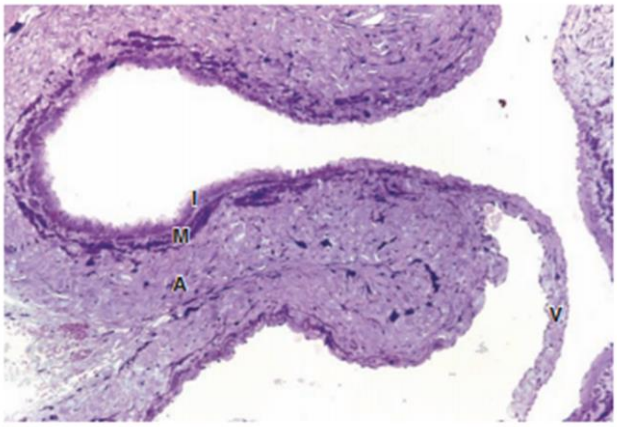


Figure 18: Veins with valve

LYMPHATIC VASCULAR SYSTEM

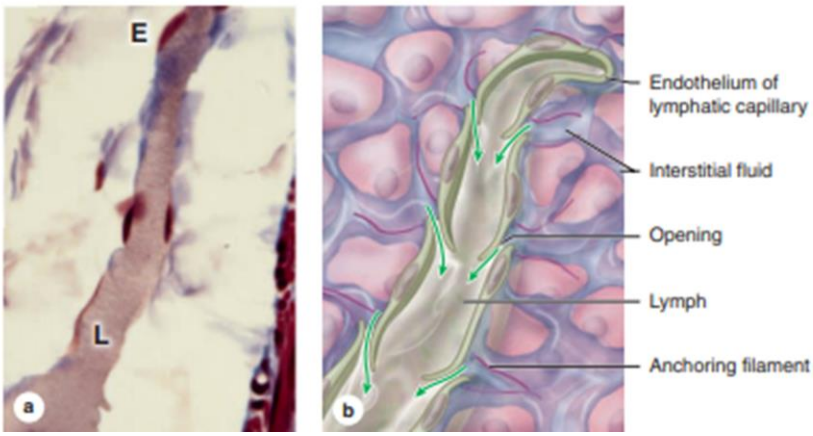


Figure 19: lymphatic capillaries

In addition to the blood vasculature, the body has a system of very thin-walled channels that collect excess interstitial fluid called lymph from the tissue spaces and return it to the blood. In normal tissues lymph does not contain red blood cells (although lymphocytes may be present), but it is usually rich in lightly staining proteins. Most tissues with blood vessels also contain lymphatic capillaries (or lymphatics) that originate as closed-ended vessels consisting of a single layer of very thin endothelial cells on an incomplete basal lamina. Openings between these cells are held open by bundles of anchoring filaments containing elastic fibers that also bind the vessels to the surrounding connective tissue. Folds of the endothelial cells across the openings prevent most backflow of lymph out of the vessel. Lymphatic capillaries converge into larger lymphatic vessels. Interposed in the path of these lymphatics are lymph nodes, With exceptions such as the central nervous system (CNS) and the bone marrow, lymphatics are found in almost all organs. The structure of larger lymphatic vessels resembles that of veins except with thinner walls and no distinct separation among tunics. They also have more numerous internal valves than veins. The lymphatic vessels are often dilated with lymph. As in veins, lymphatic circulation is aided by external forces (eg, contraction of surrounding skeletal muscle), with the valves responsible for keeping lymph flow unidirectional. Contraction of smooth muscle in the walls of larger lymphatic vessels also helps propel lymph toward the heart. Lymphatic vessels ultimately converge as two large trunks: **the thoracic duct and the right lymphatic duct**, which empty lymph back into the blood. The thoracic duct enters the cardiovascular system near the junction of the left internal jugular vein with the left subclavian vein, and the lymphatic duct near the confluence of the right subclavian vein and the right internal jugular vein. The structure of these lymphatic ducts is similar to that of large veins, with reinforced smooth muscle in the middle layer arranged both longitudinally and circularly. The adventitia is relatively underdeveloped, but it contains vasa vasorum and a neural network. Besides gathering interstitial fluid as lymph and returning it to the blood, the lymphatic vascular system is a major distributor of lymphocytes, antibodies, and other immune components which are carried through many organs to and from lymph nodes and other lymphoid tissues.

For more information please see:

13th edition, Junqueira's Basic Histology

Or Visit

http://www.langetextbooks.com/

https://www.youtube.com/watch?v=TabosXR4odA