Blood Vessels — Wall Structure of Arteries and Veins

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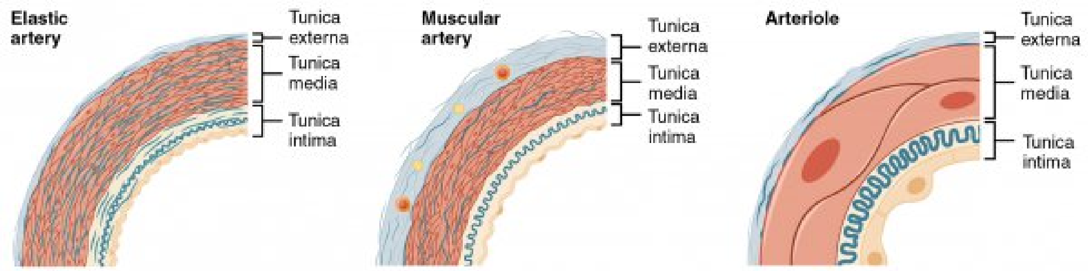
This article provides an overview of the histology of veins and arteries, as well as their functions based on that histology. It also covers the crucial structural and functional differences between veins and arteries, and the way they interact within the circulatory system.



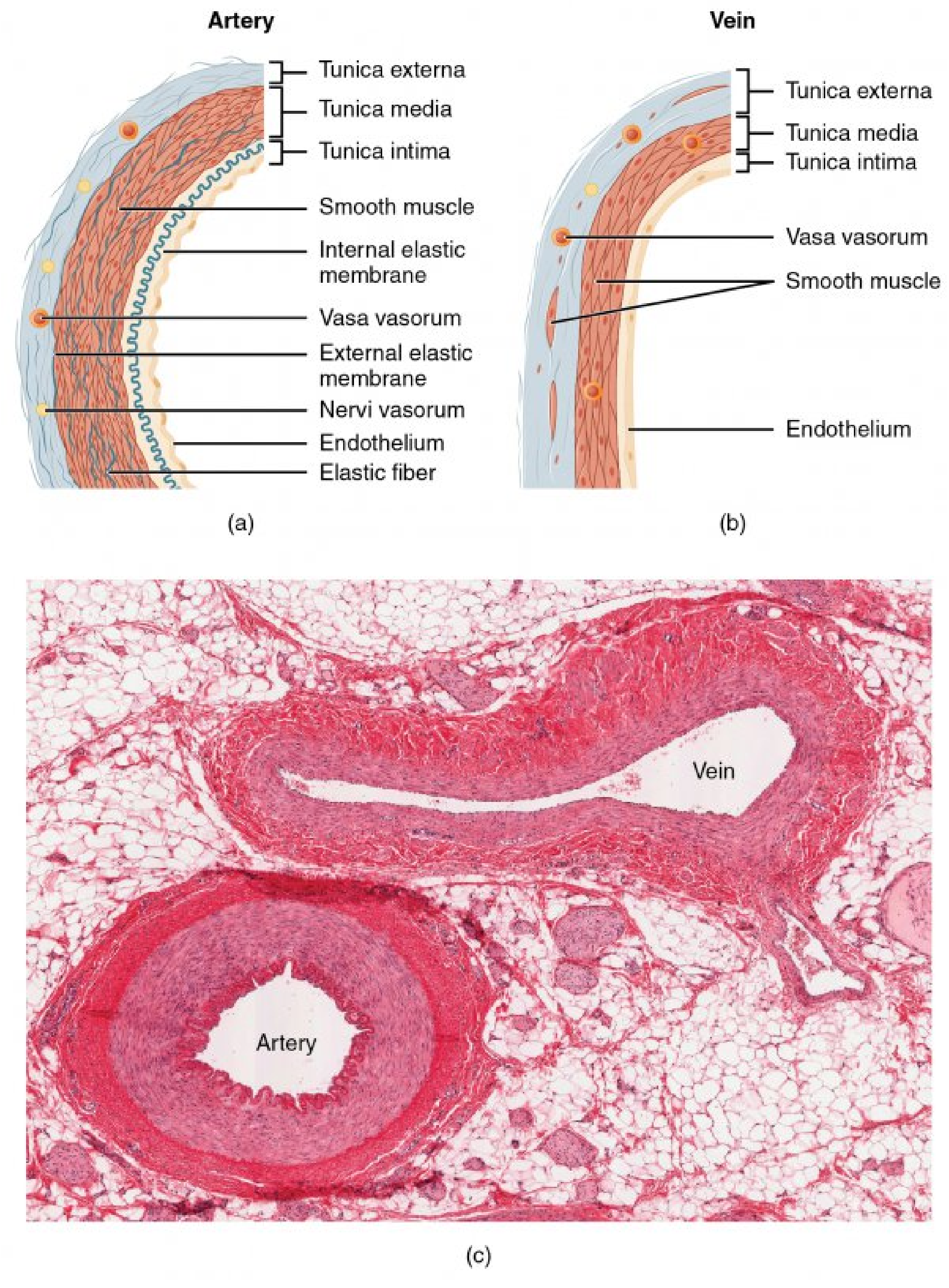
Definition of the Human Blood Circulation

In the human circulatory system, oxygenated blood is transported away from the heart through the arteries. The arteries branch into smaller blood vessels called arterioles, where they end in capillaries or where a capillary network begins. This is where substance exchange between the blood and interstitium takes place. In turn, the capillaries lead to larger vessels, the venules, which then lead to the veins. The venules then transport the deoxygenated blood from the periphery back to the heart.

The General Structure and Functions of Vessels

All larger vessels have the same general structure, which can vary depending on their location and function (i.e., from inside to outside):

- The tunica intima (the 'intima' or 'interna')
- The tunica media (the 'media' or 'muscularis')
- The tunica externa adventitia (the 'adventitia')



Comparison of layers in arteries and veins

	Arteries	Veins
General appearance	Thick walls with small lumens Generally, appear rounded	Thin walls with large lumens Generally, appear flattened

Tunica intima	Endothelium usually appears wavy due to constriction of the smooth muscle Internal elastic membrane is present in larger vessels	Endothelium appears smooth Internal elastic membrane lacking
Tunica media	Usually, this is the thickest layer in arteries Smooth muscle cells and elastic fibers dominate (their proportion varies in keeping with the distance to the heart) In larger vessels, there is an external elastic membrane	Normally thinner than the tunica externa Smooth muscle cells and collagenous fibers predominate Nervi vasorum and vasa vasorum present The external elastic membrane is non-existent
Tunica externa	In all but the larger arteries, this layer is usually thinner than the tunica media. Collagenous and elastic fibers Nervi vasorum and vasa vasorum present	Normally the thickest layer of the veins Collagenous and smooth fibers predominate Some smooth muscle fibers Nervi vasorum and vasa vasorum present

Table: “Comparison of Tunics in Arteries and Veins” von Phil Schatz. License: CC BY 4.0

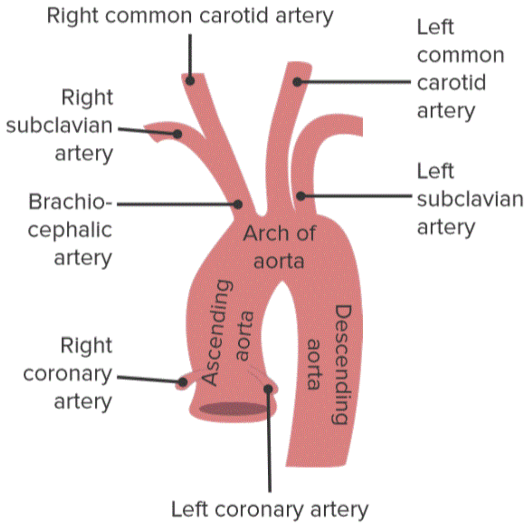
Histology and differentiation of arteries

Arteries transport oxygenated blood from the heart to the periphery of the body; this is why the arterial system is high pressure.

The arterial part of the circulatory system can be subdivided histologically into 2 types:

	Elastic type arteries	**Muscular type arteries**
Distribution	All arteries close to the heart: • Aorta • Pulmonary trunk • Brachiocephalic trunk • Common carotid artery • Subclavian artery • Common iliac artery	All arteries distant from the heart
Structural Features	Wide intima, strong stratum subendothelial to compensate for the mechanical strain. There is presence of many elastic fiber networks in the media.	Strong media rich in muscle cells
Function	Windkessel function: • The ability of vessel walls to stretch enables blood that is ejected during systole to be stored During diastole, blood is carried to the periphery by means of elastic retracting forces of the artery wall	Distribution of blood to organs and tissue: regulation of pressure within the media

Arteries narrow toward the capillary network and become **arterioles**. Arterioles have a diameter of 10–20 µm due to the absence of the stratum subendothelial of the intima. They are designated as resistance vessels since they can regulate blood flow velocity by means of their respective muscle walls (~ 120 mm Hg). The aorta is the largest and closest to the heart, beginning right after the aortic valve. The major arterial branches of the aorta comprise two coronary arteries that originate just above the aortic valve.



"Aorta" Image created by Lecturio

The next part is the capillary exchange system, which is located in the peripheral body regions and has a length of tens of thousands of kilometers, resulting in a large exchange surface. The conditions for gas and substance exchange between the blood and the interstitium are optimal, as the cross-sectional area is very small (6–12 µm) and thus the correlating flow velocity of the blood is very low (0.3 mm/s; for comparison, the flow velocity in arteries amounts to approximately 300 mm/s). Another important task performed by the capillaries is the elimination of byproducts.

The cross-section is so small that erythrocytes can, at some points, only pass through vessels by deforming themselves. The capillary wall generally consists of an endothelial layer, a basal membrane, and pericytes(contractile cells which surround the endothelial cells).

Note: Tight junction = cell contacts that connect epithelial cells to each other.

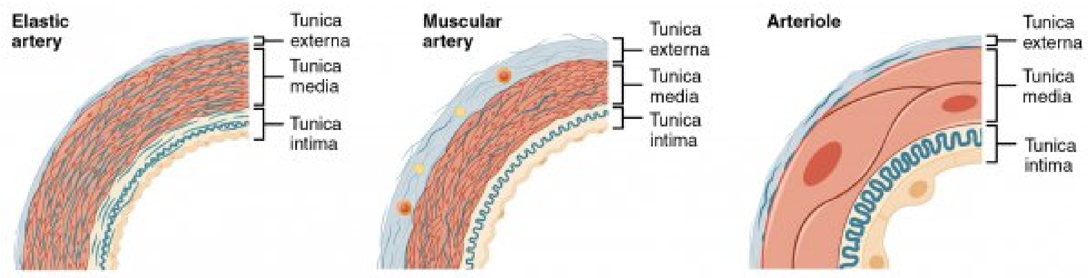


Image: "Types of Arteries and Arterioles" by Phil Schatz. License: CC BY 4.0

Under an electron microscope, 3 different types of capillaries are distinguished:

	Continuous, non-fenestrated capillary	Fenestrated capillary	Discontinuous capillary
Structure	Endothelial cells closely connected to each other via tight junctions	Gaps between the endothelial cells (60-80 nm), which are closed by means of diaphragms: gapless basal membrane	Perforated endothelial layer (pores of up to 0.5 µm) corresponding to partial absence of intercellular contacts: incomplete or absent basal membrane

Distribution	(Mostly having a barrier function) nervous system, lung, heart, skeletal muscles	(Locations with high-rate metabolism) intestine, kidney, adenoid tissue	(Locations with high blood flow) sinusoids of the liver, the spleen, and the bone marrow

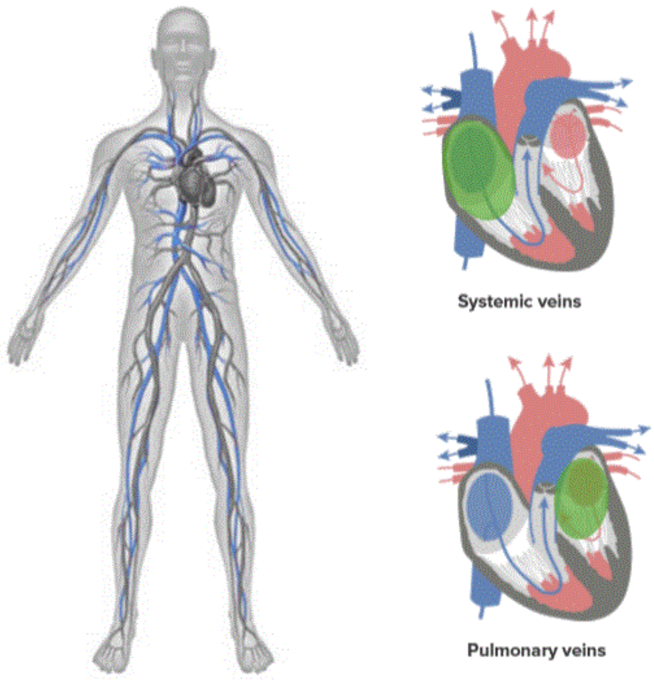
Note: Tight junction = cell contacts which connect epithelial cells to each other.

Veins and Their Special Features

Veins are vessels that transport deoxygenated blood from the periphery back into the heart. In order for this process to take place, the venous blood from the head, neck, arms, and breast gathers in the superior vena cava, and blood from the abdomen, legs, and pelvic organs gathers in the inferior vena cava. Both veins lead to the right atrium, after which the blood is transported into the pulmonary circulation system. Here, blood is reoxygenated.

The anatomy of veins is similar to that of arteries. However, the walls of veins are significantly thinner, so blood pressure within them is markedly lower. This results in a venous low-pressure system, which contains 85% of blood volume.

In histological specimens, the individual wall layers of the veins cannot be separated from each other as easily as in arteries.



“Veins” Image created by Lecturio

A special feature of veins is the so-called venous valve, which can be found in the wall of the torso as well as in the extremities. Backflow of the blood into the periphery must be inhibited by venous valves (intima duplications) since the low blood pressure found in veins is not sufficient for the transportation of blood back into the heart. This occurs via rhythmic closure of the valves, which is further supported by muscular pumping.

The veins usually run parallel to the arteries. However, the number of venous vessels is greater than the number of arterial vessels, due to the presence of both deep and superficial veins. The latter lie directly under the surface of the skin. The deep venous system is connected with the superficial system via perforating veins.

Systemic veins carry deoxygenated blood to the right atrium of the heart. Pulmonary veins carry oxygenated blood to the left atrium.

The venous system also contains smaller vessels—venules—that correspond to the smaller vessels in arteries. Their location is postcapillary, and they carry blood from the capillary network into the veins. Their diameter increases constantly from the end of the capillaries to the veins; this is accompanied by an increasing coat of muscle cells.

Blood Circulatory System

Despite the differences in structure and function, close interaction between arteries and veins occurs in the circulatory system to ensure optimal gas and substance exchange, and the transport of substances.

The circulatory system is a closed system that is divided into a greater and a lesser system. The portal vein system plays a significant role as a sub-branch. A brief overview of this system is shown below.

The greater circulation also referred to as systemic circulation, supplies organs with oxygenated blood.

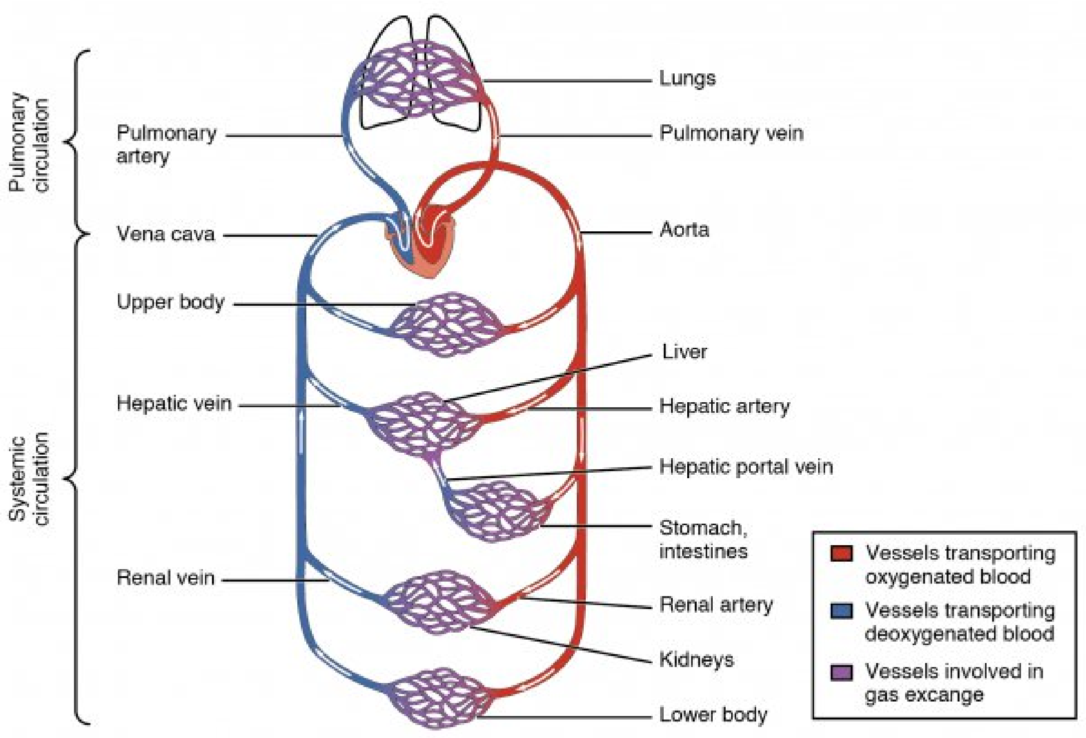


Image: "Cardiovascular Circulation" by Phil Schatz. License: CC BY 4.0

The Direction of Blood Flow

The vessels that carry blood away from the heart are arteries, and those that carry blood toward the heart are veins, irrespective of the amount of oxygen content in them.

Blood flows in the following direction within the body:

- Left atrium of the heart → mitral valve → left ventricle of the heart → aortic valve → aorta → body arteries → arterioles → capillaries (location of gas and substance exchange) → venules → veins → superior/inferior vena cava

The lesser or pulmonary circulation connects directly to the systemic circulation. Its function is to reoxygenate blood and transport it back to the greater circulation, which in turn supplies the organs with blood.

The direction of blood flow

Blood flows in the following direction within the body:

- Right atrium of the heart → tricuspid valve → right ventricle of the heart → valve of the pulmonary trunk → pulmonary trunk → pulmonary arteries → lung capillaries → pulmonary veins → left atrium of the heart

As noted, another important part of the circulatory system is the portal vein system. The venous return of the unpaired abdominal organs (the gastrointestinal tract, the spleen, and the pancreas) occurs via the liver or a common venous stem before the nutritious blood is carried back to the systemic circulation by the inferior vena cava.

The portal vein collects the venous blood and carries it to the liver, where it branches into another capillary system, the rete mirabile venosum (‘wonderful net’). The substrates that were absorbed in the gastrointestinal tract are metabolized here and any potentially poisonous substances are eliminated. The ‘detoxified’ blood then passes through the hepatic veins to reach the inferior vena cava.

The so-called first-pass effect can occur at this location due to metabolic processes; medications are thereby partially or completely degraded, meaning that they are no longer able to act via the blood.

Cardinal Angiological Symptoms and Clinical Aspects

A short overview of the most important cardinal symptoms and clinical pictures that a prospective physician should know about is as shown below, on account of the relevance and incidence of angiological problems.

Cardinal symptoms

- Pain (especially in the lower extremities, caused by ischemia)
- Paresthesia (evidence of circulatory disorders)
- Paleness (veins not filling)
- Cyanosis (reduction in venous drainage)
- Edema (especially on the lower leg and the ankle)
- Slow healing processes (due to reduced circulation)

Clinical Aspects

Arterial diseases

- Degenerative vascular diseases (arteriosclerosis, PAOD, aneurysm, embolism)
- Inflammations (e.g. vasculitis)
- Neuro-vascular compression syndromes

- Function-related diseases (e.g. blood pressure problems)

Venous diseases

Superficial Venous System	Deep Venous System
Varicosis	Phlebothrombosis
CVI (may be a consequence of varicosis)	Retrograde backflow disorder
Thrombophlebitis	Antegrade disorder (‘venous block’)

References

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Notes