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: 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.

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

<table>
<thead>
<tr>
<th>General appearance</th>
<th>Arteries</th>
<th>Veins</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Thick walls with small lumens</td>
<td>Thin walls with large lumens</td>
</tr>
<tr>
<td></td>
<td>Generally appear rounded</td>
<td>Generally appear flattened</td>
</tr>
</tbody>
</table>
Table: “Comparison of tunics in arteries and veins” by von Phil Schatz. License: [CC BY 4.0](https://creativecommons.org/licenses/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:

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

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 (approximately 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 2 coronary arteries that originate just above the aortic valve.

![Aorta Image](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 that surround the endothelial cells).

![Capillary Types Image](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:

<table>
<thead>
<tr>
<th>Continuous, non-fenestrated capillary</th>
<th>Fenestrated capillary</th>
<th>Discontinuous capillary</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Elastic artery</th>
<th>Tunica externa</th>
<th>Tunica media</th>
<th>Tunica intima</th>
<th>Tunica externa</th>
<th>Tunica media</th>
<th>Tunica intima</th>
<th>Tunica externa</th>
<th>Tunica media</th>
<th>Tunica intima</th>
</tr>
</thead>
<tbody>
<tr>
<td>Muscular artery</td>
<td>Tunica externa</td>
<td>Tunica media</td>
<td>Tunica intima</td>
<td>Tunica externa</td>
<td>Tunica media</td>
<td>Tunica intima</td>
<td>Tunica externa</td>
<td>Tunica media</td>
<td>Tunica intima</td>
</tr>
<tr>
<td>Arteriole</td>
<td>Tunica externa</td>
<td>Tunica media</td>
<td>Tunica intima</td>
<td>Tunica externa</td>
<td>Tunica media</td>
<td>Tunica intima</td>
<td>Tunica externa</td>
<td>Tunica media</td>
<td>Tunica intima</td>
</tr>
</tbody>
</table>
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, spleen, and bone marrow

**Note:** Tight junction = cell contacts that 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.

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.

The 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.

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.

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 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 understand is shown below.

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, peripheral arterial occlusive
disease, aneurysm, embolism)
- Inflammations (e.g., vasculitis)
- Neuro-vascular compression syndromes
- Function-related diseases (e.g., blood pressure problems)

### Venous diseases

<table>
<thead>
<tr>
<th>Superficial venous system</th>
<th>Deep venous system</th>
</tr>
</thead>
<tbody>
<tr>
<td>Varicosis</td>
<td>Phlebothrombosis</td>
</tr>
<tr>
<td>Chronic venous insufficiency (may be a consequence of varicosis)</td>
<td>Retrograde backflow disorder</td>
</tr>
<tr>
<td>Thrombophlebitis</td>
<td>Antegrade disorder (venous block)</td>
</tr>
</tbody>
</table>

### References


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Notes