Blood Vessels — Wall Structure of Arteries and Veins

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In this article, you will get an overview of the most important facts concerning the histology of veins and arteries, as well as their functions based on their histology. In addition, we cover 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. These 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 into the heart.

The General Structure and Functions of Vessels

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

- The tunica intima (‘intima’ or ‘interna’)
- The tunica media (‘media’ or ‘muscularis’)
- The tunica externa adventitia (‘adventitia’)

Elastic artery

Muscular artery

Arteriole
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>
Tunica intima
- Endothelium usually appears wavy due to constriction of the smooth muscle.
- Internal elastic membrane is present in larger vessels.

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.

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.

| 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, which explains the presence of the **arterial high-pressure system**.

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

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

Arteries narrow towards 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 as they can regulate blood flow velocity by
means of their respective muscle walls (~ 120 mmHg).

The aorta is the largest and closest to the heart, begins right after the aortic valve. The major arterial branches of the aorta are two coronary arteries originate just above the aortic valve.

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 ca. 300 mm/s). Another important task performed by the capillaries is the elimination of by-products.

Note: The cross-section is so small that the erythrocytes can – at some points – only pass through the 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).

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>
<tbody>
<tr>
<td>Image: &quot;Types of Arteries and Arterioles&quot; by Phil Schatz. License: CC BY 4.0</td>
<td></td>
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</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, 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 which 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 the 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 re-oxygenated.

The anatomy of veins is similar to that of arteries. However, the difference is that the walls of veins are significantly thinner, which explains why 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 has to 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 of the heart.

The venous system also contains smaller vessels, venules, which correspond to the smaller vessels in arteries. Their location is post-capillary, and they carry blood from the capillary network into the veins. Their diameter increases constantly from the end of the capillaries to the veins, and 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 transport of substances.

The circulatory system is a closed system which can be divided into the ‘greater’ and the ‘lesser’ system. Besides these two systems, the **portal vein system** plays a significantly important role as a ‘sub-branch,’ and it should not be disregarded when preparing for exams. A brief overview of this system is as shown below.

The greater circulation, also referred to as systemic circulation, performs the task of supplying organs with oxygenated blood.
The Direction of Blood Flow
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 circulation or pulmonary circulation connects directly to the systemic circulation and has the task of re-oxygenating blood and transporting it back to the greater circulation, which in turn supplies the organs.

The direction of blood flow
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

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

As mentioned, another important part of the circulatory system is the portal vein system. The venous return of the unpaired abdominal organs (the gastro-intestinal tract, the spleen, and the pancreas) occurs via the liver or a common venous stem before the nutritive 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 gastro-intestinal 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.

Note: 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, aneurism, 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>CVI (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>

Review Questions

The answers can be found below the references.

1. **Which statements are correct in relation to the structure of blood vessels?**

   A. The tunica interna consists of simple squamous epithelium.
   B. In elastic-type arteries, the stratum subendothelial is only formed to a certain degree, or not present at all.
   C. Tight junctions may be found in non-fenestrated capillaries.
   D. The blood flow velocity can be regulated via the wall muscles of the venules, which is the reason as to why they are referred to as resistance vessels.

2. **Which statement concerning the capillary exchange system is false?**

   A. The blood flow velocity in arteries is 1000 times higher than in capillaries.
   B. Erythrocytes can only pass through capillary vessels by deforming themselves, due to the small cross-section area of the latter.
   C. The walls of all capillaries consist of an endothelial layer, pericytes, and a basal membrane.
   D. Fenestrated capillaries are located in areas that have high blood circulation.

3. **Which of the following statements represents a correct deduction?**

   A. If veins are insufficiently filled, or not filled at all, paleness can be observed, which can typically be found at PAOD.
   B. Impairment of venous return can lead to cyanotic changes.
   C. Paresthesia is always caused by diseases or lesions of the blood vessel system.
   D. The first-pass-effect causes a decrease in circulation, resulting to a slower healing process.

References


**Correct answers:** 1C, 2D, 3B

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