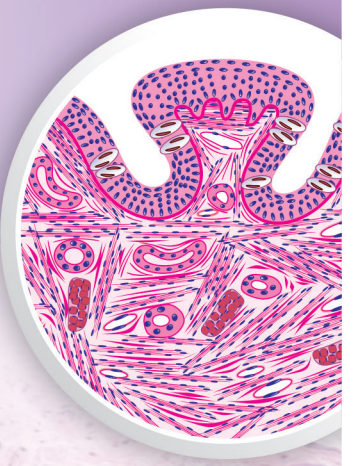


Chapter

7

Blood Vessels

"Give blood, it is meant to circulate"

AN69.1: Identify elastic and muscular blood vessels, capillaries under the microscope.
AN69.2: Describe the various types and structure–function correlation of blood vessel.
AN69.3: Describe the ultrastructure of blood vessels.

All animals and human beings require a mechanism to distribute oxygen and nutritive materials to the tissues and to collect carbon dioxide and waste products of tissue metabolism and transmit these to excretory system. This is all done by the blood vascular system.

Blood vascular system and lymph vessels consist of a heart which is the muscular pump and various types of blood vessels. The latter are described in Chapter 7 and lymph vessels described in Chapter 8. The structure of heart has been described as cardiac muscle in Chapter 5.

The various types of blood vessels are: (1) Arteries, (2) Capillaries, (3) Sinusoids, (4) Veins. This chapter gives histology of arteries and veins.

ARTERIES

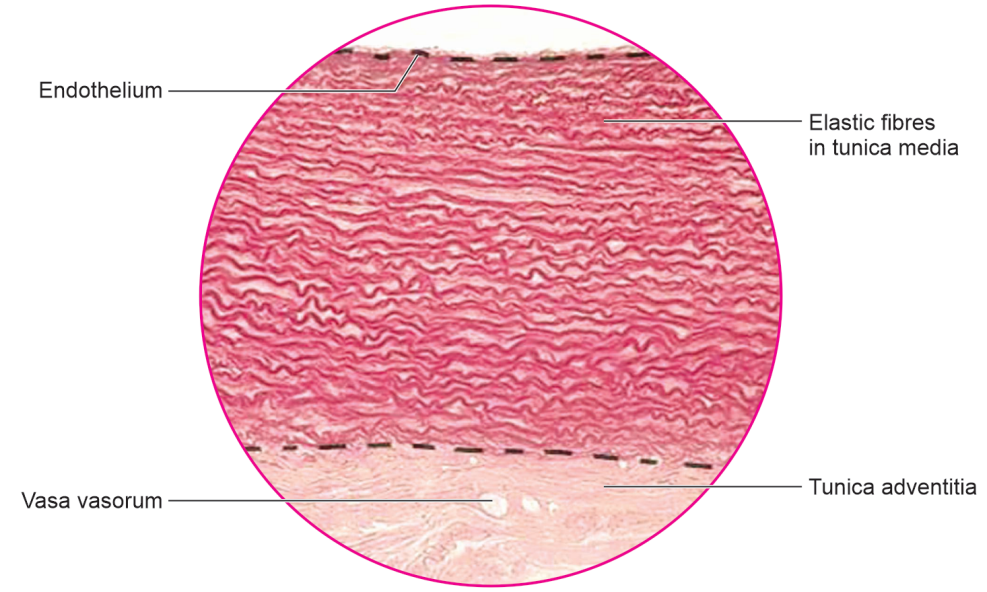
Arteries are classified as:

A. Elastic or large sized arteries, e.g. aorta (Fig. 7.1)
B. Muscular or medium sized arteries, e.g. brachial, radial, popliteal.
C. Arterioles—smallest divisions of arteries with a diameter of 100 micron.

A. ELASTIC ARTERIES

During **systole**, the elastic artery expands to accommodate increased amount of blood. During **diastole** of the heart, there is elastic recoil of the artery, so there is continuous blood flow to the peripheral parts of the body. Since these arteries have abundant elastic fibres in their walls, these are named elastic arteries. The lumen of the artery is surrounded by the three concentric coats: (i) Tunica intima, (ii) tunica media, and (iii) tunica adventitia.

i. The **tunica intima** consists of an endothelium, subendothelial connective tissue and an internal elastic lamina.
   The **endothelium** is a thin layer, made up of flattened cells, lining the luminal surface of the artery. These cells rest on a basement membrane/basal lamina.



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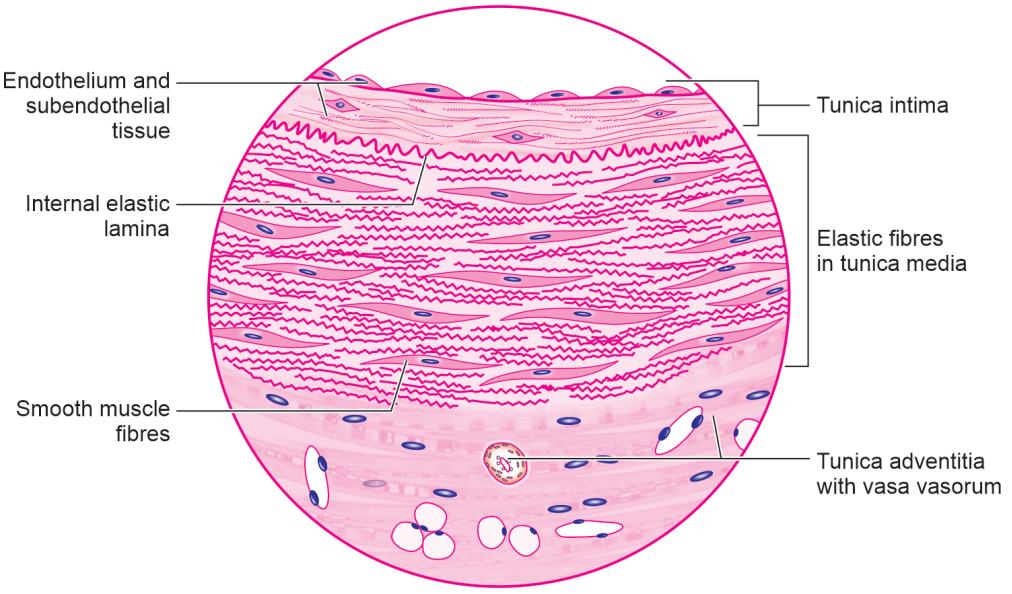


FIGURE

FACTS TO REMEMBER

1. Tunica intima well defined 2. Tunica media rich in elastic fibres and forms 2/3rd thickness of arterial wall 3. Tunica adventitia comprises 1/3rd thickness of arterial wall

Fig. 7.1: Layers of elastic artery. Stain: Haematoxylin-eosin, 100X

Cytoplasm of endothelial cells contains endoplasmic reticulum, mitochondria and microfilaments. The adjacent endothelial cells are joined by tight junctions.

Endothelium of blood vessels acts as a semipermeable membrane between the interstitial tissue and blood. It makes the inner wall of the vessel smooth to prevent platelet adhesion. Endothelium produces **nitrous oxide** which causes vasodilatation. It also produces **endothelin** which opposes action of nitrous oxide, i.e. causes vasoconstriction. It causes degradation of lipoproteins and produces some growth factors. It converts angiotensin I to angiotensin II. The latter is a vasoconstrictor and raises blood pressure.

Subendothelial connective tissue is a loose narrow layer containing elastic and collagen fibres along with nuclei of fibroblasts and macrophages.

The **internal elastic lamina** is the limiting layer of tunica intima and is made up of fenestrated elastic fibres. The internal elastic lamina is not prominent as the elastic fibres merge with the elastic laminae of the tunica media.

ii. The **tunica media** or middle layer is the thickest and is dominated by concentric laminae of elastic fibres with smooth muscle fibres. It comprises **two-thirds** of the arterial wall. The outer layer of the tunica is the **external elastic lamina**, made up of elastic fibres, which is not so conspicuous. **Nervi vasorum** are autonomic nerves which supply smooth muscles of blood vessels.

iii. The **tunica adventitia** is a layer of collagen fibres, elastic fibres and fibroblasts. It contains a few arterioles called **vasa vasorum** which nourish the tunica adventitia and outer two-thirds of tunica media, the rest being nourished by the blood flowing through the lumen of the vessels. Tunica adventitia comprises **one-third** of the thickness of the arterial wall.

B. MUSCULAR ARTERIES

These arteries control the amount of blood flowing through them according to the activity of the part.

It consists of a lumen surrounded by same three concentric coats: (i) Tunica intima, (ii) tunica media and (iii) tunica adventitia (Fig. 7.2).

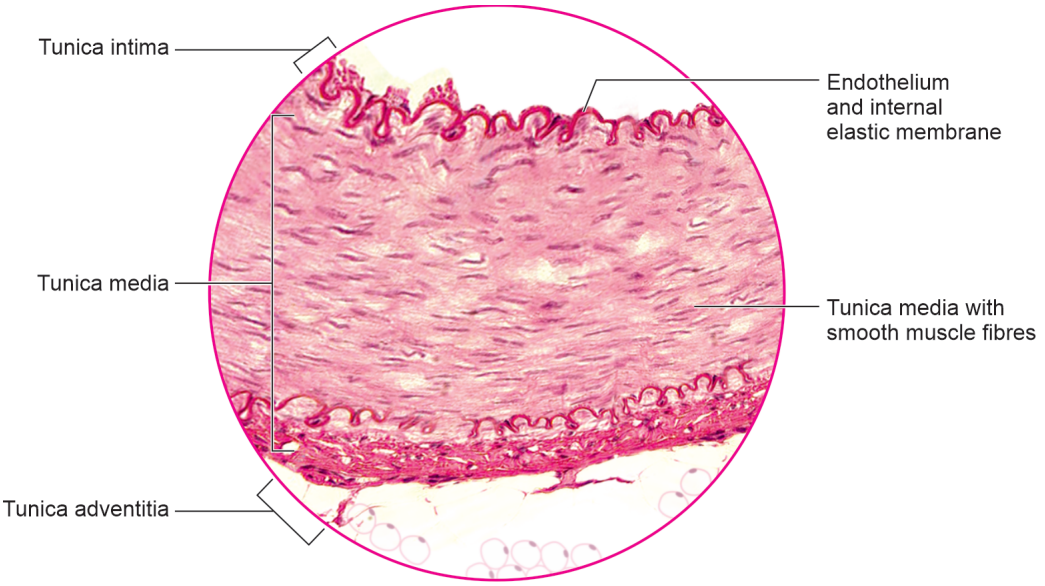
i. The **tunica intima** consists of an endothelium, subendothelial connective tissue and an internal elastic lamina. The **endothelium** is formed by lining of flattened cells, resting on a basal lamina. The **subendothelial connective tissue** consists of fine collagen and elastic fibres as well as fibroblasts.

The **internal elastic lamina** is well defined. The lamina of elastic fibres stands out well as the media mainly consists of smooth muscle fibres.

ii. The **tunica media** forms **two-thirds** of the thickness of the arterial wall. It is made up of circularly or spirally running **smooth muscle fibres**. Their control is by autonomic nervous system. Among the muscle fibres are scattered elastic fibres. Tunica media has no fibroblasts. Smooth muscle cells are connected to each other by gap junctions, which permit rapid contractions.

The **external elastic lamina** is made of elastic fibres and is better defined than in an elastic artery due to predominance of muscle fibres in the tunica media.

iii. The **tunica adventitia** is a well-defined layer comprising nearly **one-third** of the thickness of the arterial wall. It contains collagen and elastic fibres. Arterioles in the form of **vasa vasorum** are usually present in this layer.



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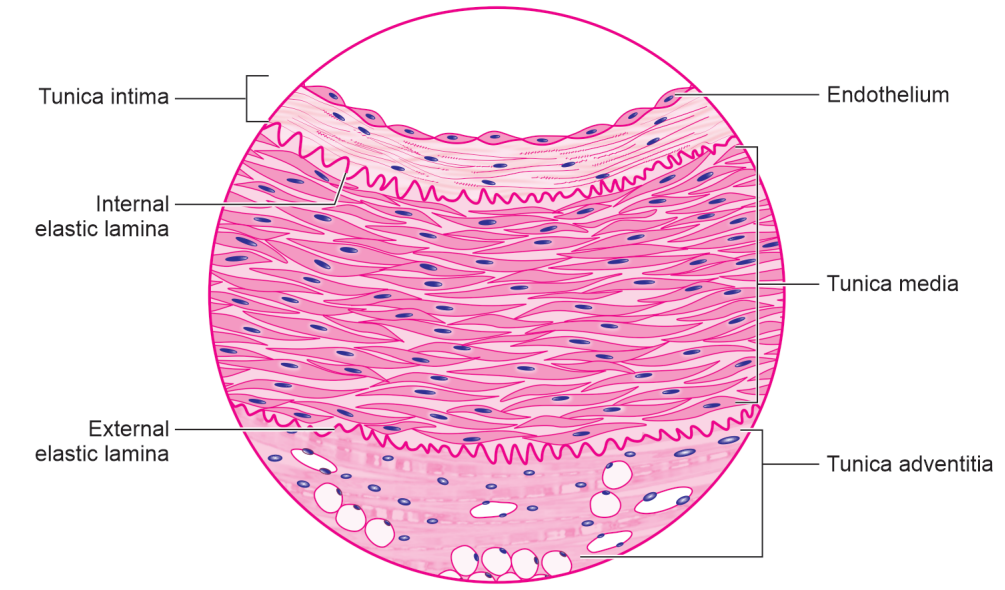


FIGURE

FACTS TO REMEMBER

1. Tunica intima shows well-defined internal elastic lamina 2. Tunica media is rich in muscle fibres and shows well-defined external elastic lamina 3. Tunica adventitia rich in collagen and elastic fibres

Fig. 7.2: Layers of muscular artery. Stain: Haematoxylin-eosin, 100X

C. ARTERIOLES

These are the smallest divisions of the arteries which have a diameter of **100 micron**. These act as resistance vessels to maintain peripheral blood pressure. Three concentric coats surrounding the lumen are (i) Tunica intima, (ii) tunica media, and (iii) tunica adventitia.

i. The **tunica intima** consists of endothelium closely applied to the internal elastic lamina with a mere trace of subendothelial connective tissue.
ii. The **tunica media** is made up of a few layers of circularly arranged smooth muscle fibres and an outer elastic lamina (Table 7.1).
iii. The **tunica adventitia** is made of collagen as well as elastic fibres and is usually a thick layer (Fig. 7.3).

Table 7.1 shows comparison of the three types of arteries.

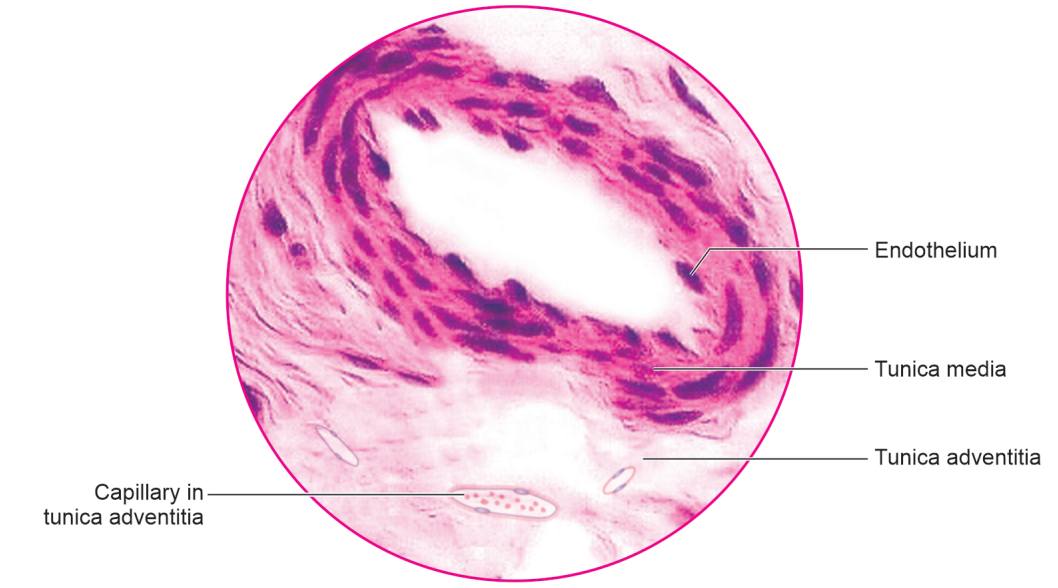
End arteries: It is single/only artery supplying an organ. Blockage of such artery leads to death of tissue, e.g. central artery of retina, labyrinthine artery. Coronary arteries are functional end arteries.

APPLIED ASPECT

- **Atheroma** are the patchy changes developed in the tunica intima of arteries. Accumulation of cholesterol and other lipid compounds, and foam cells (fat-filled monocytes) are the pathological changes in atheroma. Arteries most commonly involved are those in the heart, brain, small intestine, kidneys and lower limbs.
- **Arteriosclerosis** is a progressive degeneration of arterial walls with ageing and accompanied by hypertension. In large and medium-sized arteries, the tunica media is infiltrated with fibrous tissue and calcium. This causes the vessels to lose the elasticity which increases the systolic blood pressure and pulse pressure.
  In small arteries and arterioles, hyaline thickening of the tunica media and tunica intima causes narrowing of the lumen. This increases the peripheral resistance and blood pressure.
- **Aneurysm** is the swelling or dilation of blood vessels where part of the wall of artery inflates like a balloon. The wall of the blood vessel at the site of aneurysm is weaker and thinner than the rest of the blood vessels. Due to its likelihood to burst it poses a serious risk to health.

Table 7.1: Comparison among elastic artery, muscular artery and arteriole

Layers	*Elastic artery*	*Muscular artery*	*Arteriole*
Tunica intima	Endothelium, subendothelial tissue and ill-defined internal elastic lamina	Endothelium, subendothelial tissue and prominent internal elastic lamina	Endothelium, subendothelial tissue and internal elastic lamina poorly developed
Tunica media	40–80 fenestrated elastic membranes with thin external elastic lamina	20–40 layers of smooth muscle cells, prominent external elastic lamina, controlled by autonomic nervous system	Only 1–4 layers of smooth muscle cells
Tunica adventitia	Fibroelastic layer and prominent vasa vasorum	Fibroelastic layer, vasa vasorum not prominent	Loose connective tissue only



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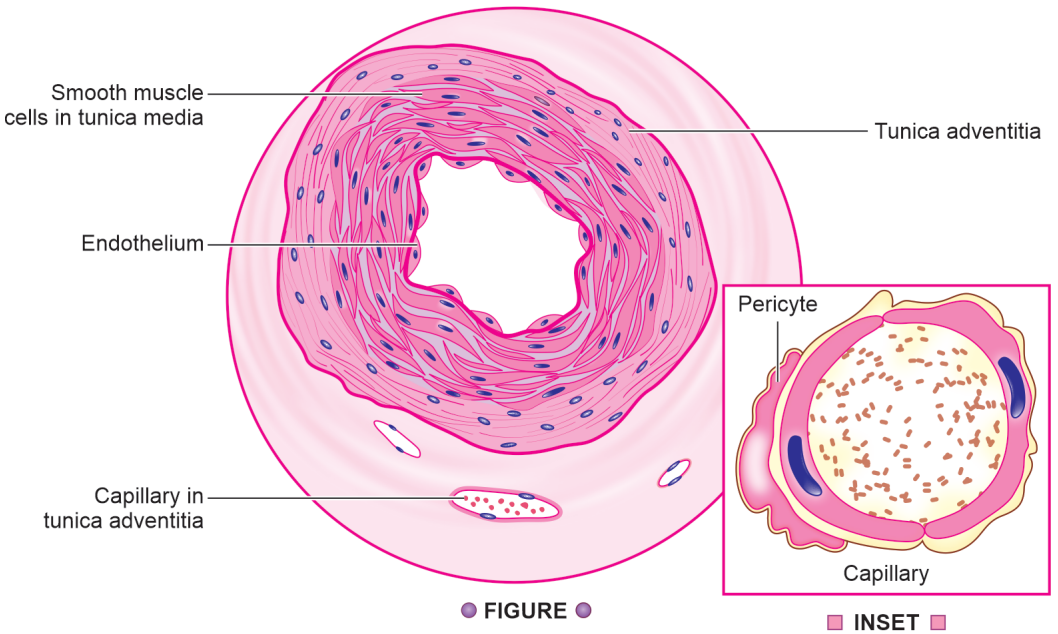


FIGURE INSET

FACTS TO REMEMBER

1. Endothelium closely applied to subendothelial connective tissue 2. Circular muscle and external elastic lamina seen 3. Tunica adventitia is thick with collagen and elastic fibres

Fig. 7.3: Layers of arteriole. Inset shows a capillary. Stain: Haematoxylin-eosin, 100X

CAPILLARIES

Capillaries: Form a link between the arterioles (smallest division of an artery) and the venules (smallest tributary of a vein). The diameter of a capillary is about 8–10 micron. Its lumen is slightly larger than the diameter of an erythrocyte. One to three endothelial cells with stretched out cytoplasm line the lumen and rest on the basal lamina. Outside the basal lamina is a fine layer of collagen and elastic fibres with **occasional perivascular cells** or **pericytes** (Fig. 7.3 inset). Usually the edges of endothelial cells fuse with those of adjacent cells, making the lining continuous. These capillaries are termed "**continuous capillaries**". The exchange occurs through the cytoplasm by the formation of pinocytic vesicles.

In viscera like kidney, small intestine and endocrine glands the capillaries are **fenestrated**, i.e. have minute apertures/pores between the adjacent endothelial cells. These apertures may be closed by thin membrane either of the basal lamina or thinned out cytoplasm of the endothelial cell. The greater exchange in fenestrated capillaries occurs through these pores.

SHUNT VESSELS OR ARTERIOVENOUS ANASTOMOSES (AV ANASTOMOSES)

In many organs in the body, the arterioles and venules may also be connected to each other through a direct channels called **AV anastomoses**. Through these, most of the blood passes directly from arteriole to venule and bypasses the capillaries. These are present in skin of lips, nose, pinna, mucous membrane of GIT and are richly supplied by sympathetic nerves. These AV anastomoses help to maintain body temperature by decreasing the flow of blood through capillaries in cold weather and enhancing the flow in hot climate.

SINUSOIDS

Sinusoids are large irregular blood containing spaces lined by flattened **endothelial** as well as **reticuloendothelial cells**. The latter type of cells is phagocytic in nature. In liver, phagocytic cells are called **Kupffer's cells**. The lining of the sinusoids is **fenestrated**. These are seen in liver, spleen, endocrine glands and bone marrow.

Table 7.2 shows differences between sinusoids and capillaries.

Table 7.2: Differences between sinusoids and capillaries

Sinusoids	*Capillaries*
1. Wider, irregular spaces	Narrow regular spaces
2. Lined by endothelial as well as reticulo-endothelial cells, which may be interrupted, and fenestrated	Lined by a few continuous endothelial cells
3. Found in endocrine glands, lymphoid tissue, liver and bone marrow	Found in all the tissues of the body
4. Basal lamina is not continuous	Basal lamina is continuous

VEINS

These are vessels which collect and bring deoxygenated blood to the heart, exceptions being the **umbilical**, and **pulmonary veins**. Smallest veins are called **venules** with extremely thin walls. These join to form medium sized and large veins (Fig. 7.4). The veins have relatively thin walls and large lumens. Many veins contain blood cells. The three concentric coats of the vein are: (i) Tunica intima, (ii) tunica media, and (iii) tunica adventitia.

i. The **tunica intima** consists of an **endothelium** which rests directly on a poorly defined **internal elastic lamina** or is separated from it by a small amount of subendothelial connective tissue.
ii. The **tunica media** is thinner as compared to the tunica media of the arteries. It forms nearly **one-third** of the thickness of the wall of the vein. It contains smooth muscle fibres and collagen fibres (Fig. 7.4).
iii. The **tunica adventitia** forms **two-thirds** of the thickness of the wall of the vein. It consists of collagen fibres with a few elastic fibres. Large veins usually show longitudinally disposed smooth muscle fibres in this layer.

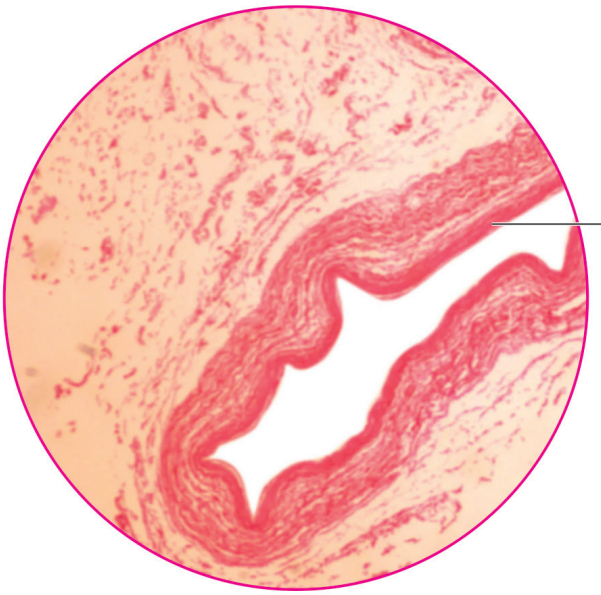
Table 7.3 shows the comparison of large vein, medium-sized vein and venules. The differences between arteries and veins have been tabulated in Table 7.4.

Table 7.3: Depicts differences among large vein, medium-sized vein and venules

Layers	*Large vein*	*Medium sized vein*	*Venules*
Tunica intima	Endothelium basal lamina, subendothelial tissue, valves may be seen	Same as in large vein	Endothelium, basal lamina and pericytes
Tunica media	Smooth muscles and connective tissue	Smooth muscles and connective tissue	A few smooth muscles and loose connective tissue
Tunica adventitia	Smooth muscle fibres seen as longitudinal bundles	Comprises fibroblasts and collagen bundles	A few fibroblasts and thin layer of collagen fibres

Table 7.4: Differences between arteries and veins

	Arteries	*Veins*
1. Lumen	Patent, RBC not seen	Lumen may be collapsed, RBC usually seen
2. Endothelial lining	Well defined	Not so well defined
3. Internal elastic lamina	Distinct	Poorly defined
4. Tunica media	Forms 2/3rd of the thickness of the wall	Forms 1/3rd of the thickness of the wall
5. External elastic lamina	Distinct	Not well defined
6. Tunica adventitia	Form 1/3rd of the thickness of the wall	Form 2/3rd of the thickness of the wall
7. Extent of vasa vasorum	Supply extends up to outer 2/3rd of tunica media	Supply extends up to tunica intima



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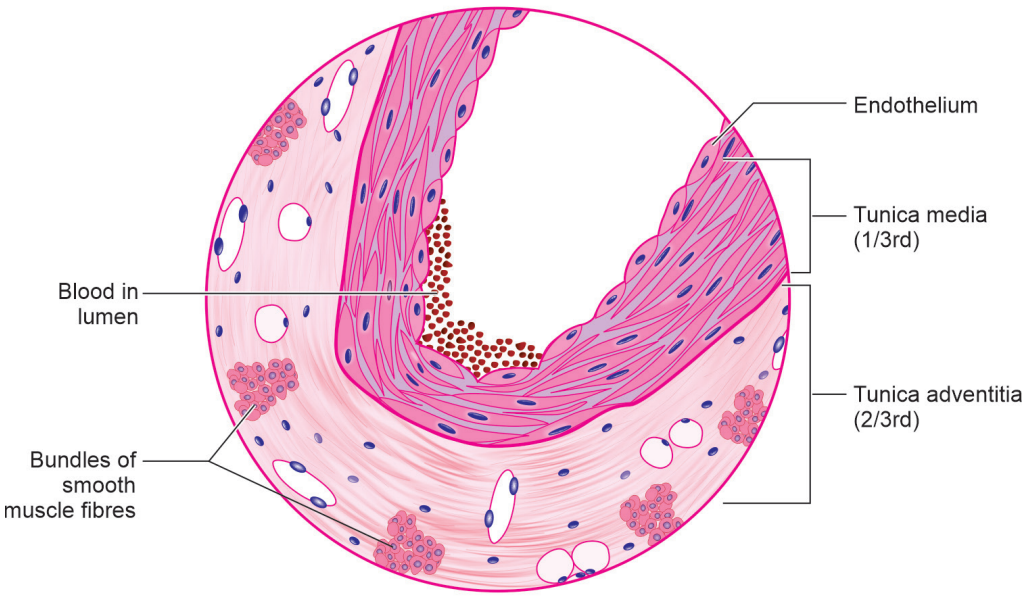

FIGURE

FACTS TO REMEMBER

1. Lumen containing RBCs seen 2. Tunica intima shows poor internal elastic lamina
3. Tunica media forms 1/3rd thickness, tunica adventitia forms 2/3rd the thickness of the wall

Fig. 7.4: Layers of large vein. Stain: Haematoxylin-eosin, 100X

APPLIED ASPECT

- **Varicose veins** are a condition with so much dilation of veins that the valves do not close to prevent backward flow of blood. Such veins lose their elasticity, becomes elongated and tortuous. Fibrous tissue replaces the tunica media in this condition.
- **Thrombophlebitis:** Inflammation in the wall of vein causes localised collection of blood cells known as thrombus. If it gets detached, it flows through the blood and may block any small artery. The condition is known as **embolism**.

Multiple Choice Questions

1. Which blood vessel has most prominent internal and external elastic lamina?
a. Elastic artery
b. Muscular artery
c. Arteriole
d. Large vein

2. In which vessel is the pericyte seen?
a. Elastic artery
b. Muscular artery
c. Arteriole
d. Capillary

3. Fenestrated capillaries are present only in:
a. Kidney
b. Spleen
c. Muscle
d. Brain

4. Proportion of tunica media to tunica adventitia in artery is:
a. 1:1
b. 2:1
c. 1:2
d. None of the above

5. Kupffer's cells are present in:
a. Spleen
b. Liver
c. Intestine
d. Lymph node

Viva Voce Questions

1. **Name the layers of blood vessels.**
2. **What are vaso-vasorum? What are its functions?**
3. **Give examples of elastic artery.**
4. **Give examples of muscular artery.**
5. **Name the types of capillaries.**
6. **Name the substances produced by endothelial cells.**
7. **What is pathophysiology of the varicose veins?**