The Cardiovascular System

Veins

The basic structure of veins is similar to that of arteries. The tunica intima, media and adventitia can be distinguished, especially in large veins. The structure of veins differs from that of arteries in the following aspects (Fig. 13.7 and Plate 13.3):

a. The wall of a vein is distinctly thinner than that of an artery having the same sized lumen.
b. The tunica media contains a much larger quantity of collagen than in arteries. The amount of elastic tissue or of muscle is much less.
c. Because of the differences mentioned above, the wall of a vein is easily compressed. After death veins are usually collapsed. In contrast arteries retain their patency.
d. In arteries the tunica media is usually thicker than the adventitia. In contrast the adventitia of veins is thicker than the media (especially in large veins). In some large veins (e.g., the inferior vena cava) the adventitia contains a considerable amount of elastic and muscle fibers that run in a predominantly longitudinal direction.
   These Fibers facilitate elongation and shortening of the vena cava with respiration. This is also facilitated by the fact that collagen fibers in the adventitia form a meshwork that spirals around the vessel.
e. A clear distinction between the tunica intima, media and adventitia cannot be made out in small veins as all these layers consist predominantly of fibrous tissue. Muscle is conspicuous by its complete absence in venous spaces of erectile tissue, in veins of cancellous bone, dural venous sinuses, retinal veins, and placental veins.
f. The internal and external elastic lamina in veins are absent.

Valves of Veins

Most veins contain valves that allow the flow of blood towards the heart, but prevent its regurgitation in the opposite direction. Typically each valve is made up of two semilunar cusps.

Each cusp is a fold of endothelium within which there is some connective tissue that is rich in elastic fibers. Valves are absent in very small veins; in veins within the cranial cavity, or within the vertebral canal; in the venae cavae; and in some other veins.

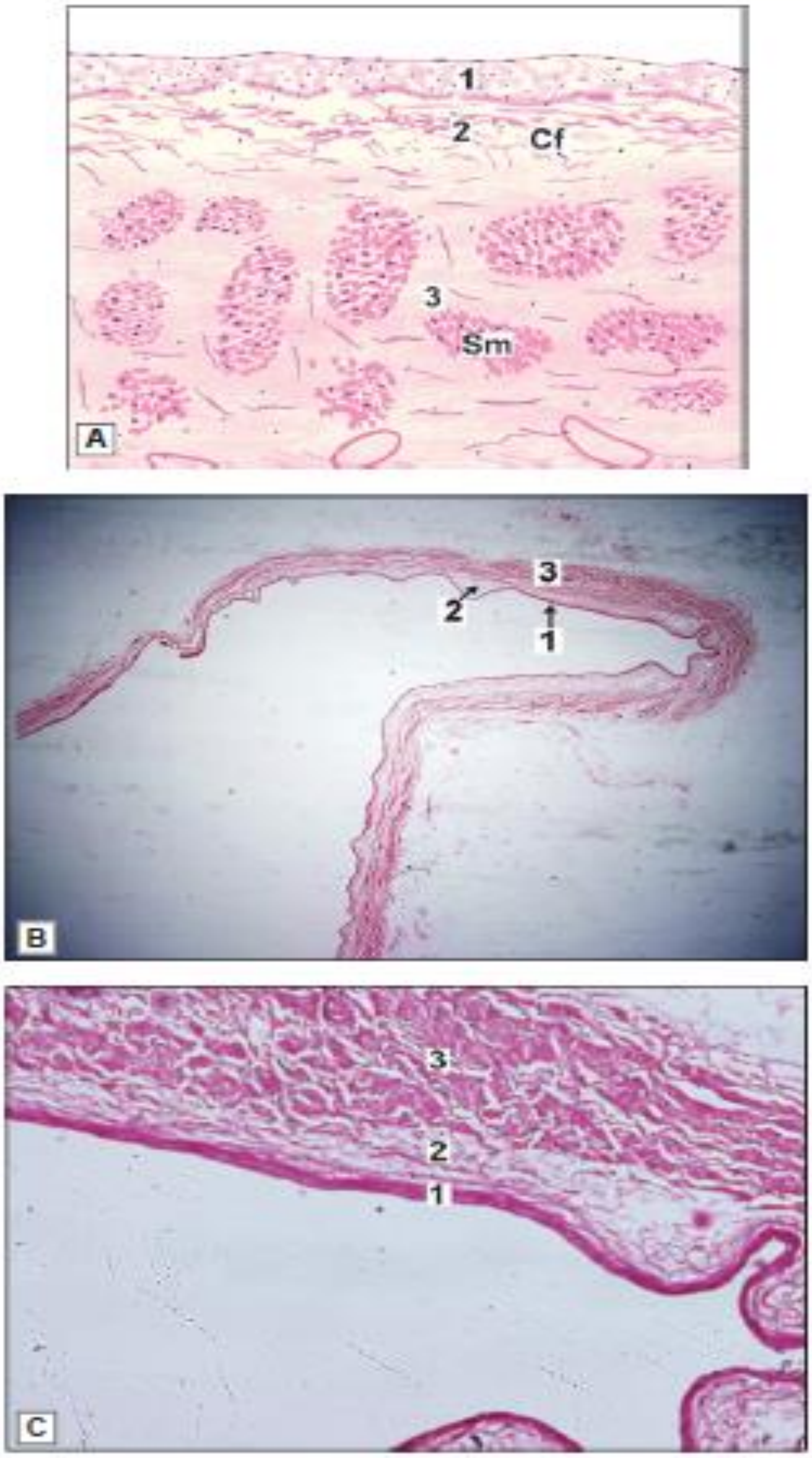
Flow of blood through veins is assisted by contractions of muscle in their walls. It is also assisted by contraction of surrounding muscles especially when the latter are enclosed in deep fascia (a thin sheath of fibrous tissue enclosing a muscle or other organ).

Clinical Correlation

Varicose Veins

Varicose veins are permanently dilated and tortuous superficial veins of the lower extremities, especially the long saphenous vein and its tributaries. About 10–12% of the general population develops varicose veins of lower legs, with the peak incidence in 4th and 5th decades of life. Adult females are affected more commonly than the males, especially during pregnancy. This is attributed to venous stasis in the lower legs because of compression on the iliac veins by pregnant uterus.

PLATE 13.3: Vein



Vein. A. As seen in drawing; B. Photomicrograph (low magnification); C. Photomicrograph (high magnification).

- The vein has a thinner wall and a larger lumen than the artery
- The tunica intima, media and adventitia can be made out, but they are not sharply demarcated
- The media is thin and contains a much larger quantity of collagen fibres than arteries. The amount of elastic tissue or of muscle is much less
- The adventitia is relatively thick and contains considerable amount of elastic and muscle fibres.

Note: The luminal surface appears as a dark line, with an occasional nucleus along it.

Key

1. Tunica intima
2. Tunica media
3. Tunica adventitia

Cf. Collagen fibres

Sm. Smooth muscles

Venules

The smallest veins, into which capillaries drain, are called venules (Fig. 13.3). They are 20–30 μm in diameter. Their walls consist of endothelium, basal lamina, and a thin adventitia consisting of longitudinally running collagen fibers. Flattened or branching cells called pericytes may be present outside the basal laminae of small venules (called post capillary venules), while some muscle may be present in larger vessels (muscular venules). The walls of venules (especially those of post capillary venules) have considerable permeability and exchanges between blood and surrounding tissues can take place through them. In particular venules are the sites at which lymphocytes and other cells may pass out of (or into) the blood stream.

Blood Vessels, Lymphatics And Nerves Supplying Blood Vessels

The walls of small blood vessels receive adequate nutrition by diffusion from blood in their Lumina. However, the walls of large and medium sized vessels are supplied by small arteries called ***vasa vasorum*** (literally 'vessels of vessels'; singular = ***vas vasis***). These vessels supply the adventitia and the outer part of the media. These layers of the vessel wall also contain many lymphatic vessels.

Blood vessels have a fairly rich supply by autonomic nerves (sympathetic). The nerves are unmyelinated. Most of the nerves are vasomotor and supply smooth muscle. Their stimulation causes vasoconstriction in some arteries, and vasodilatation in others. Some myelinated sensory nerves are also present in the adventitia.

Mechanisms Controlling Blood Flow Through The Capillary Bed

The requirements of blood flow through a tissue may vary considerably at different times. For example, a muscle needs much more blood when engaged in active contraction, than when relaxed. Blood flow through intestinal villi needs to be greatest when there is food to be absorbed.

The mechanisms that adjust blood flow through capillaries are considered below.

*Blood supply to relatively large areas of tissue is controlled by contraction or relaxation of smooth muscle in the walls of muscular arteries and arterioles.

*Control of supply to smaller areas is effected through arteriovenous anastomoses, precapillary sphincters, and thoroughfare channels.

Arteriovenous Anastomoses

In many parts of the body, small arteries and veins are connected by direct channels that constitute arteriovenous anastomoses. These channels may be straight or coiled. Their walls have a thick muscular coat that is richly supplied with sympathetic nerves. When the anastomoses are patent blood is short circuited from the artery to the vein so that very little blood passes through the capillary bed. However, when the muscle in the wall of the anastomosing channel contracts its lumen is occluded so that all blood now passes through the capillaries.

Arteriovenous anastomoses are found in the skin specially in that of the nose, lips and external ear; and in the mucous membrane of the alimentary canal and nose.

They are also seen in the tongue, in the thyroid, in sympathetic ganglia, and in the erectile tissues of sex organs.

Arteriovenous anastomoses in the skin help in regulating body temperature, by increasing blood flow through capillaries in warm weather; and decreasing it in cold weather to prevent heat loss.

In some regions we see arteriovenous anastomoses of a special kind. The vessels taking part in these anastomoses are in the form of a rounded bunch covered by connective tissue. This structure is called ***Glomus*** (Fig. 13.8). Each glomus consists of an afferent artery; one or more coiled (S-shaped) connecting vessels; and an efferent vein.

Blood flow through the glomus is controlled in two different ways:

Firstly, the wall of the afferent artery has a number of elevations that project into the lumen; and probably have a valvular function. These projections are produced partly by endothelium, and partly by muscle.

Secondly, the connecting vessels have thick muscular walls in which the muscle fibers are short and thick with central nuclei. These cells have some resemblance to epithelial cells and are, therefore, termed ***epithelioid cells*** (Fig. 13.9). They have similarities to pericytes present around capillaries. The lumen of the connecting channel can be occluded by contraction (or swelling) of epithelioid cells.

Glomera are found in the skin at the tips of the fingers and toes (specially in the digital pads and nailbeds); in the lips; the tip of the tongue; and in the nose. They are concerned with the regulation of the circulation in these areas in response to changes in temperature.

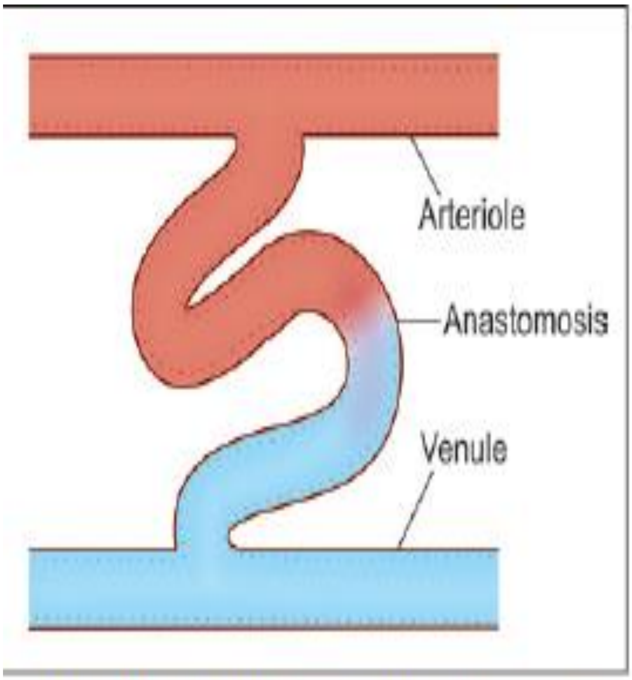


Fig. 13.8: An arteriovenous anastomosis (glomus) (Schematic representation)

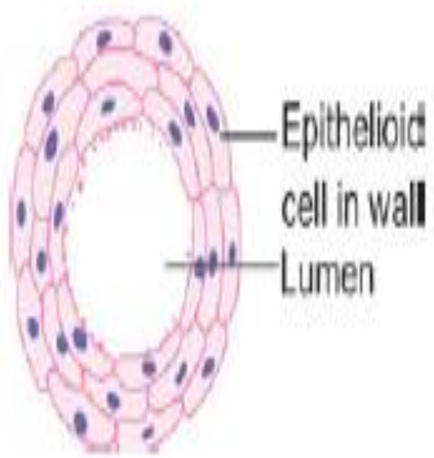
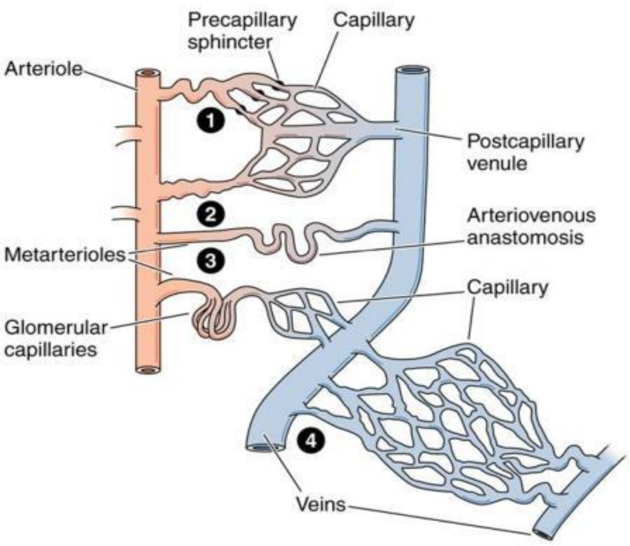


Fig. 13.9: Section across the connecting channe of an arteriovenous anastomosis showing epithelioid cells (Schematic representation)

ARTERIOVENOUS ANASTOMOSES



- In addition to capillary and sinusoidal connections between arteries and veins by **arteriovenous anastamoses.**
- In the anastomoses most commonly **between arterioles and venules.**
- Endothelium lies directly upon a specialized tunica media comprising a sphincter.
- When the **shunt is closed** arterial blood passes into the **regular capillary bed.**
- When the shunt is **open**, much of the blood **bypasses** the capillary bed and passes directly in to the vein.

Note

Arteriovenous anastomoses are few and inefficient in the newborn. In old age, again, arteriovenous anastomoses of the skin decrease considerably in number.

Precapillary Sphincters and Thoroughfare Channels

Arteriovenous anastomoses control blood flow through relatively large segments of the capillary bed. Much smaller segments can be individually controlled as follows.

Capillaries arise as side branches of terminal arterioles. The initial segment of each such branch is surrounded by a few smooth muscle cells that constitute a ***precapillary sphincter*** (Fig. 13.10). Blood flow, through any part of the capillary bed, can be controlled by the precapillary sphincter.

In many situations, arterioles and venules are connected (apart from capillaries) by some channels that resemble capillaries, but have a larger caliber. These channels run a relatively direct course between the arteriole and venule. Isolated smooth muscle fibers may be present on their walls. These are called ***thoroughfare channels*** (Fig. 13.10). At times when most of the precapillary sphincters in the region are contracted (restricting flow through capillaries), blood is short circuited from arteriole to venule through the thoroughfare channels. A thoroughfare channel and the capillaries associated with it are sometimes referred to as a ***microcirculatory unit***.

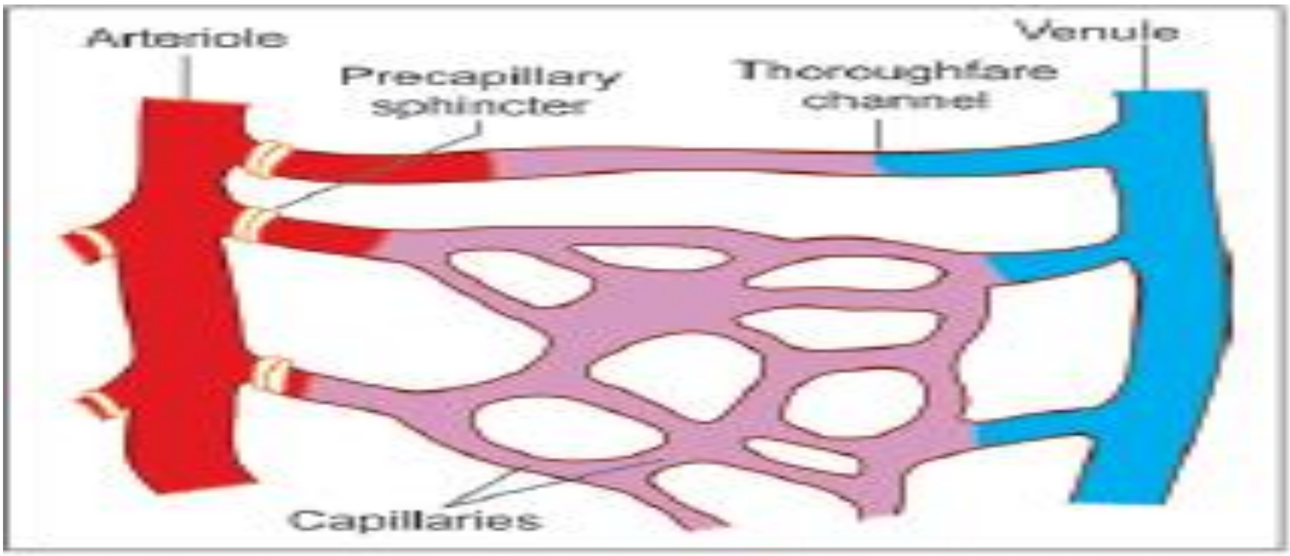


Fig. 13.10: Precapillary sphincters and thoroughfare channels (Schematic representation)

The Heart

The heart is a muscular organ that pumps blood throughout the blood vessels to various parts of the body by repeated rhythmic contractions.

Structure

There are three layers in the wall of the heart:

1. The innermost layer is called the ***endocardium***. It corresponds to the tunica intima of blood vessels. It consists of a layer of endothelium that rests on a thin layer of delicate connective tissue. Outside this there is a thicker ***subendocardial layer*** of connective tissue.
2. The main thickness of the wall of the heart is formed by a thick layer of cardiac muscle. This is the ***myocardium***.
3. The external surface of the myocardium is covered by the ***epicardium*** (or ***visceral layer of serous pericardium***). It consists of a layer of connective tissue that is covered, on the free surface, by a layer of flattened mesothelial cells.

There are rings of dense fibrous tissue. Similar dense fibrous tissue is also present in the interventricular septum. These masses of dense fibrous tissue constitute the 'skeleton' of the heart. They give attachment to fasciculi of heart muscle.

The valves of the heart are folds of endocardium that enclose a plate like layer of dense fibrous tissue.

Note:

Atrial myocardial fibers secrete a ***natriuretic hormone*** when they are excessively stretched (as in some diseases). The hormone increases renal excretion of water, sodium and potassium. It inhibits the secretion of renin (by the kidneys), and of aldosterone (by the adrenal glands) thus reducing blood pressure.

Conducting system of the Heart

Conducting system of the heart is made up of a special kind of cardiac muscle. The ***Purkinje fibers*** of this system are chains of cells. The cells are united by desmosomes. Intercalated discs are absent. These cells have a larger diameter, and are shorter, than typical cardiac myocytes.

Typically each cell making up a Purkinje fiber has a central nucleus surrounded by clear cytoplasm containing abundant glycogen. Myofibrils are inconspicuous and are confined to the periphery of the fibers. Mitochondria are numerous and the sarcoplasmic reticulum is prominent. ***Nodal myocytes*** [present in the atrioventricular (AV) node and the sinoatrial (SA) node] are narrow, rounded, cylindrical or polygonal cells with single nuclei. They are responsible for pacemaker functions. ***Transitional myocytes*** are present in the nodes, and in the stem and main branches of the AV bundle. They are similar to cardiac myocytes except that they are narrower. Conduction through them is slow.

In the SA node and the AV node the muscle fibers are embedded in a prominent stroma of connective tissue. This tissue contains many blood vessels and nerve fibers.