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Histology of the Cardiovascular System

M1 – Cardiovascular/Respiratory Sequence

A. Kent Christensen, Ph.D.
Comparing biophysical and structural characteristics of vessels.
Middle-sized (muscular) artery
Three layers of wall ("tunica" = "coat" in Latin)

**Tunica intima**
- Endothelium + c.t.
- Longitudinal orientation
- Internal elastic lamina

**Tunica media**
- Smooth muscle, to regulate blood flow
- Circular orientation
- (Ext. elastic lamina)

**Tunica adventitia**
- Connective tissue sheath
- Longitudinal orientation
- Vasa vasorum
Middle-sized artery, LM

Lumen
Internal elastic membrane
Intima
Media
Adventitia
Vasa vasorum
Nerve
Artery wall, LM

tunica intima

internal elastic membrane

tunica media
(smooth muscle)

tunica adventitia
Intima and media, LM

Lumen

Intima

Internal elastic lamina

Media
Wall of middle-sized artery, elastin stain, LM
Femoral artery wall, stained for elastin, LM
Thickening of the tunica intima

**Arteriosclerosis (normal aging changes)**
- Fibrosis, elastic fragmentation

**Atherosclerosis (pathological)**
- Eccentric fibrous thickening, foam cells, lipid deposition, calcification.


*Sternberg 1992, Histology for Pathologists, p. 196.*
Fragmentation of internal elastic membrane, LM

FIG. 4. A,B: Temporal artery from a 72-year-old female who died suddenly from coronary heart disease. There was no past history of headache or temporal arteritis. Note the fragmentation of the elastic lamella with a little associated fibrosis (red coloration in B). Changes such as these are commonplace in the elderly and must not be interpreted as evidence of previous arteritis. (Elastic van Gieson).

Comparison of companion artery and vein

Artery: smaller, round, thick wall
Vein: Larger, irregular shape, thin wall

Femoral artery and vein
Compare histology of artery and vein

*Figure 11-18.* Diagram comparing the structure of a muscular artery (left) and accompanying vein (right). Note that the tunica intima and the tunica media are highly developed in the artery but not in the vein.
Valve in a vein, longitudinal section, LM

Blood flow

Cusp

Hadley Kirkman, Stanford (originally from Columbia P&S)
Arteriole and venule, LM

- Arteriole
- Venule
- Capillary
- Nerve
SEM of smooth muscle sheath around an arteriole

Figure 12–10. Scanning micrograph of a branching arteriole showing the circumferential arrangement of the single layer of smooth muscle cells. (Micrograph from Uehara, Y., and K. Suyama. J. Electron Microsc. 27:157, 1978.)
Arteriole wall, EM

- Lumen
- Junction
- Endothelium
- Smooth muscle
- Synapse

Erlandsen slide set, slide 6/D/5
Occluding (tight) junction, endothelium of capillary, EM

Figure 12–22. Micrograph of the junction of two endothelial cells in a muscle-type capillary. At the arrows the opposing membranes are joined to form an occluding junction. (Micrograph courtesy of E. Weihe.) (From Fawcett’s Histology)
Occluding (tight) junction, endothelium, freeze fracture EM
Figure 12–15. Normal human retinal blood vessels. These have been isolated by tryptic digestion of the neural and receptor elements, leaving behind only the vessels. At left is an arteriole, at right a venule, and between them is a network of capillaries of very uniform caliber. (Courtesy of T. Kuwabara.)
Capillary, longitudinal section, LM

- Capillary
- Fat cell
Capillary, longitudinal section, LM

- Skeletal muscle fiber
- Endothelial nucleus
- RBC
Capillaries seen in cross section, cardiac muscle, heart, LM

Cardiac muscle
Capillary types, continuous and fenestrated, EM diagram

Continuous (muscular)  Fenestrated (visceral)

Continuous:  skeletal muscle, lung, CNS, connective tissue, etc.

Fenestrated:  Intestinal tract, endocrine glands, kidney, pancreas, etc.

Fenestra= “window” in Latin.

Capillary diameter ≈ 10 µm

Figure 12-23. Schematic representation of the two most common types of capillaries. A, The continuous or muscle type with an uninterrupted endothelium. B, The fenestrated type, in which the endothelium varies in thickness and the thinnest areas have small pores closed by an exceedingly thin membranous diaphragm. (After Fawcett, D. W. In Orbison, J. L., and D. Smith, eds.: Peripheral Blood Vessels. Baltimore, Williams and Wilkins, 1962.)

Bloom and Fawcett Histology, 11th ed, fig 12-23, p 387
Continuous capillary, EM
Fenestrated capillary, EM

RBC
EM of continuous and fenestrated capillary walls

Pinocytotic vesicle (~70 nm)

Fenestrations (~80-100 nm)

Figure 12-24. Micrographs of segments of endothelium from the two types of capillary. A, Endothelium of the muscle capillary endothelium has vesicular invaginations of both adluminal and abluminal plasma membranes (at arrows). B, Endothelium of fenestrated capillary from the lamina propria of the colon is extremely thin and has pores closed by thin diaphragms (at arrows). (Micrographs courtesy of E. Weihe.)
Sinusoids are large capillaries (30-40 µm), usually fenestrated. Liver sinusoids have discontinuities (holes).
Passage of proteins across capillary wall

- Basal lamina of endothelium is not a significant barrier.
- Intercellular tight junctions are usually rather impermeable to water.
- Fenestrations pass mostly water and small proteins (<20K MW).

Mechanism (bidirectional):

- Discrete shuttling of vesicles
  - Non-specific fluid phase uptake (pinocytotic vesicles).
  - Specific receptor-mediated transport (coated vesicles with clathrin). For example: albumin, insulin, transferrin, LDL.

Correlation with physiology

- Physiologist’s “large pore” transport is probably this vesicular transport.
- Physiologist’s “small pore” transport is probably between endothelial cells and through fenestrations.
EM tracer protein experiment to test for vesicle transport

- At 35 seconds, tracer protein is in the lumen and in pinocytotic vesicles, but not in pericapillary space.

- At 60 seconds, tracer protein is in the lumen, pinocytotic vesicles, and in the pericapillary space, showing that the protein has been transported across the endothelial wall.

- Tight junctions between endothelial cells prevent passage between the cells.
Pericytes (Rouget cells) are common on capillaries and on postcapillary venules, EM.
Possible pericyte functions: (1) Stem cell to repair capillary damage or for new growth, (2) contractility (has smooth muscle type myosin, actin, tropomyosin).
Arteriovenous anastomosis (shunt), a short circuit

- In cold weather you don't want to lose heat at the skin surface, so the shunts are open, and not much blood goes to the skin papillary loops (capillaries).
- In hot weather the shunts are closed, so blood goes to the skin papillary loops, and the blood can thus be cooled by evaporation of sweat at the skin surface.

Original Source: Wheaters, Figure 9.18
HEART WALL

**Endocardium** = endothelium + connective tissue (like intima)

Myocardium = thick cardiac muscle (like media)

**Epicardium** = visceral pericardium = simple squamous epith + fatty connective tissue

The AV valve margins are supported by chorda tendinae and papillary muscles.
Wall of atrium and ventricle, heart, LM

- Pericardial cavity
- Pericardium
- Epicardium
- Fat
- Coronary artery
- Atrium
- Endocardium
- Lumen
- Cardiac “skeleton” (fibrous)
- Atrio-ventricular valve

Erlandsen slide set, slide 6/B/8
Cardiac fibrous skeleton (in blue)

FIGURE 12.18
Fibrous skeleton of the heart as seen with the two atria removed. This fibrous network (indicated in blue) serves for the attachment of cardiac muscle; it also serves for the attachment of the cuspid valves between the atria and ventricles and for the semilunar valves of the aorta and the pulmonary artery. The atrioventricular bundle passes from the right atrium to the ventricular septum via the membranous septum of the fibrous skeleton.

In the heart there are atrioventricular valves (tricuspid, mitral bicuspid), and semilunar valves (aorta, pulmonary).

Valves arise from the fibrous skeleton. The valve leaflet is dense irregular connective tissue (collagen, elastin). The valve is covered with endothelium.
Diagram of heart, showing cardiac conduction system

**Sinoatrial (SA) node:** Pacemaker.

**Atrioventricular (AV) node.**

**Atrioventricular bundle (of His):** conducts across the AV septum (fibrous skeleton).

**Purkinje fibers** (composed of Purkinje cells).

Branches to supply both ventricles (apex first). In ventricle subendocardial layer.

Gray’s Anatomy, [wikimedia commons](https://commons.wikimedia.org/wiki/Gray%27s_Anatomy)
Purkinje cells, human heart

Usual cardiac muscle

Purkinje cells

Ventricular lumen

Endocardium

Source Undetermined
EM of Purkinje cell, showing sparse and disorganized myofibrils
Large (elastic) arteries: wall of aorta

Large arteries: aorta, pulmonary, brachiocephalic, common carotid.

Intima has abundant elastic fibers, oriented longitudinally.

Boundary between the intima and media often unclear by LM.

Media has abundant concentric elastic sheets (fenestrated) and smooth muscle cells (that make the extracellular matrix and elastic sheets).

Adventitia rather thin.
Wall of aorta, stained for elastin, LM
EM of aortic wall, media & adventitia

el = Elastic lamellae
sm = Smooth muscle
C = Collagen bundle
Large veins: inferior vena cava, very low power


Large veins: vena cava, external jugular, pulmonary, external iliac.
Wall of the vena cava, showing longitudinal smooth muscle in adventitia, LM
LYMPHATIC VESSELS

- Lymphatic vessels drain excess fluid from the tissues. They begin as blind lymphatic capillaries which take up excess tissue fluid. Lymph vessels contain no RBCs, but have some lymphocytes.
- Lymph flows through larger and larger collecting vessels, with histology resembling that of venules and veins (with valves).
- Occasional lymph nodes are interposed in the lymphatic vessel pathway, so the lymph flows through them (macrophages monitor the lymph, lymphocytes may engage in immune activities).
- Lymph reaches the thoracic duct and right lymphatic duct, both of which empty lymph into veins at the base of the neck, thus restoring the fluid and any content (proteins, etc.) to the blood.
Lymphatic capillary

Figure 11–22. Structure of a lymphatic capillary at the electron microscope level. Note the overlapping free borders of endothelial cells, the discontinuous basal lamina (arrows), and the attachment of anchoring fibrils (AF). (Courtesy of J James.)

Junqueira and Carneiro, Basic Histology 10th ed., 2003, page 230, fig. 11-22
Comparison of a small vein and a lymphatic vessel

Vein

Lymphatic

Valve
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