Circulatory System

- blood and lymphatic vascular systems
- Heart, artery, vein, capillary
- The lymphatic vascular system begins in the lymphatic capillaries, terminate in the blood vascular system

钟近洁 0017152@zju.edu.cn
Cardiovascular System

• Heart - pump the blood
• Arteries (A) - efferent vessels
• Capillaries - anastomosing thin tubules where interchange between blood and tissue takes place
• Veins (V) - convergence of the capillaries into a system of larger channels to the heart
General structure of three types of BV
General structure of BV
Structure of Blood Vessels – 3 Layers “Tunics”

- **Tunica intima**
  - Endothelium
  - Subendothelial layer
  - Internal elastic membrane

- **Tunica media**

- **Tunica externa**
  - External elastic membrane

- **Artery**
  - Lumen

- **Vein**
  - Lumen
  - Valve

- **Capillary**
  - Basement membrane
  - Endothelial cells

- **Capillary network**
Basic structure of vessels

• Tunica intima
  • Endothelial layer
  • Subendothelial layer
  • Internal elastic lamina (arteries)

• Tunica media
  • Concentric layers of helically arranged smooth muscle cells
  • Varying amounts of elastic fibers, reticular fibers, and proteoglycans
  • External elastic membrane-(larger arteries)

• Tunica Adventitia - longitudinally oriented collagen (type I) and elastic fibers
Artery, vein, capillary

Fig 11  Small artery and small vein
(HE stain,  high mag.)
Small artery

Endothelial layer
Smooth muscle layer
Connective tissue layer
Endothelium

Simple squamous epithelium
- A semipermeable barrier, cell junction
- Provide a non-thrombogenic surface
- W-P body, typical structure in the endothelial cell

Inflammation

Formation of new blood vessels (angiogenesis)

Vasoconstriction and vasodilation, and hence the control of blood pressure

Repair of damaged or diseased organs via an injection of blood vessel cells

Angiopoietin-2 works with VEGF to facilitate cell proliferation and migration of endothelial cells
Weibel–Palade bodies in endothelial cell

They store and release two principal molecules, von Willebrand factor and P-selectin, and thus play a dual role in hemostasis and inflammation.
Formation of thrombus

The integrity of the endothelial layer, which prevents contact between platelets and the subendothelial connective tissue, is an important antithrombogenic mechanism.
A. Normally adherens junctions open just wide enough to allow white blood cells through the gap into the tissues.

B. During Ebola virus infection, adherens junctions are so wide open that red blood cells can leak out into the tissues.
Large Elastic Arteries

- Aorta and its large branches
- Thick intima
- Media concentrically perforated elastic lamina with smooth muscle and ground substance in between
- Poorly formed external layer

Arteries - resist changes in blood pressure and regulate blood flow
Elastic artery Aorta
HE staining
Lumen of elastic artery

Muscular Artery

IEL

elastic stain
Elastic artery - elastic stain

↓ internal elastic lamina  ★ smooth muscle layer  ★ external elastic lamina
Muscular Arteries

- Most arteries in the body
- Thin intimal layer
- Well developed internal elastic lamina
- Muscle layer up to 40 layers
- Varying intermingled elastic fibers
- adventitia consists of nerves, vessels, collagen, elastic fibers, fibroblasts and adipose cells
Classic muscular artery- elastic stain

↑ internal elastic lamina  ★ smooth muscle layer  ↓ external elastic lamina
Smaller muscular artery - elastic stain
Smaller muscular artery- very thin intima, thick internal elastic lamina, prominent smooth muscle cell nuclei.
Small muscular artery
• Arterioles - < 0.5mm in dia., endothelial cells, thin subendothelial layer, most have no internal elastic layer, 1 or 2 layers of smooth muscle, no external elastic lamina

Arteriole & venule
Comparison between elastic artery and muscular artery

|                  | t. Intima                          | t. Media                                            | t. Adventitia
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ELASTIC ARTERY</strong></td>
<td>• Endothelium</td>
<td>Alternating layers of smooth muscle &amp; elastic fibres</td>
<td>collagen &amp; elastic fibres, fibroblasts</td>
</tr>
<tr>
<td></td>
<td>• Connective tissue</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>MUSCULAR ARTERY</strong></td>
<td>• Endothelium</td>
<td>• mostly smooth muscle</td>
<td>Connective tissue</td>
</tr>
<tr>
<td></td>
<td>• Internal elastic membrane</td>
<td>• collagen fibres</td>
<td>+/- external</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• occasional elastic fibres</td>
<td>elastic membrane</td>
</tr>
</tbody>
</table>

*thin layer*
Artery

Intima

Media

Endothelium

Adventitia

Vein

Internal elastic lamina

Endothelium
Veins

• Capacitance vessels - 70% of blood volume
• Venules - thin walls
• Small and medium sized veins - thin intimia, thin media, valves
Muscular vein with valve: formed from intima
venule

Arteriole

Capillary
Capillaries

• 1 or several endothelial cells
• Basement membrane
• Diameter 7 to 9 µm
• Pericytes - partly surround the endothelial cells
• Three types
  Fenestrated - kidney, intestine, endocrine
  Discontinuous (sinusoid) – liver, spleen, bone marrow
  Continuous-muscle tissue, connective tissue, exocrine glands, and nervous tissue
General structure of capillary

Both pericytes and endothelial cells share a basement membrane where a variety of intercellular connections are made.

Pericyte: contractile cells that wrap around the endothelial cells. Pericytes regulate capillary blood flow, the clearance and phagocytosis of cellular debris, and the maturation of endothelial cells.
Capillary bed
What happened in capillary
Types of microcirculation formed by small blood vessels. (1) The usual sequence of arteriole metarteriole capillary venule and vein. (2) An arteriovenous anastomosis. (3) An arterial portal system, as is present in the kidney glomerulus. (4) A venous portal system, as is present in the liver.
Structure of Capillaries: **Continuous Capillary** has many **Tight Junctions** with spaces called **Intercellular Clefts** for passage of small molecules.

(a) **Continuous capillary.** Least permeable and most common (e.g., skin, muscle).
Continuous capillary in the brain

Complete Basement membrane
Complete endothelium

Protoplasmic astrocyte
Fibrous astrocyte
Fenestrated Capillaries have pores passing right through their endothelial cells, allowing for a high rate of exchange of small molecules.

(b) Fenestrated capillary. Large fenestrations (pores) increase permeability.
Fenestrated capillary in the kidney
Basement membrane
Uncomplete endothelium
Structure of Capillaries: Sinusoids have big fenestrations, few tight junctions, and wide intercellular clefts, as well as incomplete basement membranes, allowing for exchange of large molecules (whole cells).

(c) Sinusoidal capillary. Most permeable. Occurs in special locations (e.g., liver, bone marrow, spleen).
Sinusoid
Dicontinous capillary in the liver

No basement membrane
uncomplete endothelium
Capillary EM
Which type?
Heart

- Right pulmonary arteries
- Superior vena cava
- Right atrium
- Cusp of right AV (tricuspid) valve
- Right ventricle
- Inferior vena cava
- Pulmonary semilunar valve
- Left pulmonary arteries
- Left pulmonary veins
- Left atrium
- Cusp of left AV (bicuspid) valve
- Chordae tendineae
- Papillary muscles
- Left ventricle
- Descending aorta
Tunics of the Heart Wall

• Endocardium
  • Endothelial layer
  • Subendothelial layer - veins, nerves and Purkinje cells

• Myocardium
  • Cardiac muscle cells

• Epicardium
  • Visceral layer of the pericardium - mesothelium
  • Subepicardial layer of loose connective tissues - veins, nerves and ganglia
Valve in heart

- Tricuspid valve (closed)
- Pulmonary valve (open)
- Aortic valve (open)
- Mitral valve (closed)

Looking down from the top of illustration on left.
Heart Fibrous Skeleton

• Consists of plate of fibrous connective tissue between atria and ventricles
• Fibrous rings around valves to support
• Serves as electrical insulation between atria and ventricles
• Provides site for muscle attachment
Valve: folding of endocardium, no cardiac muscle fiber
Fibrous skeleton: dense connective tissue
Conducting System of Heart

Specialised heart muscle cells
left and right bundle of His in subendocardial area
Purkinje fibers

- Subendocardial area
- Cells larger, pale cytoplasm, few myofibrils, rich in glycogen but no T tubule system
- Junctions via desmosomes and gap junctions rather than intercalated disks
Purkinje fibers