Cardiovascular System
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Cardiovascular System Lecture Objectives

• Describe the histologic structure of the 3 layers or tunics making up the wall of blood vessels and the heart.

• Discuss and compare the variation in structure and function of capillaries, arterioles, muscular arteries, elastic arteries, veins, and venules.

• Discuss the structure and function of the lymphatic vascular system.
Cardiovascular System Lecture Outline

• Introduction

• Blood vessels
  • Basic structure
  • Types of blood vessels

• Heart
  • Gross structure
  • Three layers of the heart

• Embryological development of the heart
Cardiovascular System Lecture Outline

- Introduction
Function of the Cardiovascular System

The main job of the cardiovascular system is to transport (and exchange) nutrients, oxygen, body fluids, waste material, heat, and blood cells around the body.
Components of the Cardiovascular System

• The cardiovascular system is basically a closed system of plumbing: blood circulates through pipes (blood vessels) and is propelled by an in-line pump (the heart).

• Blood flows through the system from: heart → elastic artery → muscular artery → arteriole → capillaries → venules → vein → heart
Vessels of the Cardiovascular System
Cardiovascular System Lecture Outline

• Introduction

• Blood vessels
  • Basic structure
The Three Layers (Tunics) of Blood Vessels

Artery
- Intima
- Endothelium
- Subendothelium
- Media
- Externa
- Vasa vasorum

Vein
- Intima
- Valves
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Capillaries

• Smallest diameter of all blood vessels (7-9 μm).
• Allow exchange of metabolites and waste between blood and surrounding tissue.
• Composed of a single layer of endothelial cells resting on a basal lamina.
• Three types:
  • Continuous capillaries (least permeable)
  • Fenestrated capillaries
  • Sinusoidal capillaries (most permeable)
Continuous (Tight) Capillaries

- Intact endothelium and basement membrane.
- May contain tiny pinocytotic vesicles that transport certain substances across the endothelium.
- Least permeable of all three capillary types.
- Found in muscle, connective tissue, glands and nerve tissue.
Fenestrated Capillaries

- Endothelial cells are perforated with small fenestrations (holes).
- Basement membrane is intact.
- Permeability somewhere between that of continuous and sinusoidal capillaries.
- Found in places where substances need to move quickly between tissues and blood (e.g. kidney, intestine, and endocrine organs).
Fenestrated Capillary

- Basement membrane
- Nuclei of endothelial cells
- Erythrocyte
- Intercellular cleft
- Lumen
- Fenestrations
Sinusoidal Capillaries (Sinusoids)

- Endothelial cells have big fenestrations and gaps (clefts) between cells.
- Basal lamina is discontinuous.
- Most permeable of all three capillary types.
- Located in liver, bone marrow, and spleen.
Sinusoid

- Large fenestrations
- Discontinuous basement membrane
- Lumen
- Intercellular cleft
- Nucleus of endothelial cell
Sinusoidal capillaries in spleen
Venules and Arterioles

- Relatively thin wall and big lumen.
- Media has just a few smooth muscle cells here and there.

- Relatively thick wall and small lumen.
- Media has 1-3 layers of smooth muscle cells.
Arterioles and venules
**Arteries**

**Muscular arteries**
- Thick media composed of smooth muscle cells.
- Prominent internal and external elastic lamina.
- “Named” arteries (e.g. femoral artery) are usually muscular arteries.

**Elastic arteries**
- Thick media composed of sheets of elastic fibers interspersed with layers of smooth muscle cells.
- Vasa vasorum in the externa.
- The aorta and its large branches are elastic arteries.
Small muscular artery
Elastic artery

- Tunica intima
- Tunica media with sheets of elastin and smooth muscle
- Tunica externa with vasa vasorum

Elastic artery
Veins

Medium-sized vein

- Thin intima, may have valves.
- Thin media composed of a few elastic fibers and smooth muscle cells.
- Relatively thick externa composed of longitudinal collagen and elastic fibers.

Large vein

- Thin intima, may have valves.
- Thin media, like medium-sized veins.
- Relatively thick externa composed of longitudinal collagen fibers, elastic fibers, and smooth muscle cells. Also has Vasa vasorum.
- “Named” veins (e.g., portal vein) are usually large veins.
Medium muscular artery and medium vein
Large vein

- Tunica media
- Valve
- Tunica adventitia
Lymphatic Vessels

- Lymphatic system collects interstitial fluid (lymph) that leaks from blood vessels into connective tissue, and return it to blood
- Flow is unidirectional
- Lymphatic capillaries consist of one layer of endothelial cells and a discontinuous basal lamina
- Lymphatic capillaries merge, forming lymphatic vessels (with very thin walls)
Lymphatic capillary

- Endothelium of lymphatic capillary
- Interstitial fluid
- Opening
- Lymph
- Anchoring filament

Lymphatic capillary
Venule and lymphatic vessel
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The heart is composed of three layers and surrounded by a pericardial cavity.
Endocardium

- Inner layer of heart (analogous to intima of blood vessels).
- Consists of endothelium and basal lamina resting on a thin layer of connective tissue.
- Subendocardium is a layer of loose connective tissue between endocardium and myocardium. It contains nerves, blood vessels, and branches of the conducting system of the heart.
- Valves are considered part of the endocardium.
Endocardium right ventricle: thin layer of endothelial cells
Endothelium

Dense connective tissue

Endothelium

Tricuspid valve, high power
Muscle fibers are arranged in a spiral pattern around the chambers of the heart. When the fibers contract, the heart twists and wrings out blood from the chambers.

Cardiac muscle fibers are inserted into a dense fibrous connective tissue skeleton of the heart.

Impulse-generating and conducting cells are also present in the myocardium.
Myocardium
Epicardium

- Outer layer of the heart.
- Consists of a surface of mesothelium (simple squamous epithelium) supported by a thin layer of connective tissue.
- Epicardium contains loose connective tissue, large amounts of adipose tissue, nerves, and blood vessels, including the coronary vessels.
Conducting System

- Consists of modified cardiac muscle cells (Purkinje fibers) specialized for initiation and conduction of electrochemical impulses.
- Cells are distributed in a pattern that coordinates contraction of myocardium.
Purkinje fibers: larger and lighter-staining (have more glycogen, less myofibrils than regular myocytes)
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Endocardial Heart Tubes

- Cardiovascular system starts developing in week 3.
- Mesoderm gives rise to two endocardial heart tubes.
- Tubes fuse and connect to form the primitive heart tube.
Two endocardial heart tubes
Tubes fuse, forming primitive heart tube
Four Chambers of the Early Heart

The heart tube folds upon itself, forming four primitive chambers:

1. Inflow tract (sinus venosus)
2. Primitive atrium
3. Primitive left ventricle
4. Primitive right ventricle (bulbus cordis)
Heart tube lengthens and folds
Heart tube lengthens and folds
First Heartbeat

- The first heartbeat occurs at day 21 or 22.
- Originates in the muscle, forming peristaltic waves in the sinus venosus.
- By day 28, blood flows in coordinated fashion:
  - Flows into sinus venosus, then primitive ventricle
  - Ventricle contracts, pushing blood into bulbus cordis, truncus arteriosus (future aortic sac), and then to rest of embryo
Atria are divided first by the septum primum, then by the septum secundum.

The septum secundum contains a hole called the foramen ovale.

A valve (derived from degeneration of the septum primum tissue) covers the foramen ovale.

This is an excellent design because it lets blood flow from right to left ventricle, bypassing lungs. At birth, the foramen usually closes permanently.
Septum primum and secundum formation

Superior vena cava
Septum secundum
Right atrium
Septum primum
Blood flow
Left atrium
Foramen secundum
Foramen ovale
Sectioned atrioventricular septum
Left ventricle
Muscular ventricular septum
Right ventricle
Inferior vena cava

Early 7th week (43 days)
Fetal vs. Postnatal Circulation

• Fetal circulation is designed to carry oxygenated blood from the placenta to fetal circulation, bypassing the lungs.

• At birth, the infant’s lungs expand and oxygenate the blood. Circulation of blood through the placenta ceases.

• After birth, the foramen ovale and umbilical vessels are no longer needed and they close.
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