HISTOLOGY OF THE CIRCULATORY SYSTEM

The cardiovascular system is subdivided into two functional parts

1. **Blood vascular system**

a. The blood vascular system distributes nutrients, gases, hormones to all parts of the .body; collects wastes produced during cellular metabolism

,b. The blood vascular system consists of a continuum of blood vessels (arteries .arterioles, capillaries, venules, veins) and a muscular pump (heart)

.c. Blood is the fluid found within the blood vascular system

Lymph vascular system .2

a. The lymph vascular system collects tissue fluid from tissues and returns it to the .blood vascular system

b. The lymph vascular system consists of blind-ended capillaries (lymphatic capillaries) ,.connected to venous vessels (lymphatic vessels) and various lymphoid organs (e.g .(lymph nodes

c. The fluid found within the lymph vascular system is lymph. Composition of lymph in smaller lymphatic vessels is very similar to tissue fluid.

- 1. The heart wall can be viewed as a three-layered structure.

- a. Inner layer = **endocardium**
- b. Middle Layer = **myocardium**
- c. Outer layer = **epicardium** (also called the **pericardium**)

- 2. Except for the smallest vessels, blood and lymphatic vessel walls can also be viewed as
- three-layered structures.

- a. Inner layer = **tunica intima**
- b. Middle layer = **tunica media**
- c. Outer layer = **tunica adventita**

Structure of the heart wall

- 1. The endocardium is the inner layer of the heart wall and consists of the endothelial
- lining and the underlying connective tissue layers.

- a. The lumen of the heart is lined by an endothelium consisting of a typical simple
- squamous epithelium with well-developed zonulae occludens and basal lamina.

- b. A connective tissue region consisting of three layers separates the endothelium from

- the myocardium in humans consist of:-
- (1) A thin layer of loose FECT (containing mainly fine collagen fibers) referred to as subendothelial layerwhih is next to the endothelium.

- (2) A thicker layer of moderately dense FECT (with many elastic fibers) and some smooth muscle forms the center of the connective tissue region.

- (3) A thin layer of loose FECT (often referred to as the subendocardial layer)
- containing many blood vessels joins the endocardium to the myocardium

- Purkinje fibers run in this layer in the interventricular septum.

The **myocardium** .2

- is the middle layer of the heart wall and contains the cardiac muscle throughout most of the heart.
- a. Cardiac muscle cells in the myocardium are arranged in strands whose ends attach to the dense connective tissue which surrounds the valves.
- b. Loose FECT holds bundles of cardiac muscle cells/fibers together and contains numerous blood vessels.
- c. Dense FECT (heavily collagenous) replaces the cardiac muscle in region around each of the major heart valves This connective tissue frame around each valve is called the **cardiac skeleton**

Cardiac Muscle

Intercalated Disc

The **epicardium**

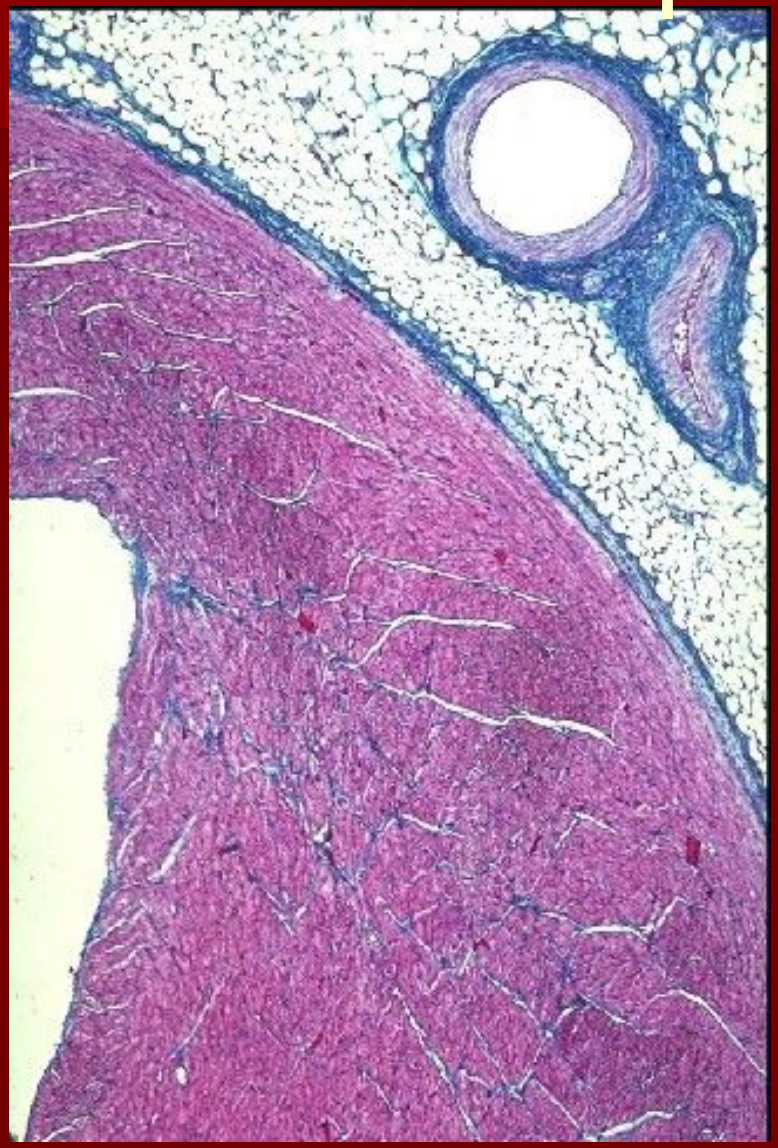
- is the outer layer of the heart and consists of a connective tissue region covered by a mesothelium on its outer surface.
- a. The connective tissue region consists of three layers in humans.

- (1) The inner two regions are referred to collectively as the **subepicardial layer** and contain large blood vessels (coronary vessels), nerves, and varying amounts of adipose tissue.

- (a) A thin layer of loose FECT lies next to the myocardium.
- (b) A thicker layer of slightly denser FECT lies outside the loose FECT layer.

- (2) A thin layer of loose FECT with many elastic fibers connects the connective tissue layers of the epicardium to the mesothelial covering.

Epicardium



- DFIACT
- Adipose Tissue
- Coronary vessels and cardiac nerves
- Mesothelium

- b. A mesothelium (simple squamous epithelium) covers the outer surface of the heart (except where the arteries leave and the great veins enter the heart). This covering epithelium closely resembles the mesothelial covering of the other thoracic and abdominal organs.

- B. The thickness of the heart wall and the thickness of the layers within the heart wall varies with location.

- 1. The myocardium is thickest in the ventricular region, especially the left ventricle, and contains more cardiac muscle in the ventricles than in the atrium. The myocardium around the valves contains only dense collagenous CT which forms the cardiac skeleton.

- 2. The endocardium and epicardium are thinner in the ventricles than in the atria

- In the atria, the cardiac muscle cells contain small granules (called atrial specific granules) in the perinuclear sarcoplasm which can be observed with TEM. These granules are the source of atrial natriuretic peptide (ANP), a hormone which influences blood pressure by affecting kidney function

Special features of the heart

- 1. **Valves** are out growths from the endocardium which prevent backflow
- of blood. Valves contain three components.

- .
- 2. The **cardiac skeleton** supports each of the heart valves. Cardiac
- muscle in the myocardium is replaced by dense regular FECT (heavily collagenous)

- 3. Cardiac muscle fibers in the atria and ventricles are highly organized.
- a. Cardiac muscle cells are attached end-to-end in branching strands.
- b. The ends of most strands of cardiac muscle fibers are attached to the cardiac skeleton

- "**Pacemakers**"
- in the heart are modified cardiac muscle cells.
- a. Cardiac muscle cells in the myocardium of the **sinoatrial (SA) node** are modified to serve as the pacemaker region. The plasma membrane of the cells has a high leakage rate, giving them the fastest intrinsic contraction rate among the populations

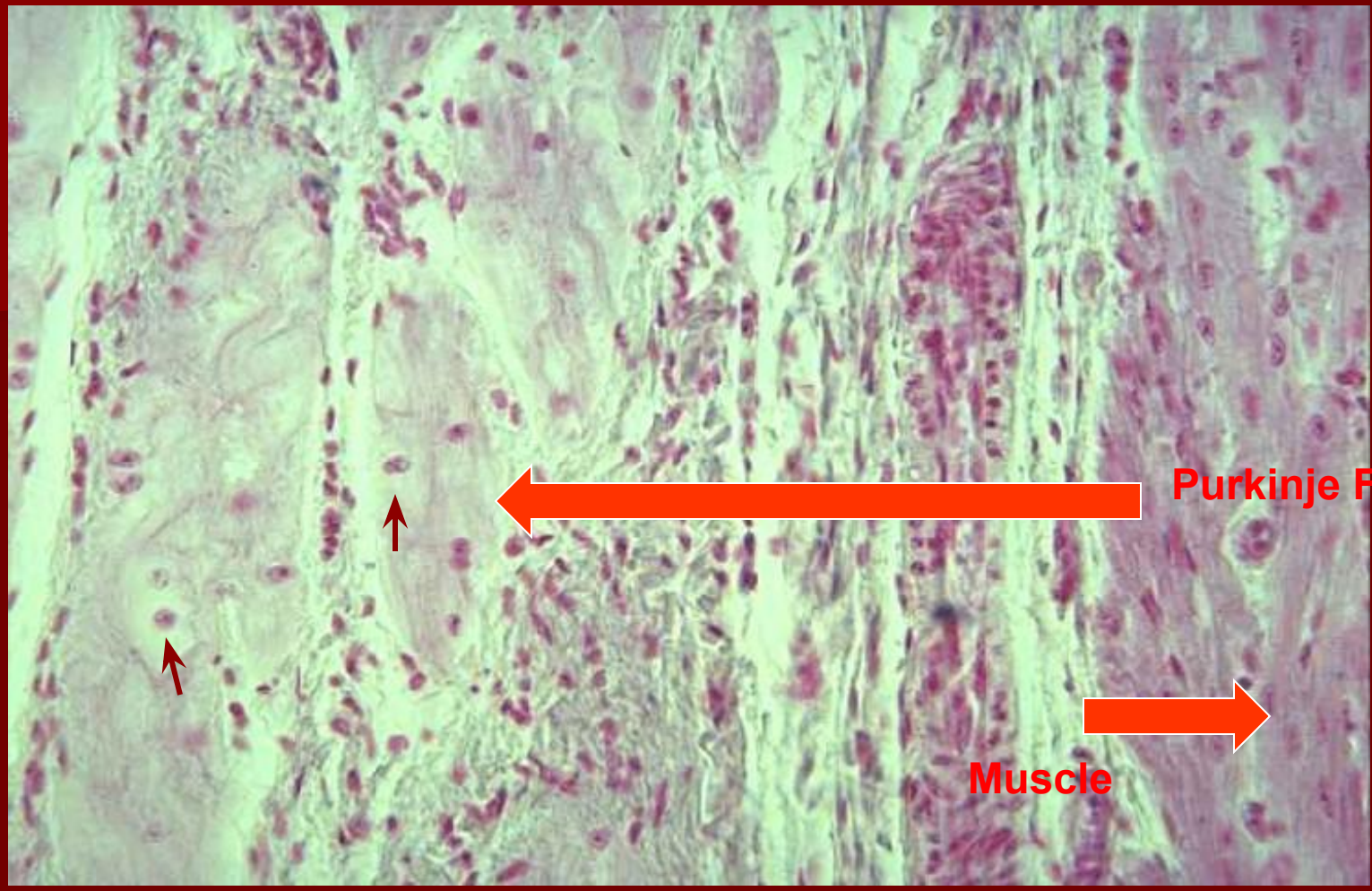
- b. Cardiac muscle cells in the **atrioventricular (AV) node** have a similar histological appearance, but have a lower intrinsic rate of contraction, so these cells do not normally act as a pacemaker region. These cells receive the wave of excitation from the cardiac muscle of the atria and pass the excitation on to the **bundle of His**.

The **impulse-conducting system**

- which connects the atria with the ventricles serves
- several functions.
- a. The impulse conducting system is made up of a series of **Purkinje fibers** which are specialized cardiac muscle cells.

- (1) Purkinje fibers are organized into a branched bundle (**Bundle of His**) which
- extends from the atrio-ventricular (AV) node, through the interventricular
- septum down to the apex of the ventricles.

- (2) Purkinje fibers are attached (by intercalated disks) to cardiac muscle cells in the
- myocardium at the apex of the ventricles and along outer walls of both
- ventricles
- b. The impulse conducting system improves heart function in two ways



= Conduction System

AV Bundle of His + Purkinje Fibers

Microanatomy of Blood Vessels

- Most larger blood vessel walls contain three major layers with sublayering.
- 1. The tunica intima is the luminal layer.

- a. The lumen is lined by an endothelium of simple squamous epithelium.
- b. A subendothelial layer of loose FECT is present in most medium to large vessels
- and may contain scattered smooth muscle in larger vessels.

- 2. An internal elastic lamina (elastica interna) marks the boundary between the tunica
- intima and the tunica media.

- 3. The tunica media contains layers of either elastic laminae/lamellae (fenestrated sheets) or FECT alternating with layers of smooth muscle.

- 4. If present, the external elastic lamina (elastica externa) marks the boundary between
- the tunica media and the tunica adventita.

- 5. The tunica adventita contains loose to moderately dense FECT, +/- scattered smooth
- muscle cells. Small and medium arteries and veins are present in the tunica adventitia of large arteries and veins

Large arteries (also called **elastic arteries** or **conducting arteries**)

- **include the aorta and its largest main branches.**
- **(a. Tunica intima - thin (relative to other layers in this type of vessel)**
- **(1) Endothelium**
- **(2) Subendothelial layer contains some smooth muscle, elastic fibers, collagen fibers**
- **b. Internal elastic lamina - not as distinct as in other arteries**
- **c. Tunica media - thick**
- **(1) 40 - 60 distinct, concentrically arranged elastic laminae**
- **(2) Between elastic laminae - fibroblasts, elastic fibers, collagen fibers, spiral (to circular) smooth muscle**

- **d. Tunica adventita - thin; consists mainly of collagen fibers, blood vessels, nerves; some elastic fibers, fibroblasts, macrophages may also be present**

- **2. Function = to conduct blood from the heart to smaller arteries and to even out blood pressure and flow. The presence of elastic laminae gives these vessels elastic properties. They expand as the heart contracts (to modulate blood pressure and store energy) and recoil during ventricular relaxation (to maintain more even pressure in large arteries).**

Medium to small arteries (also called **muscular arteries**)

- **Tunica intima** - thin
- (1) Endothelium
- (2) Thin subendothelial layer consisting of scattered fine collagen and elastic fibers and a few fibroblasts
- b. **Internal elastic lamina** - very distinct, usually folded
- c. **Tunica media** - thick
- (1) Circular smooth muscle, 5 - 40 layers
- (2) Small amount of CT with collagen fibers and elastic fibers (longitudinal orientation) between muscle
- (3) Thickness decreases as diameter of vessel decreases
- d. **External elastic lamina** (May be indistinct in smaller muscular arteries)
- e. **Tunica adventita** - thick; loose FECT
- 2. Function - to distribute blood to smaller arterial vessels. The muscular wall resists damage due to relatively high blood pressure in these vessels

Arterioles

- 1. Structure
- a. **Tunica intima** - very thin consisting only of endothelium
- b. **Internal elastic lamina** - usually present except in smaller arterioles
- c. **Tunica media** - 1 to 5 layers of smooth muscle, some elastic fibers
- d. **Tunica adventita** - thin, consisting of longitudinally arranged collagen and elastic
- fibers
- 2. Function - to redistribute blood flow to capillaries and to alter blood pressure by altering peripheral resistance to blood flow. Arterioles can change diameter very drastically therefore affecting blood pressure and flow patterns. Arterioles are referred to as peripheral resistance vessels.

Capillaries

- 1. Structure - consist only of endothelium, but may be partially surrounded by pericytes.
- Three types of capillaries may be distinguished
- .
- a. Continuous (type I) capillaries have relatively thick cytoplasm and
- the capillary wall is continuous. Lateral cell surfaces of cells are characterized by
- zonula occludens (tight junctions), so materials move across cells via pinocytosis or
- diffusion. These capillaries occur in most organs.

- b. Fenestrated (type II) capillaries (Figure 13.18) have extremely thin cytoplasm and
- the capillary wall is perforated at intervals by pores or fenestrations. Lateral cell
- surfaces are characterized by zonula occludens (tight junctions). Materials
- apparently cross the cells through the fenestrations. These capillaries are found in
- the kidney and in endocrine glands.

- c. Sinusoidal capillaries are larger in diameter than the other types and have wide
- spaces between the lateral edges of the adjacent endothelial cells, so materials
- (and some cells) can move freely in and out of the capillary. Sinusoidal capillaries
- are found in the spleen, liver, and bone marrow.
- 2. Functions
- a. Capillaries are the site of normal exchange of materials between blood and tissue
- fluid.
- b. Capillaries may be a site of exit of WBCs from blood into tissue under some conditions, although this is probably more frequent in venules.

Venules

- Size varies from 10 microns (post-capillary venules) to 1 mm (muscular venules)

- 2. Post-capillary venules
- a. Structure - larger diameter than capillaries; consist of endothelium surrounded by pericytes

- b. Functions
- (1) Collect blood from capillaries
- (2) Respond to vasoactive agents (e.g., histamine, serotonin) by altering permeability

- (3) Also a site of exchange of materials between tissue fluid and blood
- (4) Site of exit of WBCs from blood into tissue

Larger muscular venules

- a. Structure
- (1) **Tunica intima** - thin; endothelium surrounded by outer sheath of collagen fibers
- (2) **Tunica media** - thin; 1 - 3 layers of smooth muscle (circular) with collagen and elastic fibers between muscles
- (3) **Tunica adventita** - thick; loose FECT containing longitudinal collagen fibers and scattered elastic fibers and fibroblasts
- b. Function - to collect blood from post-capillary venules

Small to medium veins

- 1. Structure
- a. **Tunica intima** - thin
- (1) Endothelium
- (2) Thin subendothelial layer
- (3) May be folded to form valves

- b. **Tunica media** - thin; circular smooth muscle, collagen fibers, some elastic fibers

- c. **Tunica adventita** - well developed; loose FECT with longitudinally arranged collagen and elastic fibers, bundles of longitudinal smooth muscle

- 2. Function - to collect blood from smaller venous vessels

Large veins - vena cavae and larger branches

- 1. Structure
- a. **Tunica intima** - thicker
- (1) Endothelium
- (2) Thin subendothelial layer

- b. **Internal elastic lamina** - usually distinguishable
- c. **Tunica media** - thin, poorly developed; mostly FECT; little smooth muscle

- d. **Tunica adventita** - very thick; moderately dense FECT with spirally arranged collagen fibers, elastic laminae, longitudinal smooth muscle

- 2. Function - to collect blood from medium sized veins and return it to heart

Microanatomy of Lymphatic Vessels

- A. **Lymph capillaries**
- 1. Structure - blind-ended tubules; consist only of endothelium (which lacks cell junctions); similar to post capillary venules of blood vascular system
- 2. Function - to collect excess tissue fluid
- B. **Small to medium lymphatic vessels** (Plate 31)
- 1. Structure
- (similar to venous blood vessels of the next smaller size)
- a. **Smaller lymphatic vessels** consist of endothelium surrounded by collagen and elastic fibers and a few smooth muscle cells

Medium-sized lymphatic vessels

- b.
- (1) **Tunica intima** - thin; endothelium surrounded by few collagen and elastic fibers; may be folded to form valves
- (2) **Tunica media** - thin; helically arranged smooth muscle, elastic fibers
- (3) **Tunica adventita** - thicker; collagen and elastic fibers, few smooth muscle cells
- 2. Function - to collect lymph from lymph capillaries

Large lymphatic vessels

- C. include the thoracic duct and right lymphatic duct.
- 1. Structure
- a. **Tunica intima** - thin
- (1) Endothelium
- (2) Subendothelial layer of collagen and elastic fibers, some longitudinal smooth muscle
- b. **Tunica media** - thickest; longitudinal and circular smooth muscle bundles, loose FECT (similar to a medium blood vein)
- c. **Tunica adventita** - not well developed; coarse collagen fibers, few longitudinal smooth muscle
- 2. Function - to collect lymph from medium sized lymphatic vessels and return it to largeveins
- D. Lymphatic vessels of any size may appear empty, may contain faint pink material (proteins),or may contain lymphocytes.