CARDIOVASCULAR SYSTEM  PART 1
Dr. Larry Johnson
Objectives

Part 1
• Identify elastic and muscular arteries, arterioles, capillaries, venules and veins.
• Describe the intima, media, and adventitia of all vessels.

Part 2
• Describe the structure of the heart.
• Also regulation of blood flow, lymphatic vessels, and diseases

From: Douglas P. Dohrman  and TAMHSC Faculty 2012 Structure and Function of Human Organ Systems, Histology Laboratory Manual
Introduction
Multicellular Organisms Need 3 Mechanisms

1. Distribute oxygen, nutrients, and hormones
2. Collect waste
3. Transport waste to excretory organs
Introduction

Multicellular Organisms Need 3 Mechanisms

1. Distribute oxygen, nutrients, and hormones
2. Collect waste
3. Transport waste to excretory organs

The cardiovascular system is composed of two sets of closed vessels open only to each other. One goes to the lungs and the other to the rest of the body.
CARDIOVASCULAR SYSTEM

Brachiocephalic Trunk
Superior Vena Cava
Right Pulmonary Artery
Right Coronary Artery
Capillary Bed of the Liver
Inferior Vena Cava
Gallbladder
Capillary Bed of the Right Kidney
Ovarian Artery
Capillary Bed of the Ovaries

Configuration of arteries of the heart, liver, kidneys, and the uterus

The blood vessels of the respective organs are connected to the major arteries (aorta, light red) and veins (upper and lower vena cavae). The ovaries, where circulation is very good, can be seen adjacent to the uterus in the area of the pelvic cavity.
<table>
<thead>
<tr>
<th>COMPONENT</th>
<th>FUNCTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>HEART</td>
<td>- PRODUCE BLOOD PRESSURE (SYSTOLE)</td>
</tr>
<tr>
<td>ELASTIC ARTERIES</td>
<td>- CONDUCT BLOOD AND MAINTAIN PRESSURE DURING DIASTOLE</td>
</tr>
<tr>
<td>MUSCULAR ARTERIES</td>
<td>- DISTRIBUTE BLOOD, MAINTAIN PRESSURE</td>
</tr>
<tr>
<td>ARTERIOLES</td>
<td>- PERIPHERAL RESISTANCE AND DISTRIBUTE BLOOD</td>
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<td>CAPILLARIES</td>
<td>- EXCHANGE NUTRIENTS AND WASTE</td>
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<td>- COLLECT BLOOD FROM CAPILLARIES (EDEMA)</td>
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<td>VEINS</td>
<td>- TRANSMIT BLOOD TO LARGE VEINS, RESERVOIR</td>
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<td>LARGER VEINS</td>
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CARDIOVASCULAR SYSTEM

MUSCULAR ARTERIES - DISTRIBUTE BLOOD, MAINTAIN PRESSURE
CARDIOVASCULAR SYSTEM

MUSCULAR ARTERIES - DISTRIBUTE BLOOD, MAINTAIN PRESSURE

ARTERIOLES - PERIPHERAL RESISTANCE AND DISTRIBUTE BLOOD
CARDOVASCULAR SYSTEM

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MUSCULAR ARTERIES - DISTRIBUTE BLOOD, MAINTAIN PRESSURE

ARTERIOLES - PERIPHERAL RESISTANCE AND DISTRIBUTE BLOOD

CAPILLARIES - EXCHANGE NUTRIENTS AND WASTE

VENULES - COLLECT BLOOD FROM CAPILLARIES (EDEMA)
Smooth muscle contraction in blood vessel wall reduces the vessel caliber and restricts blood flow. A state of partial contraction is known as “tone”.

CARDIOVASCULAR SYSTEM

HEART PRODUCES BLOOD PRESSURE (SYSTOLE)
Tone – state of partial contraction of smooth muscles in arteries and veins that reduces the caliber of the lumen.

Innervations of smooth muscle cells of blood vessels controls the tone.

Normal nervous control

No nervous control
Tone – state of partial contraction of smooth muscles in arteries and veins that reduces the caliber of the lumen.

Normal nervous control

No nervous control

Innervations of smooth muscle cells of blood vessels controls the tone.
CARDIOVASCULAR SYSTEM

ELASTIC ARTERIES - CONDUCT BLOOD AND MAINTAIN PRESSURE DURING DIASTOLE
The **elasticity** of large arteries close to the heart is important as it facilitates a **more uniform blood flow**. During systole, blood moves forcefully into the large elastic arteries; however, the elastic fibers in the arterial wall stretch to compensate. This expansion of the lumen caliber dampens the rise in pressure. During diastole, both the ventricular pressure and resulting arterial pressure are low, but elastin in the wall of elastic arteries recoils to its original shape and reduces the lumen caliber and, thereby, maintains a relative high arterial pressure. How does this relate to **arteriosclerosis**?
Vessels are structurally adapted to physical and metabolic requirements.
<table>
<thead>
<tr>
<th>Cardiovascular System Overview</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Heart</strong></td>
</tr>
<tr>
<td><strong>Macrovasculles</strong></td>
</tr>
<tr>
<td><strong>Microvasculles</strong></td>
</tr>
<tr>
<td><strong>Vessel layers</strong></td>
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<tr>
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<tr>
<td><strong>Heart layers</strong></td>
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<tr>
<td></td>
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<tr>
<td><strong>Purkinje cells</strong></td>
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</tr>
</tbody>
</table>
Slide 11: Skeletal muscle

- Endothelial cell
- Arteriole
- Capillaries
ARTERIOLE - CAPILLARY - VENULE
CAPILLARY  pericyte
CAPILLARY pericyte

Endothelial cells
ENDOTHELIELIUM - ACTIVE CELL

HAS ENZYMES AND RECEPTORS
TRANSPORT WITHOUT MUCH ENERGY
FLAT FOR LESS TURBULANCE

NEGATIVELY CHARGED SURFACE
NOT WETABLE SURFACE

Blood capillary

Lymphatic vessel with valve
EM 3 & 27: Endothelial cells
## TYPES OF CAPILLARIES & BASAL LAMINA CHARACTERISTICS

<table>
<thead>
<tr>
<th>CAPILLARIES LOCATIONS</th>
<th>BASAL LAMINA</th>
<th>EXAMPLES OF</th>
</tr>
</thead>
<tbody>
<tr>
<td>CONTINUOUS</td>
<td>COMPLETE</td>
<td>MUSCLE, TESTIS, BRAIN, THYMUS</td>
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**Image:** MUSCLE
# Types of Capillaries & Basal Lamina Characteristics

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</tr>
<tr>
<td>Fenestrated</td>
<td>Complete</td>
<td>Glomerulus, Adrenal</td>
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![Muscle](image1.png)  ![Glomerulus](image2.png)
# TYPES OF CAPILLARIES & BASAL LAMINA CHARACTERISTICS

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<td>Complete</td>
<td>Glomerulus, Adrenal</td>
</tr>
<tr>
<td>Discontinuous or Sinusoidal</td>
<td>Incomplete or Lacking</td>
<td>Liver, Spleen, Bone Marrow</td>
</tr>
</tbody>
</table>

[Images of Muscle, Glomerulus, Liver]
CONTINUOUS

FENESTRATED

SINUSOIDAL
ANGIOGENESIS – growth of blood vessels
CLASSIFICATION OF VESSEL SIZE (CALIBER)

PROMINENT STRUCTURES IN WALL FUNCTION
LAYERS IN VASCULAR WALL

**TUNICA INTIMA**
- Endothelium
- Subendothelium ct. internal elastic lamina

**TUNICA MEDIA**
- Smooth muscle
- Elastic lamellae, external elastic lamina

**TUNICA ADVENTITIA**
- Connective tissue
- Longitudinal smooth muscle, vasa vasorum
LAYERS IN VASCULAR WALL

TUNICA INTIMA
TUNICA MEDIA
TUNICA ADVENTITIA
Slide 25: Muscular artery/vein/nerve (H&E)

Muscular Artery

- Tunica intima
- Tunica media
- Tunica adventitia

Large Vein

- Tunica intima
- Tunica media
- Tunica adventitia
Slide 25: Muscular artery/vein/nerve (H&E)

Muscular Artery

- Internal elastic lamina (IEL)

Large Vein

- Tunica intima with endothelium and subendothelium
Slide 26: Muscular artery/vein/nerve (elastic-collagen stain)
Muscular Artery

- Tunica intima with endothelium and subendothelium
- Internal elastic lamina (IEL)

Large Vein

- Tunica intima with endothelium and subendothelium
Tunica adventitia of large veins has bundles of longitudinal smooth muscle.

Large blood vessels have a vasa vasorum.
Tunica adventitia of large veins has bundles of longitudinal smooth muscle.

Large blood vessels have a vasa vasorum.
Fig. 7-1  Blood and Lymphatic Vessels. Stain: hematoxylin. Medium magnification.
VASCULAR VALVES

LOCATION - MEDIUM CALIBER VEINS (ESPECIALLY EXTREMITIES)
VASCULAR VALVES

LOCATION - MEDIUM CALIBER VEINS (ESPECIALLY EXTREMITIES) COLLECTING AND LYMPHATIC DUCTS
VASCULAR VALVES

LOCATION - MEDIUM CALIBER VEINS (ESPECIALLY EXTREMITIES) COLLECTING AND LYMPHATIC DUCTS

FUNCTION - INSURE UNIDIRECTIONAL FLOW
VASCULAR VALVES

LOCATION - MEDIUM CALIBER VEINS (ESPECIALLY EXTREMITIES) COLLECTING AND LYMPHATIC DUCTS

FUNCTION - INSURE UNIDIRECTIONAL FLOW

COMPOSITION FLAP OR LEAFLET WHICH ARE FOLDINGS OF THE INTIMA WITH REINFORCEMENTS OF CONNECTIVE TISSUE
EM 37, 38, & 39
Slide 63: Appendix (H&E)

Large Artery

Tunica intima  Tunica media  Tunica adventitia
Slide 63: Appendix (H&E)

Large Vein

Tunica adventitia  Tunica media  Tunica intima
Slide 63: Appendix (H&E)

- Venule
- Arteriole
- Lymphatic vessel with lymphocyte
Slide 64: Appendix (Verhoeff’s and trichrome stain)

- Large Artery
- Tunica adventitia
- Tunica media
- Tunica intima
- External elastic lamina
- Internal elastic lamina
Slide 64: Appendix (Verhoff’s and trichrome stain)

Large Vein

Tunica intima  Tunica media  Tunica adventitia
Slide 64: Appendix (Verhoff’s and trichrome stain)

Venule

Arteriole

Lymphatic vessel with lymphocytes
CARDIOVASCULAR SYSTEM

VEINS - TRANSMIT BLOOD TO LARGE VEINS RESERVOIR

LARGER VEINS - RECEIVE LYMPH AND RETURN BLOOD TO HEART, BLOOD RESERVOIR

VOLUME: 5-6 L = 12-13 PINTS/PERSON

59% of the blood volume is stored in veins
Vessels are structurally adapted to physical and metabolic requirements.
This concludes Part 1.
CARDIOVASCULAR SYSTEM  PART 2

Dr. Larry Johnson
Objectives

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- Identify elastic and muscular arteries, arterioles, capillaries, venules and veins.
- Describe the intima, media, and adventitia of all vessels.

Part 2
- Describe the structure of the heart.
- Also regulation of blood flow, lymphatic vessels, and diseases
ARTERIOLAR FUNCTIONS

ALLOW SUFFICIENT PRESSURE FOR FLOW THROUGH CAPILLARIES
LOW ENOUGH PRESSURE TO PREVENT DAMAGE
CONSTANT INTERMITTANCE OF BLOOD FLOW TO CAPILLARY BEDS

AUTOREGULATION - SMOOTH MUSCLE CELLS IN ARTERIOLES AND IN PRE-CAPILLARY SPHINCTERS RESPOND TO METABOLIC NEEDS, LOW O2 TENSION, THEN RELAX ⇒ INCREASED BLOOD FLOW (INDEPENDENT OF NERVOUS SYSTEM)
During exercise, the increase of blood flow to skeletal muscle is primarily the result meeting the metabolic needs (e.g., low O2 levels reduces the contraction of smooth muscle and their constriction of arteriolar blood flow) of the tissue due to local, nervous, and hormonal regulatory mechanisms. Also, there will be an increased heart rate.
VENULE COLLECT BLOOD FROM CAPILLARIES (EDEMA)
In most organs, the network of blood capillaries is paralleled by a plexus of capillaries of the draining lymphatic system.
LYMPH VESSELS
FUNCTIONS
RETURN PROTEIN, FLUID, AND BLOOD CELLS
LYMPH VESSELS

LYMPH FLOW
- COMPRESSION OF LYMPHATIC VESICLES (MUSCLES, PULSATING BLOOD VESSELS)

UNIDIRECTIONAL FLOW
- CONTROLLED BY VALVES

FLOW RATE
- REMARKABLY RAPID

ANCHORING DEVICE
- VESSELS OPEN
Drainage and the function of lymph vessels

- **Function:** collect excess interstitial fluid “lymph” from tissue and return it to the blood
- **Drain:** starts as lymph capillaries to lymph vessels to lymph nodes for filtration then to lymph ducts (thoracic, tracheal duct, and right lymphatic) that empty into the bloodstream.
LYMPH VESSELS

TRANSPORT ACROSS TRANSIT VESICLES

CAPILLARIES INTERCELLULAR JUNCTIONS
LYMPH VESSELS

FUNCTIONS
RETURN PROTEIN, FLUID, AND BLOOD CELLS
TRANSPORT SECRETIONS (HORMONES, ANTIBODIES)
TRANSPORT FAT (NEUTRAL FAT)
Human Spermatic cord

Veins

Lymphatic vessels

Lymphatic valves

Valves of vein

Arteries
Slide 27: Aorta (elastic/conducting artery)

- Tunica intima
- Tunica media
- Tunica adventitia
- Vaso vasorum
Slide 28: Aorta (Verhoeff’s and trichrome stains)
Slide 14: Heart (right ventricle)

- Epicardium
- Myocardium
- Endocardium
Slide 14: Heart (right ventricle)

Adipose cells

Epicardium

Myocardium

Endocardium
Slide 14: Heart (right ventricle)

- Epicardium
- Myocardium
- Endocardium
- Adipose cells
- Artery
- Vein of vasa vasorum
Slide 14: Heart (right ventricle)

- Epicardium
- Myocardium
- Endocardium
- Adipose cells
- Artery
- Vein of vasa vasorum
The epicardium is a simple squamous mesothelium supported by a layer of loose connective tissue containing blood vessels and nerves. Also there are blood vessels in the myocardium too.
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CARDIAC MUSCLE

INTERCALATED DISC
FASCIA ADHERENS
MACULAE
ADHERENS
GAP JUNCTIONS
LATERAL PORTION
Slide 14: Heart (right ventricle)

You will likely not find PURKINJE FIBERS in this image, but you can in image 23.
EM 48: Heart

Intercalated Disc

 mec (m) 1

 Z

 MA

 Mi

 mecula adherens

 gap junction

 fascia adherens

 Gap junction

 Desmosome

 Openings of transverse tubules

 Intercalated disc

 Sarcolemma

 Nucleus

 Mitochondrion

 Cardiac muscle cell

 Copyright McGraw-Hill Companies
Sinoatrial node (S-A node or pacemaker)

A-V node

Coronary sinus

I.V.C.

Aorta

Bundle of His (A-V bundle)

Right ventricular branch

Left ventricular branch

Interventricular septum
Image showing the conduction system of the heart

Internodal connections
Slide 23: Heart (ventricle – bovine)

Purkinje fibers
PURKINJE FIBERS (modified cardiac muscle cells)
Slide 24: Heart valve

- **Papillary muscle**
- **Chordae tendineae**
- **Valve**
VASA VASORUM
VEssel of vessels

THE CORONARY ARTERY IS A VASA VASORUM
CARDIAC MUSCLE

mitochondria

nerve

Capillary

VASA

VASORUM

Nucleus
## BLOOD BARRIERS

<table>
<thead>
<tr>
<th>TYPE</th>
<th>SOURCE OF BARRIER</th>
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<tbody>
<tr>
<td>BLOOD-BRAIN</td>
<td>ZONULA OCCLUDENS OF ENDOTHELIUM</td>
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<td>BLOOD-THYMUS</td>
<td>ZONULA OCCLUDENS OF ENDOTHELIUM AND SHEATH OF EPITHELIAL RETICULUM</td>
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</tr>
<tr>
<td>BLOOD-TESTIS</td>
<td>OCCLUDING JUNCTIONS BETWEEN SERTOLI CELLS IN SEMINIFEROUS TUBULES</td>
</tr>
</tbody>
</table>
Clinical Correlation

During coronary bypass surgery, the great saphenous vein of the leg can be used to bypass blocked coronary arteries.

http://www.youtube.com/watch?v=bwJCHYeGcU4

The proper distal / proximal orientation of the vein is important during bypass surgery to prevent engaging the valves of the vein and preventing blood flow.

Images from Wikipedia: Atherosclerosis
## AGE-RELATED AND/OR DISEASE-RELATED

### CHANGES IN BLOOD VESSELS

<table>
<thead>
<tr>
<th>DEFECT</th>
<th>CAUSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>ARTERIOSCLEROSIS (HARDENING OF ARTERIES)</td>
<td>ELASTIC LAMELLAE REPLACED BY OTHER CONNECTIVE TISSUE ELEMENTS</td>
</tr>
<tr>
<td>ATHEROSCLEROSIS (HEART ATTACK AND STROKE)</td>
<td>PATCHY, IRREGULAR THICKENING OF INTIMA</td>
</tr>
</tbody>
</table>
Atherosclerosis is the most common disease of blood vessels.

Tunica intima is either damaged or dysfunctional. Changes seen include the presence of foam cells, accumulation of free LDL, and entry of monocytes and macrophages as well as narrowed lumen due to fibro-fatty plaques (atheromas).
This new medical tool for treating atherosclerosis, a zapper for clogged arteries, is an experimental device, which was inspired by the movie Star Wars and invented by a cardiologist. Attached to a catheter, the laserscope is carefully inserted by the surgeon into the damaged artery, where it aims its beam on the fatty buildup that is obstructing circulation of blood. The beam vaporizes the fat. Just before the laser is fired, a balloon behind it inflates to stop the blood flow momentarily, thereby clearing a path for the beam and preventing damage to blood cells.

Laserscope has three channels: one is a conduit for the laser beam; the second is for optical fibers that permit viewing of the artery; the third is for a vacuum device that is designed to sweep up particles left behind after the firing.
FUNCTION / ACTIONS OF LYSOSONES

UNPROGRAMMED CELL DEATH
DAMAGE/DEATH TO CARDIAC CELLS IN ISCHEMIA ASSOCIATED WITH MYOCARDIAL INFARCTIONS
FUNCTION / ACTIONS OF LYSOSOMES

PRE-STENT

POST-STENT
Many illustrations in these VIBS Histology YouTube videos were modified from the following books and sources: Many thanks to original sources!

- Douglas P. Dohrman and TAMHSC Faculty 2012 Structure and Function of Human Organ Systems. Histology Laboratory Manual - Slide selections were largely based on this manual for first year medical students at TAMHSC