Cardiovascular System

Biol 105
Lecture 15
Reading: Ch 12
I. Functions of cardiovascular system
II. Components of the cardiovascular system
III. The heart
IV. Regulation of the heartbeat
V. ECG/EKG
VI. Blood pressure
VII. Circulatory circuits
VIII. Cardiovascular diseases
IX. Lymphatic system
Respiratory system moves $O_2$ into, and $CO_2$ out of the body.

Cardiovascular system transports materials to and from all other systems.

Digestive system transforms food into a form that can be transported throughout the body.

Urinary system filters bodily fluids, removes waste while conserving water and other materials.
Cardiovascular

- Function of the cardiovascular system is to transport blood containing:
  - Nutrients
  - Waste
  - Hormones
  - Immune cells
  - Oxygen
Cardiovascular System consists of three components:

1. Blood
2. The heart, which pumps blood.
3. The blood vessels, through which blood flows.
Veins
- Carry blood back to the heart

**Superior vena cava**
- Carries blood from the upper body back to the heart

**Jugular veins**
- Carry blood from head to the heart

**Pulmonary veins**
- Carry oxygenated blood from the lungs to the heart

**Renal vein**
- Carries blood from the kidney to the heart

**Inferior vena cava**
- Carries blood from the lower body back to the heart

**Iliac vein**
- Carries blood from the pelvic organs and abdominal wall back to the heart

**Radial vein**
- Carries blood from the hand back to the heart

**Femoral vein**
- Carries blood from the thigh and inner knee back to the heart
**Arteries**
- Carry blood away from heart

**Carotid arteries**
- Deliver blood to the head and the brain

**Coronary arteries**
- Deliver blood to the heart muscle cells

**Iliac artery**
- Delivers blood to pelvic organs and abdominal wall

**Aorta**
- Delivers blood to the body tissues

**Pulmonary arteries**
- Deliver oxygen-poor blood to the lungs

**Renal artery**
- Delivers blood to the kidney

**Radial artery**
- Delivers blood to the hand

**Femoral artery**
- Delivers blood to thigh and inner knee
The Heart and Lungs

Right lung  Left lung

Pericardium

(b)  Diaphragm  Rib cage

Figure 12.7b
Blood vessels

- Blood vessels are lined with epithelial cells.
- They have a layer of smooth muscles that contract or dilate the vessels.
- Blood vessels are covered with a layer of connective tissue.
- Inside the vessels is called the lumen.
Vasoconstriction and Vasodilation

- **Vasoconstriction**
  - When muscle contracts and the diameter of the lumen narrows, reducing blood flow

- **Vasodilation**
  - When muscle relaxes and the diameter of the lumen increases, increasing blood flow
The Blood Vessels

- Arteries
- Arterioles
- Capillaries
- Venules
- Veins
Arteries - Always carry blood away from the heart and usually carry O₂-rich blood.

Veins - Always returns blood to the heart and usually carry O₂-poor blood.
The Blood Vessels – Arterioles and Venules

- Arteries break down into smaller vessels called arterioles, bringing O$_2$, water, and nutrients to the tissues.
- Arterioles break down into small vessels called capillaries.
- Blood leaves the capillaries and enters venules.
- Venules take CO$_2$, water, and wastes away from the tissues.
- Venules join together to form veins.
The Blood Vessels – Arterioles

- There are sphincter muscles that contract to reduce blood flow to the capillaries,
- or they dilate to increase blood flow to the capillaries.
Capillaries

- Small vessels are called **capillaries**

- It is here that components (O$_2$, CO$_2$, nutrients, waste) can pass from the blood vessels to other tissues

- Capillaries do not have a smooth muscle layer
Can gas freely pass through the plasma membrane?

1. True
2. False
Capillaries

- The RBCs stay in the blood vessels but the oxygen leaves the RBCs and the capillaries and goes into the tissues.

- The oxygen leaves the capillaries because there is a gradient – there is more oxygen in the capillaries than in the tissues.
Capillaries

- Blood flow in capillaries is slow.

- This is important because it allows time for the exchange of substances between the blood and surrounding tissues.
Blood Vessels

Figure 12.4b

Arteriole

Venule

Sphincters relax.

Blood fills capillary bed.

Precapillary sphincters

Sphincters contract.

Blood is channeled through the capillary bed.
Blood Vessels
(c) Capillaries are so narrow that red blood cells must travel through them in single file.
Substances are exchanged between the blood and tissue fluid across the plasma membrane of the capillary or through slits between capillary cells.
Capillaries

(b) At the arterial end of a capillary, blood pressure forces fluid out of the capillary to the fluid surrounding tissue cells. At the venous end, fluid is drawn back into the capillary by osmotic pressure.
Do RBCs leave the capillaries?

1. Yes
2. No
Pressures and Their Effect on Capillaries

- At the **arterial** end of the capillaries, **blood pressure** forces fluid out of the capillary and into the tissue.

- At the **venous** end, **osmotic pressure** draws fluid back into the vessel from the tissue.

- **Diffusion** is the pressure that draws gases across the capillary.
The Blood Vessels

- **Arteries**
  - **Aorta** — largest artery.
  - **Arterioles** — smallest arteries (whether constricted or dilated affects blood pressure).

- **Veins**
  - **Vena cava** — largest veins in the body.
  - **Venules** — smallest veins.
The Heart

Superior vena cava

Right coronary vein

Right coronary artery

Inferior vena cava

Aorta

Pulmonary veins

Pulmonary trunk

Left coronary artery

Left coronary vein

(a)
The heart is composed of four chambers and lies almost in the center of the thoracic cavity.

- Two atria—thin-walled upper chambers that serve as reservoirs for blood.
- Two ventricles—thick-walled lower chambers powering the pulmonary and systemic circuits.

- Septum—separates right and left sides of the heart.
The Heart

- There are valves which keep blood flowing forward:
  - Two atrioventrical valves (AV) — between atria & ventricles, making a “LUB” sound when closing.
  - Two semilunar vales (SL) — base of major arteries making a “DUB” sound when closing.
The Heart Valves

Atrioventricular (AV) valves are located between each atrium and ventricle.

Semilunar valves are located between each ventricle and its artery.
The Heart

- **Pericardium** — thick membranous sac surrounding the heart (secretes serous fluid).

- **Myocardium** — consists of cardiac muscle tissue, which contracts to pump blood.

- The interior of the heart is lined by **endocardium**
The Heart

Figure 12.7c

Oxygen-rich blood (to body)

Oxygen-poor blood (to lungs)

Oxygen-poor blood (from body cells)

Oxygen-rich blood (from lungs)
Path of Blood Through Heart

- Superior and Inferior vena cava (O$_2$-poor) → Right Atrium.
- R Atrium → Tricuspid AV valve → Right Ventricle.
- R Ventricle → Pulmonary SL valve → Pulmonary Arteries → Lungs.
- Pulmonary veins (O$_2$-rich) → Left Atrium.
- L Atrium → Mitral AV valve → Left Ventricle.
- L Ventricle → Aortic SL valve → Aorta → rest of the body tissues.
Cardiac Cycle

- Cardiac cycle - one complete heart beat where both atria contract simultaneously (at the same time) followed by both ventricles contracting simultaneously.
  - a. Systole - when ventricles contract and pump blood out of the heart.
  - b. Diastole - when ventricles relax and receive blood from atria.
Heartbeat regulation - Intrinsic

- Intrinsic Control:
  - Sinoatrial node (SA) (pacemaker) — initiates the heartbeat and causes the atria to contract.
  - Atrioventricular node (AV) - causes the ventricles to contract.
Heartbeat regulation - Intrinsic

- The AV node relays the message to the ventricles using bundles of specialized muscle cells = atrioventricular bundle

- The bundle divides into smaller bundles of specialized cardiac muscle cells called Purkinje fibers
When the ventricles contract, which valves are closed?

1. AV valves
2. SL valves
- Extrinsic Control of Heartbeat - the autonomic nervous system and hormones can modify the rate of the heartbeat.
Which part of the autonomic NS controls the heart most of the time?

1. Sympathetic
2. Parasympathetic
Regulation of the Heartbeat

Figure 12.12 (1 of 5)
Regulation of the Heartbeat

SA node

AV node

SA node initiation
Regulation of the Heartbeat

- Atria contract
- Signal reaches AV node
• Signal conducted to Purkinje fibers
• Atria fully contracted
Ventricles contract
Electrocardiogram (ECG) - a recording of the electrical changes that occur in the myocardium during a cardiac cycle.
A typical ECG/EKG consists of three distinguishable waves

- P wave – Atrial contraction
- QRS wave – ventricle contraction
- T wave – ventricle repolarization
The ECG/EKG

Figure 12.13b

Millivolts

Seconds

(b) Atria contract

Ventricles contract

Copyright © 2009 Pearson Education, Inc.
Pulse

- As the heart pumps blood into the arteries, they expand such that one is able to feel a pulse.

- The pulse rate is the same as the heart rate.
Pulse
Blood pressure

- Systolic - when the ventricles contract, sending blood into the arteries

- Diastolic - when the heart relaxes between beats
Which blood pressure would be the highest:

1. systolic
2. diastolic
Blood pressure

- **Sphygmomanometer**
  - Measures blood pressure
  - Can provide early identification of **hypertension**, or high blood pressure, the silent killer
Blood pressure

Figure 12.14 (1 of 2)
Cardiovascular Disease Is a Major Killer in the United States

Figure 12.14 (2 of 2)
Values of blood pressure in adults

- **High**: 160 or higher
- **High normal**: 130-159
- **Optimal**: 110-129
- **Low normal**: 100-109
- **Low**: 90 or lower
Blood flow

- Blood flow in the arteries is from the blood pressure due to the heart pumping.
- The blood pressure in veins is very low.
Blood flow in veins is dependent upon:

1. Skeletal muscle contraction
2. One-way valves
3. Respiratory movements
One way valves in veins
One way valves in veins

Relaxed calf muscles

Skeletal muscles relax, and blood fills the valves and closes them.

Muscle contraction squeezes the vein, pushing blood through the open valve toward the heart.

Contracted calf muscles

Valve closed

Valve open

(b)
Cardiovascular system circuits

- **Pulmonary circuit** - flow of blood from the heart, to the lungs and back to the heart, powered by the right ventricle.

- **Systemic circuit** - flow of blood through the rest of the body, powered by the left ventricle.
Pulmonary circuit

- Pulmonary arteries—carry $O_2$-poor blood to the lungs.

- Pulmonary veins—carry $O_2$-rich blood from lungs to the left atrium.
Systemic circuit

- Aorta - carries O$_2$-rich blood to all body tissues.
- Vena cava - returns O$_2$-poor blood to the right atrium.
Systemic circuits

- **Renal circuit** - supplies blood to the kidneys.

- **Hepatic portal circuit** - supplies blood to the digestive organs especially the liver.
Systemic - Coronary circuit

- Supplies blood to the heart muscle itself.
- Coronary arteries branch off the aorta.
- Coronary arteries can become clogged and by-pass surgery may be necessary.
- Coronary veins return blood to the heart.
Coronary Circuit

- Superior vena cava
- Right coronary vein
- Right coronary artery
- Inferior vena cava
- Aorta
- Pulmonary veins
- Pulmonary trunk
- Left coronary artery
- Left coronary vein

Figure 12.10a
This pressure draws fluid back into the capillaries

1. Blood Pressure
2. Osmotic Pressure
3. Diffusion
Blood flow in veins is dependent upon: one way valves, respiratory movements and:

1. Smooth muscle
2. Skeletal muscle
When ventricles relax and receive blood from atria it is:

1. Systole

2. Diastole
Disorders of the Cardiovascular System

1. High Blood Pressure
2. Atherosclerosis and coronary artery disease
3. Heart attack
4. Thromboembolism
5. Stroke
6. Aneurism
Disorders – High Blood Pressure

- High blood pressure is also called hypertension

Causes:

- 90% of high blood pressure has no known cause.
- Can be caused by kidney not being able to balance the sodium concentration. Increased fluid in blood increases blood pressure.
- Stress can lead to high blood pressure.
Disorders – High Blood Pressure

- Result: high blood pressure causes the heart to work too hard, leads to heart failure, kidney problems, blood vessel problems and death.

- Prevention includes: lower salt intake, lose weight, exercise, and stop smoking.
Disorders - Atherosclerosis

- Atherosclerosis is a narrowing of the arteries due to fatty deposits and thickening of the wall.
- Can lead to heart attack or stroke.
- When this occurs in the arteries of the heart muscle, it is called coronary artery disease.
Cholesterol

- Remember that lipoproteins are proteins that carry cholesterol in the blood.
  - Low density lipoproteins (LDL)
  - High density lipoproteins (HDL)
This type of lipoprotein carries cholesterol away from the liver

1. LDL
2. HDL
Coronary Artery Blockage

- Some of the LDLs can become damaged through oxidative stress. The damaged LDL can get stuck in these coronary arteries.

- The immune system reacts to this by mounting an inflammatory response = blood clot.

- The oxidized material can build up and reduce the flow of blood to the heart = coronary artery blockage.
(a) A normal artery
Atherosclerosis

Lumen narrowed

(b) An artery partially obstructed with plaque
(c) An artery completely obstructed with plaque and a blood clot
Treatments of Coronary Artery Blockage

- Angiography can show **coronary artery blockage**, which can then be treated with medicines or surgical operations such as **angioplasty** or **coronary bypass surgery**

- See pages 235-236
Angioplasty

A catheter and balloon are threaded into the coronary artery to the point of blockage.

1. The balloon is inserted into the blocked area.
2. The balloon is inflated.
3. Plaque is pushed to the artery walls and held there by stent.
Coronary Bypass

Vein from leg used for bypass in heart

Blockage

Right coronary artery

Figure 12.18
Disorders - Heart Attack - myocardial infarction

- Heart muscle dies because of an insufficient blood supply during a heart attack (myocardial infarction) and is gradually replaced by scar tissue.

- Can be caused by coronary artery blockage.

- Scar tissue cannot contract, so part of the heart permanently loses its pumping ability.
Disorders - Thromboembolism

- Thromboembolism is a clot that has been carried in the bloodstream but is now stationary.
- Can result in a stroke
Disorders - Stroke

- Stroke - cranial arteriole bursts or is blocked, reducing blood supply to an area of the brain.

- The result is that a portion of the brain dies, and may result in paralysis or death.
Disorders - Aneurysm

- Aneurysm - weak spot in a blood vessel where it balloons out and may rupture

- May cause a stroke if in the brain or death if in aorta
Aneurysm
The blood supply to the kidneys is the: 

1. Hepatic portal circuit 
2. Renal circuit 
3. Cardiac circuit
Lymphatic System

- Lymphatic system - system that takes excess tissue fluid to the subclavian veins.

- Skeletal muscles and valves keep fluid moving
The Lymphatic System Functions

- Functions
  1. Return interstitial fluid from tissues to the bloodstream
  2. Transport products of fat digestion lacteals
  3. Defend the body against disease-causing organisms and abnormal cells
The Lymphatic System

Figure 12.21 (1 of 2)

- Anchoring filaments
- Interstitial fluid enters
- Endothelium
- Flaplike minivalve

Tissue cells
Components of the Lymphatic System

- Lymph
- lymphatic vessels – including lacteals
- lymphoid organs.
The Lymphatic System

Tonsils
- Protect the throat against bacteria and foreign agents

Right lymphatic duct
- Returns the lymph from the upper part of body to the blood

Thymus
- Site where T lymphocytes mature, enabling them to fight specific disease-causing organisms

Thoracic duct
- Returns lymph from most of the body to the blood

Spleen
- Site of lymphocyte production
- Removes old red blood cells, foreign debris, and microorganisms from the blood

Lymph vessels
- Return excess interstitial fluid to the blood
- Some transport products of fat digestion to the blood

Lymph nodes
- Filter lymph before returning it to the blood
- Contain lymphocytes and macrophages that defend against disease-causing organisms

(a) The lymphatic system returns the fluid to the bloodstream that previously left the capillaries to bathe the cells, protects against disease-causing organisms, and transports products of fat digestion from the small intestine to the bloodstream.
Lymphoid Organs:

1. Lymph nodes - cleanse lymph of debris and pathogens and store lymphocytes and macrophages to fight infection.
2. Spleen - cleanses the blood, remove old blood cells.
3. Red bone marrow - produces both B cells and T cells.
4. Thymus gland - where T cells mature.
5. Tonsils - function to recognize infectious agents entering the body.
(b) Lymph nodes filter lymph. Lymph flows through at least one lymph node before it is returned to the bloodstream. Lymph nodes are packed with macrophages and lymphocytes, white blood cells that help protect against disease.
These vessels always carry blood away from the heart

1. Arteries
2. Veins
What are the small blood vessels where the oxygen transfers into the tissues and carbon dioxide is taken up

1. Arterioles
2. Venules
3. Capillaries
4. Lacteals
What are the small lymphatic vessels where the fat is absorbed from the digestive tract

1. Arterioles
2. Venules
3. Capillaries
4. Lacteals
Important concepts

- Read Chapter 13 for next lecture
- What are the functions of the circulatory system?
- What are the components of the circulatory system?
- What are the components of the blood vessel and their functions, what would the cross section of a vein, artery and capillary look like?
Important concepts

- What is the path of the blood through the body, starting when it leaves the heart through the aorta, into arteries, then arterioles, then capillaries, then venules, to the veins, to the vena cava, back to the heart?

- How do arterioles affect blood pressure?

- What are the pressures that cause fluid to enter and leave the capillaries and what pressure causes gasses to enter and leave the capillaries. Be able to discuss in detail the transport of fluid, gasses, nutrients and waste across the capillaries?
Important concepts

- What is the function of capillaries?
- What are the chambers of the heart, which are the lower chambers and which are the more muscular chambers?
- What cavity is the heart located in?
- What is the path of the blood through the heart?
- Be able to describe the cardiac cycle.
Important concepts

- What are the valves in the heart, where are they located, when are they opened, when are they closed?

- How is the heartbeat regulated, both intrinsically and extrinsically?

- What records the electrical changes that occur in the myocardium during a cardiac cycle?
Important concepts

- What are the three waves on the ECG and be able to describe the events that happen during each of the waves on the ECG?

- What measures blood pressure?

- What causes blood to flow in the arteries and in the veins?

- What are the pulmonary, systemic renal, hepatic portal, and coronary circuits, what tissues do they go to?
Important concepts

- What is the function of the aorta, vena cava, pulmonary arteries, pulmonary veins, coronary arteries and coronary veins?

- What is the role of LDL and HDL in coronary artery disease?

- What are causes and effects of the cardiovascular diseases discussed in lecture?

- How can you prevent high blood pressure.
Important concepts

- What are two treatments of coronary artery blockage?

- How is coronary artery blockage detected?

- What are the function of the lymphatic system?
Important concepts

- What are the components of the lymphatic system and their functions?

- What are lacteals are what is their function?

- What causes fluids to travel through lymphatic vessels?
Definitions

- Lumen, vasoconstriction, vasodilation, osmotic pressure, blood pressure, low density lipoproteins (LDL), high density lipoproteins (HDL), septum, capillaries, arteries, veins, arteriole, venule, vena cava, aorta, sinoatrial node (SA), atrioventricular node (AV), pericardium, myocardium, endocardium,
Definitions

- Cardiac cycle, systole, diastole, atrioventricular bundle, purkinje fibers, extrinsic control, intrinsic control, electrocardiogram, pulse, systolic pressure, diastolic pressure, sphygmomanometer, coronary arteries, renal circuit, hepatic portal circuit, coronary circuit, hypertension, interstitial fluid, lacteal