Chapter 05
Lecture Outline

See separate PowerPoint slides for all figures and tables pre-inserted into PowerPoint without notes.
Cardiovascular System:
Heart and Blood Vessels
Points to ponder

• What are the functions of the cardiovascular system?
• What is the anatomy of the heart? Of blood vessels, such as veins and arteries?
• How is the heart beat regulated?
• What is blood pressure?
• What are common cardiovascular diseases and how might you prevent them?
What is the cardiovascular system?

• It includes the heart and blood vessels.

• It brings nutrients to cells and helps get rid of wastes.

• Blood is refreshed in the lung, kidneys, intestine, and liver.

• Lymphatic vessels help this system by collecting excess fluid surrounding tissues and returning it to the cardiovascular system.
What is the cardiovascular system?

Figure 5.1 The cardiovascular system and homeostasis.
What are the functions of the cardiovascular system?

1. Transport: oxygen, carbon dioxide and other wastes products, nutrients, and horomones
2. Protection: cells of the immune system are transported to help protect the body from infection
3. Regulation: maintain homeostasis of a variety of the body’s conditions
What is the main pathway of blood in the body?

- Heart – arteries – arterioles – capillaries – venules – veins – back to the heart…
Arteries and arterioles

- **Arteries** carry blood away from the heart.
- Their walls have 3 layers.
  - Thin inner epithelium
  - Thick smooth muscle layer
  - Outer connective tissue
- **Arterioles** are small arteries that regulate blood pressure.
Capillaries

• Microscopic vessels between arterioles and venules
• Made of one layer of epithelial tissue
• Form beds of vessels where exchange with body cells occurs
• Combined large surface area
5.2 The Types of Blood Vessels

Capillaries

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Figure 5.2 Structure of a capillary bed.

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5.2 The Types of Blood Vessels

Veins and venules

- **Venules** are small veins that receive blood from the capillaries.

- Venule and vein walls have 3 layers.
  - Thin inner epithelium
  - Thick smooth muscle layer
  - Outer connective tissue

- **Veins** carry blood toward the heart.

- Veins that carry blood against gravity have valves to keep blood flowing toward the heart.
How can you tell the difference between an artery and vein?

Figure 5.2 Structure of a capillary bed.
Anatomy of the heart

- Large, muscular organ consisting of mostly cardiac tissue called the myocardium
- Surrounded by a sac called the pericardium
- Consists of 2 sides, right and left, separated by a septum
- Consists of 4 chambers: 2 atria and 2 ventricles
- 2 sets of valves: semilunar valves and atrioventricular valves (AV valves)
- Valves produce the “lub” and “dub” sounds of the heartbeat
5.3 The Heart is a Double Pump

External anatomy of the heart

- left subclavian artery
- left common carotid artery
- brachiocephalic artery
- superior vena cava
- aorta
- left pulmonary artery
- pulmonary trunk
- left pulmonary veins
- right pulmonary artery
- right pulmonary veins
- left atrium
- left cardiac vein
- right atrium
- right coronary artery
- left ventricle
- right ventricle
- left anterior descending coronary artery
- inferior vena cava
- apex

Figure 5.3 The arteries and veins associated with the human heart.
5.3 The Heart is a Double Pump

Figure 5.4a  The heart is a double pump.

Internal anatomy of the heart

left subclavian artery
left common carotid artery
brachiocephalic artery
superior vena cava
aorta
left pulmonary artery
pulmonary trunk
left pulmonary veins
right pulmonary artery
right pulmonary veins
semilunar valve
left atrium
right atrium
atrioventricular (bicusp) valve
atrioventricular (tricuspid) valve
chordae tendineae
papillary muscles
right ventricle
septum
left ventricle
inferior vena cava
How does blood flow through the heart?

- Inferior and superior vena cava (1) dump blood into the right atrium (2)
- Right ventricle (3)
- 2 pulmonary arteries (4) that lead to the lungs (5) where blood becomes oxygenated
- Pulmonary veins (6) bring blood from the lungs back to the left atrium (7)
- Left ventricle (8) is large and muscular to pump blood into the aorta (9) and to the rest of the body (10)
- Eventually blood will be pumped back to each vena cava (1)
5.3 The Heart is a Double Pump

Visualizing blood flow through the heart

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Figure 5.4 The heart is a double pump.
How do the structure of the vessels and heart match their functions?

- The left ventricle is much more muscular than the right ventricle because it must pump blood to the entire body.

- The arteries are more muscular than veins to withstand the higher pressure exerted on them.

- The veins have a thinner wall and a larger center to contain blood.
How does the heartbeat occur?

• **During systole**, the atria contract together followed by the ventricles contracting together.

• This is followed by **diastole**, a rest phase, when the chambers relax.

• This cardiac cycle, or heartbeat, occurs 70 times/minute on average.
What is the cardiac cycle?

Figure 5.5 The stages of the cardiac cycle.
How is the heartbeat controlled?

Internal control

• The SA node in the right atrium initiates the heartbeat and causes the atria to contract.
• This impulse reaches the AV node, also in the right atrium, to send a signal down the AV bundle and Purkinje fibers that causes ventricular contraction.
• These impulses travel between gap junctions at intercalated disks.
How is the heartbeat controlled?

External control

• Heartbeat is also controlled by a cardiac center in the brain and hormones such as epinephrine and norepinephrine.
Visualizing the heartbeat

SA node

AV node

branches of atrioventricular bundle

Purkinje fibers

Figure 5.6a An electrical signal pathway through the heart.

5.3 The Heart is a Double Pump
5.3 The Heart is a Double Pump

Visualizing the gap junctions at the intercalated disks

Figure 5.4b The heart is a double pump
What is an electrocardiogram (ECG)?

- It is a record of the electrical changes in the heart muscle during a cardiac cycle.
- The atria produce an electrical current, called the P wave, when stimulated by the SA node.
- The contraction of the ventricles is the QRS complex.
- The recovery of the ventricles is called the T wave.
- Looking at these electrical changes allows doctors to detect abnormalities.
What does a normal ECG look like?

Figure 5.6a-b  An electrical signal pathway through the heart.
What is blood pressure?

- It is the pressure against a blood vessel wall, usually measured in an artery of the arm.
- The highest pressure, called the systolic pressure, is during blood ejection from the heart.
- The lowest pressure, the diastolic pressure, occurs when the ventricles relax.
- Average blood pressure is recorded at about 120/80 mmHg (systolic/diastolic).
- Reminder: this is controlled by the arterioles.
5.4 Features of the Cardiovascular System

What is blood pressure?

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Figure 5.7 Sphygmomanometers measure blood pressure.
How is blood pressure categorized?

<table>
<thead>
<tr>
<th>Table 5.1</th>
<th>Normal Values for Adult Blood Pressure*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Top Number (Systolic)</td>
</tr>
<tr>
<td>Hypotension</td>
<td>Less than 95</td>
</tr>
<tr>
<td>Normal</td>
<td>Below 120</td>
</tr>
<tr>
<td>Prehypertension</td>
<td>120–139</td>
</tr>
<tr>
<td>Stage 1 hypertension</td>
<td>140–159</td>
</tr>
<tr>
<td>Stage 2 hypertension</td>
<td>160 or more</td>
</tr>
<tr>
<td>Hypertensive crisis (emergency care needed)</td>
<td>Higher than 180</td>
</tr>
</tbody>
</table>
What is important about blood flow?

- Blood flow is under the highest pressure in the arteries but remember the thick, muscular walls.

- Blood flow is slower in the capillaries which is important to allow time for exchange between cells.

- Blood pressure is minimal in the veins and venules but blood flow increases.
5.4 Features of the Cardiovascular System

What is important about blood flow?

Figure 5.8 Blood velocity and pressure in the blood vessels.
If blood pressure is so low in the veins, why does the blood flow increase?

- They have help.
  1. Skeletal muscle contraction
  2. Breathing
  3. Valves

**Figure 5.9** The skeletal muscle pump.

a. Contracted skeletal muscle pushes blood past open valve.
b. Closed valve prevents backward flow of blood.
What are the 2 cardiovascular pathways in the body?

**Pulmonary circuit** – the right side of the heart that brings blood from the body to the heart and the lungs

**Systemic circuit** – the left side of the heart that brings blood to the entire body to deliver nutrients and rid it of wastes

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Figure 5.10 Overview of the cardiovascular system.
5.5 Two Cardiovascular Pathways

Figure 5.11 The major arteries and veins of the systemic circuit.
The heart’s blood supply: Coronary circulation

- There are small coronary arteries that supply the heart.

- They are separate from the systemic and pulmonary pathways of the body.
What is the hepatic portal system?

• It is a system that brings amino acid- and glucose-rich blood from the digestive tract to the liver.

• The liver synthesizes blood proteins and stores the glucose as glycogen.

• The liver also plays a role in purifying blood from the digestive tract.

• Finally, the blood will return to the heart via the inferior vena cava.
Exchange at the capillary beds is primarily a result of osmotic and blood pressure.

**Arterial End**
- Blood pressure is higher than osmotic pressure.
- Net pressure out.
- Water, oxygen, amino acids, glucose, carbon dioxide, wastes

**Venous End**
- Osmotic pressure is higher than blood pressure.
- Net pressure in.
- Water

**Figure 5.12** The movement of solutes in a capillary bed.
Exchange at the capillaries

- Lymphatic capillary beds lie alongside capillary beds.
- When lymphatic capillaries take up excess fluid it becomes lymph.
- Lymph returns to the cardiovascular veins in the chest.
- Precapillary sphincters can shut down a blood capillary, and blood then flows through the shunt.
5.6 Exchange at the Capillaries

Exchange at the capillaries

Figure 5.13 Interaction of lymphatic and capillary beds.
Why should we care about cardiovascular disease?

Cardiovascular disease (CVD) is the most common cause of death in the Western world.
Disorders of the blood vessels

- Hypertension/high blood pressure
- Atherosclerosis
- Stroke
- Heart attack
- Aneurysm
Hypertension

• High blood pressure results when blood moves through vessels at a rate higher than normal, often due to arterial plaque.

• 140/90 mmHg is considered hypertension.

• It is a silent killer because there are few symptoms.

• It can lead to a heart attack, stroke, or kidney failure.
Atherosclerosis

- It is a build up of **plaque** in blood vessels.

- Plaque that is stationary is called a thrombus, and an embolus when it detaches and can move to distant sites.

- It is associated with a stroke, heart attack, and aneurysm.
5.7 Cardiovascular Disorders

Atherosclerosis

Figure 5B  Coronary arteries and plaque.

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Stroke

- A stroke is also known as a cerebrovascular accident (CVA).
- It usually occurs when a cranial artery is blocked or bursts.
- Part of the brain dies due to lack of oxygen.
- Symptoms may include numbness of hands or face, difficulty speaking, and inability to see in one eye.
Heart attack

- A heart attack is also known as a myocardial infarction (MI).

- Part of the heart dies due to lack of oxygen.

- It can begin with angina pectoris, a pain that radiates down the left arm due to a blockage of a coronary artery.
Aneurysm

• It is a ballooning of a blood vessel.

• **Atherosclerosis** and **hypertension** can weaken a vessel and cause ballooning.

• The most commonly affected is the abdominal artery or the arteries leading to the brain.
How are disorders of the blood vessels treated?

• Dissolving blood clots
  – t-PA is a drug that dissolves clots
How are disorders of the blood vessels treated?

- Treating clogged arteries
  - Bypass surgery: usually a vein from the leg is taken and used to bypass a clogged artery
  - Stents: wire mesh cylinder inserted into a clogged artery to hold it open
  - Angioplasty: a tube with a balloon is inserted into the clogged area and the balloon is then inflated to open the vessel
  - A stent and angioplasty may be used in combination
Treatments for Atherosclerotic Plaque in Coronary Arteries

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Disorders of the heart and its treatment

• Disorders
  – Heart failure is when the heart no longer pumps properly.

• Treatments
  – Left ventricular assist device (LVAD)
  – Heart transplant either natural or artificial
Disorders of the heart and its treatment

Figure 5.15 An artificial heart.

(right): Courtesy SynCardia Systems, Inc.
Cardiovascular Disease Prevention

Preventable risk factors include:

- use of tobacco products.
- drug and alcohol abuse.
- obesity and a sedentary lifestyle.
- poor diet.
- stress.
- poor dental hygiene.