Chapter 05
Cardiovascular System
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?
5.1 Overview of the Cardiovascular System

What is the cardiovascular system?

- Includes Heart & blood vessels
- Functions:
  - Moves blood cells
  - Distributes O2 & CO2
  - Distributes nutrients/waste
  - Temperature regulation
  - Protection (immunity)
  - Hormone transport

- Organs that refresh blood:
  - Lungs
  - Kidney
  - Intestines
  - Liver
- What’s involved?

Figure 5.1 The cardiovascular system and homeostasis.
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
Figure 5.3 The arteries and veins associated with the human heart.
5.3 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 (bicuspid) valve
- atrioventricular (tricuspid) valve
- chordae tendineae
- papillary muscles
- right ventricle
- septum
- left ventricle
- inferior vena cava

Figure 5.4a The heart is a double pump.
Figure 42.7 Heart structures, associated vessels and blood flow through the heart

- **Pulmonary artery**
- **Right atrium**
- **Pulmonary Semilunar valve**
- **Atrioventricular Valve** - Tricuspid
- **Right ventricle**
- **Left atrium**
- **Aorta**
- **Pulmonary artery**
- **Aortic Semilunar valve**
- **Atrioventricular Valve** - Bicuspid/Mitral
- **Left ventricle**
- **Oxygen rich blood from lungs**
- **Oxygen poor blood from upper body**
- **Oxygen poor blood from lower body**
- **Oxygen rich blood from lungs**
- **Oxygen rich blood to upper body**
- **Oxygen poor blood to lungs**
5.3 The Heart is a Double Pump

Visualizing blood flow through the heart

Figure 5.4 The heart is a double pump.

Intercalated disc with gap junctions
What is the main pathway of blood in the body and heart?

- Heart – aorta - arteries – arterioles – capillaries – venules – veins – vena cava back to the heart…

- Vena cava → right atrium → right ventricle → pulmonary trunk → pulmonary arteries → lungs → pulmonary veins → left atrium → left ventricle → aorta
Main pathway of blood in the body?
What are the 2 cardiovascular pathways in the body?

Pulmonary circuit
Systemic circuit
5.5 Two Cardiovascular Pathways

Figure 5.11 The major arteries and veins of the systemic circuit.
5.2 The Types of Blood Vessels

Arteries, Capillaries, Veins

- **Arteries** carry blood away from the heart
- **Arterioles** are small arteries that regulate blood pressure
- **Venules** are small veins that receive blood from the capillaries
- **Veins** carry blood toward the heart (valves)

Figure 5.2 Structure of a capillary bed.

(left): © Ed Reschke; (right): © Biophoto Associates/Photo Researchers
How can you tell the difference between an artery and vein?

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Figure 5.2 Structure of a capillary bed.
5.3 The Heart is a Double Pump

Visualizing the heartbeat

- Internal control → SA Node (pacemaker)
- External control:
  - Medulla oblongata – cardiac ctr
    - Sympathetic → increase HR
    - Parasympathetic → decrease HR
  - Hormones

Figure 5.6a An electrical signal pathway through the heart.
What does a normal ECG look like?

Electrical event (Pacemaker)
Electrical event (heart muscle excitement)
Mechanical event (heart muscle contraction)

5.3 The Heart is a Double Pump

Figure 5.6a-b An electrical signal pathway through the heart.

- P wave → atrial depolarization
- QRS complex → ventricular depolarization
  atrial repolarization (relaxation)
- T wave → ventricular repolarization (relaxation)

**Electrical events** (heart muscle excitement) lead to **mechanical events** (contraction)
What is the cardiac cycle?

How often does your heart beat?
- Systolic/diastolic

Heart sounds (lup…dup)?
- Closing of the AV valves
- Closing of the semilunar valves

Figure 5.5 The stages of the cardiac cycle.
The cardiac cycle aka The Beast
What is blood pressure?

- **Systole** → atrial contraction followed by ventricles contracting together
  - Highest pressure
  - Blood ejected from heart

- **Diastole**, a rest phase → chambers relax
  - Lowest pressure
  - Ventricles passive fill with blood

- Average: 120/80 mmHg (systolic/diastolic)

- Mean arterial pressure (MAP)
  - \( DP + \frac{1}{3} \text{ Pulse pressure; (PP} = \text{SP} – \text{DP}) \)
Cardiac Output

• Amount ejected by a ventricle in 1 minute

• \( \text{CO} = \text{Heart Rate} \times \text{Stroke Volume} \)
  
  • \( \text{HR} = \) how many times your heart beats/\( \text{min} \)
  
  • \( \text{SV} = \) volume of blood ejected/beat (\( \text{mL/beat} \))

• Resting values, usually about 4 to 6L/min

• Vigorous exercise
  
  – ↑ \( \text{CO} \) to 21 L/min for fit person
  
  – up to 35 L/min for world class athlete
Determining Cardiac Output

- **End diastolic volume** = 120 ml
- **End systolic volume** = 50 ml
- **Ejection volume (stroke volume)** = 70 ml

- **Ejection fraction** = \( \frac{70\text{ml}}{120\text{ml}} = 58\% \)  
  (normally 60%)
- If heart rate (HR) is 70 beats/minute, what is cardiac output?
- **Cardiac output** = \( HR \times \text{stroke volume} \)
  = 70 beats/min * 70 ml/beat
  = 4900 ml/min 4.9 L/min
Mean Arterial Pressure

\[ \text{MAP} = (\text{CO} \times \text{SVR}) + \text{CVP} \]
5.4 Features of the Cardiovascular System

How blood pressure is measured

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

## Table 5.1 Normal Values for Adult Blood Pressure*

<table>
<thead>
<tr>
<th>Category</th>
<th>Top Number (Systolic)</th>
<th>Bottom Number (Diastolic)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hypotension</td>
<td>Less than 95</td>
<td>Less than 50</td>
</tr>
<tr>
<td>Normal</td>
<td>Below 120</td>
<td>Below 80</td>
</tr>
<tr>
<td>Prehypertension</td>
<td>120–139</td>
<td>80–89</td>
</tr>
<tr>
<td>Stage 1 hypertension</td>
<td>140–159</td>
<td>90–99</td>
</tr>
<tr>
<td>Stage 2 hypertension</td>
<td>160 or more</td>
<td>100 or more</td>
</tr>
<tr>
<td>Hypertensive crisis</td>
<td>Higher than 180</td>
<td>Higher than 110</td>
</tr>
<tr>
<td>(emergency care needed)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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How can you tell the difference between an artery and vein?

Figure 5.2 Structure of a capillary bed.

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5.4 Features of the Cardiovascular System

What is important about blood flow?

Blood flow slowest
Why???
Pressure greatest

Pressure minimal, Flow increased

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.

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5.3 The Heart is a Double Pump

Coronary circulation

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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 (bicuspид) valve
atrioventricular (tricuspid) valve
chordae tendineae
papillary muscles
right ventricle
septum
left ventricle
inferior vena cava

Coronary sinus

Figure 5.4a  The heart is a double pump.
5.3 The Heart is a Double Pump

Coronary circulation

- 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.
What is the hepatic portal system?

- Portal system → capillary to capillary
- Hepatic portal btn intestines & liver
  - Amino acids → blood proteins
  - Glucose → glycogen
- “cleanses” blood from GI tract
- Returns blood via inferior vena cava
Exchange at the capillary beds is primarily a result of osmotic and blood pressure effects. At the arterial end, blood pressure is higher than osmotic pressure, resulting in net pressure out. This allows water and solutes such as oxygen, amino acids, glucose, and carbon dioxide to pass into the tissue fluid. At the venous end, osmotic pressure is higher than blood pressure, resulting in net pressure in, allowing solutes like salts, plasma proteins, and wastes to pass back into the blood. Figure 5.12 illustrates the movement of solutes in a capillary bed.
5.6 Exchange at the Capillaries

Exchange at the capillaries

Precapillary sphincter

arteriole  tissue  cells  lymphatic capillary  blood capillary  venule

Figure 5.13 Interaction of lymphatic and capillary beds. Lymphatic duct with lymph → subclavian veins
Cardiovascular disease (CVD)

Disorders of:

- heart (cardio) and blood vessels (vascular)

**TABLE 1: RISK FACTORS FOR CVD**

<table>
<thead>
<tr>
<th>Modifiable Risk Factors</th>
<th>Nonmodifiable Risk Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overweight/obesity</td>
<td>Increasing age</td>
</tr>
<tr>
<td>Hypertension</td>
<td>Gender</td>
</tr>
<tr>
<td>Hyperlipidemia</td>
<td>Family history</td>
</tr>
<tr>
<td>Alcohol and tobacco use</td>
<td>Heredity and race</td>
</tr>
<tr>
<td>Stress</td>
<td>Menopause</td>
</tr>
<tr>
<td>High fat, high calorie diet</td>
<td></td>
</tr>
<tr>
<td>Sedentary lifestyle</td>
<td></td>
</tr>
<tr>
<td>CVD = cardiovascular disease.</td>
<td></td>
</tr>
</tbody>
</table>
Cardiovascular disease (CVD)

Risk Factors

Seven Controllable Risk Factors

- Fast food
- Smoking
- Obesity
- Alcohol consumption
- Stress

Five Uncontrollable Risk Factors

- History
- Genetic factors
- Age
- Gender
- Family history
Disorders of the blood vessels

- Hypertension/high blood pressure
- Atherosclerosis
- Stroke
- Heart attack
- Aneurysm
5.7 Cardiovascular Disorders

Hypertension

• Often due to arterial plaque.
• 140/90 mmHg is considered hypertension.
• Silent killer → few symptoms
• It can lead to a heart attack, stroke, or kidney failure

![Hypertension Causes Diagram](Image)
Hypertension

High Blood Pressure

High blood pressure is a sign that the heart and blood vessels are being overworked.

Untreated, the disease can lead to atherosclerosis and congestive heart failure.

**Hypertension Stages**

- **Normal**: <120 / <80 mmHg
- **Prehypertension**: 120-139 / 80-89 mmHg
- **Hypertension Stage 1**: 140-159 / 90-99 mmHg
- **Hypertension Stage 2**: 160-179 / 100-109 mmHg
- **Hypertensive Crisis**: >180 / >110 mmHg
- **Stroke ***!!***
Atherosclerosis

- Build up of **plaque**
- **Thrombus**
- **Embolus** $\rightarrow$ dislodged thrombus
- Associated with stroke, heart attacks and aneurysms

**Figure 5B** Coronary arteries and plaque.
Treatments for Atherosclerotic Plaque in Coronary Arteries

- Bypass surgery
- Stents: wire mesh cylinder inserted
- **Angioplasty**: a tube with a balloon inflated
Stroke

- **Stroke** aka cerebrovascular accident (CVA)
  - Cranial artery is blocked or bursts
  - Part of the brain dies
- **Symptoms may include:**
  - numbness of hands or face
  - difficulty speaking
  - inability to see in one eye

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### Types of Stroke

- **Ischemic Stroke**
  - Blockage of blood vessels
  - lack of blood flow to affected area

- **Hemorrhagic Stroke**
  - Rupture of blood vessels
  - leakage of blood in affected area

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**Embolic (embolitic) strokes**
- are caused by dislodged thrombi (emboli) that occlude cerebral arteries.

**Hemorrhagic strokes**
- are caused by cerebral arterial wall rupture.

**Thrombotic strokes**
- are caused by atheromatous plaques that occlude cerebral arteries.
Aneurysm

• Blood vessel balloons (weaken walls)
  • Atherosclerosis and hypertension
  • Most commonly affected
    – abdominal artery or the arteries leading to the brain.
Heart attack

- **Heart attack** or myocardial infarction (MI)
  - Part of the heart dies due to lack of oxygen
- **Angina pectoris:** radiating pain left arm pain
  - Blockage of a coronary artery

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**EARLY WARNINGS OF HEART ATTACK**

- Chest Pain or Pressure
- Difficulty in Breathing
- Fatigue
- Dizziness
- Changes in Heartbeat
- Continuous Sweating
- Nausea or Indigestion
How are disorders of the blood vessels treated?

- Dissolving blood clots
  - (tissue plasmogen activator)
  - drug that dissolves clots
Disorders of the heart and its treatment

• Disorders
  ➢ Congestive heart failure

• 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

Controllable Risk Factors

- High Blood Pressure
- High Cholesterol
- Diabetes
- Overweight and Obesity
- Poor Diet and Physical Inactivity
- Cigarette Smoking