Chapter 11
The Cardiovascular System

Slides 11.1 – 11.19

Lecture Slides in PowerPoint by Jerry L. Cook
The Cardiovascular System

- A closed system of the heart and blood vessels
  - The heart pumps blood
  - Blood vessels allow blood to circulate to all parts of the body
- The function of the cardiovascular system is to deliver oxygen and nutrients and to remove carbon dioxide and other waste products
The Heart

- **Location**
  - Thorax between the lungs
  - Pointed apex directed toward left hip
- **About the size of your fist**
The Heart

Figure 11.1
The Heart: Coverings

- Pericardium – a double serous membrane
  - Visceral pericardium
    - Next to heart
  - Parietal pericardium
    - Outside layer
- Serous fluid fills the space between the layers of pericardium
The Heart: Heart Wall

- Three layers
  - Epicardium
    - Outside layer
    - This layer is the parietal pericardium
    - Connective tissue layer
  - Myocardium
    - Middle layer
    - Mostly cardiac muscle
  - Endocardium
    - Inner layer
    - Endothelium
The Heart: Chambers

- Right and left side act as separate pumps
- Four chambers
  - Atria
    - Receiving chambers
      - Right atrium
      - Left atrium
  - Ventricles
    - Discharging chambers
      - Right ventricle
      - Left ventricle
The Heart: Valves

- Allow blood to flow in only one direction
- Four valves
  - Atrioventricular valves – between atria and ventricles
    - Bicuspid valve (left)
    - Tricuspid valve (right)
  - Semilunar valves between ventricle and artery
    - Pulmonary semilunar valve
    - Aortic semilunar valve
The Heart: Valves

- Valves open as blood is pumped through
- Held in place by chordae tendineae (“heart strings”)
- Close to prevent backflow
Operation of Heart Valves

**Operation of the AV valves**

1. Blood returning to the heart fills atria, putting pressure against atrioventricular valves; the atrioventricular valves are forced open

2. As the ventricles fill, atrioventricular valve flaps hang limply into ventricles

3. Atria contract, forcing additional blood into ventricles

**Operation of the semilunar valves**

1. Ventricles contract, forcing blood against atrioventricular valve cusps

2. Atrioventricular valves close

3. Chordae tendineae tighten, preventing valve flaps from evert ing into atria

As ventricles contract and intraventricular pressure rises, blood is pushed up against semilunar valves, forcing them open

As ventricles relax, and intraventricular pressure falls, blood flows back from arteries, filling the cusps of semilunar valves and forcing them to close

**Figure 11.4**

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The Heart: Associated Great Vessels

- Aorta
  - Leaves left ventricle
- Pulmonary arteries
  - Leave right ventricle
- Vena cava
  - Enters right atrium
- Pulmonary veins (four)
  - Enter left atrium
Coronary Circulation

- Blood in the heart chambers does not nourish the myocardium
- The heart has its own nourishing circulatory system
  - Coronary arteries
  - Cardiac veins
  - Blood empties into the right atrium via the coronary sinus

Slide 11.14
The Heart: Conduction System

- Intrinsic conduction system (nodal system)
  - Heart muscle cells contract, without nerve impulses, in a regular, continuous way
The Heart: Conduction System

- Special tissue sets the pace
  - Sinoatrial node
  - Pacemaker
  - Atrioventricular node
  - Atrioventricular bundle
  - Bundle branches
  - Purkinje fibers
Heart Contractions

- Contraction is initiated by the sinoatrial node
- Sequential stimulation occurs at other autorhythmic cells
Heart Contractions

Figure 11.5

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Filling of Heart Chambers – the Cardiac Cycle

Figure 11.6
The Heart: Cardiac Cycle

- Atria contract simultaneously
- Atria relax, then ventricles contract
- Systole = contraction
- Diastole = relaxation
The Heart: Cardiac Cycle

- Cardiac cycle – events of one complete heart beat
  - Mid-to-late diastole – blood flows into ventricles
  - Ventricular systole – blood pressure builds before ventricle contracts, pushing out blood
  - Early diastole – atria finish re-filling, ventricular pressure is low
The Heart: Cardiac Output

- Cardiac output (CO)
  - Amount of blood pumped by each side of the heart in one minute
  - \( \text{CO} = (\text{heart rate [HR]}) \times (\text{stroke volume [SV]}) \)

- Stroke volume
  - Volume of blood pumped by each ventricle in one contraction
Cardiac Output Regulation

Figure 11.7

KEY:
- Promotes/enhances
- Reduces

Parasympathetic nervous system controls (via vagus nerves)

Heart rate (beats/min)

Stroke volume (ml/beat)

Decreased venous return

Increased venous return

Increased contractile force of cardiac muscle

Sympathetic nervous system activity

Hormones: epinephrine, thyroxine

Crisis has passed

High blood pressure or blood volume

Low blood pressure

Crisis stressors (physical or emotional trauma, increased body temperature; exercise)

Decreased blood volume (hemorrhage)

Activation of skeletal muscle and respiratory “pumps”

Exercise

Cardiac output (ml/min)
The Heart: Regulation of Heart Rate

- Stroke volume usually remains relatively constant
  - Starling’s law of the heart – the more that the cardiac muscle is stretched, the stronger the contraction
- Changing heart rate is the most common way to change cardiac output
The Heart: Regulation of Heart Rate

- Increased heart rate
  - Sympathetic nervous system
    - Crisis
    - Low blood pressure
  - Hormones
    - Epinephrine
    - Thyroxine
  - Exercise
  - Decreased blood volume
The Heart: Regulation of Heart Rate

- Decreased heart rate
  - Parasympathetic nervous system
  - High blood pressure or blood volume
  - Decreased venous return
Blood Vessels: The Vascular System

- Taking blood to the tissues and back
  - Arteries
  - Arterioles
  - Capillaries
  - Venules
  - Veins
The Vascular System

Figure 11.8b

- Tunica interna
  - Endothelium
  - Loose connective tissue
- Internal elastic lamina
- Tunica media
- External elastic lamina
- Tunica externa

Artery

Venule

Capillary network

Lumen

Valve

Endothelium

Loose connective tissue

(b) Capillary

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Blood Vessels: Anatomy

- Three layers (tunics)
  - Tunic intima
    - Endothelium
  - Tunic media
    - Smooth muscle
    - Controlled by sympathetic nervous system
  - Tunic externa
    - Mostly fibrous connective tissue
Differences Between Blood Vessel Types

- Walls of arteries are the thickest
- Lumens of veins are larger
- Skeletal muscle “milks” blood in veins toward the heart
- Walls of capillaries are only one cell layer thick to allow for exchanges between blood and tissue
Movement of Blood Through Vessels

- Most arterial blood is pumped by the heart
- Veins use the milking action of muscles to help move blood
Capillary Beds

- Capillary beds consist of two types of vessels
- Vascular shunt – directly connects an arteriole to a venule
Capillary Beds

- True capillaries – exchange vessels
- Oxygen and nutrients cross to cells
- Carbon dioxide and metabolic waste products cross into blood

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Diffusion at Capillary Beds

Figure 11.20
Major Arteries of Systemic Circulation

- Internal carotid artery
- External carotid artery
- Vertebral artery
- Brachiocephalic artery
- Axillary artery
- Ascending aorta
- Brachial artery
- Abdominal aorta
- Superior mesenteric artery
- Gonadal artery
- Inferior mesenteric artery
- Common iliac artery
- External iliac artery
- Internal iliac artery
- Digital arteries
- Femoral artery
- Popliteal artery
- Anterior tibial artery
- Posterior tibial artery
- Dorsalis pedis
- Arcuate artery
- Common carotid arteries
- Subclavian artery
- Aortic arch
- Coronary artery
- Thoracic aorta
- Branches of celiac trunk:
  - Left gastric artery
  - Splenic artery
  - Common hepatic artery
- Renal artery
- Radial artery
- Ulnar artery
- Deep palmar arch
- Superficial palmar arch
- Deep femoral artery

Figure 11.11
Major Veins of Systemic Circulation

Figure 11.12

Dural sinuses
External jugular vein
Vertebral vein
Internal jugular vein
Superior vena cava
Axillary vein
Great cardiac vein
Hepatic veins
Hepatic portal vein
Superior mesenteric vein
Inferior vena cava
Ulnar vein
Radial vein
Common iliac vein
External iliac vein
Internal iliac vein
Digital veins
Femoral vein
Great saphenous vein
Popliteal vein
Posterior tibial vein
Anterior tibial vein
Fibular vein

Subclavian vein
Right and left brachiocephalic veins
Cephalic vein
Brachial vein
Basilic vein
Splenic vein
Median cubital vein
Renal vein
Inferior mesenteric vein

Dorsal venous arch
Dorsal digital veins

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Hepatic Portal Circulation

Figure 11.14
Circulation to the Fetus

Figure 11.15

KEY:
- High oxygenation
- Moderate oxygenation
- Low oxygenation
- Very low oxygenation
Pulse

- **Pulse** – pressure wave of blood
- **Monitored at “pressure points” where pulse is easily palpated**
Blood Pressure

- Measurements by health professionals are made on the pressure in large arteries
  - Systolic – pressure at the peak of ventricular contraction
  - Diastolic – pressure when ventricles relax
- Pressure in blood vessels decreases as the distance away from the heart increases
Measuring Arterial Blood Pressure

Figure 11.18

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Comparison of Blood Pressures in Different Vessels
Blood Pressure: Effects of Factors

- Neural factors
  - Autonomic nervous system adjustments (sympathetic division)
- Renal factors
  - Regulation by altering blood volume
  - Renin – hormonal control
Blood Pressure: Effects of Factors

- Temperature
  - Heat has a vasodilation effect
  - Cold has a vasoconstricting effect

- Chemicals
  - Various substances can cause increases or decreases

- Diet
Factors Determining Blood Pressure

Blood volume ↓

Exercise Activates

Kidney conserves water and salt

SNS Centers

Chemicals (renin, nicotine and others)

Postural changes

Blood viscosity ↑

Which brings about

SV ↑ HR ↑

Cardiac output ↑

Vasoconstriction

Peripheral resistance ↑

Arterial blood pressure ↑

↑ = increased
↓ = decreased

Figure 11.19
Variations in Blood Pressure

- Human normal range is variable
  - Normal
    - 140–110 mm Hg systolic
    - 80–75 mm Hg diastolic
  - Hypotension
    - Low systolic (below 110 mm Hg)
    - Often associated with illness
  - Hypertension
    - High systolic (above 140 mm Hg)
    - Can be dangerous if it is chronic
Capillary Exchange

- Substances exchanged due to concentration gradients
  - Oxygen and nutrients leave the blood
  - Carbon dioxide and other wastes leave the cells
Capillary Exchange: Mechanisms

- Direct diffusion across plasma membranes
- Endocytosis or exocytosis
- Some capillaries have gaps (intercellular clefts)
  - Plasma membrane not joined by tight junctions
- Fenestrations of some capillaries
  - Fenestrations = pores
A simple “tube heart” develops in the embryo and pumps by the fourth week.

The heart becomes a four-chambered organ by the end of seven weeks.

Few structural changes occur after the seventh week.