12
The Cardiovascular and Lymphatic Systems

Lecture Presentation
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The Cardiovascular and Lymphatic Systems

OUTLINE:

- Cardiovascular System
- Blood Vessels
- Heart
- Blood Pressure
- Lymphatic System
Cardiovascular System

- The cardiovascular system is composed of
  - Blood vessels
  - Heart
- This system distributes blood, delivers nutrients, and removes wastes
Figure 12.1 A diagrammatic view of the cardiovascular system.
Blood Vessels

- Blood passes through the following loop of vessels moving away from the heart
  - Arteries
  - Arterioles
  - Capillaries
  - Venules
  - Veins

- Blood returns to the heart from the venules and veins
Blood Vessels

- **Common features**
  - Lumen—the hollow interior through which blood flows
  - Endothelium—the inner lining consisting of simple squamous epithelium

- **Special features**
  - Each type of blood vessel has traits that reflect its particular function
Figure 12.2 *The structure of blood vessels.*
Arteries

- Thick, muscular vessels that carry blood away from the heart to body tissues

- Layers
  - Inner—endothelium
  - Middle
    - Elastic fibers—allow the artery to stretch and return to its original shape
    - Smooth muscle—allows the artery to contract
  - Outer—connective tissue
Arteries

Pulse

- Pressure wave created by the alternate expansion and contraction of the arteries
- Moves along the arteries with each heartbeat
- The pulse rate is the same as the heart rate
Arteries

- **Vasoconstriction**
  - Smooth muscle of the middle layer contracts and the diameter of the lumen narrows, reducing blood flow

- **Vasodilation**
  - Smooth muscle of the middle layer relaxes and the diameter of the lumen increases, increasing blood flow
Arteries

- Aneurysm
  - Occurs when the wall of an artery is weakened and swells outward
  - The primary risk is that it will burst, causing blood loss
  - If it does not burst, then it can form life-threatening clots
Arteries

- Arterioles
  - Smallest arteries
  - The prime controllers of blood pressure (pressure of blood against vessel walls)
  - Serve as gatekeepers to the capillary networks, keeping them open or closed
Capillaries

- Microscopic blood vessels connecting arterioles and venules
- Sites of exchange of materials between the blood and the body cells
  - Have walls that are one cell thick
  - Provide enormous surface area for exchange
  - Exchange occurs through endothelial cells (across the plasma membranes) or through slits between these cells
    - Blood flows very slowly, allowing more time for the exchange of materials
  - Capillary bed is a network of capillaries servicing a particular area
  - Precapillary sphincter regulates blood flow into it
Figure 12.3 *Capillaries.*

(a) Substances are exchanged between the blood and tissue fluid across the plasma membrane of the capillary cells or through slits between capillary cells.

(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.

(c) Capillaries are so narrow that red blood cells must travel through them in single file.
Figure 12.4 (a) A capillary bed is a network of capillaries. (b) The entrance to each capillary is guarded by a precapillary sphincter.
Figure 12.5 Capillaries and blood flow.
Veins

- Venules
  - Capillaries merge to form venules, the smallest kind of vein
  - Venules join to form larger veins

- Veins
  - Carry blood back to the heart
  - Walls have the same three layers as arteries, but they are thinner; also have larger lumens
  - Serve as reservoirs for blood volume
Veins

- Three mechanisms move blood (against gravity) from the lower parts of the body to the heart
  - Contraction of skeletal muscles
  - Pressure differences caused by breathing
    - Expansion of the thoracic cavity during inhalation
      - Lowers pressure and pulls blood toward the heart
      - Increases pressure in the abdominal cavity, which squeezes veins, and moves blood toward the heart
  - Valves in veins
    - Prevent backflow of blood
Figure 12.6 A vein showing a valve (a) Micrograph, (b) diagram.

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

(b) Relaxed calf muscles

Contracted calf muscles

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

- **Structure**
  - Three layers of the heart
    - Myocardium
      - The wall of the heart
      - Mostly cardiac muscle tissue
    - Endocardium
      - Thin lining of the cavities of the heart
      - Reduces resistance to blood flow through the heart
  - Pericardium
    - Thick fibrous sac that holds the heart
Heart

- The septum separates the two halves of the heart
- Each half has two chambers
  - Atrium—smaller and thin-walled
  - Ventricle—larger and more muscular
Heart

- Valves (two pairs)
  - Atrioventricular (AV) valves: separate the atria from the ventricles
  - Semilunar valves: separate the ventricles from the exit vessels

- Heart’s “lub-dup” sounds come from the valves
  - “Lub”—closing of the AV valves
  - “Dup”—closing of the semilunar valves
Figure 12.7 The human heart. (a) Photograph (b) Location. (c) Blood flow (d) diagram.
Heart

• AV valves
  • Tricuspid valve
    • On the right side of the heart, has three flaps
  • Bicuspid (or mitral) valve
    • On the left side of the heart, has two flaps
Heart

- Semilunar valves
  - Aortic semilunar valve: between left ventricle and aorta
  - Pulmonary semilunar valve: between right ventricle and pulmonary artery
  - Prevent the backflow of blood into the ventricles
Figure 12.8 The valves of the heart.

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

Semilunar valves are located between each ventricle and its artery.
Two Circuits of Blood Flow

- The right side of the heart
  - Contains blood low in oxygen
  - Pumps blood through the pulmonary circuit
    - Transports blood to and from the lungs
- The left side of the heart
  - Contains blood rich in oxygen
  - Pumps blood through the systemic circuit
    - Transports blood to and from body tissues
Figure 12.9 *Circuits of blood flow.*
Coronary Circulation

- Coronary circulation nourishes the heart muscle
  - Coronary arteries
    - The first two arteries that branch off the aorta and branch extensively
    - Bring oxygen and nutrients to the heart muscle
  - Coronary veins
    - Blood passes through capillary beds, enters coronary veins, and flows into the right atrium
Figure 12.10 Coronary circulation.
Cardiac Cycle

- All chambers relax and blood passes through atria into ventricles
  - Atria contract
  - Ventricles contract
  - Heart relaxes, and the cycle begins again
- Contraction is called systole
- Relaxation is called diastole
Figure 12.11 *The cardiac cycle.*

**Early diastole**
Atria and ventricles are relaxed and fill passively.

**Later diastole**
Ventricles are still relaxing and filling passively.

**Ventricular systole**
Both ventricles contract.
- The right ventricle forces blood into the pulmonary trunk.
- The left ventricle forces blood into the aorta.

**Atrial systole**
Both atria contract and force blood into ventricles.
Internal Conduction System

- Sinoatrial (SA) node (pacemaker)
  - Located in the right atrium
  - Causes atria to contract
  - Generates an electrical signal that sets the tempo of the heartbeat
Internal Conduction System

- Atrioventricular (AV) node
  - Located between the two atria
  - Receives the signal from the SA node
  - Transmits the signal by way of the atrioventricular bundle (located along the wall between the two ventricles) to Purkinje fibers that penetrate the walls of the ventricles, causing the ventricles to contract
Figure 12.12 The conduction system of the heart.
Internal Conduction System

- Problems with the internal conduction system can result in ventricular fibrillation (irregular contraction of the ventricles)
- Electric shock may induce the SA node to function normally
- Implantable defibrillators can be used in the long term
Internal Conduction System

The Cardiovascular System

The human heart is a muscular organ that pumps blood to and from the lungs and throughout the body. Its four chambers work together to maintain a repeated series of contractions and relaxations, called the cardiac cycle. This tutorial explores the various structures of the human heart, their functions, and their coordination during the cardiac cycle.

Press "PLAY" to begin Animation.
Electrocardiogram

- A powerful tool recording of the electrical events associated with the heartbeat
  - Abnormal patterns can indicate heart problems
- Three distinguishable deflection waves
  - P wave
    - Signals from SA node spread across the atria and cause them to contract
  - QRS wave
    - Spread of signals through ventricles and ventricular contraction
  - T wave
    - Return of the ventricles to the electrical state before contraction
Figure 12.13 *An electrocardiogram (ECG) tracing.*

- **Millivolts**
- **Seconds**

- **P** - Atria contract
- **Q** - Atria contract
- **R** - Ventricle contract
- **S** - Ventricle contract
- **T** - Ventricle contract
Blood Pressure

- The force exerted by the blood against the walls of the blood vessels (e.g., 120/80)
- Can be measured using a sphygmomanometer
  - Measures pressure in the brachial artery of the arm
Blood Pressure

- Systolic pressure
  - Highest pressure in the artery during each heartbeat (ventricles are contracting)
  - About 120 mm Hg in a healthy adult

- Diastolic pressure
  - Lowest pressure in the artery during each heartbeat (ventricles are relaxing)
  - About 80 mm Hg in a healthy adult
Figure 12.14 *Blood pressure is measured with a sphygmomanometer.*
Lymphatic System

- Components of the lymphatic system
  - Lymph: fluid identical to interstitial fluid
  - Lymphatic vessels
    - Vessels through which lymph flows
    - Have one-way valves to prevent backflow
  - Lymphoid tissues and organs
Lymphatic System

- Functions of the lymphatic system
  - Return excess interstitial fluid to the bloodstream
  - Transport products of fat digestion from the small intestine to the bloodstream
  - Defend the body against disease-causing organisms and abnormal cells
Elephantiasis

- A condition in which parasites block lymphatic vessels, preventing the return of fluid to blood
- Results in massive swelling, darkening, and thickening of the skin in the affected area
Figure 12.15 *The legs of a person with elephantiasis.*
Lymphatic System

- Lymphatic capillaries
  - Extra fluid enters these microscopic tubules
  - Differ from blood capillaries
    - End blindly
    - More permeable
  - Drain into larger lymphatic vessels
  - Lymph eventually enters ducts that join with large veins at the base of the neck
Figure 12.16 Lymphatic capillaries.
Lymphatic System

- Lymph nodes
  - Bean-shaped structures
  - Filter lymph as it flows through them
  - Contain macrophages and lymphocytes that defend against disease-causing organisms
Lymphatic System

- Lymphoid organs include
  - Tonsils
  - Thymus gland
  - Spleen
  - Peyer’s patches (nodules along the small intestine)
  - Red bone marrow
Figure 12.17 The lymphatic system.

(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.

- **Tonsils**
  - Protect the throat against bacteria and foreign agents

- **Right lymphatic duct**
  - Returns the lymph from the upper part of the 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

(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.
You Should Now Be Able To:

- Describe the organs of the cardiovascular system
- Know the structure and function of blood vessels:
  - Arteries
  - Capillaries
  - Veins
- Know the detailed anatomy of the heart
- Explain blood circulation
- Understand the heart’s internal conduction system
- Understand blood pressure and how to measure it
- Describe the lymphatic system with its organs and its circulation