Heart’s Place in the Circulation

Heart Pumps Blood into Two Circuits in Sequence
1. **Pulmonary circuit**
   - To and from the lungs
2. **Systemic circuit**
   - To and from the rest of the body

Heart’s Place in the Circulation

Three Kinds of Blood Vessels
1. **Arteries**
   - Carry blood **away** from heart and carry it to the capillaries
2. **Capillaries**
   - Connect arteries and veins
   - Exchange area between blood and cells
3. **Veins**
   - Receive blood from capillaries and carry it **back** to the heart

Heart’s Place in the Circulation

Two Sets of Pumping Chambers in Heart
1. **Right atrium**
   - Receives systemic blood
2. **Right ventricle**
   - Pumps blood to lungs (pulmonary)
3. **Left atrium**
   - Receives blood from lungs
4. **Left ventricle**
   - Pumps blood to organ systems (systemic)

The Anatomy of the Heart

**Pericardial Cavity**
- Surrounds the heart
- Lined by **pericardium**
  - Two layers
    1. **Visceral pericardium (epicardium)**
       - Covers heart surface
    2. **Parietal pericardium**
       - Lines **pericardial sac** that surrounds heart

Overview of the Cardiovascular System

Figure 12-1
The Anatomy of the Heart

The Location of the Heart in the Thoracic Cavity

Surface Features of the Heart

1. **Auricle** — Outer portion of atrium
2. **Coronary sulcus** — Deep groove that marks boundary of atria and ventricles
   - Anterior & Posterior interventricular sulcus
   - Mark boundary between left and right ventricles
   - **Sulci** contain major cardiac blood vessels
   - Filled with protective fat

The Anatomy of the Heart

The Surface Anatomy of the Heart

1. **Epicardium** (visceral pericardium)
   - Outermost layer
   - Serous membrane
2. **Myocardium**
   - Middle layer
   - Thick muscle layer
3. **Endocardium**
   - Inner lining of pumping chambers

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The Anatomy of the Heart

The Heart Wall and Cardiac Muscle Tissue

Cardiac Muscle Cells
- Shorter than skeletal muscle fibers
- Have single nucleus
- Have striations (sarcomere organization)
- Depend on aerobic metabolism
- Connected by intercalated discs
  - Make sure all cardiac muscle cells work together so the heart beats as one unit
The Anatomy of the Heart

**Internal Anatomy and Organization**

1. **Interatrial septum**
   - Separates atria

2. **Interventricular septum**
   - Separates ventricles

3. **Atrioventricular valves (AV valves)**
   - Located between atrium and ventricle
   - Ensure one-way flow from atrium to ventricle

**Blood Flow in the Heart**

1. **Superior and inferior venae cavae**
   - Large veins carry systemic blood to right atrium

2. **Right atrium sends blood to right ventricle**
   - Flows through right AV valve
   - Bonded by three cusps (tricuspid valve)
   - Cusps anchored to heart walls by chordae tendinae

3. **Right ventricle pumps blood through pulmonary semilunar valve to pulmonary arteries**
   - Flows to lungs through right, left pulmonary arteries where it picks up oxygen

4. **Pulmonary veins carry blood to left atrium**

5. **Left atrium sends blood to left ventricle**
   - Enters through left AV valve (bicuspid or mitral)

6. **Left ventricle pumps blood to aorta**
   - Through aortic semilunar valve to systems

**The Sectional Anatomy of the Heart**

**Functional Anatomy of the Heart**

1. **Left ventricular myocardium much thicker than right**
   - Why?

2. **Valves ensure one-way flow of blood**
   - Prevent backward flow (regurgitation)
The Anatomy of the Heart

Key Note
The heart has four chambers, the right atrium and ventricle with the pulmonary circuit and left atrium and ventricle with the systemic circuit. The left ventricle’s greater workload makes it more massive than the right, but the two pump equal amounts of blood. AV valves prevent backflow from the ventricles into the atria, and semilunar valves prevent backflow from the outflow vessels into the ventricles.

The Blood Supply TO the Heart
- The myocardium needs lots of oxygen and nutrients
- Coronary arteries (right, left) branch from aorta base and supply blood to the heart muscle itself
- If a coronary artery becomes blocked, a myocardial infarction (heart attack) occurs
- Blockage usually occurs because of build up of fat in coronary arteries

Anatomy of the Heart
A blocked coronary artery can be repaired by having coronary bypass surgery

The Coronary Circulation
The Anatomy of the Heart

The Coronary Circulation

The Heartbeat

Heartbeat Needs two Types of Cardiac Cells
1. Contractile cells
   - Provide the pumping action
2. Cells of the conducting system
   - Generate and spread the action potential (electrical impulse)

The Heartbeat

Differences between Cardiac and Skeletal Muscle Cells
- Cardiac action potential has long plateau phase
- Cardiac muscle has long, slow twitch
- Cardiac muscle has long refractory period
- Can’t be tetanized
Rapid Depolarization
Cause: Na\(^+\) entry
Duration: 3-5 msec
Ends with: Closure of voltage-regulated sodium channels

The Plateau
Cause: Ca\(^{2+}\) entry
Duration: ~175 msec
Ends with: Closure of calcium channels

Repolarization
Cause: K\(^+\) loss
Duration: 75 msec
Ends with: Closure of potassium channels

The Heartbeat
Action Potentials and Muscle Cell Contraction in Skeletal and Cardiac Muscle

The Conducting System
- Initiates and spreads electrical impulses in heart
- Two types of cells
  1. **Pacemaker cells (aka “nodes”)**
     - Reach threshold first
     - Set heart rate
  2. **Conducting cells**
     - Distributes stimuli to myocardium

The Heartbeat
The Conducting System (cont’d)
- **Steps in the Conduction System:**
  1. Starts in **atria**. Pacemaker cells establish heart rate
     - Pacemaker is also called **sinoatrial (SA) node**
  2. Impulse spreads from SA node across atria
  3. To **atrioventricular (AV) node**
  4. To **AV bundle** and bundle branches
     - Via **Purkinje fibers** to **ventricles**
SA node activity and atrial activation begin. Stimulus spreads across the atrial surfaces and reaches the AV node. Elapsed time = 50 msec.

There is a 100-msec delay at the AV node. Atrial contraction begins. Elapsed time = 150 msec.

The impulse travels along the interventricular septum within the AV bundle and the bundle branches to the Purkinje fibers. Elapsed time = 175 msec.

The impulse is distributed by Purkinje fibers and relayed throughout the ventricular myocardium. Atrial contraction is completed, and ventricular contraction begins. Elapsed time = 225 msec.
The Heartbeat

The Electrocardiogram (ECG or EKG)
- A recording of the electrical activity of the heart
- Three main components
  1. P wave
     - Atrial depolarization (atria contract)
  2. QRS complex
     - Ventricular depolarization (ventricles contract)
  3. T wave
     - Ventricular repolarization (ventricles rest)

Key Note
The heart rate is established by the SA node, as modified by autonomic activity, hormones, ions, etc. From there, the stimulus is conducted through the atrium to the AV node, the AV bundle, the bundle branches, and Purkinje fibers to the ventricular myocardium. The ECG shows the electrical events associated with the heartbeat.

The Cardiac Cycle
- Two phases in cardiac cycle
  1. Systole
     - Contraction phase
     - Both ventricles simultaneously
  2. Diastole
     - Relaxation phase
The Heartbeat

Heart Sounds

- Generated by closing of valves
- Two main heart sounds
  1. First sound (lub)
     - Closing of bicuspid & tricuspid
  2. Second sound (dub)
     - Closing of aortic & pulmonary valves
- Indicate start/stop of systole
- Heard with stethoscope

Heart Dynamics

Some Essential Definitions

- Heart dynamics—Movements and forces generated during cardiac contraction
- Stroke volume—Amount of blood pumped in a single beat
- Cardiac output—Amount of blood pumped each minute
Heart Dynamics

Factors Controlling Cardiac Output

- Blood volume reflexes
- Autonomic innervation
  - Heart rate effects
  - Stroke volume effects
- Hormones

Heart Dynamics

Blood Volume Reflexes

- Stimulated by changes in venous return
- VR is amount of blood entering heart
- Atrial reflex
  - Speeds up heart rate
  - Triggered by stretching wall of right atrium
- Frank-Starling principle
  - Increases ventricular output
  - Triggered by stretching wall of ventricles

Heart Dynamics

Autonomic Control of the Heart

- Parasympathetic innervation
  - Releases acetylcholine (ACh)
  - Lowers heart rate and stroke volume
- Sympathetic innervation
  - Releases norepinephrine (NE)
  - Raises heart rate and stroke volume

Heart Dynamics

Hormone Effects on Cardiac Output

- Adrenal medulla hormones
  - Epinephrine, norepinephrine released
  - Heart rate and stroke volume increased
- Other hormones that increase output
  - Thyroid hormones
  - Glucagon

Heart Dynamics

CNS Control of the Heart

- Basic control in medulla oblongata
  - Cardioacceleratory center
    - Activation of sympathetic neurons
  - Cardioinhibitory center
    - Governing of parasympathetic neurons
- Other inputs
  - Higher centers
  - Blood pressure sensors
  - Oxygen, carbon dioxide sensors

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Heart Dynamics

Key Note
Cardiac output is the amount of blood pumped by the left ventricle each minute. It is adjusted moment-to-moment by the ANS, and by circulating hormones, changes in blood volume and in venous return. A healthy person can increase cardiac output by three-fold to five-fold.