Chapter 12 The Heart
A. Function

- Blood pressure moves fluid
- One way flow
- Flow rate & force match metabolic needs
B. Location

- **Mediastinum**: thoracic cavity between lungs
- For CPR: between 2\textsuperscript{nd} and 5\textsuperscript{th} intercostal space
C. Form

- Rounded base: superior
- Apex: inferior, tipped left
- Fist size
- Pumps ~ 5 L/min at rest

Mediastinum: Front View
D. Anatomy of the Heart

1. Pericardial Cavity (contains heart)
   - Pericardium: hrt sac - surrounds/anchors
     a) Fibrous (outer): tough CT
     b) Serous (inner membranes):
        - Parietal; fluid; Visceral

Pericardium
  - Fibrous pericardium
  - Serous pericardium
    - Parietal pericardium
      - Visceral pericardium (or epicardium)
        - Pericardial cavity filled with pericardial fluid

Anterior view
2. External Anatomy

- R/L Atria (at base)
- R/L Ventricle (towards apex)
- Coronary sulcus – separates A/V & R/L Vent (ant/post interventricular sulcus)
6 veins to heart: 2 arteries from heart

One-way flow through the heart is ensured by two sets of valves.
3. Internal Anatomy

A. **Atria**: receiving chamber (from veins)
   - RA: Head – Sup. Vena Cava; body – In. Vena Cava; from heart itself – Coronary Sinus
   - Interatrial septum separates
   - LA: Pulmonary Veins-4 (↑O₂)

![Diagram of Cardiovascular System](image)
**B. Ventricle: pumping chamber (to arteries)**

- RV: PA to lungs ($\downarrow O_2$)
- Interventricular septum separates
- LV: aorta to body
- Same volumes/LV more muscular & forceful
4. **Heart valves**: prevent back flow

A. **Atrioventricular valves**: between atria & ventricle
   - Tricuspid Valve (3 cusps) = R
   - Bicuspid Valve/mitral (2 cusps) = L
- Chordae Tendineae w/Papillary Muscles
- Skeleton of Heart: fibrous CT around valves (structural support; electrical insulation)
- Ventricles relax: valves are open -> fill
- Ventricles contract: valves close -> no backflow

One-way flow through the heart is ensured by two sets of valves.
B. **Semilunar valves:** between ventricles & PA/Aorta

- **Ventricles relax:** closed -> seal exits
- **Ventricles contract:** opened w/force -> bld out
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.

(a) Semilunar valve open

(b) Semilunar valve closed
5. Blood Flow (p.320)

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6. Blood to Heart (itself)

- Coronary Arteries/Cardiac Veins (to coronary sinus-RA)
E. Histology

1. Heart Wall

A. **Epicardium** – outer epithelium
B. **Myocardium** – heart muscle
   - 1-2 central nuclei
   - ↑ capillaries -↑O₂/↑mitochondria =↑ ATP (↑ E)
   - Intercalated disks (cells=single unit; contract as one)

Endocardium – inner epithelium
2. Cardiac Muscle Cells

- Branched; 1 nucleus; striated w/ actin/myosin; ↑ mitochondria.
- W/ AP = Ca^{++}/O_2/ATP needed for contraction = cell bundles shorten & compress
- Intercalated disks w/ gap junctions pass cytoplasm = smooth AP
F. Electrical Activity of Heart

1. Action Potential

- W/AP rapid initial depolarization (w/Na⁺ in)
- Extended depolarization-Ca²⁺ in=plateau w/K⁺ out
- Repolarization w/rapid K⁺ out
- Long refractory period (betwn cntract)-hrt relaxes
2. Conduction System

- **Node** (mass of conducting cells: move AP thru)
  - Sinoatrial (SA) Node (upper RA): pacemaker
  - Internodal Bundle Fibers (R/L atria)
  - Atrioventricular (AV) Node (lower RA): delays AP allowing atria to finish contraction
  - AV Bundle (of His)/Branches: to Apex
  - **Purkinje fibers**: contraction of RV/LV

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1. Action potentials originate in the sinoatrial (SA) node and travel across the wall of the atrium (arrows) from the SA node to the atrioventricular (AV) node.

2. Action potentials pass through the AV node and along the atrioventricular (AV) bundle, which extends from the AV node, through the fibrous skeleton, into the interventricular septum.

3. The AV bundle divides into right and left bundle branches, and action potentials descend to the apex of each ventricle along the bundle branches.

4. Action potentials are carried by the Purkinje fibers from the bundle branches to the ventricular walls.
SA node depolarizes.

- Atrial Muscle (~0.5 m/sec)
- AV Node (~0.05 m/sec)
- Bundle of His (~2 m/sec)
- Left & Right Bundle Branches (~2 m/sec)

Depolarization spreads more slowly across atria. Conduction slows through AV node.

- Electrical activity goes rapidly to AV node via internodal pathways.

Depolarization moves rapidly though ventricular conducting system to the apex of the heart.

Depolarization wave spreads upward from the apex.
- Beat several hours after removal: nutrients/salt
- Ectopic beat: AP in area other than SA
3. Electrocardiogram (ECG): recorded AP signal

- P-wave: AP from SA node thru atria
- QRS wave: AP thru ventricle
- T-wave: ventricle repolarization (relaxation)
G. Cardiac Cycle: 2 phases

- Atria - primer pump/ventricles - power pump
- Diastole: relaxation - ventricles fill (dilation)
- Systole: contraction - ventricles pump
Isovolumic ventricular relaxation—as ventricles relax pressure in ventricles drops, blood flows back into cups of semilunar valves and snaps them closed.

Atrial systole—atrial contraction forces a small amount of additional blood into ventricles.

ESV = end-systolic volume, or minimum amount of blood in ventricles. $\text{ESV} \approx 65 \text{ mL}$

EDV = end-diastolic volume. The maximum amount of blood in ventricles occurs at the end of ventricular relaxation. $\text{EDV} \approx 135 \text{ mL}$

Ventricular ejection—as ventricular pressure rises and exceeds pressure in the arteries, the semilunar valves open and blood is ejected.

Isovolumic ventricular contraction—first phase of ventricular contraction pushes AV valves closed but does not create enough pressure to open semilunar valves.

Late diastole—both sets of chambers relaxed. Passive ventricular filling.
H. Heart Sounds

- **Lubb**: Vent systole: closing of AV valves
- **Dubb**: Vent diastole: closing of SL valves
- Murmur: abnormal swish; improper valve close
- Stenosed valve (narrow): swishing b/4 close

How Normal Heart Valves Work

Heart Valve Problems

Problems opening

Problems Closing
I. Heart Function

- **Cardiac output (CO)** = blood out by vent per min
- **Stroke Volume (SV)** = blood out/vent/contract
- **Heart rate (HR)** = # contract/min
- **Cardiac output** = heart rate (min) x stroke volume (beat)

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**Diagram Description:**
- **Heart Rate** (beats/min) x **Stroke Volume** (ml/beat) = **Cardiac Output** (ml/min)

- **Example:**
  - Heart Rate: 75 beats/min
  - Stroke Volume: 70 ml/beat
  - Cardiac Output: 5250 ml/min

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*Exercise activates the sympathetic nervous system, increasing heart rate, contractility, and stroke volume. Both the higher heart rate and the squeezing action of skeletal muscles on veins increase venous return, contributing to increased stroke volume.*

*Slow heart rate allows more time for ventricular filling, increasing EDV and therefore stroke volume.*
1. Intrinsic Regulations

- Contraction force = amount of blood (end vent diastole)/stretch; called preload (↑bld=↑stretch=↑contctn=↑stroke vol=↑CO)

- Starlings Law of Heart: preload/afterload (aortic pressure to overcome) affect function: ↑ volume = ↑ force of contraction

- Normal: 5 – 6 L/min

- Exercise: 20 – 30 L/min

*Left:* A graph illustrating the Frank-Starling Law of the Heart. It states that up to a point, the heart will pump all blood that returns to it. Thus, if the volume of blood at the end of the filling period (diastole) increases, the force with which the heart contracts during systole increases (up to a limit). Greater force usually results in a greater stroke volume (blood pumped per beat). The Frank-Starling law is just one illustration of the central idea of physiology -- regulation.
2. Extrinsic Regulations:

- Medulla Oblongata: Cardio Regulatory Center
  - Receptors monitor pressure/gasses (CO$_2$/pH): (carotid/aorta)
    - Low pH = ↑ rate; ↑ K$^+$ out - ↓ rate (blocks AP); ↑ Ca$^{++}$ = arrhythm
  - CNS & Hormones regulate homeostasis:
    - Sympathetic: ↑ Rate/Vol: norepi & epinephrine (adrenaline)
    - Parasympathetic: ↓ Rate/Vol: acetylcholine
J. Factors affecting heart rate

- Excitement, ↑ CO2 – sympathetic (↑ rate)
- Depression – parasympathetic (↓ rate)
- Babies fastest (120 b/m); females faster then males
- Athletes hearts may enlarge by 50%
K. Heart Disorders

- 1 in 5: heart attack before 60
- Risk: cholestrl, BP, smoke, ovrwt, ↓ exercise
- Ischemia: weak hrt muscle-↓ bld supply: ↓ O2
- Myocardial Infarction: tissue death = scars hrt
- Angina Pectoris: chest/left arm pain w/attack

Learn the Heart attack warning signs

React Act Fast! Call 9-1-1
- Nitroglycerin dilates ALL vessels: $\downarrow$ preload/ $\downarrow$ work
- Digitalis slows/strengthens contractions

The purple foxglove, *digitalis purpurea*
L. Aging

- Changes exaggerated w/exercise in elderly
- CO decreased by 30-60% with delayed functioning
- Hypertrophy: enlarged LVent. w/↑ aortic BP (hardened BV) must pump against
- Coronary Artery Disease (atherosclerosis) in 10%

- Exercise improves general heart function