Cardiovascular System: The Heart and Blood Vessels

Chapters 12 & 13
Cardiovascular System

• = The Heart and Blood vessels
• Vital to life
• Major function = transportation
  – Blood = vehicle
  – Vessels = path
  – Heart = pump
Cardiovascular System

• Brings oxygen and nutrients to all body cells and removes wastes
• Without proper circulation, irreversible damage occurs
  = death
The Heart

- Pumps ~8,000 liters of blood each day
  - (~40, 55 gallon drums)
- Contracts about 2.5 billion times in average lifetime
  - ~ 100,000 x a day
The Heart

• In thoracic cavity
• Between 2\textsuperscript{nd} rib and 5\textsuperscript{th} intercostal space
• Hollow
• Muscular
• Average size:
  \~12.5 \text{ cm long, 9 cm wide}
  – About the size of a fist
Heart Location
Heart Location
Heart Location
Heart

- Apex points to left hip
- Weighs < 1 lb
- Rests on diaphragm
- Surrounded by lungs
- Enclosed by mediastinum
Heart Coverings

- **Pericardium** - Encloses heart
  - Fibrous
  - Double layered sac:
    - 1) *Visceral pericardium* (Epicardium)
      - Thin, innermost layer
      - Covers outer surface
    - 2) *Parietal pericardium*
      - Loose, Fibrous
      - Anchors and protects
      - Lines inner surface of pericardial sac
Pericardial Cavity

• Space between parietal and visceral layers of pericardium
• Contains pericardial fluid (serous fluid)
  – Reduces friction
Heart Wall - figure 12.4

- 3 layers:
  - 1) **Epicardium** = visceral pericardium
    - Outer; serous membrane
    - Protects; reduces friction
    - Often contains adipose tissue
  - 2) **Myocardium**
    - Middle
    - Mostly cardiac muscle tissue
  - 3) **Endocardium**
    - Inner
    - Simple squamous epithelium
Heart Chambers

• Four chambers
  • Atria (2)
    – Upper chambers
    – Thin walled
    – Receiving chambers
  • Ventricles (2)
    – Lower chambers
    – Thick walled
    – Pumping chambers
Heart Chambers

• **Double pump**

• **Right side**
  – Oxygen poor blood
  – Pumps to lungs
  – Pulmonary circuit

• **Left side**
  – Oxygen rich blood
  – Pumps to body;
  – Systemic circuit

• **Interventricular septum**
  – Separates left and right sides
  – Prevents mixing of blood
Atrioventricular Valves

• **A-V valves**
  – Between atria and ventricles
  – Prevent backflow into atria
  – Consist of flaps
    • **Tricuspid valve**
      – Three flaps
      – Right side
    • **Bicuspid valve (mitral)**
      – Two flaps
      – Left side
Chordae Tendineae

• “Heart strings”
  – Strong, fibrous strings
  – Attached to **papillary muscles** = keep cusps from swinging back into atria when ventricles contract
Semilunar Valves

• **S-L valves**
  – Between ventricles and exit vessels
  – Prevent backflow into ventricles
• Three cusps
• $\frac{1}{2}$ moon-shaped
S-L Valves

• 1) Pulmonary valve
  – At entrance to pulmonary trunk

• 2) Aortic valve
  – At entrance to aortic arch
Heart Valves

• **Cardio and Resp systems 12 min**
Heart Valves
Heart Sounds

• Hear valves operate at a different times
  – “lubb”
    • AV close when the ventricles contract
    • SL valves open
  – “dupp”
    • SL close when the ventricles relax
Heart Murmur

• Backflow of blood
  – Small amount of blood regurgitates into atrium
  – Creates soft sound

• Usually prevented by valves
Heart Dissection

• Identify structures:
  – Valves
  – Chambers
  – Vessels
Coronary Circulation

• Blood supply to the heart muscle

• **Coronary arteries**
  – Originate at base of aorta in aortic sinuses
  – High pressure
Coronary Circulation

• **Cardiac veins**
  – Drain blood from heart muscle into coronary sinus
  – Posterior side of heart
  – Opens in R atrium near base of inferior vena cava
Infarct

- Interruption of blood flow causes tissue to die
- **Myocardial infarction**
  - “Coronary”
  - Heart attack
Heart Attack

• Coronary blood supply blocked
  – Lack of oxygen
  – Cells die

• Usually result from severe coronary artery disease
  – Fat build-up in walls of coronary arteries
Heart Muscle

• **Cardiac muscle tissue:**
  – Involuntary
  – Striated
  – Branching cells
  – Intercalated disks
  – Single nucleus
Cardiac Muscle

• **Heart cells**
  – Unlike skeletal muscle
  – Contract spontaneously
    • regular and continuous
  – Can be independent
  – Atrial cells
    – 60 per minute
    • Ventricular cells
      – 20-40 per minute
  – Need to be coordinated
Regulation of Heart Activity

• Nodal system
  – Intrinsic conduction system
  – Special tissue found nowhere else
  – Like a cross bw muscle and nervous tissue
  – Keeps heart beats coordinated
Conduction System

• **Sinoatrial (SA) node**
  – In right atrium
  – Tiny cell mass
  – Starts each heart beat
  – “Pacemaker”; rhythmic
  – Cells reach threshold on own
Conduction System

• **Atrioventricular (AV) node**
  – Located at junction of R. atria and R. ventricle
  – Delays signal slightly
    • all four chambers don’t contract at same time
    • Allows complete atrial contraction
Electrocardiography

• ECG or EKG
  – Recording of electrical changes generated during cardiac cycle
  – detected on body surface
Electrocardiography

• Three recognizable waves
  – 1) P wave
    • First wave
    • Small
    • Atrial depolarization
      – Before atria contract
Electrocardiography

2) QRS complex

- Second wave
- Ventricular depolarization
  - Before ventricles contract
Electrocardiography

3) T wave

- Last wave
- Small
- Ventricular repolarization
Cardiac Cycle

• Period between start of one heartbeat and start of next
  – **Systole** – period of contraction
    • Blood is pumped
    • 1\textsuperscript{st} phase
  – **Diastole** – period of relaxation
    • Chamber fills with blood
    • 2nd phase
Cardiac Arrhythmias

- Abnormal cardiac activity
- ~5% experience a few abnormal heartbeats daily = “normal”
- When heart’s pumping efficiency reduced = problem
  - Causes:
    - Damage to myocardium
    - Drug use
    - Electrolyte imbalance
Arrhythmias

- **Bradycardia** – heart rate slower than normal
  - < 60 bpm
- **Tachycardia** – heart rate faster than normal
  - > 100 bpm
Cardiac Output (CO)

- Amount of blood pumped by Left ventricle in 1 minute
- Regulated so peripheral tissues receive adequate blood supply under all conditions
  - Can increase by 300-500%
- Calculation:
  \[ \text{CO} = \text{HR} \times \text{SV} \]
  
  - \( \text{HR} = \) heart rate in beats per minute
  - \( \text{SV} = \) stroke volume in mL per beat
    - amount of blood ejected by heart in single beat
    - varies from beat to beat
Figuring CO

- HR = 75 b/m
- SV = 80 mL/beat
- What is the CO?
  - = 75 beats/min x 80 mL/beat
  - = 6000 mL/min = 6 L/min
  - = ave. for adult
Frank – Starling Principle

• Relation bw fiber length and force of contraction
• Myocardium stretched further (longer fibers) = greater force
• “more in = more out”
Heart Rate Influenced by:

• Change in:
  – blood pressure
  – body temp
  – Ion concentration (K and Ca)
Ch. 13 Blood Vessels

• Closed system
• Three types:
  – Arteries
  – Capillaries
  – Veins
Circulation Loops

- Heart
- Arteries
  - Arterioles
- Capillaries
- Venules
- Veins
- Heart
Vessels by the Numbers

• 10 billion capillaries

• If all capillaries placed end to end:
  – Circle globe
  – 25,000 miles long

• All vessels combined
  – Estimated >60,000 miles!
Arteries

• Carry blood *away* from the heart
• Blood under pressure
• Closer to pumping action of the heart
• Thick walled
  – Strong and stretchy
• Feel pulse here
Veins

• Carry blood \textbf{to} the heart
• Blood pressure is low
• Far from pumping action of heart
• Thin walled
• Have \textbf{valves}
  – No pulse here
Valves

• Folds of endothelium
• Prevent backflow
  – Blood must overcome force of gravity
Distended Veins

- Walls weaken
  - Valves don’t work well
    • Blood pools
- Uncomfortable!
- **Varicose veins**
  - Occurs in thighs and legs
- **Hemorrhoids**
  - Occurs in lining of anal canal
Walls of Arteries and Veins

• 3 layers:
  – 1) **Tunica intima** (interna)
    • Endothelium, connective tissue w elastic fibers
    • Inner layer
    • Smooth surface
      – Helps prevent blood clotting
  – 2) **Tunica media**
    • Middle layer
    • Smooth muscle
    • Collagen and elastic fibers
    • Controls diameter of vessel
Walls of Arteries and Veins

• 3) **Tunica externa** (adventitia)
  – Sheath of connective tissue
  – Irregularly organized collagenous fibers
  – Anchors vessel
Capillaries

• Tiny!
  ~ diameter of RBC
• Connect arterioles and venules
• *Only* vessels that allow exchange bw blood and surrounding material
  – Thin walls
    • One cell thick!
• Gases exchanged
• **Capillary bed**
  – Interweaving network of capillaries
Precapillary Sphincter

• Band of smooth muscle
  – At entrance to each capillary

• Regulate opening and closing of capillaries
  – Route blood flow to different body parts
Vessel diameter

• **Vasoconstriction** - decrease in diameter of arteries
  – Smooth muscle contracts

• **Vasodilation** – increase in diameter of vessel
  – Smooth muscle relaxes
Review: Two Loop Circulation

• **Pulmonary circulation**
  – From heart to lungs and back

• **Systemic circulation**
  – From heart to body and back
  – Longer
    • L. ventricle has thicker walls
Blood Pressure

• Force blood exerts against inner walls of blood vessels
• Most commonly = pressure in arteries supplied by aorta
• Decreases as distance from L. ventricle increases
  – high to low pressure
Pulse

- Pulse
  - The alternating expansion and recoil of arterial wall
  - Each beat of the left ventricle
  - Felt in arteries close to surface
Measuring Blood Pressure

• Systolic / Diastolic
  – Ex: 120 / 70

• Systolic pressure
  – Ventricles contract
  – Higher
  – 1st #

• Diastolic pressure
  – Ventricles relax
  – Lower
  – 2nd #
Pulse Pressure

- Dif bw systolic and diastolic pressures
- Lessens as distance from heart increases
Blood Pressure

• **Normal:**
  – Systolic 110-140
  – Diastolic 75-80
  – Varies with age, weight, race, mood, physical activity, and posture
Blood Pressure

• **Low** = **Hypotension**
  – Systolic below 100
  – expected result of physical conditioning
  – longer life
Blood Pressure

• High = **Hypertension**
  – Sustained elevated arterial pressure of 140/90 or higher
  – Common
  – dangerous
  – Larger, weaker heart
    • Works harder
  – “silent killer”
5 Factors Affecting Blood Flow

• 1) **Pressure**
• Directly related
  – Increase pressure, increase flow
  – Greater the difference in pressure, faster flow
5 Factors Affecting Blood Flow

2) **Resistance**
   - Opposes movement
   - Inversely related
     * Increase resistance, decrease flow
   - **Peripheral resistance** = resistance in arterial system
     * *arteriole diameter important!*
     * Depends on
       - Vascular resistance
       - Viscosity
       - Turbulence
5 Factors Affecting Blood Flow

- 3) Vascular Resistance
- Largest component of peripheral resistance
- Resistance of vessels to flow
  - Depends on length and diameter
    - Higher friction when longer and/or narrower
5 Factors Affecting Blood Flow

- 4) **Viscosity**
  - Resistance of flow
  - Depends on molecules in blood
  - Higher = more pressure needed for flow
  - Blood 5x more viscous than water
5 Factors Affecting Blood Flow

• 5) Turbulence
  – Blood does not flow smoothly
    • Injury, disease, sudden change in vessel diameter
    • Interior of vessel not smooth
  – Slows flow, increases resistance

• Fastest flow in center of vessel, slowest near walls. . . WHY?
Arteriosclerosis

• Thickening and toughening of arterial walls
  • (Skleros = hard)
  • ~ 50% of deaths in U.S.
• If in arteries leading to brain, can cause stroke
Atherosclerosis

• Form of arteriosclerosis
• Formation of lipids in tunica media
• Caused by fat in blood, cholesterol
• Forms plaque – fatty mass
• Leads to CAD
• Risk factors:
  – Age
  – Male
  – High bp
  – Smoking
  – Diabetes
  – Obesity
  – Stress
Coronary Artery Disease

• CAD

• Arteriosclerosis of coronary vessels
  – Fatty deposits in vessels
  – Cardiovascular disease
Healthy Heart

• Aerobic exercise
  – Rate higher than normal for extended time
    • Removes fatty deposits
    • Pulse rate decreases
    • Blood pressure decreases
  – Can cut heart attack risk in half
Review: Pulmonary Circulation

- Deoxygenated into R. atrium via the inferior and super vena cava.
- Thru tricuspid valve to R. ventricle
- Thru pulmonary valve into pulmonary trunk into arteries to lungs
- Becomes oxygenated in lungs through capillaries and returns to heart via the pulmonary veins and dump into Left atrium
Review: Systemic Circulation

– Oxygenated blood in the L atrium passes thru bicuspid valve into L. ventricle.
– Goes through aortic valve and out through the aorta
– Distributes oxygen body and comes back to heart via inferior vena cava and superior vena cava

Coronary sinus also returns blood to R. atrium after
Major Arteries

R and L Coronary Arteries
- branches of aorta
  -- supply heart tissues with blood
  -- must be continuous

-Pulmonary Trunk (branches into pulmonary arteries)
  - Takes blood from the R ventricle
    -- deoxygenated blood to lungs

-Aorta
  - Takes blood from L ventricle
    - Oxygenated blood to body
Major Veins

Inferior and Superior Vena Cava
- brings blood to R atrium
- deoxygenated blood from body

Pulmonary Veins –
- return blood to L atrium
- oxygenated blood from lungs

Coronary Sinus –
Large vein that empties into R atrium
- deoxygenated blood
Heart Dissection
Heart Structure
Heart Dissection