The Cardiovascular System: The Heart

- Heart pumps over 1 million gallons per year
- Over 60,000 miles of blood vessels
Heart Location

- Heart is located in the mediastinum
  - area from the sternum to the vertebral column and between the lungs
Heart Orientation

- Heart has 2 surfaces: anterior and inferior, and 2 borders: right and left
Pericardium

• Fibrous pericardium
  – dense irregular CT
  – protects and anchors the heart, prevents overstretching

• Serous pericardium
  – thin delicate membrane
  – contains
    • parietal layer-outer layer
    • pericardial cavity with pericardial fluid
    • visceral layer (epicardium)
Layers of Heart Wall

- **Epicardium**
  - visceral layer of serous pericardium

- **Myocardium**
  - cardiac muscle layer is the bulk of the heart

- **Endocardium**
  - chamber lining & valves
Chambers and Sulci of the Heart

• Four chambers
  – 2 upper atria
  – 2 lower ventricles

• Sulci - grooves on surface of heart containing coronary blood vessels and fat
  – coronary sulcus
    • encircles heart and marks the boundary between the atria and the ventricles
  – anterior interventricular sulcus
    • marks the boundary between the ventricles anteriorly
  – posterior interventricular sulcus
    • marks the boundary between the ventricles posteriorly
Chambers and Sulci

Anterior View

- Brachiocephalic trunk
- Superior vena cava
- Right pulmonary artery
- Right pulmonary veins
- Right auricle of right atrium
- Right coronary artery
- Coronary sulcus
- Anterior cardiac vein
- Right ventricle
- Inferior vena cava
- Left common carotid artery
- Left subclavian artery
- Arch of aorta
- Ascending aorta
- Ligamentum arteriosum
- Left pulmonary artery
- Pulmonary trunk
- Left pulmonary veins
- Left auricle of left atrium
- Left coronary artery (anterior interventricular branch)
- Anterior interventricular sulcus
- Greater cardiac vein
- Left ventricle
- Descending aorta
Chambers and Sulci

Posterior View
Right Atrium

- Receives blood from 3 sources
  - superior vena cava, inferior vena cava and coronary sinus
- Interatrial septum partitions the atria
- Fossa ovalis is a remnant of the fetal foramen ovale
- Tricuspid valve
  - Blood flows through into right ventricle
  - has three cusps composed of dense CT covered by endocardium
Right Ventricle

- Forms most of anterior surface of heart
- Papillary muscles are cone shaped trabeculae carneae (raised bundles of cardiac muscle)
- Chordae tendineae: cords between valve cusps and papillary muscles
- Interventricular septum: partitions ventricles
- Pulmonary semilunar valve: blood flows into pulmonary trunk
Left Atrium

- Forms most of the base of the heart
- Receives blood from lungs - 4 pulmonary veins (2 right + 2 left)
- Bicuspid valve: blood passes through into left ventricle
  - has two cusps
  - to remember names of this valve, try the pneumonic LAMB
    • Left Atrioventricular, Mitral, or Bicuspid valve
• Forms the apex of heart
• Chordae tendineae anchor bicuspid valve to papillary muscles (also has trabeculae carneae like right ventricle)
• Aortic semilunar valve:
  – blood passes through valve into the ascending aorta
  – just above valve are the openings to the coronary arteries
Myocardial Thickness and Function

- Thickness of myocardium varies according to the function of the chamber
- Atria are thin walled, deliver blood to adjacent ventricles
- Ventricle walls are much thicker and stronger
  - right ventricle supplies blood to the lungs (little flow resistance)
  - left ventricle wall is the thickest to supply systemic circulation
Thickness of Cardiac Walls

Myocardium of left ventricle is much thicker than the right.
• A-V valves open and allow blood to flow from atria into ventricles when ventricular pressure is lower than atrial pressure
  – occurs when ventricles are relaxed, chordae tendineae are slack and papillary muscles are relaxed
Atrioventricular Valves Close

• A-V valves close preventing backflow of blood into atria
  – occurs when ventricles contract, pushing valve cusps closed, chordae tendinae are pulled taut and papillary muscles contract to pull cords and prevent cusps from everting
Semilunar Valves

- SL valves open with ventricular contraction
  - allow blood to flow into pulmonary trunk and aorta
- SL valves close with ventricular relaxation
  - prevents blood from returning to ventricles, blood fills valve cusps, tightly closing the SL valves
Valve Function Review

Atria contract, blood fills ventricles through A-V valves

Ventricles contract, blood pumped into aorta and pulmonary trunk through SL valves
One Cardiac Cycle

• At 75 beats/min, one cycle requires 0.8 sec.
  – systole (contraction) and diastole (relaxation) of both atria, plus the systole and diastole of both ventricles
Auscultation

- Stethoscope

- Sounds of heartbeat are from turbulence in blood flow caused by valve closure
  - first heart sound (lubb) is created with the closing of the atrioventricular valves
  - second heart sound (dupp) is created with the closing of semilunar valves
Heart Sounds

Where to listen on chest wall for heart sounds.
Blood Circulation

• Two closed circuits, the systemic and pulmonic
• Systemic circulation
  – left side of heart pumps blood through body
  – left ventricle pumps oxygenated blood into aorta
  – aorta branches into many arteries that travel to organs
  – arteries branch into many arterioles in tissue
  – arterioles branch into thin-walled capillaries for exchange of gases and nutrients
  – deoxygenated blood begins its return in venules
  – venules merge into veins and return to right atrium
Blood Circulation (cont.)

• Pulmonary circulation
  – right side of heart pumps deoxygenated blood to lungs
  – right ventricle pumps blood to pulmonary trunk
  – pulmonary trunk branches into pulmonary arteries
  – pulmonary arteries carry blood to lungs for exchange of gases
  – oxygenated blood returns to heart in pulmonary veins
Blood Circulation

- Blood flow
  - blue = deoxygenated
  - red = oxygenated
Coronary Circulation

• Coronary circulation is blood supply to the heart
• Heart as a very active muscle needs lots of O$_2$
• When the heart relaxes high pressure of blood in aorta pushes blood into coronary vessels
• Many anastomoses
  – connections between arteries supplying blood to the same region, provide alternate routes if one artery becomes occluded
Coronary Arteries

- Branches off aorta above aortic semilunar valve

- Left coronary artery
  - circumflex branch
    - in coronary sulcus, supplies left atrium and left ventricle
    - anterior interventricular art.
    - supplies both ventricles

- Right coronary artery
  - marginal branch
    - in coronary sulcus, supplies right ventricle
    - posterior interventricular art.
    - supplies both ventricles
Coronary Veins

- Collects wastes from cardiac muscle
- Drains into a large sinus on posterior surface of heart called the coronary sinus
- Coronary sinus empties into right atrium
Cardiac Muscle Histology

- Branching, intercalated discs with gap junctions, involuntary, striated, single central nucleus per cell
Conduction System of Heart

Coordinates contraction of heart muscle.
Conduction System of Heart

• Autorhythmic Cells
  – Cells fire spontaneously, act as pacemaker and form conduction system for the heart

• SA node
  – cluster of cells in wall of Rt. Atria
  – begins heart activity that spreads to both atria
  – excitation spreads to AV node

• AV node
  – in atrial septum, transmits signal to bundle of His

• AV bundle of His
  – the connection between atria and ventricles
  – divides into bundle branches & purkinje fibers, large diameter fibers that conduct signals quickly
Rhythm of Conduction System

- SA node fires spontaneously 90-100 times per minute
- AV node fires at 40-50 times per minute
- If both nodes are suppressed fibers in ventricles by themselves fire only 20-40 times per minute
- Artificial pacemaker needed if pace is too slow
- Extra beats forming at other sites are called ectopic pacemakers
  - caffeine & nicotine increase activity
Congestive Heart Failure

• Causes of CHF
  – coronary artery disease, hypertension, MI, valve disorders, congenital defects

• Left side heart failure
  – less effective pump so more blood remains in ventricle
  – heart is overstretched & even more blood remains
  – blood backs up into lungs as pulmonary edema
  – suffocation & lack of oxygen to the tissues

• Right side failure
  – fluid builds up in tissues as peripheral edema
Regulation of Heart Rate

- Nervous control from the cardiovascular center in the medulla
  - Sympathetic impulses increase heart rate and force of contraction
  - Parasympathetic impulses decrease heart rate.
  - Baroreceptors (pressure receptors) detect change in BP and send info to the cardiovascular center
    - Located in the arch of the aorta and carotid arteries

- Heart rate is also affected by hormones
  - Epinephrine, norepinephrine, thyroid hormones
  - Ions (Na\(^+\), K\(^+\), Ca\(^{2+}\))
  - Age, gender, physical fitness, and temperature
Regulation of Heart Rate

INPUT TO CARDIOVASCULAR CENTER (nerve impulses)
- From higher brain centers: cerebral cortex, limbic system, and hypothalamus
- From sensory receptors:
  - Proprioceptors—monitor movements
  - Chemoreceptors—monitor blood chemistry
  - Baroreceptors—monitor blood pressure

OUTPUT TO HEART (increased frequency of nerve impulses)
- Increased rate of spontaneous depolarization in SA node (and AV node) increases heart rate
- Increased contractility of atria and ventricles increases stroke volume
- Decreased rate of spontaneous depolarization in SA node (and AV node) decreases heart rate

Cardiovascular (CV) center
Cardiac accelerator nerves (sympathetic)