Chapter 14
The Cardiovascular System: The Heart

- Heart pumps over 2.6 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

- Apex - directed anteriorly, inferiorly and to the left
- Base - directed posteriorly, superiorly and to the right
- Anterior surface - deep to the sternum and ribs
- Inferior surface - rests on the diaphragm
- Right border - faces right lung
- Left border (pulmonary border) - faces left lung

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

**Surface Projection of the Heart**

- Superior right point at the superior border of the 3rd right costal cartilage
- Superior left point at the inferior border of the 2nd left costal cartilage 3cm to the left of midline
- Inferior left point at the 5th intercostal space, 9 cm from the midline
- Inferior right point at superior border of the 6th right costal cartilage, 3 cm from the midline
Muscle Bundles of the Myocardium

- Cardiac muscle fibers swirl diagonally around the heart in interlacing bundles.

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

- Left common carotid artery
- Lateral sinus
- Right common carotid artery
- Sphenoparietal sinus
- Vertebral artery
- Superior vena cava
- Inferior vena cava
- Coronary sinus
- Right pulmonary vein
- Left pulmonary vein
- Right atrium
- Left atrium
- Right atrial appendage
- Left atrial appendage
- Ascending aorta
- Descending aorta
- Pulmonary trunk
- Lefl pulmonary vein
- Flow through heart

Posterior View

- Left common carotid artery
- Lateral sinus
- Right common carotid artery
- Sphenoparietal sinus
- Vertebral artery
- Superior vena cava
- Inferior vena cava
- Coronary sinus
- Right pulmonary vein
- Left pulmonary vein
- Right atrium
- Left atrium
- Right atrial appendage
- Left atrial appendage
- Ascending aorta
- Descending aorta
- Pulmonary trunk
- Lefl pulmonary vein
- Flow through heart

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

**Left Ventricle**

- 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.

Fibrous Skeleton of Heart

- Dense CT rings surround the valves of the heart, fuse and merge with the interventricular septum
- Support structure for heart valves
- Insertion point for cardiac muscle bundles
- Electrical insulator between atria and ventricles
  - prevents direct propagation of AP’s to ventricles
Atrioventricular Valves Open

- 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 tendineae 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
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 O₂
- 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.
- 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

- 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

**Timing of Atrial & Ventricular Excitation**

- SA node setting pace since is the fastest
- In 50 msec excitation spreads through both atria and down to AV node
- 100 msec delay at AV node due to smaller diameter fibers- allows atria to fully contract filling ventricles before ventricles contract
- In 50 msec excitation spreads through both ventricles simultaneously

**Electrocardiogram---ECG or EKG**

- EKG
  - Action potentials of all active cells can be detected and recorded
- P wave
  - atrial depolarization
- P to Q interval
  - conduction time from atrial to ventricular excitation
- QRS complex
  - ventricular depolarization
- T wave
  - ventricular repolarization
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
- End diastolic volume (EDV)
  - volume in ventricle at end of diastole, about 130ml
- End systolic volume (ESV)
  - volume in ventricle at end of systole, about 60ml
- Stroke volume (SV)
  - the volume ejected per beat from each ventricle, about 70ml
  - $SV = EDV - ESV$

Phases of Cardiac Cycle

- Isovolumetric relaxation
  - brief period when volume in ventricles does not change— as ventricles relax, pressure drops and AV valves open
- Ventricular filling
  - rapid ventricular filling: as blood flows from full atria
  - diastasis: as blood flows from atria in smaller volume
  - atrial systole pushes final 20-25 ml blood into ventricle
- Ventricular systole
  - ventricular systole
    - isovolumetric contraction
      - brief period, AV valves close before SL valves open
      - ventricular ejection: as SL valves open and blood is
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.

Exercise and the Heart

- Sustained exercise increases oxygen demand in muscles.
- Benefits of aerobic exercise (any activity that works large body muscles for at least 20 minutes, preferably 3-5 times per week) are:
  - increased cardiac output
  - increased HDL and decreased triglycerides
  - improved lung function
  - decreased blood pressure
  - weight control.
Developmental Anatomy of the Heart

- The heart develops from mesoderm before the end of the third week of gestation.
- The tubes develop into the four-chambered heart and great vessels of the heart.

Risk Factors for Heart Disease

- Risk factors in heart disease:
  - high blood cholesterol level
  - high blood pressure
  - cigarette smoking
  - obesity & lack of regular exercise.
- Other factors include:
  - diabetes mellitus
  - genetic predisposition
  - male gender
  - high blood levels of fibrinogen
  - left ventricular hypertrophy

Plasma Lipids and Heart Disease

- Risk factor for developing heart disease is high blood cholesterol level.
  - promotes growth of fatty plaques
  - Most lipids are transported as lipoproteins
    - low-density lipoproteins (LDLs)
    - high-density lipoproteins (HDLs)
    - very low-density lipoproteins (VLDLs)
  - HDLs remove excess cholesterol from circulation
  - LDLs are associated with the formation of fatty plaques
  - VLDLs contribute to increased fatty plaque formation
- There are two sources of cholesterol in the body:
Desirable Levels of Blood Cholesterol for Adults

- TC (total cholesterol) under 200 mg/dl
- LDL under 130 mg/dl
- HDL over 40 mg/dl
- Normally, triglycerides are in the range of 10-190 mg/dl.
- Among the therapies used to reduce blood cholesterol level are exercise, diet, and drugs.

Coronary Artery Disease

- Heart muscle receiving insufficient blood supply
  - narrowing of vessels--atherosclerosis, artery spasm or clot
  - atherosclerosis--smooth muscle & fatty deposits in walls of arteries
- Treatment
  - drugs, bypass graft, angioplasty, stent

Clinical Problems

- MI = myocardial infarction
  - death of area of heart muscle from lack of O₂
  - replaced with scar tissue
  - results depend on size & location of damage
- Blood clot
  - use clot dissolving drugs streptokinase or t-PA & heparin
  - balloon angioplasty
- Angina pectoris----heart pain from ischemia of cardiac muscle
By-pass Graft

Percutaneous Transluminal Coronary Angioplasty

Stent in an Artery

- Maintains patency of blood vessel
• Pericarditis
• Cardiac Tamponade
• Rheumatic Fever
• Arrhythmias
• Congenital Heart Defects