Cardiovascular System Study Guide

Location
- Within mediastinum
- Posterior to sternum
- medial to lungs
- anterior to vertebral column
- base lies beneath 2nd rib
- apex at 5th intercostal space
- lies upon diaphragm

Size
- base - wide superior portion
- apex - inferior point
- average size - 14 cm long + 9 cm wide

Coverings of the heart
- 3 layers
  - Fibrous Pericardium (outermost)
  - Parietal Pericardium (middle)
  - Pericardial cavity filled with serous fluid (between visceral and parietal)
    - Epicardium/ Visceral Pericardium (innermost)

Wall of the Heart
- 3 layers
  - Epicardium (outermost)
  - Myocardium (muscular wall)
  - Endocardium (lining + valves)
4 Chambers of the Heart

- **2 Atria** (upper chambers)
  - Interatrial septum separates right and left
  - RECEIVES blood
  - thin-walled
  - ear like flaps called auricles provide more volume

- **2 Ventricles** (lower chambers)
  - Interventricular septum separates right & left
  - PUMPS blood
  - thick walled (left thicker than right)

***Septum - a partition separating two chambers***

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Valves

- **2** types
  - **Atrioventricular (A-V valves)**
    - between atria and ventricles +constructed of flaps called **cusps**
    - **Tricuspid** - between right atrium and ventricle
- **Bicuspid** - between left atrium and ventricle (*mitral valve*)
  - *Papillary Muscle* → muscle that controls closing of valve
  - *Chordae Tendineae* → fibrous cords that prevent cusps from swinging back into atria

- **Semilunar valves**
  - between ventricles and major arteries
  - *Pulmonary valve* - between right ventricle and pulmonary artery (trunk)
  - *Aortic valve* - lies between the left ventricle and the aorta
Pulmonary vs. Systemic Circuit

Systemic circuit delivers oxygen to all body cells and carries away wastes.

Oxygenated blood pumped to all body tissues via aorta.

Deoxygenated blood pumped to lungs via pulmonary arteries.

Oxygenated blood returns to heart via pulmonary veins.

Pulmonary circuit eliminates carbon dioxide via the lungs and oxygenates the blood.

Deoxygenated blood returns to heart via venae cavae.

Pathway of Blood through the Heart

Blood from systemic circuit
Venae cavae
Right atrium
Right ventricle
Pulmonary trunk
Pulmonary arteries
Alveolar capillaries (lungs)
Pulmonary veins
Left atrium
Left ventricle
Aorta
Blood to systemic circuit

Tricuspid valve
Pulmonary valve
Mitrval valve
Aortic valve
Cardiac Cycle

- all events associated with one heart beat
- the atria and ventricles alternately contract and relax
  - the two atria contract together and the two ventricles contract together
- Blood flows from areas of high pressure to areas of low pressure
  - (contraction = systole = high pressure; relaxation = diastole = low pressure)

Ventricular Systole and Atrial Diastole

- Atria fill with blood
  - pressure low but rises as filling continues
- Blood is forced from ventricle onto arteries (pulmonary & aorta)
  - pressure is high
- AV valves are closed
- SL valves are open

Atria Systole and Ventricular Diastole

- Blood is forced from atria into ventricle
- pressure is high
- Ventricle fill with blood
  - pressure is low but rises as filling continues
- AV valves are open
- SL valves are open

**Heart Sounds**

- **Lub**
  - first heart sound
  - occurs during ventricular systole
  - A-V valves closing
- **Dupp**
  - second heart sound
  - occurs during ventricular diastole
  - pulmonary and aortic semilunar valves closing

***Murmur → abnormal heart sounds because valves do not close properly and blood leaks back into previous chamber***

**Myocardium**

- Cardiac muscle fibers form a functional syncytium
  - group of cells that function as a unit
    - atrial syncytium
    - ventricular syncytium

**Cardiac Conduction System**

- Sinoatrial Node (S-A node) - Pacemakers are put here
  - located in uppermost right atrial wall
  - self-exciting tissue
  - initiates cardiac impulse 60-100 times per minute
impulse begins in S-A node → passed from one cardiac conduction system component to the next
Finally reaches Purkinje fibers in papillary muscles of the ventricles causing ventricular contraction

Electrocardiogram
- recording of electrical changes changes that occur in the myocardium
- used to assess heart’s ability to conduct impulses
- P wave → atrial depolarization
- QRS wave → ventricular depolarization
- T wave → ventricular repolarization
Large Q can indicate heart attack.
Regulation of Cardiac Cycle

- cardiac center of brain regulates autonomic impulses to the heart
- Autonomic nerve impulses alter the activities of the S-A and A-V nodes
  - Parasympathetic impulses decrease heart action
  - Sympathetic impulses increase heart action

Additional Factors that Influence HR

- body temperature
- physical exercise
- Concentration of various ions (K + Ca)
- Drugs/Medications

Blood Vessels

- **Veins** → carry blood toward the heart
  - branch into *venules* which merge veins with capillaries
  - thin walled
  - carry blood under low pressure
  - carry blood high in CO2 + low in O2
- **Arteries** → carry blood away from the heart
  - branch into *arterioles*
  - strong + thick walled
  - Carry blood under great pressure
  - Carry blood high O2 + low in CO2 (exception in the pulmonary arteries)
  - 3 LAYERS
- Tunica interna - epithelium - lining
- Tunica media - thick smooth muscle
- Tunica externa - elastic + collagen fibers

**Valves in Veins**
- Muscle contraction moves blood through veins
- Vein have valves that prevent backflow of blood

**Capillaries**
- Thinnest blood vessels
- Only one layer of epithelium
- Permits the exchange of gases, nutrients, and wastes between blood and tissues
- Connects arterioles to venules

**Arterial Blood Pressure**
- Blood pressure → force the blood exerts against the inner walls of the blood vessels
- Arterial Blood Pressure
  - rises when ventricles contract
  - falls when ventricles relax
  - Systolic pressure - max pressure
  - Diastolic pressure - min pressure
- Measured with an Aneroid Sphygmomanometer
Blood Flow

- **Vasoconstriction**
  - muscles in blood vessels contract
  - blood vessels constricts decreasing blood flow
  - blood pressure increases
- **Vasodilation**
  - muscles in blood vessels relax
  - blood vessels dilate increasing blood flow
  - blood pressure decreases

**Pulse** → alternate expanding and recoiling of the arterial wall that can be felt

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**Life-span Changes**

- cholesterol deposition in blood vessels
- heart enlargement
- death of cardiac muscle cells
- increase in fibrous connective tissue of the heart
- increases in adipose tissue of the heart
- increases in blood pressure
- decrease in resting heart rate
- **Atherosclerosis**
  - refers to the buildup of fats in and on your artery walls (plaques), which can restrict blood flow
  - these plaque can also burst causing a blood clot

**KNOW THESE**
Clinical Application + Green Boxes

1. **Pericarditis**
   - inflammation of pericardium due to viral/bacterial infection
     - produce adhesions that attach to layers of pericardium; painful + interferes with movements

2. **Natriuretic peptide (ANP)**
   - secreted when blood volume stretches muscle cells associated w/ atria
   - inhibits renin from kidneys and aldosterone from adrenal cortex
     - $↑$ Na ions + water from kidneys & $↓$ blood volume + pressure
   - may be used to treat high blood pressure?

3. **Mitral Valve Prolapse (MVP)**
   - common: 6% of U.S. pop.
   - one/both cusps in mitral valve stretches and bulges into left atrium during ventricular contraction
     - can regurgitate blood into left atrium
       - pain, palpitations, anxiety, and fatigue
   - click at end of contraction
   - can result from damage from *Streptococcus bacteria*
● susceptible to **Endocarditis** → inflammation of endocardium due to infection (plant-like growth)
  ○ reason for antibiotics before visiting the dentist

4. **Magnetic Resonance Imaging (MRI)**
   ● coronary arteries view
   ● blood appears as bright signal; areas of diminished/absent/turbulence is blank
   ● less invasive than **coronary angiography** → catheter in blood vessel to heart + contrast agent

5. **Angina Pectoris**
   ● thrombus/embolus that blocks/narrows coronary artery + deprives myocardial cells of O; also produces *ischemia* (inadequate blood supply)
     ○ heavy pressure, tightening/squeezing, diaphoresis (profuse perspiration), dyspnea (difficulty breathing), nausea, or vomiting
   ● ↑ pain when exercising + emotional stress; ↓ pain when resting
     ○ felt behind sternum/ anterior portion of upper thorax → radiate to jaw, neck, throat, upper limbs, back, and upper abdomen
   ● coronary thrombosis → blood clot obstructing coronary artery
     ○ myocardial infarction → heart attack

6. **Replacing the Heart**
   ● *heart transplant* replaces the recipients failing heart EXCEPT for posterior walls of right & left atria + their connections to the venae cavae + pulmonary veins
     ○ donor is attached to atrial cuffs remaining in recipients thorax
       ➢ recipient’s aorta and pulmonary arteries are connected to donor heart
     ○ scarce
   ● *left ventricular assist device (LVAD)* for eventual heart transplant; temporary
   ● *implantable artificial heart* ; newer
     ○ 2 lbs; titanium + plastic → motor driven w/ battery
   ● stem cells help hearts heal (differ by sex)
     ○ induce blood vessel growth
   ● *Heart patches* are currently being tested on pigs to see if the human embryonic cells that have been stimulated to become cardiac muscle can help heart attack recovery

7. **Bundle branch block**
   ● Normally, the base of aorta that contains aortic valves is enlarged and protrudes somewhat into interatrial septum close to AV bundle
     ○ Inflammatory condition EX: bacterial endocarditis affecting the aortic valves, aortic vulvitis, can affect AV bundle
       ➢ If damaged, the bundle may no longer conduct pulse normally
         ● cardiac pulses reach ventricles at two different times and fail to contract together

8. **Familial Amyloidosis**
   ● Causes a significant percentage of heart failure in adults of African descent
Protein called amyloid forms deposits in the heart
  ➢ Angina (chest pain), cardiomyopathy (failure of cardiac muscles), blockage of nerve impulses, and arrhythmia

- Echocardiography can detect
  - Different treatments than arrhythmia so important to identify

9. **Electrocardiogram (ECG)**
- repeating subpatterns of other waves that occur a different time scales + irregular pattern
  - disrupted in **congestive heart failure**

10. **Arrhythmias**
- Ventricular Fibrillation - rapid, uncoordinated depolarization of ventricles
- Tachycardia - rapid heart beat
- Atrial Flutter - rapid rate of atrial depolarization

11. **Calcium + Potassium Ion Irregularities**
- hyperkalemia
  - excess potassium → decreased rate/force of contractions
  - may block conduction of cardiac impulses → **cardiac arrest** (sudden stop)
- Hypokalemia
  - below normal potassium → life-threatening arrhythmia
- hypercalcemia
  - excess calcium → increases heart action
  - danger of prolonged contraction
- hypocalcemia
  - below normal calcium
  - depresses heart action because these ions help initiate muscle contraction

12. **Altering Angiogenesis**
- formation of new blood vessels = *endothelial cells* divide and assemble into tubules that form capillaries/innermost linings of blood vessels
  - normally is essential for new blood supply routes/healing
- Heart attacks: promoting angiogenesis
- clot → lack of oxygen → releases hypoxia inducible factor (HIF-1) aka transcript protein
  - stimulates *glycolysis* (anaerobic respiration) → signals kidneys to make erythropoietin → angiogenesis by turning on vascular endothelial growth factor (VEGF)
    - forms new capillaries
  - fibroblast growth factor also assists
- still part of the heart can die
  - TREATMENT: coronary bypass surgery/angioplasty
  - when that doesn't work…
    - time-release capsules implanted near small vessels w/large ones surgically bypassed
Gene therapy → deliver growth triggering genes to starved areas of heart

13. **Capillaries** can stretch from 25,000 - 60,000 miles

14. **Ascites**
   - Right ventricle becomes unable to pump → other parts of body may develop edema (too much excess watery fluids) b/c blood backs up ↑ blood pressure/ back pressure/ osmotic pressure of blood
     - In terminal stages of heart failure edema is widespread
     - Collects in lower extremities

15. **Blood Vessel Disorders**
   - **Atherosclerosis** → deposits fatty materials, mostly cholesterol, called *plaque* protrude into lumen
     - Ischemia (blood deficiency) + necrosis
     - **Arteriosclerosis** → losing elasticity & become sclerotic
       - May rupture
     - CAUSES: fatty diet, elevated blood pressure, tobacco smoking, obesity, lack of physical exercise, emotional factors, and genetic factors
   - **Aneurism** may form
     - Pulsating sac in weakened wall
     - Common in thoracic or abdominal aorta + *circle of willis* (arterial circle @ base of brain)
     - CAUSES: trauma, high blood pressure, infections, inherited disorders (EX: *Marfan syndrome*), and congenital defects in blood vessels
   - **Phlebitis** → inflammation of a vein w/ injury or infection after surgery
     - Occurring in superficial vein → blood flow may be rechanneled through other vessels
     - Occurring in deep vein → thrombophlebitis; blocks normal circulation
       - Blood clot dislodges → pulmonary embolism
   - **Varicose veins** → abnormal + irregular dilations in superficial veins
     - Prolonged increased back pressure within the affected vessels due to gravity
       - Enlarged veins lose ability to stop backflow of blood and enlarges regions + ↑ pressure
       - Becomes edematous + painful
     - CAUSES: hereditary, pregnancy, obesity, and standing for long periods
     - TREATMENT: elevating legs + surgical removal

16. **Blood Volume**
   - Injection of a known volume of an indicator (EX: radioactive iodine)
     - Thorough mixing then drawn and calculated
       - Blood volume = amount of indicator injected/concentration of indicator in blood sample

17. **Measurement of Arterial Blood Pressure**
- **Sphygmomanometer** → inflatable cuff connected by tubing to a compressible bulb and a rise in pressure is indicated by pressure gauge
  - Pressure expressed in mm of mercury (but not mercury anymore b/c dangerous)
- Cuff is wrapped around brachial artery
- Air is pumped into cuff until it exceeds pressure in the artery
- Blood flow is stopped and stethoscope is placed at distal end of border cuff
- As cuff pressure is released, artery opens causing **Korotkoff's sound** → artery opens up enough for small amounts of blood to spurt through producing a sharp sound
- **Arterial Systolic Pressure** → pressure indicated on the pressure gauge when Korotkoff's sound happens
- **Arterial Diastolic Pressure** → when Korotkoff's sound become abruptly muffled and disappears; when the cuff is equal to the fully opened artery
  - Blood pressure is indicated in a number like 120/80
    - Top number is SP and bottom is DP
    - Differences in the numbers are normally around 40 mm Hg
    - DP + 1/3 PP = **Mean Arterial Pressure**; also of interest because represents force that is effective throughout the cardiac system for driving blood

18. **Space Medicine**
   - Examines anatomic and physiologic responses to conditions in spaces
   - Extending periods of exposure to microgravity/ weightlessness can have effects on the body
     - Decreased muscle mass, mineral-depleted bones, and low blood volume
     - **Orthostatic intolerance** → feeling unsteady upon entering the atmosphere
       - normally gravity helps blood flow and without it, blood pools in blood vessels in the center of the body
       - Body interprets this as access blood therefore kidneys are told to excrete more fluid
         - Upon return to earth the body has a pint to a quart less blood and if blood vessels cannot constrict sufficiently enough to counter plummeting blood pressure, orthostatic intolerance results
     - Space suits have vacuum force that helps draw blood to lower limbs to help prevent dehydration

19. **Hypertension**
   - Persistently elevated/ high blood pressure
   - Common diseases of the cardiovascular system in industrialized nations
   - **Essential Hypertension** → high blood pressure with no reason
   - **Secondary Hypertension** → high blood pressure as a result from something else (EX: arteriosclerosis or kidney disease)
20. **Exercise and the Cardiovascular System**

- Response to intense aerobic exercise
  - ↑ blood flow/oxygen delivery
  - **Vasoconstriction** → diminishes blood flow where it is not immediately needed (EX: digestive tract)
    - Maintained in brain + kidneys
  - respiratory movements and skeletal movements ↑ venous return to the heart
  - ↑ heart rate
- Conditions the cardiovascular system; athlete's heart may enlarge 40%+
- Responds “beautifully” for slow buildup activities but not sudden intense workout such as shoveling snow/runs for 3 miles
  - Reason exercising can be deadly but good at the same time

21. **Acute Cardiac Tamponade**

- blood/fluid accumulation in pericardial cavity increases pressure
- Can be life threatening
- **SYMPTOMS**: visible engorgement of veins on the neck, anxiety, rapid/difficulty breathing, lightheadedness, palpitations, pallor, and chest pain
- **CAUSES**: bacterial/viral infection, injury, acute myocardial infarction, advanced lung cancer, and dissecting aortic aneurysm

22. **Pulmonary Edema**

  - Lung fill with fluid
  - Can accompany a failing left ventricle
- Blood may back up in pulmonary circuit causing ↑ alveolar pressure flooding interstitial space with fluid
- Destroys membranes and the person may suffocate

23. **Compression of Superior Vena Cava**
- Life-threatening
- CAUSES: lung cancer, enlarged lymph node, and aortic aneurysm
- SYMPTOMS: pain, shortness of breath, distension of veins draining into superior vena cava, and swelling in face, head, and lower limbs

24. **Molecular Causes of Cardiovascular Disease**
1. **Connective Tissue Defect**
   - **Marfan syndrome** → an inherited condition that also caused
2. **Myosin Defect**
   - **Familial hypertrophic cardiomy** → overgrowth of heart muscle
3. **Metabolic Glitch**
   - Inability to metabolize long chains of fatty acid
4. **Controlling Cholesterol**
   - LDL (low-density lipoprotein) receptors on liver cells admit cholesterol into the cells, keeping lipid from building up in the blood stream + occluding arteries (negative feedback system)
   - **Familial Hypercholesterolemia** → a person inherits 2 detective copies of the gene encoding the LDL receptors
   - **Niemann-Pick type C disease** → defective protein causes cells to keep producing cholesterol and LDL receptors instead of abiding to the normal negative feedback system
5. **Homing in on Homocysteine**
   - **Homocystinuria** → causes homocysteine to build up in the blood, changes in arterial linings develop that increase cholesterol plaque deposition
   - B6+B12= preventing heart people

25. **Coronary Artery Disease**
- SYMPTOM: angina pectoris (chest pain)
- **Exercise stress test** → walked on an inclined treadmill + ECG; when heart reached desired rate, radioactive thallium - 201 was injected into vein
  - **Scintillation counter** → scans heart with thallium
- TREATMENT: no smoking, ↓ intake of foods with high saturated fats, cholesterol, refined carbs, and sodium, exercise, and ↓ stress
- **Coronary angiogram** → x-ray procedure which inserts a catheter into the femoral artery and pushed into the heart through the aorta; radiopaque dye released at right moments
  - **X-ray fluoroscopy** → monitors catheter progress
- **Percutaneous Transluminal coronary angioplasty (PTCA)** → enlarge lumens of blood vessels to help restore flow; balloon sent in with catheter and expands with high pressure to open up vessel
To prevent occluding afterwards (restenosis) a coronary stent might be placed

- If failed: **coronary bypass surgery** → portion of internal mammary wall or saphenous vein might be removed and sutured at a location past the obstruction