I. Heart
   A. Location
      1. Located within the thoracic cavity in a space between the lungs called the **mediastinum**.
   B. The pericardium
      1. The **pericardium** is a two-layered membrane that surrounds and protects the heart.
      2. It is composed of 2 layers.
         a. The outer layer is the **fibrous pericardium**, composed of dense irregular connective tissue, and helps to anchor the heart in place.
         b. The inner **serous pericardium** is the serous membrane that surrounds the heart.
            i. The outer **parietal layer** is fused to the fibrous pericardium.
            ii. The inner **visceral layer** adheres to the surface of the heart and is synonymous with the **epicardium** of the heart.
            iii. The space between the layers of the serous pericardium is referred to as the **pericardial cavity** and contains **serous fluid (pericardial fluid)** to reduce friction between the layers.
            iv. **Pericarditis** is inflammation of the pericardium.
               (a) Can result in a build-up of pericardial fluid within the pericardial cavity.
               (b) The fluid build-up compresses the heart and can stop the heart from beating.
   C. Layers of the heart wall
      1. The **epicardium** is the outermost layer of the heart and is synonymous with the visceral portion of the serous membrane.
      2. The **myocardium** is the middle layer of the heart.
         a. Consists of cardiac muscle.
         b. Responsible for the pumping action of the heart.
         c. Is organized into two motor units, one forming the walls of the atrial chambers and one forming the walls of the ventricular chambers.
            i. Each motor unit contracts separately, so the two atria contract separately from the two ventricles.
         d. The myocardium is thickest on the left side of the heart to provide the power needed to drive blood through the body (the right ventricle just pumps blood to the lungs).
      3. The **endocardium** is the innermost layer of the heart and consists of a thin layer of simple squamous epithelium.
         a. Provides a smooth surface that reduces friction between the blood and the wall of the heart.
         b. Is continuous with the epithelium lining the walls of the blood vessels.
   D. Chambers of the heart
      1. The top two chambers of the heart are the **atria**.
         a. The atria are separated by a thin wall known as the **interatrial septum**.
      2. The bottom two chambers of the heart are the **ventricles**.
         a. The ventricles are separated by a thick wall known as the **interventricular septum**.
   E. Valves of the heart

1. The **cuspid (Atrioventricular) valves** separate the atria and ventricles.
    a. The **tricuspid valve** separates the right atrium and right ventricle.
        i. Consists of three thin flaps (cusps) of tissue that create a one-way passage.
        ii. The edges of the flaps are connected to **papillary muscles** (cardiac muscle projections on the inner surface of the ventricles) via **chordae tendineae**.
        iii. When the ventricle (and papillary muscle) contracts it tightens the chordae tendineae preventing the valve flaps from pushing up into the atria.
    b. The **bicuspid (mitral) valve** separates the left atrium and left ventricle.
        i. Consists of two thin flaps (cusps) of tissue.
        ii. Works the same way as the tricuspid valve.
2. The semilunar valves
    a. The **pulmonary semilunar valve** consists of three semilunar cusps that attach to the wall of the pulmonary trunk where it attaches to the right ventricle.
        i. Prevents blood from flowing back into the right ventricle.
        ii. After the blood is ejected into the pulmonary trunk if it tries to flow backwards into the heart it fills the cusps with blood, tightly closing the valve.
    b. The **aortic semilunar valve** consists of three semilunar cusps that attach to the wall of the aorta where it attaches to the left ventricle.
        i. Works the same way as the pulmonary valve.
        ii. Prevents blood from flowing back into the left ventricle.

F. Major blood vessels attached to the heart
1. The vena cavas
    a. Large veins that deliver blood, low in oxygen, to the right atrium.
    b. The **superior vena cava** delivers blood from the upper body (primarily above the heart).
    c. The **inferior vena cava** delivers blood from the lower parts of the body (primarily below the heart).
2. The **pulmonary trunk** carries blood from the right ventricle to the pulmonary arteries, delivering the blood to the lungs.
3. The **pulmonary veins** carry oxygenated blood away from the lungs delivering it to the left atrium.
4. The **aorta** carries oxygenated blood away from the left ventricle to deliver it to the body.

G. Coronary Circulation
1. The blood flow through the vessels of the heart (**coronary vessels**) supplying the tissues of the heart itself.
2. The **right** and **left coronary arteries** branch off the aorta to deliver oxygenated blood to the heart.
    a. These vessels continue to branch to circulate the blood to the heart.
3. The deoxygenated blood is collected by large veins and drained into the **coronary sinus** on the posterior surface of the heart.
    a. The coronary sinus empties the deoxygenated blood into the right atrium.

H. Circulation of blood through the heart
1. The right atrium receives blood from the superior and inferior vena cavas and the coronary sinus; the left atrium receives blood from the 4 pulmonary veins.

2. As the blood enters the atria and the walls of the atria contract it increases the pressure.
3. This increased pressure (greater than the pressure of the ventricles) opens the cuspid valves and allows the blood to flow into the ventricles.
4. As blood fills the ventricles and the walls of the ventricles contract (**systole**) it increases the pressure within the ventricles and closes the cuspid valves.
5. The increased pressure within the ventricles also pushes the blood through the semilunar valves into the pulmonary trunk and the aorta.
6. When blood pressure in these vessels is higher than in the ventricles the semilunar valves close.
7. At the end of the ventricular contraction the myocardium relaxes (**diastole**) and pressure is decreased in the chamber allowing the cuspid valves to reopen and the cycle to begin again.

I. Heart sounds
   1. "**lubb**" is the first sound heard as the cuspid valves close at the beginning of ventricular contraction.
   2. "**dupp**" is the second sound heard as the semilunar valves close at the end of ventricular contraction.

J. The conduction system of the heart
   1. Autorhythmic cells
      a. Specialized cardiac muscle cells that can generate an action potential and continuously depolarize.
      b. These cells form a conduction system that routes action potentials throughout the heart muscle.
      c. The **sinoatrial (SA) node** is a group of autorhythmic cells located in the right atrial wall inferior to the opening of the superior vena cava.
         i. An action potential spontaneously arises in the SA node which is spread through **intercalated discs (gap junctions)** throughout the myocardium of the atria.
         ii. This action potential stimulates the simultaneous contraction of the atria.
         iii. Because the cells of the SA node depolarize more frequently than any other heart region (100 times/minute) it is referred to as the **pacemaker** for the heart.
         iv. The action potential generated by the SA node also reaches the atrioventricular (AV) node.
      d. The **atrioventricular (AV) node** is another group of autorhythmic cells located in the interatrial septum.
         i. The action potential moves more slowly through the cells of the AV node to allow the atria to contract.
         ii. Note: The AV node can act as a pacemaker if the SA node is destroyed, but at a much slower pace (40-50 beats/minute).
      e. From the AV node the action potential enters the **atrioventricular bundle (bundle of His)** which transmits the impulse into the interventricular septum.
      f. The **bundle of His** splits into the **right and left bundle branches** which stimulate cells of the septum.

g. At the apex of the heart the two bundle branches generate the **purkinje fibers** which conduct the action potential first to the apex of the heart, then upward through the remainder of the ventricular myocardium.
h. This action potential stimulates the simultaneous contraction of the ventricles.

K. Regulation of the heartbeat
1. The heart rate is regulated out of a **cardiovascular center** located within the **medulla oblongata**.
2. The cardiovascular center receives sensory information to determine if changes to the heart rate are required to maintain homeostasis.
   a. **Baroreceptors** (pressoreceptors) in the aorta and the carotid artery monitor blood pressure.
      i. These are referred to as the **aortic** and **carotid sinuses**.
      ii. Stimulation of the sinuses by higher blood pressure results in them sending a greater frequency of impulses on the **glossopharyngeal** and **vagus** nerves to the cardiovascular center.
         (a) Results in a decrease in heart rate.
      iii. Stimulation of the sinuses by lower blood pressure results in them sending fewer impulses on the glossopharyneal and vagus nerves to the cardiovascular center.
         (a) Results in an increase in heart rate.
   b. **Chemoreceptors** in the aorta and the carotid artery monitor carbon dioxide, oxygen and hydrogen ion levels.
      i. These are referred to as the **aortic** and **carotid bodies**.
      ii. Stimulation of the bodies by high carbon dioxide (also high hydrogen ion or low oxygen levels) results in them sending more impulses on the **glossopharyngeal** and **vagus** nerves to the cardiovascular center.
         (a) Results in an increase in heart rate.
      iii. Stimulation of the bodies by low carbon dioxide (also low hydrogen ion levels) results in them sending less impulses on the glossopharyngeal and vagus nerves to the cardiovascular center.
         (a) Results in a decrease in heart rate.
3. The cardiovascular center uses nerve pathways of the sympathetic and parasympathetic nervous systems to alter the heart rate accordingly.
   a. To increase the heart rate the cardiovascular center uses sympathetic neurons that travel in the **cardiac nerve**.
      i. The neurons release **norepinephrine** which binds to **beta receptors** on the SA node, the AV node and the myocardium.
   b. To decrease the heart rate the cardiovascular center uses parasympathetic neurons that travel in the **vagus nerve**.
      i. The neurons release **acetylcholine** which binds **to muscarinic receptors** on the SA node and the AV node.
4. Certain chemicals can also influence the heart rate.
   a. The hormone **adrenaline (epinephrine)** released by the medulla of the adrenal gland can also bind to beta receptors on the heart.
      i. Increases the heart rate and the force of contraction.

ii. Because it is a hormone it will have a longer effect than nervous stimulation to the heart.

b. Blood levels of certain ions can also influence the heart rate.
   i. Elevated levels of potassium (**hyperkalemia**) or sodium (**hypernatremia**) decrease the heart rate.
   ii. Increased levels of calcium (**hypercalcemia**) can increase the heart rate.

L. Cardiac Output (CO)
1. **Cardiac output** is the volume of blood ejected per minute from the left ventricle of the heart.
2. Cardiac output is calculated by multiplying **heart rate (HR) x stroke volume (SV).**
   a. Heart rate is the number of heartbeats per minute (average of 75 bpm).
   b. Stroke volume is the amount of blood ejected by the ventricle during one contraction (average of 70 mL).
      i. Is determined in part by the volume of blood returning to the heart by the veins (**venous return**).
         (a) The more blood that returns to the heart, the greater the amount that must be ejected with the next heartbeat (input must be equal to output).
      ii. Is also determined by the amount of stretch of the heart muscle (**Starling's law of the heart**).
         (a) Starling's law states "the energy of contraction is proportional to the initial length of the cardiac muscle fiber", so the more the heart is stretched as it fills, the greater the force of the following contraction.
         (b) **Note**: cardiac muscle can be overstretched resulting in a weaker contraction.
3. When either the heart rate or the stroke volume varies, one or the other tries to compensate to keep the cardiac output stable.

M. The **electrocardiogram** (**EKG** or **ECG**)
1. An EKG is a recording of the electrical activity of the heart.
2. The **P wave**
   a. Is representative of the depolarization of the atria.
   b. This depolarization is stimulating the atria to contract.
3. The **QRS complex**
   a. Represents the depolarization of the ventricles and the repolarization of the atria.
   b. The depolarization is stimulating the ventricles to contract, while the atria are relaxing.
4. The **T wave**
   a. Represents the repolarization and relaxation of the ventricles.