- Cardiovascular System (work in progress)

Heart chambers, inflow veins, outflow arteries

- This is a quick inventory of the basic components of the heart.
- There are four chambers; one in each quadrant of the heart. The heart is divide into a right and a left side. It is also divided into a top and a bottom.
- The two chambers on the right side receive un-oxygenated blood from the body, and then pump it to the lungs for oxygenation and excretion of waste carbon dioxide.
- The two chambers on the left receive oxygenated blood from the lungs and then pump it to the body, completing the circulatory cycle.
- The top chambers are called Atria. The right atrium receives blood from the body through the anterior and posterior vena cava. The left atrium receives blood from the lungs through several pulmonary veins. The atria are smaller chambers then the bottom ventricle chambers. The atria only need the capacity to store the blood that is received during the brief period of ventricular contraction (less than .2 second in a horse) which is called systole. During the much longer period of ventricular relaxation, or diastole, the blood received by the atria will simply flow through the open AV valves into the ventricle.
- The bottom two chambers, the ventricles, are the muscular chambers responsible for pumping blood. The ventricles contract during systole. Systole increases pressure in the ventricles causing closure of the AV valves and forces blood through the semilunar valves into the outflow arteries leading away from the heart.

Heart Valves,

- Two Atrioventricular (A-V) valves
  - These valves lie between the atrium and the ventricle on their respective sides of the heart.
  - The Tricuspid valve is the A-V valve in the right side of the heart.
  - The Bicuspid valve is the A-V valve in the left side of the heart. It is also called the Mitral valve.
- Two Semilunar (outflow) valves
  - Each valve lie between their respective ventricle and the base of the outflow artery. Both of these valves normally have 3 cusps
  - Un-oxygenated blood from the right ventricle flows through the Pulmonary valve, which maintains blood pressure in the pulmonary artery suppling blood for oxygenation to the lungs.
  - Oxygenated blood from the left ventricle flows through the Aortic valve, which maintains blood pressure in the Aorta, supplying blood to the entire body.
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The Pericardium; A non-elastic, fibrous membrane surrounding the heart and the base of the great vessels

- The small volume of serous fluid in the pericardial sac lubricate the rapid movement of the heart
- Protect the heart and great vessels by fixing them into the proper location and orientation
- Prevents overfilling of the heart
- Due to the inelastic nature of the pericardial sac; if it develops a serous or inflammatory effusion, compression will interfere with heart filling during diastole. This serious condition is referred to as cardiac tamponade. Pericardial effusion, if left untreated will lead to congestive heart failure.

Diastole and Systole

- Diastole is the relaxation phase of the heart. All four chambers of the heart are relaxed at the beginning of diastole. This allows blood returning from the peripheral circulation to flow into the right atrium and actually through the atrium and the opened AV valves into the right ventricles. Similarly blood returning from the pulmonary circulation flows into the left heart chambers
- Systole begins with an electrical action potential, an actual depolarization similar to a nerve depolarization. The depolarization originates at the Sinoatrial (SA) node. The SA node is located near the top of the atrium, near the anterior (superior) vena cava. The SA node is the natural pacemaker for the heart cycle. The SA node cells; and all electrical conducting "bundle fibers" and "purkinje fibers" in the heart are actually myocytes that are modified for electrical conduction and minimized contractility. The action potential first spreads out through the atria causing atrial systole. After atrial systole has occurred the electrical action potential reaches the Atrioventricular (AV) node in the floor of the right atrium, between the tricuspid valve and the atrial septum. Here the action potential is augmented and sent out to both of the ventricles via more bundle fibers and ultimately the purkinje fibers. This action potential causes ventricular systole and the actual pumping of blood to the lungs and body. Once systolic electrical conduction and myocyte contraction has occurred the cells of the heart will begin repolarization. At the time of repolarization myocyte relaxation also begins ad that marks the beginning of diastole

The route of blood through the heart

- Un-oxygenated blood from the body flows through the superior and inferior vena cava veins into the atrium chamber of the right side of the heart.
- The blood from the right atrium and vena cava flow passively from the atrium into the right ventricle during ventricular diastole. *Diastole is the relaxation phase allowing for filling and expansion of the ventricles with blood.* During the last second prior to ventricular systole the atrium contracts. This is called Atrial Systole forcing the atrium to completely empty.
- The right ventricle will then contract; called ventricular systole. Ventricular systole occurs synchronously for both the right and left ventricles. The increased blood pressure in the ventricle causes the AV valve to close. A few milliseconds later, as the pressure continues to rise, the right semilunar valve will open and blood will flow through pulmonary artery to the lungs. Blood is then oxygenated in the alveolar capillary bed. Pulmonary veins then carry the oxygenated blood back to the left side of the heart.
- Oxygenated blood returning from the lungs enters the left atrium chamber through two right pulmonary veins and two left pulmonary veins.
- The blood from the left atrium and pulmonary veins flow passively into the left ventricle during ventricular diastole. In synchrony with the right atrium, left atrial systole occurs at the end of diastole.

Auscultation

- Normal "heart beat" sounds and the heart valves that make them
  - S1 - Is the normal 1st sound of the cardiac cycle. The sound represents closure of the 2 atrioventricular (AV) valves at the beginning of systole. The right AV valve is also called Tricuspid valve. The left AV valve has two aliases: the bicuspid valve and the mitral valve. The 2 AV valves should close simultaneously at the beginning of ventricular systole creating the single S1 "Lub" sound. S1 represents the beginning of systole.
  - S2 - Normal sound of the two Semilunar valves closing at the beginning of diastole. Closure of the pulmonary valve and the aortic valves occur nearly simultaneously and creates the "Dup" sound. S2 occurs as soon as the ventricles repolarize and the pressure in the outflow arteries exceed that of the now empty ventricles. The semilunar valves are responsible for maintaining the blood pressure required for normal circulation in the aorta and pulmonary

arteries. Sometimes the two semilunar valves do not close synchronously and the result is split S2 sounds. A split S2 may be normal for some horses and the split sound can be confused with an S3 sound.
    - S3 – is an extra heart sound that occurs very soon after S2. S3 is attributed to opening of the mitral and tricuspid valves, creating “ventricular filling sounds” in early diastole. S3 is often associated with ventricular disease or restrictive pericardial disease. The S3 heart sound occurs early in diastole as blood first begins to fill the ventricles
    - S4 - is an “atrial systole sound” at the end of ventricular diastole, just prior to the beginning of ventricular systole and S1. S4 is usually associated with pathology.
    - It is often said that horses have "normal" extra heart sounds and "normal" murmurs. Anytime extra heart sounds are heard; a deeper look is warranted. An otherwise normal athletic horse is usually where extra heart sounds occurs that may be normal.
- Systole and Diastole by the heart sounds
    - The S1 to S2 interval represents ventricular systole
    - The S2 to S1 interval represents ventricular diastole.
    - Diastole is nearly twice as long as systole.
- Heart murmurs - To Come Next

Electrocardiography - To Come

Echocardiography

- Ultrasonography
- 2 dimensional, real time image of heart
- 1 dimensional X time image of specific area of heart, M-mode
- Doppler real time imaging reveals rate and turbulence in blood flow (using color enhancement of fluid flow)

Exercise testing, tread mill

Radiography

Cardiac catheterization

- Pulmonary Arterial Pressure test (PAP test), in cattle
    - Hypoxia that occurs at high elevation causes increased cardiac output
    - Genetic predisposition to thickened pulmonary arteries with decreased elasticity leads to elevated PAP especially at altitudes over 5000 feet
    - Chronically Elevated PAP causes right heart failure
    - Right heart failure in cattle living in the mountains is called “Brisket Disease” or “High Mountain Disease”
    - Peripheral edema especially ventral edema, dyspnea and weakness are main symptoms. Brisket edema is common.
    - PAP testing bulls and elimination of those with elevated PAP reduces the incidence of this deadly condition