## The Cardiac Cycle:

The cardiac cycle diagram shown below depicts changes in aortic pressure (AP), left ventricular pressure (LVP), left atrial pressure (LAP), left ventricular volume (LV Vol), and heart sounds during a single cycle of cardiac contraction and relaxation. These changes are related in time to the electrocardiogram. A single cycle of cardiac activity can be divided into two basic stages. The first stage is **diastole**, which represents ventricular filling and a brief period just prior to filling at which time the ventricles are relaxing. The second stage is **systole**, which represents the time of contraction and ejection of blood from the ventricles.



The cardiac cycle is usually divided into seven phases. The first phase begins with the P wave of the <u>electrocardiogram</u>, which represents atrial depolarization. The last phase of the cardiac cycle ends with the appearance of the next P wave.

**Phase 1**: Atrial Contraction. Atrial depolarization causes contraction of the atrial musculature. As the atria contract, the pressure within the atrial chambers increases, which forces more blood flow across the open atrioventricular (AV) valves, leading to a rapid flow of blood into the ventricles. Blood does not flow back into the vena cava because of inertial effects of the venous return and because the wave of contraction through the atria moves toward the AV valve thereby having a "milking effect." Atrial contraction normally accounts for about 10% of left ventricular filling when a person is at rest. At high heart rates, however, the atrial contraction may account for up to 40% of ventricular filling.

**Phase 2**: This phase of the cardiac cycle begins with the appearance of the <u>QRS complex</u> of the ECG, which represents ventricular depolarization. The AV valves close as intraventricular pressure exceeds atrial pressure. Ventricular contraction also triggers contraction of the papillary muscles with their attached chordae tendineae that prevent the AV valve leaflets from bulging back into the atria and becoming incompetent (i.e., "leaky"). During the time period between the closure of the AV valves and the opening of the aortic and pulmonic valves, ventricular pressure rises rapidly without a change in ventricular volume (i.e., no ejection occurs). Ventricular volume does not change because all valves are closed during this phase. Contraction, therefore, is said to be "isovolumic" or "isovolumetric."

**Phase 3**: This phase represents the initial and rapid ejection of blood into the aorta and pulmonary arteries from the left and right ventricles, respectively. Ejection begins when the intraventricular pressures exceed the pressures within the aorta and pulmonary artery, which causes the aortic and pulmonic valves to open. No heart sounds are ordinarily noted during ejection because the opening of healthy valves is silent.

Phase 4: Aortic and Pulmonic Valves Open; AV Valves Remain Closed.

**Phase 5**: When the intraventricular pressures fall sufficiently at the end of phase 4, the aortic and pulmonic valves abruptly close (aortic precedes pulmonic) causing the **second heart sound (S**<sub>2</sub>) and the beginning of isovolumetric relaxation. Valve closure is associated with a small backflow of blood into the ventricles and a characteristic notch (**dicrotic notch**) in the aortic and pulmonary artery pressure tracings. Although ventricular pressures decrease during this phase, volumes remain constant because all valves are closed. The volume of blood that remains in a ventricle is called the **end-systolic volume** and is ~50 ml in the left ventricle. The difference between the end-diastolic volume and the end-systolic volume is ~70 ml and represents the **stroke volume**.

**Phase 6**: As the ventricles continue to relax at the end of phase 5, the intraventricular pressures will at some point fall below their respective atrial pressures. When this occurs, the AV valves rapidly open and ventricular filling begins. Despite the inflow of blood from the atria, intraventricular pressure continues to briefly fall because the ventricles are still undergoing relaxation. Once the ventricles are completely relaxed, their pressures will slowly rise as they fill with blood from the atria.

**Phase 7**: As the ventricles continue to fill with blood and expand, they become less compliant and the intraventricular pressures rise. This reduces the pressure gradient across the AV valves so that the rate of filling falls. In normal, resting hearts, the ventricle is about 90% filled by the end of this phase. In other words, about 90% of ventricular filling occurs before atrial contraction (phase 1).

