

## Unit 1 Lecture 3

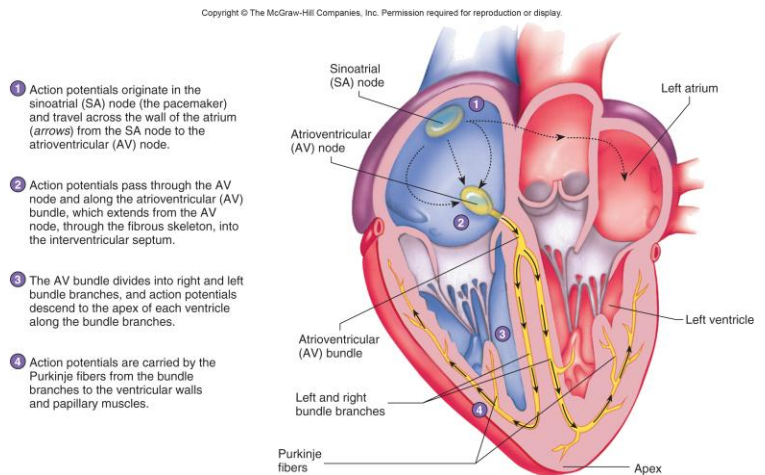
### The Heart

#### Conduction system and Pacemaker

The heart is composed mostly of cardiac muscle, myocardium. Cardiac muscle cells contract without nervous stimulation. These specialized autorhythmic cells are also called the pacemaker for the heart. Cardiac muscle cells differ from skeletal muscle. The cardiac fibers are smaller than skeletal muscle fibers and have a single nucleus per fiber. Individual cells branch and join neighboring cells end-to-end. Cell junctions are known as intercalated discs linked by desmosomes that tie adjacent cells together. This prevents the rupture of cells from each other. The t-tubules of cardiac muscles are larger than those found in skeletal muscles whereas the sarcoplasmic reticulum is smaller. Mitochondria occupy 1/3 of the cell volume reflecting the high energy demands of these cells. Cardiac muscle cells are electrically connected to each other via gap junctions in the intercalated discs allowing waves of depolarization to spread rapidly from one cell to the next.

The action potential of cardiac muscle is similar to neural and skeletal muscle action potentials. The main difference is that there is a lengthening of the action potential in cardiac muscle due to calcium entry (200 msec or more in cardiac muscle versus 1-5 msec in skeletal muscle). In addition, a long refractory period prevents tetanus of the muscles because the contraction and the refractory period end almost simultaneously.

For the heart to act as an efficient pump for blood circulation it's important that there is a precise and sequential activation of contraction of the atria and the ventricles during each heart beat. Autorhythmic cells are self excitable cardiac muscle fibers that act as a pacemaker for the entire heart and form the conduction system or the route for conducting impulses throughout the heart. The components are: the Sinoatrial node (SA) located in the upper right atrial wall, the Atrioventricular node in lower interatrial septum, the Atrioventricular bundle (bundle of His) which electrically connects atria and ventricles, the right and left bundle branches that are located in interventricular septum and conduction myofibers (Purkinje fibers) that conduct impulses into ventricular muscle mass. Electrical impulses from the SA node pass through the atria stimulating atrial contraction. The impulse is delayed at the AV node and then passes through the rest of the



conduction system causing ventricular contraction when it enters the ventricular muscle mass. The impulse doesn't go straight through the entire heart because of a layer of connective tissue that insulates the atria from the ventricles. The delay at the AV node is important because it allows the ventricles to fill with blood. If the SA node is damaged, the AV node and rest of system will compensate somewhat but not enough. The person needs a pacemaker implant.

### **Electrocardiogram (ECG or EKG)**

An [ECG](#) is a record of electrical changes during each cardiac cycle. It does not measure mechanical performance of the heart. It is used to determine if the conduction pathway is normal, if the heart is enlarged, and if certain regions are damaged. A normal ECG consists of a P-wave (atrial depolarization) when the atria start to contract, a QRS-complex (ventricular depolarization) when the ventricles start to contract, and a T-wave (ventricular repolarization) when the ventricles relax.

### **Cardiac Cycle**

The heart contracts and relaxes once during a cardiac cycle. The cardiac cycle describes pressure, volume and flow phenomena in the atria and ventricles over time. Phases of the cardiac cycle consist of systole (contraction) and diastole (relaxation) of both atria and both ventricles. When atria contract, the ventricles are relaxed and when the ventricles contract, the atria are relaxed. During the relaxation period at the end of a heartbeat, blood flows from the pulmonary trunk and the aorta back toward the ventricles. As a result the semilunar valves close causing a dicrotic wave on the aortic pressure curve. This is represented by the T-wave on the ECG, atria and ventricles are relaxed, pressure drops in the ventricles. When both the semilunar valves and the AV valves are closed, no blood enters the ventricles. This is known as isovolumic ventricular relaxation.

Ventricular filling occurs when the ventricular pressure falls below atrial pressure and the AV valves open, rapidly filling the ventricles. During diastasis a small amount of blood enters the ventricle. During atrial systole about 30 cc of blood is added to the ventricle. During ventricle systole, ventricular ejection occurs when the left ventricle pressure surpasses aortic pressure (@ 80 mm hg) and right ventricular pressure exceeds pressure in the pulmonary trunk (@ 15-20 mm hg). Just prior to ventricular contraction is the isovolumic contraction. All valves are closed again. Atrial filling occurs continuously during the cardiac cycle except during atrial systole.

To review:

1. Late diastole-both sets of chambers are relaxed and ventricles fill passively.

2. Atrial systole-atrial contraction forces a small amount of additional blood into the ventricles.
3. Isovolumic ventricular contraction-first phase of ventricular contraction pushes AV valves closed but does not create enough pressure to open semilunar valves.
4. Ventricular ejection-as ventricular pressure rises and exceeds pressure in the arteries, the semilunar valves open and blood is ejected.
5. Isovolumic ventricular relaxation-as ventricles relax, pressure in ventricles falls, blood flows back into cups of semilunar valves and snaps them closed.

### **Heart Sounds (auscultation)**

During each cardiac cycle four sounds are generated but you can only hear the first two. Lubb, the first sound is the loudest and is created by blood turbulence associated with closing of the AV valves. Dupp, the second sound, is associated with closing of semilunar valves. Heart murmur is an abnormal sound that consists of a flow noise that is heard before, between, or after lubb-dupp sounds or it may mask the normal heart sounds. Often it indicates a valve disorder such as mitral stenosis, mitral insufficiency, aortic insufficiency, or mitral valve prolapse.

### **Cardiac Output & Regulation of the Heart**

Cardiac output is the volume of blood ejected from either ventricle each minute. The formula is

$$\text{CO} = \text{SV} \times \text{HR}$$

where SV is defined as stroke volume and HR is the heart rate. In a normal resting adult the cardiac output is about 5.25 liters per minute.

$$\text{CO} = 70\text{mL/heart beat} \times 75 \text{ beats/minute}$$

This volume also represents the entire amount of blood in the body. Therefore, the blood in your body flows through your pulmonary and systemic circulation each minute. Three factors that regulate stroke volume are: preload (the degree of stretch on the heart before it contracts), contractility (forcefulness of the contraction), and afterload (the pressure that must be exceeded before ventricular ejection can begin).

Nervous control of the cardiovascular system originates in the cardiovascular center of medulla oblongata. Sensory receptors (proprioceptors, chemoreceptors, and baroreceptors) send impulses to the medulla. Output sympathetic impulses increase the heart rate and force of contraction and parasympathetic impulses decrease the heart rate.