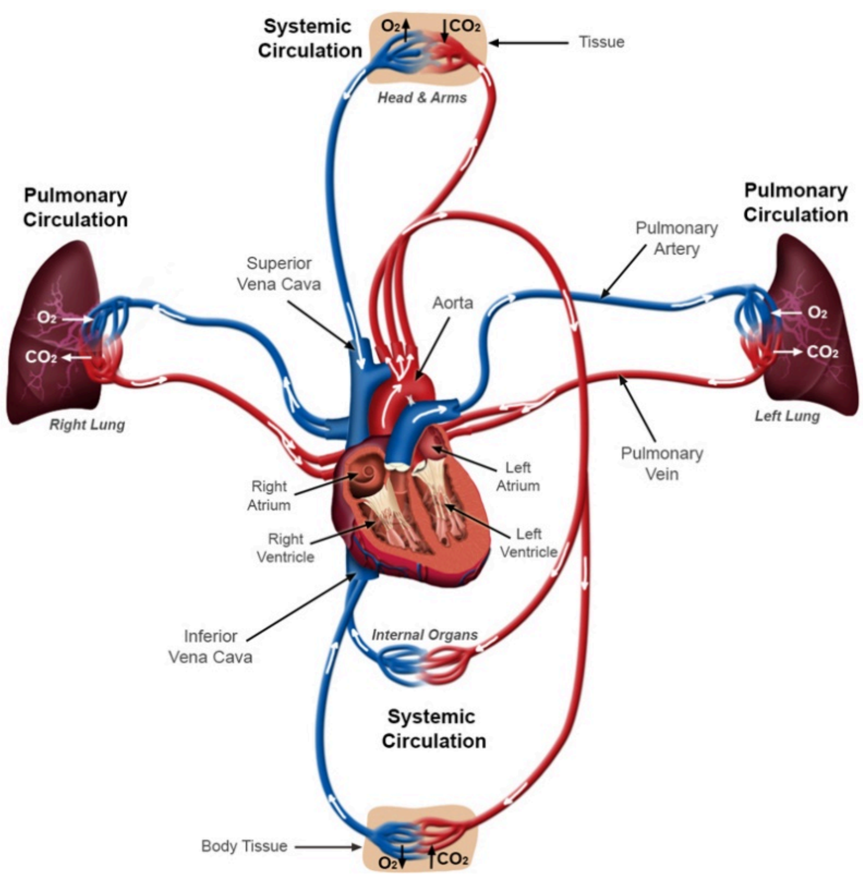
3.1.1

Chambers and Circulation

The heart is composed of two pumps. The right side of the heart receives oxygen-poor blood, known as deoxygenated blood, from the systemic circulation and pumps the blood to the lungs where oxygen and carbon dioxide are exchanged. The left side receives oxygen-rich, known as oxygenated blood, from the lungs and pumps it to the rest of the body. These two circulations are referred to as the **pulmonary circulation** (to the lungs) and the **systemic circulation** (to the rest of the body), respectively.



Systemic and Pulmonary Circulation.

Image created by BYU-Idaho student Tabitha Daughtery Spring 2014

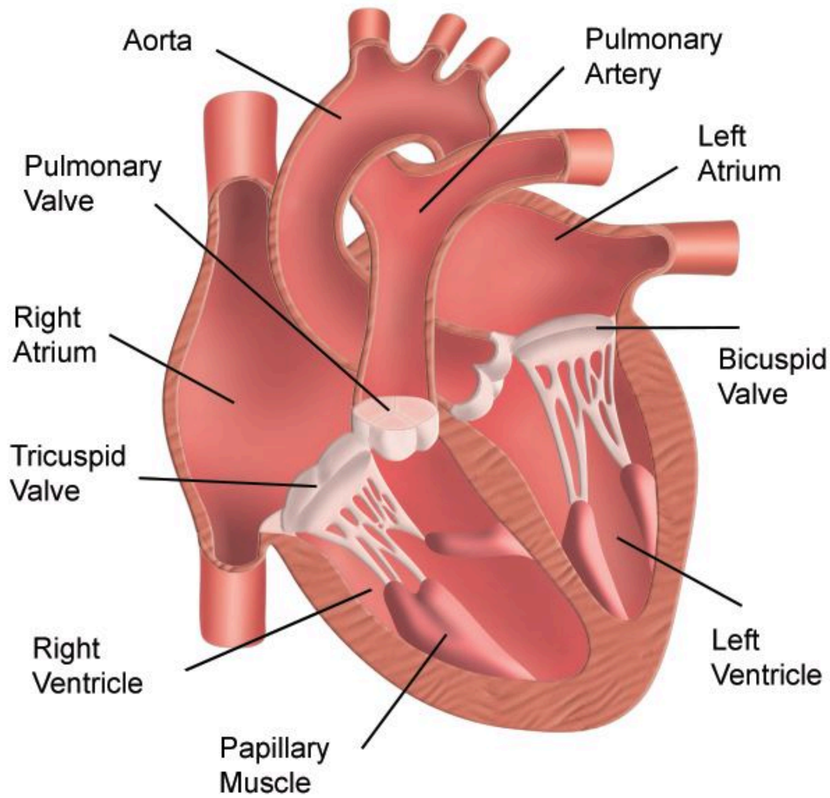
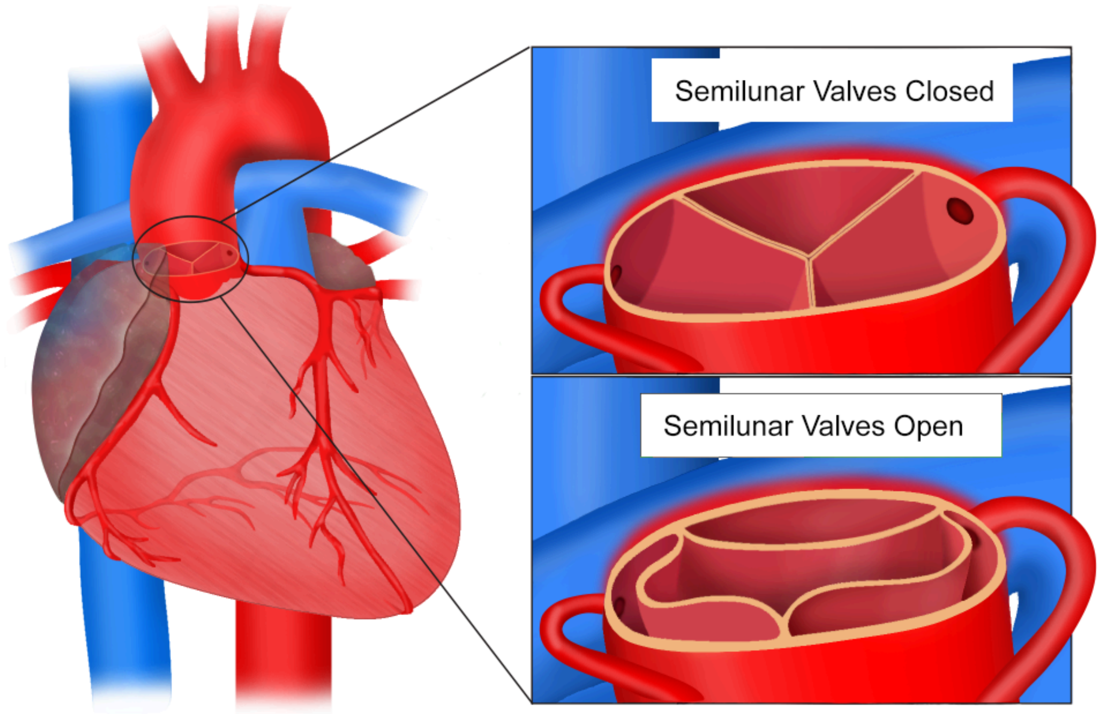


Image created by BYU-Idaho student Nate Shoemaker Winter 2016



Aortic semilunar valves
Image by BYU-I Student Becky Torgerson – S18

Notice how coronary arteries receive blood during diastole. During systole, the blood opens the semilunar valves and rushes through. Blood does not easily enter the coronary vessels easily during systole.

Heart Chambers

Mammalian hearts have four chambers, two receiving chambers called **atria** and two pumping chambers called **ventricles.** The right side of the heart is separated from the left side of the heart by a thick wall known as the **septum**. The right atrium receives oxygen-poor blood from the systemic circulation and the left atrium receives oxygen-rich blood from the pulmonary circulation. Blood from the right atrium enters the right ventricle, which then pumps the blood to the lungs. The right side of the heart is a low-pressure system and seldom produces pressures above 40 mmHg. Blood from the left atrium enters the left ventricle, which pumps the blood to the systemic circulation. Blood is pumped through the systemic circulation starting at the aorta, a major artery in the body. Branching immediately from the aorta are two smaller arteries called **coronary arteries (See image above)**. These arteries supply the heart with oxygen-rich blood. The left side of the heart is a high-pressure system and routinely produces pressures of around 120 mmHg and during times of physical stress can generate pressures over 200 mmHg.

Heart Valves (See Images above)

To ensure that the blood moves efficiently through the heart, two sets of one-way valves prevent the blood from flowing backward. The **atrioventricular (AV) valves** are located between the atria and the ventricles. Between the right atrium and right ventricle is the **right AV or tricuspid valve** and between the left atrium and left ventricle is the **left AV, the bicuspid or the mitral valve**. The names bi- and tricuspid are derived from the number of cusps or flaps that make up the valve. A closer look at these valves reveals that they are supported by small tendon-like attachments called **chordae tendineae,** which attach the edges of the valves to small nipple-like projections of muscle called **papillary muscles**.

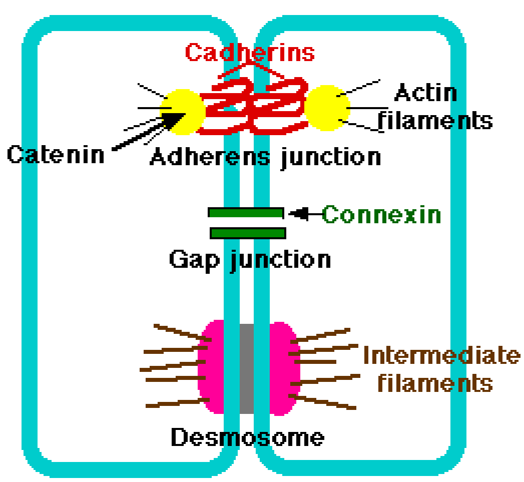
This arrangement prevents the valves from pushing back into the atria when the ventricles contract, a condition known as **prolapse** of the valve.

The **semilunar valves** are located between the ventricles and the large arteries that receive blood from them. Between the right ventricle and the pulmonary trunk is the **pulmonary semilunar valve** or simply pulmonary valve, and between the left ventricle and the aorta is the **aortic semilunar valve** or aortic valve. The structure of these valves is different from the AV valves. Each valve is composed of three pocket-like structures. When blood from the large arteries moves back toward the ventricles, these valves balloon out like small parachutes. Their three cusps come together preventing blood from moving backward.

Heart Murmurs

Heart murmurs can be caused by improperly functioning heart valves. There are two basic types of problems that can occur. The valve may become stiff and not open properly. This is referred to as valvular stenosis. The stenotic valve creates turbulent flow as the blood passes through which creates a sound or murmur that can be detected with a stethoscope (The art of listening to body sounds via a stethoscope is called auscultation). Conversely, the valve may not close properly and blood will backflow through the valve. This is referred to as valvular regurgitation. Again, the backflow of blood creates turbulent flow, generating a detectable murmur. Not all murmurs are due to valve disease. It is not uncommon to detect murmurs in young, thin individuals or during times of greatly increased blood flow as would occur during strenuous physical activity. These murmurs are considered normal and do not pose a risk to the individuals. Valvular disease, on the other hand, increases the workload on the heart and if severe and not treated can lead to heart failure. Historically, it was a fine art to detect the type of valvular abnormality based on the sound and timing of the murmur. Modern technology, such as cardiac ultrasonography, has made it much easier to determine the nature of the valvular disease and determine the proper course of treatment.

Cardiac muscle cells are much smaller than skeletal muscle cells and they are branched. In addition, cardiac muscle cells are connected end-to-end by special structures called **intercalated discs** (in-ter'kă-lā-ted). Located on the intercalated discs are different types of **cell junctions** that are part of keeping communication open between the cells. These are desmosomes, and gap junctions.



Cell Junctions.

Desmosomes tightly connect the cells together. Recall that skeletal muscle attaches to bone via tendons so that when it contracts, it pulls on the bones generating movement. Cardiac muscle cells, on the other hand, do not connect to anything except other cardiac muscle cells. When cardiac muscle contracts, the desmosomes all pull against each other causing the diameter of the chambers to decrease, which generates the pressure necessary to pump the blood.

The intercalated disks also contain **gap junctions** which allow communication between the connected cells. This allows movement of cytoplasm, including ions, between the cells, effectively lowering the resistance, and more importantly, this allows action potentials to spread from one cell to the next. The gap junctions along with the intricate branching of the muscle cells allow an electrical signal to spread from cell-to-cell resulting in contraction of the entire heart. Hence, even though there are millions of cells in each chamber, functionally they act as a single cell. This arrangement is referred to as a **functional syncytium** (syn = together; cyt = cell).

Other differences between cardiac and skeletal muscle include the following:

- The arrangement of the **sarcomeres** (the main unit of the striated muscle tissue) in cardiac muscle is not as ordered as in skeletal muscle so the cross striations are not as distinct. These striations are caused by the arrangement of the structural proteins actin and myosin. If looking at the cardiac muscle under a microscope, myosin filaments are thicker and create dark bands and actin filaments are thinner and create lighter bands. During the process of excitation-contraction coupling, which will be discussed in detail later, the interactions between the actin and myosin are what cause the sarcomere to lengthen or shorten and allow the myocyte to contract.

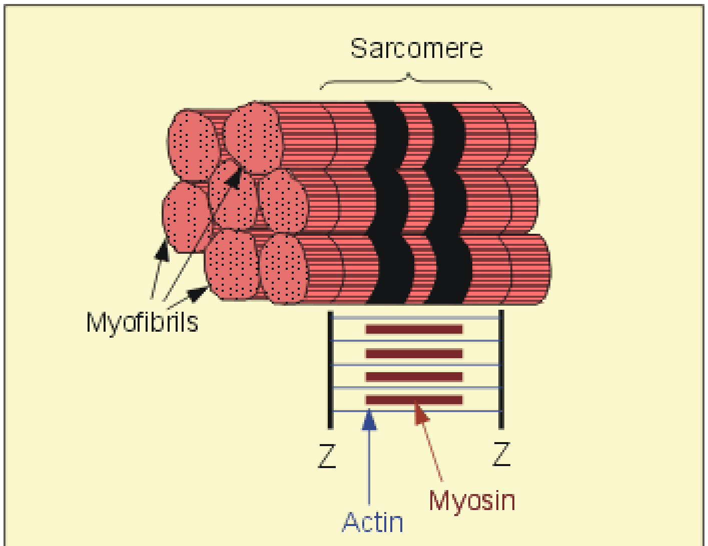


Figure 1. Cardiac myocyte composed of myofibrils, each of which contains myofilaments. The sarcomere lies between two Z-lines.

Cardiac Sarcomere

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- Cardiac muscle cells have a single nucleus located roughly in the center of the cell.
- The**T-tubules** in cardiac muscle are large and branch longitudinally within the cell.

- The **sarcoplasmic reticulum** (note the dark blue webbing in the “Cardiac Muscle Anatomy” picture) is less extensive in the cardiac muscle which enables the heart muscle to be more flexible and allow it to beat over and over. We shall see later in the section on excitation-contraction coupling that some of the calcium that triggers contraction comes from the extracellular compartment (10%) of the sarcoplasmic reticulum.

- Cardiac muscle cells have more **mitochondria**, comprising up to a third of the intracellular volume. These are needed because cardiac muscle cells derive all of their energy from aerobic respiration. Skeletal muscle can rest if it becomes fatigued but cardiac muscle does not have that luxury. Because of the high oxygen demands, cardiac muscle extracts 70-80% of the oxygen in the blood as it passes through the coronary circulation. Other tissues, including skeletal muscle at rest, only extract about 25% of the available oxygen, providing a large reserve when more oxygen is needed. For cardiac muscle to get more oxygen the only way is to increase blood flow to the muscle. Cardiac muscle, like other tissues can use glucose as an energy source, however, since it essentially derives all of its energy from aerobic metabolism its nutrient of choice is energy-rich fatty acids. Interestingly, during exercise the cardiac muscle cells will also extract lactate (lactic acid) from the blood to be used for energy.