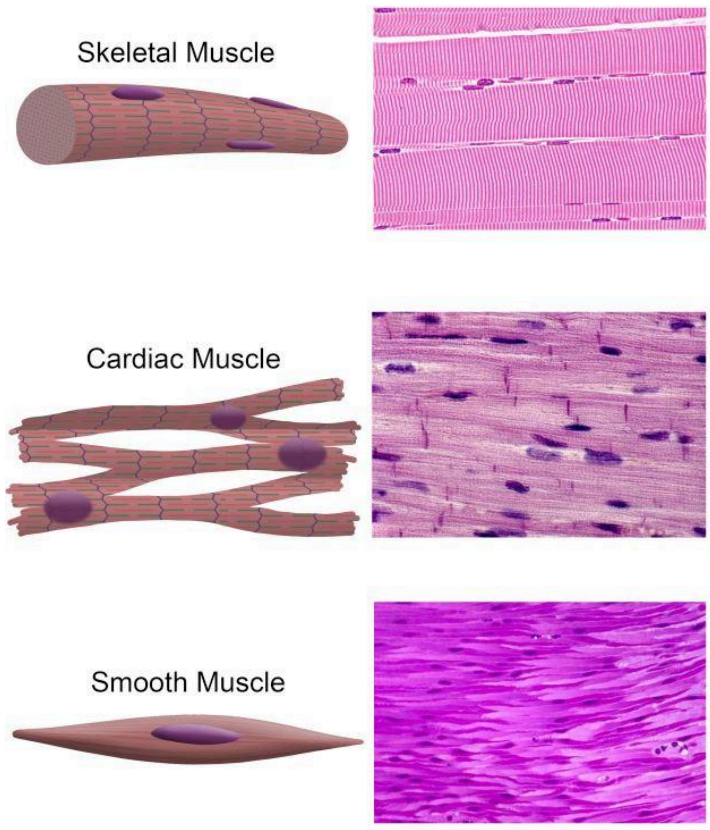
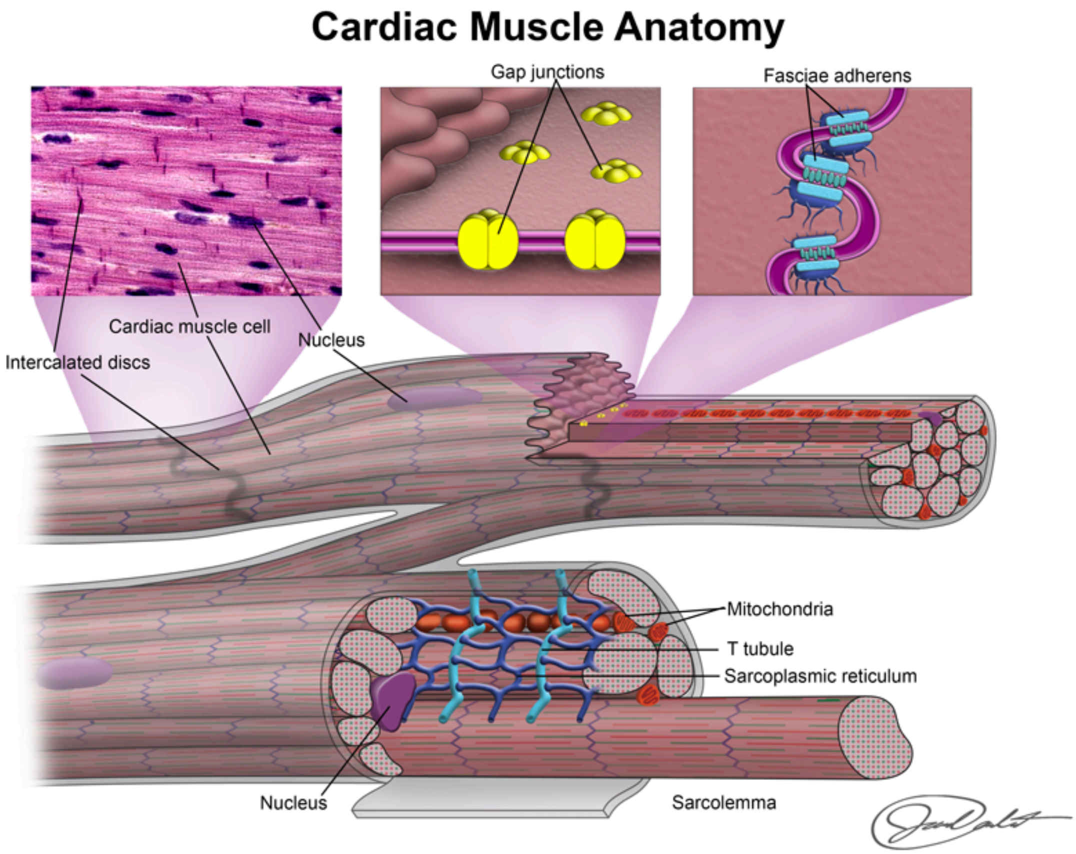
1.1.3

Cardiac Muscle Histology and Organization



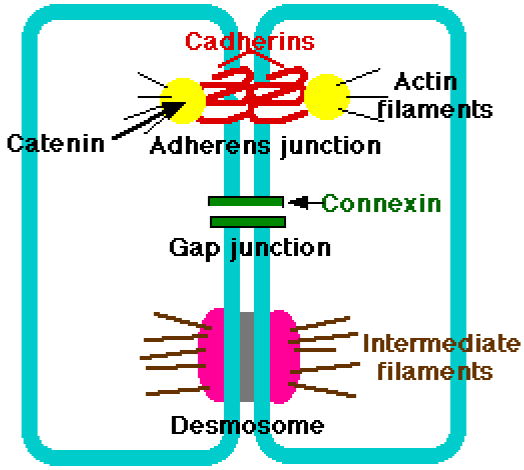
Skeletal, Cardiac and Smooth Muscle.
BYU-Idaho image: Created Fall 2014

Cardiac muscle, like skeletal muscle, is a type of striated muscle. The cross-bridge cycling that results in shortening of the muscle is the same as it is in skeletal muscle so we will not repeat the mechanism. If you have forgotten how that works you may want to search Wikipedia: muscle contraction or refer back to the BIO264 textbook. Although the contraction of the cardiac muscle is similar to the contraction of a skeletal muscle, there are some striking differences between the two muscle types. In this section we will mainly examine how cardiac muscle differs from skeletal muscle.



Cardiac Muscle Anatomy.
BYU-Idaho image created Winter 2015

Cardiac muscle cells are branched and much smaller than skeletal muscle cells. In addition, cardiac muscle cells are connected end-to-end by special structures called **intercalated discs** (in-ter'kă-lā-ted). Intercalated discs allow the cells to communicate with each other. To keep communication links open between cells the intercalated discs contain different types of **cell junctions.** Two major types are desmosomes, and gap junctions.



Cell Junctions.
Author: John W. Kimball. Site: https://books.byui.edu/-tBGb License: CC BY 3.0

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.

Gap junctions allow electrical 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, even if the signal is started in a distant location of the 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:

1. 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. 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 (muscle cell) to contract.

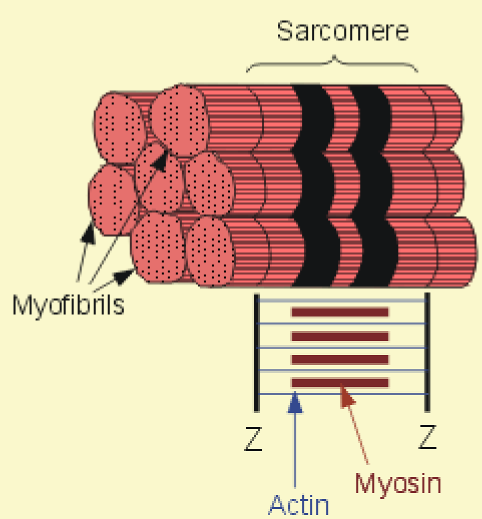


Figure 1. Cardiac myocyte composed of myofibrils, each of which contains myofilaments. The sarcomere lies between two Z-lines.

Cardiac Sarcomere.
Author: Richard E. Klabunde. Site: https://books.byui.edu/-tEKL License: [CC BY-NC-SA 4.0](#). Permission kindly granted by the author in February of 2017 for use.

2. Cardiac muscle cells have a single nucleus located roughly in the center of the cell.

3. The **T-tubules** in cardiac muscle are larger and more branched within the cell.

4. 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 the less extensive sarcoplasmic reticulum and resultant reduction in calcium (since calcium is stored in the sarcoplasmic reticulum) is compensated for by using extracellular calcium (10%).

5. Cardiac muscle cells have more **mitochondria,** comprising up to a third of the intracellular volume. More mitochondria 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. Being able to extract 80% of the oxygen provides a large and immediate reserve when more oxygen is needed. Thus, 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.