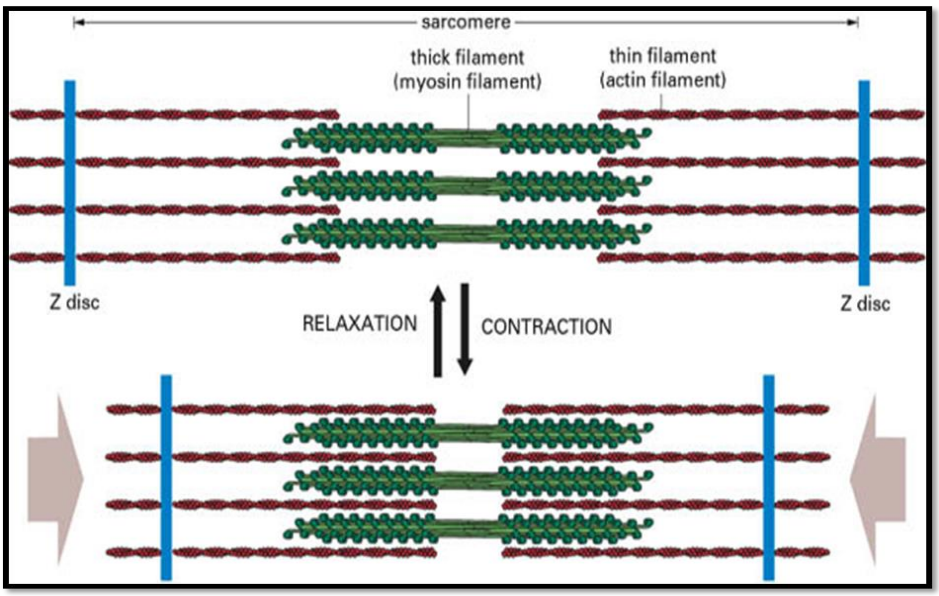
Mechanism of contraction

During resting sarcomeres consist of partially overlapping thick and thin filaments. During contraction, neither the thick nor thin filaments changes their length. Contraction is the result of an increase in the amount of the overlap between the filaments caused by the sliding of thin and thick filaments past one another, using ATP as a source of energy (Figure 1).



(Figure 1): Mechanism of contraction of sarcomere.

Muscle fibers are contain contractile units called **sarcomeres**. The muscle contracts when thick and thin filaments slide with one another, as a result of the sliding, the Z discs are pulled closer together and sarcomere shorten from both sides. This is called the **sliding filament mechanism**.

There is a number of myosin heads extend from the myosin filaments during the contraction where attach to actin filaments with available **actin-binding sites** (Figure 2). The action is known as **the sliding filament mechanism** of muscle contraction. As the result bound myosin heads move the actin.

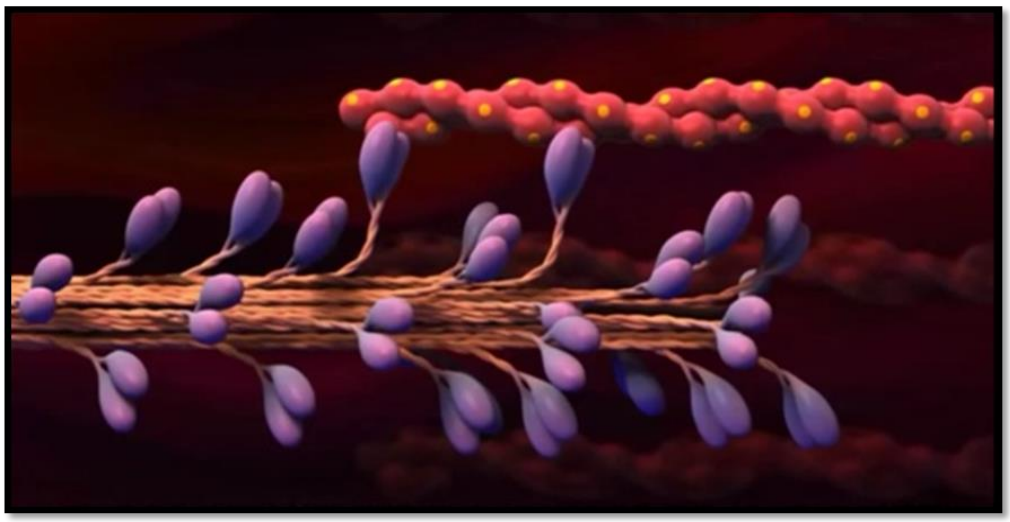


Figure (2): The sliding filaments mechanism.

The contraction of a muscle fiber begins when bound **ATP** is hydrolyzed the **ADP** and **inorganic phosphate**. This causes the myosin heads to extend and attach to a binding site on actin filaments forming a **cross-bridge**. Muscle contraction are controlled by the actions of calcium(Figure 3).

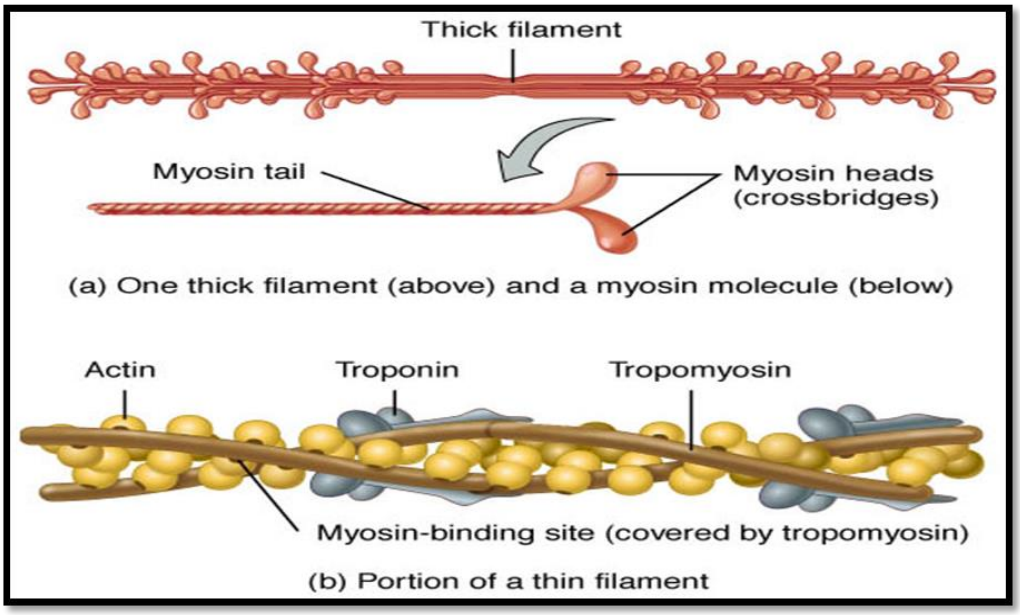


Figure (3):The structure of thick and thin filaments.

The thin actin filaments are associated with protein called **troponin** and **tropomyosin** (Figure 4). When the muscle is relaxed tropomyosin blocks the **cross-bridge binding site** on actin. When calcium ion levels are high enough and ATP is present, calcium ions bind to the troponin which displaces tropomyosin, exposing the myosin binding sites on actin (Figure 5). This allows myosin to attach to binding sites on actin forming a **cross bridge**. **Calcium ions** are stored in the sarcoplasmic reticulum and are released in the response to signals from the nervous system to contraction.

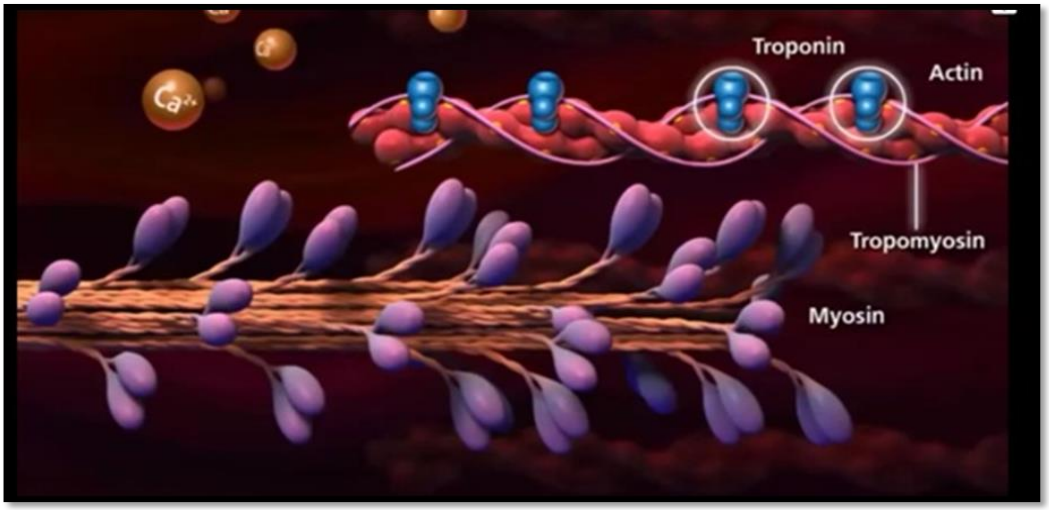


Figure (4): The association of actin with troponin and tropomyosin.

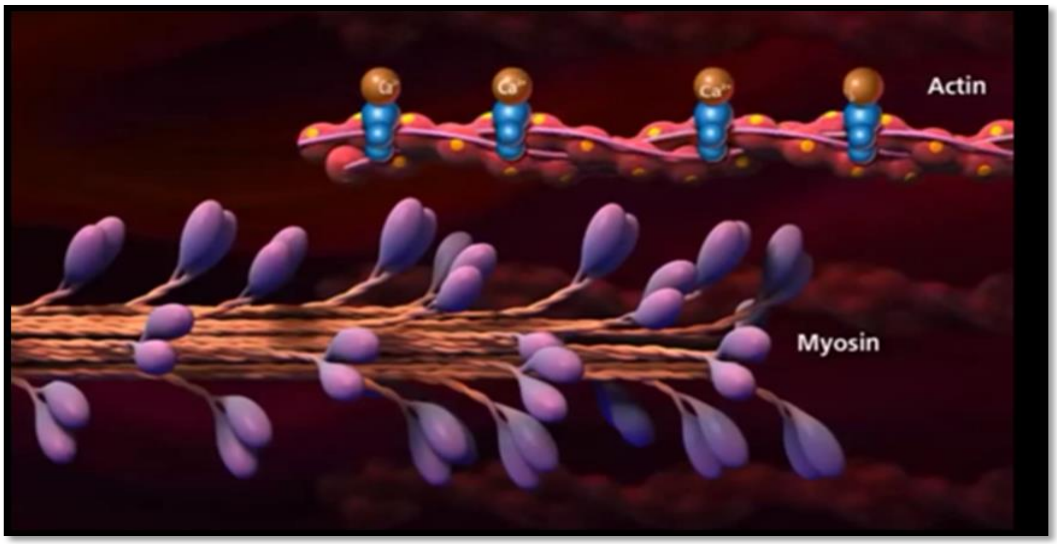


Figure (5): The calcium ions bind to the troponin on actin.

Muscle contraction begins when the nervous system signal reaches the neuromuscular junction, where the motor neuron release of **acetylcholine** into the motor end plate. Acetylcholine depolarized of the muscle fiber, where the **electrical impulse** is spread through the muscle fiber via the **transverse tubules** (**T tubules**) (Figure 6).

The electrical impulse triggers the release of **calcium ions** from the sarcoplasmic reticulum into the sarcomere with its thick and thin filaments. Calcium ions play a important role in initiating muscular contractions. This causes the actin and myosin slide along each other and the entire sarcomere shorten. As the sarcomere in myofibrils contract, the entire muscle fiber will shorten.

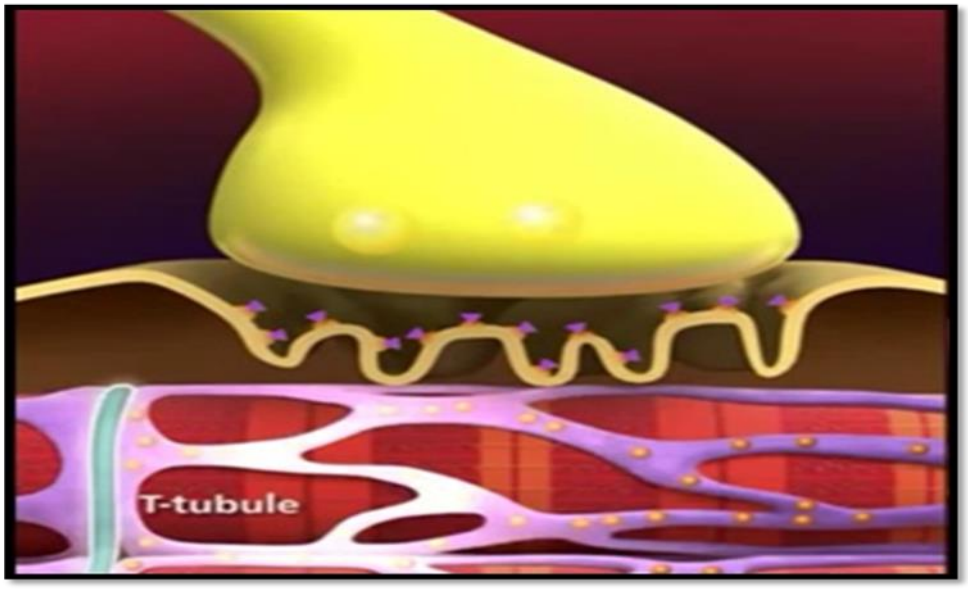


Figure (6): The electrical impulse travels down the T-tubule.

Cardiac muscle

The **cardiac muscle** is striated involuntary muscle also called **myocardium**, found only in the heart and responsible for contraction of cardiac tissue and distribution of blood. Cardiac muscle fibers are cylinders in shaped, extensively branched and are connected to each other by **intercalated discs**. Each muscle cell possesses oval or spherical nuclei only one or two which is located in the central region of the cell (Figure 7). **Intercalated discs** present as dark-staining transverse lines that cross the chain of cardiac cells at irregular intervals (Figure 8). Intercalated discs responsible for connecting the ends of the myocytes together and they are transmit the forces of contractions from cell to cell.

There are many **junctional complexes** are present in Intercalated discs. Transverse regions of these disks have **fascia adherents** and **maculae adherents** (desmosomes) where serve to bind cardiac cells firmly together. Also have **gap junction** which forms channels that providing pathways for various ions to pass between adjacent cells and electrical impulses from one cardiac muscle cell to another.

Surrounding the muscle cells is a delicate sheath of **endomysial connective tissue** containing rich capillaries for blood supply and to support the cardiac tissue. The cardiac muscle cells exhibit a cross striated banding pattern identical to that of skeletal muscle. The structure and function of the contractile proteins in cardiac cells are the same as in skeletal muscle.

The contraction by means of the **sliding filament mechanism** using actin and myosin proteins, contractile fibers are rapid in contraction and relaxation. The **T tubules** are more numerous and larger in cardiac than skeletal muscle and the sarcoplasmic reticulum is less well developed. Also contain numerous mitochondria due to the high energy requirements.

The heart have two type of cells: **Atrial muscle cells** and **ventricular muscle cells**. The arrangement of myofilaments is the same in both, but atrial muscle has fewer T tubules and the cells are smallest.

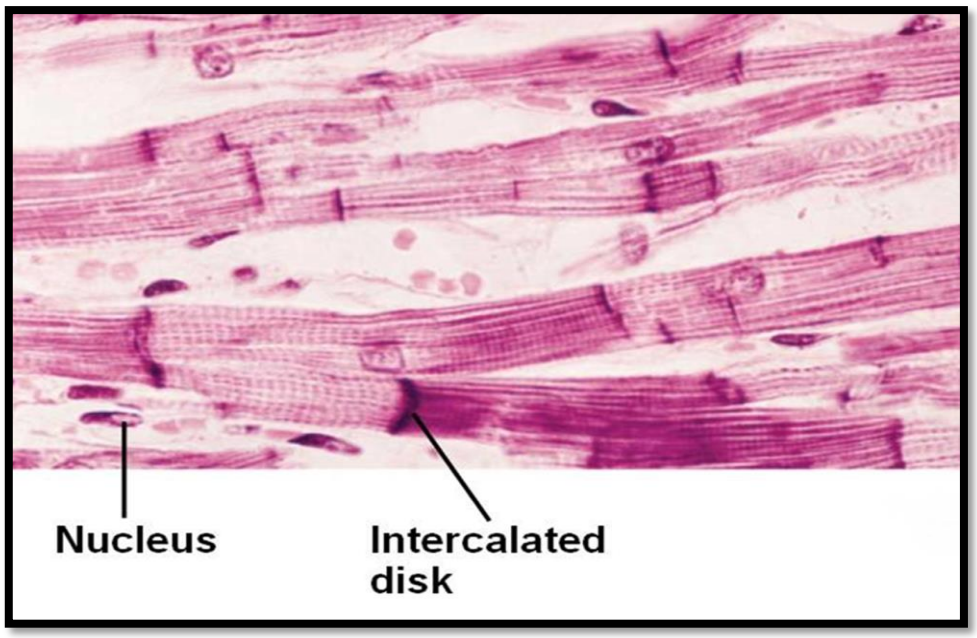


Figure (7): The characteristic features of cardiac muscles.

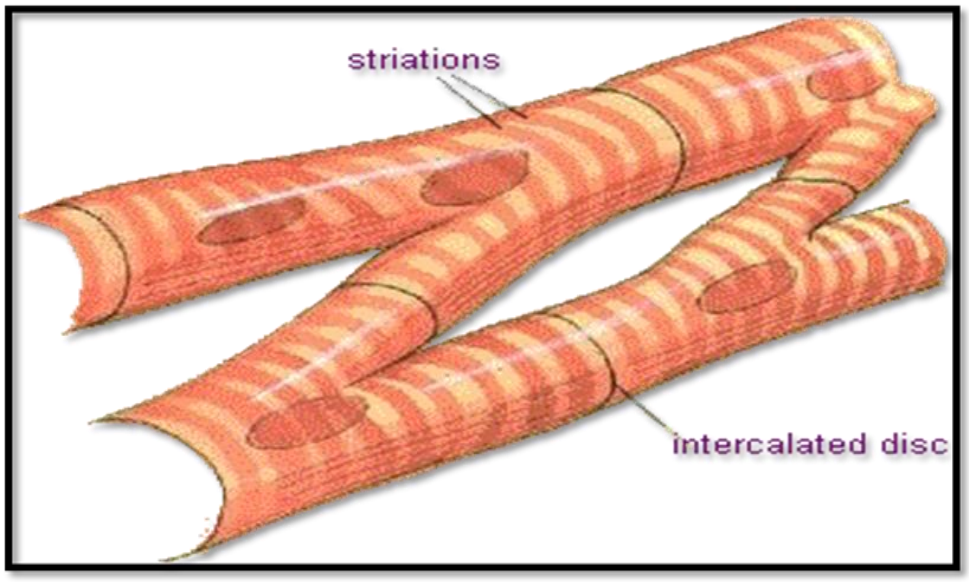


Figure (8): The distribution of intercalated disc.

Purkinje fibers

They are modified cardiac muscle which consider a part of **cardiac conduction system**. They are found in the heart as network beneath the endocrine and the internal surface of the heart. These fibers are larger and more thicker than cardiac muscle cells, They are appear lighter in appearance due to less abundant of myofibrils, many mitochondria, lots of glycogen, and no T-tubules (Figure 9). **Purkinje fibers** are specialized for the transmission of excitation, where they are specific for the generation of the heart impulses.

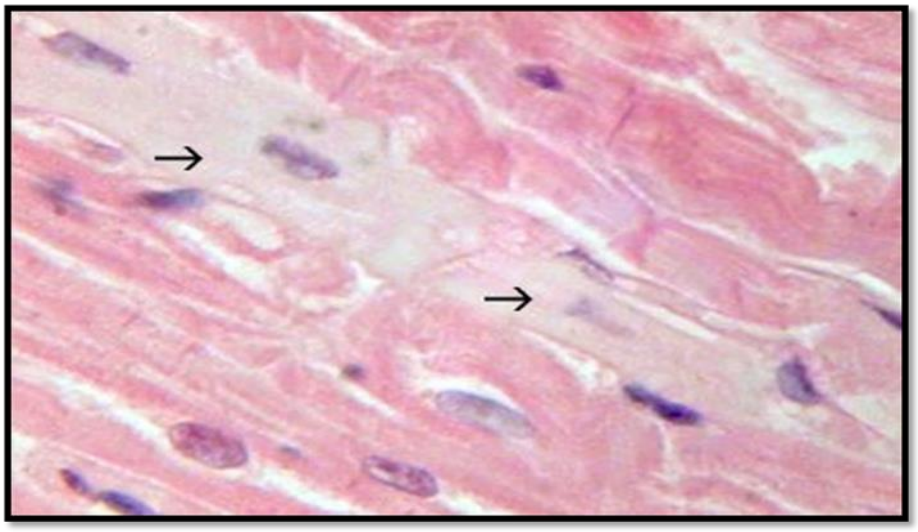


Figure (9): The characteristic features of Purkinje fiber.

Smooth muscle

Smooth muscle fibers are elongated, non striated **involuntary muscle**. These cells are fusiform in shaped, each cell has single nucleus located in the center of the broadest part of the cell. The narrow part of one cell lies adjacent to the broad parts of neighboring cells (Figure 10). Concentrated near the nucleus are mitochondria, polyribosomes, cisternae of RER, and Golgi

complexes. The **smooth muscle cells** are anchored to the surrounding connective tissue by a basal lamina. It is found in the lining of blood vessels, urinary bladder, kidneys, esophagus and small intestine.

In smooth muscle cells, the organization of actin and myosin filaments differ from that present in striated muscle. These myofilaments crisscross through the cell obliquely forming lattice-like network in the muscle cell. The dense bodies and the myofilaments that are found in sarcoplasm causes the muscle fiber to contract.

The contraction mechanism in smooth muscle differs from skeletal and cardiac muscles. The smooth muscle cells lack troponin complexes and instead use complexes with protein calmodulin, a calcium-binding protein that is also involved in the contraction of muscle cells. Contraction of smooth muscle is not under voluntary control, but is regulated by autonomic nerves and certain hormones.

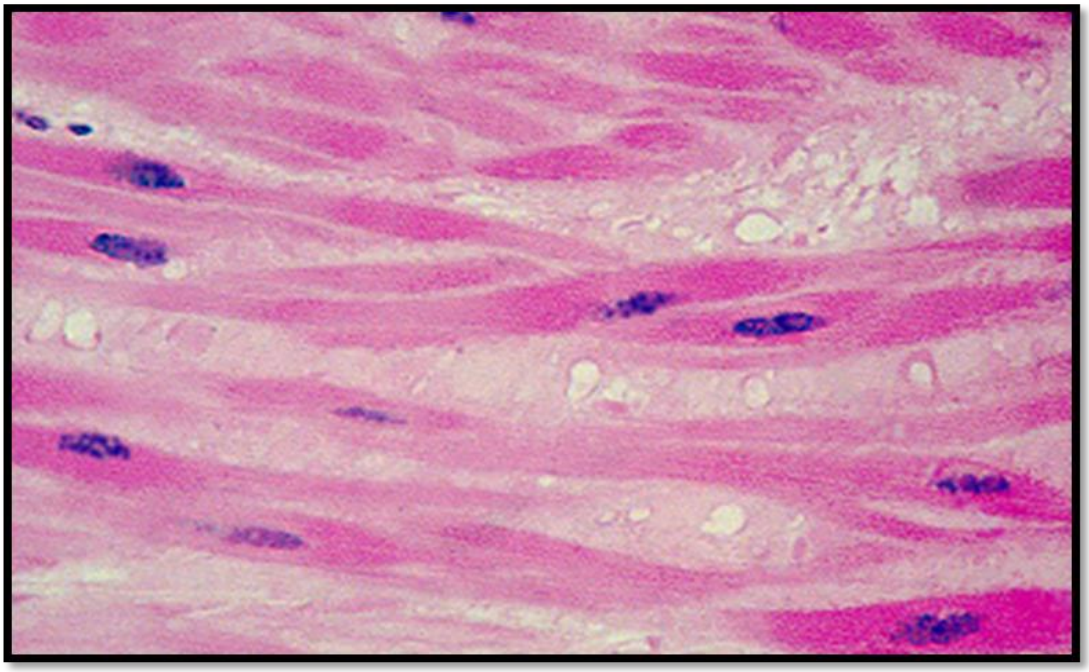


Figure (10): The characteristic features of smooth muscles.

Regeneration of muscle tissue

The three types of muscle have different potential for regeneration after injury. **Cardiac muscle** during any defects or damage (infraction) in the heart muscle are generally replaced by the proliferation of connective tissue forming myocardium scars.

In **skeletal muscle**, the source of regenerating cells is satellite cells. These cells are located outside the sarcolemma of the muscle fibers. After injury or other stimuli, the satellite cells become activated, and proliferating and fusing to form new skeletal muscle cells. Satellite cells can regenerate muscle fibers to a very limited extent. If a cell is damaged to a greater, the muscle fibers are replaced by scar tissue in a process called fibrosis.

The **Smooth muscle** is capable of an active regenerative response. After injury, viable mononucleated smooth muscle cells and pericytes from blood vessels undergo mitosis and provide for replacement of the damaged tissue.