Muscle Functions

Muscle plays four important roles in the body:

1. Producing Movement

Just about all movements of the human body are a result of muscle contraction. Mobility of the body as a whole reflects the activity of skeletal muscles, which are responsible for all locomotion and manipulation.

These are distinct from the smooth muscle of blood vessel walls and cardiac muscle of the heart, which work together to circulate blood and maintain blood pressure, and the smooth muscle of other hollow organs, which forces fluids and other substances through internal body channels.

2. Maintaining Posture

We are rarely aware of the workings of the skeletal muscles that maintain body posture. Yet, they function almost continuously, making one tiny adjustment after another so that we can maintain an erect or seated posture despite the never-ending downward pull of gravity.

3. Stabilizing Joints

As the skeletal muscles pull on bones to cause movements, they also stabilize the joints of the skeleton. Indeed, muscle tendons are extremely important in reinforcing and stabilizing joints that have poorly fitting articulating surfaces (the shoulder joint, for example).

4. Generating Heat

The fourth function of muscle, generation of body heat, is a by-product of muscle activity. As ATP is used to power muscle contraction, nearly three-quarters of its energy escapes as heat. This heat is vital in maintaining normal body temperature. Since skeletal muscle accounts for at least 40 percent of body mass, it is the muscle type most responsible for heat generation.

Skeletal Muscle Activity

Muscle cells have some special functional properties that enable them to perform their function. The first of these is *stimulation*, the ability tot receive and respond to a stimulus. The second, *contractility*, is the ability to shorten when an adequate stimulus is received.

The Nerve Stimulus and the Action Potential

Skeletal muscle cells must be stimulated by nerve impulses to contract. One motor neuron (nerve cell) may stimulate a few muscle cells or hundreds of them, depending on the particular muscle and the work it does. One neuron and all the skeletal muscle cells it stimulates are a **motor unit.** When a long threadlike extension of the neuron, called the *nerve fiber* or **axon,** reaches the muscle, it branches into a number of **axon terminals,** each of which forms junctions with the sarcolemma of a different muscle cell. These junctions are called **neuromuscular junctions** (fig.1). Although the nerve endings and the muscle cells' membranes are very close, they never touch. The gap between them, the **synaptic cleft,** is filled with tissue (interstitial) fluid.

When the nerve impulse reaches the axon terminals, a chemical referred to as a **neurotransmitter** is released. The specific neurotransmitter that stimulates skeletal muscle cells is **acetylcholine** or **ACh**. Acetylcholine diffuses across the synaptic cleft and attaches to receptors (membrane proteins) that are part of the sarcolemma. If enough acetylcholine is released, the sarcolemma at that point becomes *temporarily* more permeable to sodium ions (Na^+), which rush into the muscle cell and to potassium ions (K^+) which diffuse out of the cell. However, more Na^+ enters than K^+ leaves. This gives the cell interior an excess of positive ions, which reverses the electrical conditions of the sarcolemma and opens more channels that allow Na^+ entry only. This generates an electrical current called an **action potential.** Once begun, the action potential is unstoppable; it travels over the entire surface of the sarcolemma, conducting the electrical impulse from one end of the cell to the other. The result is contraction of the muscle cell.

It should be mentioned that while the action potential is occurring, acetylcholine, which began the process, is broken down to acetic acid and choline by enzymes (acetylcholinesterase, or AchE) present on the sarcolemma. For this reason, a single nerve impulse produces only one contraction. This prevents continued contraction of the muscle cell in the absence of additional nerve impulses. The muscle cell relaxes until stimulated by the next round of acetylcholine release.

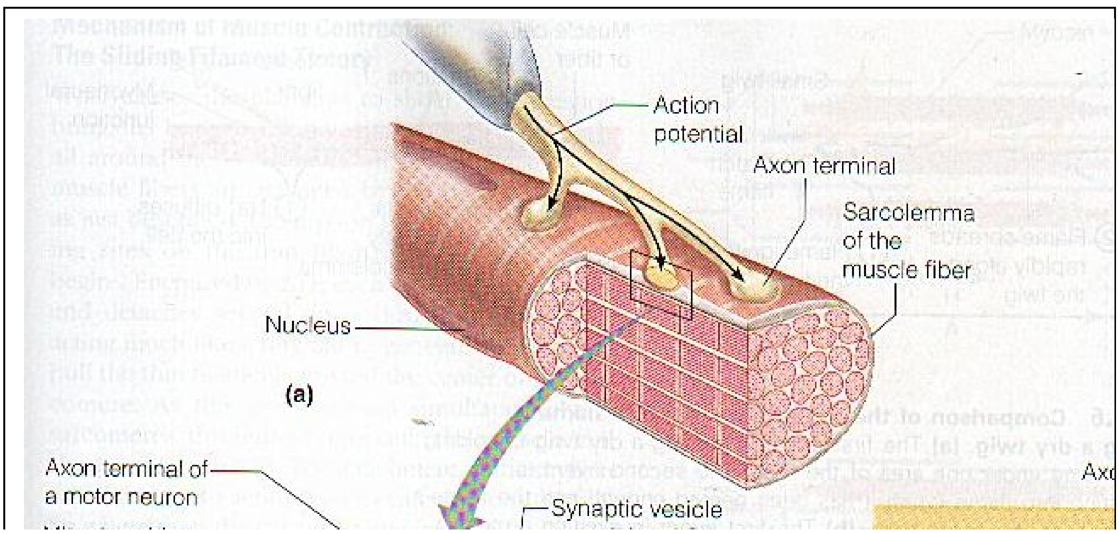

Fig. (1):Scheme of neuromuscular junction; (a):Axon terminal neuron with a muscle fiber, (b): Synaptic cleft, (c):Ach diffusion.

Mechanism of Muscle Contraction: The Sliding Filament Theory

When muscle fibers are activated by the nervous system, the myosin heads attach to binding sites on the thin filaments, and the sliding begins (fig.2). Energized by ATP, each cross bridge attaches and detaches several times during a contraction and pull the thin filaments toward the center of the sarcomere. As this event occurs simultaneously in sarcomeres throughout the cell, the muscle cell shortens. The attachment of the myosin cross bridges to actin requires calcium ions (Ca^{2+}). Inside the cell, the action potentials stimulate the sarcoplasmic reticulum to release calcium ions into the cytoplasm. The calcium ions trigger the binding of myosin to actin initiating filament sliding. When the action potential ends, calcium ions are immediately reabsorbed into the SR storage areas, and the muscle cell relaxes and settles back to its original length. This whole series of events takes just a few thousandths of a second.

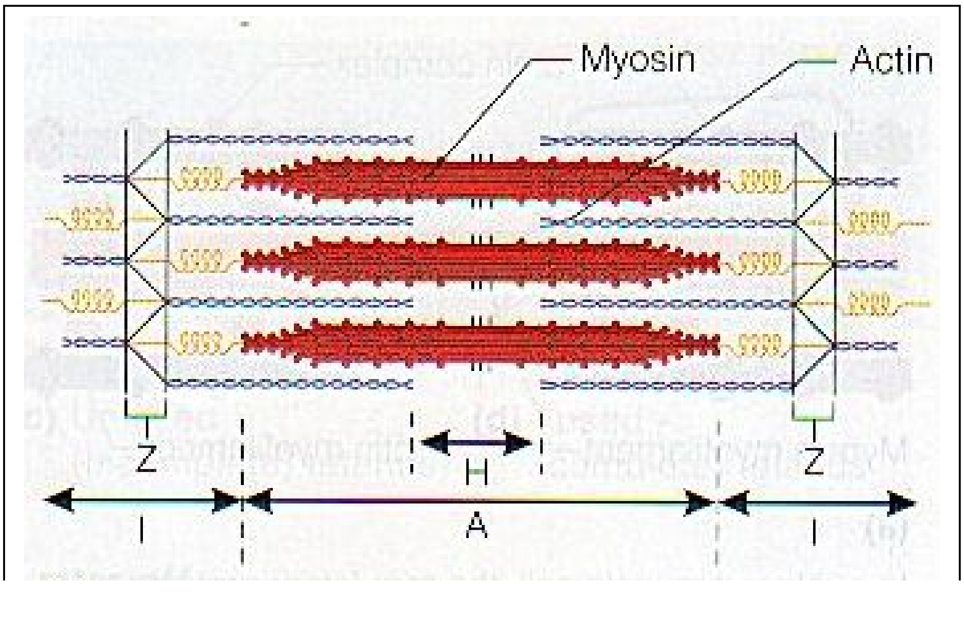

Fig. (2):Scheme of sarcomere; (a):Relaxed, (b): Fully contracted