

## Muscle Biochemistry: The Molecular Basis of Muscle Contraction and Energy Production

Antonio Motter\*

Department of Biochemistry and Molecular Biology, University of Nevada School of Medicine, USA

## DESCRIPTION

Muscles are essential for the movement and function of the human body. Muscle biochemistry, a multidisciplinary field that combines biochemistry, physiology, and molecular biology, focuses on understanding the intricate processes that occur within muscles at the molecular level. This field of study seeks to elucidate the structure, function, and metabolism of muscles, providing insights into their role in human health and disease. In this article, we will explore the fundamental concepts of muscle biochemistry, including the structure of muscle fibers, the molecular mechanisms of muscle contraction, and the metabolic pathways involved in muscle energy production. Muscle fibers are the basic structural units of muscles. They are specialized cells that contain unique organelles and proteins that enable them to contract and generate force. Muscle fibers are classified into three types: skeletal, cardiac, and smooth. Skeletal muscles are responsible for voluntary movements, cardiac muscles are found in the heart and are responsible for involuntary contraction, and smooth muscles are found in organs such as the digestive tract and blood vessels. Skeletal muscle fibers are multinucleated cells that are organized into bundles called fascicles, which make up the whole muscle. Each skeletal muscle fiber is surrounded by a plasma membrane called the sarcolemma, which contains specialized invaginations called Transverse Tubules (T-tubules) that play a role in transmitting signals for muscle contraction.

The cytoplasm of muscle fibers is known as sarcoplasm and contains abundant mitochondria for energy production, as well as other organelles such as the Sarcoplasmic Reticulum (SR), which stores Calcium Ions ( $Ca^{2+}$ ) needed for muscle contraction. The contractile units of skeletal muscle fibers are called sarcomeres, which are composed of overlapping thick (myosin) and thin (actin) filaments. The myosin filaments are anchored in the center of the sarcomere, while the actin filaments are attached to the Z-discs at the ends of the sarcomere. Molecular Mechanisms of Muscle Contraction is a complex process that involves the interaction of various proteins and the generation of

Adenosine Triphosphate (ATP), the primary source of energy for muscle contraction. The molecular mechanisms of muscle contraction can be divided into several steps such as excitation, coupling, and contraction. Excitation refers to the generation of an action potential in the sarcolemma of a muscle fiber, which is triggered by a nerve impulse. The action potential travels along the T-tubules, which are in close proximity to the Sarcoplasmic Reticulum (SR). The depolarization of the T-tubules causes the release of calcium ions ( $Ca^{2+}$ ) from the SR into the sarcoplasm, a process known as excitation-contraction coupling. Coupling refers to the interaction between the calcium ions and the proteins in the muscle fiber that ultimately lead to muscle contraction.

Calcium ions bind to a protein called troponin, which is located on the actin filaments. This binding causes a conformational change in troponin, which allows the myosin heads of the thick filaments to bind to the actin filaments, forming cross-bridges.

Contraction is the process by which the cross-bridges formed between myosin and actin filaments generate force and cause the sarcomeres to shorten. The myosin heads undergo a series of conformational changes, known as the cross-bridge cycling, which involves the hydrolysis of ATP to ADP and Inorganic Phosphate (Pi). This energy released from ATP hydrolysis allows the myosin heads to interact with actin, resulting in the sliding of the thin filaments along the thick filaments and the shortening of the sarcomere. This process is repeated multiple times, leading to muscle contraction. After muscle contraction, ATP is needed to dissociate the myosin heads from the actin filaments and allow for relaxation. ATP is also required for the reuptake of calcium ions into the sarcoplasmic reticulum through a calcium ATPase pump, which restores the calcium ion concentration back to its resting level and allows for the muscle to relax.

Metabolic Pathways Involved in Muscle Energy Production are Muscles require a continuous supply of energy to sustain their contraction and relaxation processes. The primary source of energy for muscle contraction is ATP, which is produced through

Correspondence to: Antonio Motter, Department of Biochemistry and Molecular Biology, University of Nevada School of Medicine, USA, E-mail: anmott@er.edu

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several metabolic pathways, including glycolysis, oxidative phosphorylation, and creatine phosphate metabolism. Glycolysis is the process by which glucose is broken down into two molecules of pyruvate, with a net production of two molecules of ATP. Glycolysis can occur in the absence of oxygen (anaerobic glycolysis) and is the main source of ATP production during high-intensity, short-duration activities, such as weightlifting and sprinting. However, anaerobic glycolysis also produces lactate as a byproduct, which can accumulate in the muscle and contribute to muscle fatigue.