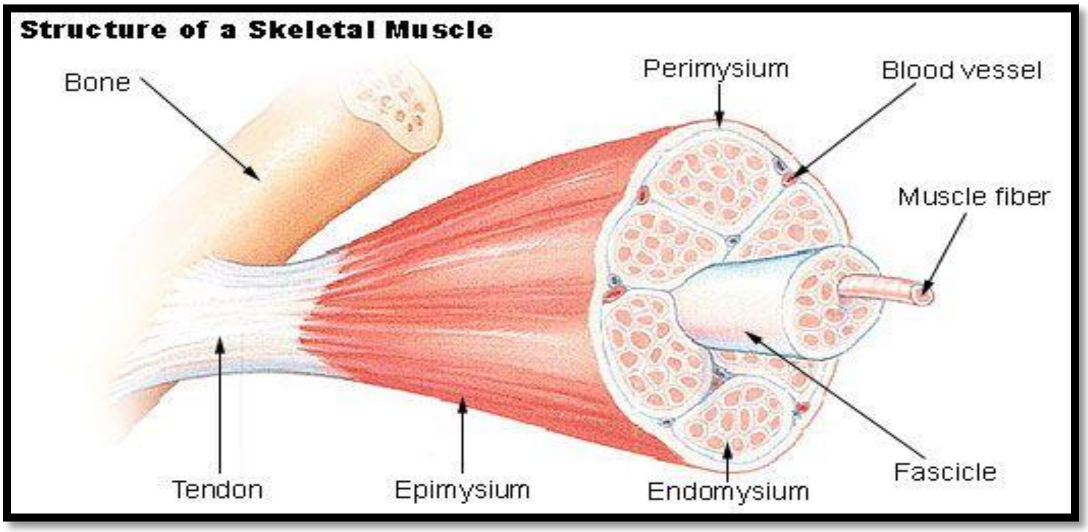
Lecture 4 / Muscular system

The 3 types of muscle tissue are cardiac, smooth, and skeletal

1- Skeletal muscle

Each skeletal muscle fiber is a single cylindrical muscle cell. An individual skeletal muscle may be made up of thousands of muscle fibers bundled together and wrapped in a connective tissue covering. Each muscle is surrounded by a connective tissue sheath called the **Epimysium**.. Portions of the epimysium project inward to divide the muscle into compartments. Each compartment contains a bundle of muscle fibers. Each bundle of muscle fiber is called a **Fasciculus** and is surrounded by a layer of connective tissue called the **Perimysium**. Within the fasciculus, each individual muscle cell, called a muscle fiber, is surrounded by connective tissue called the **Endomysium** (see in figure 1). Skeletal muscle cells are multinucleated from the fusion of muscle cells



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2- Cardiac muscle

Cardiac muscle is a type of involuntary mononucleated, striated muscle found exclusively within the heart. Its function is to "pump" blood through the circulatory system by contracting. Unlike skeletal muscle, which contracts in response to nerve stimulation, and like smooth muscle, cardiac muscle is myogenic, meaning that it stimulates its own contraction without a requisite electrical impulse coming from the central nervous system. A single cardiac muscle cell, if left without input, will contract rhythmically at a steady rate. This transmission of impulses makes cardiac muscle tissue similar to nerve tissue, although the cells are connected by Intercalated discs, which conduct electrical potentials directly, rather than the chemical synapses used by neurons.

3- Smooth muscle

Smooth muscle is a type of non-striated muscle, found within the "walls" of hollow organs; such as the bladder, the uterus, and the gastrointestinal tract, and also lines the lumen of the body, such as blood vessels. Smooth muscle is fundamentally different from skeletal muscle and cardiac muscle in terms of structure and function. Smooth muscle is spindle shaped, and like any muscle, can contract and relax. In order to do this it contains intracellular contractile proteins called actin and myosin. While the fibers are essentially the same in smooth muscle as they are in skeletal and cardiac muscle, the way they are arranged is different. As non- striated muscle, the actin and myosin is not arranged into distinct sarcomeres that form orderly bands throughout the muscle cell. The cells themselves are generally arranged in sheets or bundles and connected by gap junctions. In relaxed state, each cell is spindle-shaped, 25-50 µm long and 5 µm wide. The cells that compose smooth muscle have single nuclei

	Table. Comparison of Muscle Types		
Characteristic	Muscle Types		
	Skeletal	Cardiac	Smooth
Nuclei	Multinucleated; peripherally located	Single nucleus; centrally located	Single nucleus; centrally located
Banding	Actin and myosin form distinctive bands	Actin and myosin form a distinctive bands	Actin and myosin , NO distinctive bands
Z disks	Present	Present	Z disks not present; cytoplasmic dense bodies are present
T tubules	T tubules at A-junction; triads present	T tubules at Z disk; diads present	No T tubules; no triads or diads

	skeletal	cardiac	smooth
Cellular junctions	No junctional complexes	Intercalated disks	Gap junctions
Neuromuscular junctions	Present	Not present; contraction is intrinsic	Not present; contraction is intrinsic, neural, or hormonal
An aerobic capacity	High	Low	Low
Striation Not Striated	Striated	Striated	Not Striated
Electrical activity origin	Neurogenic	Myogenic	Neurogenic/Myogenic
Presence	Leg, Arm	Heart	Arterioles, Got
	Voluntary	Involuntary	Involuntary

Muscle structure

Looking at muscle anatomy shows that each muscle is made up of Muscle cells or (Myofibers). The functional characteristics of a skeletal muscle cell:

- Each muscle cell (myofibers) is organized into sections along its length. Each section is called a **Sarcomere** and they are repeated right along the length of a muscle fiber. The sarcomere is the smallest contractile portion of a muscle fiber.

- The cell membrane is called the **Sarcolemma,** which is structured to receive and conduct stimuli.

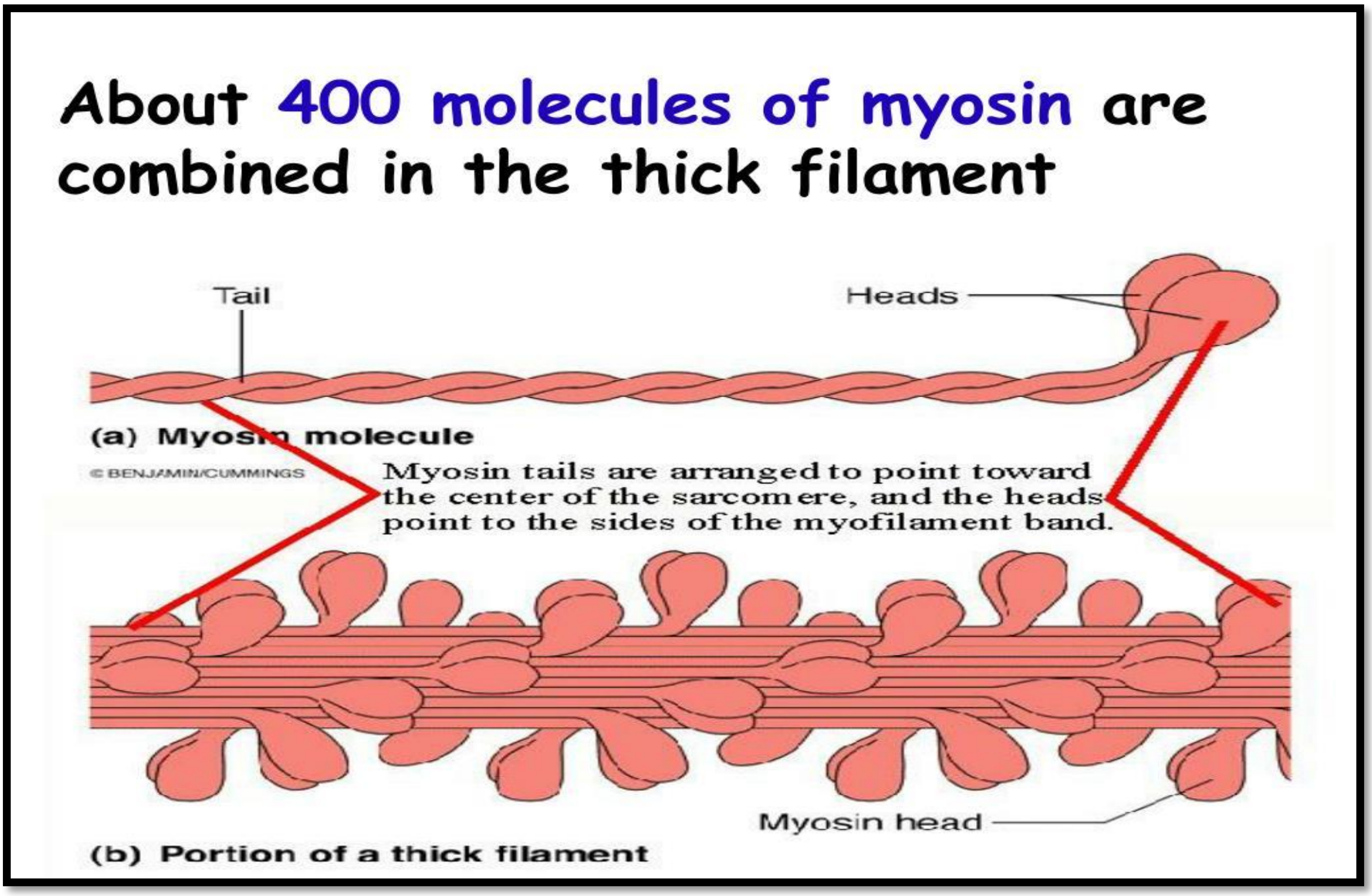
- The Sarcoplasm of the cell is filled with contractile Myofibrils or Myofilaments and this result in the nuclei and other organelles being relegated to the edge of the cell. Sarcoplasm contains glycogen, fat particles, enzymes and the mitochondria.

- Muscle fibers (Myofibers) are grouped into bundles (of up to 150 fibers) called Fasciculi.

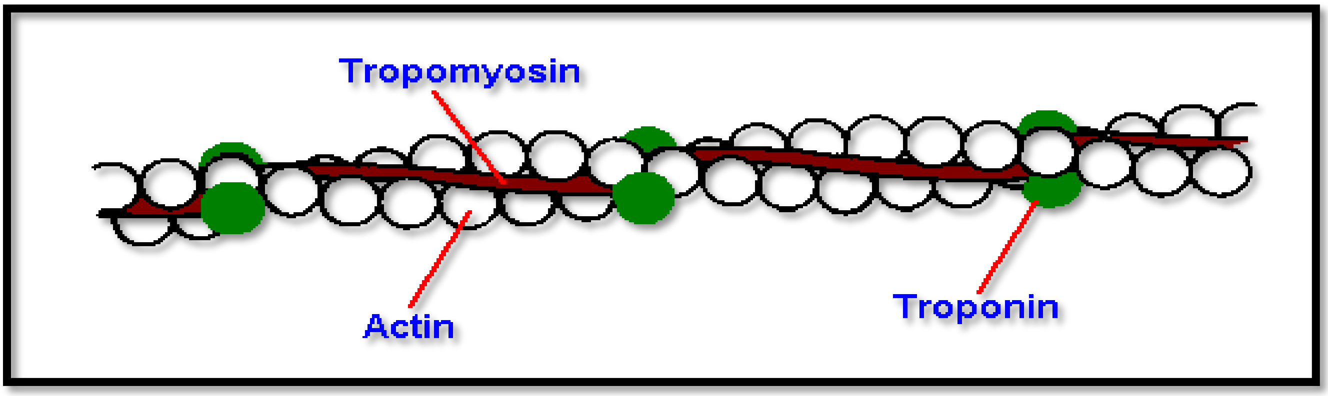
- Myofibrils or Myofilaments are contractile units within the cell which consist of a regular array of protein myofilaments.

- There are two types of protein filaments Actin and Myosin, which is run in parallel to each other along the length of the muscle fiber.

- Myosin (1): is made of multiple molecules of a protein called Myosin. Each myosin molecule is composed of two parts: the globular "head" and the elongated "tail". They are arranged to form the thick filaments. The tiny globular heads protrude from the filament at regular intervals. These are called Cross bridges and play a pivotal role in muscle action.



Actin (2): is made of multiple molecules of a protein called Actin, which is composed of globular proteins (G actin units) arranged to form a double coil (double alpha helix) to form the thin filament.



- Each thin myofilament is wrapped by a tropomyosin (3) protein, which in turn is connected to the troponin (4) complex.

- The sarcomere is often divided up into different zones to show how it behaves during muscle action. The Z-line separates each sarcomere. The H-zone is the center of the sarcomere and the M-line is where adjacent myosin filaments anchor on to each other.

- The arrangement of the thick myosin filaments across the myofibrils and the cell causes them to refract light and produce a dark band known as the A Band. In between the A bands is a light area where there are no thick myofilaments, only thin actin filaments. These are called the I Bands. The dark bands are the striations seen with the light microscope.

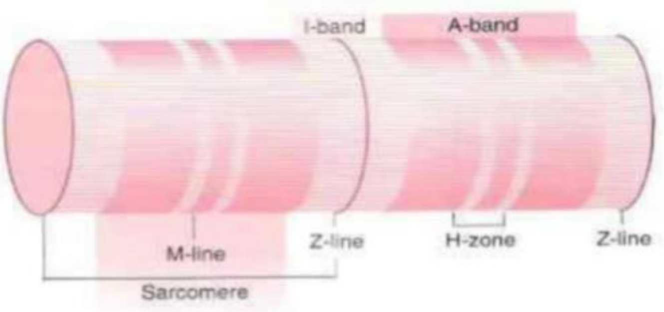


Figure 2: Myofibril divided into 2 sarcomeres

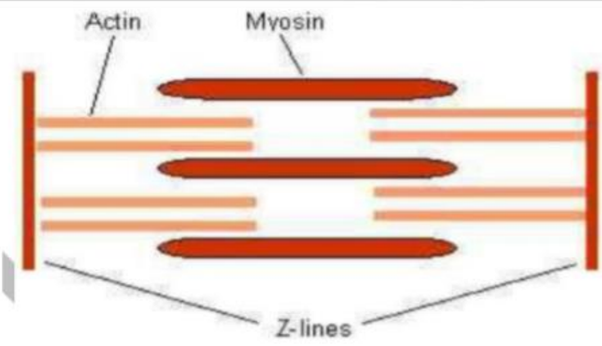


Figure 3: Arrangement of actin and myosin filaments in a single sarcomere

 As the sarcomeres contract the myofibrils contract. As the myofibrils contract the muscle cell contracts. And as the cells contract the entire muscle contracts.

 Terminal cisternae: An expanded portion of the sarcoplasmic reticulum in which Ca+2 ions is stored during relaxation of the muscle.

 Transverse tubules: (or T-tubule) is a deep invagination of the sarcolemma, which is the plasma membrane of skeletal muscle and cardiac muscle cells. These invaginations allow depolarization of the membrane to quickly penetrate to the interior of the cell

Motor Units

All motor neurons leading to skeletal muscles have branching axons, each of which terminates in a neuromuscular junction with a single muscle fiber. Nerve impulses passing down a single motor neuron will thus trigger contraction in all the muscle fibers at which the branches of that neuron terminate. This minimum unit of contraction is called the **motor unit**.

Although the response of a motor unit is all-or-none, the strength of the response of the entire muscle is determined by the **number of motor units** activated. Each muscle cell is stimulated by a motor neuron axon. The point where the axon terminus contacts the sarcolemma is at a synapse called the **neuromuscular junction**. The terminus of the axon at the sarcolemma is called **the motor end plate.**

Motor end plate : The specialized region of the sarcolemma of the muscle fiber at the neuromuscular junction , that surrounding the terminal end of axon . The neuromuscular junction is the synapse between the nerve fiber and muscle fiber

Mechanism of Muscle Contraction

1. The axons of the nerve cells of the spinal cord branch and attach to each muscle fiber forming a neuromuscular junction.

2. An action potential passes down the nerve.

3. The nerve releases Ca++ that results in the release of Acetylcholine (ACh).

4. ACh binds with receptors and opens Na+ channels (Na+ Channels open and Na+ in) .There is a decrease in the resting potential.

5. Na + rushes in and the sarcolemma depolarizes.

6. The positive patch in the membrane changes the adjacent patch of the membrane. Thus depolarization spreads.

7. Immediately after the action potential passes the membrane permeability changes again. Na+ channels close and K+ channels open. K+ rushes out of the cell. Cell reploraizes

8. Ca++ is stored in the sarcoplasmic reticulum. Depolarization releases the Ca++.The Ca++ clears the actin binding sites.

9. During muscle contraction the thin actin filaments slide over the thick myosin filament. When Calcium is present the blocked active site of the actin clears.

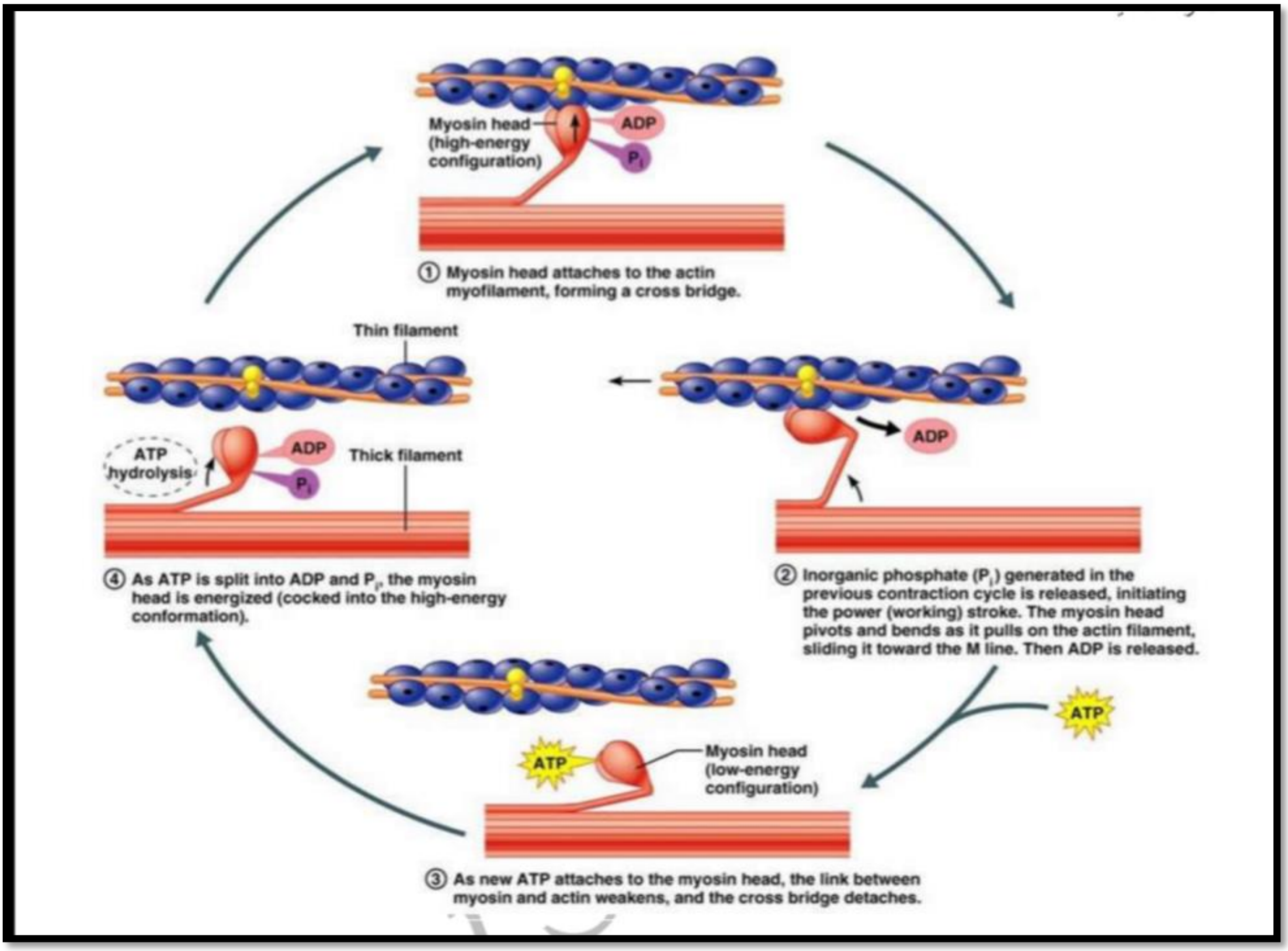
10. Myosin head attaches to actin. (High energy ADP + P configuration).

11. Power stroke: myosin head pivots pulling the actin filament toward the center.

12. The cross bridge detaches when a new ATP binds with the myosin.

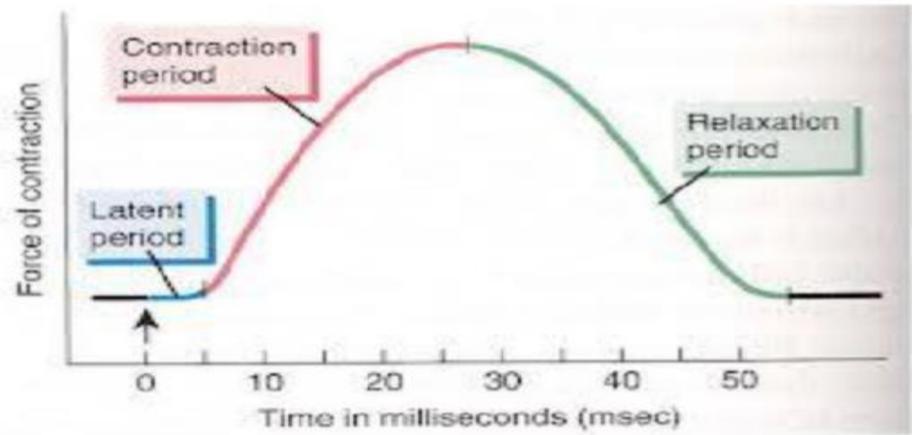
13. The end result is a shortening of the sarcomere. The distance between the Z discs shortens The H zone disappears, the dark A band increases because the actin & the myosin overlap more The light I band shortens.

14. Ca++ is removed from the cytoplasm. Tropomysin blocks the actin site.



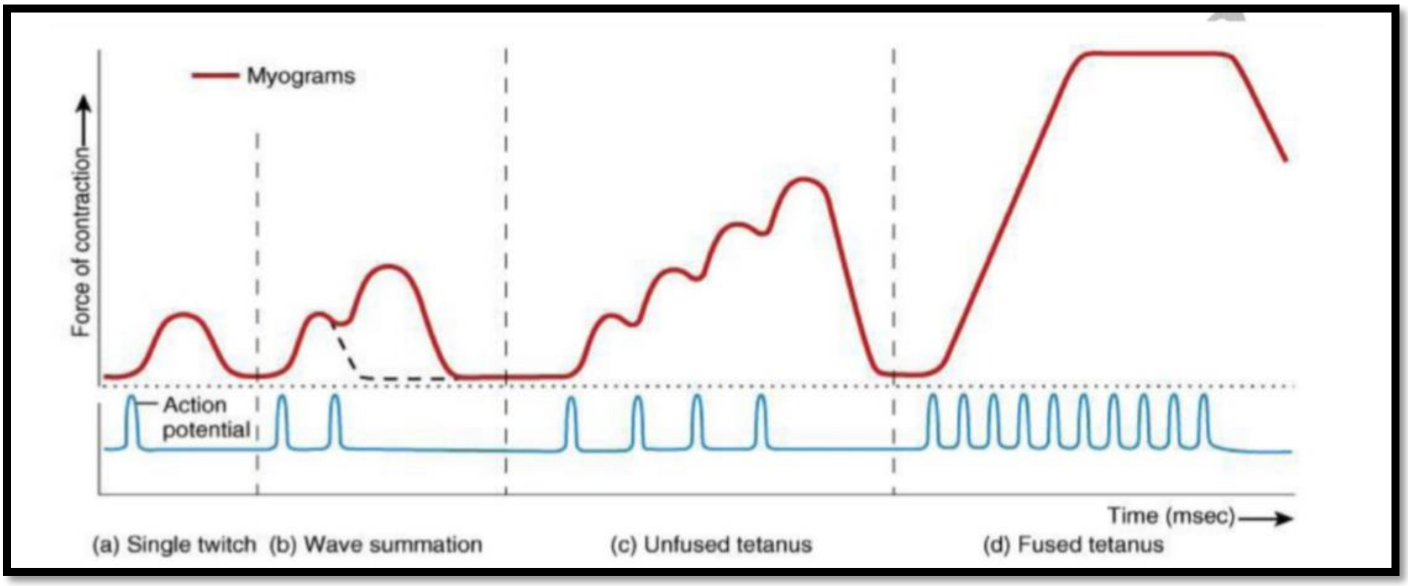
Muscle twitch:

A Myogram can record a twitch. There is a brief delay between the stimulation and the beginning of contraction, called the **latent period.** It corresponds to the change in Na+ and Ca++ ions occurring in the cell. In the second phase, the **contraction phase**, the muscle contracts. Myosin heads bind to actin and slide along it. It lasts 10-100 msec. The third phase or **relaxation period** lasts slightly longer than the contraction period. It corresponds to the calcium ions being shipped back into the sarcoplasmic reticulum. Shortly after initial stimulation, the muscle fiber cannot contract. It is the **refractory period,** lasting a short time in this muscle and is due to the depolarized state of the muscle membrane.



The process of contracting takes some 50 msec; relaxation of the fiber takes another 50–100 msec. Because the refractory period is so much shorter than the time needed for contraction and relaxation, the fiber can be maintained in the contracted state so long as it is stimulated frequently enough (e.g., 50 stimuli per second). Such sustained contraction is called Tetanus.

In the figure, · When shocks are given at 1/sec, the muscle responds with a single twitch.· At 5/sec and 10/sec, the individual twitches begin to fuse together, a phenomenon called Clonus or Summation. · At 50 shocks per second, the muscle goes into the smooth, sustained contraction of tetanus.



Muscle fatigue: is a Physiological Inability of a muscle to contract. Muscle fatigue is a result of a relative depletion of ATP. When ATP is absent, a state of continuous contraction occurs. This causes severe muscle cramps.

Fueling Muscle Contraction: ATP is the immediate source of energy for muscle contraction. Although a muscle fiber contains only enough ATP to power a few twitches, its ATP "pool" is replenished as needed. There are three sources of high-energy phosphate to keep the ATP pool filled.

- Creatine phosphate
- Glycogen
- Cellular respiration in the mitochondria of the fibers.