Lecture # 11

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Muscle Tissue

Function of the muscles:

1) **Movement :**
   - Muscle contraction means Shortening, approximation between the origin and insertion.
   - When the skeletal muscle contracts & relaxes, it produces bodily movement because it is attached to bone.
   - BUT not all the muscles contraction leads to movement from point A to B (locomotion), like the heart muscle for ex. which squeezes & relaxes in order to pump blood throughout our body. In addition, smooth muscles are located inside the wall of hollow organs like the wall of our digestive tract. Smooth muscle tissue contracts in sequence to produce a peristaltic wave, which propels a ball of food along the tract

2) **Maintenance of posture :**
   - The contractions of your neck & back muscles produce a balanced upright posture.

3) **Joint stabilization:**
   - Muscles act as flexors or extensors, and at the same time they stabilize the joint they cross

4) **Heat generation :**
   - In order for the muscle to contract, it needs ATP (chemical form of energy). By the contraction of the muscle, the chemical energy is transferred into mechanical energy (bodily movement) & the heat is a byproduct of this process.
   - Why do we shiver when we feel cold?
     Because our brain sends impulses to our peripheral muscles to contract and heat is produced as a byproduct

we have 3 types of muscles:

Type	Skeletal MS	Cardiac MS	Smooth MS
Location	Attach to skeleton (bones) to produce bodily movement.	Present only in the heart.	Located inside the walls of hallow organs (viscera & tube like structures) like: walls of the blood vessels, esophagus, GI tract & stomach
Show striation	Striated	Striated	Non striated.
Conscious control	Under our conscious control (voluntary)	Involuntary	Involuntary

Similarities:

1) **Muscle tissue is composed of muscle cells**
   The muscle cells are fiber like (look like fibers, they are elongated structures).
   NOTE → muscle cell = muscle fiber.
2) **in their cytoplasm you find high amount of myofilaments in order to contract :**
   ***** Actin
   *****myosin
   Note that: pre-suffix myo refers to muscle.
3) **Because the muscle cell is a highly specialized cell, with unique structure and arrangement (specialized for contraction), we give its parts special names like:**

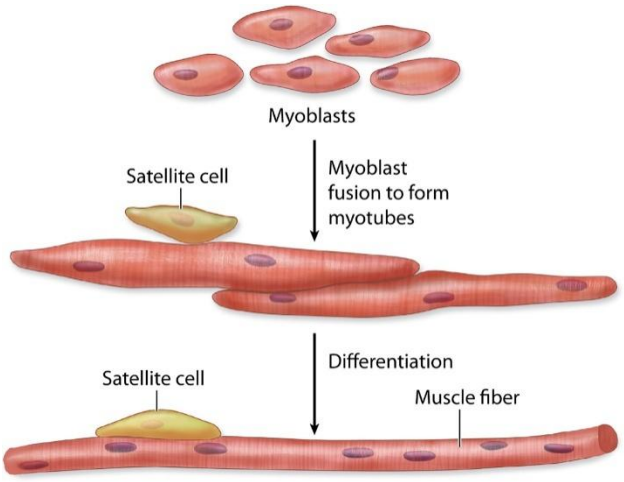
- Sarcolemma → plasma membrane of the muscle cell .
- Sarcoplasm → cytoplasm of the muscle cell.
- Sarcoplasmic reticulum (SR) → smooth endoplasmic reticulum inside the muscle cell.

Why the SR is important in the muscle cell?
Because it's the storage site of the Ca ions. Ca ions are necessary for the contraction .

✓ Note: the pre-suffix " sarco " refers to the MS, sarco means fleshy part

Skeletal muscle

- The origin of the skeletal MS from **mesoderm** (middle layer of the developing fetus). Mesenchymal cells differentiate into **Myoblasts**.
- (Myo = muscles, blast = building cell in histology [active], progenitor cell in embryology) .
- Each myoblast is **single** nucleated (have single nucleus).
- These cells fuse to form long structure called **myotube**.
- The myotube will differentiate into muscle fiber (cell) (by synthesizing high amount of myofilaments).
- So the MS cell is multi- nucleated, why?
  Because it's a result of fusion of many myoblasts.
- The skeletal muscle cell is an elongated cylindrical structure, it looks like a fiber and it is multi-nucleated
- The nuclei are located exactly under the sarcolemma.
- Satellite cells are also present in muscle tissue.
  Satellite cells are undifferentiated cells (stem cells)
  In case of injury, they can differentiate into MS cells BUT this is very limited because they are few in number.



The Muscle is composed of 2 parts:

a) Fleshy part of the MS (red in color).
b) Tendon that connects the MS to the bone (white in color).

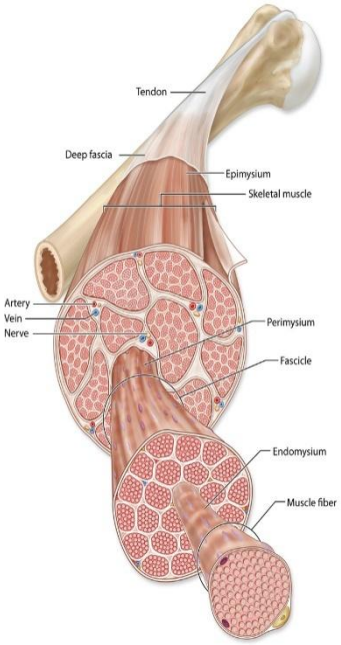
❖ The fleshy part of the MS is surrounded by connective tissue membrane (dense irregular type of CT looks like a capsule), we call this capsule (CT) **Epimysium** (Epi = above , mysium = refer to MS).

- The epimysium sends septa to divide the interior of the MS into groups, we call each group muscle **fascicle.**
- Each fascicle is surrounded by dense type of CT layer (BUT it's less dense than epimysium), we called it **perimysium .**
- Each fascicle is composed of MS cells (fibers), each MS cell is surrounded by a loose CT we called it **endomysium** (endo means = inside).

NOTE: As you go deep in the muscle, the connective tissue becomes looser.

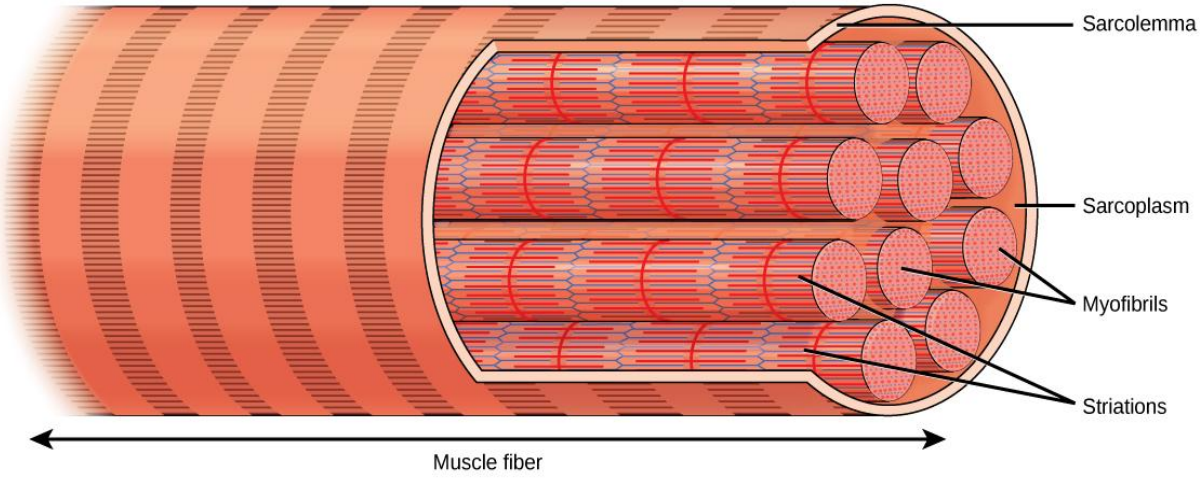
So, we have 3 CT coverings:

1) **epimysium** → surrounding the whole MS → dense.
2) **perimysium** → surrounding each group of the MS cells (fascicle) → less dense .
3) **endomysium** → surrounding each MS cell → loose .



- **They all converge to form tendon which attaches the MS to the bone.**

Remember… tendon: Dense regular type of CT.

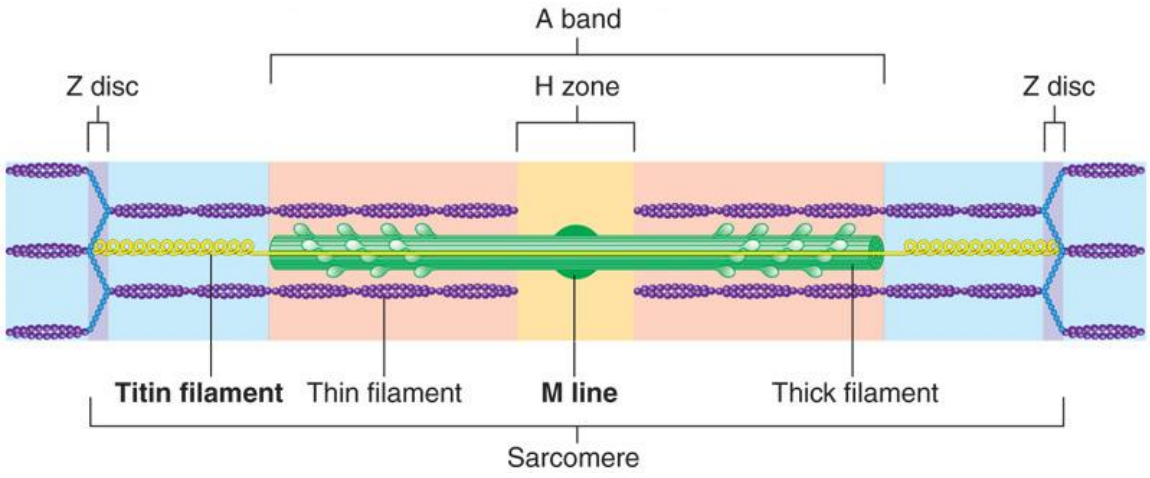


- ❖ The sarcoplasm of the MS cell has many myofibrils
- ❖ Each myofibril is composed of thin and thick filaments (myofilaments)
- ❖ The myofilaments are arranged in a highly regular manner (sarcomeres)
- ❖ The myofibril is an elongated structure, composed of repeating units of sarcomeres
- ❖ The sarcomere .(قطعة عضلية) is the smallest functional unit in the MS cell .

MS cell → myofibrils → myofilaments

The structure of sarcomere:

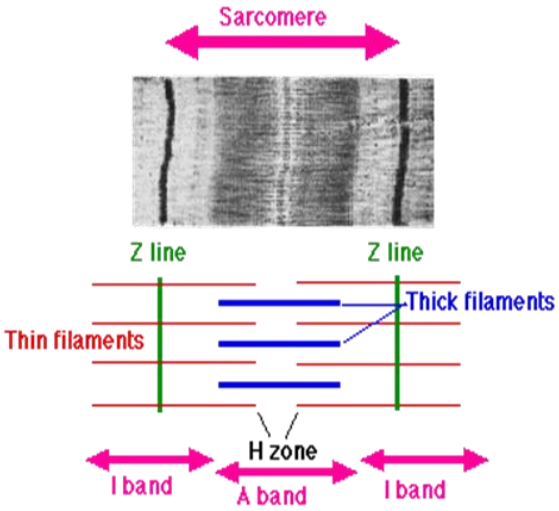
- Sarcomeres are contractile units of skeletal muscle consisting of components between 2 Z discs
- M lines are structural proteins that anchor myosin during contraction
- Titin is elastic protein attaching myosin to Z disc that contributes to elastic recoil of muscle, and keeps the correct alignment of the sarcomere
- A band is dark, contains thick filaments (mostly myosin)
  - Light area at center of A band is H band = area where actin and myosin don't overlap
- I band is light, contains thin filaments (mostly actin)
  - At center of I band is Z line/disc where actins attach



How does the sarcomere look like using the electron microscope?

- The sarcomere is composed of myofilaments (thick and thin), thin filaments are attached to the Z line and the thick filaments are attached to M line, these filaments appear as alternating dark & light bands , and this what gives the skeletal MS it's striations

- The dark band of sarcomere is called **A-band** (A : anisotropic)
- When we view the tissue under the polarizing microscope, the thick filaments have something called birefringence (خاصية انعكاس الضوء) they change the direction of the polarizing light, so it appears dark in color .
- The light band of the sarcomere is called **I-band** (I : isotropic).
- The thin filaments don't change the direction of the polarizing light, so it looks light.
- NOTE that the Z-line bisects the I-band (light band) in the middle.
- Z-line (Z refers to zwischen in German and it means in-between).
- M-line (M refers to Mitte in German, means Middle).
- H-zone (H refers to Hell in German, means bright)
- Z-line is composed of many proteins that anchor the actin filaments to each other (ex. Alpha actinin).
- M-line is composed of many proteins that anchor myosin (thick filament) to the M-line.



Again again & again, you should remember that :

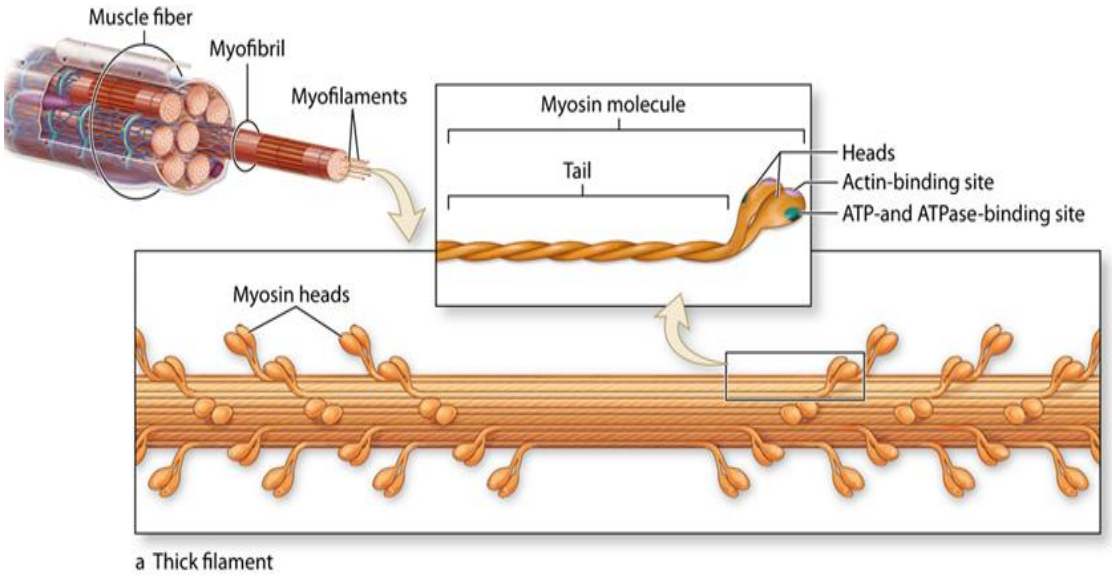
- Each muscle cell (fiber) is composed of myofibrils. Each myofibril is composed of myofilaments. Myofilaments (thin and thick) form sarcomeres

Now, let's talk about the structure of **thick filaments**

- A thick myofilament contains 200-500 molecules of myosin

- **Myosin molecule:** Myosin is composed of 2 identical heavy chains and two pairs of light chains
- heavy chains are twisted together as tail
- The four light chains form two heads (at one end of each heavy chains)
- each head has 2 binding sites :

- One for the ATP .
- One for the Actin



a Thick filament

Now, let's talk about the structure of **thin filaments**

NOTE: Thin filament is **not only** Actin.

- Actin filaments are composed of two thin helical twisted strands composed of G-actin monomers
- Contain a myosin binding site
- Are anchored to the Z line by alpha-actinin
- Associated with:

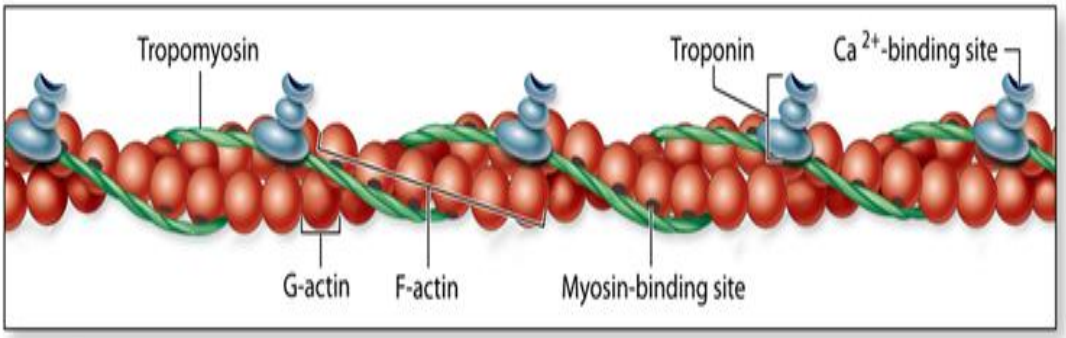
A- **Tropomyosin**: coil of two peptide chains located in the groove between the two twisted actin strands

B- **Troponin** a complex of 3 subunits :

<u>Subunit T: interacts with **T**ropomyosin</u>

Subunit C: interacts with **C**alcium ion

Subunit I: Regulatory subunit (**i**nhibitory)



b Thin filament

In relaxed muscles, **tropomyosin** occludes or masks the myosin binding sites on actin, myosin heads can't interact with the actin filaments because the myosin binding sites are covered/ occupied by tropomyosin.

When the muscle is stimulated, the level of calcium elevates, the calcium has a binding site on the troponin, when it binds to this binding site, troponin changes its shape, these conformational changes unmask the binding sites covered by the troponin-tropomyosin complex on the actin myofilament and allowing the myosin cross-bridges to connect with the actin. In other words, binding of Calcium to troponin C causes conformational changes which lead to dislocation of troponin complex and finally tropomyosin leaves the binding site for myosin on actin leading to contraction of muscle.

- Muscle contracts because myofibrils get shorter
- Shortening occurs because thin filaments slide over and between thick filaments towards center
- Shortening distance from Z disc to Z disc
- Note that Actin & Myosin will not shortened ,, the overlap between the thin and the thick filaments increases, and this is called **sliding filament model ,** the thin filament (Actin) will slide over the thick filaments toward the **M-line** .

What will happened for the ..

1) A-band?

Nothing, because the A-band represents the actual length of the Myosin filaments.

2) H-ZONE?

Shortening, H zone is composed of Myosin only without the overlapping Actin. When overlaps increases, H zone shortens

3) I-band?

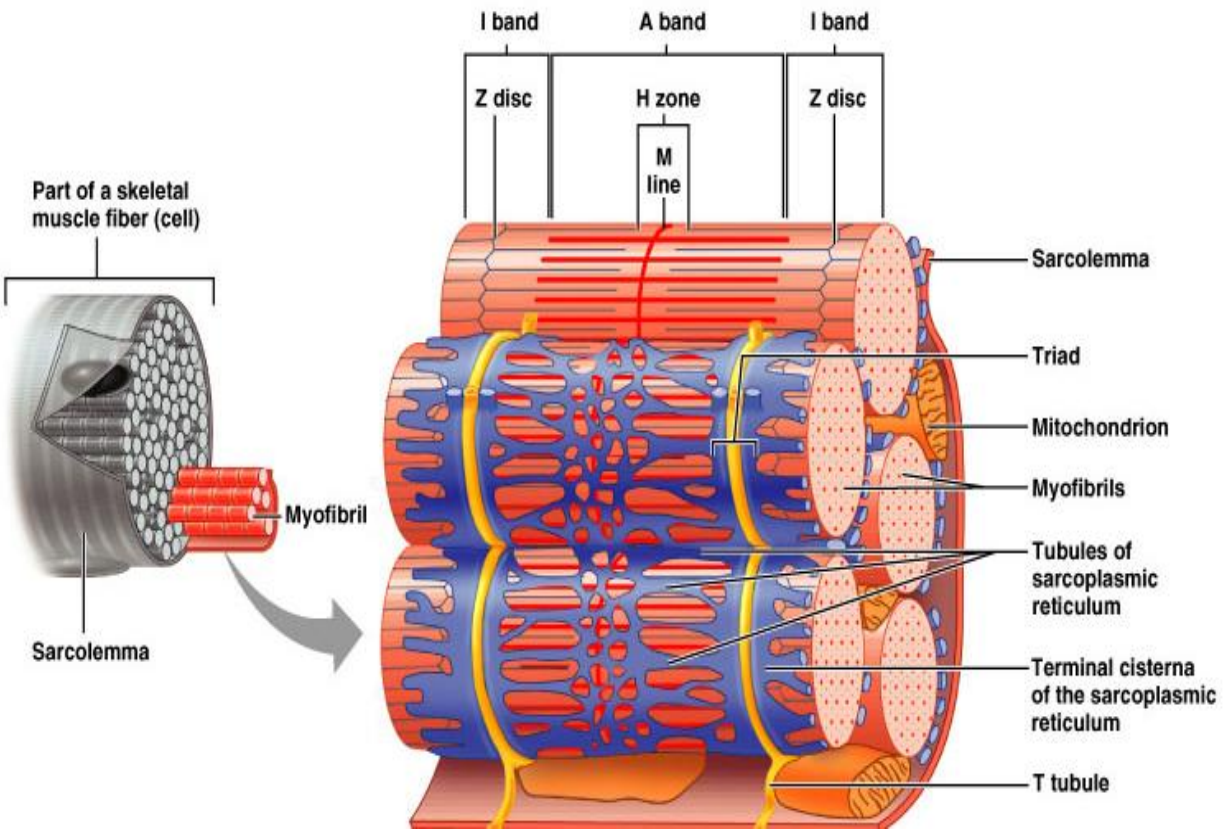
Shortening, I band is only composed of thin filaments. When overlaps increases, I band shortens.

- Each myofibril is surrounded by a network of smooth ER (sarcoplasmic reticulum) (storage site of Ca ions) .
- SR forms a network in the middle area. As you go away, it forms tubules running with the longitudinal axis of myofibril, these tubules are called **longitudinal tubules**. Longitudinal tubules ends as terminal cisternae
- The sarcolemma of muscle cell has many pores.
- These pores are invaginations of the plasma membrane that go inside to wrap (surround) each myofibril, we call them **T-tubules** (T : transverse) .
- T-tubules run transversely to the longitudinal axis of the myofibril.
- A **T-tubule** (or **transverse tubule**) is a deep invagination of the sarcolemma
- T-tubules permit the conduction of electrical impulses.
- In order for the MS to contract, it should be stimulated by nervous input. When action potential reaches the sarcolemma, it causes depolarization (changes of ion gradient across the plasma membrane). The presence of T-tubules helps the depolarization to pass deep inside the MS cell itself to reach every myofibril.

- L-tubules → part of the SR.
- T-tubules → invaginations of the plasma membrane of the muscle cell.

- a **triad** is the structure formed by a T tubule with a sarcoplasmic reticulum (terminal cisterna) on either side
- triad is located at A-I band junction

❖ In the skeletal MS cell, each sarcomere has 2 triads.



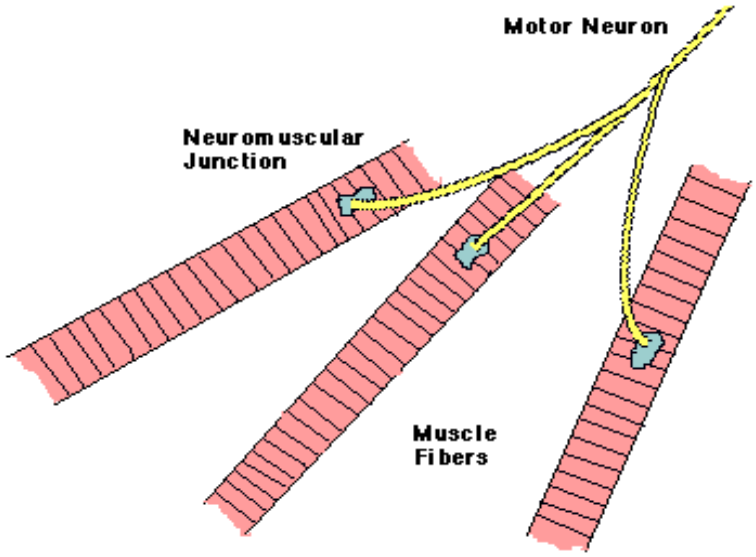
❖ What is the importance of triad?

- Depolarization of the sarcolemma (t tubules) will cause the release of Ca ions from the 2 sides of triad (terminal cisternae of SR), When Ca^{++} levels rise, Ca^{++} binds to troponin causing conformational change which moves tropomyosin and exposes binding sites, allowing crossbridges to occur (interaction between myosin heads and actin)
- NOTE: this process needs energy (remember that myosin head also has ATP binding site).
- In order for the myosin head to detach from actin, ATP binding is required

✓ **Rigor mortis** (rigor=stiffness, mortis =death) is one of the noticeable signs of death. There is no ATPs as the mitochondrial activity stops after death. The myosin heads stay attached to actin and the muscle cannot relax

✓ If there are no Ca ions, what will happen?
The Tropomyosin is going to occlude the myosin binding site on Actin and the MS is relaxed.

- One Nerve cell is called neuron, and the long part of the nerve cell is called axon.
- Motor neurons innervate muscle fibers
- Motor end plate is where they meet. This called also neuromuscular junction or synapse
- Neurotransmitters are released by nerve signal: this initiates calcium ion release and muscle contraction
- **Motor Unit**: a motor neuron and all the muscle fibers (cells) it innervates (these all contract together)
- Note that each motor neuron branches to innervate a variable # of muscle fibers
- Average is 150, but range is four to several hundred muscle fibers in a motor unit
- The finer the movement, the fewer muscle fibers /motor unit. For example, in quadriceps muscle, the size of motor unit is large (hundreds of muscle cells are innervated by single neuron), this produces gross contraction. While the muscles of the eye and the small muscles of the hand have small motor unit (single neuron innervates few number of muscle cells (1-10)), this results in fine movement



Big thank for DR.HEBA ..and yala nel3ab ♥ :

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