Histology

faculty of medicine - JU2017

◉ Sheet ○ Slides

Number

12

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Muscle tissue

Functions of the muscles:

1) Movement:

The movement that results from muscle contraction and relaxation is not restricted to locomotion (walking, jumping, or moving from point A to point B), movement is also important to keep us alive, for example, the heart muscle, which is basically a pump that squeezes and relaxes in order to pump the blood to all blood vessels of the body, the same concept applies to smooth muscles in the walls of stomach, blood vessels, etc.

2) Maintenance of posture:

While you are sitting for example, the muscles of your back and your neck are contracted even if you're not moving, to maintain a balanced sitting posture. You have what is called "slight contraction of the muscles" and this is called "muscle tone" (minimal contraction to keep the muscles tense)

3) Joint stabilization:

Because muscles are inserted into bones, they help in stabilizing joints. The muscle should at least cross one joint in order to produce movement.

4) Heat generation:

Muscles produce movement by contraction (contraction is shortening of the muscle, approximation between origin and insertion) and this will produce body movements.

This process needs energy (this energy is chemical energy in the form of ATP then it is converted to mechanical energy) and the byproduct of this process is Heat.

When we feel cold we shiver . why?

CNS subconsciously sends stimuli to the muscles to contract and when the muscle contracts, it produces heat. And this is the reason why infants have brown fat to supply them with heat (they haven’t developed heat production mechanisms yet (they don’t shiver)).

- **Muscle classification:**

Muscle tissue is classified according to a **morphological** classification or a **functional** classification.

➢ **Morphological** classification (based on histological appearance)

There are two types of muscle based on the morphological classification system

1. Striated
2. Non striated or smooth.

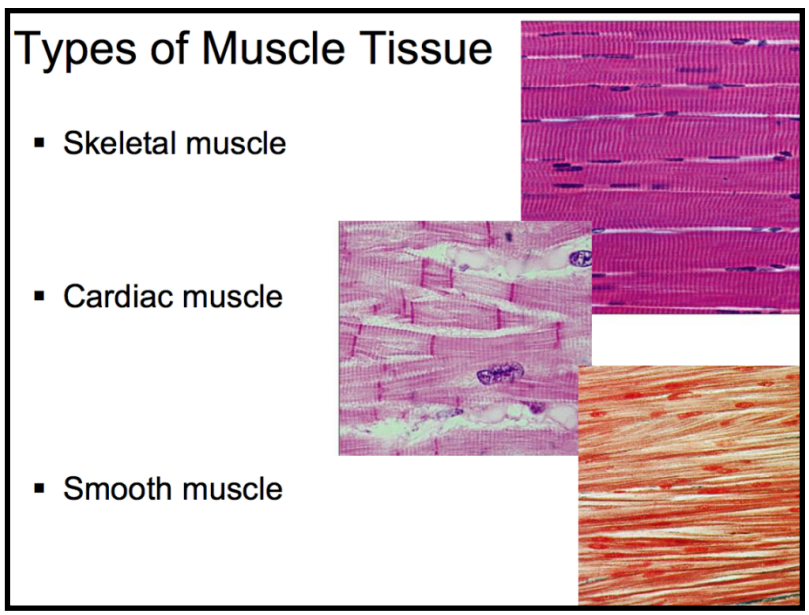
➢ **Functional** classification

There are two types of muscle based on a functional classification system

1. Voluntary : under conscious control
2. Involuntary : under unconscious control

- **Types of muscles:** there are generally considered to be three types of muscles in the human body:

1. **Skeletal** muscles: which are striated and voluntary (they move the skeleton this is why they are called skeletal).
2. **Cardiac** muscles: (only inside the heart) which are striated and involuntary.
3. **Smooth** muscles: which are non -striated and involuntary.



*** Where can we find smooth muscles?**

In the wall of internal organs (hollow organs, viscera, and tubes).

(Examples: walls of the blood vessels, esophagus, stomach, urinary bladder.)

*** Now, what is the importance of smooth muscles?**

Note: the wall of bronchi is composed of smooth muscles.

The smooth muscles in the bronchi can control the diameter of these tubes. So when you are exercising you need more oxygen, so these muscles (of the bronchi) are going to relax in order to increase the diameter in order to get more oxygen. At the same time the blood vessels that supply skeletal muscles (also have smooth muscles in their wall) will increase in diameter (vasodilation). They are going to relax, because you need more blood flow to supply your muscles.

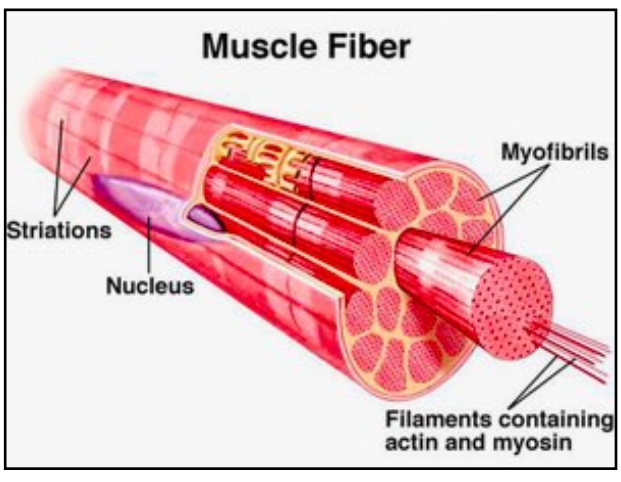
What about the blood vessels of the GI tract?
The smooth muscles in their walls are going to constrict because it is not important to supply the GI tract with blood during exercise.

>> (Contraction decreases the diameter while relaxation increases the diameter) <<

*** Muscle cell = muscle fiber**

- The muscle cell is called a muscle fiber (because they're elongated)
- Has high amount of contractile filaments (Actin and Myosin) we call them inside the muscle cells **myofilaments** to differentiate them from filaments present in other cells.

- Muscle cells like any other cells in our body are composed of: **plasma membrane, nucleus**, **cytoplasm** and **organelles**, but they are highly specialized and highly differentiated.
- The plasma membrane of the muscle fiber is called **sarcolemma**.
- Inside these muscles we find high amounts of smooth ER (called sarcoplasmic reticulum in muscle cells) (remember: SER functions in lipid



synthesis, steroid synthesis and it is **a storage site for calcium**)

❖ **Note** that the pre-suffix sarco and myo both refer to muscle. Therefore if you see a word with either of these, you should immediately think of MUSCLES.

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* Now let's talk about the skeletal muscle:

The origin of the skeletal muscle:

- From mesenchymal cells (mesoderm) >>> mesenchymal cells differentiate into myoblasts.
- These myoblasts fuse together to form elongated structure called myotube. (note that each myoblast contains one single nucleus)
- This myotube differentiates until we end up with a structure of a long fiber (this long fiber is the muscle cell) and each muscle cell has many nuclei, **why**?

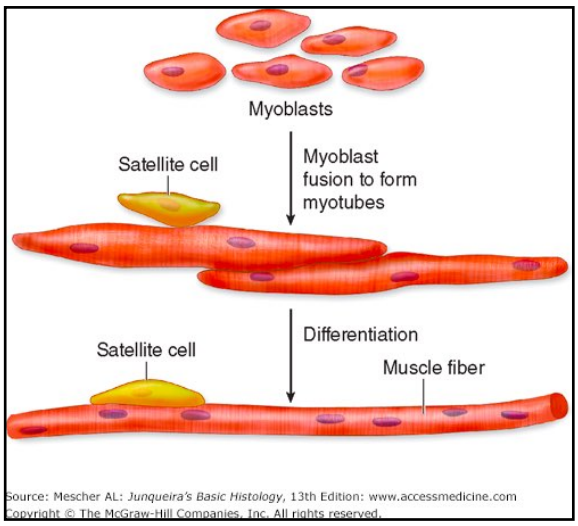
- **Because** the origin of it was the fusion of many myoblasts together.

❖ **Note** that the muscle cell is multinucleated! & the nuclei are exactly under the sarcolemma)

* Now look at the shape of the cell

➢ It is long, cylindrical in shape and that's why it is called muscle fiber. (Because it looks like a fiber)

➢ So again these cells are multinucleated, long, and cylindrical in shape and they show striations.



➢ Next to these cells we can find small, undifferentiated cells called **satellite cells**. These are mesenchymal cells, and in case of an injury to the muscle they differentiate into muscle cells (they are stem cells) (few cells present only)

➢ Because of the low numbers of the satellite cells, it's not enough to replace the damaged muscle tissue by these cells

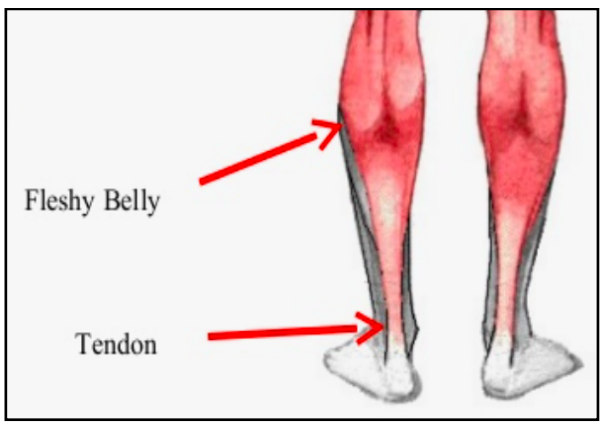
➢ **For example**: if muscle is injured, the satellite cells are going to differentiate into muscle cells, but due to the low number of satellite cells, they're not enough to repair the muscle.

⇒ **So, how do you expect that the muscle is repaired? let's see :**

- The muscle fiber is highly differentiated, thus it does **not** undergo mitosis.
- The highly differentiated the cells are the **less** possibility to go under mitosis.
- Injured muscle tissue is **repaired mainly by Collagen fibers** produced by **fibroblasts** from the connective tissue surrounding the muscle.

*** The skeletal muscle is composed of two parts:**

1. The fleshy part (belly part).
2. The tendon which connects the fleshy part to the bone.



>> **histologically**: the tendon is a dense regular type of connective tissue.

>> **The fleshy part:-**

- The fleshy part of the muscle is surrounded by a connective tissue membrane (dense irregular type) which is called epimysium>> epi =above, mysium=muscle.
- This Epimysium sends septa to divide the muscle into groups/bundles, each group is called a fasciculus or fascicle (plural: fasciculi).
- Now each fascicle is surrounded by a connective tissue which is called perimysium>>peri=around, mysium=muscle.

*the connective tissue here is of a dense type but it is less dense than that of the epimysium.

>> The fascicle:-

- Each fascicle is composed of muscle cells.

*the muscle cell (muscle fiber) is a tube like structure and it is multi nucleated

- Each muscle cell is surrounded by a loose type of connective tissue called endomysium.

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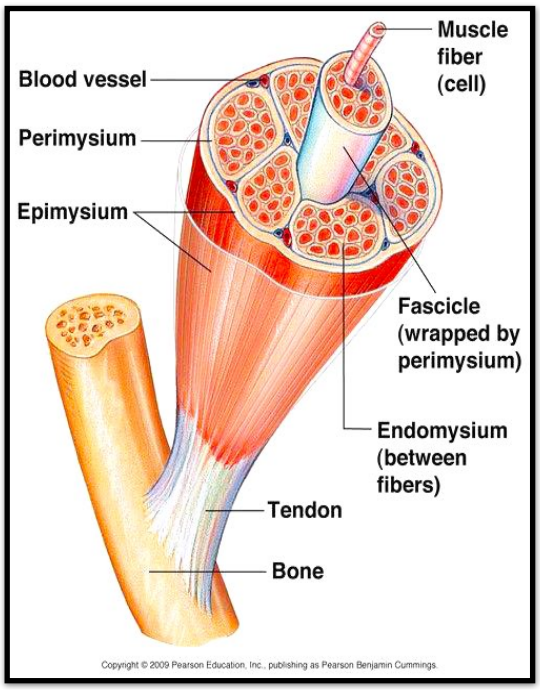
summary

There are 3 types of connective tissue coverings:

1. The **epimysium** is the outer most layer that covers the whole muscle
2. The **perimysium** which surrounds each fasciculus.
3. The **endomysium** surrounds each muscle cell (muscle fiber), its rich in reticular fibers.



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>> **Epimysium** is a dense irregular type of connective tissue

>> **Perimysium** has a dense type of connective tissue (thinner than the epimysium connective tissue).

>> **Endomysium** has a loose type of connective tissue

- As we go towards the internal part of the muscle the connective tissue becomes more loose (thinner), same thing in the glands.

- - The main function of the connective tissue is to support, connect, and to carry blood vessels (vascular)

- These three coverings (epimysium, perimysium and endomysium) will converge to form the tendon that connects the muscle to the bone.

* **The skeletal muscle cell (muscle fiber):-**

- The muscle cell is striated, it has alternating light and dark areas.
- The muscle cell-like any other cell- has cytoplasm (which is called sarcoplasm) and organelles.
- The sarcoplasm is filled with cylindrical shaped structure which is called a myofibril.

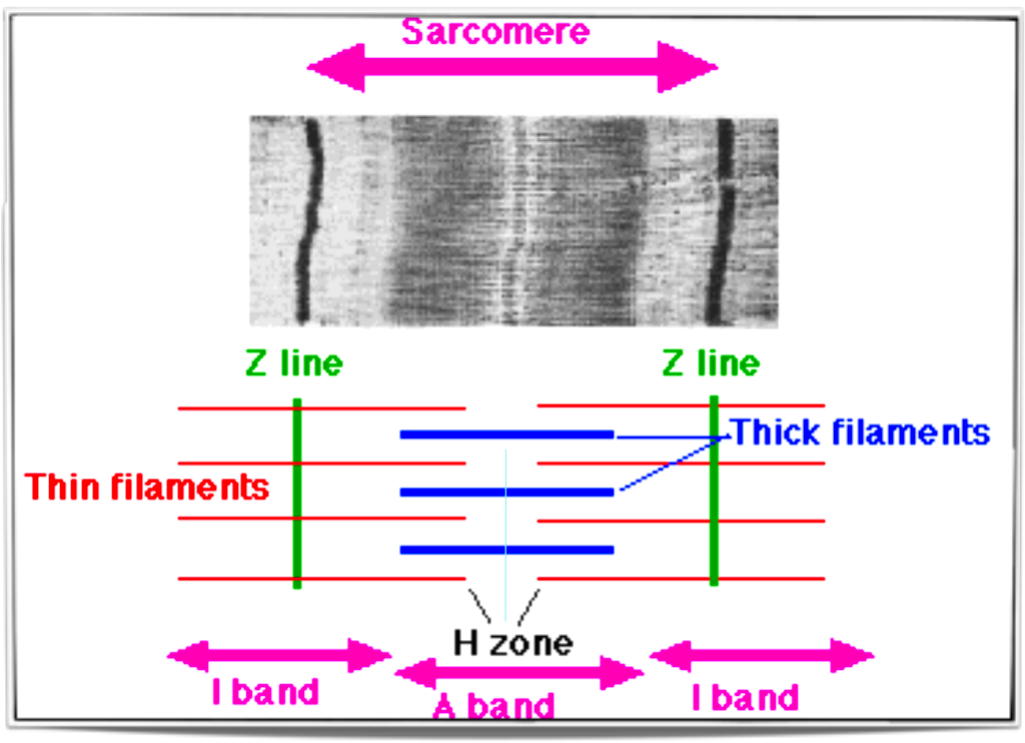
- A myofibril is an organelle within the sarcoplasm.
- So a single muscle cell is composed of myofibrils.
- We can also see the nuclei located at the periphery of the cell directly under the sarcolemma.

- **Now** if we magnify the myofibril, we will see that it is composed of thick and thin filaments (myofilaments) and they are highly organized along the myofibril to form the sarcomeres.

- The sarcomere is the smallest functional unit of the muscle (in the compact bone the smallest functional unit is the osteon).

- Myofibril is composed of repeating units of sarcomeres.

- The **sarcomere** is composed of the thick and thin filaments organized in a highly regular manner.



*** Under the electron microscope, the sarcomere is composed of :-**

1- The A band >> dark band >> composed of thick filaments and some overlapping areas that contain thin filaments (the letter **A** refers to **A**nisotropic). A band corresponds to the length of thick filaments.

- Anisotropic means that when the tissue is exposed to a polarizing light these filaments have the ability to alter the direction of the light and appear dark.

2- The I band >> light band >> composed of thin filaments only (the letter **I** refers to **i**sotropic).

- Isotropic means that when the tissue is under polarizing light the light passes through these filaments and they are less birefringent so they don't alter the polarizing light and that's why they appear light in color.

3. **Two Z lines** (it is called z line because **z**wischen means in between in German).

4- **the M line**. >> we have it in the middle(**m**itte in german means middle)

5- **The H zone** is an area in the middle of the A band and it looks light because it is only composed of thick filaments (myosin) >> **H** stands for **H**ell which means **bright** in German.

*** Another facts in regards to sarcomere :-**

- The thin filaments (actin) are attached to the Z line and the thick filaments (myosin) are attached to the M line.

- The muscle as a whole looks striated because again it is composed of myofibrils and the myofibrils are composed of myofilaments.

- The Z line is bisecting the middle of the I band and so a sarcomere is composed of an A band and 2 halves of I bands.

- The Z line is composed of proteins that attach to the actin filaments>>

ex:-Alpha Actinin.

- The M line is also composed of proteins that anchor the myosin filaments to the midline.

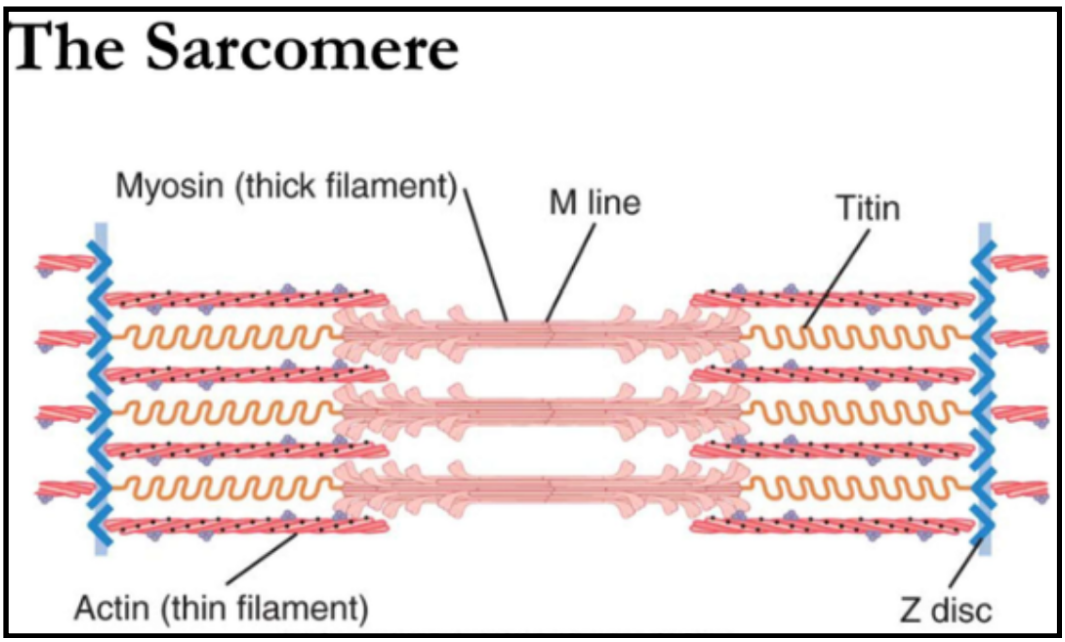
- The thick filaments are also attached to the Z line by a protein called Titin>>this protein looks yellow and coiled because it's elastic.

*** Function of the Titin protein is:-**

1- It keeps the sarcomere aligned.

2- Prevents over stretching of the muscle because it's elastic.

3- Anchors the myosin filaments to the Z line.



*** Ultra structure of thick and thin filaments:-**

A thick filament is not only a single myosin molecule, the single thick filament is composed of around 300 molecules of myosin that aggregate and form the thick filament.

Myosin: it has two heads and one tail. The myosin molecule is composed of six subunits, two heavy chains are helical and twisted around each other to form the tail (we have only one tail) and four light chains forming two heads, each head has two light chains.

>> The heads have binding sites (two binding sites) >> one binds to actin and the other binds to ATP because the process of contraction needs energy.

- Now about the structure of **the thin filament**? it's mainly composed of actin protein.

>> The **actin** protein is composed of monomers globular in shape called G actin, when they aggregate and polymerize they form a long and helical strand called filamentous actin (F actin). Two strands are twisted to form actin filament

***A single thin filament is composed of:**

1) Two twisted strands of filamentous (F) actin .

2) Two other proteins: a helical protein called tropomyosin, and a 3 subunit protein called troponin.

- On the G actin there are binding sites for the myosin head (myosin has two heads one of them binds to actin and the other binds to ATP).

- When the muscle is relaxed, myosin cant bind to the actin binding site because tropomyosin masks these binding sites.

- **Troponin** is composed of **three subunits**: one interacts with calcium (subunit C), one for regulation (subunit I) and the largest one interacts with tropomyosin (subunit T).

- Contraction of the muscle: is the approximation between the origin and the insertion (shortening of the muscle).

- **Myofilaments** (actin and myosin) **DO NOT SHORTEN** they only overlap and that causes the shortening of the muscle.

*** SO what happens during contraction?**

>> Actin filaments slide over the myosin filaments and they move toward the midline, this leads to shortening of the sarcomere and thus the whole muscle cell will shorten and eventually the whole muscle shortens.

>> myofibril is composed of repeated units of sarcomeres so when every sarcomere shortens the overall muscle cell will shorten.

***What happens to the bands Upon contraction?**

1- The A band will not be shortened because it only corresponds to the length of the thick filaments (myosin) and these filament will not be shortened.

2- The I bands are mainly composed of actin filaments, actin filaments will slide over the myosin upon contraction and that will lead to the shortening of the I band.

3- The H zone: it's the area where myosin doesn't overlap with actin , when contraction happens this area will also be shortened.

- **So** again the single muscle cell is surrounded by the sarcolemma, its cytoplasm (sarcoplasm) is filled with myofibrils, each myofibril is composed of thick and thin filaments. Inside the cytoplasm, we can also find the sarcoplasmic reticulum (smooth endoplasmic reticulum) and each myofibril is surrounded by this smooth endoplasmic reticulum which acts as a calcium reservoir (is important for the muscle contraction).

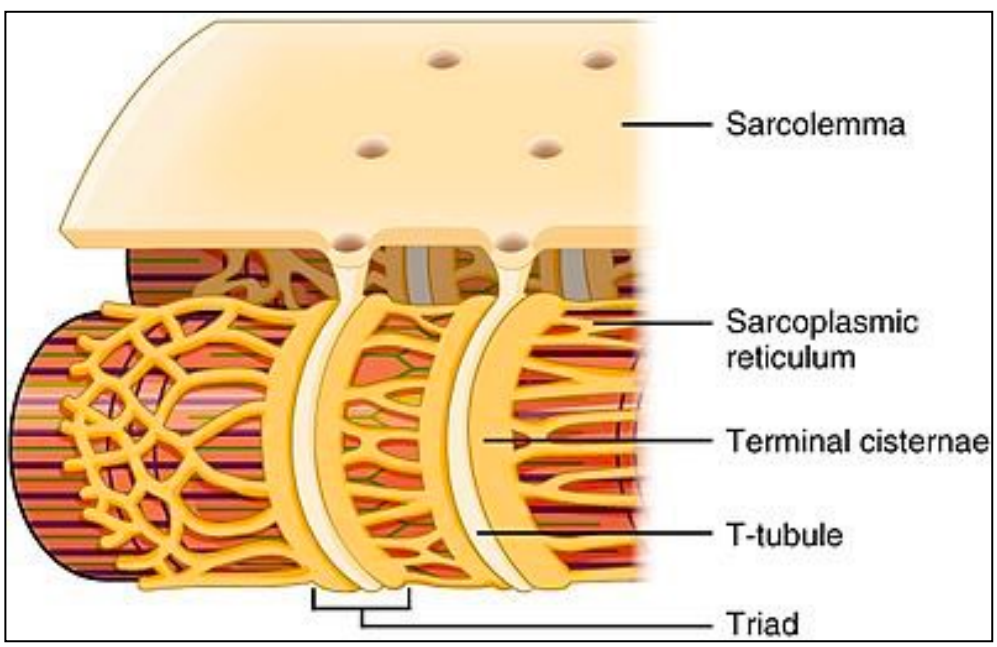
- This sarcoplasmic reticulum forms a network, it's tubules (called L tubules) run longitudinally with the long axis of the myofibril and they terminate with dilated sacs called the terminal cisternae (the tubules and sacs of the endoplasmic reticulum are called cisternae).

- The sarcolemma (plasma membrane) sends invaginations inwards that surround each myofibril and they are called T tubules, these tubules run transversely to the long axis of the myofibril and that's why they are called Transverse tubule (T tubules).

***what is the function of T tubules?**

In order for the muscle to contract it needs nerve supply (without the nerve supply muscles will be paralyzed) and that nerve supply carries electrical signals (action potential), so when these electrical signals reach the sarcolemma depolarization happens (change of charges across the sarcolemma) and if the T tubules were absent only myofibrils on the periphery will be stimulated while in the presence of these T tubules all the myofibrils within the muscle cell will receive that stimulation and will contract.

>> **Triad**:-is a structure composed of a T tubule in the middle and terminal cisternae of SR on each side, its located at the junction between the A and the I bands.



- Each sarcomere has two triads because we have two junctions (A and I junction).

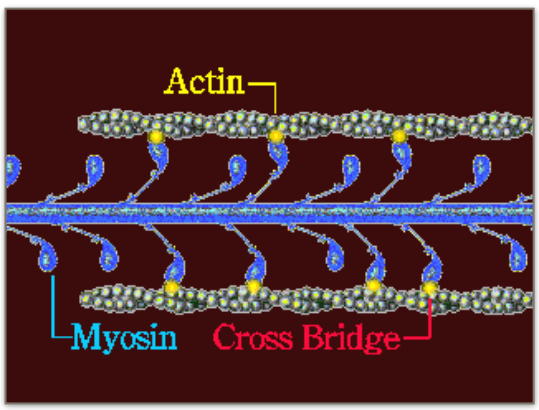
- When action potential reaches the muscle through T tubules, calcium will be released and that will lead to muscle contraction.

- When stimulation occurs nerve endings will release certain neurotransmitters and they will attach to certain receptors on the sarcolemma and that will lead to depolarization and that depolarization will propagate and reach each myofibril and once it reaches the triad area it will release calcium ions from the sarcoplasmic reticulum.

- Calcium (from the sarcoplasmic reticulum) will bind to troponin causing conformational changes that stimulate tropomyosin to leave the complex exposing the actin binding sites and now the myosin head will interact with the binding site of actin.

- We call the binding between actin and myosin >>> cross bridge.

- In order for the myosin head to be released from actin it needs ATP >>> the cross bridge will be removed.



- **After death** we have something called rigor mortis (rigor=stiffness, mortis=death) and that's because after death there is no ATP >>> myosin will not be able to detach from actin. Thus, the muscle is unable to relax.

- The **junction** between the **neuron** and the **muscle** cell is called the neuromuscular junction or the neuromuscular synapse