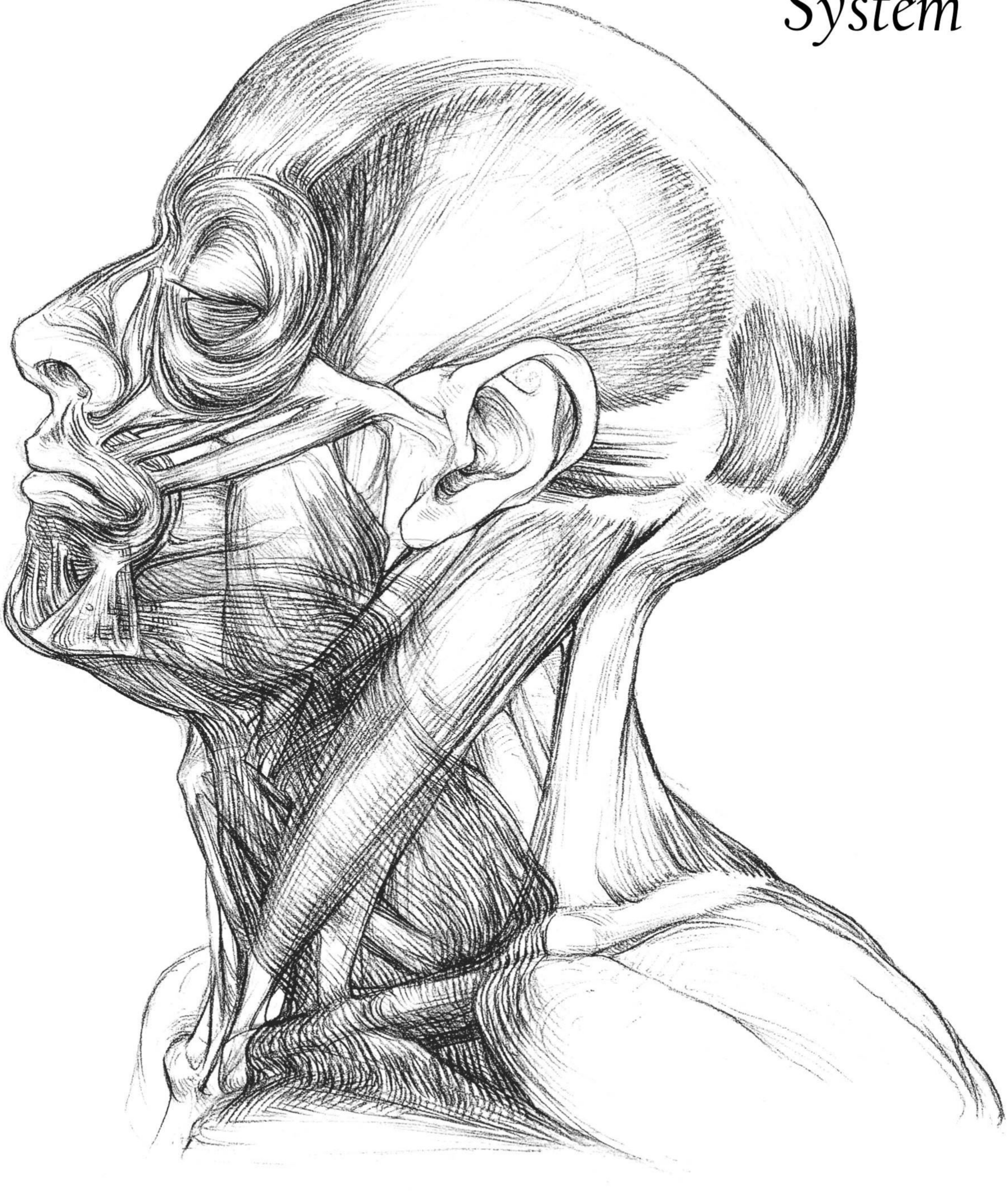
Medical Committee
The University of Jordan

The Skin and
MUSCULOSKELETAL
System



PHYSIOLOGY

SLIDES ☐
SHEET ■
LECTURE # 3

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Revision:

- We have two types of muscles:

1- Striated muscles : represented by skeletal and cardiac muscles .

Q. why do we call them striated?

A. Because at the level of myofibrils; contractile proteins (thick and thin filaments) are organized in a way that gives you that striation.

Note: The striation can be seen at the level of one muscle fiber, not the whole muscle.

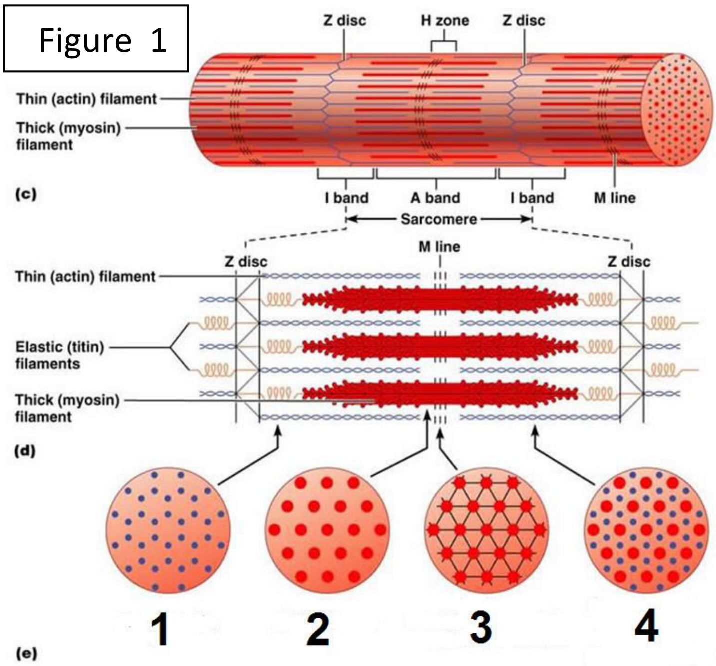
2- Non-striated muscles: represented by smooth muscles (widely distributed in our body).

**Figure 1 represents a sarcomere and cross sections (1 ,2 ,3 and 4) at different sites of the sarcomere:

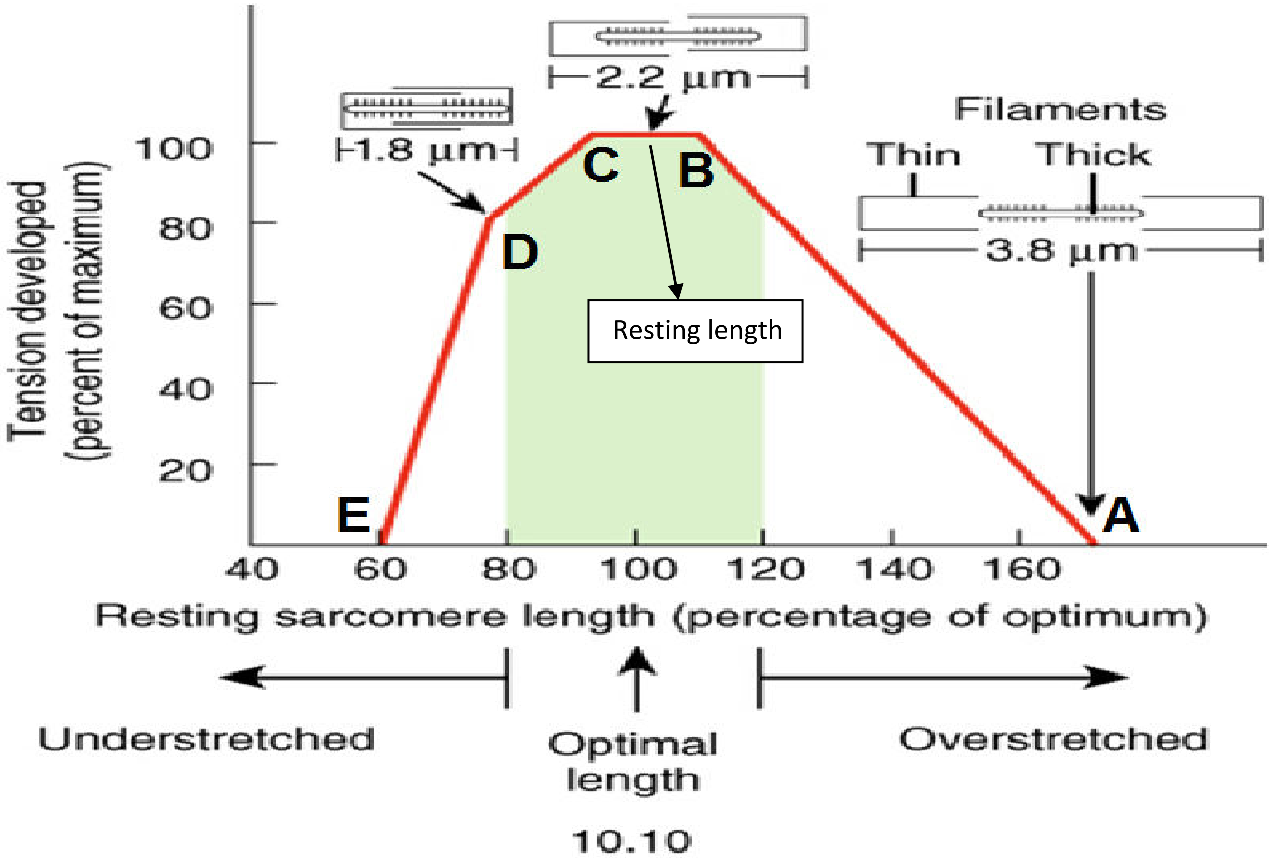
1- This is a cross section at **I** band where we have thin filaments only.
2- A cross section at **H** zone , here are thick filaments only with no overlap.
3- A cross section at **M** line (or **M** disk), thick filaments only.
4- A cross section at the outer edge of **A** band , thick filaments are overlapped by thin filaments , as you see each thick filament is surrounded by six thin filaments, while each thin filament is surrounded by three thick ones , so the ratio between thin and thick filaments is (2 : 1).

This way of organization gives the muscles the striation at the level of the muscle fiber.

Figure 1



Last lecture we discussed the structures of thick and thin filaments and how they interact with each other, we also talked about the energy supply to the muscle.



** Figure 2 represents the relationship between overlap (or length) of a sarcomere and the tension developed of that sarcomere . Note that :

Going from point A to E :

- At point A in the figure, the whole preparation is stretched up to 3.8 μm in length, at this length we have no overlap between the thin and thick filaments at all, so the tension equals zero at that point.
  Note: the length of the sarcomere here is equal to the length of the thick filament plus the length of the two thin filaments on both sides.
- If we decrease the stretch to have a lower length (hence more overlap), the tension will increase.
- The maximum tension can be achieved at resting length of the sarcomere when it is 100% of the optimal length which is 2.2 μm, here each thin filament is overlapping most of the one half of the thick filament.
- From C to D , with even more shortening of the sarcomere and even more overlap , the thin filament starts overlapping the second half of the thick

filament, thus the tension becomes lower and lower because there will be opposite forces.

Length-Tension Relationship:

** Figure 3 represents the length-tension curve of the whole muscle, even if it is composed of one muscle fiber only.

- By stretching that muscle, as it is an elastic tissue we create tension at the level of the muscle without any stimulation (without any activity of the muscle), this is called **passive tension**. At resting muscle length, the passive tension is zero (simply it's not stretched). As we stretch the muscle, we increase the passive tension more and more.
- Now, if we stimulate that muscle (thus contracting it) at a length that is not stretched at all (resting length or less), we will record only a tension called active tension which is due to the process of contraction.
- If we stimulate the muscle when it is at some stretch (meaning that the length is more than resting muscle length) then we will record what we call **total tension** which is the summation of passive tension (due to stretching the muscle) and active tension (due to the process of contraction).
  Q. Can the active tension be calculated here?
  A. Yes, since it is the difference between the total tension and the passive tension. (active tension = total tension – passive tension)
- Note that even at the level of the whole muscle, the active tension decreases by increasing the tension (i.e. the passive tension) on that muscle. And the highest value of active tension is recorded again at resting length of the muscle (remember that here we have the maximum overlap between one thin filament and one half of thick filament, so we get the maximum tension).

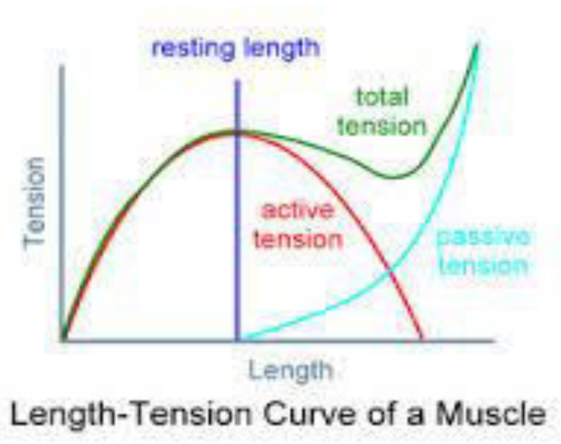


Figure 3

Load-Velocity of Shortening Realtionship:

** Figure 4 represents the relationship between the load over a muscle (by grams) and the velocity of contraction of that muscle.

- Here we get shortening of the muscle (in the previous example we stretch and fix the muscle so there was no shortening).
- The highest velocity of shortening is achieved when there is no load on the muscle.
- By loading that muscle with any load, the velocity of shortening decreases.
- If the load is very high, then there is no more shortening (hence the velocity is zero).
- This curve is recorded at the level of one muscle fiber.

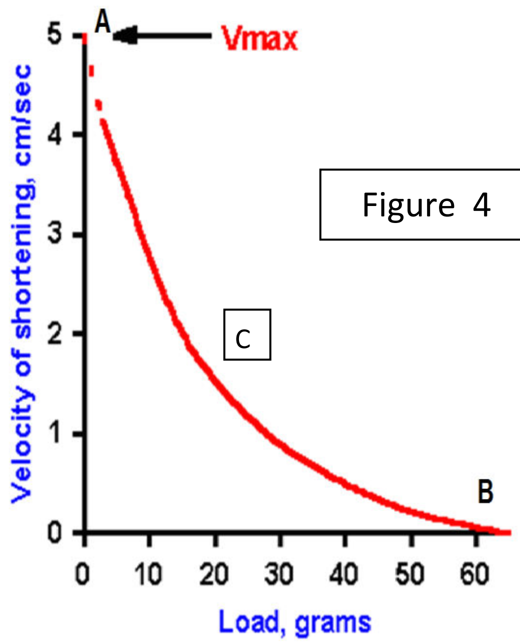


Figure 4

The Simple Musle Twitct:

** Figure 5 represents the simple muscle twitch experiment in which the muscle is stimulated and then the contraction is recorded. We get a contraction period, relaxation period (from the tip to the end of the curve) and latent period (which is the period between the stimulation and the start of contraction.)

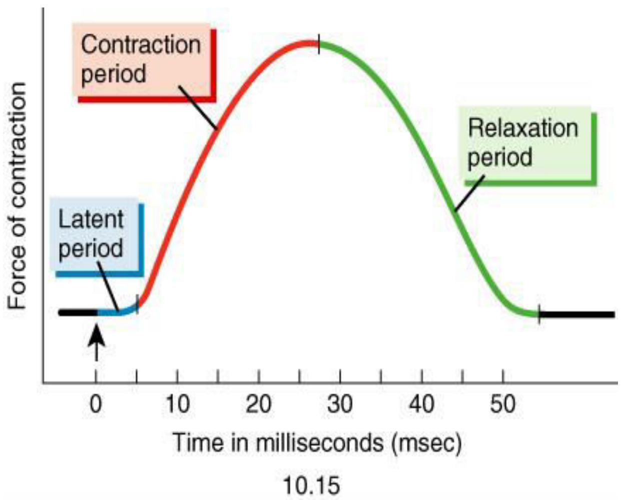


Figure 5

A student asked about the isotonic and isometric types of contraction. And here is the doctor's answer: (refer to figure 4)

-isotonic means that the tension is constant (be careful, constant does not necessarily mean zero) but there is shortening (change in length).

- isometric means that the heads are fixed, hence there is no shortening.
- at point A, you have both heads of the muscle free to contract and shorten without any load, so you will record no change in tension, but there is shortening (here you will record the highest change in length), thus the velocity is maximum. This is an isotonic contraction.
- By loading that muscle, the velocity will decrease because you need more tension now to overcome the load and then to shorten the muscle.
- At point B, the load is very high, here there is contraction, and you are changing the tension, but the length is not changed. This is an isometric contraction.

So contraction does not always mean change in length.
Here you get the lowest velocity (zero), but because there is interaction between thin and thick filaments, the tension changes and you get the highest possible tension.
- in between the two points , to say at point C , we have combination of both conditions, so we have tension which is higher than that of A but lower than that of B. Also, we have velocity which is lower than that of point A and higher than that of point B.

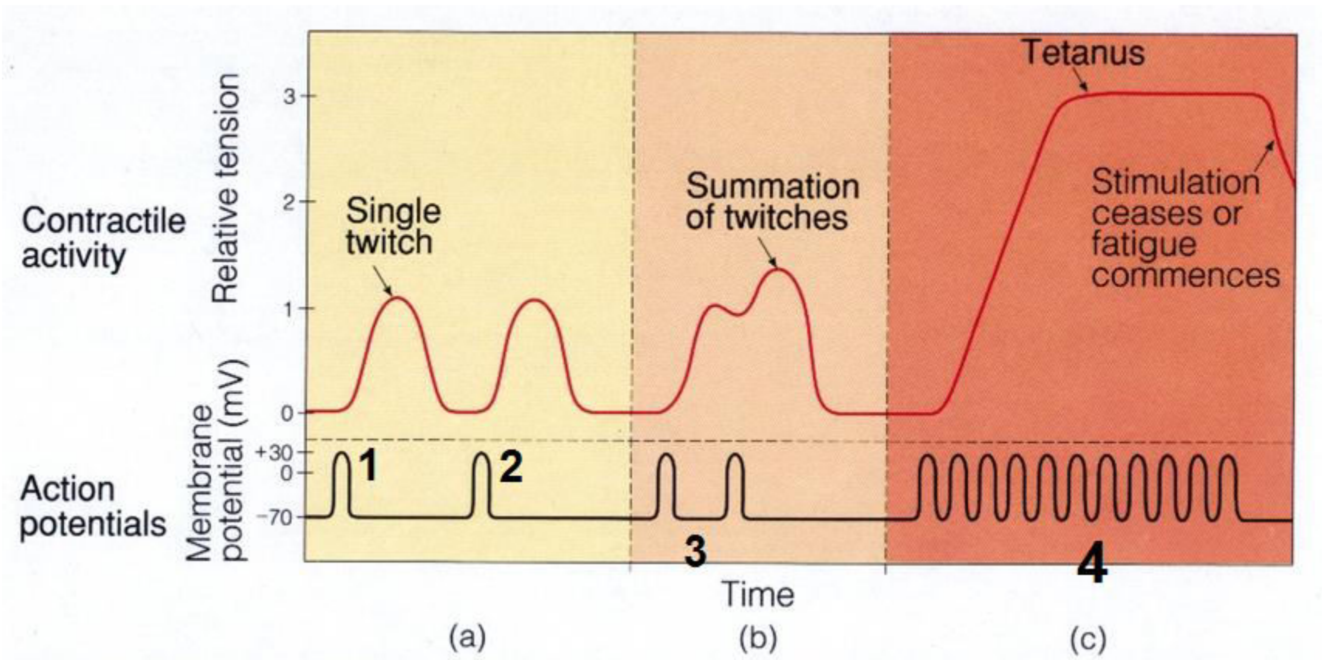
Another student asked: why is the active tension at its highest value at resting length of the muscle?
(refer to figure 2)

Starting from point C for example, here we have the maximum overlap between the thin filament and one half of the thick filament, this means that the probability of interaction is maximum, as a result the tension is maximum.
By decreasing the length even more, the filament starts overlapping the other half of the thick filament. So you will have two forces that work against each other. Thus these two forces eliminate each other, reducing the tension.

Summation of Contraction:

** Figure 6 represents the summation of contraction.
Refer to the numbers on the figure:

1- This is the stimulus; it has very short period and is present in the latent period and does not cover the contraction or relaxation period.
2- This is another stimulus, but there is enough time between both stimuli so you get another simple muscle twitch.
3- If you have two stimuli (one acting after another before relaxation is complete), you will have **wave summation** (sometimes called frequency summation).
4- If you have many stimuli one coming after another, then you will get tetanization.
   So tetanization is getting contraction without any relaxation because of **repetitive** stimuli.
   Tetanization is considered to be part of wave (or frequency) summation.



The duration of the action potentials is not drawn to scale but is exaggerated.

Figure 6

Motor Unit Summation:

** Figure 7 represents another type of summation, the Motor unit summation:

- Each motor neuron has one axon (one nerve fiber), but multiple terminals. Each terminal ends at one muscle fiber (one muscle cell).
- If you stimulate one motor neuron, you won't get contraction of the whole muscle, rather you will get contraction of the muscle fibers that are innervated by that motor neuron only (the fibers to which the terminals of that motor neuron are attached) . Remember that each muscle is composed of multiple muscle fibers.
- All muscle fibers which are innervated by one motor neuron are called motor unit.
- If you stimulate one motor unit, you will get contraction of certain number of muscle fibers (the muscle fibers that participate in that motor unit). By stimulating more motor units, more muscle fibers will contract.
- The highest amplitude of contraction can be achieved when all the motor units of the muscle are stimulated.
- If the muscle is going to do a simple action (lifting a light object for example), only a few motor units are stimulated. But if you want to lift a heavier object, you need to stimulate more motor units. So not all motor units are involved in contraction during each muscle activity.
- This is called **Motor unit summation;** which refers to the involvement of more motor units to get higher contraction.

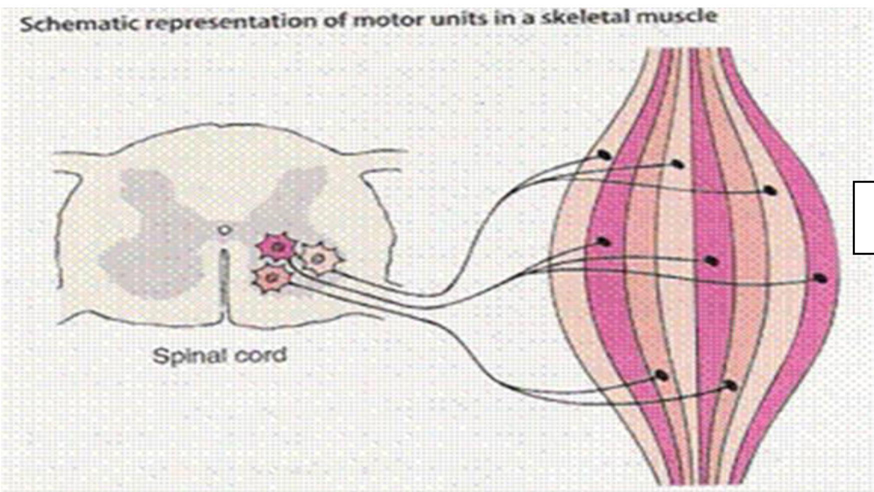


Figure 7

Be careful … The **None or All principle**

The None or All principle: if you reach the threshold, you will get all action potential. If you don't reach the threshold, you will get small depolarization only, but NOT action potential.

So this principle refers to the electrical activity, not the muscle contraction.

Q. Can this principle be applied to muscles?
A. If we are working on one muscle fiber or even one motor unit, then yes it can. But if we are talking about the whole muscle, then it can't be applied. So you can stimulate the muscle by a small current getting some of the motor units contracted not the whole muscle. As we increase that current, we get more and more motor units involved in contraction until we reach a point where ALL the muscle fibers are involved, here we have the highest contraction.
What we get here when we increase the current, is the motor unit summation (so the none or all principle is not applied here).

Motor units differ from each other by the number of muscle fibers that participate in each unit; the main factor that determines the number is the function of that muscle.

Some muscles function in fine movements (like writing or lip muscles when talking), these muscles need more control over them. So the number of muscle fibers that participate in each motor unit is small, like 5-10 muscle fibers/unit.

On the other hand, the muscles of the back function in maintaining equilibrium of the body. It's not a fine movement, you need higher number of muscle cells per each motor unit.

A student asked: Does the ratio between white and red muscle cells affect the number of muscle fibers/motor unit?
The doctor said he has no idea but he thinks that fast muscles (white muscles), like muscles of the lip or the eyelid, form motor units with lower number of muscle fibers per unit, because they are usually needed for fine movements.

While the red muscles (mainly muscles of the back) form motor units with a much higher number of muscle fibers.

So you have some relation but you can't take it as a rule. The main factor here is the function of that muscle.

The NeuroMuscular Junction (NMJ):

- NMJ is the junction between one nerve **terminal** and one muscle cell.
- The terminal has the neurotransmitter acetylcholine contained in vesicles.
- There is small space between the terminal and the muscle cell. The part of the muscle cell membrane which is beneath that terminal is highly specialized.
  Q. What makes it a highly specialized membrane?
  A. The fact that it has a lot of folds, and over these folds there are receptors for acetylcholine that are linked to Sodium channels. So they are chemical gated Sodium channels.
- In addition; we have an enzyme in the membrane called acetylcholine esterase. It functions in destroying the acetylcholine. This enzyme is activated immediately after releasing the acetylcholine.
  Q. Why do you need to destroy the acetylcholine?
  A. Because we don't need the muscle to always be contracted. When the neurotransmitter is released, we want the muscle to contract, then the enzyme destroys the neurotransmitter to reduce its concentration in the space between the terminal and the membrane of the muscle so that the muscle relaxes again.
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Sorry for any mistake.

No dedication عشان ما حد يزعل

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