Mechanics of Human Movement
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Lecture – 05
Skeletal Muscles: Structure Part – II

So, we call this.

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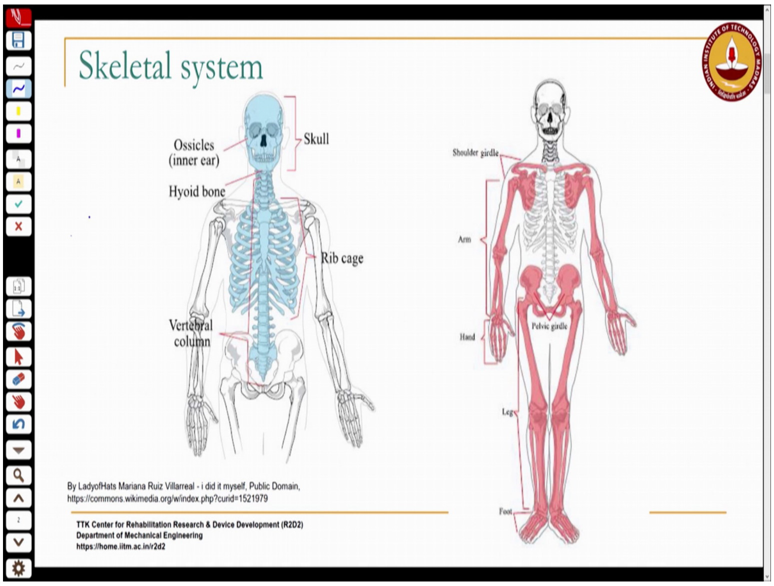

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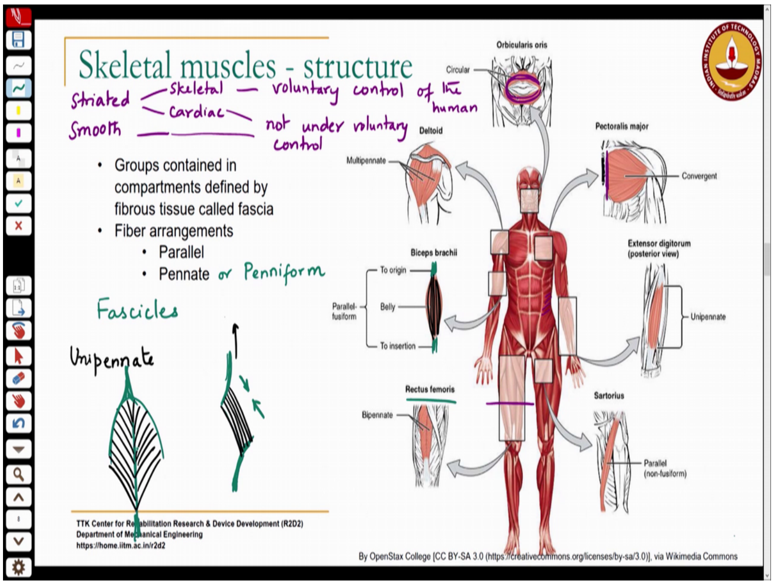

We were looking at the fiber arrangements in the muscles, and the two broad classification are the parallel and the penniform or pennate arrangement, also known as penniform arrangements. And these you know when we say fibers at this sort of macroscopic level when we are talking about the muscle; they are actually called fascicles ok. We will see why when we look at the structure of the muscle fiber, because we will go into the fascicles then into that etcetera

So, but we when you are talking about the arrangements and we say muscle fibers we know what, what it means ok, we are talking about. So, if you look at the tendon. So, the muscle fiber is what is between one tendon and the other ok, and it is that configuration that we talked about in this parallel arrangement or the pennate arrangement. So, if you look at the parallel arrangement as we saw here. This would be your tendon ok, you have the tendon and then you have.

So, you see here, actually you see the white tendon here right. So, those are the tendons and then between those you have the muscle fibers running parallel ok. So, this is the parallel arrangement. You have tendon at either end and between them the muscle fibers are parallel

Now, the penniform or the feather like arrangement is you know we. I said there are three you could have a unipennate arrangement, where essentially you may have a tendon like this, a tendon like this.

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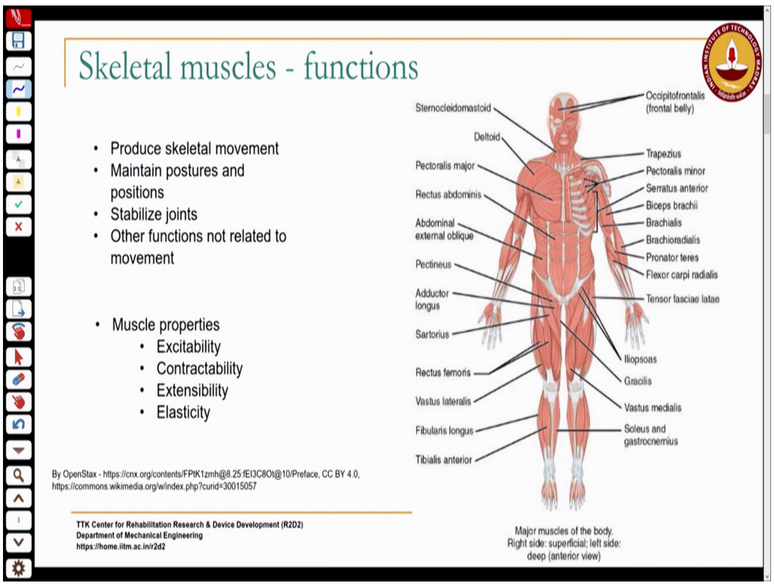

I should turn off the touch on this and then the muscle fibers, the muscle fibers actually run at an angle between the two tendons to the direction of pull. So, the tendon will be pulling on, you know whatever it is the bone that is pulling on, it will be attached to the bone here and here ok

So, the tendon is pulling like that, but the muscle fibers are at an angle to the tend. So, the unipennate would be something like this. So, that is. So, it may not be very evident in this figure, you see here, the both the fusiform and the unipennate look more or less the same, but this is what is happening with the unipennate.

So, when the muscle fibers can tract these two, they are contracting in these direction ok, but the force that is being applied to the bone is at an angle to that ok. So, its not the full. So, these muscle fibers are generally shorter, but you can pack a lot more muscle fibers in that muscle ok. And so they are the amount of force that they can generate is much higher

So, in the case of the parallel um arrangement you get a lot of contraction, you get a lot of displacement with the penniform arrangement, you do not get as much displacement, but you can get larger forces, although its only a portion of the force that is being applied along the tendon, it is still larger forces are possible, because you are trying to sort of, the body is trying to maximize you know depending on the configuration maximize the area for that particular muscle yes.

Student: Like tendons are part of bone or they are separate.

They are separate, they are connective e tissue, so their composition they are not part of bone. They are what connect the muscle to the bone. So, their composition is different from the muscle composition; bone composition is different, tendons are different, ligaments are close to tendons, but they are still different. So, if you look at their chemical composition everything will be, even the structures will be slightly different.

Student: Mam tendons do they flexibility.

Yes they do have flexibility, because they move around joints ok, they can bend, they are like flexible members ok, they and their also elastic to some extent. Not as much as muscle, but they can undergo slight strains. We will talk about tendons a little bit more ah as we move along, but yes they are elastic, they are non-linear. So, they actually function more like non-linear springs in the body ok. Your muscles are your actuators similar to you are not exactly motors, but more like hydraulic actuators ok, but they can only contract and apply tension. So, this is the unipennate.

The bipennate similarly you can probably look up some examples like the rectus femoris, but they may have. So, these tendons may have like a central, the tendon may have like a central thing from which you have and then you have the other tendons perhaps and the muscle fibers between them could be like this.

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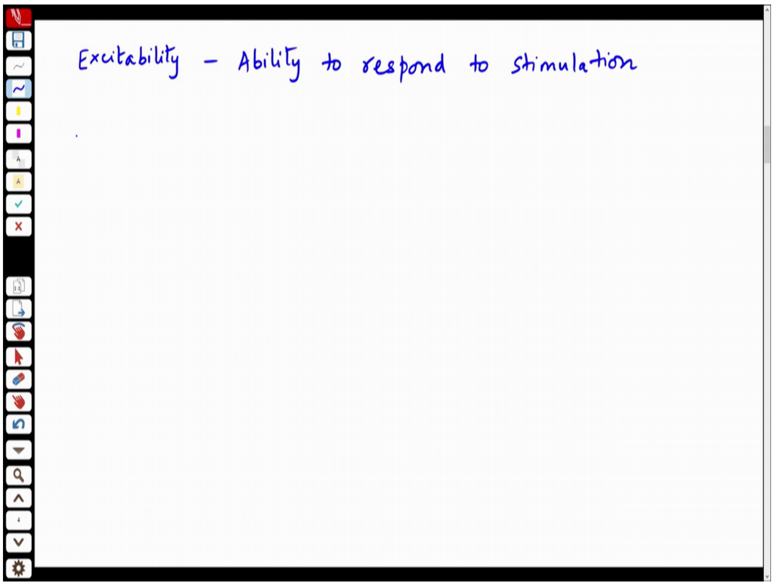

Something like that, that be like a feather and you have the tendon on either side. The tendon maybe something like this, then like ok. So, that is your bipennate, multi pennate muscles, more than, more branches than this, you know this tendon instead of just one central it has multiple ones then you have like a multipennate muscle, fiber arrangement

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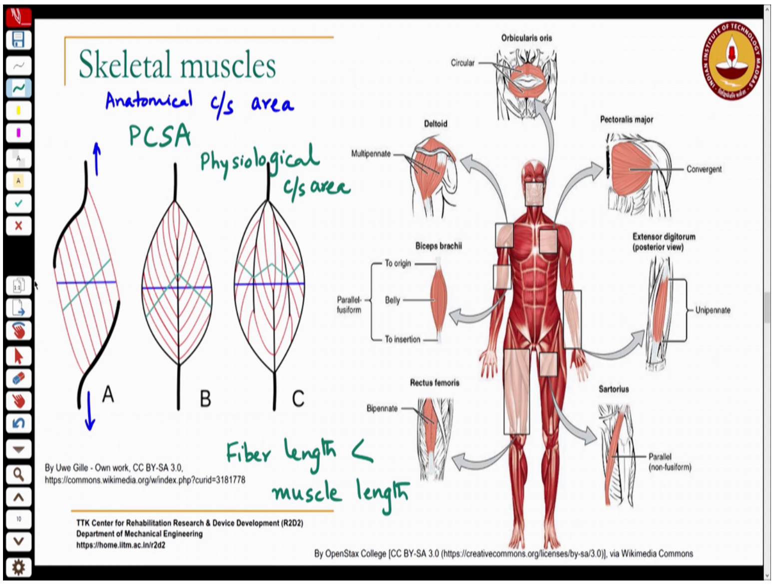

So, you can see here. Yeah this is a, you can see the black parts are the tendon, it shows here, I presume that is what the person who is drawn this, is trying to say here also, but essentially you look at a muscle fiber, it has to connect from one tendon to another ok, that is the way you identify the arrangement. You see how it is connected to the other tendon. So, this is your.

And here if you look at it, you can see that if this is the direction of pull ok, then this blue thing is your anatomical cross sectional area ok, but it is not really. Let me just. So, if you take a slice of the muscle, perpendicular to the direction of pull, then that is your anatomical cross sectional area. I should actually draw this the other way, because um. No, the muscle is subjective; the muscle exerts tension, so this is going to be for this way right, the force on the muscles

Now, the green if you take a cross section perpendicular to the fibers; that is really the measure of the force production of the muscle, muscle ok. So, the green thing is what is your P C S A. This is your physiological cross sectional area ok. So, in a multi pennate muscle, the sum of all these areas gives you a measure of the total force that muscle can produce, whether that is, that is all that force may will not be along the line of action of your tendon, but, but you can also seen the penniform muscles, the fiber lengths are shorter than the tendon or or what is known as the whole muscle length ok.

So, they are shorter than the muscle length. So, in the penniform you have fiber length less than the muscle length. Now, this is defined as the physiological cross section area give you the (Refer Time: 10:50).

Student: Mam.

Yes.

Student: Fiber is something that makes of the muscles straight.

Yeah.

Student: So, fiber is constituting muscles then it should be equivalent to muscle length so

So, we will, we will look at how the muscle is, what the muscle structure is ok. So, when we same muscle length it is from the end to where the tendon, you know from end of one tendon to this; that is your muscle length. So, this to this is my muscle length ok that, the distance between that is my muscle length, but you can see that the fiber length is less than they muscle length, in the penni. In the parallel muscle, in the parallel arrangement they more or less equal ok.

They are, the muscle length is equal to the fiber length in most cases. here the fiber length is generally less than the muscle length. So, with the penniform arrangement you make another copy also.

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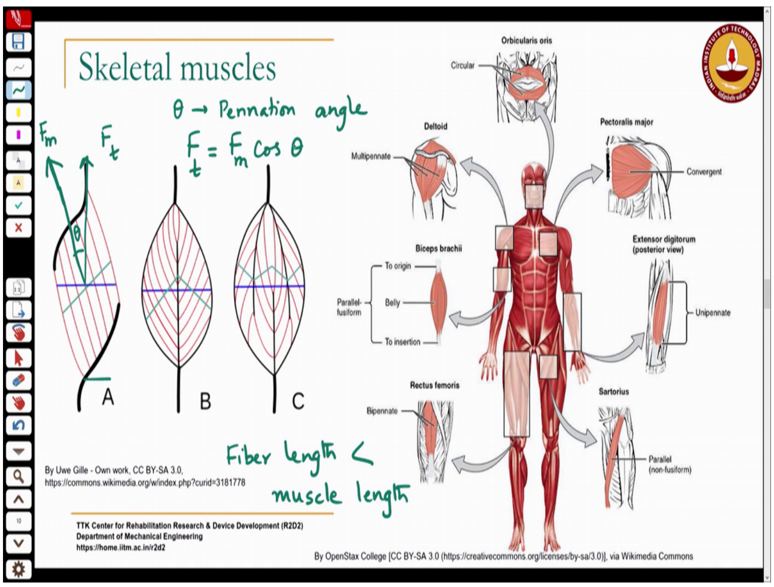

In the penniform arrangement you can see that the force, the muscle force, let us call it F m is this and the force that is transmitted to the tendon is F t, because this is at an angle theta, the theta is called the pennation angle and the force that is transmitted to the tendon equals that times cos theta ok.

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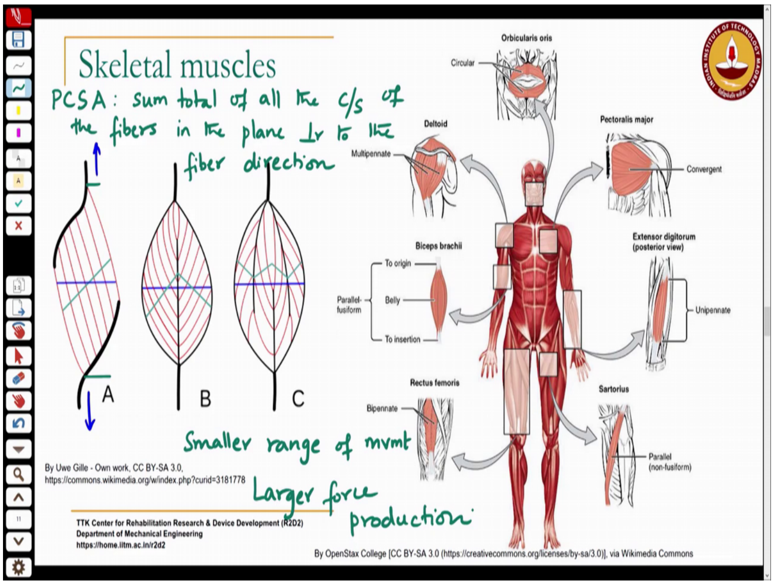

So, the definition of P C S A is the sum total of all the cross sections of the fibers in the plane. Sorry perpendicular to the fiber direction. So, because the fiber length is smaller than the muscle length the, you have smaller range of movement, but larger force production in the pennate type of arrangement ok

So, now we will look at. So, this is, like I said, we first started off with muscles are in compartments, then an individual muscle. I say I can see fibers you know in the muscle, I can look at that arrangement. Now let us go in a bit into the structure of the muscle.

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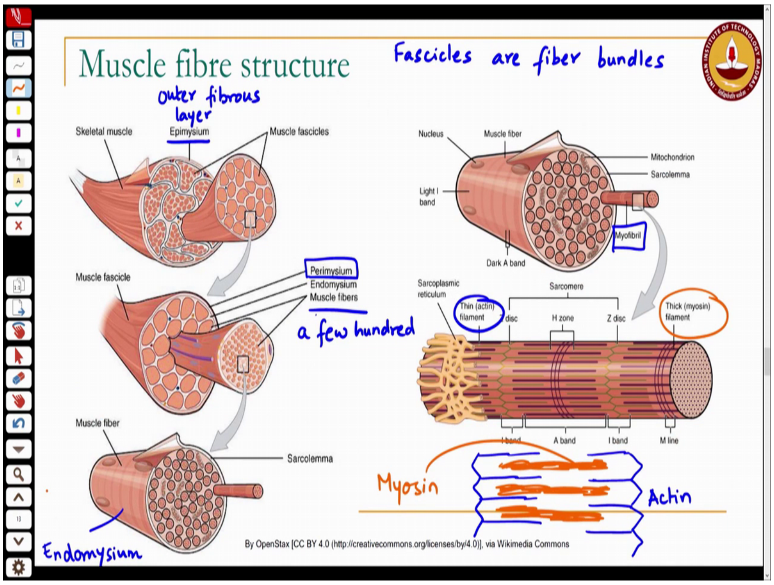

So, if you look at the muscle its covered by. So, it has these fascicles right, each muscle may have. So, these fascicles are like fiber bundles fascicles are. So, each muscle will have hundreds to thousands of these fiber bundles, lots of bundles in one muscle and then the fascicle itself will have hundreds of fibers will have several fibers inside. So, it is like tubes within tubes, within tubes, bundles within bundles within bundles ok.

So, you have, let me tell you. So, the outer fibrous layer this is called the epimysium and this is what transfers the tention to the tendon ok. So, this epimysium contains all the bundles fascicles ok, then you are look at. So, you have several of thousands of these fascicles inside the epimysium then each fascicle may have muscle fibers ok

So, if you take a fascicle that also has a few maybe up to 200 muscle fibers, a few 100 of them muscle fibers and each fascicle is covered by the perimysium. So, you have the bunch of fascicles covered by the epimysium, then each fascicle covered by a perimysium. So, these coverings are important the perimysium you know that is where a lot of the blood vessels, the nerves go into the muscle.

So, these are like the junctions, these tissues that are covering these fibers that is they provide the pathways for the blood vessels for the nerves signals etcetera to reach the contractile element of the muscle, and all of these are also provided. They also provide elasticity to the muscle ok. So that is the role of the perimysium and the epimysium then. So, the fibers if you look at it, they are covered by the endomysium, again which carry more of the capillaries, these smaller blood vessels and the nerves to innervate the muscle.

So, these are also very cylindrical and they are thread like ok, and they are fairly long also like their depends, but they could be 15 to 30 centimeter long and they are kind of and they generate the force. So, in the muscle fiber you have thread like structures called the myofibrils ok. So, the myofibrils make up the fiber. About 80 percent of the fiber is made up of these myofibrils ok, and if you look closely at a myofibril then you see the structure that is responsible for the contraction of the muscle.

So, you have what are known as filaments in this myofiber. So, you have some thick filaments. So, I will this you have these, these are thin filaments called. Let me erase this, you have some thick filaments and thin filaments. Now these can kind of move relative to each other ok. So, this, the thick filament is called the myosin; that is your myosin and the thin filament is called the actin ok. So, you have the actin and the myosin ok. So, we started off, we started off at the level of compartments.

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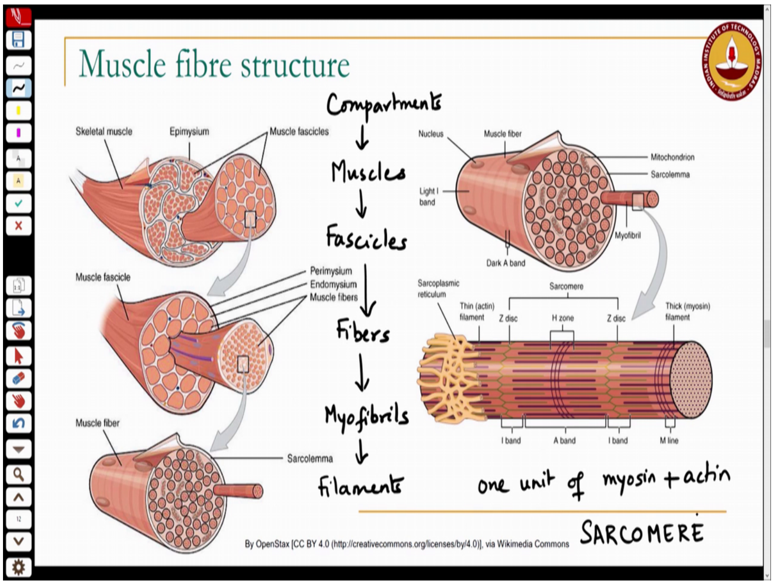

And then we came to compartments are groups of muscles. Muscles are groups of fascicles are groups of fibers, fibers are groups of myofibrils and myofibrils have these filaments ok. So, these are like a series of start together these filaments. So, one filament is like what I showed you here, this is one filament and they are kind of stucked like that.

So, this is the structure that of the muscles. So, one unit filaments, one unit is one unit of myosin plus actin is called the sarcomere. So, that is considered the fundamental unit for the muscle ok. So, myofibrils is the, this filament structure, bunch of the sarcomeres ok. The individual unit in the myofibril is a sarcomere.

Student: As the longer muscle.

Yeah. So, longer a muscle you have more of this sarcomeres start, and so we, you can probably guess what happens in the contraction right, its like a sliding action that takes place, it is called the sliding filament theory. So, when you have more of these start right you get more.

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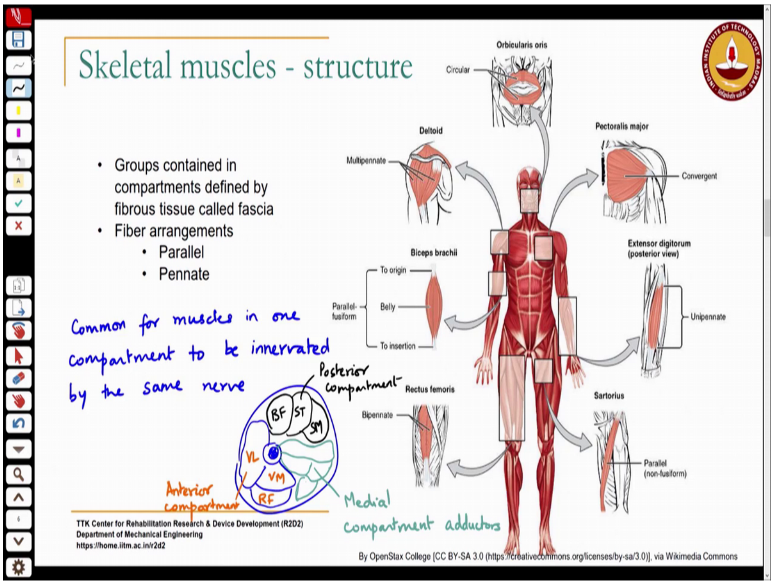

That is shortening and that is why the longer fibers can contract more than the shorter ones in the penniform arrangement ok. So,. So, this is a better picture of the myosin and actin filaments.

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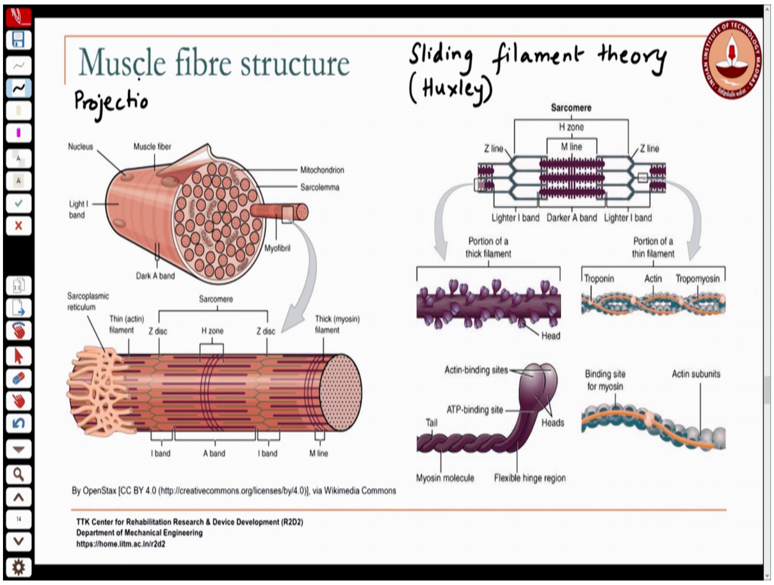

I will not go into the chemistry of it or how it does the chemical action that causes it, but essentially what it does is, when there is a stimulation these the myosin filaments have like these heads ok. If you look closely at the myosin filaments, they have these flexible heads and they basically act as hooks onto the. So, the heads have a flexible region, they hook onto the actin filament from, form like a cross bridge that is what it is called and then pull it and then relax again and do that again ok

So, when they are activated, it hooks on pulls it like a rowing action, it does this then back, then again another sight, it latches on to ampules. So, this stays where it is, it pulls the actin filaments closer together to close this gap this hatch zone that you have, that is the gap that can be closed by this action, that is cause, that is what is causing the, that is what is your contraction. Contraction is basically closing of that gap. So, in the contracted state the actin filaments basically move closer to together ok

So, this is called the sliding filament theory, this is the most commonly used explanation for muscle contraction. It was proposed by Huxley and. So, the thin actin elements, the projections may just hold.

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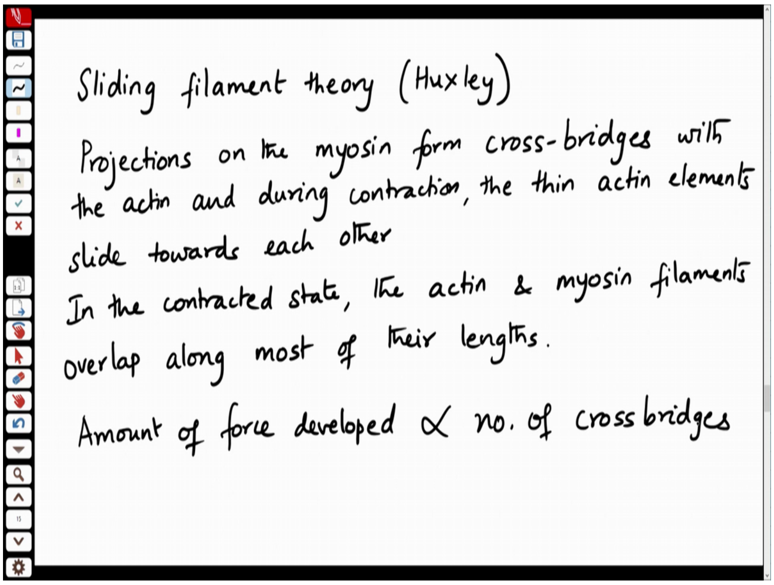

I will just use a new page projections on the myosin form cross bridges with the actin, and during contraction the thin acting elements slide towards each other. So, in the contracted state filaments, kind of overlap and the amount of force developed is proportional to the number of cross bridges that are formed

So, even when a muscle is not moving right like when it is not if it is, when we say if it is contracting, it means the cross bridges are holding on to one another. There may not be movement between the two like and we will talk about the different types of muscle action, later we call the isometric action right when there is no movement. Like if you are standing still and nothing is really moving, but your muscles are contracting or I could contract my muscles without causing movement ok; that is called an isometric contraction where there is no movement.

So, my muscles are acting muscles are contracting and the force that is produced is even though there is no movement the cross bridges are being formed and that is what is resisting that is what is producing the tension in the muscle.

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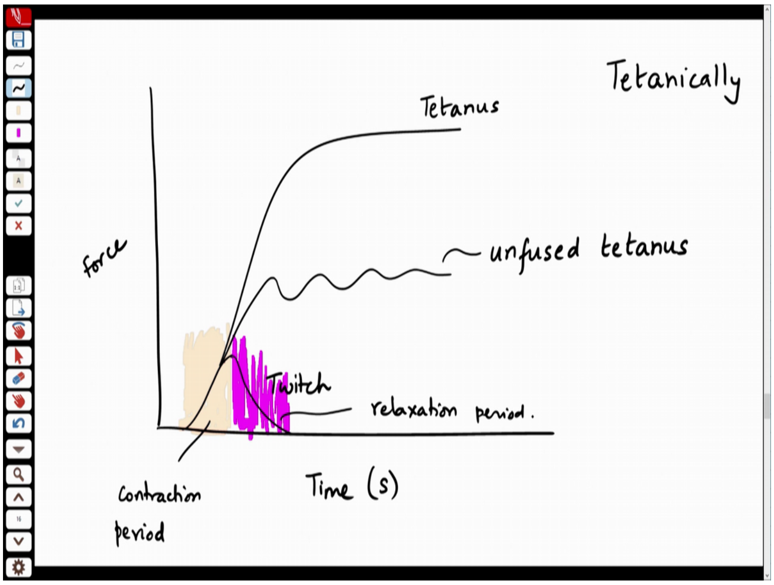

So, when a muscle is given is given a stimulus. So, it will contract and then relax. This is called a twitch for it to develop force these twitches happen. So, one twitch, it it it has to build one upon the other and then so for instance it will go like this. So, a bunch of twitches together form a somewhat steady force, but when it finally, reaches that steady force production ok; that is called tetanus.

So, when there which is build upon one another to maintain that force then the muscle is said to be contracting tetanically. So, this limit is called the tetanus and the muscle is said to be contracting tetanically ok. So, the nerves have to send this signals and they have to kind of build upon one another to reach this steady limit here, it is called an unfused tetanus. So, these are terms you will come across um, you know muscle tetan, tetanic muscle contraction.

So, you will know what it means, you know when the signals, when the frequency of the signals is such that it reaches that steady force production that is your tetanus, because this initially in a twitch, this is your contraction period and then that is your relaxation period. So, this is your relaxation. So, before it fully relaxes you give it another twitch and then that is how it builds up.

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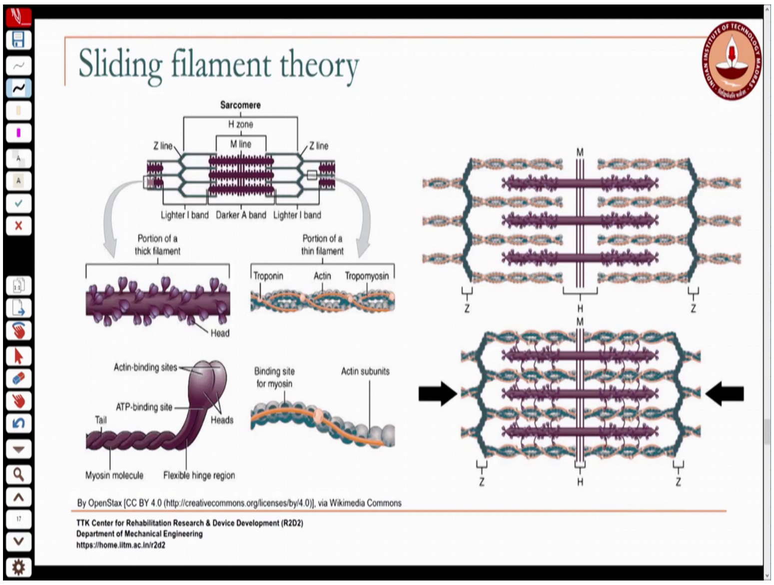

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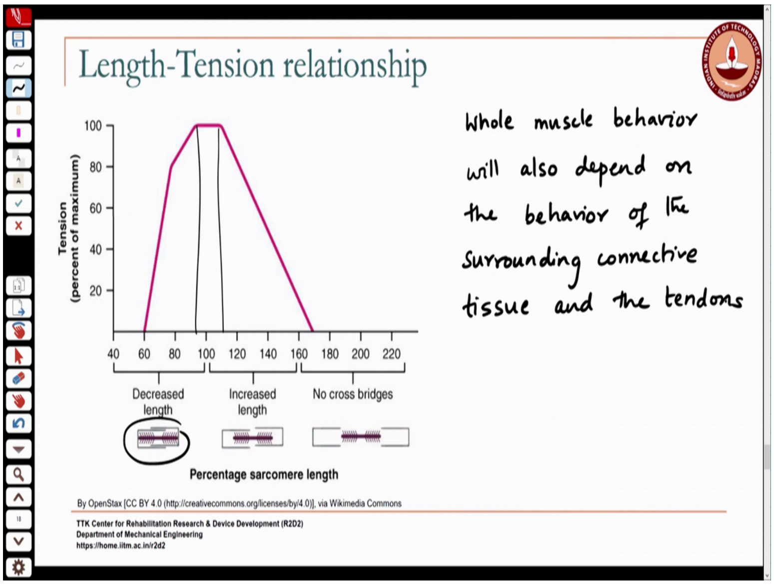

So, if you look at the length tension relationship for a sarcomere so at that level ok. Then they have done experiments like this and looked at. So, if you look at, on the x axis you have percentage of the sarcomere length. So, 100 percent means it is at its resting length ok. If it is less than that then it is shorter than its resting length. So, if it is at 60 percent, it is at a 60 percent of its decreased length that is what the x axis tells you here. Then you are look at. So, you look at the titanic force production ok, at these different lengths of the sarcomere. So, if the muscle is, and the tension is expressed in terms of the maximum tension that can be produced by that sarcomere.

So, this here is here 100 percent of the tension that the muscle is capable of producing. You find that its capable of producing the maximum tension close to its resting length right; that is where it is capable of producing maximum tension in the muscle. If it is shorter than that then you can see here ok, the actin elements are kind of overlapped and that interferes with. So, the number of cross bridges are affected by this kind of overlapping of the actin elements, and so the force production falls off steeply.

Similarly if the sarcomere, if the muscle contracts when it is lengthened ok. So, something else is lengthening it and then you apply a signal to contract the muscle, then not enough cross bridges can be formed. So, again the force drops off when it is beyond the resting length. So, under the resting length, beyond the resting length your force production falls off quite dramatically, close to your resting length is where you have the best force production in the muscle, because the cross bridge formation is maximized in that ah

Student: In anatomical position that we in the diagram.

So, we are now looking at the sarcomere, we are looking at the microscopic level, but we will come yeah you.

Student: And that position then person should feel which muscle should have a high tension in the muscles.

If you contract them, you can you can contract them.

Student: But its in the natural state you are getting the maximum tensions on this term, at 100 percent of length.

The maximum tension at the in the anatomical position.

Student: (Refer Time: 40:05).

That may or may not be the case, because if I look at the biceps for example, I am in the stretched position here. I am not in the resting position for the biceps brachii right in. So, its not necessary that. So, the anatomical position that is why it is only like a reference position ok. It is a reference position for us engineers to talk about relative positions and movements and to define.

So, it is basically for that yes.

Student: This implies at the resting position I can apply hundred percent of the (Refer Time: 40:46).

Yes, you can apply if the muscle is capable. That is the maximum tension the muscle is capable of supporting.

Student: That means, if i.

Applied.

Student: (Refer Time: 40:58) from the resting position.

At the muscles resting positioned so, you have the sarcomere ok, it is capable of generating some maximum tension that maximum tension will happen close to its resting position. It cannot exert, it cannot generate tension greater than that amount ok. So, if you change the length, it is only going to go down from there; that is that is what this means ok

So, this is the behavior of the muscle, the contractile element of the muscle alone the sarcomere. So, when we talk about this length tension relationship here at the sarcomere level, we are talking about only the contractile component, but you know that there is a lot of connective tissue also involved in this whole structure. So, the whole muscle behavior, we will also depend on behavior of the surrounding connective tissue as well as the tendons and the, and how the tendons behave ok. And I think I will, we will talk more about that in the next class, because we are almost out of time.