Animal Physiology
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Lecture – 13
Anatomy of Skeletal Muscle

Welcome back to the 3rd lecture of week 3. So, let us have a small recap of what we did in the last two class of the 3rd week. So, we start with the muscle. So, in the last class I told you the organisational hierarchy of the muscle. It starts with those stem cells or progenitor cells which are destined to become muscle. They move to their specific site of formation of muscle. There they get transformed into the cells which are destined to that particular cell type which are called the myoblast.

As I told you myo means muscle and blast means these are the ones which will further divide to from myocytes. So, this myoblast word probably I missed out in the previous class to add it. So, from myoblast there are division of these myoblast to form myocytes. Then, these myocytes divide further and then, they align with each other forming a long cylindrical tubes like this. So, there are multiple cylindrical tubes. So, those of you have seen in a construction sites, you have seen those hollow pipes which are kept there. So, hollow pipes like you must have seen, muscle is exactly a same analogy of the hollow pipes. You can have the analogy. It is just at a micron dimension which goes all the way up to you know few centimetres.

So, the logic is the same. So, this is how these myocytes align led to the formation of what we termed in the last class as myotubes and I told you these myotubes say for example, one hollow pipe you attach another hollow pipe from both the ends. So, these myotubes attach with each other to form what we call as the myofibers or myofibril sometime you will see in the books or wherever you prefer to read these myofibrils form supercoil assemblies to form further fibril structure which eventually lead to the formation of the muscle.

Now, from the anatomical perspective, suppose this is the muscle, right. This is my muscle out here. Now, I take a part of it and I cut it like this say for example, I cut the

muscle like this. What you will be able to see just try to imagine. So, I give you this analogy that muscles are more like this, ok.

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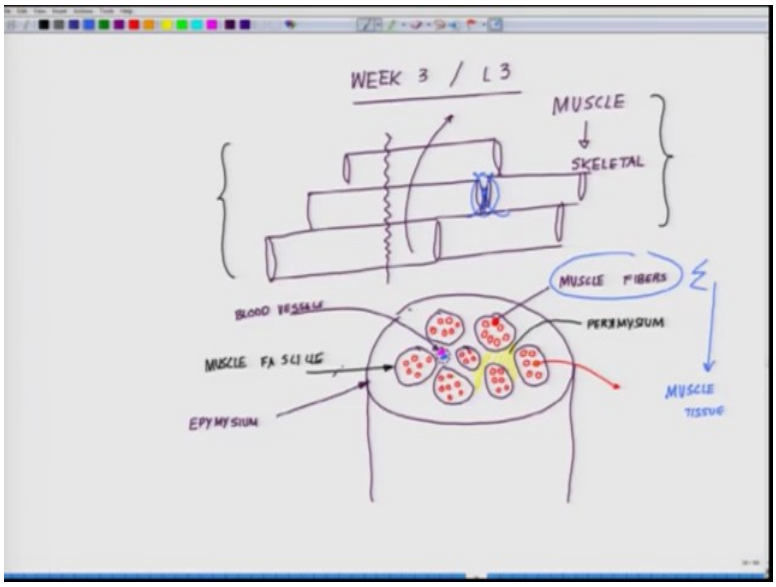

So, just before getting into, we are in week 3 lecture 3 muscle and especially now we are dealing with skeletal muscle. So, I give you the analogy that they are more like those hollow pipes which are setting like you have seen this right at any construction site if you walk you will see it right. So, now I request you to make a cut like this. You will be cutting it like this. So, this is this pen which I am holding here. If you consider this as a muscle, you cut it like this, like this. So, this is where you are giving the cut. If you give a cut like this, what the kind of a structure what will be emerged will be something. So, this I am just after giving a cut, I am now changing the angle making it at a 90 degree. So, once I make it as a 90 degree angle, you will see the face of it as how it looks like. So, the face of the muscle will look very similar to what I am going to draw now.

So, on the face of the muscle you will see very interesting, this as if there are even more tubes in it and these tubes are arranged in colonies. You know you will see multiple tubes. It is something like inside one tube, you have multiple such tubes which are placed there and each community of tubes are separated by the other and within this, you will see further. Now, if I follow each one of them, you will see further tubes like this and we

will come to it what the terminologies which are used and from there we will go further down in the molecular players who helps in generation of the force. So, this is how it looks like.

Now, there are terms which are used. These are called muscle fascicles, kind of a cover muscle fascicle and within this you will see a lot of use some other colour, very closing something like this. These two, what you see is pink and blue colour. I am just circling it. So, these are the blood vessels which are following very closely to the muscle.

The outer coating out here what you see is termed as Epimysium, absolutely outer coating and then, what you are having these are those muscle fibres or myofibers what we are talking about. So, look at the amount of self assembly which has taken place and in between this is space what you see out here. So, this is space. Now, let me shade it in yellow. You see this is space and this is called Perimysium. So, this is the overall cross geometry of it and if you look at it loop, further you will see a lot of in a further finer details if you pick up any of these muscle fiber say for example, I pick up one of these muscle fibers. Now, if you look at further detail of that muscle fiber, you will observe is a further self assembly which has taken place.

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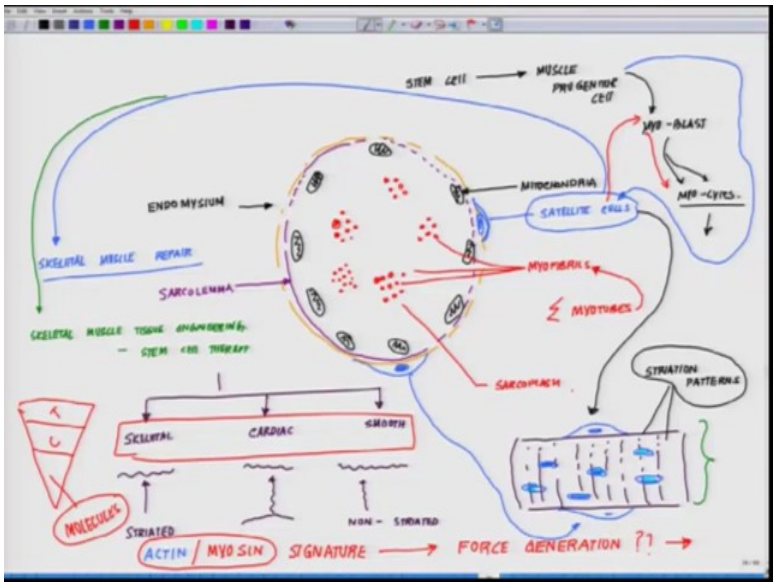

Now, that is something like this is. I am now highlighting one individual. So, out here I am only talking about one of these how that looks like. So, you are having a lot of these fibers which are present and then, I am going to put the fibers there. So, within this what you see is this is your epimy Endomysium which is covering the individual fiber and there are lot of these kind of organelles which from your very basics you will remember. These are the mitochondria or the powerhouse of the cell mitochondria and the density of mitochondria is very high because they need to generate lot of energy and then, there is an inner lining out here which is called the Sarcolemma.

Coming to that once again, this inner lining is called the Sarcolemma and within this you have like colonies of very similar to what you saw for the individual myo individual fibers, muscle fibers. If you remember you see here the individual you have these muscle fibers which are present there, right. I told you that these are the individual fibers. So, now what we are doing? We are looking at the individual muscle fiber. So, do not get confused. So, within these individual muscle fibers you see even further self organisation of these are all the Myofibrils.

Myofibrils and I told you how the Myofibrils are originated. Myofibrils are the summation of the Myotubes. They form myofibrils and then, you see this zone and this is called the sarcoplasm and on the side, you see something very interesting out here, a very special kind of big cells. They may be present in varied numbers. These are called the satellite cells. These satellite cells are a interesting community of cells. Soon I will come to that what does that mean and you see lot of nuclei out here. So, essentially what you are seeing is at different level of self-organisation of the muscle. So, now just before you lose track, let me take you back again to the basics. We talked about the cells which are destined to become muscle, right.

Those are which are destined to become muscle, move to the site of specific cartilage where they will be covering it up. There they get transformed into Myoblast. These Myoblast eventually divides into Myocytes. These Myocytes divide and align together and then, they lose their individual identity to form multinucleated tubes called Myotubes. Now, from there those Myotubes further form a next level of higher self-assembly called Myofibers. These different myofibrils or myofibers or myofibrils club

together like you have seen that when you make the ropes. So, individual myofibrils, these assembly of individual myofibrils come together to form a single muscle fiber.

Then, individual muscle fibers as you could see out here individual muscle fibers, then come together to form what summation of it is what we call as the muscle tissue and at different level, it has different level of organisational set up and it supply to bug blood vessels covering and everything, but one hallmark out here is that it has lot of mitochondria and in its vicinity. So, this is how this skeletal muscle looks like and if you take a cross-section of a skeletal muscle, you will see something very interesting and this will bring us to the second level of classification. What you observe say for example, you take any of these skeletal muscle and take a cross-section, you see lot of striations something like you have seen the surface of the zebra, you have seen the black stripes almost similar to that you will see striation like this in the skeletal muscle in a way. That is another way of classifying muscle. Striated muscle, non-striated muscle are all the skeletal muscles with different name at different anatomical region of your body, where as non-striated muscles are the smooth muscles forming your elementary canal and then, the cardiac muscle where also you hardly see striations, you see of course different kind of you know pattern which we will come later to that.

Now, let us just put it down out here. So, one more small classificational setup for muscle we have talked about based on force generation. If you remember I told you based on force generation, we can classify them as skeletal cardiac and smooth, right. Now, we introduced another way of classifying them. Skeletal, these are striated muscle and smooth are non-striated muscles and of course, cardiac has a different kind of somewhere in between and this classification is based on purely microscopic observations. These whole pattern of striations and if you look what I really meant by striations, if you take a section of the skeletal muscle, this is how it will look like. These are the striations what will you observe and within the striations I am, just one second. So, within the striations you will see the nuclear presence like this and of course, there is one more thing which I did not mention out here those big cells. Those big cells are these cells which are present there. I just distinguished them form the nuclei. Nuclei I am just putting another colour code.

So, this pattern what you observe here is the striation pattern and this particular cell, satellite cells I told you will talk about it and just briefly talk about it. So, I told you that there are stem cells or progenitor cells which are destined to become muscle travel to the specific muscle location. Muscle progenitor cells and a population of it gets converted into a significant population get converted into myoblast. I told you this myoblast eventually lead to the formation of myocytes and these myocytes of course from the myotubes and so on and so forth. Yet there is some population of this muscle progenitor cells which do not differentiate and remain in close proximity of the muscle.

These are called the satellite cells. These satellite cells comes very handy for we needed to know this is satellite cells are comes very handy for skeletal muscle repair because whenever they are damaged, they have the tremendous potential to divide and take up this route again from here, take up the route of myoblast to myocytes and so on so forth plus there is another attractive alluring area of this that is in skeletal muscle, tissue engineering or specially in stem cell therapy.

For cases like muscular dystrophy and all other very complicated cases where you do not have any option, but to resort to some cellular genetics, a rout to cure it definitely these stem cells comes very handy. So, several people who studies the regeneration of adult muscle takes the sample of the muscle and isolate these satellite cells by several complex or cell separation techniques because they are large and they have very unique markers, and take those cells, put them in conditions where they can divide and conserve that population and allow them to form these complex structure or they can even re-implant them back to the patient. So, these are the kind of the futuristic therapies of regenerative medicine where the whole world is slowly marching, especially those people who are interested in this area of reprogramming the different tissue and organisation of the body.

So, from the perspective of where all these anatomical feature and understanding is very critical as a biomedical or biological scientist in future you really needed to have a complete or fundamental understanding of the anatomy because one day mankind will be making artificial organs, all right. In order to even make an artificial tissue outside the system unless you really know the anatomical signatures, the features you do not have any like point where you really can develop the whole story. So, that is why

understanding these are very important.

So, coming back where I was, I told you about the striation pattern. So, this striation pattern is a very critical landmark in the study of the muscle biology. Why is it? So, before I get in the striation pattern, I will add one more drawing for you people that is if I do in previous slide, previous to previous slide, I do this drawing right, remember. Now, I will just make this drawing little bit more anatomical that will give you an idea.

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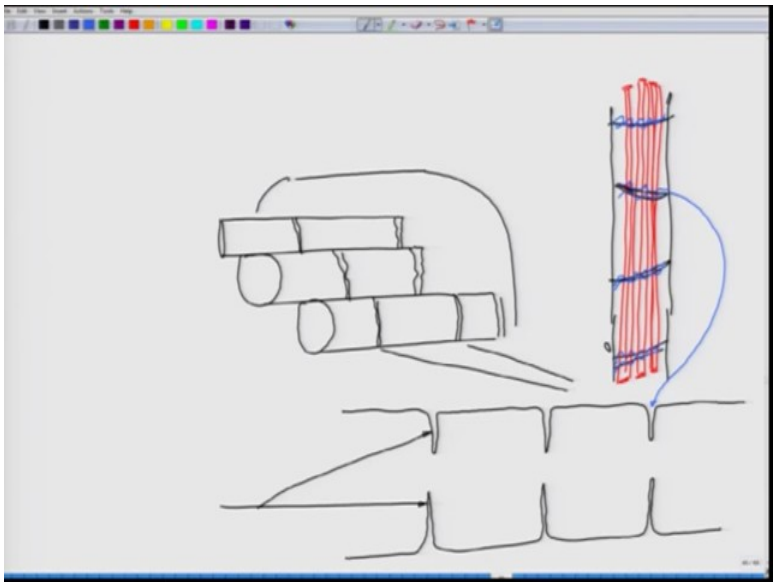

So, if you really take a muscle like this and you have a cross-section like this from the sidewise, I told you the view will be something like this and what you will be seeing is something like this or something like this. These tubes are popping out within them. You see the zones of something like this. You must have seen bamboos, right. It is almost like within the bamboo you see this kind of striations, almost very similar to that and you will see there are gaps here. So, it seems the structure which looks very cylindrical is not that cylindrical rather the structure is something like this and there is significance to this. I will come to that what are the significance of it. So, the structures of these muscle tubes which are attached together, there is a discontinuity here and you see the structures like this and these kind of spaces what you observe is something which is very critical for the functioning of these muscles especially in terms of their contraction process.

Just remember for the time being this specific feature. There are a specific name to these features and I will come slowly into that part. At this point just remember this that this whole process and if you forget it, the easiest way to remember is bamboo which is something like this. All of you have seen bamboos like this, right. So, this part it is almost like you can kind of remember it like this make a brain map. So, the muscles imagine that your myotubes are inside this. These are individual myotubes and this is how you have to develop your mind map of how the muscles really looks like. So, this is where you are, right. So, what you will observe here is I will pick up another colour. There are gaps like this something very similar to what I drew here like this, fine. So, keep this in mind while I drew this picture, one second. So, this part there is a small. So, it looks like this now coming back where I was. So, these we have talked about the satellite cells.

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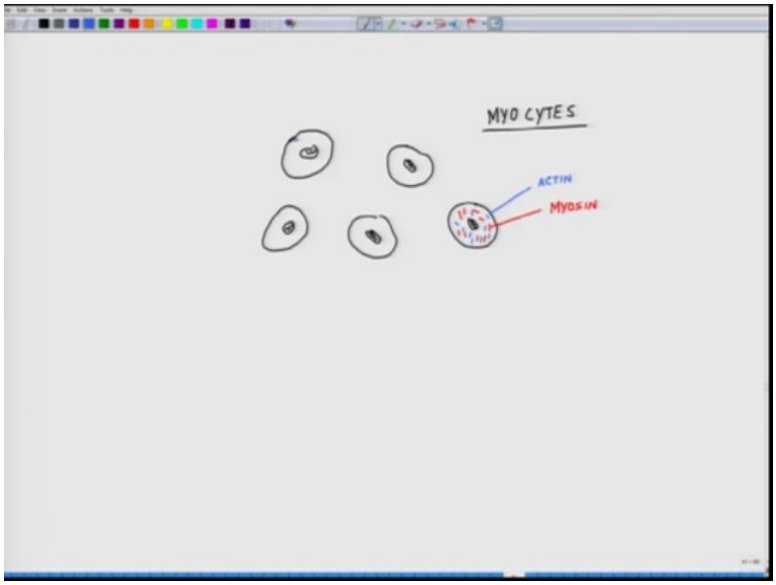

So, when individual Myo cytes were formed, I told you these Myo cytes this is much earlier than the myotubes. So, I am talking about back to the cellular level. These myocytes have two interesting proteins in them. So, here you have the myocytes, here you have the nucleus all over and those two interesting proteins I label them with different colours are kind of linear proteins. Just let me put pick up two colours, green and oh sorry blue and red. So, one of them is called myosin; the other one is called actin.

This is one of the hallmark of a tissue or a cell which will become muscles cells. So, that brings us to another point.

The previous to previous slide I told you about this satellite cells. So, one of the feature of these satellite cell has to be, they should have a higher propensity to make these actin and myosin filaments. These actin and myosin filaments are critical and now coming here, while now I am introducing third part which is our actin and slash myosin proteins. Now, see from tissue level we came to the cellular level. From cellular level now you are moving to the molecular level like see this. So, it is a reverse. Now, I am going tissue cell, C stands for cell, T stand for tissue and here molecules now we are in the molecular level.

These actin and myosin filaments are those key players which are involved in the force generation. Whatever muscle you study, which ever animal you study mostly, most of the fourth generation in the muscle is governed by these two proteins. Now, having said this let me add one small clue for you. If these are the ones actin and myosin are involved in the force generation and if we have classified the muscle based on their different kind of force generation, it means by the logic you can infer that different muscle generating difference force whether it is an skeletal muscle or it is a cardiac muscle or it is a smooth muscle, they will have different isoform.

We call it Isoform. Different forms of a same thing, different isoform or different molecular signatures of myosin and actin. So, the take home message from this point on word for you people for rest of the life, always remember do not panic whenever you see how this is a complex thing. No no no no do not panic. It is very straight forward. You just ask the other person, tell me the myosin type and the actin type. Mostly the myosin type because these are the ones as I will come in the subsequent class, these are the ones which generate this force.

So, based on the molecular signature of actin and myosin, the muscle can be classified or even the myocytes can be classified because you remember these stem cells, they can be or the satellite cells they can be differentiated into different muscle type provided you give the exact condition what kind of myosin filaments they are going to synthesise. One

of that brings us to. I have invoke much more bigger question, much more fundamental question who decides which muscle will become cardiac, which will become skeletal, which will become smooth because they are originating from the same lot, but those are the questions of the future where mankind will have to really work, strive, people like you will have to work very hard to figure that out because those are the signatures where we are heading for like the same pool it is coming like. But then because within them, there are a lot, there is a family cluster which are destined to become a muscle, but how they decide, how they you know demark it into a bigger classification, but what is most important may be you know 50 years down the line, we will not teach it like that we will teach the reverse way.

We will say the classification will not be this big broad classification. It will be more of a molecular classification where this signature of actin and myosin will be critical in determining that what is the force generation because this has a direct relation to the force generation based on that you will be classifying the muscle.

So, I will close in here. In the next class, we will talk about the molecular arrangement of the actin and myosin filaments within the muscle, their rearrangement and how that leads to the formation of the word which I introduced today, the striations thank you and in the next class, we will talk about the molecular architecture and the rearrangement of the actin and myosin filaments.