Basics of Biology
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Module - IX : Human Physiology (Part-II)
Lecture – 41
Muscular System (Part-I)

Hello everyone, this is Dr. Vishal Trivedi from Department of Biosciences and Bioengineering, IIT Guwahati. And what we were discussing, we were discussing about the different properties of the living organisms, and in that context, in the current discussion, we are discussing about the human physiology.

So, in the previous module, we have discussed about the digestive system, so the purpose of the digestive system is that it is actually going to provide the nutrition into the system. So, it is actually going to generate that nutrients can, which are going to be provided after the digestion is going to be utilized into the different types of metabolic reactions and that is how they are actually going to provide the energy into the system.

Once you have the energy from these nutrients, then this energy can be utilized for performing the other physiological processes such as circulatory system, muscular system, nervous system, endocrine system, and the excretory systems. So, in today's lecture we are going to discuss about the muscular systems, but before we getting into the detail of the muscular system, let us discuss about the requirement and the possible mechanisms through which the different animals are doing the locomotions. So, the first question is that, what is locomotion?

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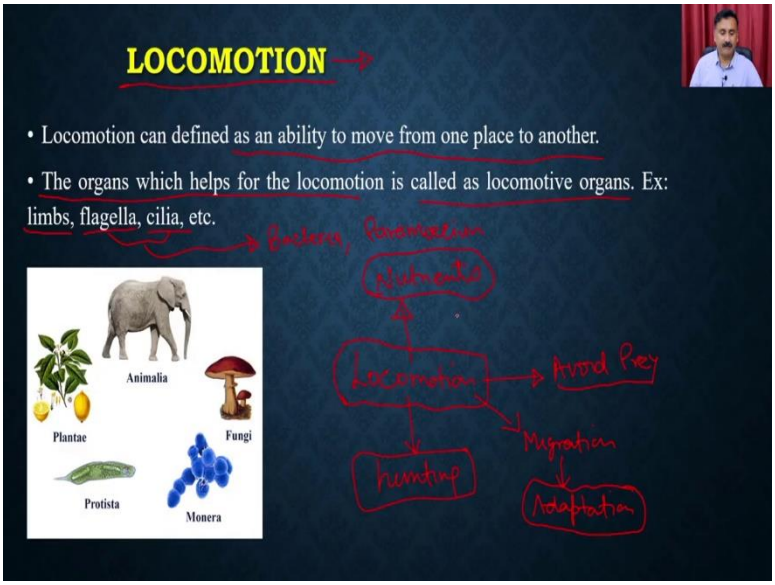

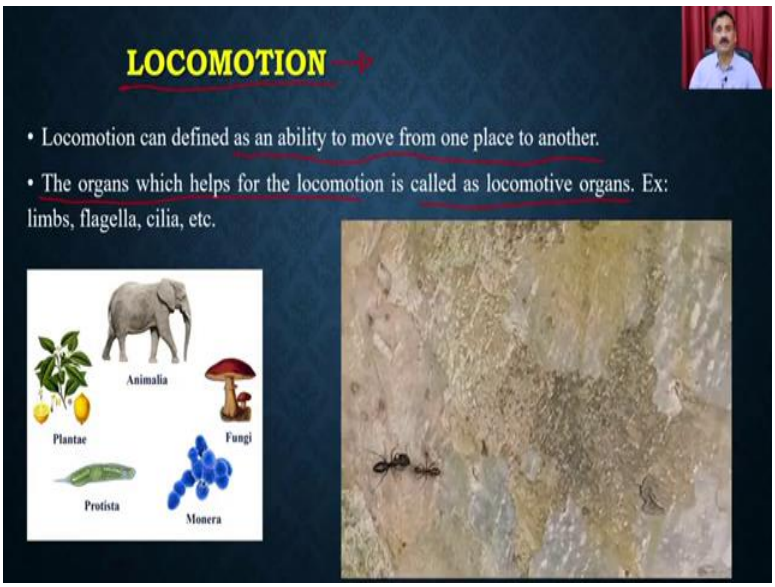

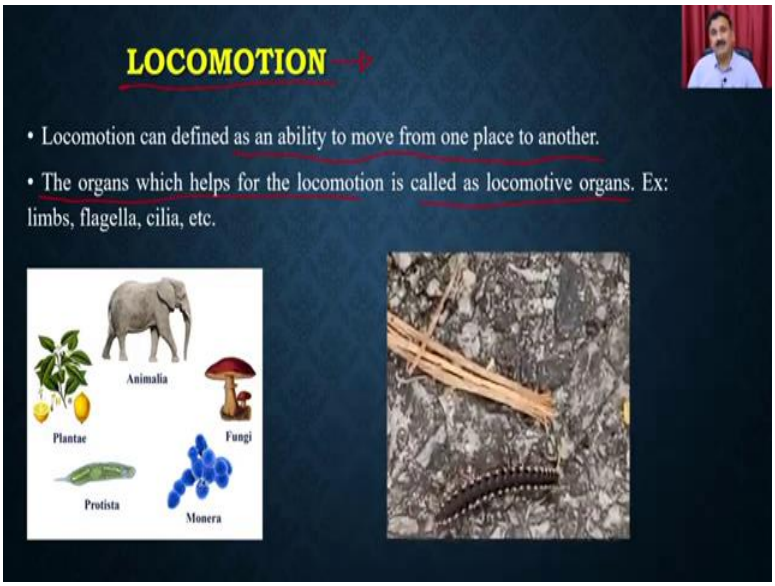

So, the locomotion is a very well-defined process by which the locomotion is being defined as an ability of an organism to move from the one place to another place, which means the locomotion is a submission of the activities which are responsible for the organisms to move from the one place to another place. The organs which are actually going to help in the locomotion is called as the locomotive organs, okay.

And if you recall in our module number one, we have said that the organisms are going to be classified into the different kingdoms or different types of organisms are being found. So, you can have the bacteria, you can have the fungi, you can have the archaea bacteria, and you can have the plants, or you can have the animals, all these different class, different kingdoms of the organisms are actually utilizing the different types of locomotive organs for the locomotion's.

For example, you might have seen that the ants, they are actually using the legs for their locomotion's. Similarly, you might have seen the centipede or the millipedes, so they have the hundreds of the tiny legs and then they use these tiny legs to crawl from the one place to another place.

Apart from that, the birds are even if you go to the higher animals or if you go to the plants, you will see that the plants are also having the different types of you know, so movement from one place to another place, so some are, some plants are free moving plants, so they can actually move from one place to another plant.

Apart from that, you might have seen the higher animals, so higher animals are actually having the limbs and they actually utilize the limbs. In some of the plants or in some of the higher animals, the limbs are also being converted into the feathers, and these are called birds, so you might have seen the different types of birds which actually utilizes the feathers to fly into the air and they also have the two pairs of limbs so that actually they can also do, you know, walk on to the surface also.

You might have seen the ducks, so you might have seen, they have different you, they have the feathers, and they also use the completely modified limbs and that is how they actually walk onto the surface also.

So, these are the few of the examples, how the different organisms are utilizing the different types of locomotive organs for the locomotion's. I have given you example of like the limbs,

flagella, and cilia. So, flagella and the cilia are the locomotive organs into the bacteria or the paramecium.

So, you might have seen the paramecium which has the Celia all over the body and then they utilize that Celia to move from one place to another place. Similarly, the bacteria's are actually having the flagellated bacteria or other kinds of bacteria which also they use to move from one place to another place.

So, what is the purpose of the locomotion? So, locomotion is actually been required or the most movement from one place to another place is required for many purposes. For example, locomotion is allowed to take you the nutrition, so sometimes the locomotion is actually been directed by the loco nutrition's, so then it is actually called as the chemotactic movement. Sometimes, the locomotion is required because you want to avoid a particular prey, so that time you are actually going to run away, so that locomotion is going to help the organism to avoid the prey and it is actually going to get saved from the particular prey.

The locomotion is also required for hunting, so you might have seen many of these lion or other kinds of big animals that they are actually running very fast and that is how they are actually capturing their host, so that is how they are actually catching the different types of animals and that is how they are using them for taking up the nutrition. locomotion is also been used for migration of the organisms from the one location to another location, so locomotion is also required for the migration, so that is how you are actually going, that help in the organism for the better adaptations.

You might have heard about the different types of migratory birds like which actually runs all over the place from Siberia too and then they come to the Asian countries in the different locations. So, that they do because they have to adopt for a very low temperature, so when they are, there is a low temperature in Siberia, they actually migrates to the less colder places.

So, locomotion is a very important activity because it allows the organism to explore the many things and locomotion in the higher animal is a combination where you have a very you require a well-defined machinery, so that you can be able to perform the, you can be able to move from one place to another place.

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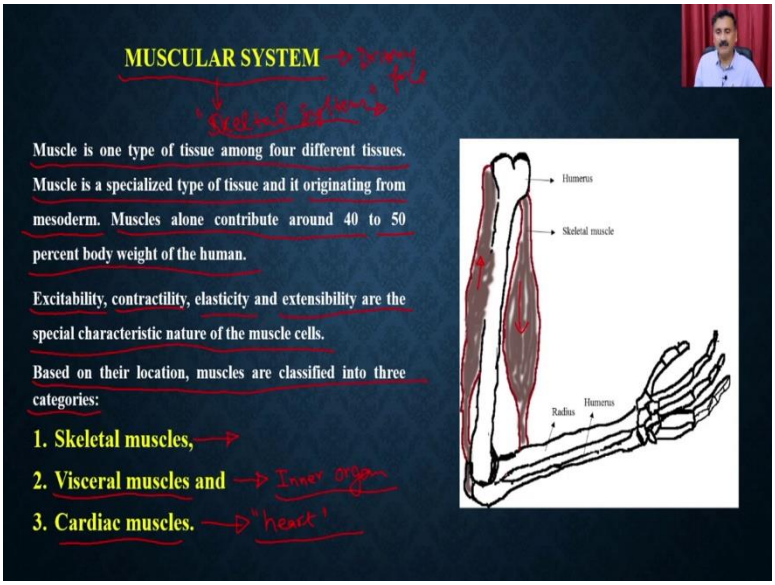

So, the machinery what is required for movement in the higher animals like the humans is called as the muscular system but the muscular system is not working in alone. Muscular system in addition to the skeletal system is actually a part of the locomotion in the case of humans.

So, what you see here is that this is the humerus, and then humerus is actually been connected to the different types of muscles and these muscles are actually allowing the movement of the hands, okay. So, if you want to move your hand you are actually going to use these muscles, so this bone is actually going to provide the framework but the movement is also always going to be generated by the muscular system.

So, the muscular system is actually going to generate the driving force and the skeletal system is actually going to provide the strength into the system, so that is how you can actually be able to carry the bucket of water or that is how you can actually be able to walk. Because if you remove the skeletal system right the same kind of machinery is actually allowing the worms or other kinds of lower animals to crawl from the one place to another place, so they have a thick muscle and these thick muscles are allowing them to crawl. But since we have the skeletal system, we can be able to you know stand up and we can be able to walk.

So, muscle is a one type of tissue among the four different tissues. Muscle is a specialized type of tissue and it is originating from the mesoderm. So, you know that when we were talking about the different types of developmental layers, the muscles are actually going to be produced from the mesoderm. Muscles alone contribute around 40 to 50 percent of the body

weight of the human, so this flesh what you are actually going to see in the human body is nothing but the muscles, like you have the muscles in your hand, you have the muscles in your limb, you have the muscles in your ribs, and all other places.

So, wherever you are actually requiring a movement whether a moment of the ribs, so that you can be able to breathe or whether it is the moment of the hand or leg, so that you can be able to perform the different types of tasks, it is all been done by the muscular system and that is why the muscular system contributes 40 to 50 percent of the body weight of the humans.

What are the things they will actually going to do is, muscles are actually going to do the excitability, they will do the contractility, elasticity and the extensibility are the special characteristic nature of the muscle cell which means the muscles can actually get excited when they are actually going to get the signal from the brain, they also can contract, so they can actually go into the contraction. So, they can actually you know, pull, they can be elastic also so they can be get relaxed, so they can be very relaxed conditions and then they can also be able to stretch, so they are also very flexible in terms of stretching, so these are the very feature of the muscle cells.

And based on the location the muscles are classified into the three different categories, you have the skeletal muscles, so as the name suggests the skeletal muscles are always going to be associated with the skeleton. Then, we have the visceral muscles, so these visceral muscles are actually going to be present all the muscles which are going to be present into the internal organ.

And then you have the cardiac muscles the cardiac muscles which are the muscles which are actually going to make the heart. These, all these three different types of muscles have their own structures, their own morphology, and their own composition, and that is why they have the different functions to contribute into the different aspects of the locomotion's.

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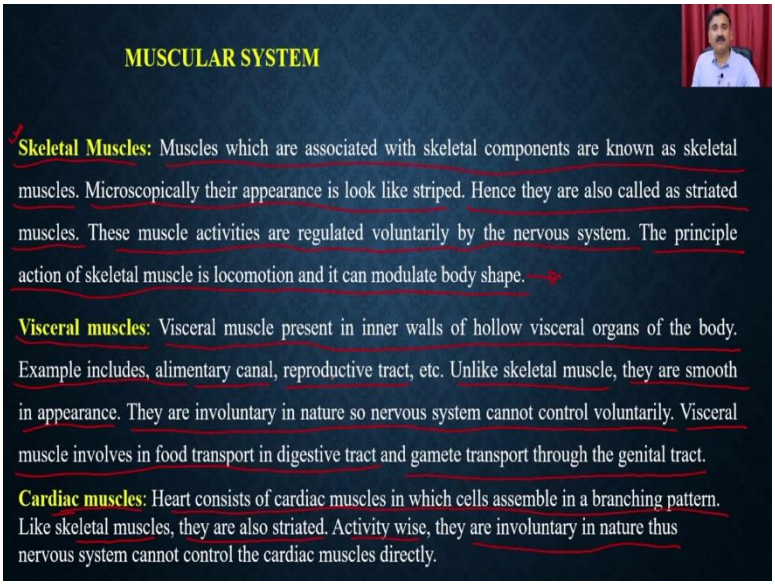

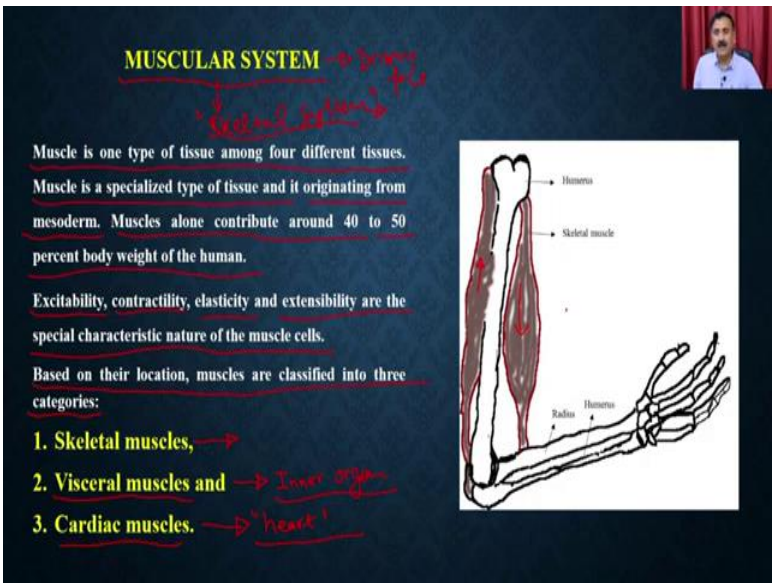

Now, let us talk about these skeleton muscles. So, muscles which are associated with the skeleton component are called as the skeleton muscles. Remember, that in the previous slide I have shown you the two skeleton muscles. These are the skeletal muscles because you have a bone which is called humerus, so this is the hand bone, these are the radial ulna, so these are the humerus, this is the radio ulna what you have, and these are all connected to their different types of muscles and these muscles are the skeletal muscles and because they can actually be able to stretch, they can be able to pull, that is why you can be able to move your hand like this, okay.

So, the skeleton muscles are always been associated with the skeleton of the body. The microscopically their appearance is look like the striped, so they are actually having the fiber

like appearances, hence they are also called as the striated muscles. These muscles activities are regulated voluntarily by the nervous system, which means the skeletal muscles are actually the, can be regulated by the voluntarily, voluntarily by the nervous system, which means our brain actually can control their activity. So, you can actually be able to you know uplift your hand, you can do different types of activities with your hand, because the brain is sending the signal to these muscles. So, these muscles are under the tight control of the nervous system.

The principal action of the skeletal muscles is the locomotion and it can modulate the body shape as well. So, skeleton muscles are the major muscles what are going to be present in the human body and they are actually going to be striped muscles, so they are actually going to have the striped like the fibre kind of thing, and they are also being regulated voluntarily by the nervous system, which means they can be as per the wish of the person, they can actually be able to move.

Then, we have the visceral muscles. So, this as the name suggests, the visceral muscles are going to be present along with the inner body. So, visceral muscles are present in the inner wall of the hollow vessel organ of the body like for example the muscles which are actually going to present in the elementary canal or the muscle which are present in the other part of the human internal organs. Examples includes like the muscles which are performing in the elementary canal, reproductive tracts.

Unlike skeleton muscles they are smooth in appearance which means, they are not fibre like, so they are not striped, they are unstriped or the smooth muscles, they are involuntarily in nature. So, nervous system cannot control voluntarily, which means these muscles are actually going to function without under the control of the nervous system. So, you cannot control your muscles which are regulating the peristatic movement, for example in your stomach or the other part of the elementary canal, so that is involuntarily, as soon as they will actually going to have the food, the muscle the stomach is actually going to have the peristatic movement.

Same is true for the oesophagus also, oesophagus is also one, as soon as it has food it is actually going to have the peristatic movement, so that the muscle, the food is actually going to move downwards. So, that is why that could be the reason that you cannot actually control the vomiting. You cannot stop the vomiting simply by giving an instruction from the, your brain, because they are involuntarily in nature, so they cannot be controlled by the brain.

Visceral muscles are involved into the food transport within the digestive tract and the gamete transport within the genital tract. Apart from that, you also have the cardiac muscles, so heart consists of the cardiac muscles in which the cells assemble in a branching pattern and like the skeletal muscles, they are also striped, so they are also striped. And the activity wise, they are involuntarily in nature and this nervous system cannot control the muscular cardiac muscles directly. This means the cardiac muscles are actually a hybrid of the skeletal muscle and the visceral system, except that there are some specialized features associated with the cardiac muscles.

So, the feature which are associated with the visceral muscles are that they are involuntarily in nature, and the feature which are associated with the skeleton muscle is that they are striped in nature, so they are actually going to you know function into the heart, so that heart can actually be able to do the contraction and relaxation for a very very long time.

And then they are involuntary which means, even if you keep the message from the brain that, okay, stop heart, please do not beat, it is not going to work, so it is not under the control of the brain, and that is why you know that why it is so important, heart has to beat irrespective of the instruction from the brain. So, let us discuss the, since we have the three different types of muscles, all these three different types of muscles have the contrasting features and that we can actually discuss in the tabular format.

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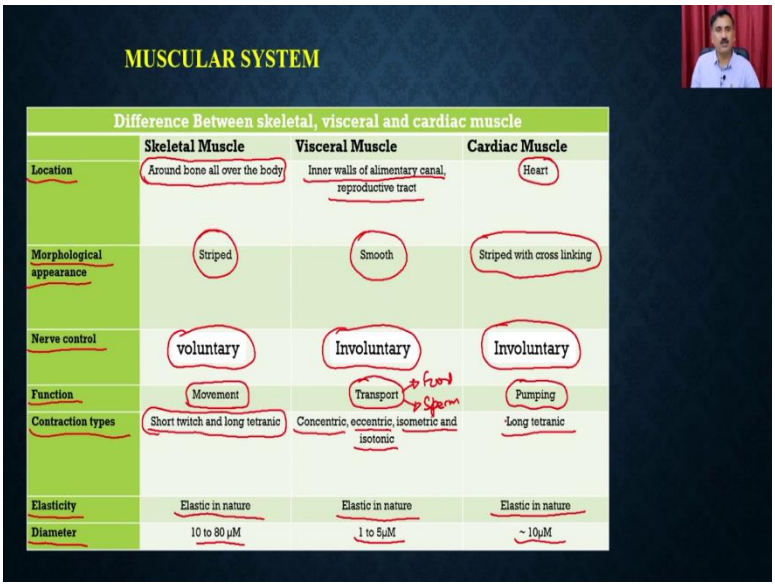

So, as far as the so we have a differences between the skeleton, visceral, and cardiac muscles. So, as for the location is concerned the skeletal muscles are present all over the body, so they are present around the body and they are present in the throughout the body. Whereas the

visceral muscles are present in the inner wall of the elementary canal and the reproductive tract and their main function is to contribute into the movement of the food or the movement of the gametes.

Whereas the cardiac muscles are present in the heart. Morphological appearances, morphological appearances these skeletal muscles are striped, visceral muscles are smooth, whereas the cardiac muscles are striped with the cross linking. So, you see that cardiac muscles are actually having the hybrid properties of the skeletal muscles as well as the visceral muscles.

Then, the nervous control, so the skeletal muscles are voluntarily which means they are under the control of the brain, whereas the visceral muscles or the cardiac muscles are involuntary, which means the brain cannot control their activities.

Then the functions, the function of the skeletal muscle is that it is actually going to help in the movement whether it is actually going to allow the movement of the individual hands or legs or is actually going to help in the terms of locomotions. Whereas the visceral muscles are always been going to function in the proper in the form of the transport, so it is actually going to transport the food or it actually going to transport the gametes like the sperms or the ovum.

The cardiac muscles are helping only the pump, so they are actually going to be present in the heart and then they are actually going to help in the contraction as well as the relaxation of the heart. Then the contraction type, so contraction type is going to be short twitch and long tetranic, so these are the cardiac contraction type what is going to be present in the skeletal muscles.

Then in the case of visceral muscles, it is going to be concentric, eccentric, and the isometric as well as the isotonic contractions. And then, in the cardiac muscles you are going to have the longed tetranic conditions contractions. Do not worry about this contraction types or if you could not be able to follow right now, because we are going to discuss about the different types of contractions what is present in the muscular system or what are the actually going to be generated by the different types of muscles in our subsequent lecture.

So, elasticity, elasticity is that the skeletal muscles are elastic in nature, they all are elastic in nature, so they can actually be able to relax, and contract, and all those kinds of things. As far as the size is concerned, the skeletal muscles are 10 to 80 micrometre, voluntary muscles,

visceral muscles are 1 to 5 micrometres, and the cardiac muscles are more than 10 micrometres.

So, let us start discussing about the structure as well as the function of the individual muscles, so that it will actually help you to understand how these muscles are contributing into the different types of activities, whether it is related to movement, whether it is related to transport, or whether it is related to pumping the blood within the body.

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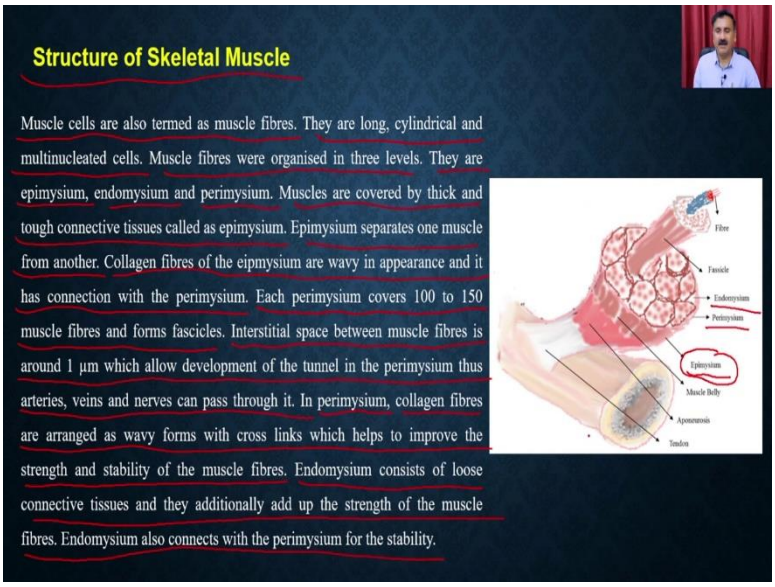

So, let us start with the structure of the skeletal muscles. So, this is what you see here is the skeletal muscle where you have the fibre like structure. So, all these fibres are arranged and they are actually going to have the different types of coverings, so the muscle cells are also called as the muscle fibre. They are long, cylindrical, and multi-nucleated cells, so these the individual muscles what you see here is going to be, come together and that is how they are actually going to form a very long, cylindrical, and multinucleated cells.

The muscle fibres were organized in the three levels, okay. They are epimysium, endomysium, and the perimysium, so they are actually going to have the three different level of organizations. You can have the endomysium, you can have the perimysium, and then you can also have the epimysium. See, muscles are covered by the thick and the tough connective tissue which is called as the epimysium. So, what you see here is actually the outer thick covering that is called as the epimysium.

The epimysium separates one muscles from the another muscle, so epimysium is actually going to allow making a bunch of the muscle but it actually separates the one muscles from

the another muscles. The collagen fibres of the epimysium are wavy in appearances and it has the connection with the perimysium, so epimysium is going to have the collagen fibres, and they are actually going to have the wavy appearances, and they are connected with the perimysium.

Each perimysium covers 100 to 150 muscle fibres and form the fascicles, so perimysium is going to have the individual fascicles and these fascicles are going to become together into the perimysium's. Interstitial space between the muscle fibre is around 1 micrometre which allows the deployment of the tunnel in the perimysium thus the arteries, veins, and nerves can pass through. So, between these individual fascicles, you have the spaces and these spaces are actually going to be used by running the arteries, veins, and all other kinds of materials, so that they can be able to get these muscle cell, actually, can actually be able to get the nutrition, oxygen, and all other kind of things.

In perimysium, the collagen fibres are arranged as wavy form with crosslink which helps to improve the strength and the stability of the muscle fibres. Then we have the endomysium, so endomysium is consist of the loose connective tissue and they additionally add up the strength of the muscle fibres. Endomysium are also connected with the perimysium for the strength, okay.

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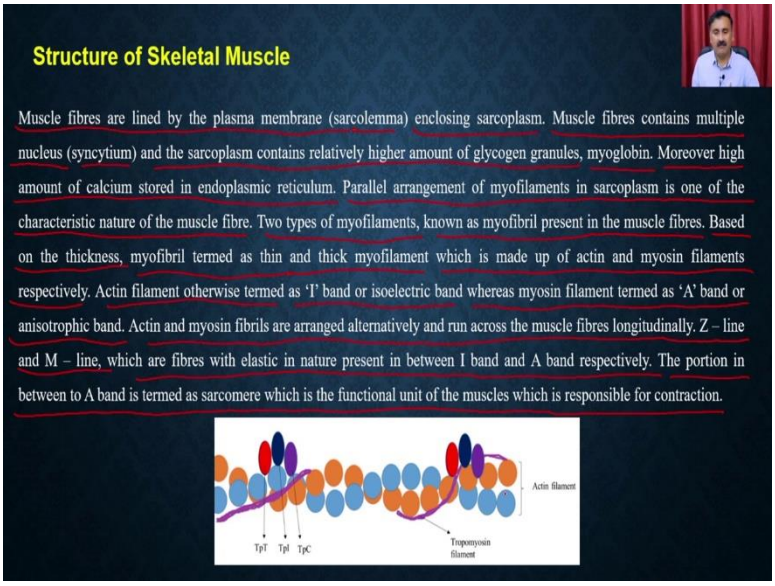

Now, apart from this you also going to have the, so all the individual muscle fibres are lined by the plasma membrane which is called as the sarcolemma, which is enclosing the sarcoplasm, okay. Muscle fibre contains the multiple nuclei or the syncytium and the sarcoplasm contain relatively high amount of the glycogen granules, myoglobin, okay. So

glycogen granules, that is actually going to provide the nutrition, and the myoglobin, which is actually going to provide the oxygen.

Moreover, the high amount of calcium stored into the endoplasmic reticulum. So, muscle cells are actually going to have the very high concentration of the calcium in their endoplasmic reticulum. Parallel arrangement of the myofilament in the sarcoplasm is one of the characteristic nature of the muscle fibres there are two types of myofilament known as the myofibril present in the muscle fibres.

Based on the thickness the myofibril termed as the thin as the thick myofilament which is made up of the actin and the myosin filaments, okay, so what you see here is the actin as well as the myosin. The actin filament otherwise termed as the 'I' band or the isoelectric band whereas the myosin filament are termed as the 'A' band or the anisotropic band.

Actin and the myosin filaments are arranged alternatively and run across the muscle fibre longitudinally into the Z-line and the M-line which are fibres with the elastic in nature present in between I band and the A band respectively. So, what you see here is the actin filament and you are also going to have the myosin filament which goes into the alternatively. The portion in between to A band is termed as the sarcomere which is a functional unit of the muscles which is responsible for the contractions. So, the individual skeleton muscles are actually going to have the different types of proteins which are actually going to per contribute in terms of the formation of the fibres or the other kinds of activities. So, let us see what are the different proteins which are responsible for the formation of the fibres.

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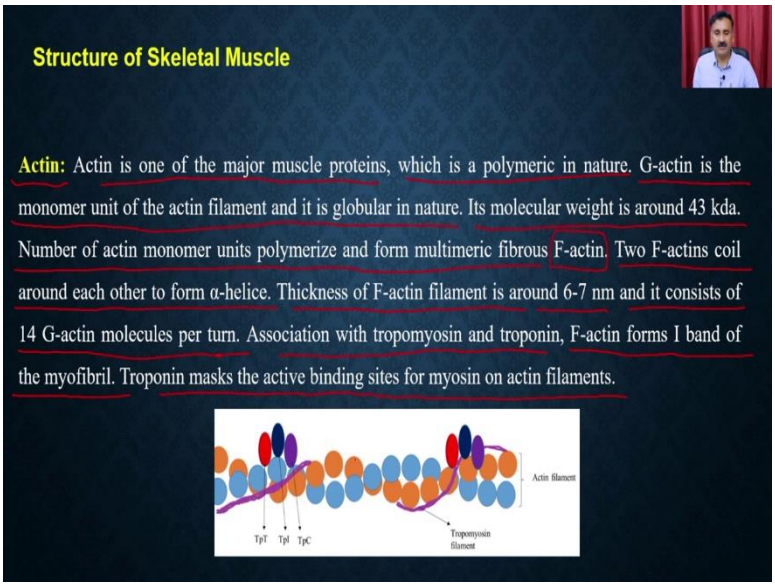

So, the first protein what you have is the actin protein. So, actin is one of the major muscle proteins which is polymeric in nature. So, the G-actin is the monomeric unit of the actin filament and it is globular in nature its molecular weight is approximately 43 kilo Dalton the number of actin monomer units polymerize and form the multimeric fibre which is called as the F-actin, so F-actin is called as the polymeric fibres or fibrous actin.

The two F-actin coiled around each other to form the alpha helices. So, this is what you see here is the one actin monomer, another actin monomer, and that is how they are actually forming a coiled coiled structure, so they are actually forming the helices. Thickness of the F-actin filament is approximately 6 to 7 nanometre and it consists of the 14 G-actin monomer or the molecule per turn.

Association with the tropomyosin and troponin F-actin forms the 'I' band of the myofibrils. Troponin masks the active binding site for the myosin on the actin filament. So, apart from this you also have the tropomyosin and troponin and that is actually going to help in terms of the muscle contractions.

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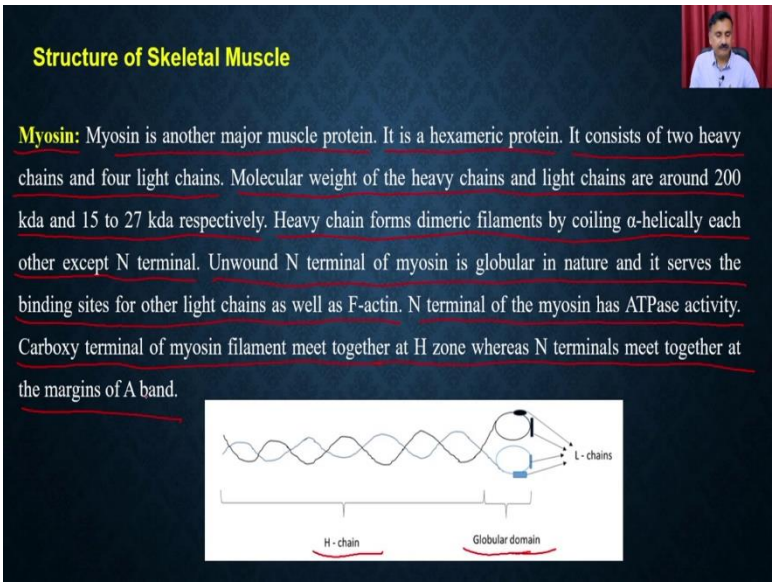

Then we have another protein which is called as the myosin. So, myosin is another major muscle. So, myosin is actually going to provide the driving, so myosin is called as the motor proteins, so they are actually going to provide the strength into the muscles and the actin is actually going to provide the strength. So, it is a hexameric protein, it consists of the two heavy chain and the four light chains. Molecular weight of the heavy chain and the light chains are approximately 200 kilo Dalton and 15 to 27 kilo Dalton respectively.

Heavy chain forms the dimeric filament by coiled, by coiling alpha helically each other except the N terminal, so this is what you see here is that the myosin filaments. So, you have the myosin filament where you have the globular domain and then you have the H chain. So, this is a heavy chain what you have, and these are the light chains what you have.

The unbound N terminal of the myosin is globular in nature and it serves as the binding site for another light chain as well as the F -actin. So, these are actually the globular domain which are actually going to bind the actin fibres and they are also going to bind the light chains. The N terminal of the myosin has the ATPase activity, so this is the portion which actually going to have the ATPase activity whereas the carboxy terminal of the myofilament meet together at the H zone whereas the n terminals meet together at the margin of the A band.

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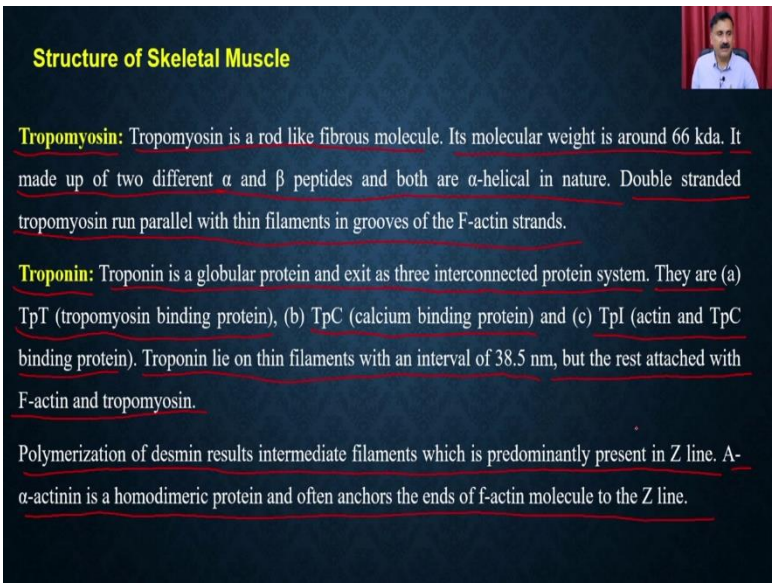

Apart from that you also have the tropomyosin and troponin. So, tropomyosin is a rod-like fibrous protein molecule. Its molecular weight is approximately 66 kilo dalton. It made up of the two alpha, two different alpha and beta peptides and for both are alpha helical in nature. The double stranded tropomyosin runs parallel with the thin fibre in the grooves of the F-actin strands.

Then we have the troponin. Troponin is a globular protein and it exists as three interconnected protein system. They are TpT like tropomyosin binding protein, TpC which is calcium binding protein, and the TpI which is the actin and the TpC binding proteins. Troponin lies on the thin filament with an interval of the 38.5 nanometer, but the rest attached with the F-actin and the tropomyosin.

Polymerization of the desmin results intermediate filament which is predominantly present in the Z-line. And A alpha actinin is a homodimenic protein and often anchors the end of the f - actin into the Z-line. So, these are the scalp, the must, the proteins which are actually going to contribute into the formation of the fibres and that is how these fibres are actually going to perform the muscles contractions.

But as I said you know, the skeleton muscles are voluntary muscles, so skeletal muscles should actually get the signal from the brain, and that is why these skeletal muscles are also going to have the well-developed, the neural muscular junctions.

Neuromuscular junction is a place where actually the neurons are actually going to communicate with the muscles and that is how they are actually going to give the signal to the muscles, whether they are supposed to contract or whether they are supposed to relax, so they are actually going to give the signal using the neuromuscular junctions.

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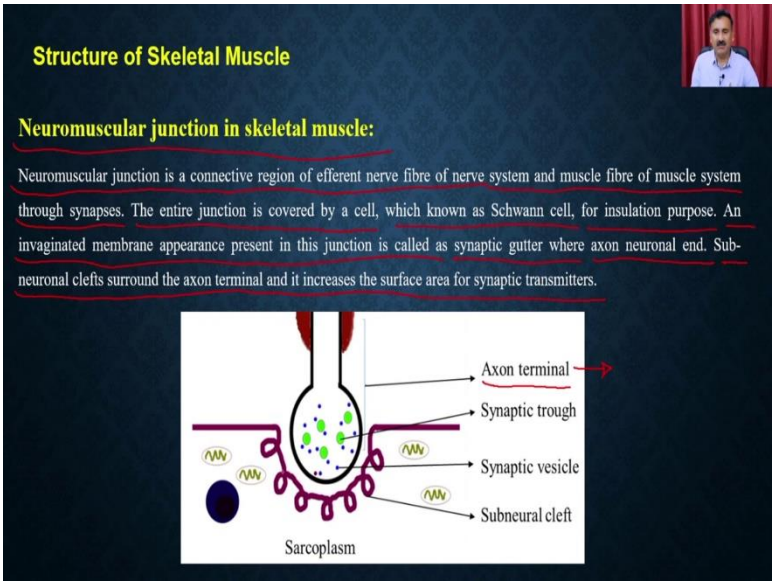

So, the neuromuscular junction in these skeletal muscles is look like something like this, okay, where you have the muscle cells and these are the axons, okay, so exon is a part of the neurons, okay. This is anyway we are going to discuss when we are going to discuss about the nervous systems.

So, the neuromuscular junction is a connective region of the efferent nerve fibre of the nervous system and the muscle fibre of the muscular system through the synapses. So, this the region where you they both are going to cross talk to each other, that is how they are actually going to provide the neurotransmitters and these neurotransmitters are going to give

the signal to the muscles are called as the synapses. These are the places where you are actually going to have the communications.

The entire junction is covered by a cell which is called as the Schwann cells for the insulation purposes. So, the Schwann cells are going to be present here and these Schwann cells are actually going to make the whole synapse as the insulated. An invaginated membrane, appearance present in this junction is called as the synaptic gutter where the axon neurons, axonal neuron ends. The sub-neural clefts around the axon terminal and it increases the surface area for the synaptic transmitters. So, this is what you see here is the terminal portion of the axon and that is going to communicate with the lower, in lowering the muscle cells and that is how they are actually going to communicate.

In many of these cases or many of the neural diseases, this communication is going to be broken. And in that case, it is actually not, even the muscle cells are completely healthy they will not going to get any kind of contraction and that is the portion that is the disease which when it is called as the paralysis, then the paralysis the brain is not been able to communicate with the muscle cell and that is why you cannot move your hand or legs or something like that. Now, let us move on to the next muscles type.

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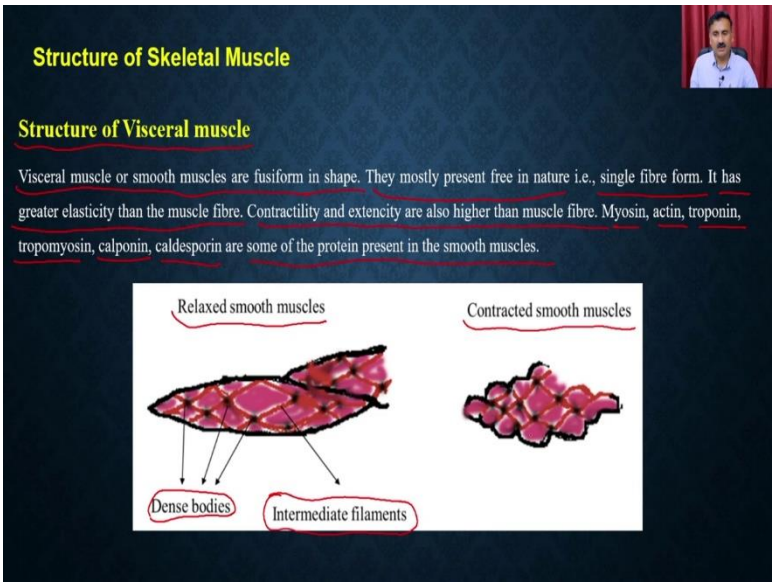

So, the next muscle type is called as the visceral type, okay, so these are the visceral muscles. So, the structure of the visceral muscles, so visceral muscles or the smooth muscles are fusiform in shape. So, these are the visceral muscles and they are smooth in shape. So, these are the relaxed smooth muscles whereas this is a contracted smooth muscle. They mostly present free in nature that is the single fibre form. And it has the greater elasticity than the

muscle fibre. Contractility and extencity are also higher than the muscle fibres. The myosin, actin, troponin, tropomyosin, calponin, caldesporin are some of the protein which are present in the smooth muscle cells.

So, what you see here is they are actually going to have the dense bodies in a relaxed mode, and then they are also going to have the intermediate filaments. So, intermediate filaments are going to be formed by the some of these muscles proteins and they are actually going to be smooth muscles. When they contract these are the contracted muscles, okay, so the structure of the contracting muscles.

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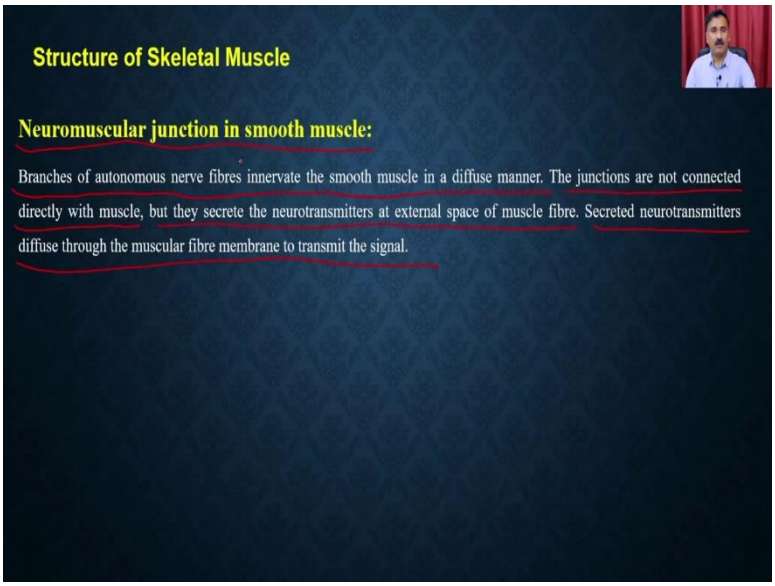

Neuromuscular junctions, so although they are not been voluntarily being controlled but they still require the signal from the neural and nervous systems. So, the branches of the autonomous nervous fibres intervene the smooth muscles in a diffuse manner. The junctions are not connected directly with the muscles but they secrete the neurotransmitter at the external space of the muscle fibre. Secreted neurotransmitter diffuses through the muscle fibre membrane to transmit the signal.

So, neuromuscular junction in the smooth muscles is actually not going to be voluntarily being controlled. So, they are not going to be voluntarily being controlled but there are and they are not directly connected to the smooth muscle cells also, what they will do is the neural cells are actually going to secrete the neurotransmitters and that is how they are actually going to give the signal to the smooth muscles to go for the contraction or the relaxations.

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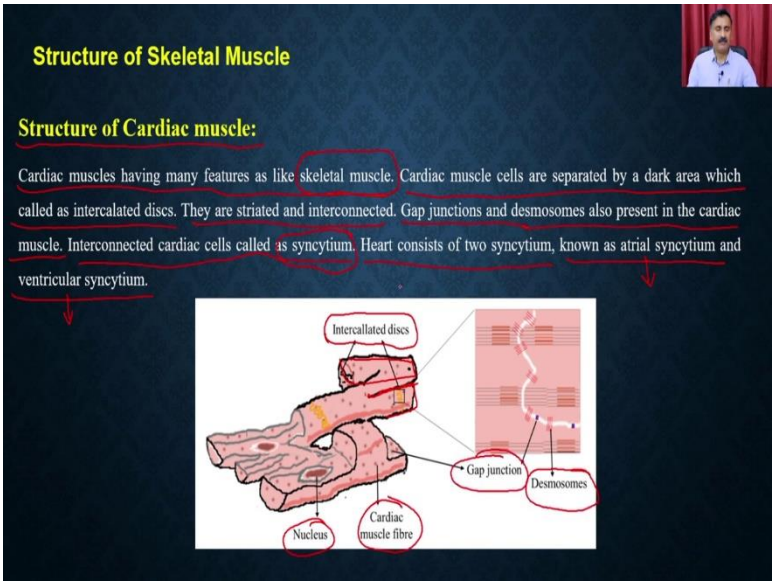

Now, let us move to the next part, the next part is the structure of the cardiac muscles. So, the cardiac muscles are having feature like the skeletal muscles, so they are actually going to have the hybrid features. So, as far as the functionality is concerned, they are actually going to follow the features of the skeletal muscles, but as far as the control is concerned, they are actually going to have the features of the smooth muscles.

Cardiac muscles are separated by a dark area which is called as the intercalated disc. So, cardiac muscles are going to be separated from each other. So, this is the cardiac, one cardiac fibres, and this is another cardiac fibre, and this is going to be separated from a intercalated disc. They are striped and the interconnected, so these are the different fibres which are interconnected. Just like skeletal muscles, they are also striped and interconnected.

The gap junction and the desmosomes are also present in the cardiac muscles. And the interconnected cardiac muscle cells are called as syncytium, okay, so this means they are actually going to have diffuse cells. The heart consists of the two different types of syncytium known as the arterial syncytium as well as the ventricular syncytium.

So, you can actually have the two different types of cardiac muscles or the cardiac muscles will have the two different types of syncytium's, either it can be arterial syncytium, so that will be present in the arterial region and you can also have the ventricular syncytium which is going to be present in the ventricles.

So, this is just a description about the structure. So, you can have the nucleus, you can have the fibres, and these fibres are actually going to be separated from the intercalated disc. And

if you see the structures, they are also going to have the desmosomes and the gap junctions and all that.

So, with this brief discussion about the machinery what is going to be responsible for the contraction as well as the relaxation in the muscular system. So, what we have discussed? We have discussed about the cardiac muscles, we have discussed about the smooth muscles, and then we also discussed about the skeletal muscles, and within the skeletal muscles, we have discussed about the different types of proteins which are responsible for making the muscle fibres, such as the actin fibres, muscular, the myosin fibres, tropomyosin, and the troponin, and all these proteins are actually going to function in coordination with each other and that is how you are actually going to perform the muscle contractions.

So, in our subsequent lecture we are actually going to discuss about the mechanism of the muscle contractions and how the muscle contraction is happening in the smooth muscles? and how the muscle contraction is happening in the skeletal muscles? and so on. So, with this I would like to conclude my lecture here, thank you.