Biomechanics
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Lecture - 63
Tissues and its Constituents

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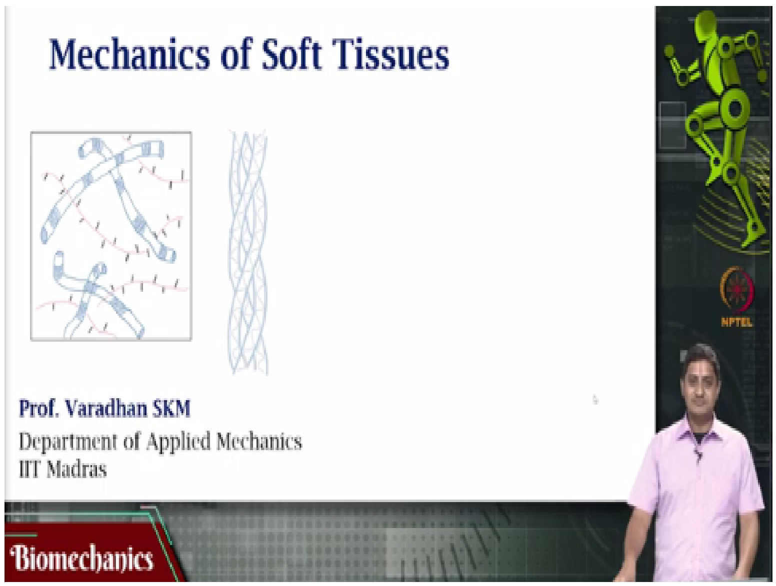

Welcome to this video on biomechanics. In the past week we looked at biomechanics of bone which can be considered to be a hard tissue. In this week we discuss the biomechanics of soft tissues. So, we begin this discussion in this video. So, in the picture you see some examples of soft tissues the triple helix structure of collagen for example.

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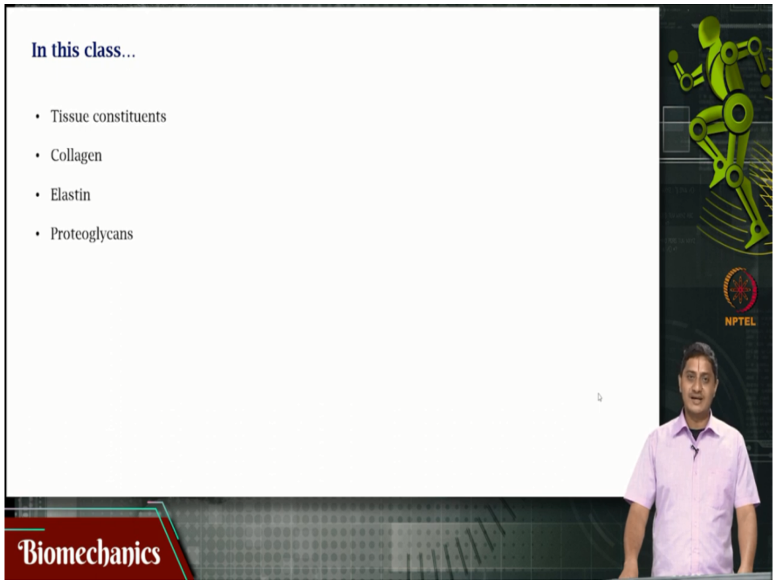

In this video we will be looking at various constituents of tissues, we will be looking at collagen, how much collagen is present in each type of biological material, elastin, how much elastin is present in various types of biological materials and proteoglycans. So, what are soft tissues?

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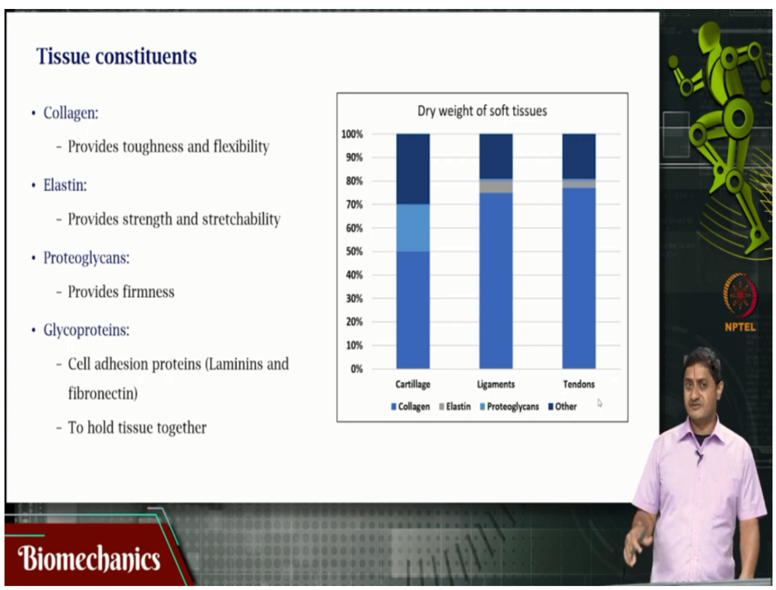

Different soft tissues exist ligaments, tendons, cartilage and all of this are composed of collagen, elastin, proteoglycans and other glycoproteins and they have different functions. The important function of collagen is to provide strength or toughness and flexibility, so collagen provides a flexibility. Elastin provides strength and stretchability, like elastic the word elastin similar to elastic. So, it is able to stretch stretchability.

Proteoglycans provides firmness and then there are glycoproteins like laminins and fibronectin that hold tissue together they are also called as cell adhesion proteins. Adhesion means what addition means to adhere together, to stick together to hold on together. So, cartilage for example has about 20 30 percent collagen about 10 20 percent proteoglycans and some about 50 percent cartilage for example has about 50 percent collagen.

And about 20 percent proteoglycans, ligaments have about 60 70 percent collagen and maybe even more. Tendons also have a comparable amount of collagen but as we will see in future slides although the amount of collagen is similar between ligaments and tendons it is a structure that differentiates the function, we will discuss that in a little bit.

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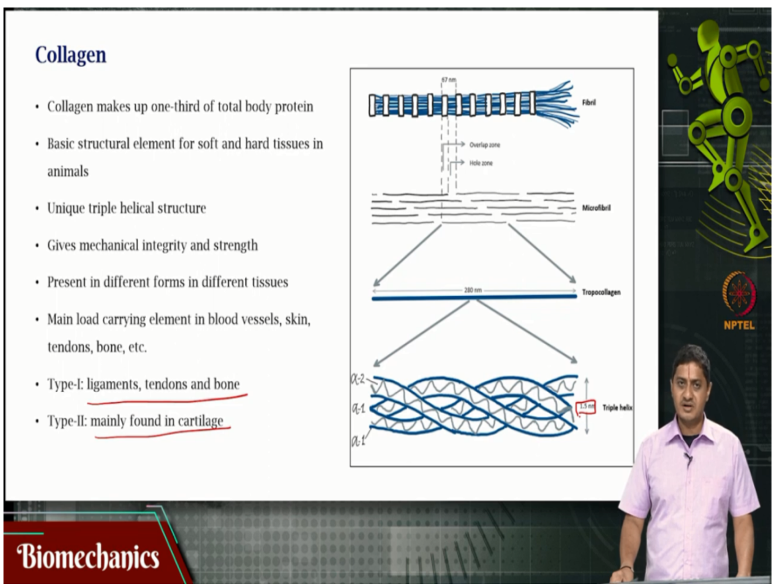

So, collagen is one of the most abundant protein in the body, is present throughout the body is present everywhere practically. So, it makes up about one third of the total amount of protein in the body, it is the basic structural element for both soft tissues and hard tissues you may think that it is not forming part of bones for example. It does actually collagen forms a very important part of bones and how they are aligned to the bone axis determines the strength of the bones.

Something that we; have not discussed in the bone lecture. But something that we can now mention collagen and how they are aligned to the bone affects the strength of the bone. So, it forms a structural element for both soft tissues and hard tissues and it has a unique triple helical structure, it gives a mechanical integrity and mechanical strength and it performs the crucial role of load carrying in you know in blood vessels, in skin, in bones, in tendons.

And turns out that it comes in many types only type 1 and 2 are mentioned but it also comes in other types not mentioned here. Type 1 is found in abundance in ligaments tendons and bone, type 2 is mainly found in cartilage. And here the size-based analysis of collagen under structure are discussed, so if you have a fibril. So, if you take fibril of a tendon and you subjected to microscopy what you will see is micro fibred that are at the nanometre resolution or hundreds of nanometre resolution.

Then you see tropocollagen and then you have the unique triple helix structure of collagen at a resolution of one and half nanometre. So, a different scale you can observe the function of the collagen fibres and it turns out their alignment. And how much crimp they have defines the function of the tissue in which they are present.

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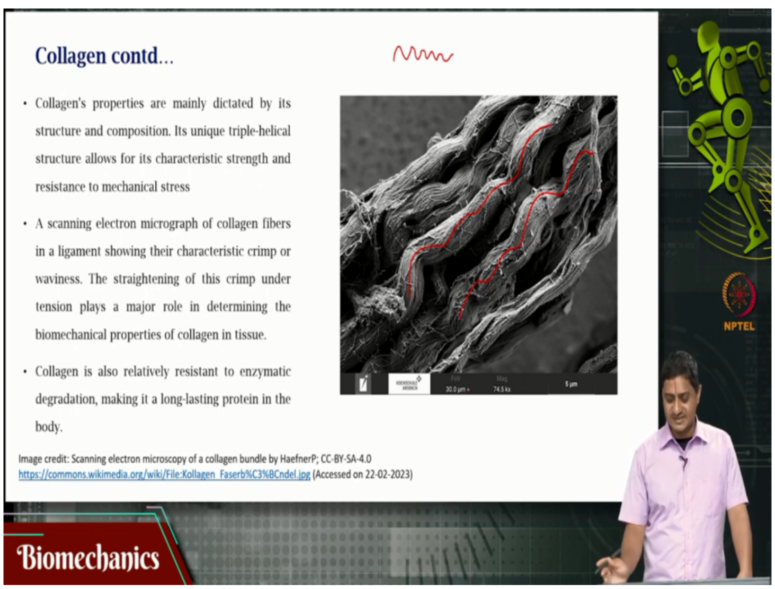

As with all the other biological materials that we have discussed the properties of collagen are determined by the structure and composition. Remember in the beginning of the course we said that we are mostly interested in the structure function relationships. We are mostly interested in documenting and discussing the relationship between structure and function, between anatomy and physiology. Mostly it turns out that function determine structure in many cases.

We discuss function defines form or function dictates from something that we have discussed. In some cases, form also dictates function so, both of these are present in different cases but we have discussed some of these previously. So, likewise for collage and also the properties are determined by structure and composition it has a unique triple helical structure. That allows it the unique characteristic strength and resistance to mechanical stress.

So, what is present in here is an electron micrograph of collagen fibres in a ligament and you can see that characteristic waviness, crimp you can see here waviness or crimp characteristic it is unique for collagen. The straightening of this waviness or crimp; under stress place and important role play, so, crucial role in the biomechanics are the mechanical property of the tissue in which collagen is present.

And collagen is present in many different tissues we just discussed that it is present in tendons, it is present in ligaments, it is present in cartilage, it is present practically everywhere many different tissues. It is present in many different tissues because one of the most abundant proteins is it not. And it turns out that collagen is also resistant to degradation by enzymes. So, it is one of the longest lasting proteins in the human body. So, it is not something that is degraded by enzyme so easily something to keep in mind.

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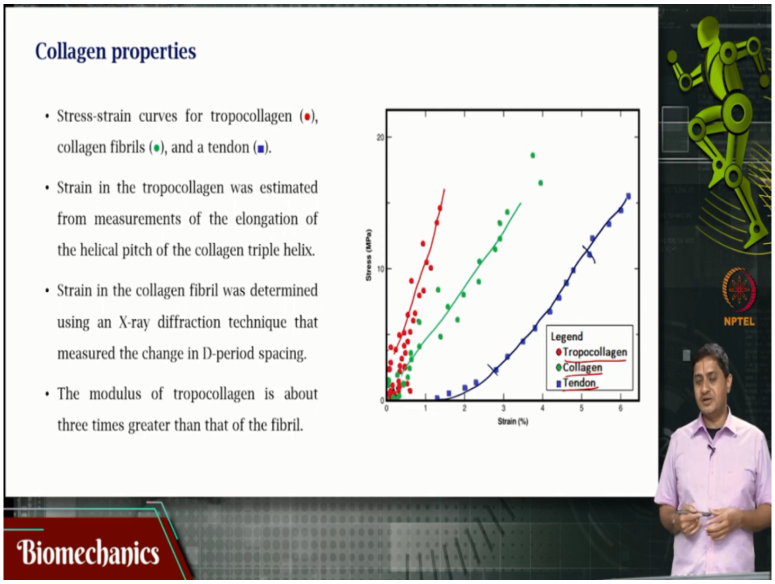

Here what is shown is the stress strain curve for tropocollagen, collagen and tendon. Of course, these estimates are by measurements of elongation of helical pitch of the collagen triple helix in the tropocollagen. And in the collagen fibril this was determined using an X-ray diffraction technique and what you observe is that in general suppose I am performing a linear regression I get a line like that for tropocollagen and a line like that for collagen suppose I find the slope.

Suppose I try to actually this is not exactly the modulus but suppose I was to linearize this and find the slope or whatever is an equivalent of this of the modulus. Then you find that the modulus of tropocollagen is about three times as much as the modulus of the collagen fibre and in blue you see the of course by the way in blue what you see is not a linear curve, so this is for a tendon.

So, that is for example at some part about maybe from here to about here maybe somewhere here maybe a linearized version. But clearly in this region the modulus is not linear, we will discuss this in future slides and in future classes. Of course, the tendon stress strain curve does not exactly resemble or relate easily with collagen because the tendon is composed not just of collagen there are other things, there are other components of the tendon tissue. So, the whole tissue property is a function of many of these properties.

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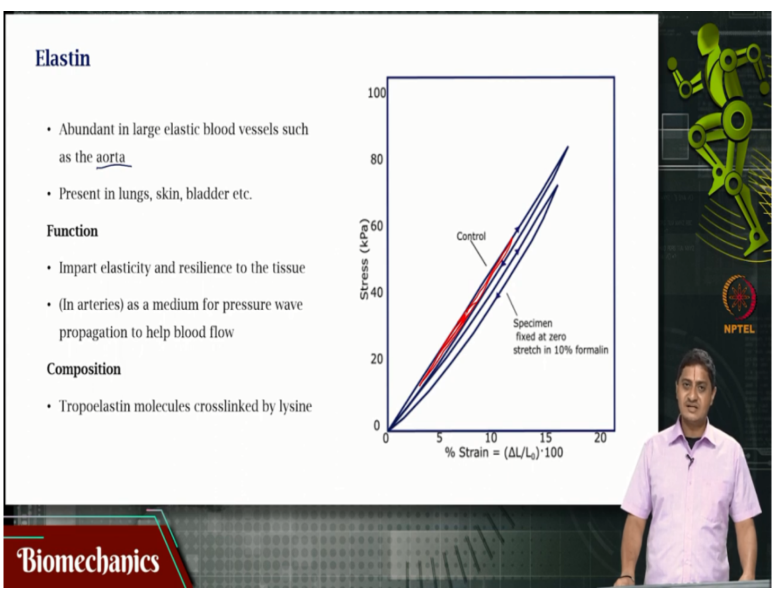

Elastin is found in abundance in blood vessels that are elastic. In particular in arteries will have to expand a lot, for example the aorta which is the biggest artery aorta is the biggest artery it undergoes a lot of defamation a huge amount of deformation. That is when the heart is pumping blood pure blood through the aorta it expands a lot. Yet when it is receiving when the heart is receiving impure blood or when there is no pumping through aorta, aortic wall is closed for example aorta is relatively small.

So, it keeps expanding, so that happens every time the heart pumps so this expansion that is because of the presence of elastin with this it is present in lungs, skin, bladder and many other tissues. What is its function? Elasticity, resilience and elasticity to the tissue so last in the name sounds. Now gives a clue to its important function which is elasticity it imparts or it provides with elasticity.

In arteries an important function is to allow for the pressure wave propagation and blood flow. So, it is composed of tropoelastin molecules that are cross linked by another protein called lysine. Here what is plotted is a stress strain curve and of course what you immediately realize is that the loading and unloading curves are not the same. Of course, we cannot expect the loading and unloading curves to be similar that is indeed an area, that area.

For example, that area that is now shaded in red for example that is this area that is now shaded in red that is the hysteresis loop for this essentially because of the viscoelastic nature of this tissue. In the previous week we saw what is viscoelasticity and developed and discussed some models of viscoelasticity. Remember bone is viscoelastic and many other tissues and materials biomaterials or biological materials in the human body are viscoelastic. Likewise, elastin is also viscoelastic as you will see from this stress strain curve.

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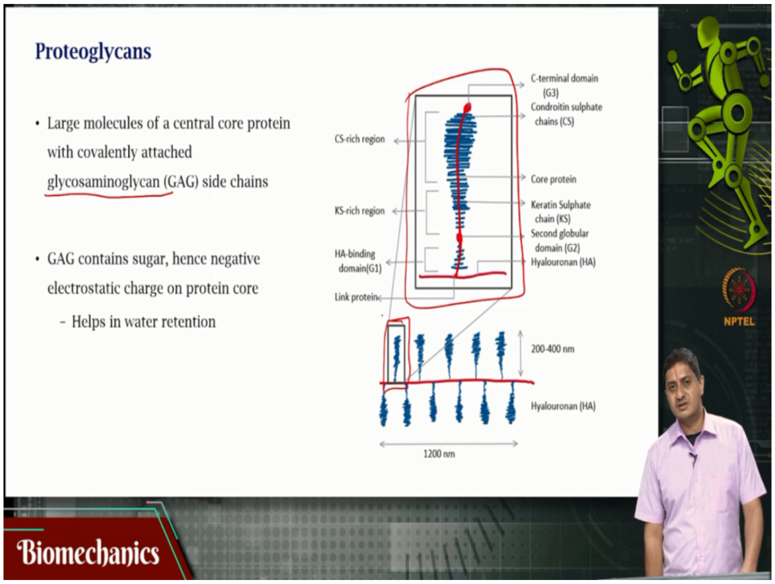

Proteoglycans are huge or large molecules that are composed of one central core protein that is shown in red here for example, this is the central core protein that is marked in red here with what are called as GAG side chain, GAG means glycosaminoglycan side chain with which they have covalent bonds, these are all the side chains that are now marked in blue. This glycosaminoglycan contains sugar because of this there is at negative charge on the protein core.

This helps to retain water and you see many of these, in a proteoglycan like this; what is shown here is only the zoomed-out version of just one of this. Again, this composition and structure contributes to its important function.

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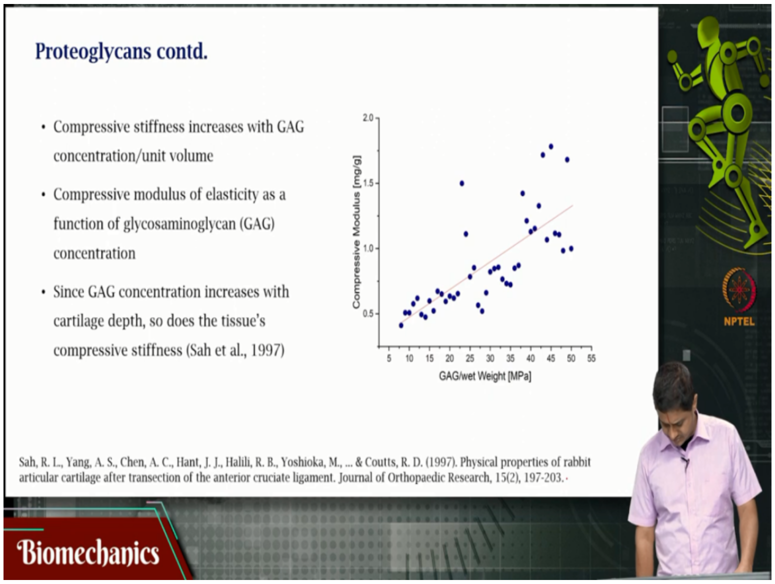

And it turns out that compressive stiffness increases with the amount of GAG concentration per unit volume of course and modulus of elasticity as a function of the concentration of GAG. If you plot, we see that as GAG increases the modulus keeps increasing you can try to model this and you see in general as the GAG concentration increases the strength a compressive modulus increases.

And it turns out that GAG concentration in general increases with the depth of cartilage. So, tissues compressive stiffness increases with the GAG concentration and the depth of the concentration in cartilage or how much cartilage **(()) (16:45).**

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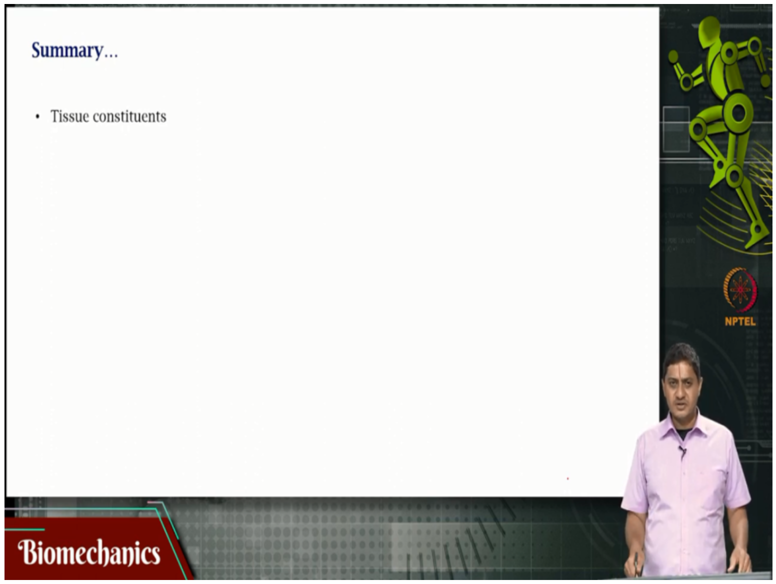

So, in this video we looked at some of the important constituents of soft tissues, specifically we looked at collagen and its unique characteristics. Elastin and its properties and proteoglycans and how concentration of the GAG in proteoglycans suffixes properties. Remember throughout we have been discussing about structure function relationships, composition function relationships, so that theme in the course will continue. So, with this we come to the end of this video, thank you very much for your attention.