Biomechanics
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Lecture - 52
Bone Microstructure and Cells

Vanakkam. Welcome to this video on biomechanics. In this video, we will be continuing our discussion on mechanics of biological materials.

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In the previous video, we saw the types of tissues based on material property and defend a special type of tissue whose property may change based on whether it is active or not and some examples of hard and soft tissues. In this video, we will be looking at bone and its microstructure, the types of cells within the bone and a special system that is found in the bone called as a Haversian system.

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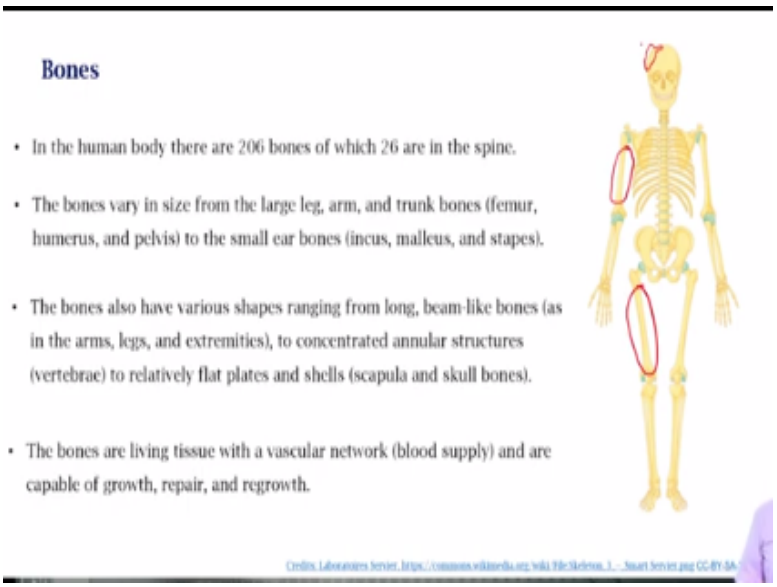

So what gives structure to the human body? That is the bone or the set of bones or the skeletal system. This skeleton is what gives structure to the bone. If one or a few of these bones are not there, the organs within that part of the body will just look like a bag, they will have no structure. So the underlying rigid body within any part of the body right is the bone. So that which gives structure to the human body is the skeletal system or the bones.

There are 206 bones within the human body. Of these 26 bones are present in the spine alone and they are of different types. They come in various sizes and shapes, right? Some of these are long and hollow bones. For example femur, long bone, this is a very long bone. Practically it can be modeled as a cylinder although not exactly, you can model it as a cylinder. It is a long bone.

There are other similar bones. For example, this is the humerus right, an another long bone. So essentially the bones of the limbs are long, hollow bones mostly. So that is you know humerus, radius, ulna, femur, tibia, fibula are all long bones, right? And then the bones that form the trunk or the ribs, right?

And then you have irregularly shaped bones, know very special bones that are not you know that cannot be simply modeled using such a simple tricks like modelled as a cylinder type of bones, irregularly shaped bones. For example, pelvis. It is not exactly a bone that can be modeled as a simple geometrical structure. And then there are these

very special bones within the ear that are performing specialized functions, you know incus, malleus and stapes, specialized bones.

Other shapes right, beam like bones as in the arms and legs are of course, we have discussed. Then annular structures you know concentrated structures that have a hole in the middle, like the vertebra. We discussed the function of the vertebra, their function is to pass the spinal cord which is a bundle of nerves safely through a strong bony structure so that those bundle of nerves are not damaged.

This is an important or critical function of the spinal cord of the vertebral column. I said this, right? So these are concentrated annular structures such as vertebra and then relatively flat bones. For example, scapula and bones in the skull are relatively flat that are sutured together. It is a miracle how this could even happen. But it happens. These bones are not actually fused when the human is born.

So when an infant is born, or when a neonate is just born, these bones are not fused together. So these are bones that can move relative to each other. Take a couple of years for this fusing to happen, for the suturing to happen. It is such an amazing feat by evolution for this to happen, right? So these flat bones are tied together and kept together. There is very little or no articulation in the skull of course, but that is beside the point.

Here we are discussing shapes and sizes and the material property of bone, right? So these flat shaped bones, flat plates are joined or fused together to form the skull, whose essential functionality is to protect the brain right, in the absence of the skull, then the brain cannot be protected. So very crucial function that it has, the skull bones. And these are not plastic like nonliving tissues.

They are living tissue that receive blood supply and undergo metabolic changes, as we will see actually undergo growth and degrowth, as we will see in future slides or future videos. So these are living tissues that undergo metabolism and that receive inputs, that receive nutrients through the vascular network and also you know excrete waste. So they do, they are like any other tissue.

They are not passive plastic like materials. These are active tissues. So they are capable of, they are not just capable of growth, repair and regrowth, they almost always keep on growing, repairing and regrowing itself. Of course, as a function of age, the ability of the bone to repair themselves reduces. That would be obvious, although it is not obvious. I mean one would, once I say it, it is obvious to you.

Yet it is when you observe you will see that children or those in their adolescence or early 20s are more likely to heal their bones faster post fracture. Suppose someone falls and there is a fracture, there is a greater likelihood that they will recover much faster when compared with an older adult, for example, someone who is more than 60 years old, although even in the older adults, there is an ability for the bone to repair and regrow itself.

But this ability is compromised or the rate at which this growth happens is reduced. That starts to happen at about 30, 35 years of age and then it keeps on deteriorating, right? So at a young age, there is a greater propensity for the system to regenerate itself, to repair itself, to regrow itself, which is also the reason why children fall so much and quite miraculously recover.

So you will be observing, wow, they are recovering. That is because by design, they are in a position to recover. So it is not exactly a miracle although from our point of view, it will appear like a miracle. But from the material property point of view and their ability for regeneration and regrowth point of view, it is not exactly a miracle, it is a well-known researched fact.

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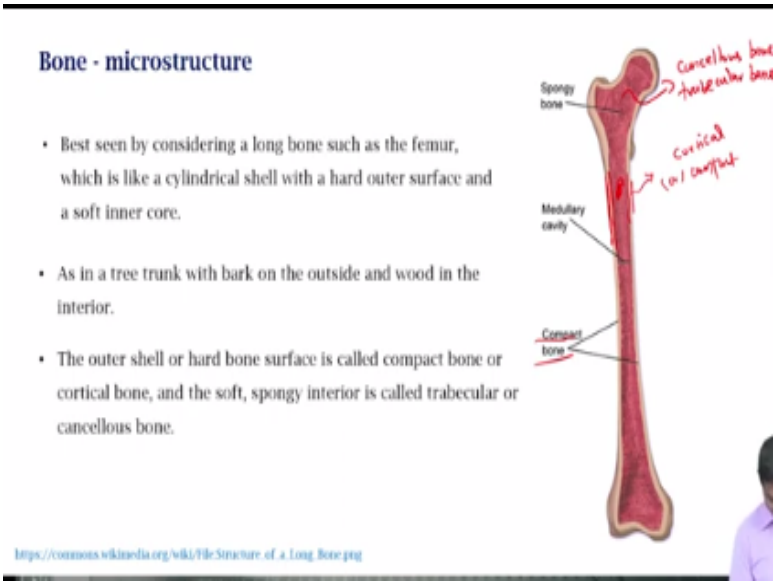

So when we look at a bone, we take an example of a long bone, cylindrical bone like a femur for example. So here is a femur which I told earlier can be modeled as a cylinder, which is more like a cylindrical shell with a hard outer surface. So there is a hard, very hard outer surface, that has an amount of thickness for this outer surface right, that is the hard outer surface and a relatively spongy, soft inner core like you have a tree with a bark on the outside and inner wooden component, right?

The outer shell or the hard bone is called, this is called cortical bone, cortical or compact bone. Here it is mentioned as compact. The other name for this is cortical, not to be confused with the neural term cortical which is referring to the cortex in the brain. Here cortical bone means the outer strong compact bone, okay? The bone that is found in the middle the soft spongy bone, sponge like bone is called cancellous bone. This part is called cancellous bone or trabecular bone.

This is called cancellous bone or rubber colored book. Remember, when we discuss cortical bone and cancellous bone, it is not like these are two different bones. For example, it is not like the femur is a cortical bone and the finger bone is a cancellous bone. No. Within each of this there is a hard outer shell. Within the femur there is a hard outer shell which is the cortical bone and within the femur there is also the cancellous bone that is the trabecular bone, okay?

These are types of bone found within the same bone okay, something to keep in mind. That is compact bone or cortical bone and cancellous bone or trabecular bone are

found within the same bone. These are two types of materials found within the same bone.

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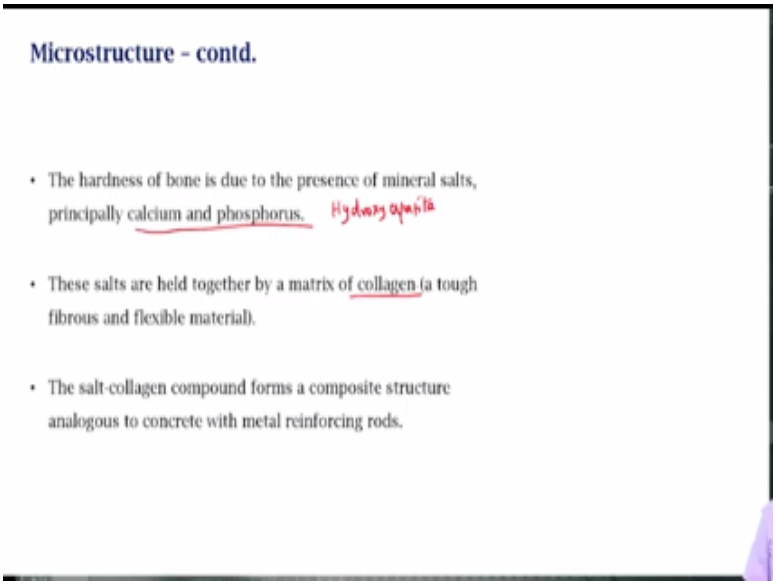

A question that arises is why do you have to have this arrangement? Why do you need a compact bone or a cortical bone and a spongy cancellous bone? Why not simply have the cortical bone everywhere? That is an interesting question. We will have to answer this question at some point. We will answer this question in a future video. For now let us continue because I am still curious.

But let us retain this curiosity, let us retain this suspense for some more time. Where is this hardness of the bone coming from? That is coming from inorganic materials such as calcium and phosphorus, from a material called hydroxyapatite. Hydroxyapatite is a material, an inorganic material that is responsible for the hardness that you find in the bone, right?

These inorganic materials are held together by an organic matrix by a organic material called collagen, matrix of collagen, a matrix of organic material, which is a tough fibrous but flexible material. So bone has both of this, both hydroxyapatite both inorganic and organic material, both hydroxyapatite and collagen, right?

This combination between the hard hydroxyapatite and the soft collagen fibers is similar to the composite structure that you can find in concrete with metal reinforcing rods. So you have reinforced concrete, right? Its strength is coming not merely from

the cement or not merely from the rods, it is coming from the interaction of these two. So essentially bone is a composite material.

Its properties are coming from both of these, coming from the hard inorganic material that is hydroxyapatite and relatively softer fibrous and flexible material like collagen, just organic material. These together produce this magic of strength that forms the bone.

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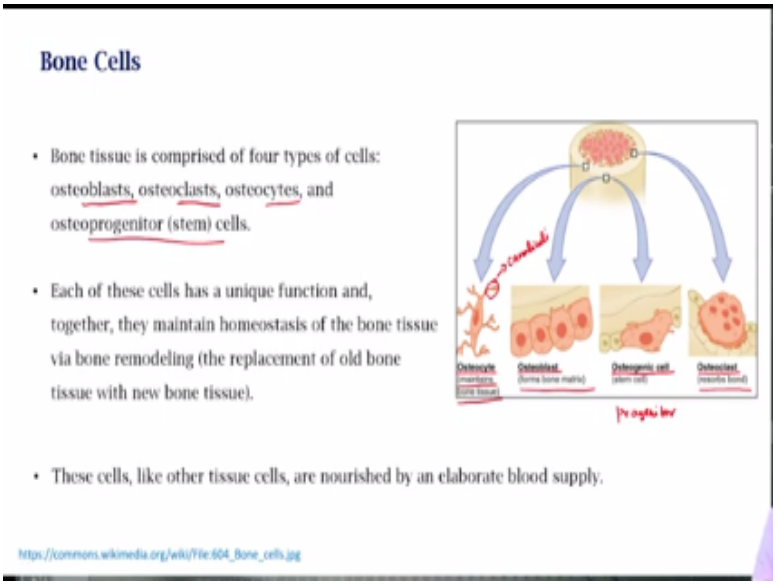

Bone has four types of cells. The so called osteoblasts, osteoclasts, osteocytes, and the osteoprogenitor or the stem cells, okay? These four types of cells, each of them have a unique function. And together they function together to maintain the homeostasis of the bone via remodeling of the bone, replacement of old bone tissue with a new bone tissue. Remember, what is homeostasis?

If you still do not know what is homeostasis please check what is homeostasis, okay? And all of these cells are nourished by blood supply. Again these are not material that are plastic like or inactive or passive that do not require any type of nourishment. These are like any other cell that requires nourishment and that also excrete waste and secrete a variety of materials.

Osteoblasts are cuboid like cells that are packed very densely together and are capable of generating or producing or secreting various types of materials including collagen, various types of protein and inorganic material. So together all this material form the

matrix that is called as the bone that is together forming the bone. So osteoblasts forms the, or builds the bone matrix.

It forms the matrix of the bone or it builds the bone matrix. Osteocytes are osteoblasts in their previous lives or in other words osteoblasts when they are surrounded by the material that they secrete, they become osteocytes. Osteoblasts divide and continue to grow, but osteocytes do not divide. So osteocytes are osteoblasts that are surrounded by the material, fully surrounded by the material that they secrete.

These form a very large proportion of the bone tissue, osteocytes, and the material that they secrete and the material that they are surrounded with form a very large proportion of the bone tissue. This is what maintains the bone tissue and in other words, although they are not like osteoblasts in which they secrete the materials, osteoblasts secrete these materials, osteocytes do not secrete these materials, but they are surrounded by the material that they secrete and they live for many years.

They may have a long life like 20 years 25 years like that. Osteocytes also communicate with other cells by the branches that they have. They are called canaliculi, special form of communication channels through which they communicate with other cells, they are called canaliculi. Then you have a special type of cell called osteogenic cell or osteoprogenitor cell.

Progenitor means something that is going to generate new cells, stem cells. So these stem cells give rise to osteoblasts which then go on to become the osteocytes. So these osteoprogenitor cells are the stem cells from which osteoblasts start growing. So they are the precursor to the osteoblasts and the osteocytes, right? Then, you have a special type of cell called as osteoclasts.

Please remember the distinction between blasts and clasts. Blast is what spreads around. Clast is what absorbs, okay? Osteoclasts are special type of bone cells that are originating from macrophages and monocytes, right or other stem cells other than the osteoprogenitor cells. From the osteoprogenitor cells, we are going to have osteoblasts and osteocytes. Osteoclasts are originating from other cells, other progenitor cells.

And their function is to break down old bones, to break down unused cells. So to reabsorb, to recycle, to take unused things or the unused cells and dissolve them and destroy them. So in a way osteoblasts are more like the cells from which generation or growth or expansion happens. Osteoclasts are those in which dissolution, death or a form of reabsorption happens.

So these are having two opposite functions. Remember that osteoclasts are not originating from the osteoprogenitor cells. Osteoprogenitor cells give rise only to the osteoblasts and osteocytes. Osteoclasts are originating from other cells.

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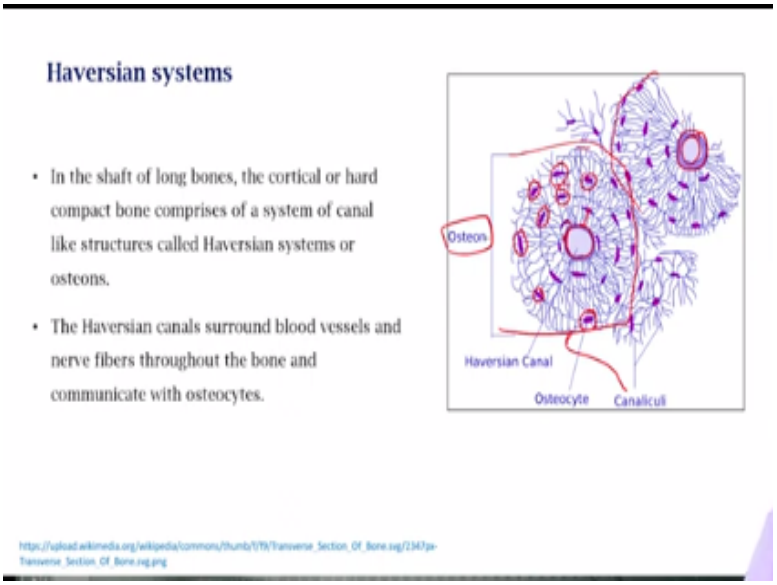

So in long bones such as the femur for example, the hard bone or the cortical or the compact bone has a system of canal like structures called Haversian systems or osteons. What are these? These are essentially osteocytes, here is an osteocyte, here is an osteocyte, here is an osteocyte, here is an osteocyte, and what are those branches surrounding this osteocytes?

Those are all the various canaliculi. For each of these osteocyte there is a canaliculi. This is the canaliculi of this osteocyte, right? The osteocyte and all the canaliculi together they form a network and in the center, you have what is called as a Haversian canal, right? These Haversian canals surround the blood vessels and the neurons or the nerve fibers throughout the bone.

And so they are the means through which communication with these osteocytes, all the osteocytes that are surrounding this canal happens. This unit, sub unit is called as an osteon. And then here is another osteon with its own Haversian system. So and there are many such Haversian systems within each compact or cortical bone of interest.

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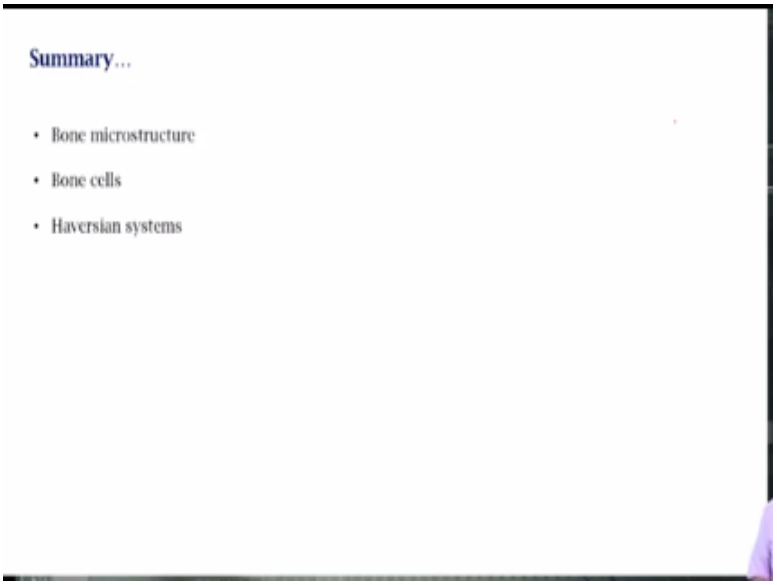

So in this video, we looked at the microstructure of a bone. We looked at what is compact bone, what is cancellous bone or cortical bone and trabecular bone. We looked at the types of bone cells. What are the types of bone cells? Osteoblasts, which are the cells that divide and grow on to become the matured bone cells or the osteocytes. Osteocytes are those that communicate with other osteocytes through canaliculi, right?

And osteoprogenitor cells are the stem cells from which osteoblasts and osteocytes further develop. And then osteoclasts that have a special stem cell from which it grows and whose job it is to digest to reabsorb and to destroy and use our old bone cells, right. So we saw these types of bone cells. And we saw the Haversian system, the canal that is communicating with the osteocytes that surround this, right.

With this, we come to the end of this video. Thank you very much for your attention.