Animal Physiology
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Lecture - 10
Bone & Cartilage – II

Welcome back to the 5th class of the 2nd week. So, in the previous class we talked about what cartilage is, the cells which constitute cartilage, the chondrocyte and the matrix material which is proteoglycan which is the chondroitin sulphate forming composites with the proteins and other fibers in and around it from the proteoglycan, then we talked about that two mechanisms by which the cartilage cells grows.

One is interstitial growth what the cartilage individual cartilage cells expand or divide in a confine area and secrete more and more matrix material proteoglycans and increases the volume by now putting pressure. The second one we talked about the appositional growth, where we talked about where in the close proximity of the chondrocytes, there are fibroblasts which get transformed into chondrocytes and this newer fibro, a newer chondrocytes which differentiated from the fibroblast secrete matrix material and expand the matrix of the cartilage.

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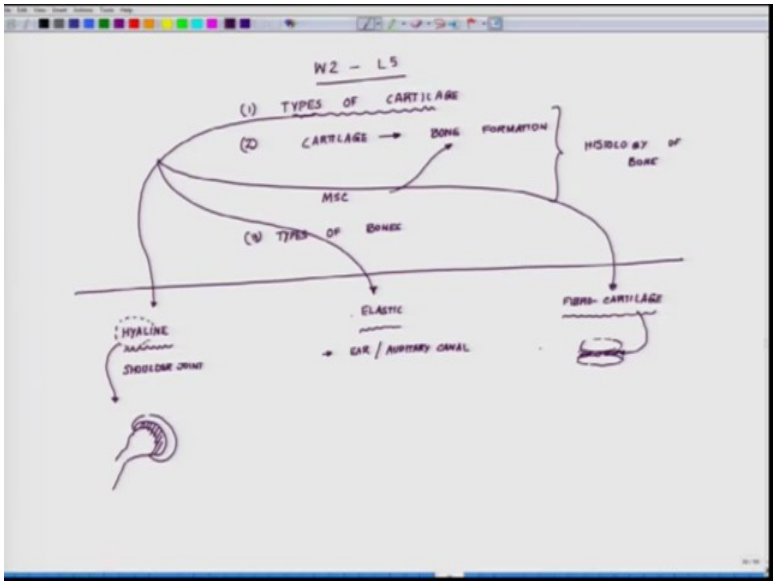

Now, today what we will do? So, let us start today's lecture. So, this is our week 2 lecture 5. We will talk about three things. We will talk about types of cartilage, cartilage

to bone formation, then we will talk about another mechanism of bone formation which is from the mesenchymal stem cells, then we will talk about types of bones and of course, in between we will talk about the histology of bone. So, let us start with the type of cartilage.

So, there are three different types of cartilage which are present in our body. One is called the hyaline cartilage which is one of the most prominent one and the second one is called elastic cartilage and the third one is called fibro cartilage and they have different level of proteoglycans and chondrocytes concentration as well as their location. Hyaline basically the word from where it got derived is called hyaloss. Hyaloss means glass and we are present in the shoulder joint out here, this joint where you see the bone, you are having cartilage out here.

This whole movement what you see a shoulder joint consist of cartilage, the hyaline cartilage elastic cartilage essentially is out here, you see this part, this is a cartilaginous material. So, this is the elastic cartilage. So, the example is oracles of the external here. The ear you will have, they have auditory canal is consisting of elastic cartilage, whereas fibro cartilage is the disc which separate. So, you have this vertebral disc, you know that through which the spinal cord moves, these vertebral disc in between you have the fibro cartilage.

So, these hyaline cartilage it is stiff, but somewhat flexible supports or reduces frictions between bony surfaces something like this if for example, the shoulder joint if you look at it very carefully is something like this. So, it is kind of a ball and a socket. So, between these two surfaces, there is always a friction. This friction is kind of taken care by the hyaline cartilage whereas, elastic if you look at it, it provides support, but tolerate distortion your senior year, you can really distorted like this, right. You can move it like this. Still it comes back to its original position. So, that is a classic example of elastic cartilage. You compress it, it will come back to its original position.

Now, talking of the fibro cartilage which is between the discs, what you see. It resists compression; prevent the bone to bone contact, limits relative motion. So, you have this whole spinal column. So, if the bone hits with each other, there will be a lot of friction. See in order to remove this friction, suppose you put as sponge material in between. What will happen? It will act as a shock absorber. Of course, it does not allow a lot of

movement. It only allows this kind of compression to their adjusted, they should not come in contact and there is precisely what fibro cartilage does. So, these are three important cartilage what I wish you prefer to you know remember.

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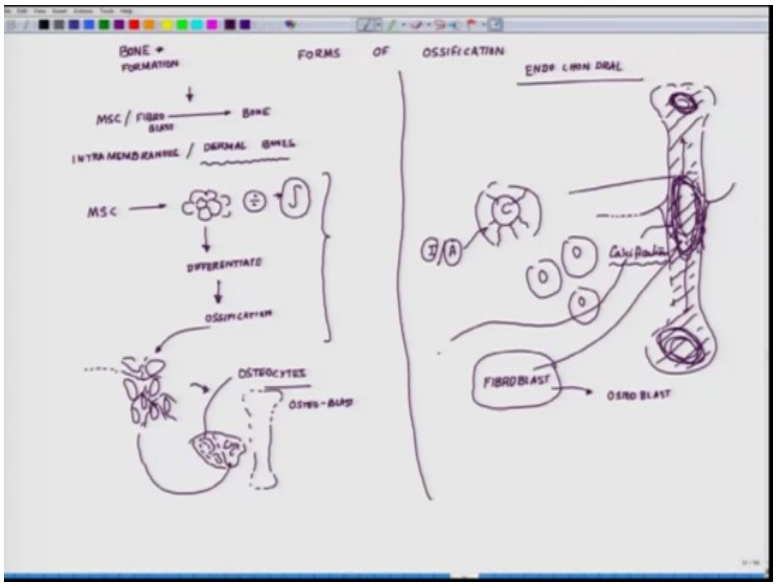

Now, from here we will close in on cartilage. We will move on to the next process which is the process of ossification or formation of bone. The process, the major form of ossification now we are moving to bone formation or forms of ossification. So, I have already highlighted two processes; one where I told you mesenchymal stem cells and even fibroblast cells are converted or ossified into bone. This process is called inter membranous, intra membranous or slash dermal bones.

Why this word comes dermal bones? So, in the previous integumentary system, I told you about dermis layer, remember. The lower layer of a skin if you dermis in the dermis layer deep layer, the bones which are formed in the dermis layer are called dermal bones. That is why this word come dermal. At most of the dermal bones are formed by the intra membranous process and mesenchymal stem cells or the fibroblast cell gets converted into bone.

So, that is why this word dermal bone appears here. So, what happens here mesenchymal stem cell, MSC lot of MSC's aggregated a point there is an aggregation process. These aggregation or aggregate and divide. I am just putting for your kind of you know

remembering brain map putting the integral sign. They are kind of integrated together at one point, then they differentiate. There is no further division taking place.

They differentiate and there is a ossification process which starts and the bone expand as a series of spicules all over the process and this results in these osteoblast started to form and with the formation of osteoblast, it allows the blood vessels to grow in and around it and eventually overtime, the bone assumes the structure for initial the spongy bone with morocco cavities and eventually it attains some kind of a structure like this and with lot of cavities in and around the osteoblast cells, we will come to these different cells osteocytes osteoblast. We will come about this when you talk about the histology of it osteoblast cells lot of blood vessels which will interspersed through it.

This is how this whole process forms. So, it is almost kind of 3 or 4 stage process depending on what the end up detail you wanted to go into it. The other formation is much more interesting if you look at it. So, that process is called endo chondral development. Endo chondral development is where basically all your limps, all these limps like structure. So, you remember in the beginning of the 4th class, I told you our framework is the body is already form, but those in that framework all the big what eventually turn out to be the big bones like you know something like this. These structure initially are all nothing, but cartilage and I you if you remember that I shaded it like this. So, just let us start from there. So, you are now studying the system probably from the 6th week post conceiving the embryo.

Now, this is all filled with cartilage in a tissue. Now, what will happen is that these cartilages in tissues at some specific location especially somewhere in the centre, these cartilages in a tissues started to enlarge. So, there is chondrocyte. You remember chondrocyte you talk about. I am representing in by see this chondrocytes started to enlarge. So, the chondrocyte size increases. So, if in a specified zone the chondrocyte size increases, there will be lot of chondrocytes which are expanding out. So, this is the first kind of growth and this growth is of two types.

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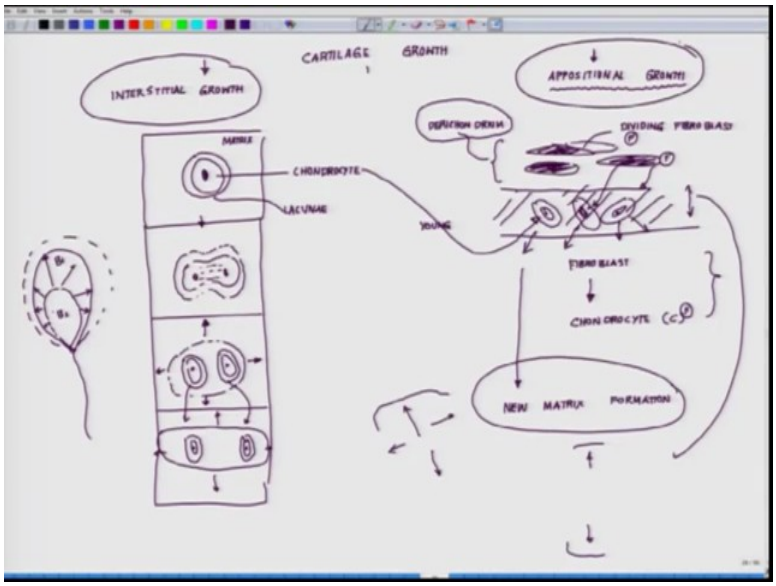

If you remember in the previous slides, I told you it could be interstitial growth or it could be appositional growth. There are two ways by virtue of it. These chondrocytes is to grow interstitial growth and appositional growth of chondrocytes I am representing by i and a.

So, now followed by this, there is the interesting process happens here, then that is called calcification. There is deposition of calcium followed by the deposition of calcium, this enlarge chondrocyte is started to die out and when they started to die out, they form a lot of wide spaces out there and when this happens, this allows the blood vessels to come closing because you remember I told you in the previous class that the blood vessels cannot grow. Now, what happens in this region, the blood vessels started to proliferate, come close.

As the blood vessels is started to move into this region, it brings with it a lot of fibroblast cells. These fibroblast cells which gets migrated because of the presence of the blood vessels in this location gets into a region which is well calcified in a milli which is well calcified with and the dead debry of all the original chondrocytes, they get transform into osteoblast cells.

These osteoblast cell: now started to remodel this whole region. Once it started to remodel, it started to expand further and this expansion all the way happens out here to out here where again the cartilage out here get transformed into a bony matrix.

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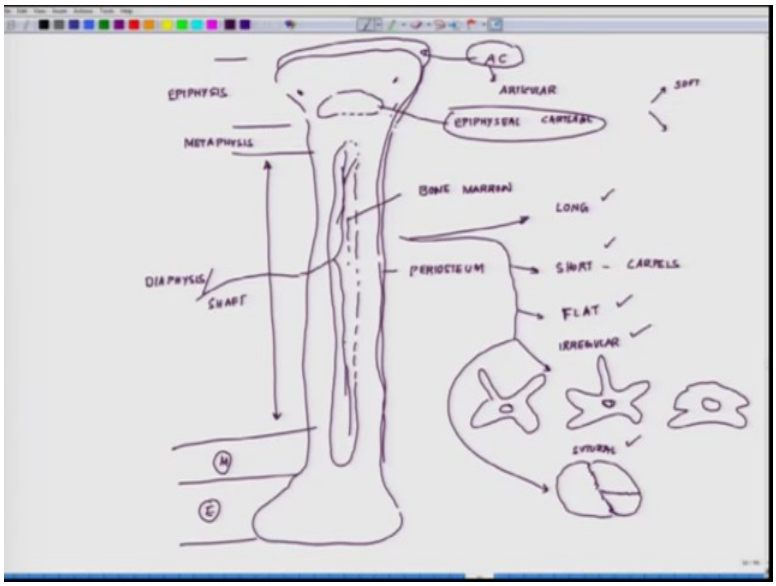

So, what is left now is if you look at the bone, the bone is something like this. This is how bone eventually looks like, where you are having residual cartilage which is remained here which we called as I am representing at a c, where a stand for articular cartilage and c stand for cartilage. There is another form of cartilage which is left behind at the border out here which is called epiphyseal cartilage whereas, this whole central region and string in one side, it is actually on both sides is called the bone marrow.

This is the bone marrow and this bone marrow is having a series of blood cells which are there while we will talk about the development of blood cells and everything will talk about in and these are the blood vessels which are you know innervating this region and this bone structure has a covering called periosteum. This is the bone marrow or the marrow cavity and the bone at typical bone can be divided into four regions.

This region is called epiphysis. This is small region which is called metaphysis and in between the sore shaft area, what is seen is this long shaft. It is called diaphysis or shaft diaphysis or shaft. Similarly, again the metaphysis and the epiphysis- so this is how the structure of the bone really looks like. In your sponge bones here, you have articular cartilage here, you have epiphyseal cartilage here. So, originally it was all cartilage then turn out to be only a small part of it which remain cartilage and if you are to classify the bones, you can classify in several ways. These are the typically long bones, and then you have bones which are short bones. If you forget all is remember look at your fingers.

These are those short bones you know their several short bones carpals, metacarpals which are present here. These are the short bones carpals, metacarpals which are present there.

Then very flat bones whenever you cannot remember flat bones think of some of this skull brain, skull bones. If flat bones there are several regions where there are very flat bones, then you are having vertebral bones which are filled irregular. There was shape something like this like with a cannellini between and then, some of them are like this, like there are several such variations within them which you can come across. These are irregular bones and then, you are having the sutural bones which are in the skull, there are bones which are attached like this you know through sweaters. So, these are called sutural bones.

So, these are some of the basic classification of bones, long bones, short bones, flat bones, regular bones, sutural bones as well as there is another we took an classify them and there could be hard bones, there could be soft bone. That actually is determined by the matrix which is present there.

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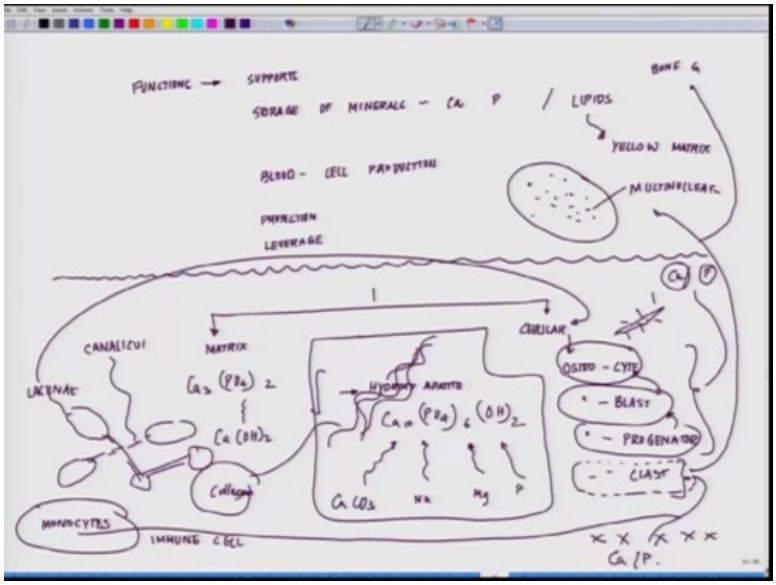

So, now we will move on to let us summarize the functions of the bones. So, one of the major function of the bone is, it supports the framework of our body, right. It is a storage of minerals especially calcium, phosphorus and storage of lipids and it is this lipid which makes what we call as the yellow matrix. I told you there are red matrix in the bone

marrow and yellow matrix. This is involved in blood cell production. We will come back to this when we will talk about the blood cell and you must have heard this word bone marrow transplantation in cancer treatment. So, this is that blood cell production site in the bone marrow. This offers a protection and a leverage protection and leverage.

These are some of the functions of the bones and if you look at the oscy tissue or the bony tissue. So, organization of the bone can be classified if the bone could be you know divided into two parts. It has a matrix component just like the cartilage you remember and it has a cellular component. We will come in the cellular component later. Let us look at the bony component. It is dense contains lot of calcium CA3 PO4 to calcium phosphate and it mix with calcium hydroxide OH2 and for may hydroxyl apatite which is CA10 PO4 6 OH2 and this has lot of chelating property of chelating with sodium magnesium, phosphorus, calcium carbonate. It forms a lot of complex and along with this, it structure forms interesting complex with another fiber which is the collagen fiber and this collagen is secreted by the cellular component.

So, this collagen is coming from the cellular component and this form a composite which is very strong almost like or maybe more powerful than you know seem intents steel and all those kind of things and this whole composite material creates this kind of species which are connected with the small canal like a structure. These canals like a structure are called canaliculi and these species are called the lacunae and it is on these lacunae structure that the cellular component grows. Now, coming to the cellular component of it, so these cellular components could be classified into PO4 groups. All start with osteo; osteocyte, osteoblast osteoprogenitor and osteoclasts. So, among these three, these three falls in one family. This one osteoclasts is the another family. Why is it so?

So, all these three osteocytes are essentially are mature bone cells which are kind of located in those canaliculi space something like this whereas, you have immature blast cell or osteoblast cell, immature bones cells secreting organic compounds of the matrix yet you have osteoprogenitor cells which divides to become osteoblast which eventually become osteocytes, but all these have one common feature. They all have this property of absorbing calcium and phosphorus they absorb whereas, osteoclast this is one type of cells which is present in the bony matrix which dissolves calcium and phosphorus and origin of these cells, these are originatd from the macrophage on the monocytes which are immune cells. We will come later into that.

What are monocytes? These are type of blood cells which are the immune component of the blood cells, ok. So, the origin of osteoclast is from, an osteoclast are very interesting kind of cells. Osteoclast are cells with almost like you know 50 to 60 nuclides, some multinucleated structure and what is the role of it. So, there is always a kind of balance between osteoblast and osteoclast because osteoblast helps in the growth, osteoclast help in breaking. This is one how bone can expand and a particular region. Now, they are confined with osteoblast say for example, now these osteoclast what they will do, they will kill some of these osteoblast and they will expand, open up the space and then, again this osteoblast will grow and grow up again. This osteoclast will kill. So, it is a very fine balance between osteoclast and osteoblast which determines the formation of the bone, but if there is a disbalanced for some immune reaction, something our bones become brittle if the osteoclast activity is more than the osteoblast activity.

So, nature has given us all sorts of tools of it is almost like a double edge. One edge will help us to grow; the other edge can create a lot of problems, lot of complications. So, it is the thing balance between these two components, osteoclast and osteoblast which determines the bone growth. So, this is what I was supposed to share with you about the development of the bone.

So, let us summarize what we have talked about. So, I have told you that bone can be formed by two processes; one where cartilage is converted or differentiated into bone and the other where mesenchymal stem cells or a fibroblast gets converted or differentiated into bones. Then, we talked about the bony matrix and the bone cells. Bone cells which are called osteocyte, osteoblast osteoprogenitor and unique kind of cells which are present in the bone, but their origin is not the bone. Their origin is more a side are called osteoclast country to that their prove their forefathers which are the cutlet cells are called chondrocytes and chondrocytes divide by two different techniques we have talked about. One I told you like a balloon within one confined space, one chondrocyte develop divides and secret matrix and unexpand. The other way is where fibroblast converted into chondrocytes for the secret a lot of metric material and in six pans.

Then, we talked about how the bone is formed, where a whole bone which is filled with chondrocytes at a particular region which is a centre. We talked about the shaft development within the shaft which is the central area of the those long bones where these chondrocytes grows and become enlarged and then, get calcified and then, dies out

and create a lot of wide space because the chondrocyte dies, those factors which are secreted by the chondrocyte of not allowing the blood vessels to penetrate there, now the blood vessels penetrate there and allows the fibroblast on mesenchymal stem cells to come there. And in that matrix which is left behind by the living chondrocytes, very calcified matrix, these cells get converted into osteoblast. Then, eventually form of suicides and secret different component and spreads out all over leaving behind a small amount of cartilaginous material in the form epiphyseal cartilage and articular cartilage at the fag end at the epiphysis region and metaphases region.

So, these are the cartilages which are left behind and overall we have already talked about the bone cells. Chondrocytes are the cartilage cells. So, this is the whole geometry. What we will do in the next week, the third week, we will talk about muscle. Kust before talk about muscle, we will talk about different numbers of bones. You do not have to go to the detailed of the skull. This is not needed for this course. That is kind of in a medical and atomy you needed, but we will just talk about what the axial skeleton and appendicular skeleton and the articulation is. So, we will briefly talk about it or I will give you some nodes in case and then, we will move on the muscle and thereby followed by, we will move on to the nerve system.

So, this is what all you needed to know about the bone biology of cartilage bone and the transformation, and this whole process of cartilage development and bone development and based on that I believe you will be able to develop your own understanding of the subject.

Thank you.