

Human Physiology
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Week - 06
Lecture - 01

Hello everyone, welcome to another brand-new class of human physiology. This is the seventh week; hopefully, we have learned from all the last few slides up to week 6, and you are enjoying the classes. In the seventh week, we will go through various bone structures, joint structures, muscles, their functions, and different diseases of bones and their treatments. Hopefully, this 7th week will be enjoyable, and let us start with it. So, today in class, we will mostly go through bones, human bones, their functions, different types of bones, the overall skeletal system, the structure of bones, composition, types of bone tissue, and types of bone cells. We will also see the detailed mechanism of how bone cells grow, how overall bone growth happens, and a few laws related to bones.

So, mostly today's class will discuss the bones of the human body. Now, let us start with the skeletal system. We all know that the whole skeletal system in our body is basically divided into two sections. One is the axial section you can see the axial section if you see the components of it first one is the skull and then you have like the rib cage.

This is the ribcage area, and then we have the vertebral column, or this spinal area. So, as a whole, you can see that this is the axial part of the skeletal system, and then we have the appendicular skeleton, where we mostly have the upper extremities, and along with that, we also have the lower extremities. Apart from the pelvic area and shoulder area. So, the distinct two parts are the axial division and the appendicular skeleton. So, what are the functions of this? Basically, as we all know, the skeletal system provides us with structural integrity.

So, basically, our skeleton gives a structural type of support and also protects our vital organs. For example, all the intraperitoneal organs, lungs, heart, and everything else are protected by our skeletal system. The bones and skeletal system as a whole also help in terms of our body movement. It also acts as a levers. For example, we can also do load-bearing applications using our bones.

And lastly, but very importantly, bones are also a storage house of minerals. Several crucial components of minerals are present in the bones that overall help in our human body growth, maturation, and development. So, we all know the total number of bones present in our body; if you see the number here, we have around 206 bones in the human body. So, if you divide the bones into the axial section and the appendicular section again, you will see that in the axial section we have around 80 bones. I mostly told you in the last slide that the axial part of the skeletal system consists of our skull, and it also contains the rib cage and the spinal cord.

So, almost 80 total bones are present in the axial component of the skeletal system. Some of them are the cranium, face, hyoid, vertebral column, thorax, etc. And then if we go to the appendicular section, you will see how many bones we have in the appendicular section, which is around 126. So, the axial skeleton has 80 bones, and then the appendicular skeleton has

around 126 bones. And as you know, a lot of important bones, like the tibia, fibula, patella, and femur, are all leg bones.

Apart from that, we have a total of 206 types of bones present in our body. And each of them has different functions, but most importantly, they give us structural support. They help us in terms of movement, load-bearing applications, and housing various minerals. Next, if we look in detail at the different types of skull bones, you will see that in our skull we have one frontal bone. So, in the frontal region, we have one bone.

Then we have two parietal bones; right, you can see in this parietal region that we have two parietal bones. Then in the occipital region, we have one occipital bone here; you can see the right occipital bone, and then we have two temporal bones in the temporal region. two temporal bones, one sphenoid bone, and one ethmoid bone. So, there are about 8 skull bones present in the skull. And very importantly, as you see this region, the frontal lobe, occipital lobe, and parietal lobe are located exactly below the skull bone, where we have the brain.

And in part of the brain exactly under the frontal bone, you will find the frontal region of the brain; under the occipital bone, you will find the occipital region of the brain; under the parietal bone, you will find the parietal region of the brain. So, again in the brain class, we will discuss the brain structure and function, but just to remind you, you can kind of remember this. So, it is also very important to mention that the skull has another 14 facial bones. So, if you see what the different facial bones are, we have two inferior nasal conchae, two lacrimal bones, one mandible, two maxillae, two nasal bones, two palatine bones, one vomer, and two zygomatic bones. So, these are mostly part of the inside of our facial area.

So, how many skulls are there, and how many total facial bones does a skull have? We have a total of around 14 facial bones. And if you go to the last slide one more time, if you recapitulate, we have around 8 cranial bones. So, together we have 8 cranial bones and a total of 14 facial bones. So, we have a total of around 22 skull bones in our skull. I hope it is clear.

The next very important component of the axial part is the vertebral column. So, as you see this beautiful vertebral column, you all know how important our spinal cord is in order to provide us with agility, movement, and balance. So, the spine basically holds up the whole balance of our body system. And if we see that our spinal cord contains a series of irregularly shaped bones called vertebrae, this is the house of the spinal cord, as you all know. So, what are the different divisions of the spinal cord? You can see we have around 7 cervical vertebrae; this is the cervical area.

So, here we have around 7 cervical vertebrae, from C1 to C7. These terminologies or notations are very important in the case of medical physiology because if there are any issues with any vertebrae, for example, degeneration, a slipped disc, or any other types of diseases like inflammation, or even in rare cases like cancer, doctors need to do the imaging and identify the exact location of the vertebrae where they need to operate. So, after the C1 and C7 cervical vertebrae, we have 12 thoracic vertebrae. This is like T1 through T12. Then we have five lumbar vertebrae, L1 to L5, and finally, one sacral vertebra and one coccyx.

The coccyx is also known as the tailbone, even though during birth the coccyx is a little bit taller, and it gradually becomes smaller with age. So, overall, how many vertebral bones do we have? If you total the number, you will see that we have a total of 26 vertebral bones. So, C1 to C7, T1 to T12, L1 to L5, and then 1 sacral and 1 coccyx; this is very important, and also

during our study of the spinal cord and the nerves, we will see how the nerves generally go from these vertebrae, and that nomenclature is also similar to the location of these bones. We will see that later in our neuron and nerve class. Then what are the different types of bones present in our body? So, mostly we know what long bones are, right? If you see here, you will see that these are examples of long bones, like the tibia and fibula.

And then we have short bones, like in our arm and in our hand; we have various short bones right in the wrist. Then there are flat bones, which are generally thin and composed of two nearly parallel plates of compact bone. There are few irregular bones, mostly in the vertebrae; just in the last slide, we discussed those irregular bones. They also have some complex shapes, and they cannot be grouped into the previous category. And finally, there are some bones called sesamoid bones that develop inside or near tendons, like the patella in our knee area; you can also see some sesamoid bones.

So, in the leg, you can see a lot of long bones; in the wrist area, you can see short bones. So, these are like long bones, and you can see short bones near the wrist area, right? And a lot of irregular bones can be seen in the spinal cord area, right? Sesamoid bones can be seen near this knee joint, which is called the patella. And then there are some cranial bones; these are mostly flat bones, right? So, these are different types of bones present in our body. The structure of long bones has mostly a few distinct components, which are the epiphyses; these are mainly the end areas of the long bones. Then you have this middle area, which is called the diaphysis; you have this epiphyseal plate area, which is kind of like a connection between the epiphyseal area and the diaphysis area.

Then you have a layer that is mostly like a collagen layer and a cell layer; this is the periosteum. You can see this is like a hard membrane. Finally, you have the medullary cavity because, as you know, there is this cavity present inside the bone; this is called the medullary cavity, and from the cavity, a lot of blood vessels and lymphatic vessels grow. Why is this important? Because, as you know, in this epiphyseal area, there is this spongy cancellous part where a lot of red bone marrow is present. And what are the functions of this red bone marrow? They basically produce the RBCs, and through these blood vessels, the capillaries and the lymphatic vessels, what they do is circulate those red bone marrow cells throughout our blood system, and the lymphatic vessels also act as a drainage for the waste components.

So, the medullary cavity contains a lot of marrow, and importantly, there are two types of marrow: one is yellow marrow and the other is red bone marrow. We will discuss it further. And finally, you can see there is an articular cartilage area which basically acts as a soft pad or cushion so that if there are two connective bones or adjacent bones, there is no friction. So, this acts like a soft pad between the cushions. So, again, what are the important components then for a long bone epiphysis area where you will find this soft sponge bone where red bone marrow cells are produced, which basically produces the RBCs (red blood cells), and then you have this middle area, the diaphysis, the long part, the shaft part, where the medullary cavity is located.

A lot of blood vessels and lymphatic vessels go through from there. Then, as I said, there are two types of bone marrow: one is the yellow type, which mostly contains fat, and it mostly provides the right environment for the bone to function. Fat means it has adipose-type cells and also stores triglycerides. Then that means it does not prepare or synthesize the RBC; it mostly provides structural integrity or the right environment for the bone to function. And then another type, and also importantly, the yellow type is present mostly in the middle area of the medullary

cavity of the bone, and with increasing age, human bones start having a greater amount of yellow matter compared to the red type matter.

So, as age increases, the red type of bone marrow in old age gets replaced by the yellow type of bone marrow. And next is the red type, which we all know is mostly present in the end part of the epiphysis area in the sponge part. There are a lot of red bone marrow present; it produces RBCs. It is present in the developing bones, like in the fetus, right? So, there are two types of bone marrow, as you can clearly see: one is yellow and the second is red. Then, what is the composition of bones? It is very important.

So, the composition of bones, if you see, is about 25 percent water, about 25 percent collagen fiber, and the remaining 50 percent consists of various crystallized mineral salts. So, the most abundant mineral salt in the bones is calcium phosphate. So, you can see $\text{Ca}_3(\text{PO}_4)_2$, calcium phosphate. It combines with other mineral salts, such as calcium hydroxide, to form hydroxyapatite. So, this is very important in the bone: calcium phosphate and calcium hydroxide, and once they are combined, they form hydroxyapatite.

As the crystal forms, they combine with other mineral salts like calcium carbonate, magnesium, fluoride, potassium, and sulfate. We also need to know what the roles of this right are. So, calcium and phosphorus make the bone extracellular matrix hard. So, it kind of acts as a way of making the bones' extracellular matrix stronger and harder. Magnesium helps to form the bone extracellular matrix; fluoride also helps in a similar way, as it helps to strengthen the bone extracellular matrix.

Manganese has a specific role; it activates various enzymes involved in the synthesis of the bone extracellular matrix. So, in general, you can see all these ions have a significant role in terms of bone development, maturation, and strengthening the extracellular matrix of the bone. There are mostly two types of bone tissue: one is the compact bone, which mostly presents as the outer layer of the bone, and as you go inside the bone, you will see that the outside part is mostly like the compact bone, while the inside part of the bone is like the spongy bone, which is softer in nature. Spongy bone is also called a cancellous bone. So, what are the differences between the compact bone and the spongy bone? So, compact bone is dense bone found primarily in the shafts of long bones.

It is composed of organized structural units. So, compact bone is composed of organized structural units which are called osteons. Then what different types of bone cells are present? You can mostly see that we have osteogenic cells. So, these are like unspecialized stem cells that undergo cell division, resulting in the formation of the osteoblast. So, what happens is that osteogenic cells are a type of stem cell, and when they undergo differentiation and division, they form osteoblast cells, which are the main structural cells of the bone and can also be called bone-building cells.

What do bone-building cells, or osteoblasts, do? They basically synthesize and secrete collagen fibers and other organic components that are needed to build the extracellular matrix of the bone. When the bone cells mature, these osteoblasts convert to the osteocytes. And osteocytes basically maintain metabolism on a daily basis. In the osteoclast, there is another type of cell, so basically, during the growing years, the number of osteoblasts is higher because, in early life, when a baby is born, osteoblastic activity is greater; this is because the baby is growing and requires rapid growth and development. However, as people age and become older, osteoclasts, which are basically monocyte cells, become more prevalent.

So, 50 monocytes basically combine to form an osteoclast cell and then release a powerful acidic type of lysosomal enzyme to chew off this protein and mineral component. So, osteoclasts basically destroy the present bone environment, and osteoblasts help to grow the bone environment or build the bone. So, as people get older and older, osteoclastic activity becomes more prevalent compared to osteoblastic activity, and during younger ages, osteoblastic activity is more prominent. So, as age increases, osteoclastic activity becomes more prominent, whereas in early ages, osteoblastic activity is greater than that of osteoclasts. So, I hope you understood how the bone cells work in terms of building new ones and destroying the old ones.

Then finally, bone growth is basically like the bone growth, or the process by which bone growth occurs, is called ossification. Two types of mechanisms are there; one is intramembranous ossification, which happens mostly in early ages, where the steps you can see are the development of the ossification center, calcification, formation of the trabeculae, and development of the periosteum. The second mechanism is endochondral ossification, which occurs mostly during the growing ages. What are the different types of stages for endochondral ossification? The first step is the development of the cartilage model, the second step is the growth of the cartilage model, the third is the development of the primary ossification center, and the development of the medullary cavity. Next is the development of the secondary ossification center and, finally, the formation of the articular cartilage and the epiphyseal plate.

We will see how it happens at the edge of the calcification as it grows into a full bone where both yellow marrow and red bone marrow start. And then there are few laws related to bone, mostly the Wolff law. So, bone basically has a beautiful load-bearing application, and once you apply stress to bone, it adjusts to that environment. So, any pressure you apply to the bone will adapt itself to that pressure situation or to the stress situation, and with that pressure, with that gravity, with that weight, the bone becomes stronger and more adaptive. But if you remove the pressure, for example, if you remove the pressure from the bone, it becomes much more brittle.

So, this is called Wolff's law, which states that bones remodel themselves in response to applied stress or pressure; in turn, they become more adaptive, and their strength also increases. So, that is why the sports person who likes running, swimming, and cycling will have much stronger bones, and even weightlifting will contribute to this. Finally, there are a few interesting fun facts. So, orthodontics, as you can see, is the branch of dentistry. Right, concerned in between, like examining the tooth and jaws, this is an ever-evolving field nowadays.

You see, in response to this artificial stress, osteoclasts and osteoblasts remodel the sockets so that teeth align properly. So, once stress is applied, there is osteoblastic and osteoclastic activity that remodel the socket. And this is the activity question for all of you: Do you know if astronauts go to space and start losing bone weight and bone density? Why is that? Why does this happen? You try to read about it and find out the answer. Why do astronauts start to lose bone density and bone mass? Thank you.

So, I hope you enjoyed the bone class. So, in detail, we discussed various types of bones, the total number of bones present (206), and then we discussed the different types of bones, the different compositions of bone, how bone cells grow, and the osteoblastic and osteoclastic activities. Right, and finally, we also discussed a few fun facts. So, I hope you enjoyed these classes on bone and let us meet in the next class with another subject. Thank you.