Biomechanics of Joints and Orthopaedic Implants
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Lecture - 02
Musculoskeletal System

Good morning everybody, welcome to the lecture on Musculoskeletal System.

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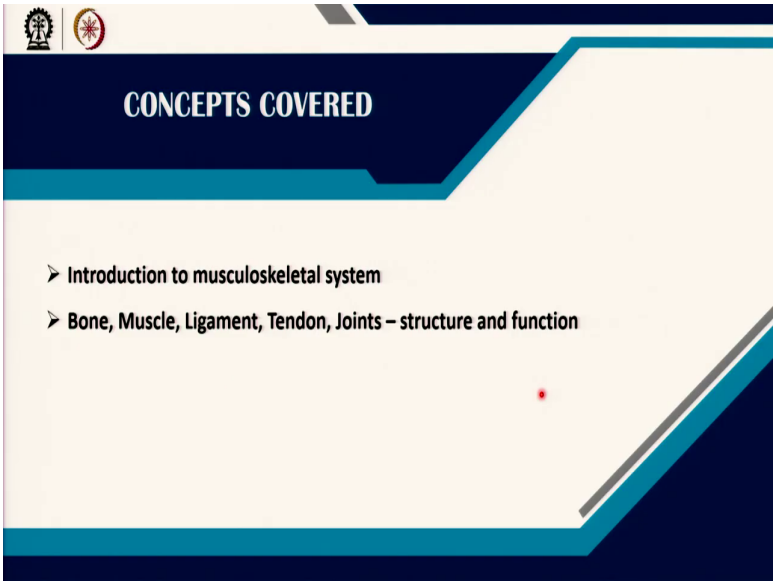

In this lecture, we will be covering the topics: introduction to musculoskeletal system, and muscle, ligament, tendon and joints- structure and function of bone. Now, before we discuss about biomechanics, it is important to know the biological system with regard to the relationship between the structure and the function. A detailed knowledge of the structure and function is essential for better understanding of the mechanics involved in the system.

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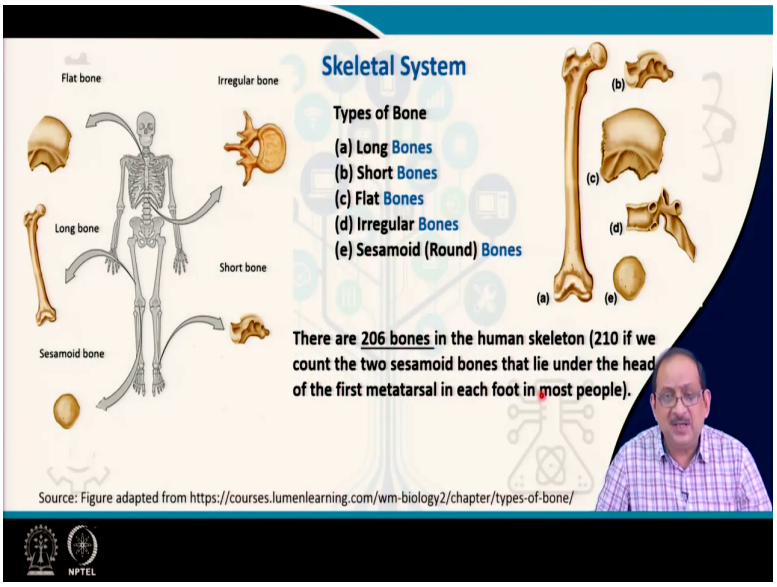

The skeletal system consists of different types of bone such as long bone, short bone, flat bone, irregular bones and sesamoid round bones. These bones are shown in the figure presented on the left as well as on the right. There are in total 206 bones in the human skeleton. The number is 210, if we count the two sesamoid bones that lie under the head of the first metatarsal in each foot in most people.

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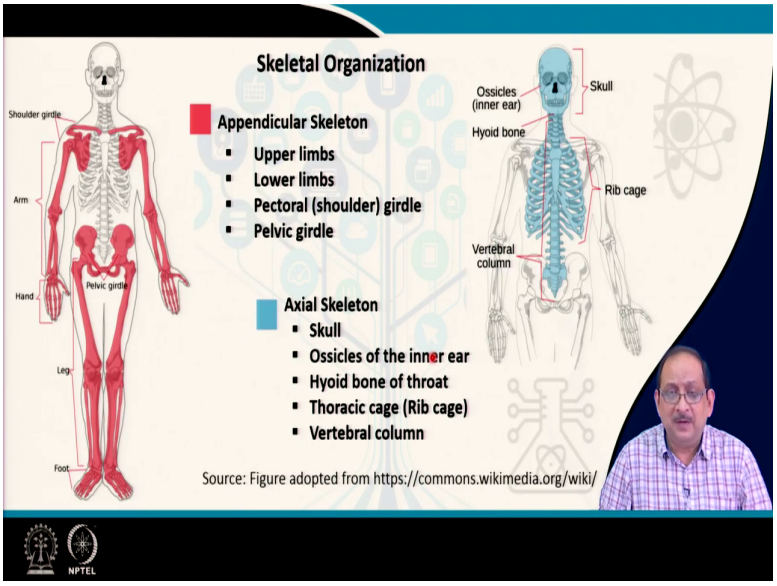

The skeletal system comprises of the appendicular skeleton and the axial skeleton as shown in the figure. On the left, the group of bones or the skeleton which is marked in red is the appendicular skeleton. On the right, the skeleton marked in blue is the axial skeleton. The

appendicular skeleton consists of the upper limbs, the lower limbs, the pectoral or shoulder girdle and the pelvic girdle. as shown in the figure. Whereas, the axial skeleton consists of the skull, the ossicles of the inner ear, higher bone of the throat, thoracic cage or the rib cage, and the vertebral column.

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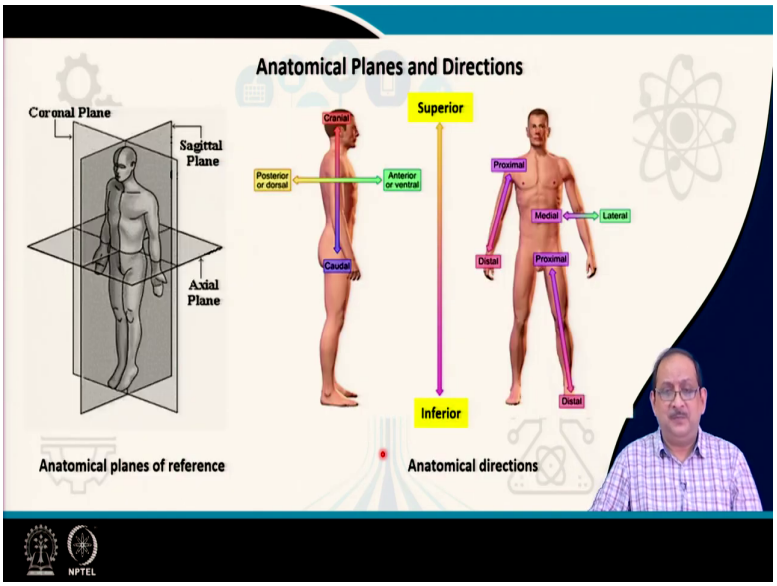

Now, it is important to define the anatomical planes of reference and some anatomical directions in order to describe the position and orientation of a structure in space. On the left, we can see three mutually perpendicular planes defined as the coronal plane, the sagittal plane and the axial transverse plane.

So, these planes are actually known as the anatomical planes of reference which are required to define the position of the structure in space. The anatomical directions are useful to describe the position of a structure with respect to another structure. Therefore, certain directions have been designated as superior, inferior, anterior, posterior proximal, distal, medial, lateral as shown in the figure in this slide.

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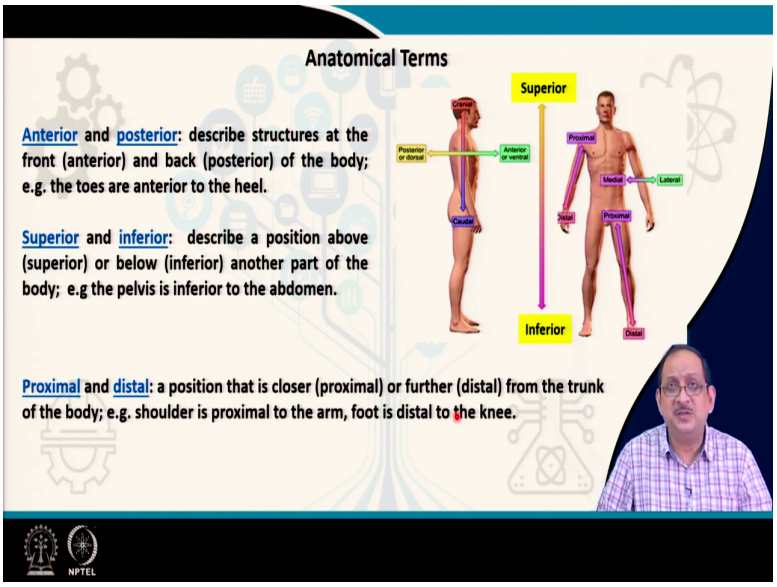

Now, the anterior and posterior directions are used to describe structures towards the front that is the anterior side or towards the back which is designated as the posterior side of the body. Example are the toes are anterior to the heel.

Part ‘A’ is considered to be superior to part ‘B’, if part ‘A’ lies above part ‘B’. Whereas, if the part ‘A’ lies below the reference part ‘B’, we can say that part A is inferior to part B. An example is the pelvis is inferior to the abdomen.

The proximal and distal are also anatomical terms which are frequently used to position. So, it is used to describe a position, that is proximal or further away from the trunk of the body. So for example, shoulder is proximal to the arm whereas the foot is distal to the knee.

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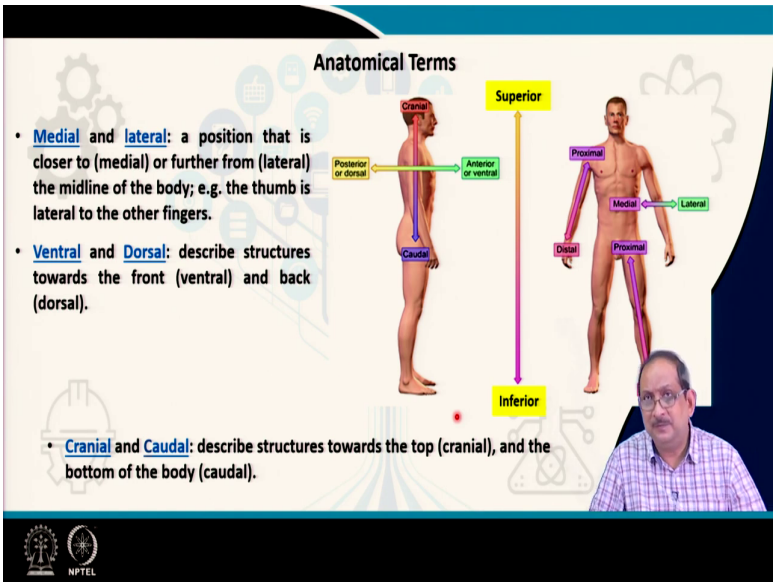

The terms medial and lateral correspond to position that is closer to the midline. Closer to midline of the body is medial and further away from the midline is lateral. Example, the thumb is lateral to other fingers (Palms are facing forward in the neutral anatomical position).

Ventral and dorsal also terms are used to describe structures towards the front. Towards front is ventral and towards back is dorsal. Cranial and caudal describes structures towards the top and towards the bottom of the body, respectively.

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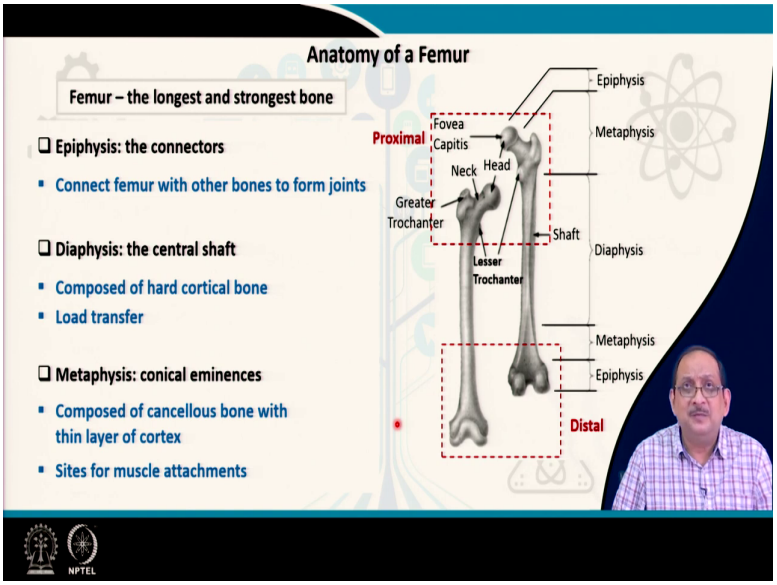

Now, let us consider the structure of the longest and the strongest bone in the human body. The femur actually has three major regions: the epiphysis, metaphysis and the diaphysis. The femur is consisting of several bony structure. To start with, the femur head which is spherical in nature, the neck of the femur which is a critical bony structure within the femur, the cross section of the femur neck reduces abruptly from the head.

Then we have two more bony landmarks known as the greater trochanter and the lesser trochanter as shown in the figure. As we move from the proximal end of the femur down towards the shaft of the femur, it consists of the diaphysis of the femur.

If we go even further down, it forms the metaphysis part of the femur. Finally, the distal condyles of the femur, the distal part of the femur consists of the medial and the lateral condyles of the femur which forms the epiphysis of the femur.

Let us now consider the three main regions of the femur. The epiphysis is the connector; they are known as the connectors they connect femur with other bones to form joints. The second part is the diaphysis of the femur, which is the central shaft of the femur. Femur shaft is composed of hard cortical bone which actively takes part in transferring the load from the upper part of the femur towards the lower part of the femur.

The metaphysis are bony regions which are composed of cancellous bone covered by thin layer of cortical bone or cortex. So these regions, metaphysis region towards the proximal and the distal end of the femur are attachment sites for muscles. So, the proximal end and the distal end of the femur also shown in the slide.

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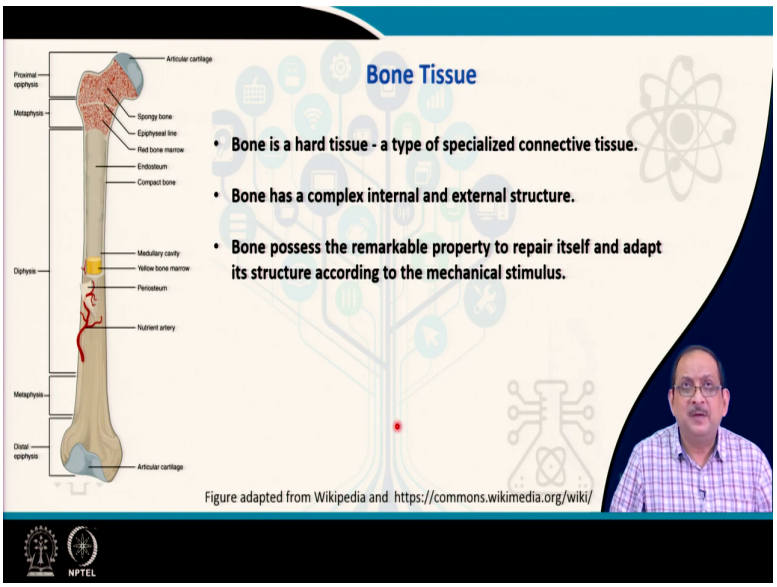

Now, let us consider the bone tissue. The bone is a hard tissue and it is a specialized type of connective tissue. Bone has a very complex internal and external structure and bone possesses the remarkable property to repair itself and adapt its structure according to the mechanical stimulus or loading it receives.

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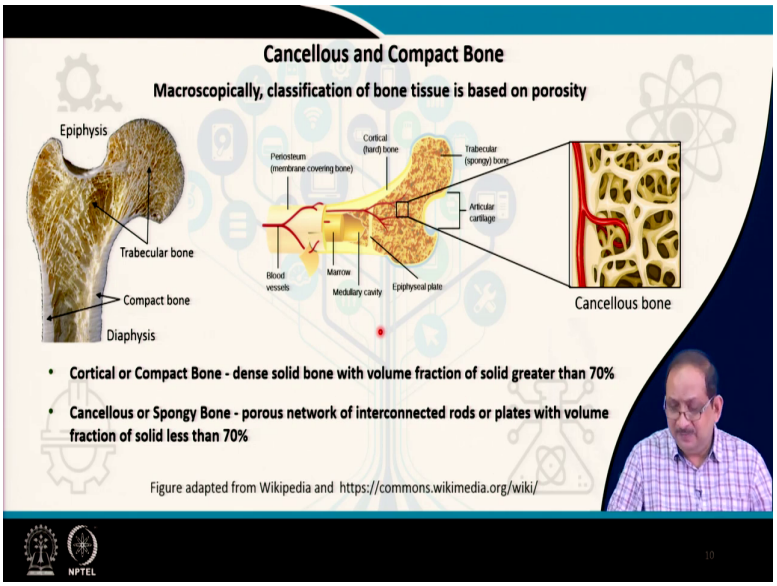

Bone can be macroscopically classified based on porosity. So you can see the figure on the left which is a coronal section through the femur, where we can see the trabecular bone (the cancellous bone) and the compact bone (the cortical bone) regions very clearly. So, in the figure we can see the cancellous bone and the cortical bone regions in the femur.

So, we would define cortical or compact bone as a dense solid bone with volume fraction of solid greater than 70 percent. Whereas, the cancellous or spongy bone or trabecular bone is a porous network of interconnected rods and plates with volume fraction of solid less than 70 percent.

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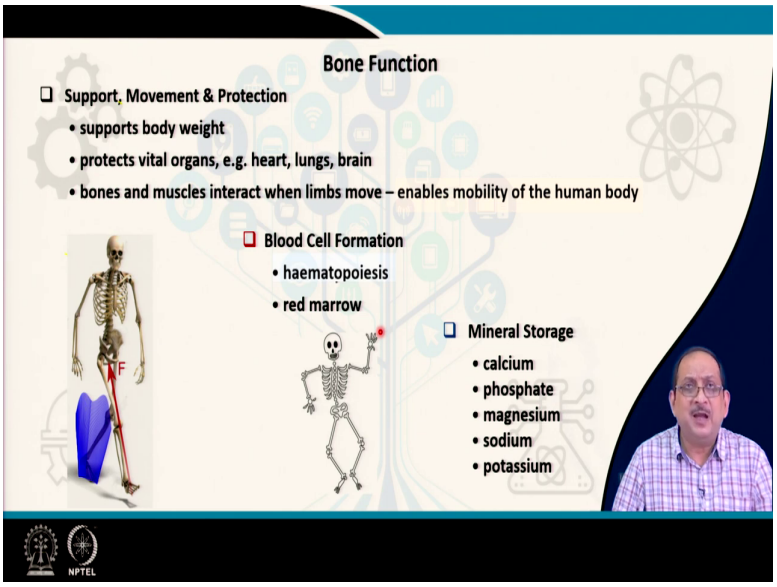

Now, what are the functions of bone? Bone supports the body weight. It protects vital organs like heart lungs and brain. Limbs move when bone interacts with muscles. So, it provides mobility to the human skeleton.

Bone is responsible for blood cell formation through the process of haematopoiesis and is also responsible for formation of red marrow in the bone marrow. Haematopoiesis is a process of formation of blood cellular components. Hematopoietic stem cells are the stem cells that give rise to other blood cells. Bone also acts as a mineral storage, it stores essential minerals like calcium, phosphate, magnesium, sodium and potassium.

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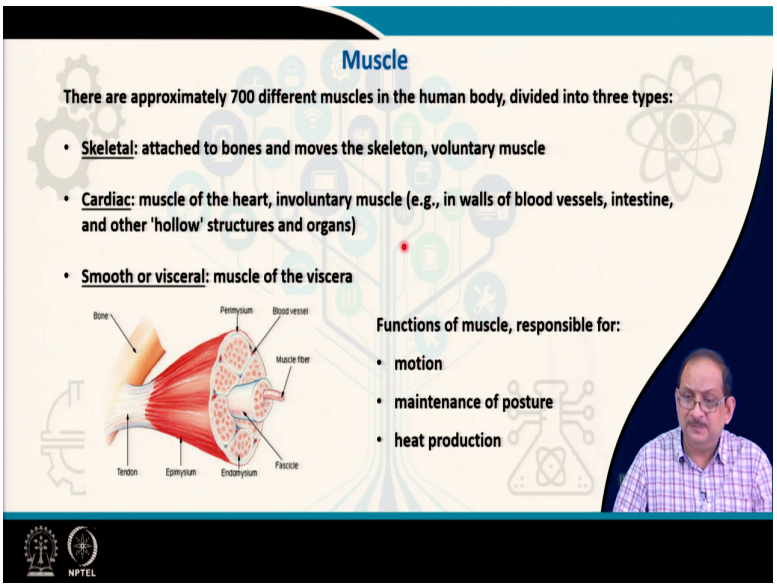

There are actually 700 different muscles in the human body which can be classified into three types. So, the muscles can be actually three types, skeletal muscles, cardiac muscles and smooth or visceral muscles. The skeletal muscles are attached to bones and they are as responsible for movement of the skeleton and they are designated as voluntary muscles.

The cardiac muscles are the muscles of the heart, they are designated as involuntary muscles examples in walls of blood vessels, intestine and other hollow structures and organs. The smooth or visceral muscle are the muscles of the viscera.

The functions of the muscles are as follows: muscles are responsible for motion; so all the motions that generally comes out of the human body are because of the muscle activation. It is responsible for maintenance of posture. it is also responsible for heat production.

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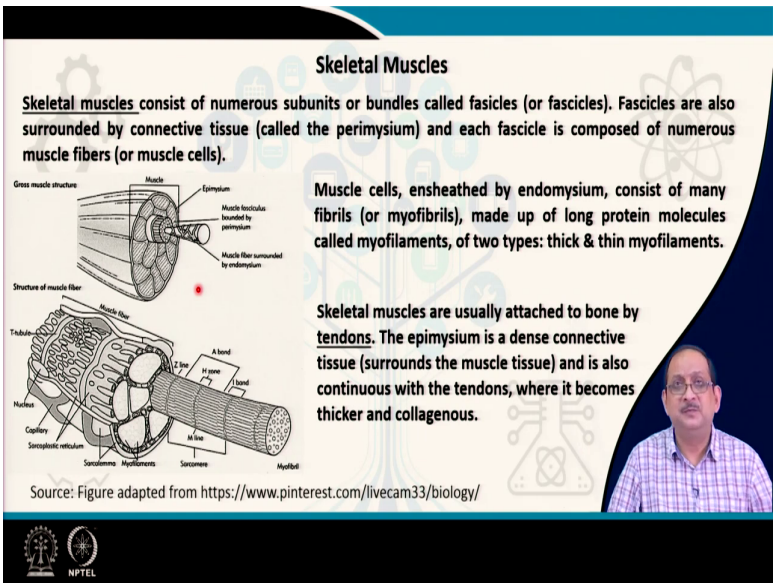

Now, let us consider more in detail on the skeletal muscles. The skeletal muscles consist of numerous sub units or bundles called fascicles. The fascicles are surrounded by connective tissue called the perimysium and each facile is composed of numerous muscle fibres or muscle cells.

As you can see here in the picture presented in the slide. Muscle cells are enclosed by a sheet of endomysium consist of many fibrils or myofibrils made up of long protein molecules called myofilaments. These myofilaments are of two types, thick myofilaments and thin myofilaments.

The skeleton muscles are usually attached to the bone by tendons. The epimysium is basically a dense connective tissue that surrounds the muscle tissue and is also continuous with the tendons where it becomes thicker and collagenous. Therefore, the tendon and the muscles are connected via the epimysium.

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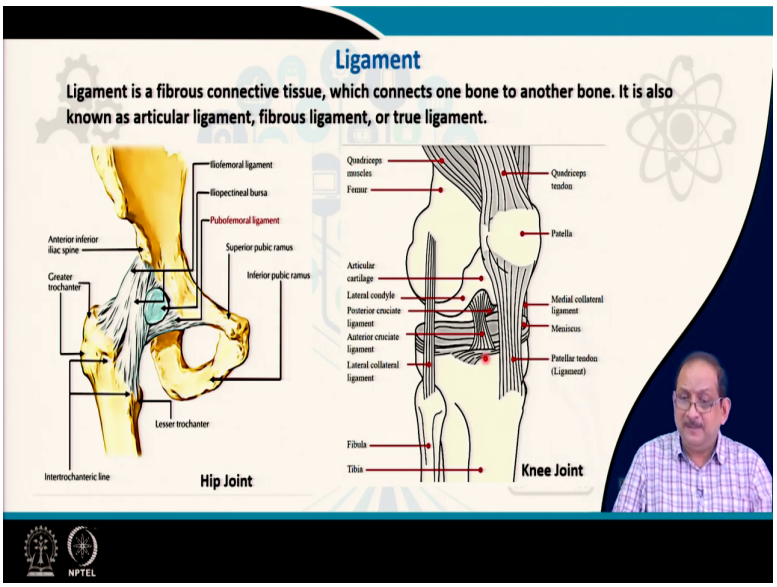

Let us come to the ligament. Ligament is a connective tissue; it connects one bone to another bone, it is also known as articular ligament, fibrous ligament or true ligament. Let us see the ligaments which actually provide stability to the hip joint and the knee joint.

The primary function of the ligament is to provide stability to the joint capsule. So, here you can see the hip joint which is formed by the femur head articulating in the acetabular cavity. This joint cavity is supported by iliofemoral ligament and pubofemoral ligament.

In the knee joint, there is a number of ligaments that actually provides stability to the joint cavity. On the left, we have the lateral collateral ligament; On the right, we have the medial collateral ligament. More towards the central part of the joint cavity, we have the cruciate ligaments, the anterior cruciate ligament and posterior cruciate ligament which criss-crosses the knee joint cavity.

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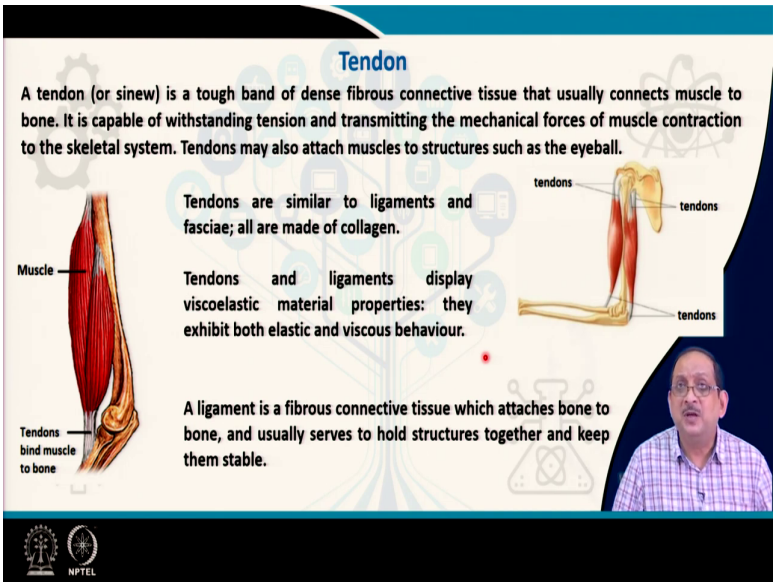

A tendon is a tough band of dense fibrous connective tissue that usually connects muscle to bone. It is capable of withstanding tension and transmitting the mechanical forces of muscle contraction to the skeletal system. So it transmits the mechanical forces of muscle contraction to the skeletal system.

The tendon may also attach muscles to structures such as the eyeball. In comparison to the ligaments presented earlier, tendons are somewhat similar to ligaments and fasciae because all of these are made of collagen. The tendons and ligaments display viscoelastic material properties which means they exhibit both elastic and viscous behaviour.

In comparison to a tendon, a ligament is also a fibrous connective tissue but it attaches bone to bone and serves to hold the structures together and keep them stability. Thereby, ligaments mainly provide stability to connected structures.

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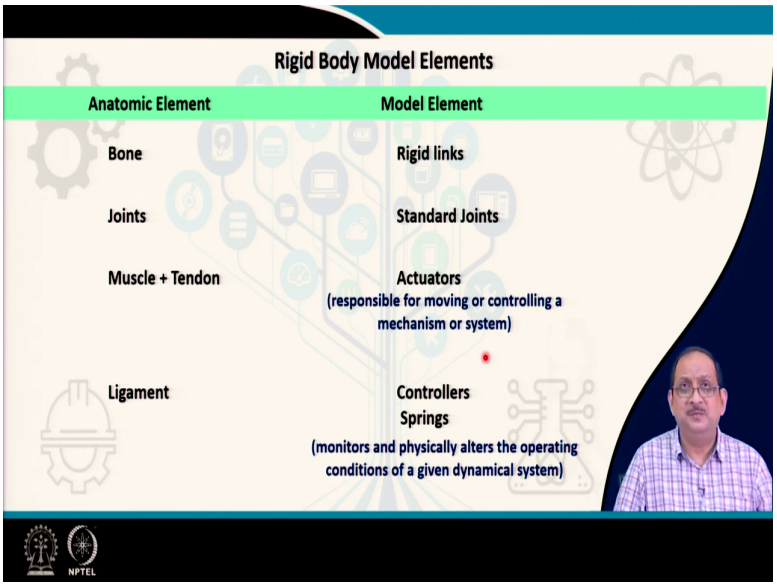

We can now compare each and every basic anatomic element with some model mechanical element. For example, the bone may be comparable to rigid links, the joints can be compared to standard mechanical joints, the muscle and tendon combination actually acts as actuators, which are responsible for moving or controlling a mechanism or system. Whereas, the ligament are basically controllers or springs which monitors and physically alters the operating conditions of a given dynamic system.

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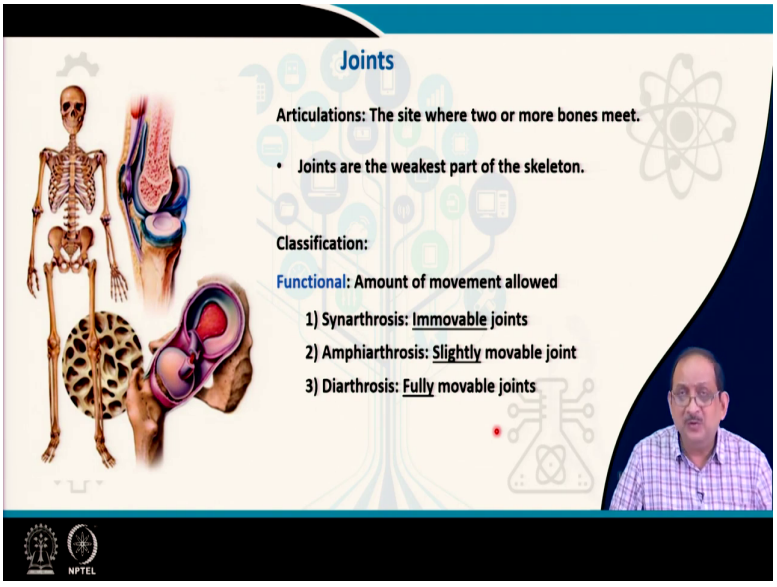

Now, let us move to the second part of the lecture which is the joints. Now, joints are articulations and they are the sites, where two or more bones meet. The joints within the

skeleton system are the weakest part of the skeleton or the weakest link in the whole structure.

The joints may be classified as functional, which is based on the amount of movement allowed in the joint. So, the functional classification consists of synarthrosis which is immovable joint characterized by immovable joint, amphiarthrosis which is characterized by slightly movable joints and diarthrosis which is fully movable joints.

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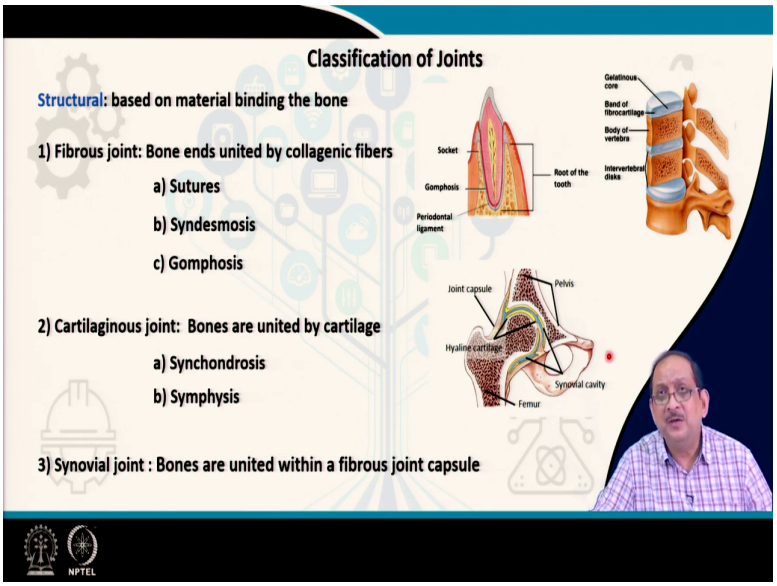

The classification of joints may be also structural based on material binding the bone. There are three classifications within this category; we have the fibrous joints, cartilaginous joints and the synovial joint. Each of these type of joints is presented on the right.

The fibrous joint is the type of the joint where the bone ends are united by collagenic fibers and is further classified into sutures, syndesmosis and gomphosis.

The cartilaginous joint is the type of joint where the bones are united by cartilage and is further classified into are synchondrosis and symphysis.

The third type is the synovial joints where bones are united within a fibrous capsule as shown in the figure. So, this is a typical hip joint which is designated as the synovial joint.

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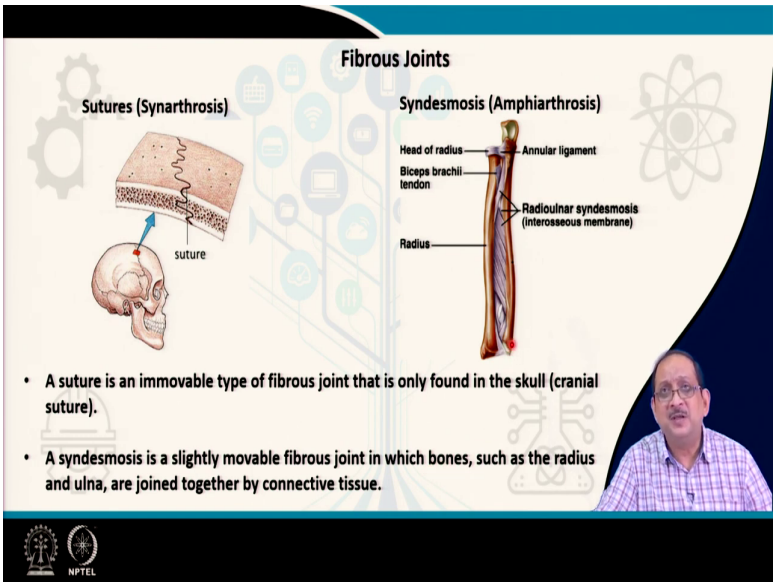

Now, let us consider more in detail the fibrous joints. Fibrous joints can be classified into sutures which belongs to the class of synarthrosis, since it's an immovable type of fibrous joint.

On the right is syndesmosis, a syndesmosis is a slightly movable fibrous joint (Amphiathrosis) in which bones such as the radius and ulna are joined together by connective tissue (annular ligament).

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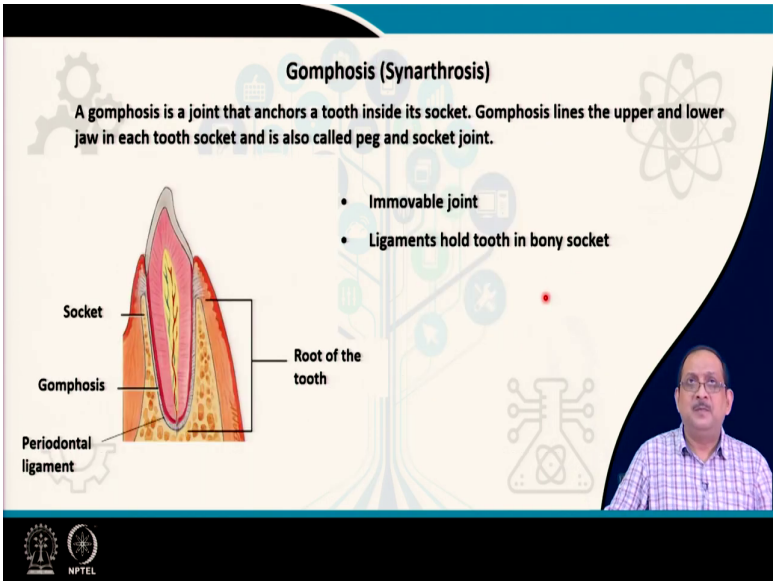

Now, gomphosis is a joint that anchors a tooth inside its socket. The gomphosis lines the upper and lower jaw in each tooth socket and is also called peg and socket joint. So, the gomphosis is the joint indicated in the figure on the left. It is basically an immovable joint (Synarthrosis) and the ligaments hold the tooth in the bony socket. In this case it is the periodontal ligament that holds the tooth in the bony socket.

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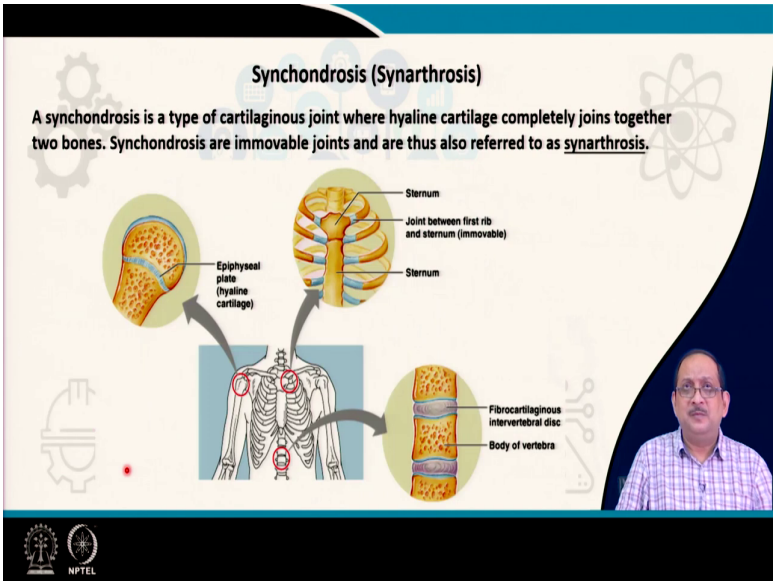

The synchondrosis is a type of cartilaginous joints where hyaline cartilage completely joins together two bones. Examples of synchondrosis are epiphyseal plate in the femur bone, the joints between the first rib of the sternum and also fibrocartilaginous intervertebral discs joints in the vertebral body. The synchondrosis are immovable joints and therefore it belongs to the class of synarthrosis.

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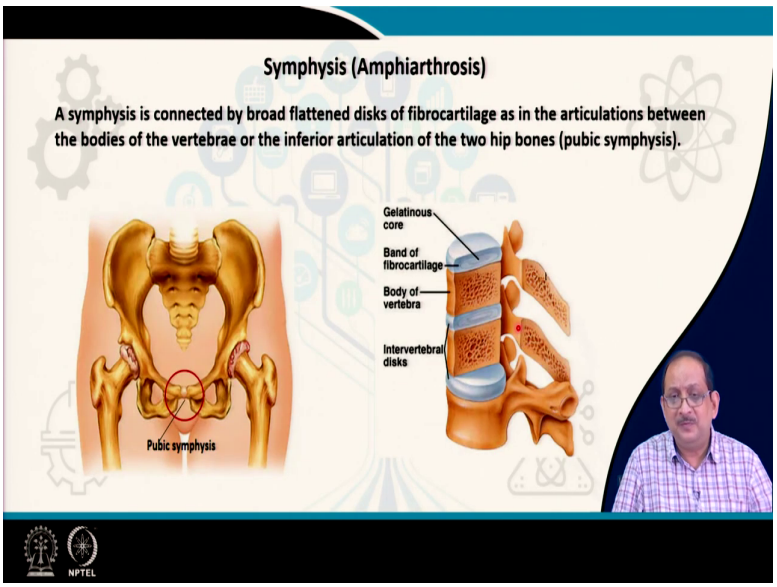

The symphysis is connected by broad flattened discs of fibrocartilage as in the articulations between the bodies of the vertebra or in the inferior articulation of the hemi pelvises. So, the pubis symphysis is a symphysis joint which connects the two hemi pelvis.

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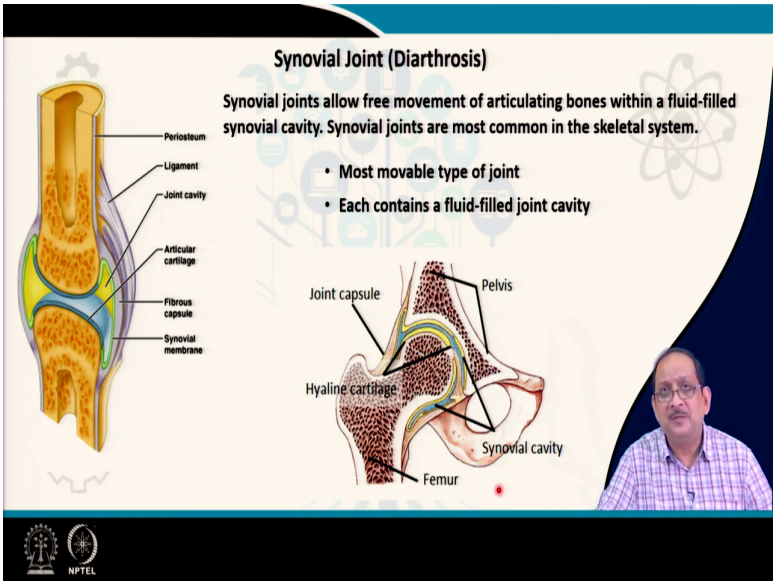

Let us now come to the most common joint that is the synovial joint. The synovial joint allows free movement of articulating bones within a fluid filled synovial cavity. The synovial joint is the most common in the skeletal system. It is the most movable type of joint and each joint contains fluid called the synovial fluid inside the joint cavity.

In this figure, we can see a typical synovial joint where we have a joint cavity which is formed by a capsule and enclosed by a fibrous capsule. Now, the joint cavity has a lining or membrane which is called the synovial membrane which holds the synovial fluid within the joint cavity. The joint cavity is enclosed by fibrous capsule as well as ligaments.

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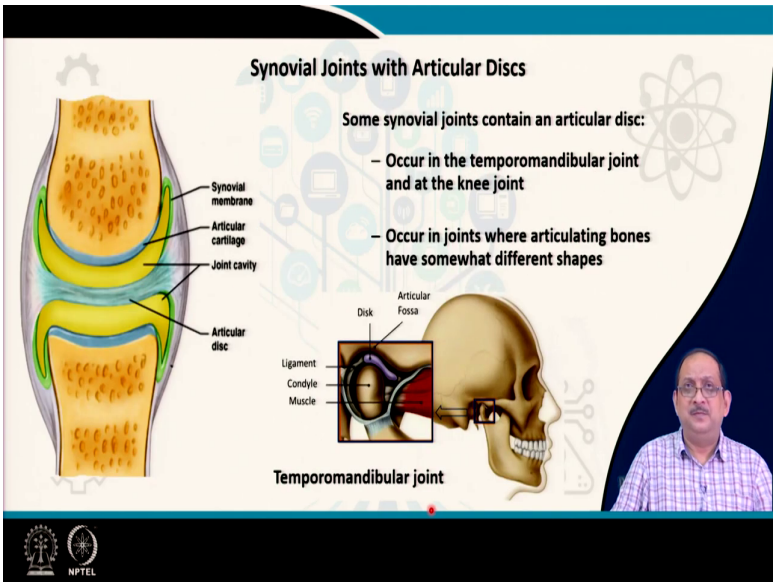

The synovial joints with articular discs are found in some cases where the articular bones have somewhat different shapes. Examples of synovial joints with articular discs are the temporomandibular joint and the knee joint.

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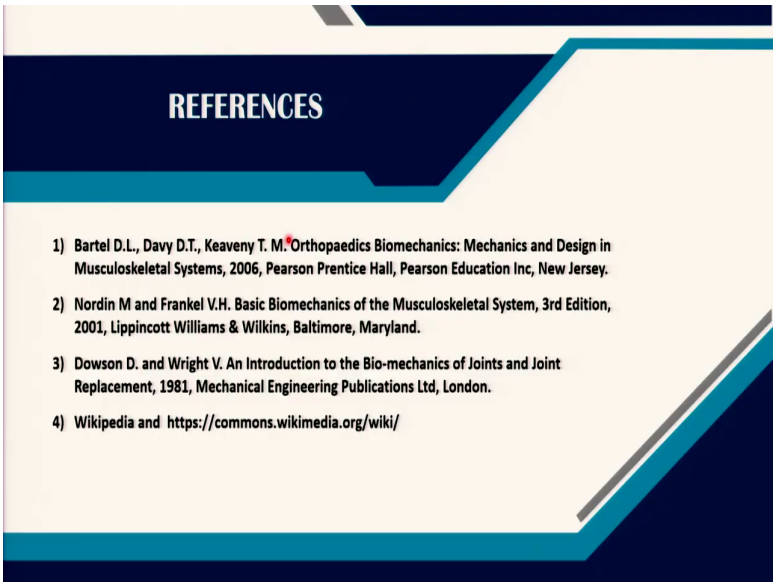

The list of references is presented in here based on which the lecture has been prepared. Thank you for listening.