UNIT 16

SUPPORT AND MOVEMENT

Major Concept

16.1 Human Skeleton
16.2 Disorders of Skeleton
16.3 Muscles

Learning Outcomes

Students will be able to:

- Describe the structure of bone and compare it with that of cartilage.
- Explain the functions of osteoblasts, osteoclasts and osteocytes.
- Identify the main divisions of human skeleton.
- List the bones of appendicular and axial skeleton of man.
- Describe three types of joints *i.e.* fibrous joints, cartilaginous joints and synovial joints and give example of each.
- Describe the disorders of human skeleton (disc-slip, spondylosis, sciatica, arthritis) and their causes.
- State different types of fractures (simple, compound and complicated) and describe the repair process of simple fractures.
- Describe the injuries in joints (dislocation and sprain) and their first aid treatment.
- Describe the first-aid treatment for fracture.
- Compare smooth muscles, cardiac muscles and skeletal muscles.
- Explain the ultra-structure of the skeletal muscle.
- Explain the sliding filaments model of muscle contraction.
- Describe the action of antagonistic muscles in the movement of knee joint.

Introduction

The movement refers to change in shape or position of body parts. Movement is different from locomotion, as in **locomotion** whole organism moves from one place to another. In animals, movement is provided by muscles. **Support** means to provide proper shape and structure to the body so that body can perform it's vital functions. In animals, **support** is provided by hydrostatic skeletons, bones and cartilages. In this unit we will study about skeletal tissues *i.e.* bones and cartilages, muscular tissues, some muscular and skeletal disorders.

16.1 Human Skeleton

Human's skeleton is the main supportive framework of the body. It mainly includes bones and cartilages. The muscles are attached to the skeleton for the production of effective movements of the body.

Skeletal tissues:- Skeletal tissues are bone or cartilage

Bone:- Bone is one-third of connective tissue. It is impregnated with calcium salts. The composition of bone tissue is different from other tissues in the body. Bone is a hard tissue, provides support to the body, gives environment for the production of blood cells and protects internal organs of the body.

16.1.1 Structure of Bone

Bone tissues are of two types; **compact** (hard and dense) and **cancellous** (spongy) tissues. The outer part of bone is hard, called compact bone while the inner part is spongy, called spongy bone.

Compact bone

Compact bone, also called **cortical bone**, is a hard white bone tissue that surrounds all the bones in human body. The fundamental units of compact bone are called **osteons** or **Haversian systems.** Each osteon consists of concentric layers called **lamellae** (singular: lamella). In the centre of each osteon, **central canal** or **Haversian canal** is present which contains blood and nerve supply of the bone. The central canal communicates with the **perforating canal** (also called **Volkmann's canal**), which transmits blood vessels from periosteum (a dense layer of vascular connective tissue enveloping the bone) into the endosteum (The thin layer of cells lining the medullary cavity of a bone).

The **osteocytes** are located in the small cavity called **lacunae** (singular: lacuna), situated between the lamellae. **Canaliculi** are the microscopic channels that create a network which transport nutrients, to the osteocytes and also remove wastes from them.

Spongy bone

Spongy bone, also called cancellous or **trabecular bone**, is a porous and highly vascular bone. It is mostly located at the end of the long bones. Unlike compact bone, the lacunae of spongy bone are found in a lattice-like network of matrix spikes called **trabeculae** (singular: trabecula). The **osteocytes** of spongy bone are irregularly placed within the trabeculae. The spaces between trabeculated networks make spongy bone lighter and less dense than compact bone. The spaces in some spongy bones contain **red bone marrow**, where the blood cells are formed. (Fig.16.1)

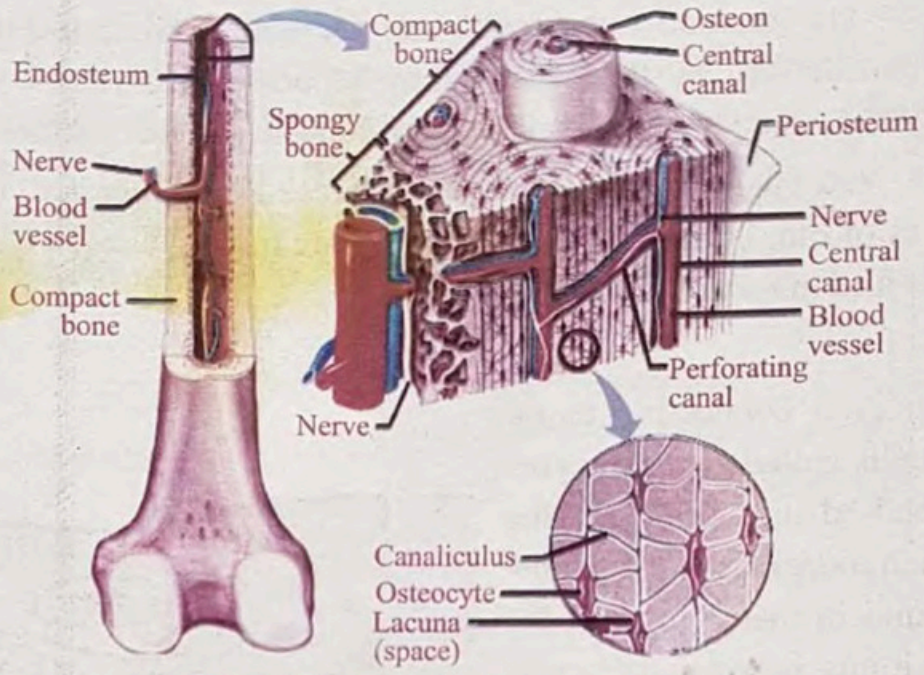


Fig.16.1: Internal Structure of Bone

Types of Bone Cells

The process of bone growth and repair is carried out by four different types of cells. These cells are involved in making and breaking the bone.

1. **Osteogenic Cells** are the stem cells that are found in the cellular layer of endosteum and periosteum. These are undifferentiated cells and have ability to divide. The osteogenic cells develop into osteoblasts.

2. **Osteoblasts** are involved in the formation of new bone. They are mostly found in the areas where bone growth occurs. These cells secrete collagen.

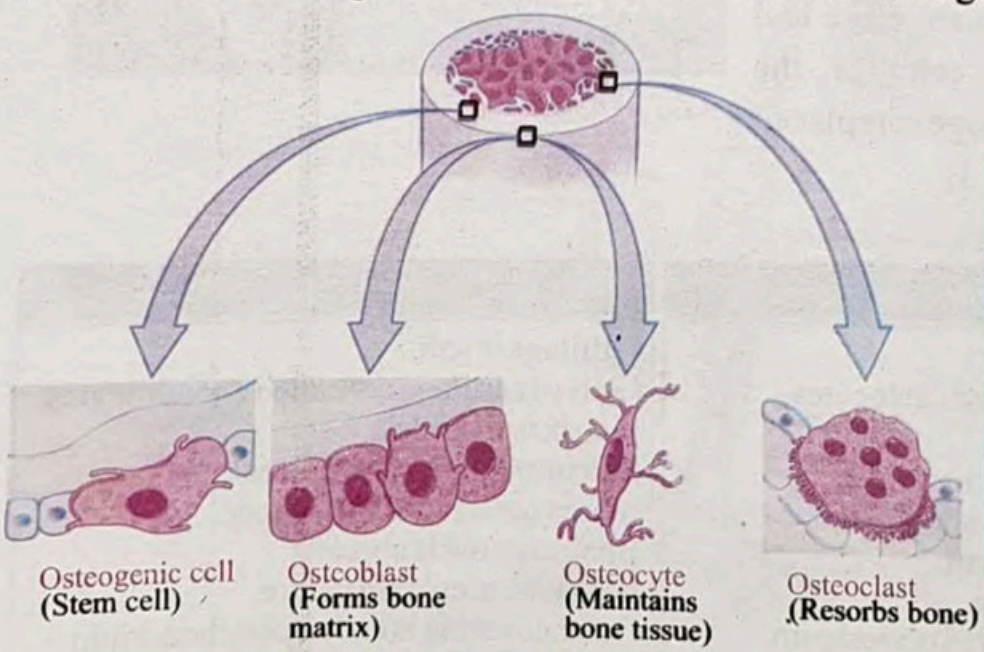


Fig.16.2: Types of Bone Cells

Extra Information

A new "inner you" is about ten years old. In adult human every year about 10% bone is replaced, that means as the mineral content in bones is renewed, we get a new skeleton about every ten years.

3. **Osteocytes** are matured bones cells and are entrapped in the matrix. When osteoblasts are surrounded by the matrix, they become osteocytes. By the help of secretion of enzymes, osteocytes maintain mineral concentration of the matrix.

4. **Osteoclasts** take part in bone resorption and breakdown processes. These cells are found at the sites of old, injured bone. Osteoclasts are multinucleated and are derived from **monocytes and macrophages**. (Fig.16.2)

16.1.2 Cartilage

Cartilage is a connective tissue compos-ed of cells called **chondrocytes** and fibers embed-ed in a firm, gel like matrix. It is much more elastic than bone. Cartilage is found in many areas of the body including joints, between the bones, *e.g.* the elbow, knees and ankles.

The general features of cartilage include that it has no blood vessels or lymphatics. The nutrition of cells diffuses through the matrix. Cartilage has no nerves, it is therefore, insensitive. Cartilage is surrounded by a fibrous membrane called **perichondrium**, which is similar to periosteum in structure and function. When cartilage calcifies, the chondrocytes die and cartilage is replaced by bone like tissue. (Fig.16.3)

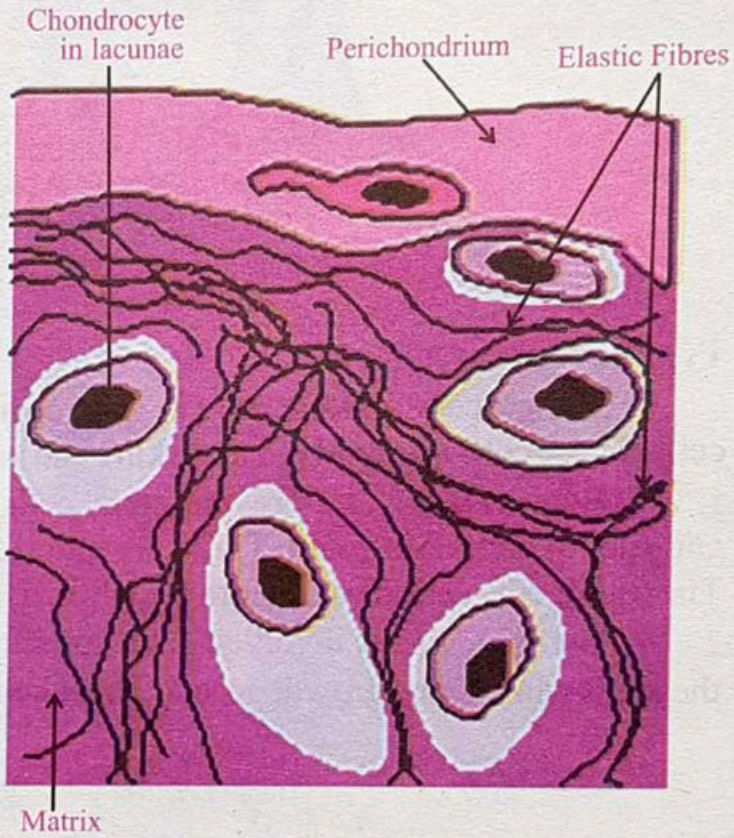


Fig.16.3: Structure of Cartilage

Table 16.1 The comparison between bone and Cartilage

S.No.	Bone	Cartilage
i)	Bone is hard.	Cartilage is soft.
ii)	Cells of bone are called osteocytes.	Cells of cartilage are called chondrocytes.
iii)	Matrix is inflexible.	Matrix is flexible.
iv)	Matrix possesses calcium salts.	Calcium salts are not present.
v)	Bone has rich blood supply.	It does not have blood supply.
vi)	Bone marrow is present.	Bone marrow is absent.
vii)	It is vascular in nature.	It is non-vascular in nature.
viii)	Outer covering is called periosteum.	Outer covering is called perichondrium.
ix)	Provide skeletal support to the body.	Provide flexibility to the body.

16.1.3 Functions of Human Skeleton

Human skeleton is located inside the organism with muscles attached outside therefore, it is called endoskeleton. It is made up of living tissues which grow with the growth of organism. It is made up of either cartilage or bone. Human skeleton performs various functions in the body. Some functions of skeleton are as follows:

- It gives support to the body. Without the skeleton, the body would be flabby and shapeless

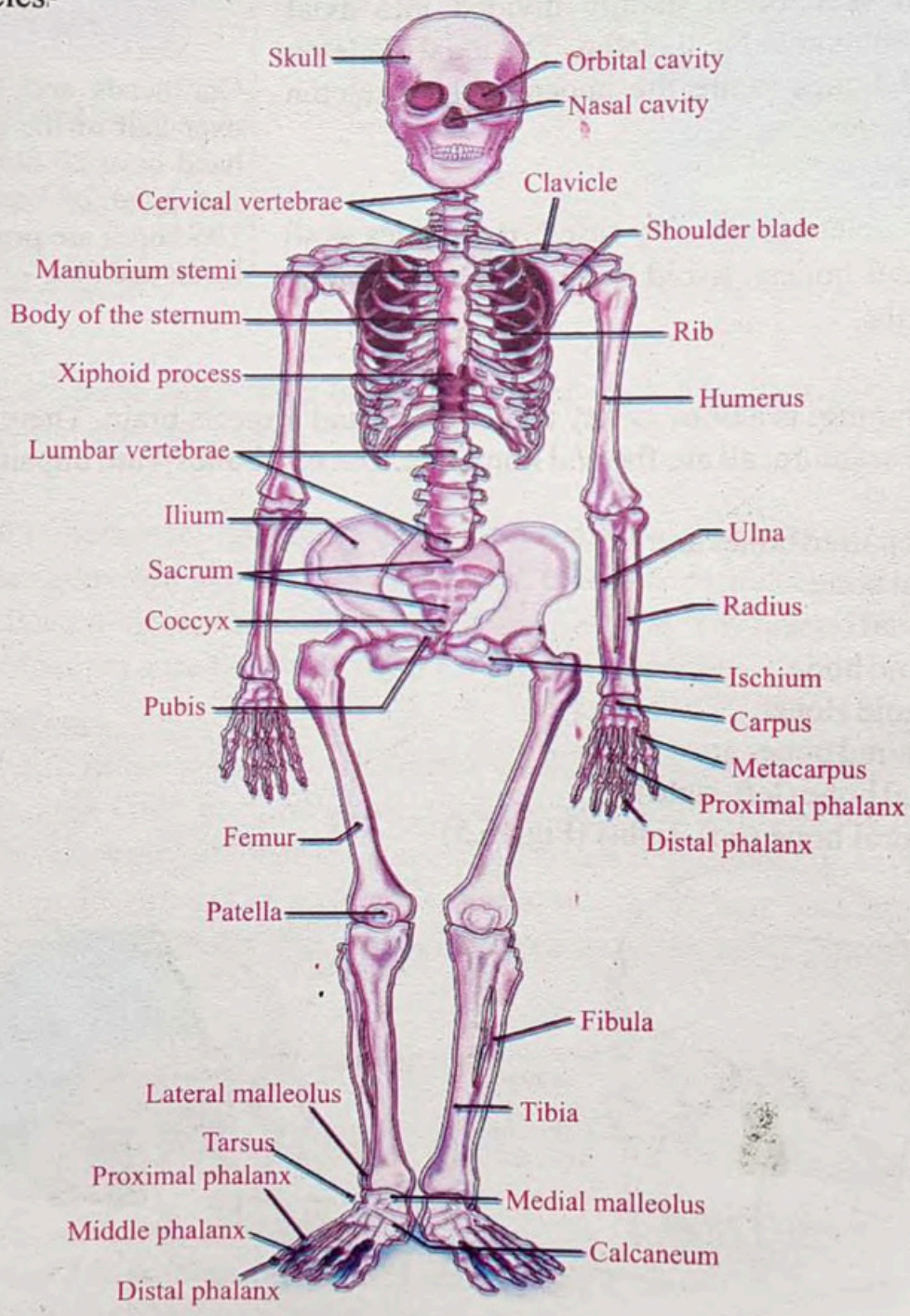


Fig.16.4: Human Skeleton

- It provides surface for the attachment of muscles, ligaments and tendons.
- It stores 97% of the body calcium and phosphorus.
- Blood cells are made in red bone marrow, which are mostly present in the ribs and limb bones.
- The bones and joints work with muscles, enable us to walk and run.

Divisions of human skeleton

Human skeleton is mainly divided into axial skeleton and appendicular skeleton. The axial skeleton consist of 80 bones while the appendicular skeleton contains 126 bones.

Interesting Information

Our hands and feet contain over half of the bones. Each hand have 27 bone and each feet have 26 bones, so total 106 bones are present only in hands and feet.

Axial skeleton

Axial skeleton is mostly fused. It includes skull (cranium, facial bones), hyoid bone, vertebral column, sternum and ribs.

Cranium

The cranium is a bony cavity that contains and protects brain. There are 8 bones present in the cranium, all are flat and immobile. Out of 8 bones 4 are unpaired and 2 are paired.

The unpaired bones are:

- Frontal bone
- Occipital bone
- Ethmoid bone
- Sphenoid Bone

The paired bones are:

- Parietal bone (left, right)
- Temporal bone (left, right) (Fig.16.5)

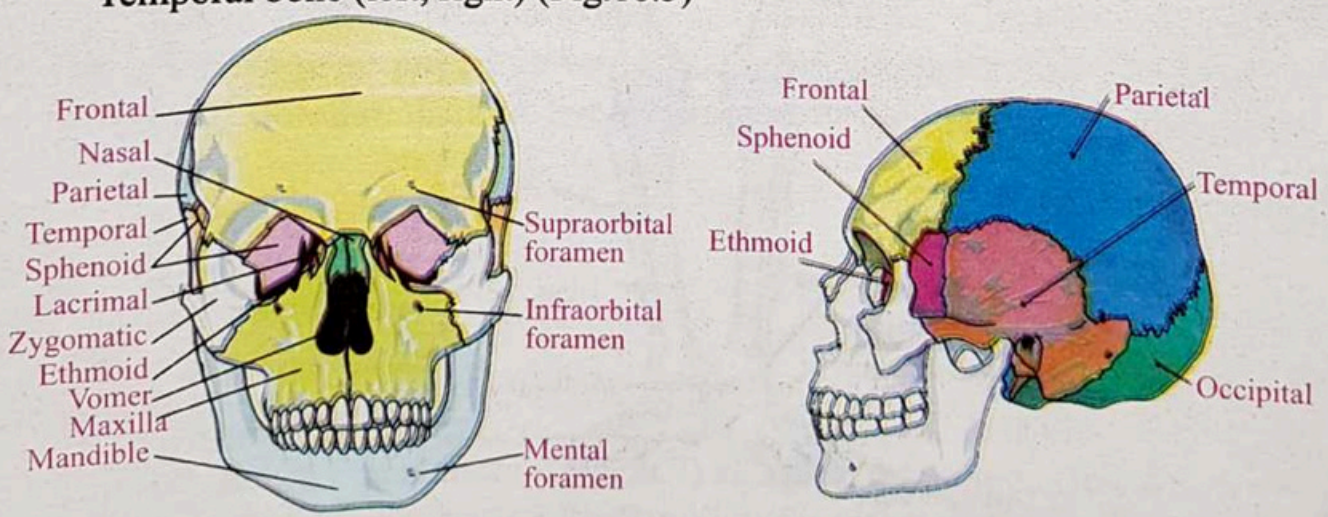


Fig.16.5: Human Skull (Front and Lateral Views)

Facial bones

Facial bones are attached to cranium. These bones give protection to the sense organs of sight, smell and taste and provide a frame for various muscle attachments. There are 14 facial bones, out of which 2 are unpaired and 6 are paired.

The unpaired bones are:

- Mandible
- Vomer (movable bone)

The paired bones are:

- Maxilla
- Zygomatic bones
- Nasal bones
- Inferior nasal concha
- Lacrimal bones
- Palatine bones

Extra Information

Bone stop growing in length after puberty. However, bone density and strength will change over the course of life.

Ear Bone

There are three pairs of ear bones collectively called **ossicles**. One pair malleus, one pair incus and one pair stapes.

Hyoid bone

Hyoid bone is also known as **lingual bone** because it gives attachment to the tongue. It also provides site for the attachment of different muscles associated with swallowing. It is a u-shaped bone present in the neck region. The unique feature of hyoid bone is that it does not articulate with any other bone of the body.

Vertebral Column

Vertebral column is also known as **back bone**. It has **four curvatures** that provide great support to the skull, pectoral girdle, thoracic cage and maintain the posture of the body. It also provides protection to the spinal cord which is present in its cavity. There are 33 vertebrae that are present in vertebral column, which are later fused to become 26. According to location, there are five groups of vertebrae which are as follows:

1. Cervical vertebrae
2. Thoracic vertebrae
3. Lumbar vertebrae
4. Sacral vertebrae
5. Coccygeal vertebrae

1. Cervical vertebrae

These are 7 in number (C1 to C7) and present in the neck region. The first two vertebrae (atlas and axis) are modified to allow the movement of the head.

2. Thoracic vertebrae

These are 12 in number and are numbered (T1 to T12). They form a backward curve down to thorax. Ribs are attached to these vertebrae. These vertebrae provide support to the rib cage.

3. Lumbar vertebrae

These are 5 in number (L1 to L5) and are present in lumbar region. These are the largest vertebrae in the vertebral column because of their weig

4. Sacral vertebrae

These are 5 in number, represented by the symbols (S1 to S5). These vertebrae later fuse to form a single bone called **sacrum.**

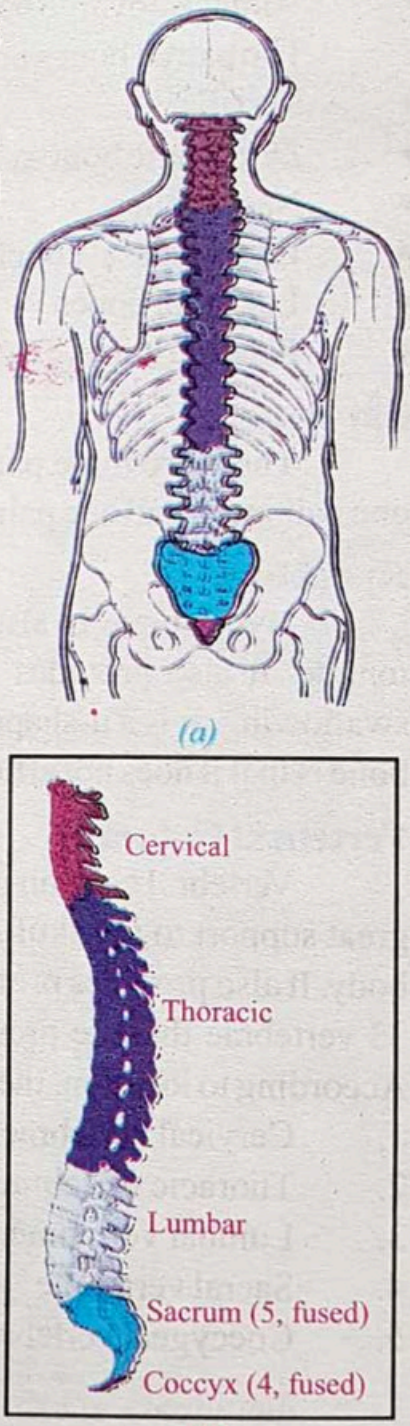
5. Coccygeal vertebrae

These are also called **coccyx** or **tail bone**. These are 4 in number and later fuse together to form a tiny tail like structure. (Fig.16.6)

Sternum and Ribs (Ribcage)

Sternum is the elongate, flat bone that lies in the midline of anterior chest wall. It is also known as **breast bone**. The sternum consists of three main parts: manubrium, body of sternum and xiphoid process. **Manubrium** is the upper part of sternum. It articulates with the 1st costal cartilage and the upper part of 2nd costal cartilage on each side. **Body** is the middle part of sternum and is relatively long. It articulates with the lower part of 2nd costal cartilage to the 7th costal cartilages on each side. **Xiphoid process** is the lower part of sternum. It does not articulate with the ribs and costal cartilages.

Ribs are long, twisted flat bones that form the major part of rib cage. Rib cage encloses and protects the heart and lungs. It also provides a framework onto which many muscles are attached. There are 12 pairs of ribs in human skeleton. Posteriorly, the ribs articulate with the thoracic vertebrae and anteriorly, the ribs have different relations that allow ribs to be categorized as true ribs, false ribs and floating ribs. Pairs 1 to 7 are called true **ribs** because these ribs are connected to the sternum through individual costal cartilages. Three pairs are



(a) (b)

Fig.16.6: Human Vertebral Column

floating ribs (**false ribs**) (8 to 10), which are attached with 7th rib and form costal arch. The last 2 pairs of ribs (11th and 12th) are not attached to sternum. These are called **floating ribs**. (Fig.16.7)

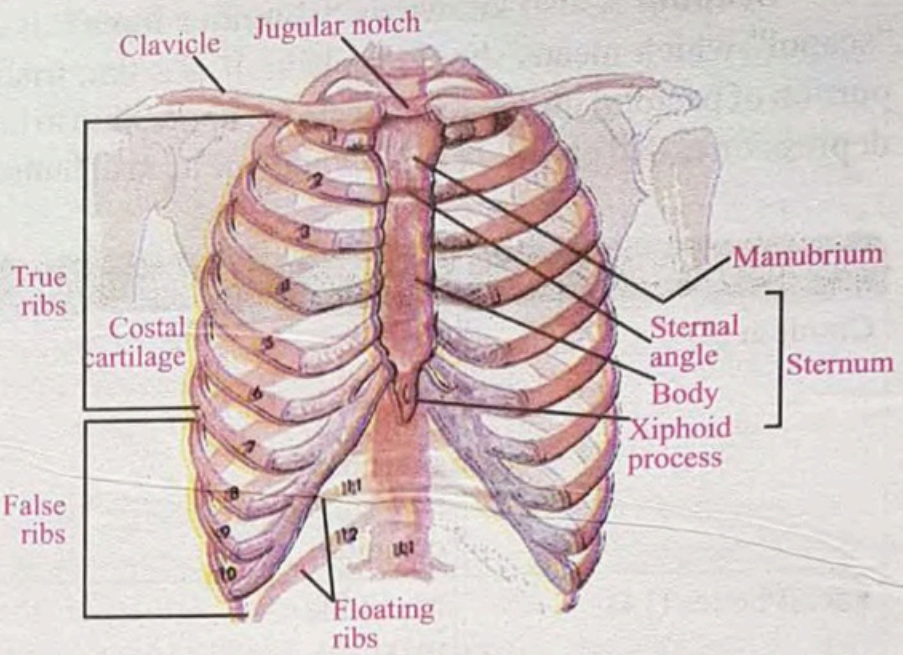


Fig.16.7 Human Rib Cage

Appendicular Skeleton

Comparing with the axial skeleton, the appendicular skeleton is unfused. It consists of **girdles** (pectoral and pelvic) and **limbs** (fore limb and hind limb).

Pectoral Girdle

Pectoral girdle is the part of appendicular skeleton. It is also known as **shoulder girdle**. In human skeleton, clavicle and scapula form the shoulder girdle which connects the arm on each side.

Clavicle is also known as **"collar bone"**. The word clavicle is derived from Latin word "clavicul" which means key. It is a curved bone which resembles with an old style key. It is present between sternum and scapula and forms the front part of pectoral girdle. It has two ends; the sternum end and the acromial end. At sternum end, it articulates with sternum and forms **sternoclavicular joint** whereas at acromial end, it articulates with the acromion of scapula and forms **acromioclavicular joint**.

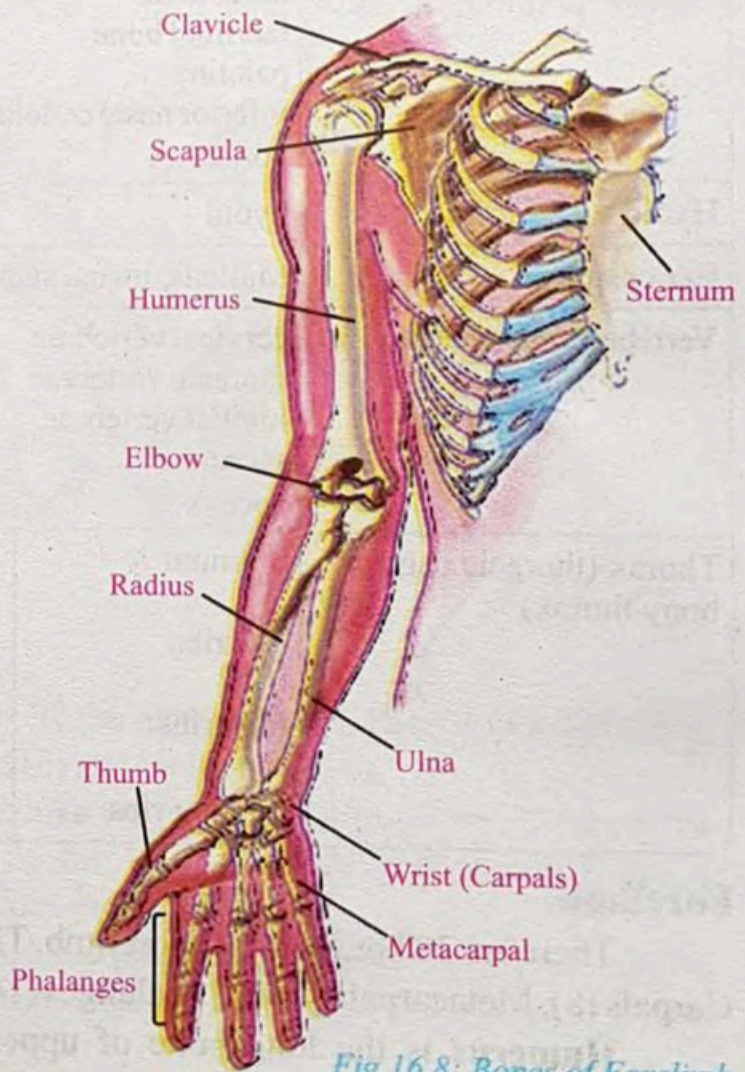


Fig.16.8: Bones of Forelimb

Scapula is also known as **"shoulder bone"**. It is also derived from Latin word "scapul" which means shoulder blade. It is a flat, triangular bone that forms the back portion of pectoral girdle. It connects the upper limb to the trunk. On lateral side, there is a depression called **glenoid cavity** where the head of humerus inserts.

Tables 16.2: The list of bones present in axial skeleton

General Description	Name of Bone		No of Bones
Cranium (8)	frontal		1
	parietal		2
	temporal		2
	sphenoid		1
	ethmoid		1
	occipital		1
Facial bones (14)	Mandible		1
	maxilla		2
	zygomatic bone		2
	nasal bone		1
	lacrimal bone		1
	palatine		1
	inferior nasal concha		
	vomer		
Hyoid	hyoid		1
Ear ossicles	Malleus, incus, stapes		6
Vertebral column (26)	cervical vertebrae		7
	thoracic vertebrae		12
	lumbar vertebrae		5
	sacrum		1
	coccyx		1
Thorax (thoracic cage or bony thorax)	Sternum		1
	true ribs	(7 pair)	14
	false ribs	(3 pair)	6
	floating ribs	(floating [2 pair] ribs)	4

Forelimb

There are 30 bones in each forelimb. These are Humerus (1), Radius (1), Ulna (1), Carpals (8), Metacarpals (5) and Phalanges (14).

Humerus is the long bone of upper arm. Proximally, the head of humerus

articulates with the glenoid cavity of scapula and forms **glenohumeral joint.**

Radius and **ulna** are the bones of forearm. Radius is present on the lateral side (thumb side) while ulna is present on the medial side of forearm.

Carpals are the bones of wrist. These are two rows of 8 short bones (4 bones in each row). The proximal row articulates with the radius and ulna while distal row articulates with the metacarpals. These bones provide stability and some movement.

Metacarpals are 5 bones that form the palm located between the carpal bones and phalanges. The bones are identified by number (1-5).

Phalanges (Phalanx) are 14 bones that form the fingers. Each finger consists of 3 bones except the thumb which consists of 2 bones.

Pelvic Girdle

The pelvic girdle is made up of three skeletal elements, the ilium, ischium, and pubis which form the **coxa**. The **ilium** is the upper flattened bone, **ischium** is lowest portion of coxal bone while the **pubis** is anterior part of the coxal bone. The two halves of the pelvic girdle are joint by pubic bones which articulate with each other at the **symphysis pubis** (Pubic Symphysis). The outer surface of the hip bone has a deep depression called **acetabulum**. It is the cavity in which the head of femur inserted. (Fig.16.9)

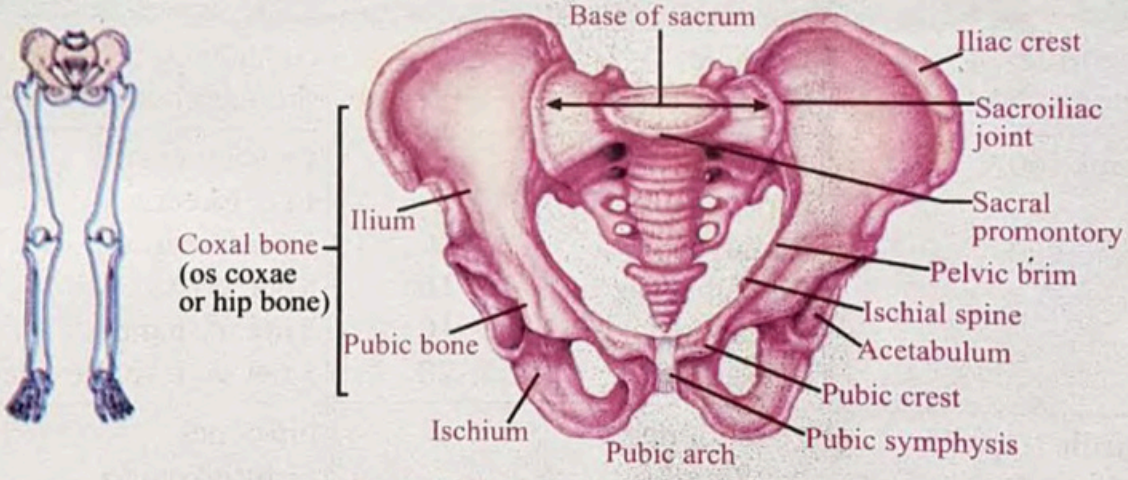


Fig.16.9: Bones of Pelvic Girdle

Hind limb

There are 30 bones in each hind limb. These are femur (1), Patella (1), Tibia (1), Fibula (1), Tarsal bones (7), Metatarsal bones (5) and Phalanges (14).

Femur is the longest and strongest bone in human skeleton. At the proximal end the head of femur articulates with the acetabulum to form the hip joint and at distal end it articulates with tibia and patella to form the knee joint. (Fig.16.10)

Patella or **knee cap** is situated in front of the knee joint. It is embedded in a long tendon which runs over the knee joint. The posterior surface of patella articulates with the **condyles** of the femur.

Tibia and **fibula** are the bones of lower leg. The tibia, or **shin bone** is the large weight-bearing medial bone of the lower leg. The fibula or **calf bone** is located on the lateral side of lower leg.

Tarsal bones are the bones of **ankle**. Proximally these bones articulate with tibia and distally articulate with metatarsals. These are seven in number and form the ankle, heel and instep of foot.

Metatarsal bones resemble with the metacarpals of the hand. The metatarsals are numbered (1 to 5) from medial to lateral side. These are present between tarsal bones and phalanges to form the **sole of the foot**.

Phalanges are the small bones that resemble with the digits in hand. Each toe has three phalanges except the big toe, which possess two phalanges.

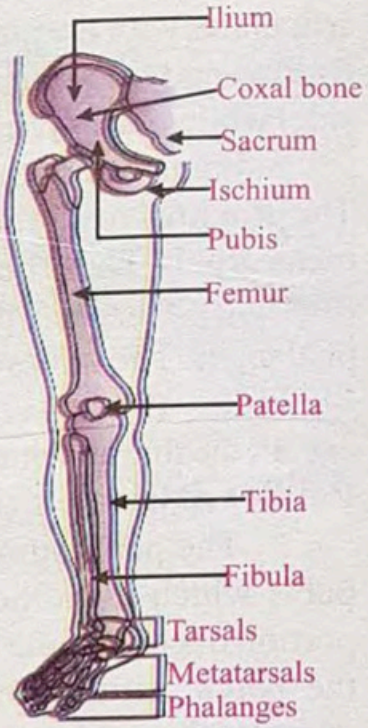


Fig.16.10: Hind Limb

Table 16.3. Appendicular Skeleton Bones (126 bones)

General Description	Name of Bone	No of Bones	Additional Information
Pectoral girdle (shoulder girdle)	Clavicle Scapula	2 2	collar bone shoulder bone
Upper limb (60)	Humerus Ulna Radius Carpals Metacarpals Phalanges	2 2 2 16 10 28	1 per upper arm 1 per forearm 1 per forearm 8 per wrist 5 in each hand 3 per digit (pollex has 2)
Pelvic girdle (hip) (2)	Coxal Bones 1. Ilium 2. Ischium 3. Pubis	2	hip bones (3 fused pairs)
Lower limb (60)	Femur Patella Tibia Fibula	2 2 2 2	1 per upper leg 1 per leg 1 per lower leg 1 per lower leg
	Tarsal	14	7 per ankle
	Metatarsals Phalanges	10 28	5 per foot 3 per digit (hallux has 2)

16.1.4 Joints

Joint is the point of attachment between two bones or bone and cartilage. There are more joints in a child than in adult because some of the bones fuse together as the growth proceeds. There are 360 joints in adult human skeleton. The scientific study of joints is called **arthrology**.

Extra Information

Ligaments are short bands of tough fibrous connective tissue that function to connect one bone to another bone in the joint.

Types of joints

On the basis of tissue present in the joint, there are three types of joints: fibrous joints, cartilaginous joints and synovial joints.

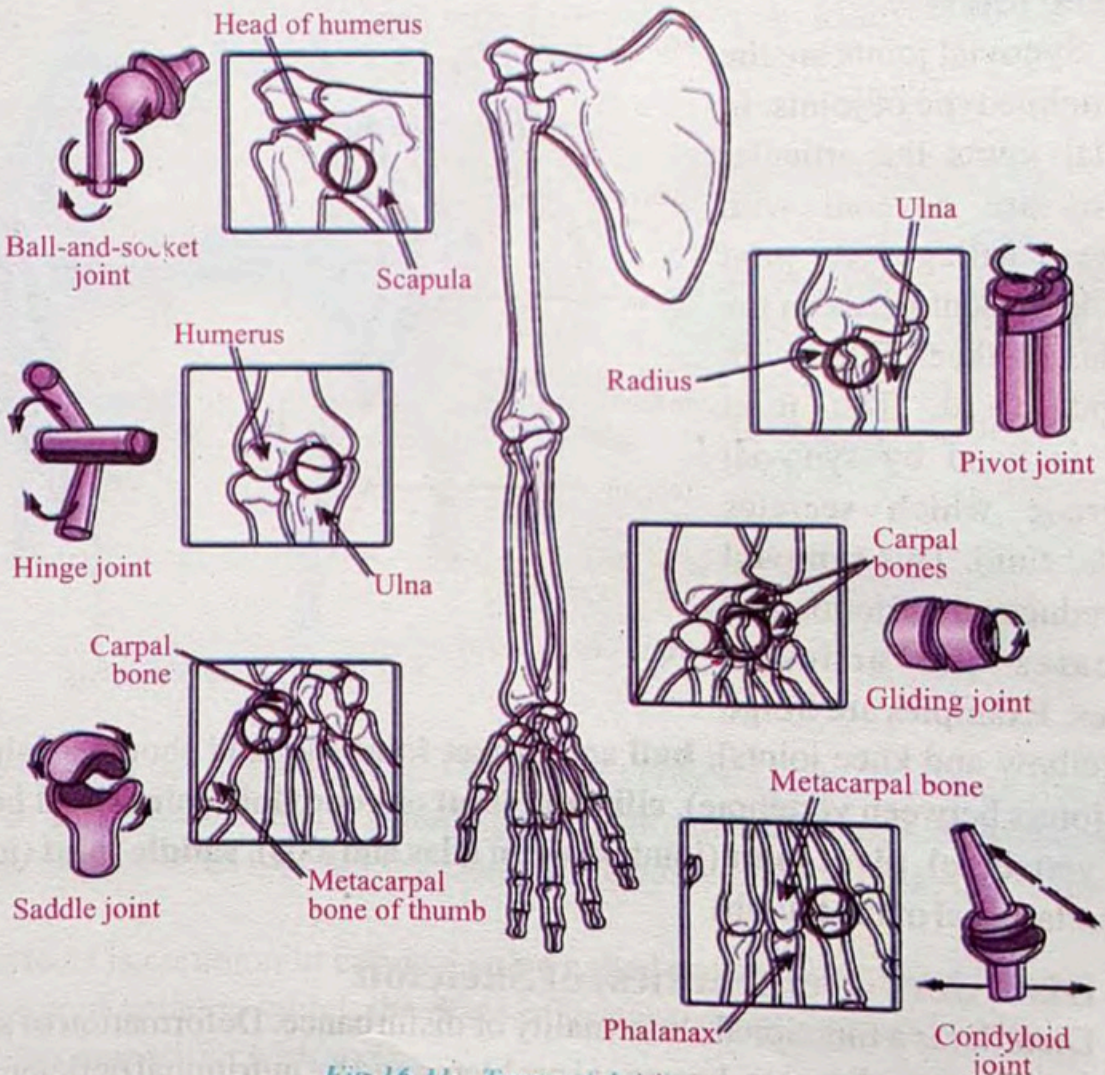


Fig 16.11: Types of Joints

Fibrous joints

When the articular surface of the bones are connected to each other by fibrous connective tissue, it is called **fibrous joint**. Fibrous connective tissue is a dense

connective tissue consisting mainly of collagen. These joints are also called immovable joints because they do not allow movement. Examples, includes joint between skull bones called **sutures**, joint between tooth and its socket and joint between long bones *e.g.* tibia and fibula.

Cartilaginous joints

When the articular surface of the bones is connected by cartilage (fibrocartilage or hyaline cartilage), it is called **cartilaginous joint**. These joints are also called **slightly movable joints** because they allow little movement. **Hyaline cartilage** is seen in the costal cartilages that attach ribs to the sternum, **fibrocartilage** is seen in intervertebral disc and pubic **symphysis**.

Synovial joints

Synovial joints are the most mobile type of joints. In synovial joints the articular surfaces are covered with hyaline cartilage. A joint cavity is present between the articular surfaces filled with synovial fluid. The joint cavity is lined by synovial membrane which secretes synovial fluid. This **synovial fluid** reduces the friction and lubricates the articular surfaces. Examples are **hinge joint** (elbow and knee joints), **ball** and **socket joint** (hip and shoulder joints), **gliding joint** (joints between vertebrae), **ellipsoid joint** or **condyloid joint** (joint between skull and 1st vertebrae), **pivot joint** (joint between atlas and axis), **saddle joint** (joint between carpometacarpal of the thumb).

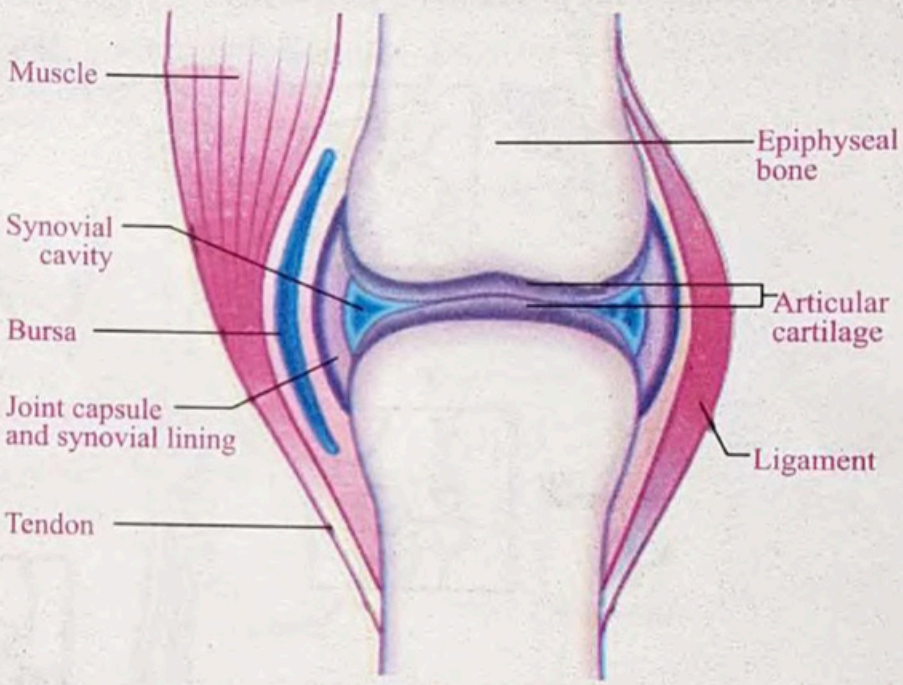


Fig.16.12: Synovial Joints

16.2 Disorders (Deformities) of Skeleton

Disorder is a functional abnormality or disturbance. Deformation of skeleton may occur due to genetic diseases, hormonal problems and by nutritional deficiencies.

16.2.1 Common Disorder of Skeleton

Some common conditions that affect the skeletal system include slip disc, spondylosis, sciatica and arthritis.

Slip disc

The bones in the vertebral column are cushioned by discs. These discs protect the vertebral column by absorbing the shocks from daily activities like walking, running, lifting, twisting, bending, *etc.*

Each intervertebral disc consists of an outer strong ring called **annulus fibrosus** and soft gelatinous inner portion called **nucleus pulposus**. If annulus fibrosus ruptures and allows the inner gelatinous portion to split out, it results in **herniation of disc**.

A herniated disc can affect and damage the nearby nerves by pressing them. This results in severe pain, numbness or weakness in the arm or leg. Herniated disc can be prevented by performing strengthening exercises, by maintaining good posture and a healthy weight. Slip disc can be treated with bed rest and pain killers. If these doesn't work, disc may be removed surgically. (Fig.16.13)

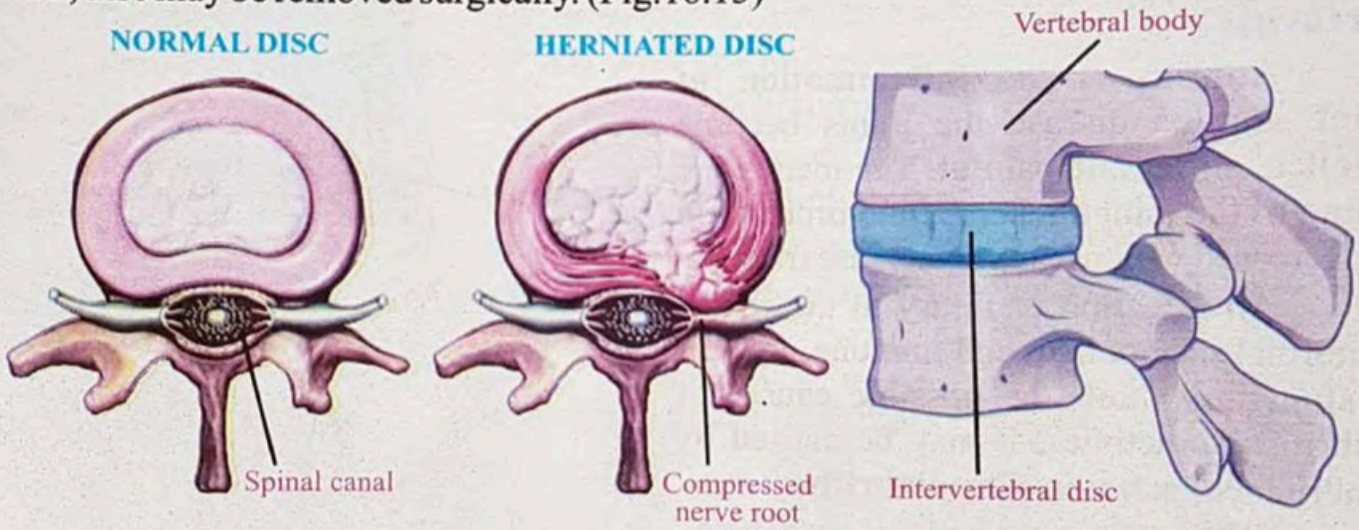


Fig.16.13: Structure of Normal and Herniated Disc

Spondylosis

Spondylosis is the immobility and fusion of vertebral joint. It occurs due to the degeneration of intervertebral discs, spinal injury, ligaments stiffness, formation of bone spurs with age and overuse of spine. Genetic disposition is also a risk factor for spondylosis.

Spondylosis is common in cervical spine called the **cervical spondylosis**. It is a painful condition of spine in which the discs of cervical spine gradually breaks down, lose fluid, and become stiffer with age.

Sciatica

Sciatica refers to the back pain caused by a problem with sciatic nerve. Sciatic nerve is a large nerve that travels from lower **lumbar spine** to the back of each leg. Any injury to sciatic nerve cause pain in the lower back that travels to the hip, buttocks and

leg. Recovery from sciatic injury is usually slow and incomplete.

Common causes of sciatica include; a herniated disc, any injury to proximal sciatic nerve, **spondylolisthesis** (a condition in which one vertebra slips forward over another one), muscle spasm in the back or buttocks, improper administration of injection into the buttocks. The pregnant women have a great chance of getting a herniated disc and develop sciatica. Diabetes can also cause nerve damage.

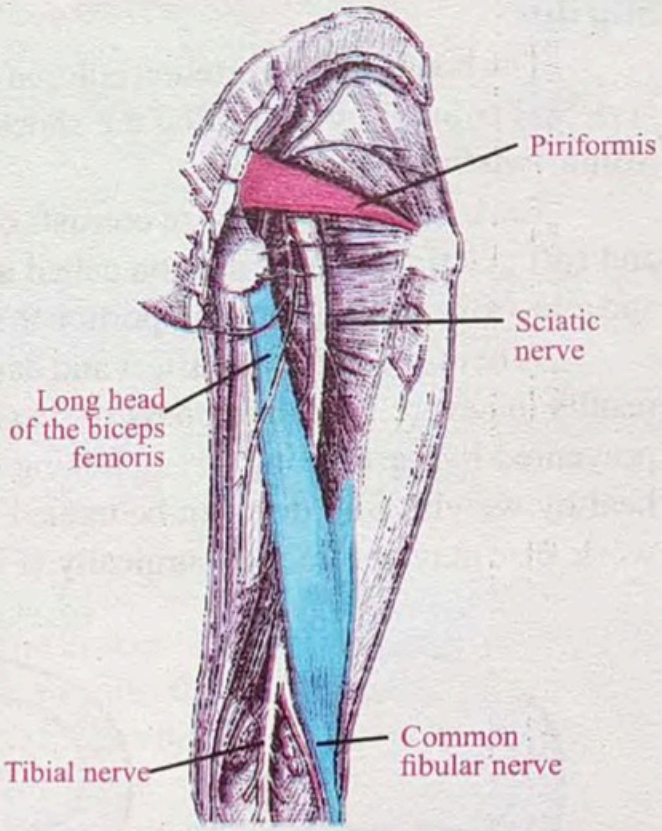


Fig.16.14: Location of Sciatic Nerve in Leg

Arthritis

Arthritis is the **inflammation of joint**. In this disease the joints become swollen, stiffer and painful. The membrane lining of the joint thickens, fluid production is decreased which leads to increase friction.

An infection or injury to the joints, abnormal metabolism and immune system dysfunction are the possible causes of arthritis. Sometimes, it may be caused by inheritance such as in **osteoarthritis**.

Chronic arthritis includes osteoarthritis, rheumatoid arthritis and gouty arthritis. **Osteoarthritis** is the most common type of arthritis. It can cause inflammation of any joint. It occurs when the joint cartilage is degenerated.

Rheumatoid arthritis is the inflammation of hand and wrist joints. **Gouty arthritis** develops in people who have high level of uric acid in their blood. It is caused by the deposition of needle like crystals of uric acid in a joint.

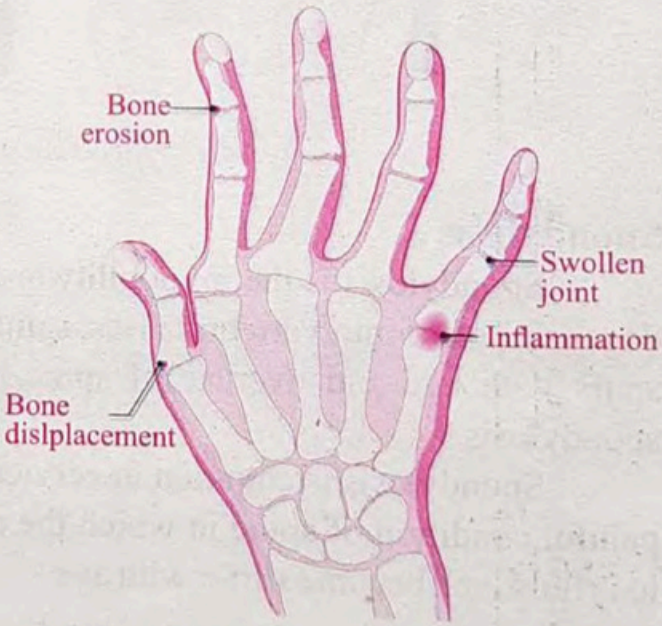


Fig.16.15: Rheumatoid Arthritis

16.2.2 Bone Fracture

When there is a partial or complete break in the continuity of the bone, it is called bone fracture. Fractures occur mostly when a bone is impacted by more force than it can

bear. There are different types of fractures. In more severe cases, the bone may be broken into many pieces. A fracture is treated by **reduction** (orthopaedic surgery).

Reduction is a procedure through which the bone fractures are repaired by realigning parts of broken bone. Reduction is done according to the type and complication of fracture. There are two types of reduction, closed reduction and open reduction.

1. **Closed reduction** is a procedure in which the bone fragments are coaxed back to their initial position by physician's hands without the surgical exposure of the bone fragments.
2. **Open reduction** is a procedure in which surgery is performed by dissecting the tissues and fracture fragments are secured together with the help of pins or wires.

Types of bone fractures

There are different types of bone fractures. Some common types are as follows.

1. **Simple fracture or Closed fracture:** The broken bones remain within the body. The skin remains intact and there is no damage to the surrounding tissues.
2. **Compound or Open fracture:** When the broken bones penetrate the skin or if the force of injury breaks the skin, causing a risk of infection.
3. **Complicated fracture:** When broken bone damages the surrounding structures (Organs). There may be a damage to arteries, veins and nerves. The complicated fracture heals more slowly. (Fig.16.16)

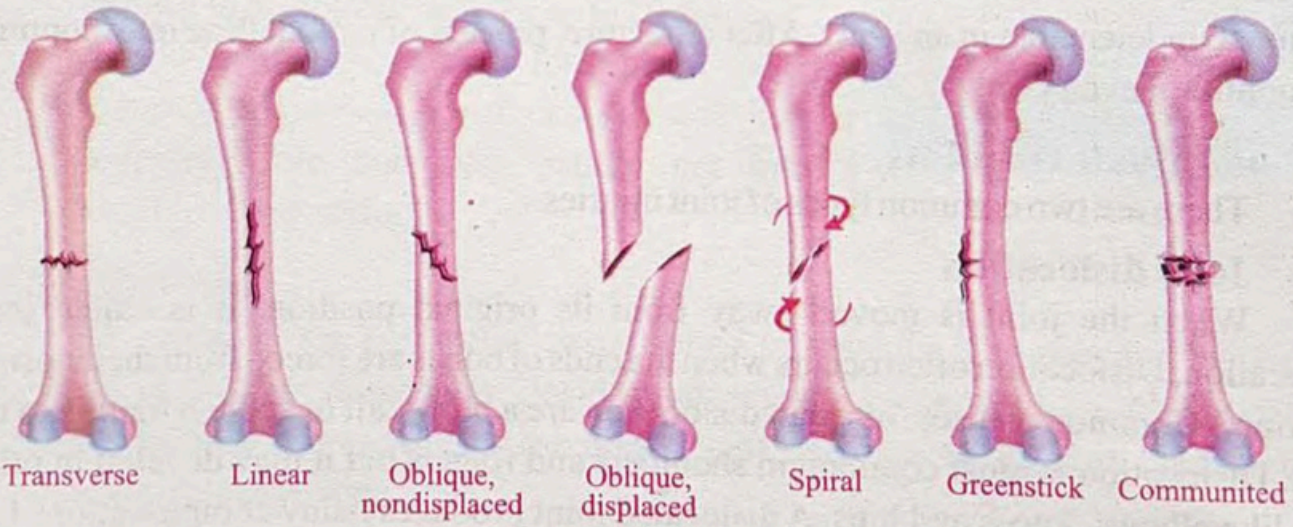


Fig.16.16 Types of Fractures

16.2.3 Healing process of a simple fracture

Bone healing is a natural process which, in most cases, will occur automatically. Healing time is usually 8-12 weeks, but it is much longer for large weight bearing bones. Healing process is usually slow in elder people due to their poor blood circulation. The repair process of a simple fracture takes place in four phases.

1. **Hematoma formation:** It is the first stage of healing after the bone fracture. Due to fracture, the blood vessels are injured, so much bleeding occurs at the fractured site. This blood starts to clot at the fractured site and forms **hematoma**. Bone cells deprived of nutrients begin to die. This also damages the nearby tissues and tissues at the fractured site become swollen and causing a lot of pain.

2. **Soft callus formation:** Within the few days after the bone is broken, the soft callus begins to produce. The capillaries grow into the **hematoma** and phagocytic cells clear up the debris (dead cells). The **fibroblast** and osteoblasts enter the fracture site and begin to reconstruct the broken bone. Fibroblasts produce collagen fibres that connect the ends of broken bone, while osteoblasts start to form spongy bone. Some bone spicules may also appear at this time. Soft callus lasts for approximately 4-6 weeks from the time of injury.

3. **Hard/bony callus formation:** During this stage, osteoblasts and osteoclasts multiply rapidly, continue to move inward and convert the soft callus into bony callus. The woven bone is transformed into the lamellar bone. In the mending process. A ring of new bone tissue is formed around the fracture, so the mended bone is slightly thicker in the region of fracture.

4. **Bone remodelling:** The bony callus is then remodelled by osteoblasts and osteoclasts. The unwanted bits are broken down and reabsorbed. The final mended bone is almost undetectable in an x-ray. After a fracture, process of remodelling may continue for months or even years.

16.2.4 Injuries to joints

There are two common types of joint injuries.

a) Joint dislocation

When the joint is moved away from its original position, it is called joint dislocation. Dislocation often occurs when the ends of bones are forced from their normal position. Common causes of joint dislocation are a blow, fall or sudden trauma to the joint. Dislocation is most common in shoulders and fingers but it may develop in other sites like elbows, knees and hips. A dislocated joint produces many compli-cations like tearing of muscles, ligaments and tendons that support the injured joint. There is also a risk of nerve or blood vessel damage in or around the affected joint. Common symptoms of joint dislocation include intense pain, swelling, bruising, joint immobility and stiffness of muscles. Most joint dislocation returns to normal function when treated properly. Sometimes surgery may be needed to repair the ligaments. However, some joints may have an increased risk of repeat dislocation, such as shoulder joint.

b) Sprain

Stretching, tearing or twisting of ligaments is called **sprain**. Common symptoms of sprain are bruising, pain, swelling and limited movement for the affected joint. Usually sprains are caused by injury. It happens when the ligaments are pushed from their normal capabilities. The most common type of sprain is an ankle sprain (such as twisting ankle). Initial treatment of sprain includes rest, ice, compression and elevation. Mild sprain can be treated at home successfully. Severe sprains require surgery to repair the torn ligaments.

16.2.5 First aid treatment for fractures

First aid treatment is very useful for fractures as it prevents further injury and promote recovery. There are following first aid treatments for fractures.

1. Apply pressure to the injured area to control any bleeding. Pressure can be applied with the help of clean cloth or bandage.
2. Immobilize the injured area by providing support. This can prevent any further damage.
3. Apply ice packs to the injured part. This will limit swelling and relives pain. Don't apply ice directly to the skin, wrap the ice in a towel or cloth and apply it to the injured area for up to 10 minutes.
4. Keep checking the casualty for signs of shock. If the patient loses responsiveness, check his/her breathing rate and help patient get into a comfortable position.

Extra Information

The largest muscle of the body is gluteus maximum which is main extensor muscle of the hip. It supports the trunk and maintain proper posture.

16.3 Muscles

The muscle is a contractile tissue found in animals. The primary function of muscle is to produce movement. Besides movement muscles also hold body parts in postural positions, movement of the body fluids and heat production. The study of muscles is called **myology**.

16.3.1 Types of Muscle

There are over 640 muscles in the body of human which are divided into following three groups:

Skeletal Muscles

These are located on skeleton so called skeletal muscles. They are **voluntary muscles**, meaning that we can control them at will. They typically control movement

through activation by the somatic branch of peripheral nervous system with a rapid speed of contraction. Skeletal muscles also play a role in temperature regulation, using rapid muscle contraction. They are striated, meaning that its tissue is crossed with light and dark bands. They get fatigue easily. (Fig.16.17a)

Smooth Muscles

Smooth muscles are **involuntary muscle** tissue controlled by the automatic nervous system. They are located in all visceral organs (except heart) such as the stomach, intestines, bladder as well as our blood vessels. Smooth muscle contracts more slowly than skeletal and cardiac. The function of smooth muscle is to move substance through an organ or vessel. It does so by contracting in waves, known as **peristalsis**. The cells of these muscles are **spindle shaped** with a single nucleus located in the middle of the cell. They do not get fatigue.

Cardiac Muscles

They are located only in heart. They are involuntary muscles so controlled by autonomic nervous system. Like skeletal muscle, these muscle cells are also striated. In between its fibres are intermittent spaces, which contain connective tissues and many capillaries to ensure a constant supply of oxygen. The cells are **uninucleated** and branched. Adjacent cells joint together to form branching fibres by specialized cell to cell attachment called **intercalated discs**. The comparison of these three types of muscles are given in table 16.4. (Fig.16.17c)

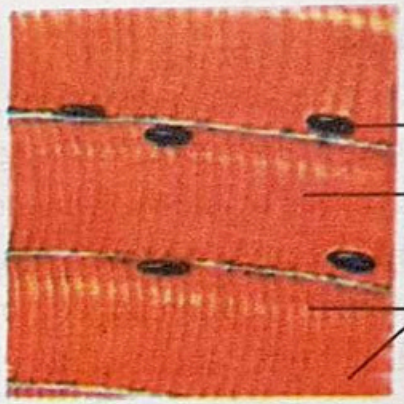


Fig.16.17(a): Skeletal Muscle

Fig.16.17(b): Smooth Muscle

Fig.16.17(c): Cardiac Muscle

Extra Information

The hardest working muscle in the body are cardiac. The heart pump about 2500 gallon of blood per day.

Table 16.4: Comparison of Three Types of Muscles

	Skeletal	Cardiac	Smooth
Location	Attached to bones	The heart	Internal organs and skin
Shape	Elongated and cylindrical 	Branched 	Spindle 
Nucleus	Several peripherally located nuclei	Single centrally located nucleus	Single centrally located nucleus
Striation	Striated	Striated	Non-striated
Function	* Movement of bone * Heat production	Beating of the heart	Movement of the viscera
Control	Voluntary	Involuntary	Involuntary

16.3.2 Structure of skeletal muscles

Each skeletal muscle is attached with two bones. The end of skeletal muscle attached with immovable bone is called origin of muscle, while the other end of skeletal muscle is attached with moveable bone is called insertion of muscle. The muscle attaches with bone by a connective tissue known as tendon. Within a typical skeletal muscle is a bundle of long fibres running parallel to the length of muscle. Each fibre is a single cell with multi nuclei (each nucleus is derived from one of the embryonic cell). These embryonic cells fused to form the muscle cell. Inside a muscle cell lies a longitudinal bundle of myofibrils, which contain the thin and thick filaments. Each thin filament mostly consists of **actin filaments**. The thick filaments are called **myosin**. The **myofibrils** are made up of repeating sections called **sarcomeres**, which are the basic contractile units of skeletal muscle. Theborders of the sarcomere

Extra Information

The smallest muscles (stapedius) of the body lie in the ear along with smallest bone (Stapes), while the strongest muscle, based on its weight, is the masseter, in the jaw.

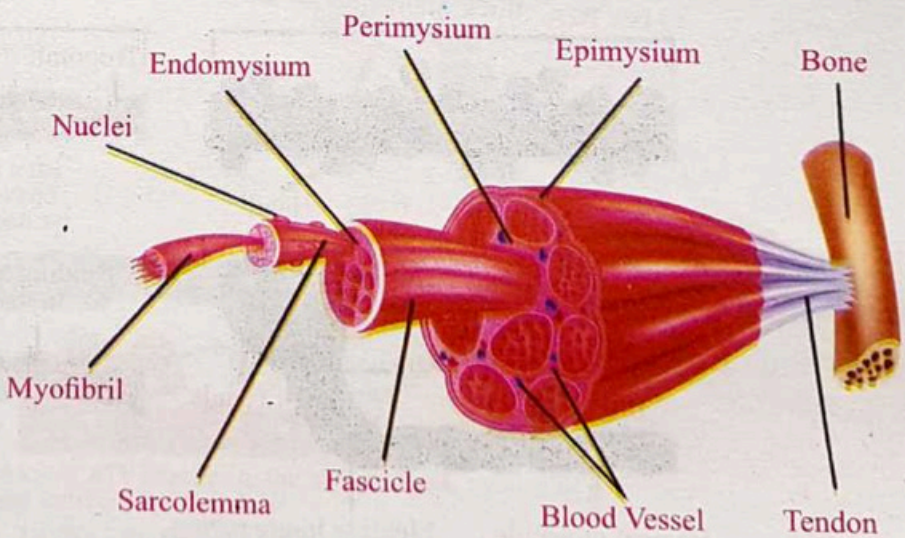


Fig.16.18: Structure of Skeletal Muscle

line up in adjacent myofi-brils, forming a pattern of light and dark bands (striations) visible with light microscope. That is why skeletal muscles are called **striated muscle**. The thin filament attached with **Z line** (zwisch line means between), while thick filaments are anchored at M-lines **(middle line)** centered in sarcomere. In relaxed state, the thick and thin filaments partially overlap. Near the edge of sarcomeres there are only thin filament and this portion of sarcomere is called I-band (isotropic). The zone of sarcomere in the center contains thick band and called A-band (Anisotropic) *i.e.* complete length of myosin partially covered by actin filament. The middle portion where only myosin filaments are present are called **H-Zone** (Hele Zone means bright). This arrangement is the key to how the sarcomere and whole muscle contract.

Ultra-structure of Skeletal Muscles

The sarcomere is the structural and functional unit of muscle fibre (muscle cell). A muscle fibre is a cylindrical cell which contains all the parts of a typical cell like plasma membrane (sarcolemma), cytoplasm (sarcoplasm), endoplasmic reticulum (sarcoplasmic retialum), mitochondria, nuclei, *etc.*

Extra Information

Muscles are built during sleep, not in gym or during exercise because at this time more blood circulation and hormones are released.

Under electron microscope, in the sarcomere two types of filaments are visible. Thick filaments are called myosin while thin filaments are called actin.

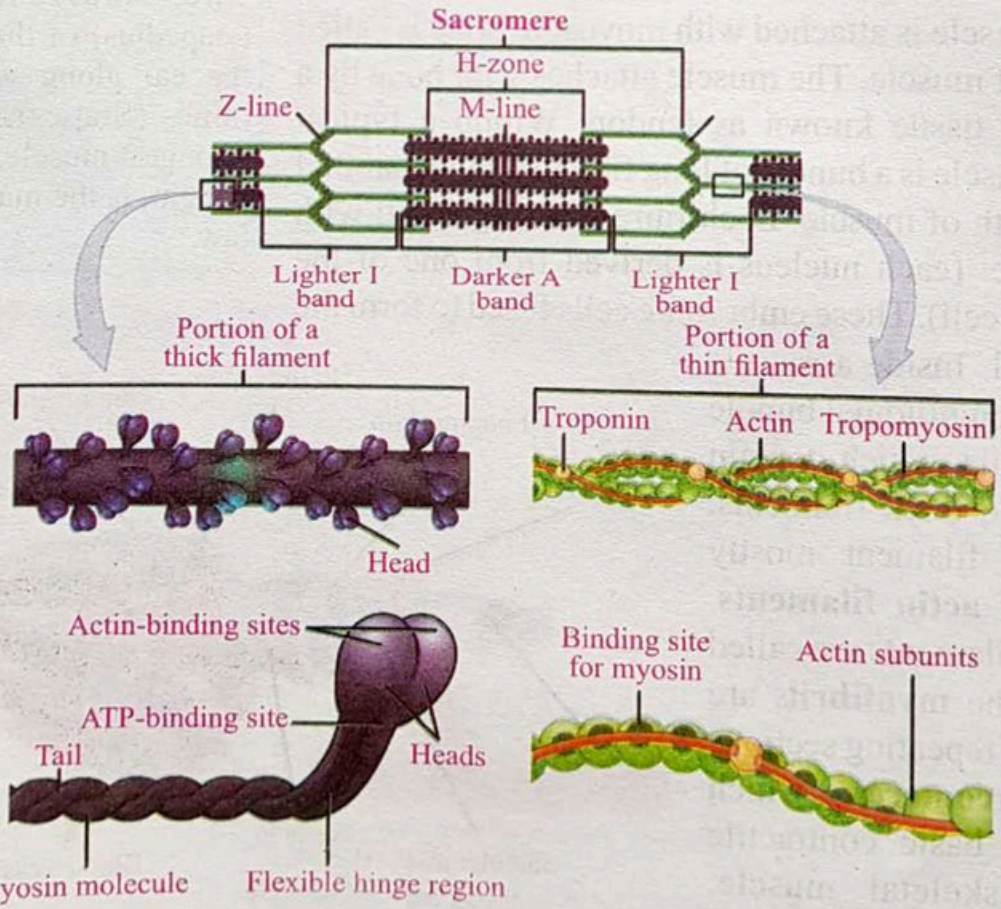


Fig.16.19 Ultra Structure of Actin-myosin Filaments and Structure of Muscle Fibre

Myosin filament

These filaments consist of myosin protein. Each thick filament is 15nm in diameter. Each filament consists of hundreds of molecules of myosin protein. A myosin molecule is shaped like a golf club, with a tail formed of two intertwined chains and a double globular head projecting from it at an angle. Half of the myosin heads projecting from it at an angle to the left and half of them angle to the right, creating an area in the middle of the filament known as bare zone.

Actin filament

Thin filaments are called actin filaments. An actin filament is about 7nm in diameter, and consists primarily of actin protein. There are two chains of actin protein molecules twisted together, each actin filament also contains 40-60 molecules of **tropomyosin**, the protein which block the active sites of thin filaments when the muscle is relaxed. Each tropomyosin molecule has a smaller calcium binding protein called troponin, is bound to it. (Fig.16.19).

16.3.3 Muscle contraction – sliding filament model

According to sliding filament theory of muscle contraction, the actual length of actin and myosin filament does not change but actin filaments slide over myosin filaments. The actual trick is played by myosin filaments. This happens when myosin

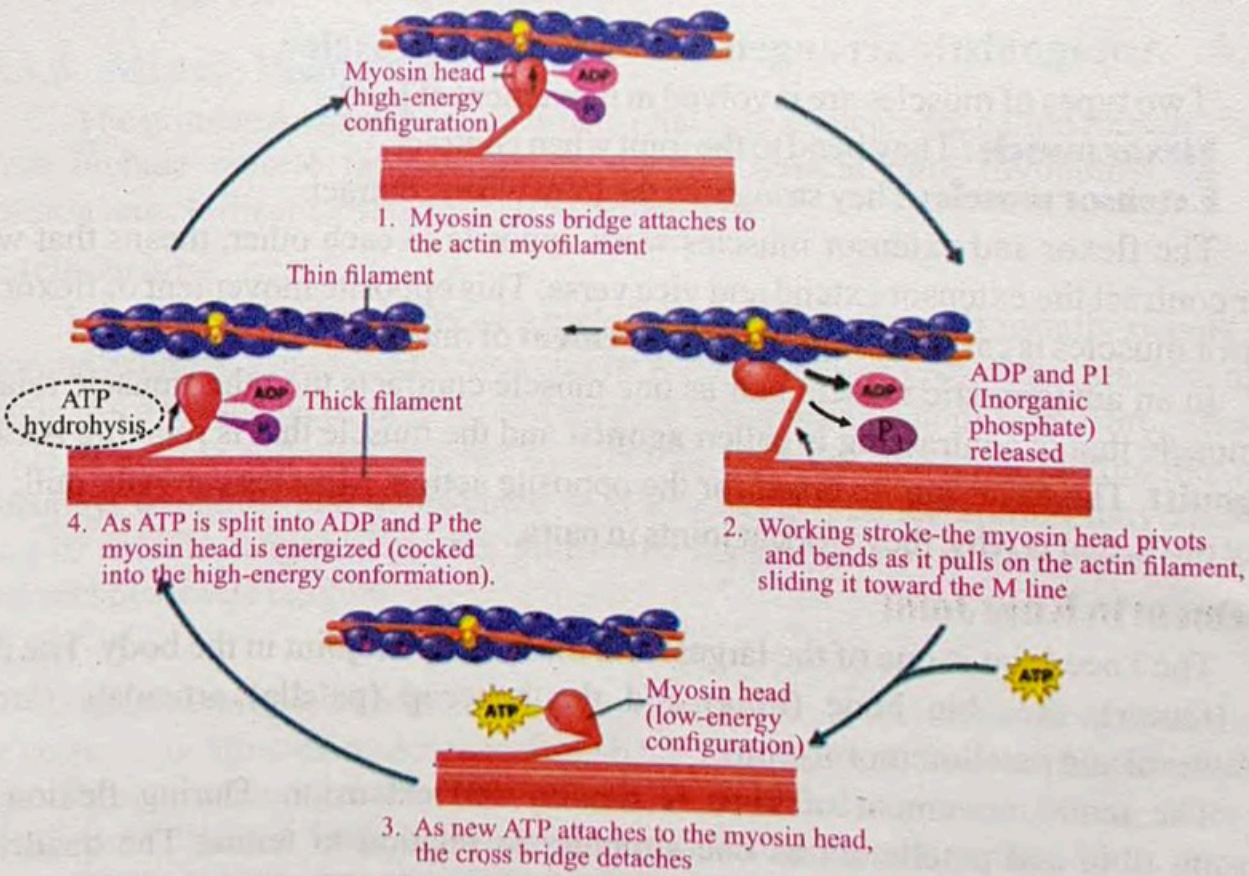


Fig.16.20: Sliding Filament Model

heads attach with actin filament at the site of troponin protein. When these heads bend, these pull the actin filaments over the myosin filaments. This theory was proposed by Z. Huxley and A.F Huxley in 1954. During full muscle contraction the I-band and H-zone disappear and only dark zone *i.e.* A-band appears. During the sliding process the Z-lines come close together and as a result sarcomere shortens. ATP provides energy for muscle contraction. The sliding filament theory or model is universally accepted. (Fig.16.20)

Control of Cross Bridges and Role of Calcium Ions

Muscle contraction is initiated when nerve impulse arrives at the **neuromuscular junction** within the muscle fibre, the action potential spreads deep into the interior, following infolding of plasma membrane called **transverse tubules** (T-tubules). These make close contact with the sarcoplasmic reticulum (SR). As the action potential spreads along the **T-tubules**, it triggers changes in SR, opening Ca^{++} channels. Calcium ions stored in the SR flow through open channels into the cytosol and bind to the troponin protein and cause them to slightly move. As a result, tropomyosin diphase and expose the binding site for myosin head. Once the myosin head attaches with actin filament, ATP is hydrolysed to adenosine diphosphate (ADP) and inorganic phosphate (Pi) and the cross bridges are broken down. The formation and break down of cross bridges occur again and again and movement of muscle occurs.

16.3.4 Antagonistic arrangement of Skeletal Muscle

Two types of muscles are involved in movement of joint.

1. **Flexor muscle:** They bend to the joint when contract.
2. **Extensor muscle:** They straighten the joint when contract.

The flexor and extensor muscles work opposite to each other, means that when flexor contract the extensor extend and vice versa. This opposite movement of flexor and extensor muscles is called **antagonistic movement** of muscle.

In an antagonistic muscle pair as one muscle contracts the other muscle relaxes. The muscle that is contracting is called **agonist** and the muscle that is relaxing is called **antagonist**. The terms are reversed for the opposite action. Muscles can only pull; they cannot push, that is why, they work at joints in pairs.

Movement in Knee Joint

The knee joint is one of the largest and most complex joint in the body. The thigh bone (femur), the shin bone (tibia) and the kneecap (patella) articulate through tibiofemoral and patellofemoral joint.

The main movement of knee is flexion and extension. During flexion and extension tibia and patella act as one structure in relation to femur. The quadriceps muscle group is made up of four different individual muscles. They join together forming

one single tendon which inserts into anterior tibial tuberosity, embedded in tendon in patella, a triangular **sesamoid** bone and its function is to increase the efficiency of the **quadriceps contractions**. Contraction of quadriceps pull the patella upwards and extends the knee. The **hamstring muscle** group consist bicep femoris, **semitendinosus** and **semimembranosus**. They are situated at the back of the thigh and their function is flexing or bending the knee as well as providing stability on either side of the joint line. (Fig.16.21)

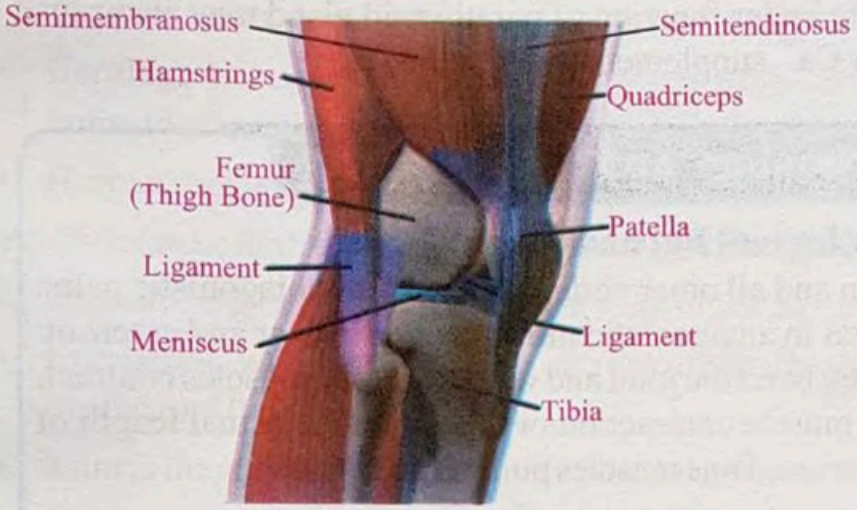


Fig.16.21: Movement of Knee Joint

Extra Information

The quadriceps and hamstrings (leg muscles) work together to move legs, when you bend your legs, the hamstrings contract and quadriceps relax and vice versa.

16.3.5 Muscle Disorders

The problems, diseases or disorders related to muscles are called muscle disorder. These include muscle fatigue, cramp, tetanus, muscle pull, myopathy, *etc.* Some common muscle disorders are discussed below.

Muscle fatigue

It is decline in the ability of a muscle to generate force. It usually occurs due to vigorous exercise. Due to heavy exercise or work anaerobic respiration starts in skeletal muscle. As a results lactic acid is produced and accumulates in muscle fibre. This drops the pH of muscle and muscle aches by breaking glucose. The other factors like muscle dystrophy, weakness and atmosphere with low oxygen concentration may also be the cause of muscle fatigue. The rest, nutritional supplement or caffeine are the possible treatment of muscle fatigue.

Cramp

Muscle cramp is sudden, involuntary contractions that occur in various muscles. The commonly affected muscles include back of lower leg, back of thigh and front of thigh. These contractions are often painful. A sudden sharp pain, lasting from a few seconds to 15 minutes, is the most common symptom of muscle cramp. There are several causes of muscle cramp *e.g.* over use of muscle as in exercise, dehydration, muscle

injuries, low level of minerals like Ca, K, Na, Mg, low blood supply, *etc.*

The muscle cramp can be prevented by limiting the exercises, warm up before exercise, drinking fresh juices and mineral water and milk regularly.

Tetany

It is a condition in which involuntary muscle cramps and contraction occur usually in the hand and feet. But these spasms can extend throughout the body and even in the larynx causing breathing problems. Tetany can be the result of an electrolyte imbalance, like low Ca^{++} level. The under function of parathyroid gland may also cause tetany. The tetany can be treated by Ca^{++} supplement and vitamin D.

Science, Technology and Society (STS)

- **Justify why do the muscles pull but do not push.**

Skeletal muscles of human and all other vertebrates work as antagonistic pairs. Two types of muscles are involved in antagonistic movement *i.e.* flexor and extensor. When flexor muscles contract, they bend the joint and when extensor muscles contract, they straighten the joint. During muscle contraction or relaxation the actual length of actin myosin filament does not change. Thus muscles pull but do not push.

- **Relate improper posture to bone joint problem.**

The regular blood supply is needed to parts of body muscles bone and joints. If we use some joints in muscles more frequently than other *e.g.* as in during study and teaching, the students and teacher may show improper postures for long time. This increases stress on their specific bones, joints and supporting structure that result in injury, pain and early degeneration of bones and joints. So proper posture is important to avoid such disorders.

- **Reason out rigor mortis.**

Rigor mortis means stiffness of death. In this condition all of the body muscles become stiff and joint become immoveable after death. It is because energy is required for movement of muscles. After death the production of ATP stops and ATP stores deplete quickly. Therefore, cross bridges lock and muscle movement stops because there is no energy to break these cross bridges. That is why eyes, mouth and part of body are immediately closed after death. The condition of rigor mortis starts after about 4 hours of death and continue up to 40 hours. After 40 hours due to decomposition of protein the muscles start degenerating and condition is reverse now.

- **Name the techniques for joint replacement.**

Joint replacement procedure is called arthroplasty. Now due to advancement in medical science, it is possible to replace natural defective joint to artificial joints. Artificial joints are usually composed of metals, in combination of modern plastics.

SUMMARY

- Skeleton is the main supportive frame work of the body. It includes bones, cartilage, tendons ligaments and joints.
- Bone tissues are of two types; compact and cancellous.
- The process of bone growth and repair is carried out by 4 different types of cells. These are osteogenic, osteoblast, osteocytes and osteoclasts.
- Cartilage is connective tissue composed of cells called chondrocytes and fibres embedded in a firm, gel-like matrix.
- Human skeleton is mainly divided into axial skeleton and appendicular skeleton.
- Hyoid bone is also called lingual bone because it gives attachment to the tongue.
- Ribs are long twisted flat bones that form major part of rib cage.
- Comparing with axial skeleton, the appendicular skeleton is unfused. It consists of girdles and limbs.
- Joint is the attachment between two bones or bone and cartilage.
- Deformation of skeleton may occur due to genetic diseases, hormonal problems and nutritional deficiencies.
- Sciatica refers to the back pain caused by a problem with sciatic nerve.
- When there is a partial or complete break in the continuity of the bone, it is called bone fracture.
- When the joint is moved away from its original position, it is called dislocation of joint.
- The muscle is the contractile tissue, found in animals and the primary function of muscle is to produce movement.
- Cardiac muscles are located in heart and these are involuntary in function so controlled by autonomic nervous system.
- According to sliding filament theory, the actual length of actin myosin filament does not change but actin filament slide over myosin filament.
- The flexor and extensor muscles work opposite to each other. This opposite movement of flexor and extensor muscle is called antagonistic movement.
- The knee joint is one of the largest and most complex joints in the body.
- The problems, disorders and diseases related to muscles are called muscle disorders.

EXERCISE

SECTION-I: OBJECTIVE QUESTIONS

Multiple Choice Questions (MCQs)

A. Select the correct answer.

1. Which one of the followings is not an unpaired bone:
   (a) Mandible (b) Vomer
   (c) Sphenoid (d) Nasal
2. The fusion of four posterior vertebrae present in the pelvic region form:
   (a) cervical (b) lumber
   (c) thorcic (d) coccgial
3. Osteoarthritis is the most common chronic arthritis which is a degenerative joint disease also caused by:
   (a) Genetic defect (b) Hormonal defect
   (c) Nutritional cause (d) Environmental cuase
4. Disease appearing due to low Ca^{+2} level in blood:
   (a) Cramp (b) Arthritis
   (c) Spondylosis (d) Tetany
5. The end of muscle which remains fixed when muscles contract:
   (a) Insertion (b) Origin
   (c) Tendon (d) Ligament
6. The human skeleton consists of
   (a) 80 bones (b) 126 bones
   (c) 200 bones (d) 206 bones
7. The mature bone cells are called
   (a) Osteoblast (b) Osteocytes
   (c) Osteoclast (d) Osteogenic
8. Cartilage is a connective tissue composed of
   (a) Lymphocytes (b) Monocytes
   (b) Myocytes (d) Chondrocytes
9. Acetabulum provides articular surface for the
   (a) Femur (b) Humerus
   (c) Fibula (d) Radius
10. The number of bones in tarsal are
    (a) 8 (b) 5
    (c) 7 (d) 3

11. Rheumatoid arthritis is inflammation of ·
(a) Knee bone (b) Elbow bone
(c) Finger bone (d) Big toe

12. Bone breaking cells are called
(a) Osteocytes (b) Osteoblast
(c) Osteology (d) Osteoclast

13. Human internal organs are protected mainly by
(a) Axial skeleton (b) Appendicular skeleton
(c) Hydro skeleton (d) Exoskeleton

14. Which of the following protein is the component of skeletal tissue
(a) Hemoglobin (b) Myoglobin
(c) Fibrinogen (d) Collagen

15. Stretching, tearing or twisting of ligaments is called
(a) Dislocation (b) Sprain
(c) Fracture (d) Reduction

16. The cardiac muscle cells are
(a) Uninucleated (b) Polynucleated
(c) Dinucleated (d) Non-nucleated

17. The end of muscle attached with moveable bone is called
(a) Origin (b) Flexing of muscle
(c) Insertion of muscle (d) Belly of muscle

18. The diameter of actin protein filament is about
(a) 16nm (b) 7mm
(c) 6cm (d) 7nm

19. The in folding muscle fibre membrane is called
(a) Sarcoplasmic reticulum (b) Z-line
(c) Dark band (d) T-tubules

20. Which ions are required for muscle contraction?
(a) Sodium (b) Potassium
(c) Calcium (d) Magnesium

B. Complete the following sentences.

1. Skeletal tissues are either bone or .....
2. Osteocytes are located in the small cavity called .....
3. The axial skeleton consisting of 80 bones and appendicular skeleton consists of ..... bones.
4. The unique feature of hyoid bone is that it does not ..... with any

other bone of the body.

5. The word clavicle is derived from Latin word .....
6. Ball and socket joint, hinge joint and pivot joint are the example of ..... joints.
7. Each intervertebral disc consists of an outer strong ring called annulus fibrous and soft gelatinous inner portion called .....
8. Arthritis is the inflammation of .....
9. When the joint is moved away from its original position, it is called joint .....
10. The study of muscle is called .....
11. The muscle is attached with bone by a connective tissue known as .....
12. The sarcomere is the structural and functional unit of muscle .....
13. The opposite movement of flexor and extensor muscles is called ..... movement.
14. Largest and complex joint of human body is ..... joint.
15. The muscle that is contracting is called agonist and the muscle that is relaxing is called .....

SECTION-II: SHORT QUESTIONS

C. Give the short answers of the following questions.

1. Describe the four types of cells associated with bone.
2. Differentiate between bone and cartilage.
3. Enlist the main functions of skeleton.
4. Write the names of the cranium bones.
5. Write the names of facial bone.
6. Illustrate the three types of ribs.
7. Differentiate between carpals and tarsals.
8. Differentiate between Fibrous and cartilaginous joints.
9. Differentiate between two types of reductions.
10. Write difference between simple, compound and complicated fractures.
11. Illustrate the first aid treatment for fractures.
12. Briefly explain sliding filament theory.

13. Define antagonistic arrangement of muscle.
14. Write short note on muscle fatigue.
15. Differentiate between tetany and cramp.
16. Describe the sciatica.
17. Define arthritis and its types.

SECTION-III: EXTENSIVE QUESTIONS

D. Give detailed answers of the following questions.

1. Describe the structure of bone.
2. Explain the bones of fore limb in detail.
3. Define joint and explain different type of joints.
4. Explain the steps of healing process of a simple fracture.
5. Define antagonistic movement and explain the movement of knee joint.
6. Describe the structure of skeletal muscle.