ORTHOPEDICS
Anatomy & physiology

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Course Description

This course will introduce the basic structure and function of the locomotors system. This involves acquiring detailed knowledge, and understanding of structure and function of the human skeletal muscle in health and disease as well as bone structure, formation and mineralization in health and disease. Other structures will bw gently handled as joints and its surrounding tissues as skin, facia and ligaments.
Students will learn about basic concepts of processing information as well as the skills to related to orthopedics

Core Knowledge

By the end of this course, students should be able to:

- Describe the general and basic structure of the bone & joints of the human body.
- Describe the sequence of events taking place during early prenatal development of the human embryo or common causes of congenital malformations
- Discuss the anatomical features of any structure (fascia, regions, muscles, vessels nerves) of the bone & joints.
- Describe the developmental process and/or congenital anomalies of the bone & joints.
- Discuss the skeletal muscle mechanisms of Contraction, relaxation
- Explain the difference between voluntary contraction and reflex contraction of the skeletal muscles.
- Expect the type of muscle fibers used and source of energy according to the pattern of contraction.
- Deduce the role of calcium in excitation contraction coupling and in skeletal muscle contraction and relaxation.
- Deduce the role ATP as a source of energy in muscle contraction and relaxation.
- Explain how the muscle performance may be altered in disease.
- Differentiate between the expression bone modeling and bone remodeling
- Discuss the general function of the skeleton.
- Mention the function of each structural components of the bone
- Mention how the processes of bone formation and bone resorption are coupled and its role in healing of fracture
- Outline the factors affecting bone formation and mineralization.

- Discuss the hormonal regulation of calcium level, bone formation and mineralization

- Differentiate between osteoporosis and osteopetrosis
- Mention some causes for the defective bone Formation
- Outline types of bone marrow , function, and common diseases

Core Skills

By the end of this course, students should be able to:

1. Identify marked bony features or attachments on real bones or projected pictures of bones of the human skeleton.
2. Identify marked structures (e.g., muscles, vessels, nerves, ligaments, viscera … etc.) in the human body in dissected cadavers, plastic models or projected pictures.
3. Identify and examine the muscle tone, power and reflexes.

PART I
Anatomy

Second

Chapter 1

General

Definition of Anatomy:

It is the study of the structure of the body and the relationship of its constituent parts to each other. Anatomy comes from the Greek word (anatomies) which means to dissect or cut apart.

Anatomical study:

It can be done on dead and living bodies both macroscopically and microscopically.

I - Macroscopical Anatomy (Gross morphology):

It is the study of body details which can be seen by the naked eye. It includes two main methods of study:

1) Regional (topographical) anatomy: study of various structures found within a certain region of the body, e.g. thorax, abdomen, etc.
2) Systematic anatomy: study of a particular system, e.g. nervous system, cardiovascular system.

II - Microscopical Anatomy:

It is the study of the fine structure of the body tissues using the light and electron microscope.

Other Fields of Anatomy

1) Developmental anatomy (Embryology): includes the sequence of events taking place to produce a full-term human being.
2) Applied and clinical anatomy includes the structural observations which are significant in medicine to help in diagnosing and treating diseases.
3) Surface anatomy:
   a. To locate organs in relation to body surface
   b. To palpate parts of the skeleton
   c. To locate arterial pulses
4) Instrumental anatomy: This field entails the use of helpful instruments to visualize deeply seated living organs, many methods are included:
   A - Endoscopy;
   B – Radiology;
   C – Ultrasonography
   D –Magnetic Resonance Image (MRI).

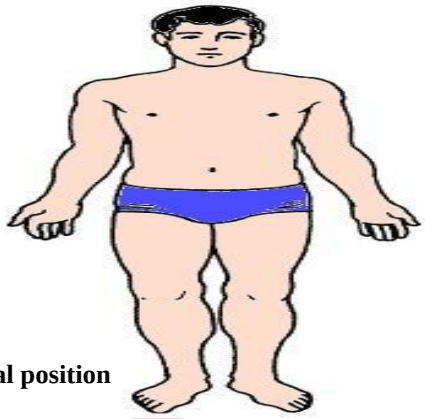
5)Comparative anatomy: It is the study of the anatomical differences between the species.

Objectives

Describe the Anatomical position & planes

Anatomical position:

1- The person is standing erect.
2- With the arms straight by the side.
3- The legs close together.
4- The eyes and palms are facing forwards.

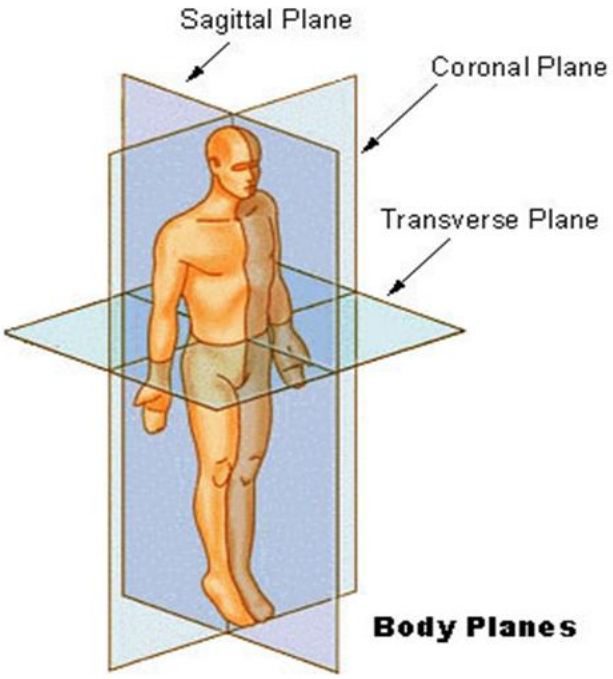


Anatomical position

Planes:

1- **Median (sagittal) plane:** Vertical plane which divides the body into right and left symmetrical halves.
2- **Coronal plane:** vertical plane perpendicular to the median plane which divides the body into anterior and posterior part.

Transverse plane: Perpendicular to both the median and coronal plane, it divides the body into upper and lower parts.



Body Planes

***Q: HOW TO Describe the Anatomical Movements*:**

N.B:Axes:

1- **Vertical axis:** Perpendicular to the median plane.
2- **Antero-posterior axis:** Perpendicular to the coronal plane.
3- **Transverse axis:** Perpendicular to the median plane.

N.B: Flexion is the approximation of two surfaces. It takes place around a horizontal axis.

- Extension occurs in the opposite direction i.e. is the return back from flexion i.e. straightening.

Examples:

- Flexion of the upper limb. - Extension of the upper limb.
- Flexion of the lower limb. - Extension of the lower limb.

- Plantar flexion and dorsiflexion: these movements occur at the ankle joint and are substituted for flexion and extension, respectively.

- Abduction or lateral flexion: this movement brings the part away from the median plane or the central axis of the body or of a limb.

Examples:

*Abduction (lateral flexion) of the trunk.
*Abduction of the limbs.
*Abduction of the hand (radial deviation).

N.B: Adduction: this movement brings the part towards the median plane or the central axis of the body. ***Examples***:

*Adduction of the limbs.

*Adduction of the fingers.

- Opposition of the thumb: this movement brings the thumb to touch other fingers i.e. flexion and medial rotation.

- Rotation: means turning the part along its longitudinal axis.

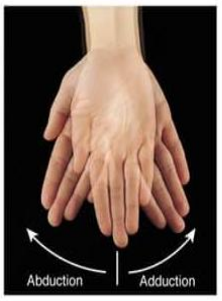
***Examples*:**

Pronation: medial rotation in the forearm so that the palm faces backwards.
Supination: lateral rotation in the forearm so that the palm faces forwards.
Inversion: rotation of the foot so that the sole faces inwards.
Eversion: rotation of the foot so that the sole faces outwards.

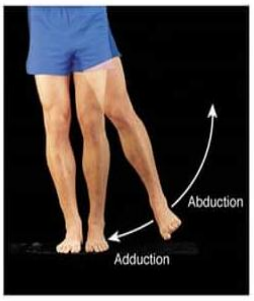
- **Protraction and retraction** are to move the part forward and backward, respectively e.g. of the mandible at the Temporomandibular joint.

- **Circumduction** is a combined movement including flexion, abduction, extension and adduction in the same order of sequence. It is a feature of multi-axial joints like shoulder and hip joints.

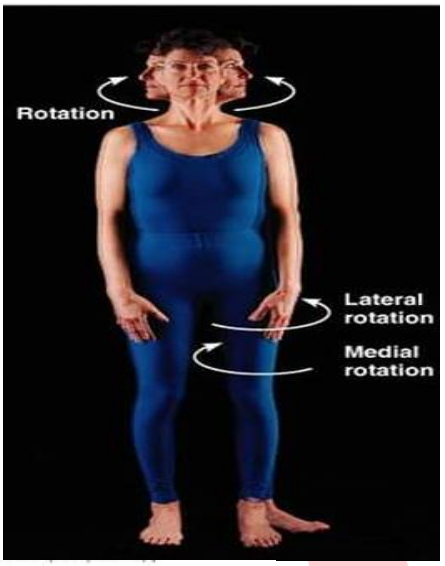
(a) Shoulder joint

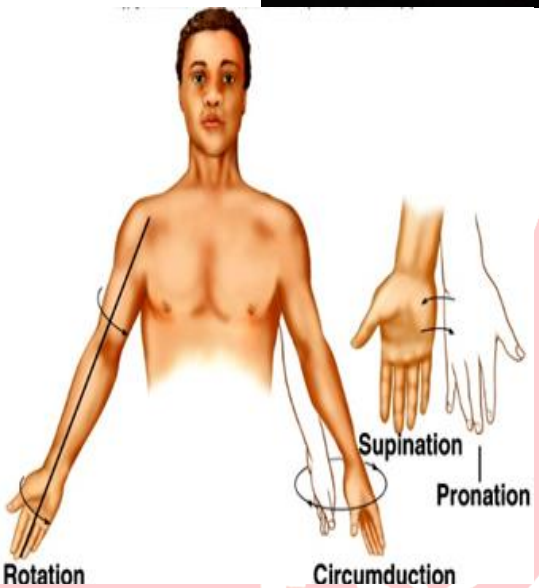


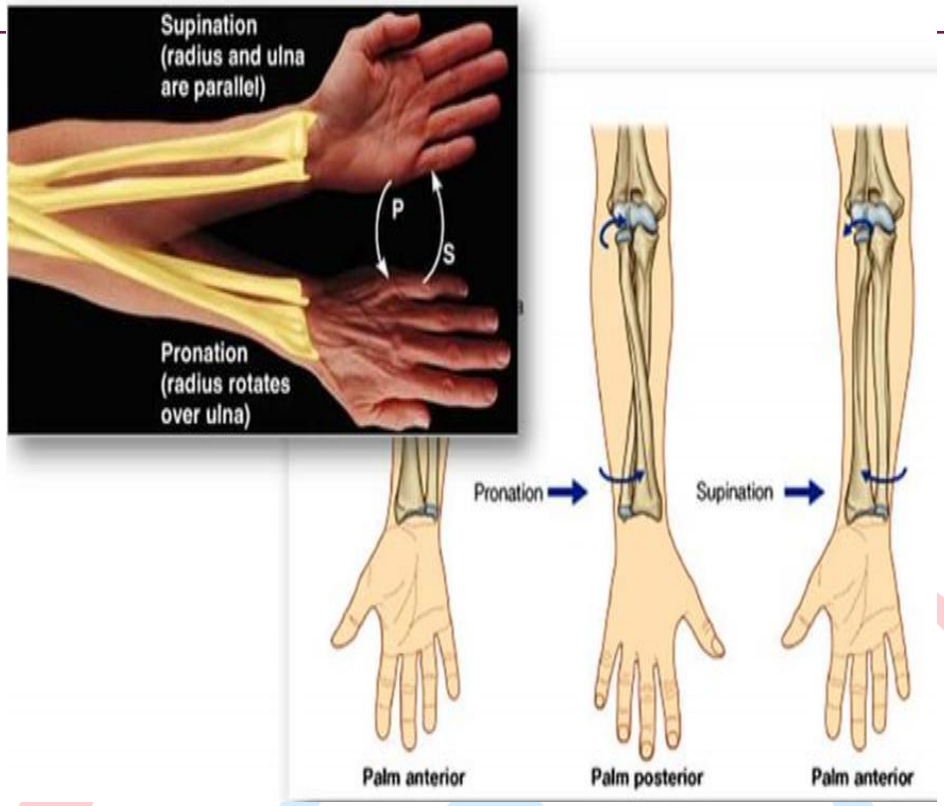
(b) Wrist joint

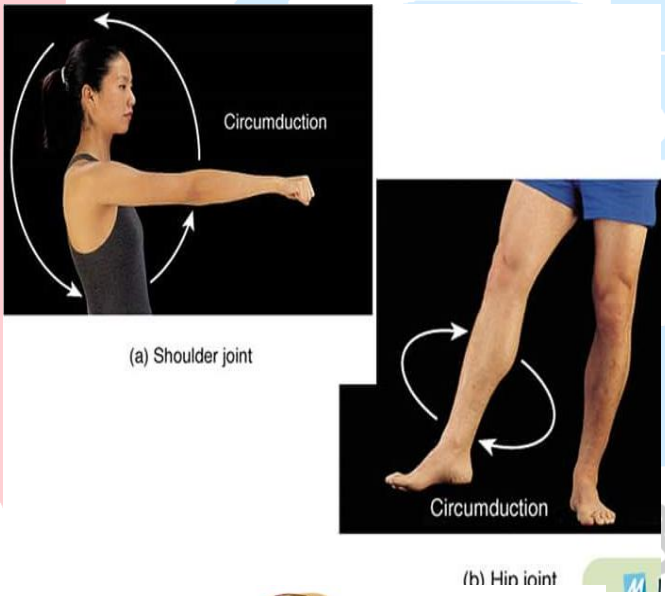


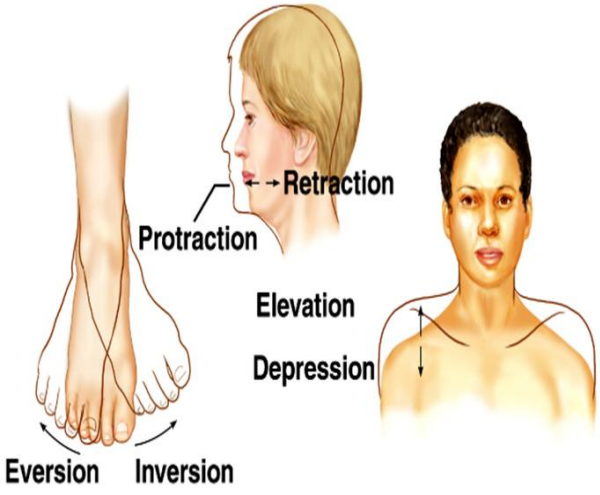
(c) Hip joint






Supination
(radius and ulna
are parallel)
P
S
Pronation
(radius rotates
over ulna)
Pronation
Supination
Palm anterior
Palm posterior
Palm anterior

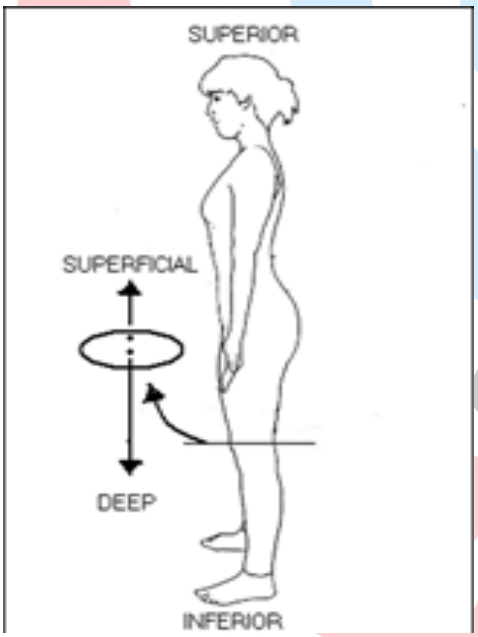

Circumduction
(a) Shoulder joint
Circumduction
(b) Hip joint

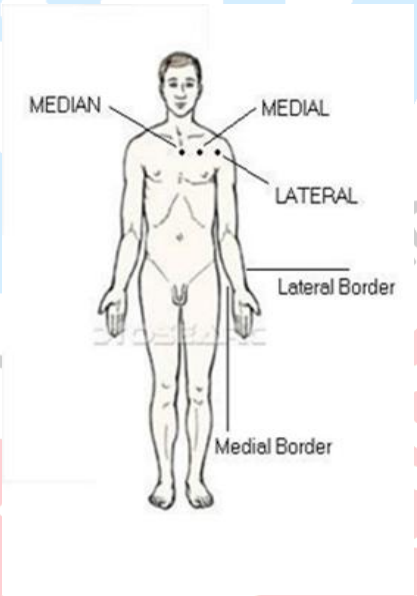

Retraction
Protraction
Elevation
Depression
Eversion
Inversion

Anatomical adjectives:

- **Anterior (ventral):** Is towards the front of the body.
- **Posterior (dorsal):** Is towards the back of the body.
- **Proximal:** Is close to the origin of the structure.
- **Distal:** Is away from the origin of the structure.
- **Medial:** Is near the median plane.
- **Lateral:** Is away from the median plane.
- **Middle:** means mid-point between two fixed ones.
- **Superficial:** means towards the surface of the body.
- **Deep:** means away from the surface of the body.
- **External (outer):** means towards the surface and applies to the hollow-out structure.
- **Internal (inner):** means towards the cavity of a hollow-out structure.
- **Central:** means towards the center of the body.
- **Peripheral:** means away from the center of the body.
- **Ipsilateral:** means of the same side of the body.

Contralateral: means of the opposite side of the body





Q: Discuss the anatomy of Skin & Fascia

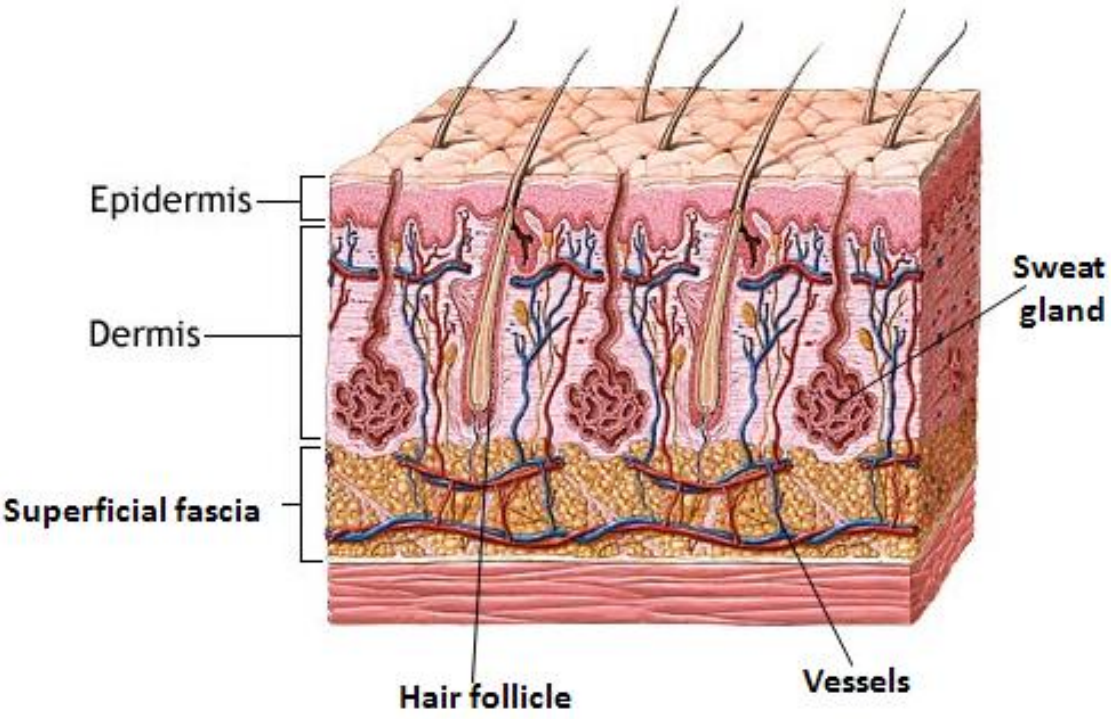
Skin:

The skin consists of an outer stratified squamous epithelium, the **epidermis** and underlying connective tissue, the **dermis which contains sweat glands, hair follicles, sebaceous glands, blood vessels, lymphatics and nerves**

N.B (Melanin& melanocytes) The colour of the skin depends mainly on the amount of melanin produced and secreted by melanocytes located in the epidermis.

Fascia:

The fascia is the tissue that lies under the skin. It consists of two layers:



A) Superficial fascia

It is a mixture of loose areolar tissue of collagen & elastic fibers and adipose tissue. This mixture unites the dermis with the underlying deep fascia.

Functions:

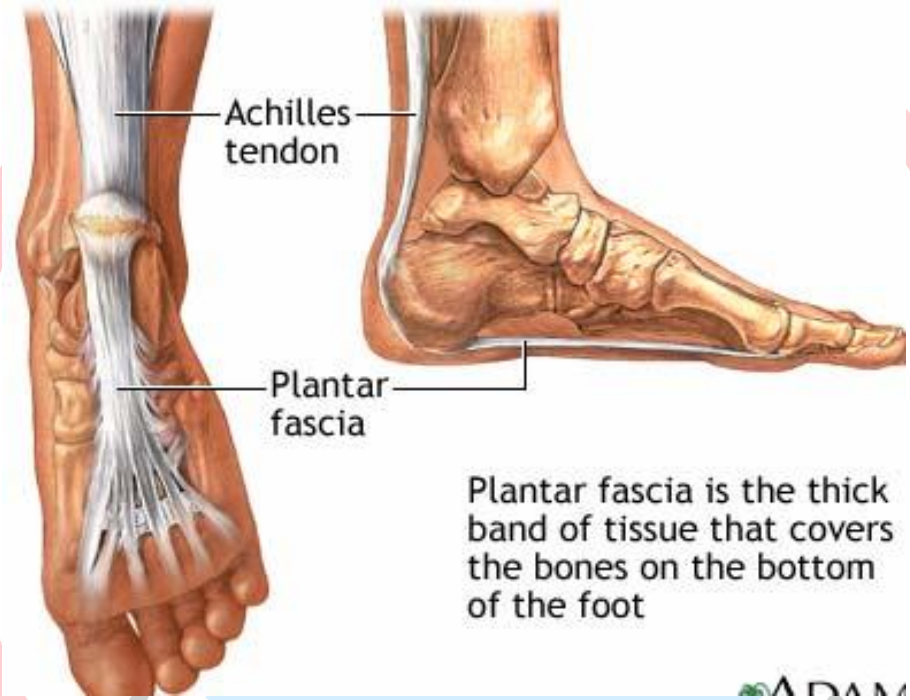
1) Facilitates the movement of the skin.
2) Acts as a bad conductor to heat, so it diminishes the heat loss and keeps warmth of the body.
3) Gives the body its full rounded appearance and smooth outline.
4) Contains the blood vessels, nerves, lymph glands and sometimes thin sheets of subcutaneous muscles.

B) Deep fascia

It is a condensed fibrous tissue which forms membrane under the superficial fascia that invests the muscles and other deep structures **e.g.** plantar fascia.
tear that occurs in these regions

Functions:

1) It covers the underlying muscles, .
2) From its deep surface **septa** pass between muscles.
3) It is thickened in the plam and sole forming **palmar and plantar aponeuroses** which provide protective function to deeper structures.
4) It is thickened around distal joints (e.g. wrist & ankle) to form strong bands called **retinacula** which hold the underlying tendons in position..



Chapter 2 : The Musculoskeletal System.

Discuss the anatomy of the musculoskeletal system

The connective tissues

The connective tissues of the body are composed of cells embodied in ***a matrix*** which varies in its quantity and composition. The cells can be categorized by the nature of the intercellular material, of which there are three types:

1● Bony — osteoid (produced by osteoblasts)
2● Cartilaginous — chondroid (produced by chondroblasts)
3● Fibrous — collagenous tissue (produced by fibroblasts).

In each case the matrix is mainly composed of a complex mixture of proteoglycans and glycoproteins, forming a ground substance in which is embedded a meshwork of fi brils, mostly of collagen, a protein. At least ***four genetically different type***s of collagen are now recognized — bone contains Type I and hyaline cartilage Type II. ***Skin contains Types I and III*** and, being a convenient tissue for ***biopsy***, is used for the study of certain collage related bone diseases. Elastin, a different protein, is found within skin and to a lesser extent in tendon.

Matrix disorders cause a wide variety of clinical manifestations. For example, in the so - called ‘ mucopolysaccharoidoses ’ , an enzyme defi ciency interferes with the breakdown of large mucopolysaccharide molecules, which accumulate in the tissues causing widespread abnormalities.

Connective tissues grow by cell proliferation and deposition of intercellular material Bone

* ***Macroscopic structure***

A long bone is characteristically tubular with expanded ends and is remarkably strong for its weight. The shaft is called the diaphysis and the zone adjacent to the epiphyseal line is the metaphysis. This is the part of the developing bone that is most likely to be the seat of disease, probably because it is the most metabolically active area and has the greatest blood supply. Damage to, or abnormal development of, the epiphyseal plate itself is likely to result in growth disturbance

The short bones consist of a cancellous core surrounded by a layer of cortical bone, partly covered by articular cartilage. They contain red marrow in their trabecular spaces and the vertebral bodies are important sites of

blood formation throughout life.

A normal bone can resist large compressive forces and considerable bending stresses, and only breaks when subjected to considerable violence. It may, however, be weakened by disease and can then fracture as a result of minimal trauma. Such

pathological fractures are often orientated transversely across the bone.

*The bones form fixed points for muscle attachments and their periosteal sheaths blend with the collagen of ***the tendons and ligaments***.

*** Microscopic structure**

Bone consists of ***osteoid***, which is resilient and is heavily infiltrated with calcium salts, giving it hardness and strength. The mechanism of mineralization is not well understood. The mineral is mainly deposited in crystalline form as hydroxyapatite, but there is also an amorphous phase which is found particularly in newly formed bone. It is worth noting that various ions, such as strontium, fluoride and lead, can enter the crystal lattice of bone mineral.

A normal bone is composed of concentric cylinders of matrix with cells lying in lacunae between the layers, the whole forming a ' Haversian system ' . In the hard cortex, the Haversian systems are packed tightly together; in the spongy or cancellous bone, they are more loosely arranged . The bony trabeculae are structured and orientated to withstand the stresses of weight - bearing and muscle activity, obeying Wolff ' s Law. The interstices of the cancellous bone and the hollow centres of the shafts of long bones are fi lled with marrow. Hemopoiesis occurs in the marrow throughout the bones in the child, but in the adult is confined to the short bones, particularly the vertebral bodies, and to the ends of the long bones.

Each bone is ensheathed by ***fibrous periosteum*** with an underlying layer of osteoblasts, and is ***Fibrous t issue***

****Fibrous tissue*** is widespread throughout the body and consists mainly of collagen fi bres with relatively little matrix.

Disorders of collagen metabolism are being extensively studied because of their dramatic effects on body structure and development. These conditions are sometimes called ' true collagen diseases ', as opposed to the non - developmental diseases of collagen, such as rheumatoid arthritis. Osteogenesis imperfecta , is an example of an inherited disorder of collagen metabolism, mainly affecting the structure and strength of bone.

Collagen growth is an important aspect of general body development and fi broblasts are frequently to be seen proliferating and laying down collagen fi bres. This is particularly the case in any situation where repair of tissues is required. The usual end - result of repair, the scar, consists almost entirely of collagenous material. In situations where there is continuing damage to the tissues, with concomitant repair, the scar tissue formed can be extremely dense. ***As it matures, collagenous scar tissue tends to contract,***

sometimes producing distortion and obstruction of internal structures or contractures of skin and joints. Occasionally, the healing of a skin wound may be complicated by the formation of over - exuberant scar tissue, producing a wide and thickened scar known as ' keloid ' . This is more common in races with black skin.

THE MUSCLES

The functions of joints and muscles are closely interrelated. Not only are muscles important for moving the joints, but their co - ordinated action is essential for joint stability. This is very evident in paralytic conditions where the lack of stability may have to be compensated by the use of external splints.

Skeletal muscle is composed of fibers whose length varies from a few millimetres to about 30 cm. Each fiber contains many nuclei embedded in its syncytium and the fiber itself is built up of many myofibrils, each of which consists of units of the proteins actin and myosin. These are arranged in interlocking bands. They give the fibres its characteristic cross - sections and are the contractile elements of the muscle.

The form of a muscle determines its power and contractility. If the fibres are arranged parallel to the line of pull, the contractility is greatest: where there are many fibres arranged obliquely to the line of pull, the power is greater but the ability to shorten is less.

Q .Describe Skeletal , Smooth and Cardiac muscles.

(1) Skeletal Muscle

* They are **voluntary** muscles.
* They are made of striped muscle fibers.
* Each has 2 attachments at least; **origin & insertion.**
* The fleshy part of muscle is called belly.
* The ends of each muscle are attached to bone, cartilage or ligaments.
* They produce the **movements of skeleton.**

N.B:*Synovial sheath: Serous sac surrounds the tendons of the muscles.*
****-Bursae: Small serous sac lies between muscles & bones to minimize their frictions.***

SKELETAL MUSCLE MORPHOLOGY

1. Epimysuim: dense connective tissue that surrounds the entire muscles.
2. Perimysium: thin septa of connective tissue that extends inwards from the epimysium and surrounds a bundle(fascicle)of muscle fibers.
3. Endomysium: delicate connective tissue that surrounds each muscle fibre.
4. Myofibrils; long,cylindrical bundles that fill the sarcoplasm of

each fiber

5. Myofilaments: actin and myosin are within the each myofibril and organize into units called sarcomeres.

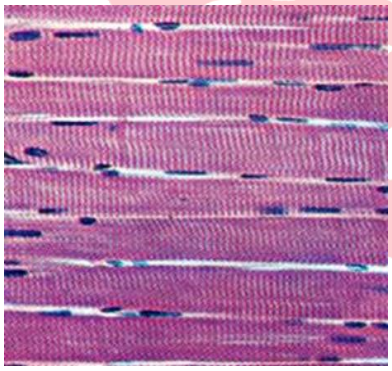
6. Sarcomeres have thick and thin filaments .thick filaments are centrally located in sarcomeres/ where they interdigitate with thin filaments. The I bands contain thin filaments only while H bands contain thick filaments only .and the A bands contain both thick and thin filaments

N.B: <u>The attachment of the muscle to the bone may take one of following shapes</u>:

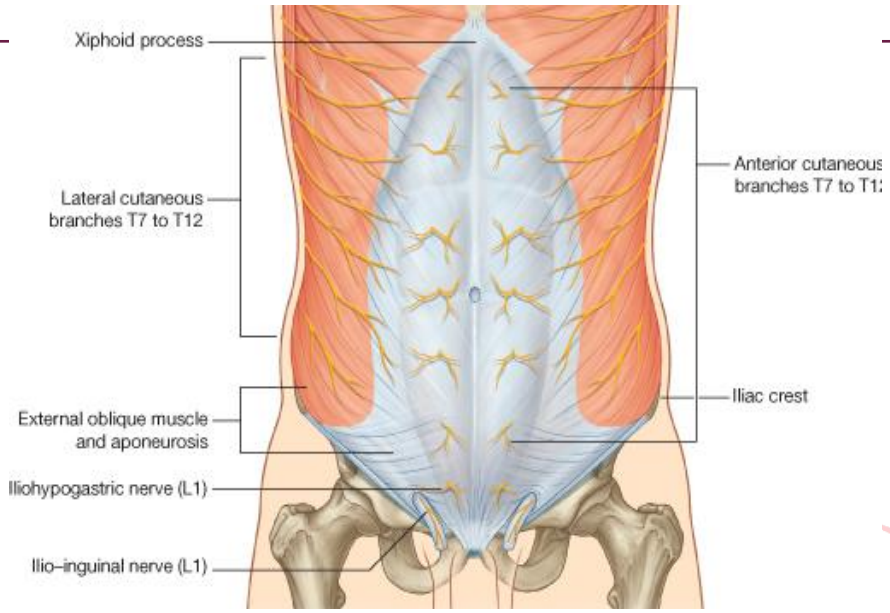
A. <u>Tendon</u>: a cord of fibrous tissue

B. <u>Aponeurosis</u>: Strong sheet of fibrous tissue.

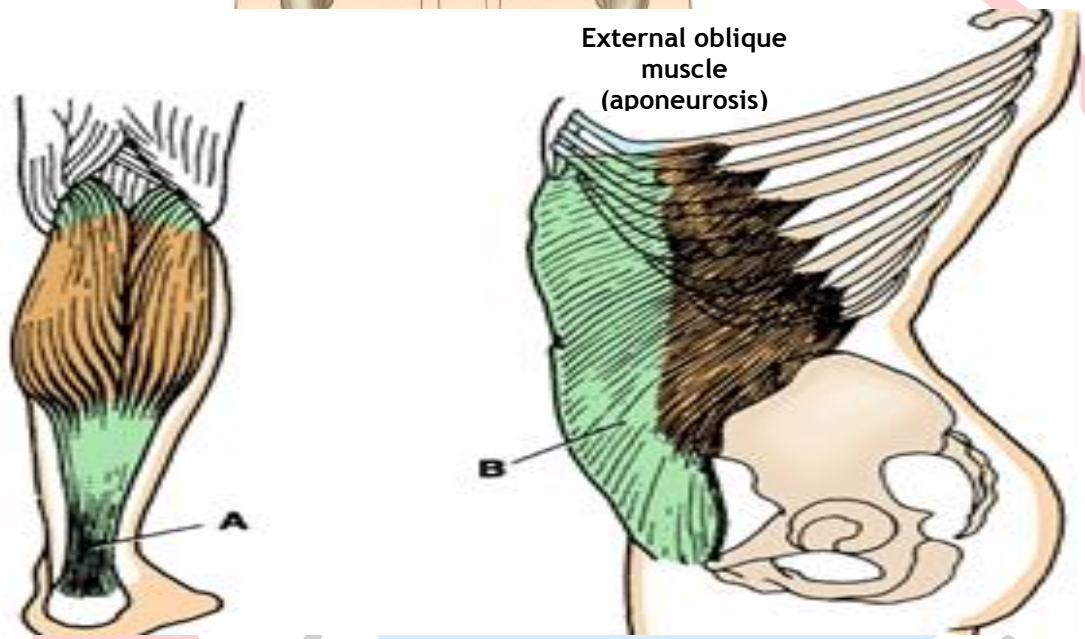
C. <u>Raphe</u>: This is the interdigitation of tendinious ends of fibers of flat muscles. Tendons and bursae



mylohyoid muscle (raphe)



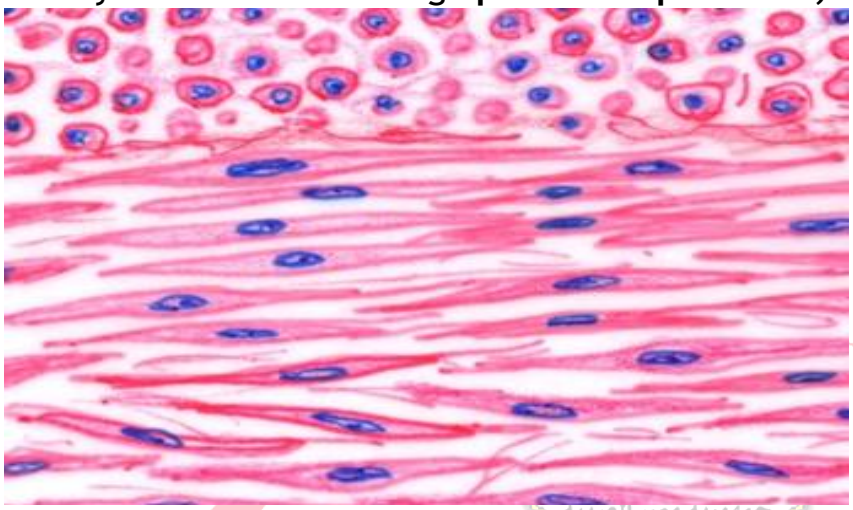
External oblique muscle (aponeurosis)



Gastrocnemius muscle (tendon)

(2) Smooth Muscle

* They are formed of long **spindle-shaped cells,** closely arranged in bundles.



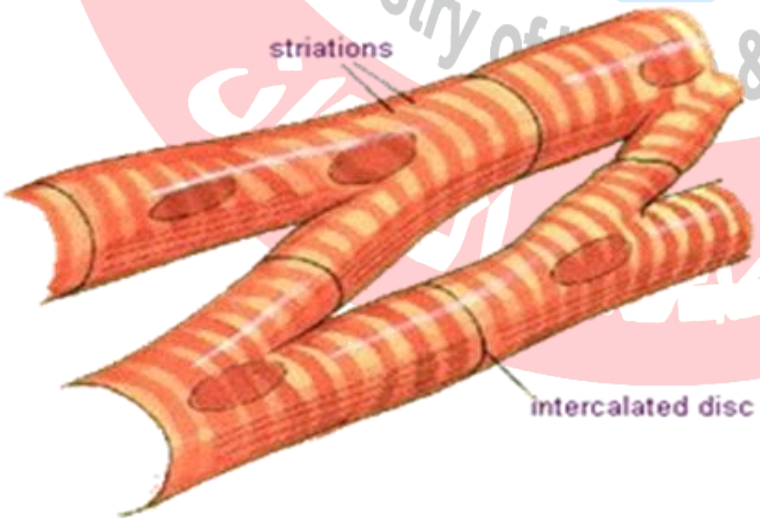
Smooth muscles (microscopic picture)

* ***In G.I.T,*** it is responsible for peristalsis, which is a wave of contraction that runs along the digestive tube.
* This movement is responsible for:
    1. Propelling contents through lumen.
    2. Mixing ingested food with digestive juices.

* ***In storage organs***, such as urinary bladder & uterus, its contraction is slow & helps in expulsion of the contents of the organ.
* ***In walls of blood vessels***, smooth muscles modify caliber of the lumen.
* It is **involuntary in action**, and its stimulation to contract is either by autonomic nerves or by hormonal stimulation.

(3) Cardiac Muscle

* It is a **striated** muscle consisting of muscle fibers which branch & unite with each other.
* It forms the myocardium of the heart.



***Q. Compare between cardiac and smooth Muscles*.**

Chapter 3 : The skeletal System

N.B.AT THE END OF THE COURSE STUDENTS SHOULD BE ABLE TO:
1. DESCRIBE the types of joints.
2. Compare between Appendicular & Axial Skeleton.
3.Name parts of long bone
4. Discuss the anatomy of the skeleton.

THE SKELETON

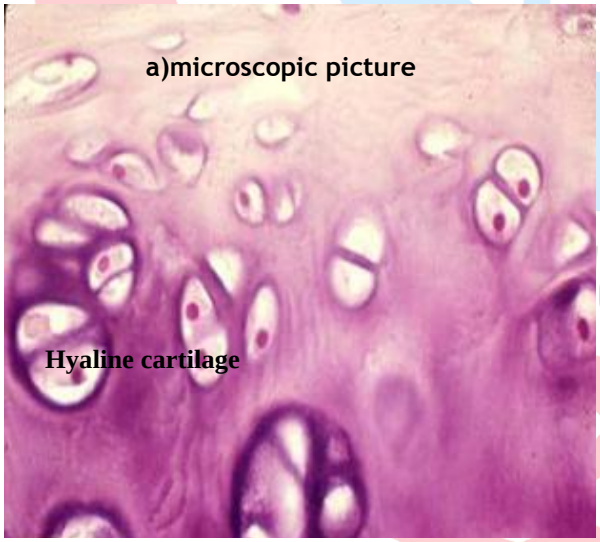
*It consists of cartilages, bones, joints and ligaments.

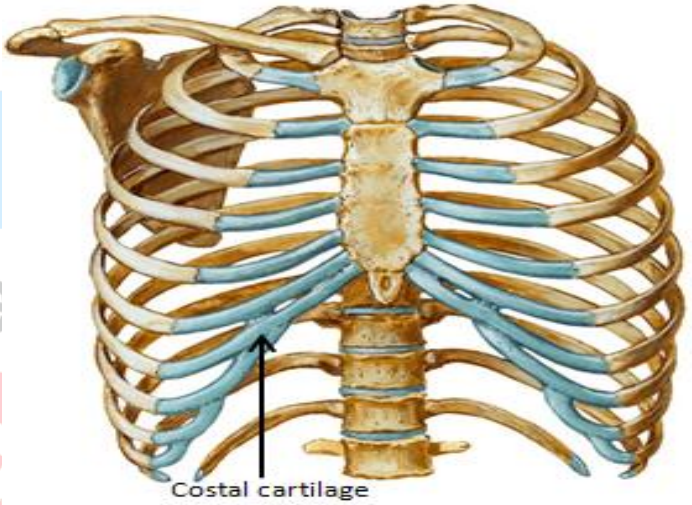
Cartilages

* Avascular dense flexible connective tissue.
*It is formed of chondrocytes (cartilage cells) & matrix.
*According to the nature of the matrix, there are 3 types of cartilages.

1. *Hyaline cartilage*:

* Has a homogenous & transparent matrix.
*Sites: Foetal bones, articular cartilages of synovial joints & costal cartilages

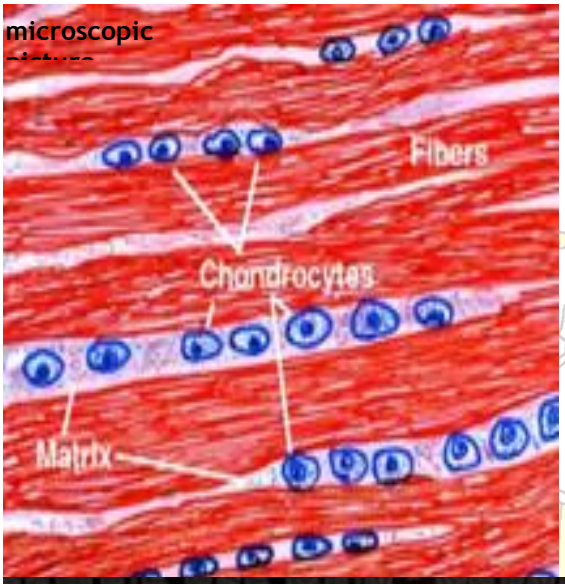




thoracic cage

2. *White fibrocartilage*

* The matrix is rich in collagenous bundles which add strength & durability to this cartilage.
* Sites: Symphysis pubis, intervertebral discs & labrum of some synovial joints (Hip & Shoulder).

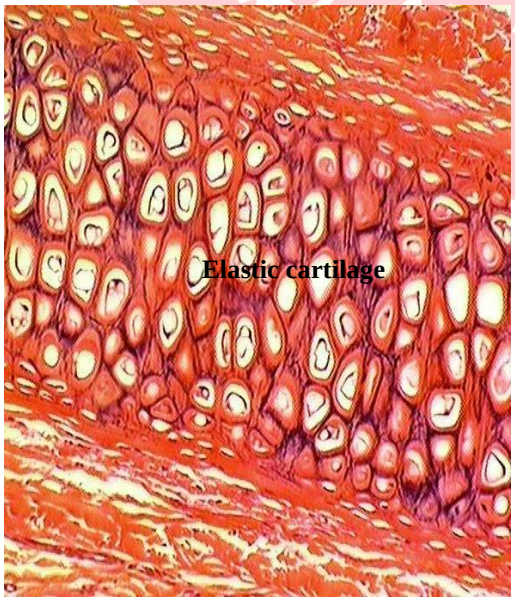


microscopic

3. Yellow elastic cartilage:

* The matrix is rich in elastic fibers which provide flexibility to this form of cartilage.

*Sites: Ear pinna, Tip of nose & laryngeal cartilages.



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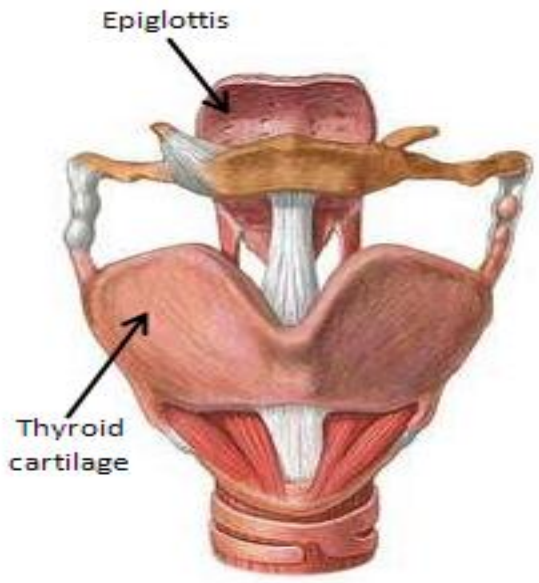


Bones

Bones form a hard type of connective tissue. Its hardness is due to its content of

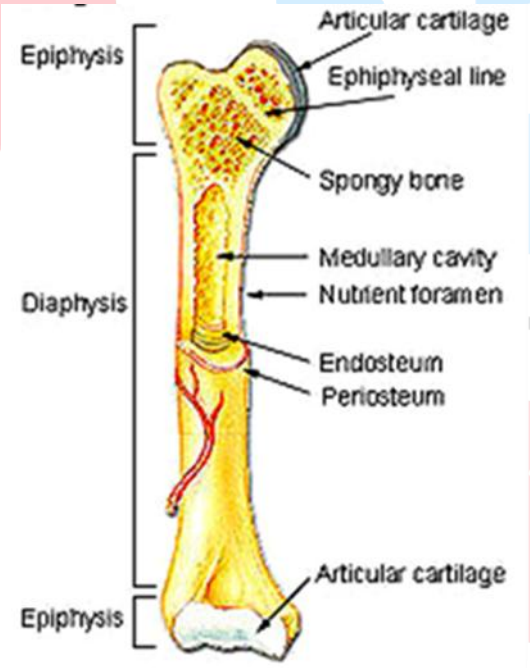
calcium.

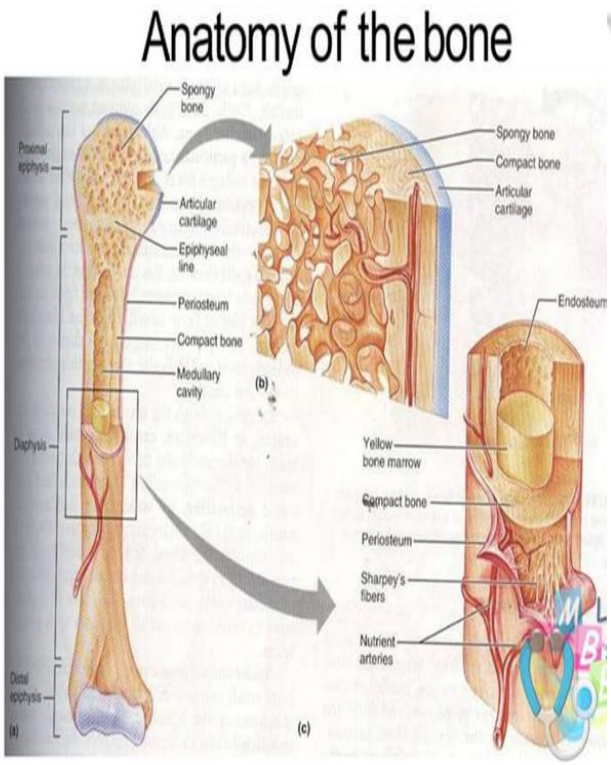
N.B: Q: Parts of a growing long bone:

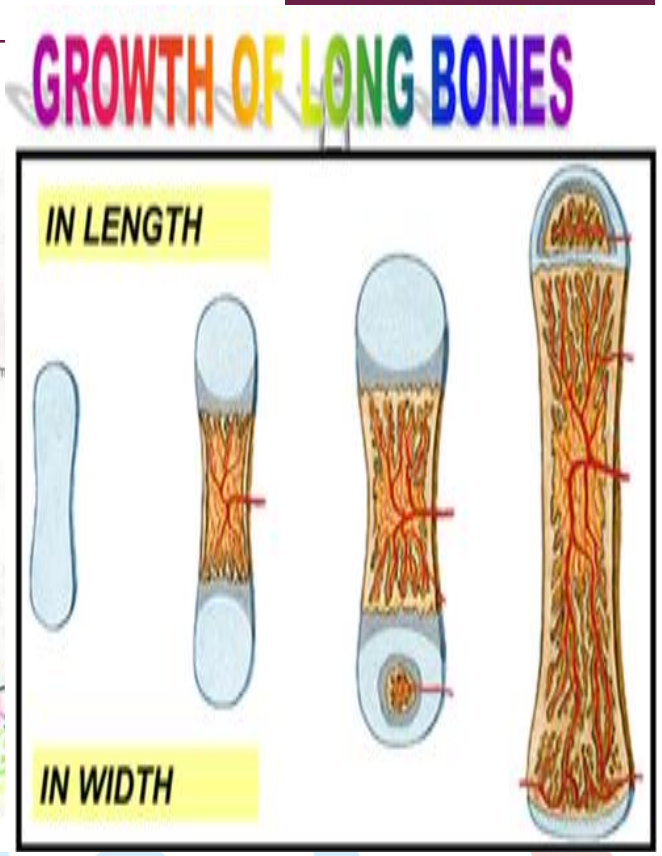
it is formed of a shaft and 2 ends:

1. 2 ends each is called epiphysis .Ossify by the secondary centers of ossification. the medullary cavity does not extend into them.their free ends are covered by articular hyaline cartilage .they are separated from the metaphysis of the shaft by 2 cartilaginous plates called the epiphyseal cartilages.
2. A shaft called diaphysis. ossifies by the primary center of ossification.it encloses a linear space called the medullary cavity which contains the bone marrow cavity.the cavity is lined by a cellular membrane called enosteum.the outer surface of diaphysis is covered by a dense fibrous membrane called the periosteum.
3. Epiphyseal plate of cartilage between the diaphysis & epiphysis. This is the most important factor for the growth of bone in length.

4. The part of the shaft close to the plate is called metaphysis.







1)Growth in length:
Along bone can grow from both ends by the activity of the epiphyseal cartilages. Each epiphyseal cartilage proliferates, and the resulting extra cells are transformed into bone which is added to the metaphyseal side and not to the epiphyseal side. The net result of this continuous process is a gradual progressive increase in the length of the shaft in contrast to the epiphyseal cartilages and epiphysis which keep their sizes. the growth rate of both ends is unequal, one end(the growing end)is more active than the other end(the less growing end).By time ,the activity of the epiphyseal cartilages diminishes and eventually the epiphysis and metaphysis fuse together. abolishing the epiphyseal cartilages. Now the bone can no longer increase in length. The cartilage of the growing end disappears later than that of the less growing end.

N.B :the date of fusion of the epiphysis varies from 15_22 years.it depends on herd hereditary and nutritional factors as well as sex.

N.B: the dates are earlier in females by 1_2 years

2)growth….in width :
by the periosteal activity which adds new bone on the surface of the shaft…. .

N.B:Anatomical functions of The Periosteum:

*This is a fibrous strong membrane which covers the shaft of the bone.

*It has the following functions:

1. Protection of the bone.
2. Provides muscular attachment.
3. Carry blood supply & sensory nerves to the bone.
4. Has an osteogenic power (bone forming ability) which plays an important role in the growth of bone in width & the healing of bones after fractures.

 # Note that the bone grows in length by epiphyseal plate of cartilage & in thickness (breadth) by the periosteum

The following table shows the difference between the 2 ends and the shaft of a long bone:

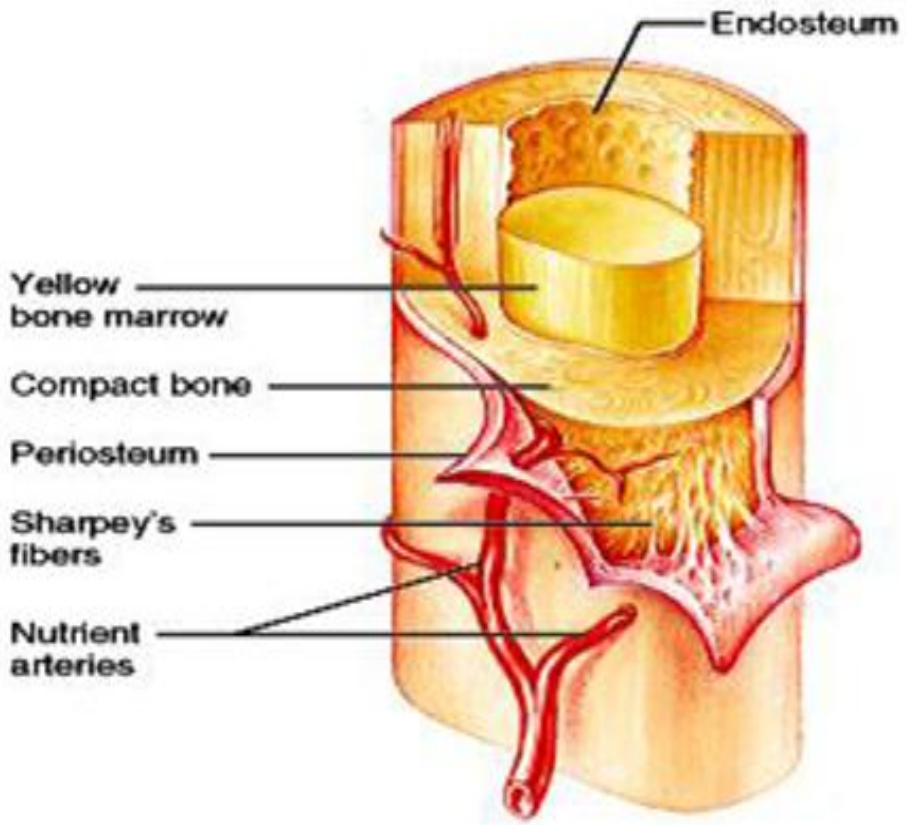
	The 2 ends	The shaft
1. Name:	epiphysis	diaphysis
2. Develops from:	2ry center of ossification	1ry center of ossification
3. Covered by:	Articular hyaline cartilage	Periosteum
4. Medullary (bone marrow) cavity:	Absent	Present
5. Formed of:	Spongy bone	Compact bone

N.B: The blood supply of bone

:1.Nutrient artery.

2.periosteal arteries

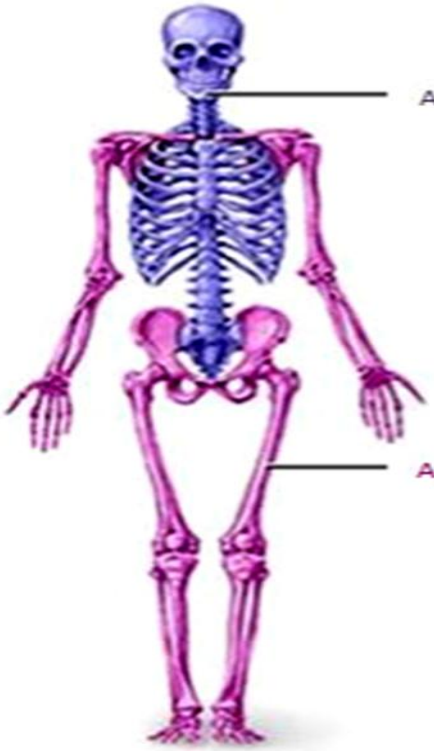
3.Arteries of the attached muscles



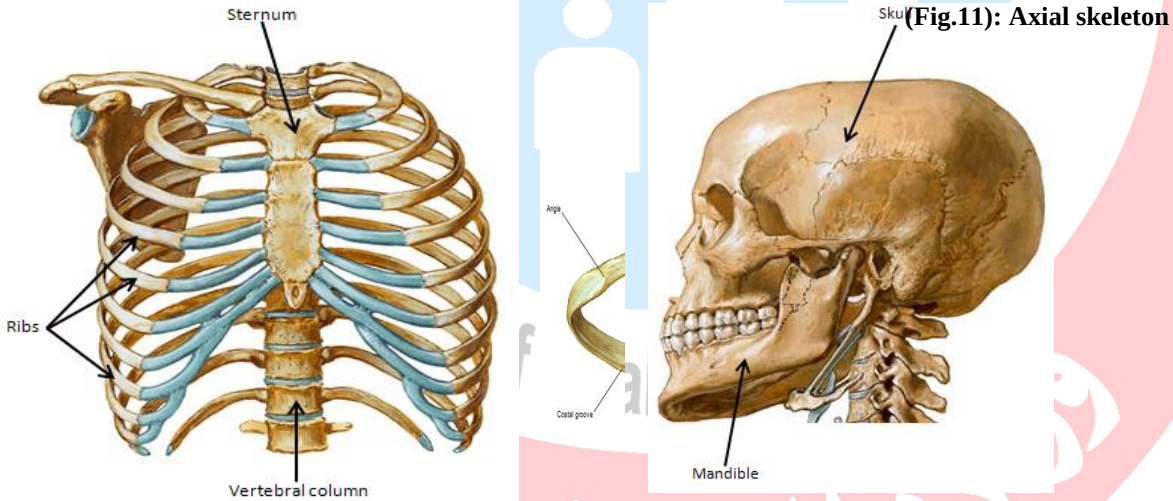
Q.Regional classification of bones:

The human skeleton is divided into:

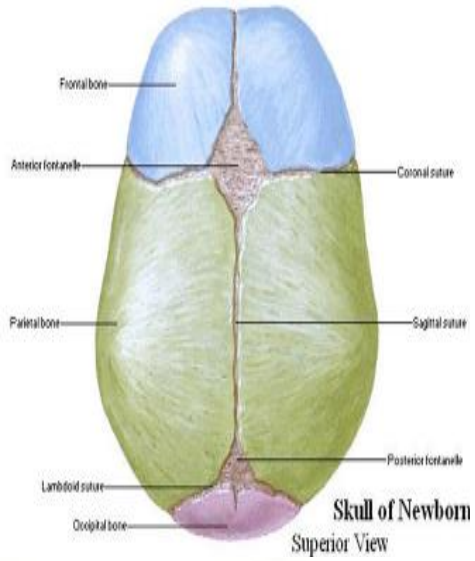
1. Axial skeleton: This includes skull, vertebral column, ribs & sternum.

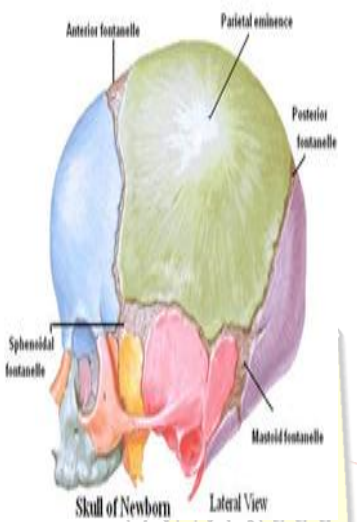


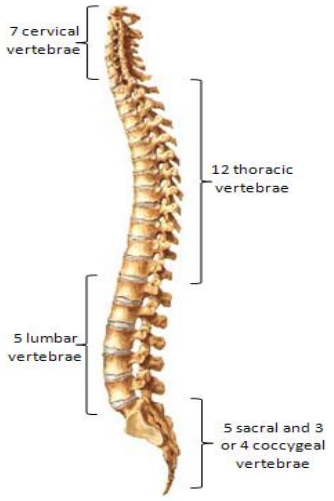
1. Axial skeleton

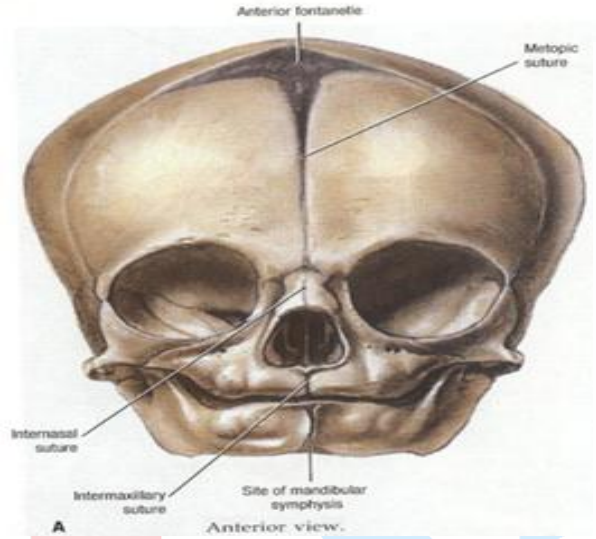


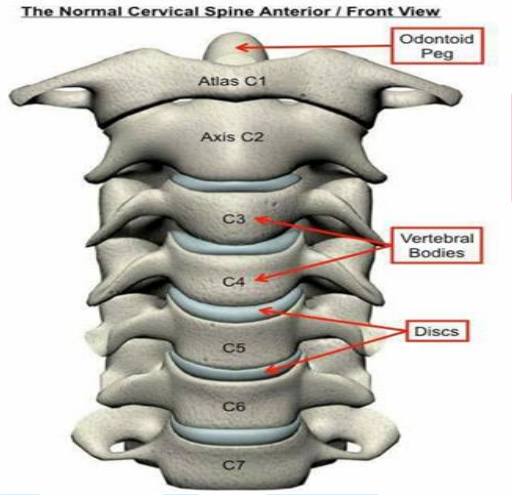
(Fig.11): Axial skeleton



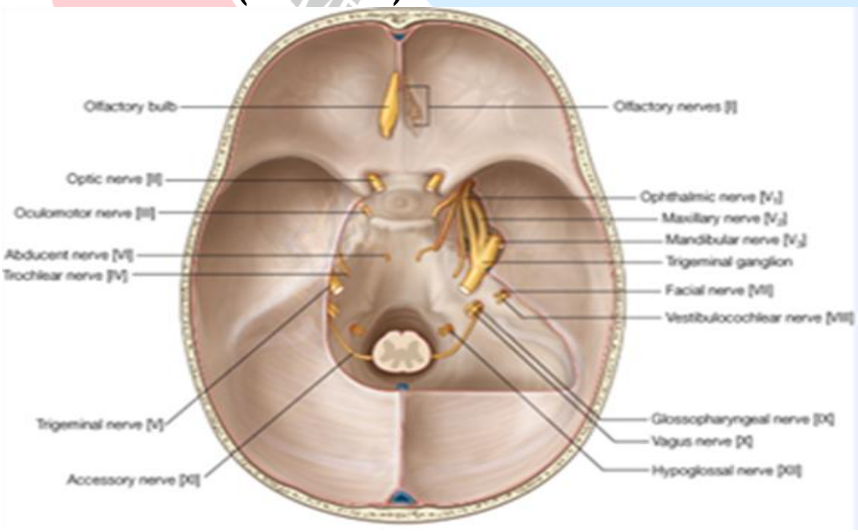








1. **The skull (cranium) + the mandible** → form the skeleton of the head.



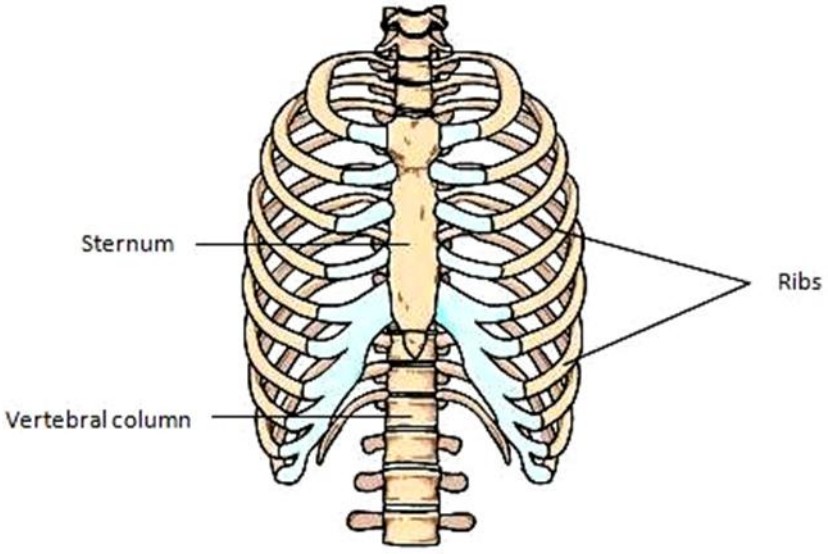
2.**Ribs & sternum** share in thoracic cage.

THE STERNUM

***The sternum is a flat, bone located in the middle of the chest. Along with**

the ribs, it forms the rib cage that protects the heart, lungs, and major blood vessels.

***The sternum is composed of three parts**



1- The manubrim (handle) is located at the top of the sternum and moves slightly. It is connected to the first two ribs.

2- The body (blade) is located in the middle of the sternum and connects the third to seventh ribs directly and the eighth through tenth ribs indirectly.

3- The xiphoid process (tip) is located on the bottom of the sternum. It is often cartilaginous

3. **The vertebral column**: is formed of a series of bones called vertebrae (Which are 32 or 33 vertebrae).

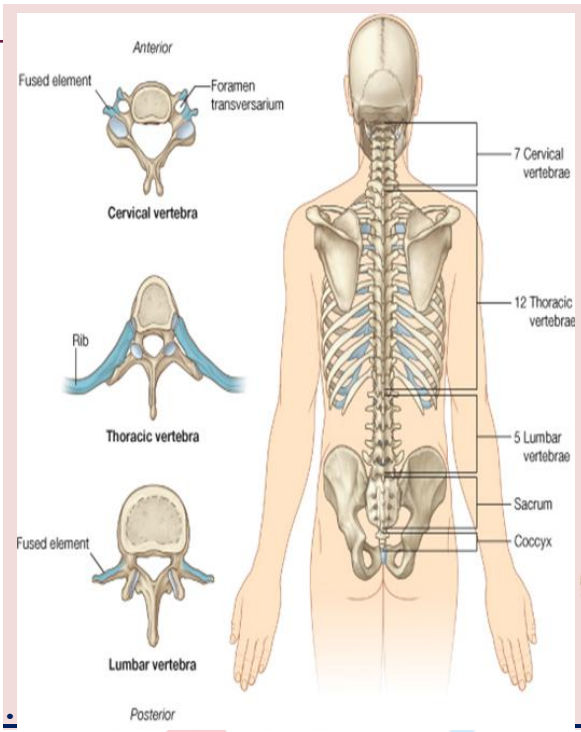
N.B: The vertebrae articulate together by white fibrocartilagenous intervertebral discs.

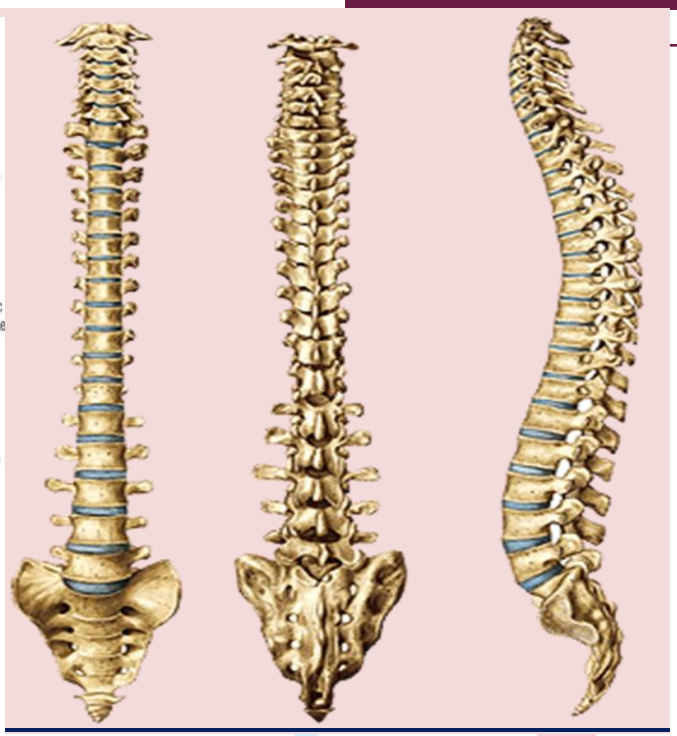
N.B: The vertebral column is divided into 5 regions of vertebrae:

* 7 cervical.
* 12 thoracic.
* 5 lumbar.
* 5 sacral (fused to form the sacrum).
* 3 or 4 coccygeal (fused to form the coccyx).

Q .Functions of the vertebral column:

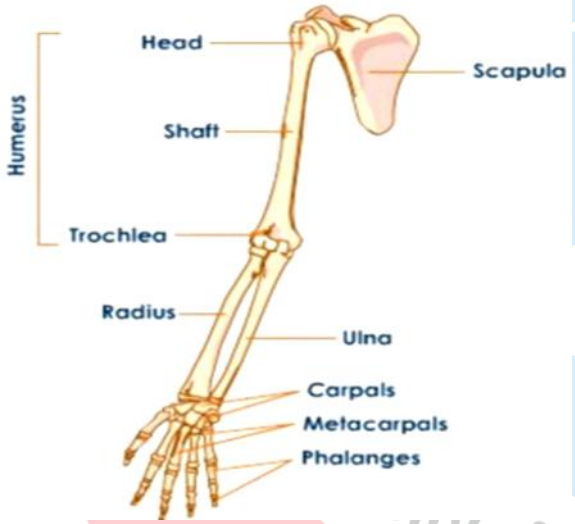
1. Forms the axial skeleton of the body.
2. Supports the weight of the body.
3. Protects & surrounds the spinal cord.



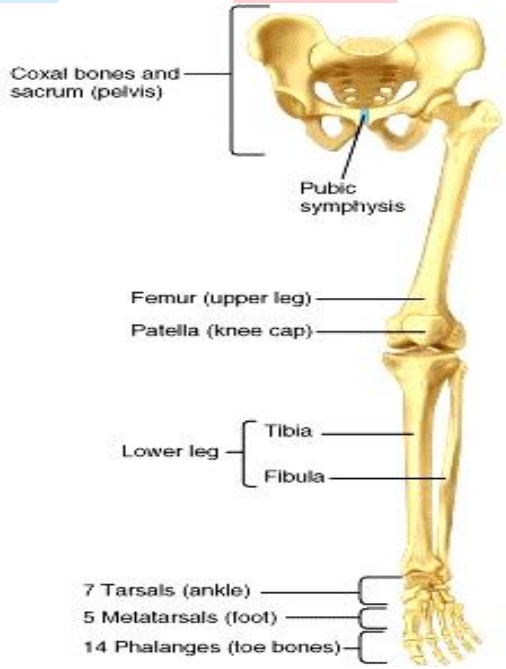


2. Appendicular skeleton:This includes

1.Bones of Upper limb:



1 **Upper arm**: Humerus.
2. **Forearm**: Ulna (medially) & Radius (laterally).
3. **Hand:** Formed of 3 regions (from proximal to distal); Carpus, Metacarpus & Phalanges.



2. Bones of Lower limb

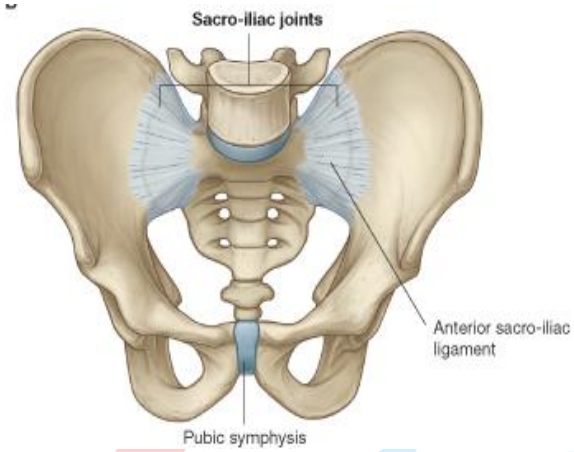
1. **Thigh:** Femur.
2' **Leg:** Tibia medially & Fibula

3' **Foot**: ***Formed of 3 regions (from proximal to distal); Tarsus, Metatarsus & Phalanges***.

N.B: Each limb is connected to the axial skeleton by a girdle (formed of 2 bones in the upper limb and 1 bone in the lower limb). 1.**Shoulder girdle**

Clavicle & Scapula

2.Pelvic girdle: Hip bone



Q. Anatomical functions of bones:

1. Supporting the framework of the body.
2. Attachment of muscles & locomotion.
3. Protection of underlying organs.

Q: Classification of Bones:

1. Morphological (Anatomical) classification according to shape of bone:

A. Long bones: have 2 ends & a shafts as bones of proximal & intermediate segments of the limbs (humerus, radius, ulna, femur, tibia & fibula).

B. Short bones: as carpal & tarsal bones. These bones are strong & help in limited movements.

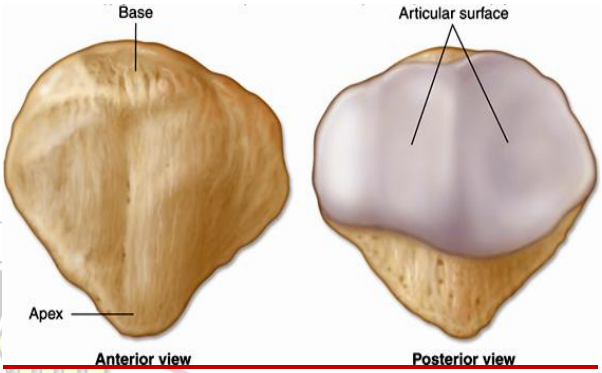
C. Flat bones: as scapula & skull cap. These have wide surface for muscle attachment or protection.

D. Irregular bones: as vertebrae & skull base.

E. Pneumatic bones: are air-filled spaces (paranasal sinuses) in skull to reduce the weight of skull & help in resonance of voice.

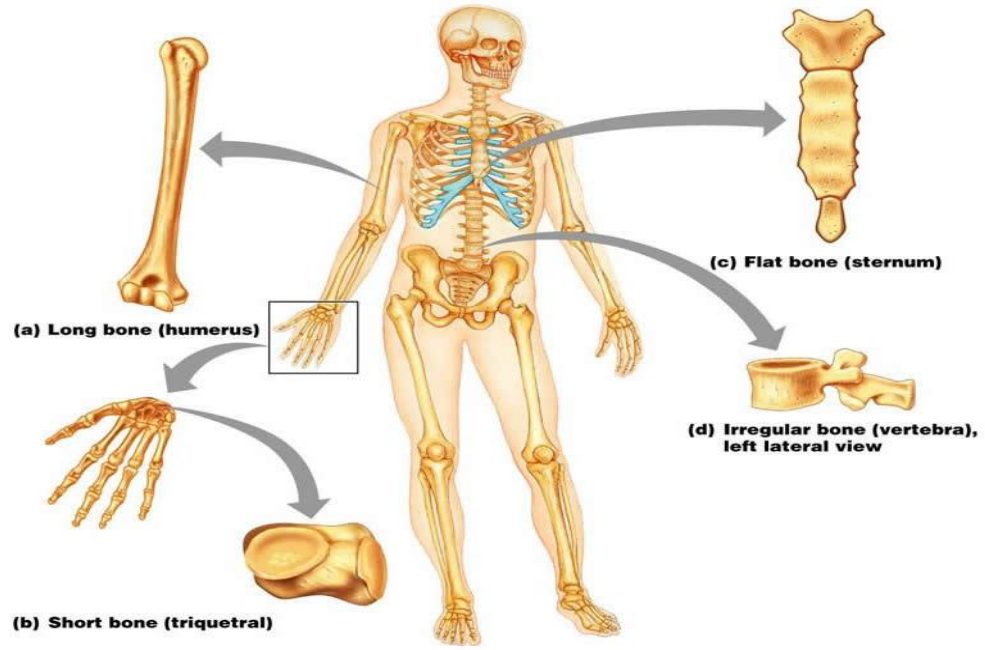
***N.B: Sesamoid bone: are small nodules of bone found in the tendons of certain muscles to reduce friction over bony surfaces. e.g. patella & pisiform bones*. ***

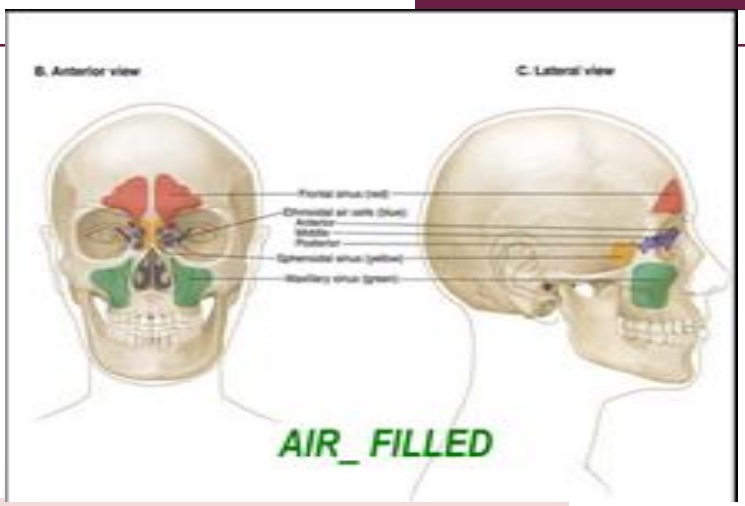
The Patella



- The patella or kneecap is a large, triangular sesamoid bone between the femur and the tibia.

- The patella protects the knee joint and strengthens the tendon that forms the knee

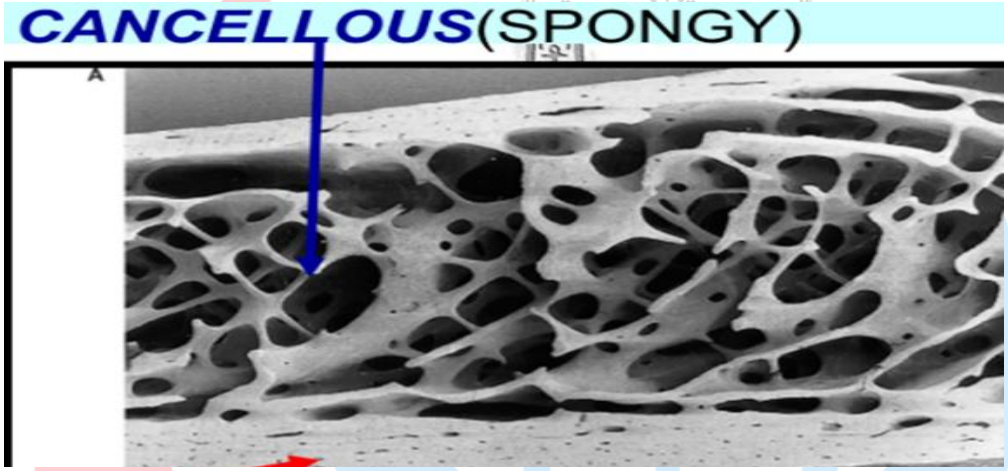




(e) Pneumatic bones (paranasal sinuses)

Q Histological classification according to structure of bone:

1. Compact (Ivory) bone: Outer hard layer in shaft of long bones
2. Spongy (Cancellous) bone: Has pores & forms the inner delicate trabeculated layer as in Sternum.



Histological types of bone

Q.Developmental classification: according to ossification of bone:

This means the transformation of the mesodermal tissue into bone. It has 2 types:

1. Intracartilagenous ossification (Cartilagenous bone):

*In most of long bones.
*Early in the intrauterine life (6-8 weeks), a 1ry center of ossification appears in the shaft, where calcification spreads (cartilage model) to help the ossification (bone formation).
* After birth, 2ry centers of ossification appear at the 2 ends of the bone. The shaft & the 2 ends become completely ossified but still separated by a plate of cartilage (epiphyseal plate) to help the growth of bone in length. Finally, they become ossified at certain age.

2. Intramembranous ossification (membranous bone):

* In flat bones (as skull cap & scapula) & clavicle: rapid ossification for protection.

* Centre of ossification develops at the mesenchymal tissue then transformed into bone without cartilage formation.

N.B:Bone marrow

**** It occupies the marrow cavity in long & short bones & the pores of cancellous bones in flat & irregular bones.***

**** 2 types: red type (blood forming or hematopoietic) & yellow type.***

****With aging the red marrow decreases & the yellow marrow replaces it.***

**** In adults the red marrow is restricted to the bones of the skull, vertebral column, thoracic cage, girdle bones & the head of the humerus & the femur.***

Q: Discuss Functions of the skeleton

1.Support

The skeleton provides the framework which supports the body and maintains its shape. The pelvis and associated ligaments and muscles provide a floor for the pelvic structures. Without the ribs, costal cartilages, and the intercostal muscles the lungs would collapse.

2.Movement

The joints between bones permit movement, some allowing a wider range of movement than others, e.g. the ball and socket joint allows a greater range of movement than the pivot joint at the neck. Movement is powered by skeletal muscles, which are attached to the skeleton at various sites on bones. Muscles, bones, and joints provide the principal mechanics for movement, all coordinated by the nervous system.

3.Protection

The skeleton protects many vital organs:

- The skull protects the brain, the eyes, and the middle and inner ears.
- The vertebrae protect the spinal cord.
- The rib cage, spine, and sternum protect the lungs, heart and major blood vessels.
- The clavicle and scapula protect the shoulder.
- The ilium and spine protect the digestive and urogenital systems and the hip.
- The patella and the ulna protect the knee and the elbow respectively.
- The carpals and tarsals protect the wrist and ankle respectively.

4.Blood cell production (hematopoiesis)

The skeleton is the site of haematopoiesis, which takes place in red bone marrow. Marrow is found in the center of long bones.

5.Storage

Bone matrix can store calcium and is involved in calcium metabolism, and bone marrow can store iron in ferritin and is involved in iron metabolism. However, bones are not entirely made of calcium, but a mixture of chondroitin sulfate and hydroxyapatite, the latter making up 70% of a bone

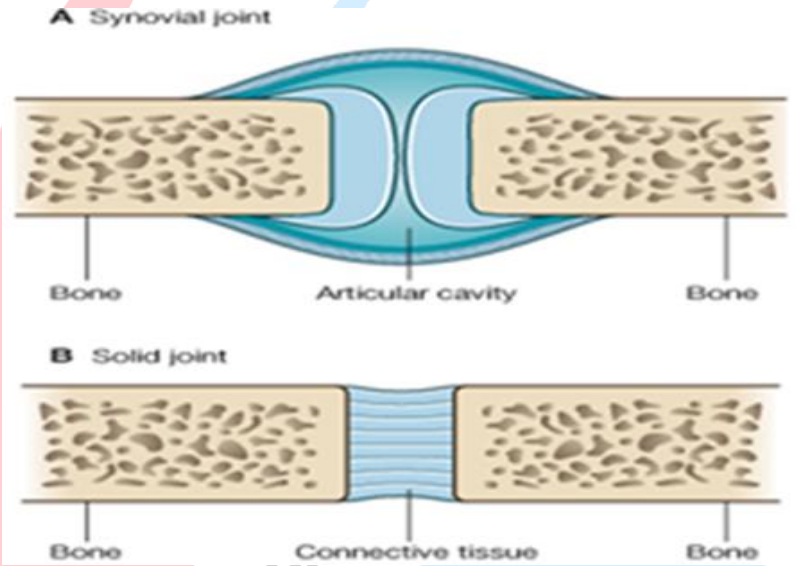
Chapter 4: The Joints

N.B.AT THE END OF THE COURSE STUDENTS SHOULD BE ABLE TO:
1.Describe the anatomy of joints.
2.Classify the types of joints.

Joints

**The site of meeting between 2 or more bones.*

**According to their structure and mobility they are classified into Solid (Non_synovial) and synovial joints.*



**Solid (Non-synovial) :* (fibrous and cartilaginous) joints

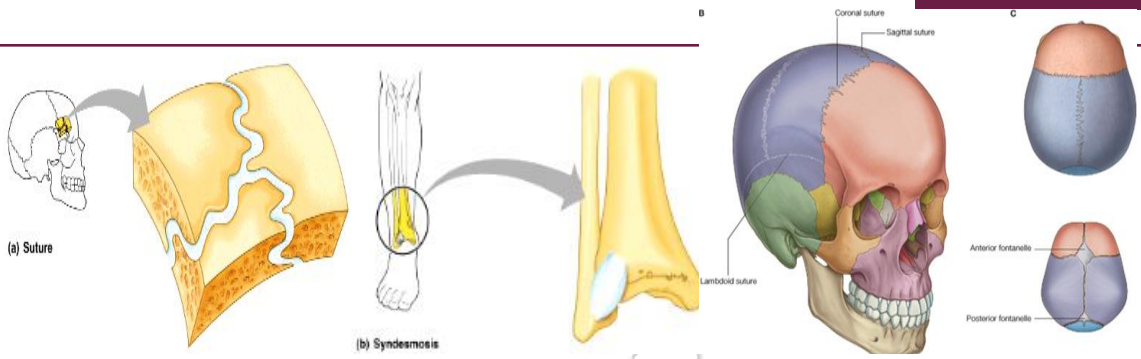
1) Fibrous joints:

The articular surfaces are connected together by strong fibrous tissue and no movements are permitted. Fibrous joint includes:

a- Sutures of the skull

b- Inferior tibio-fibular joint

c- Joints between the teeth and the jaw.

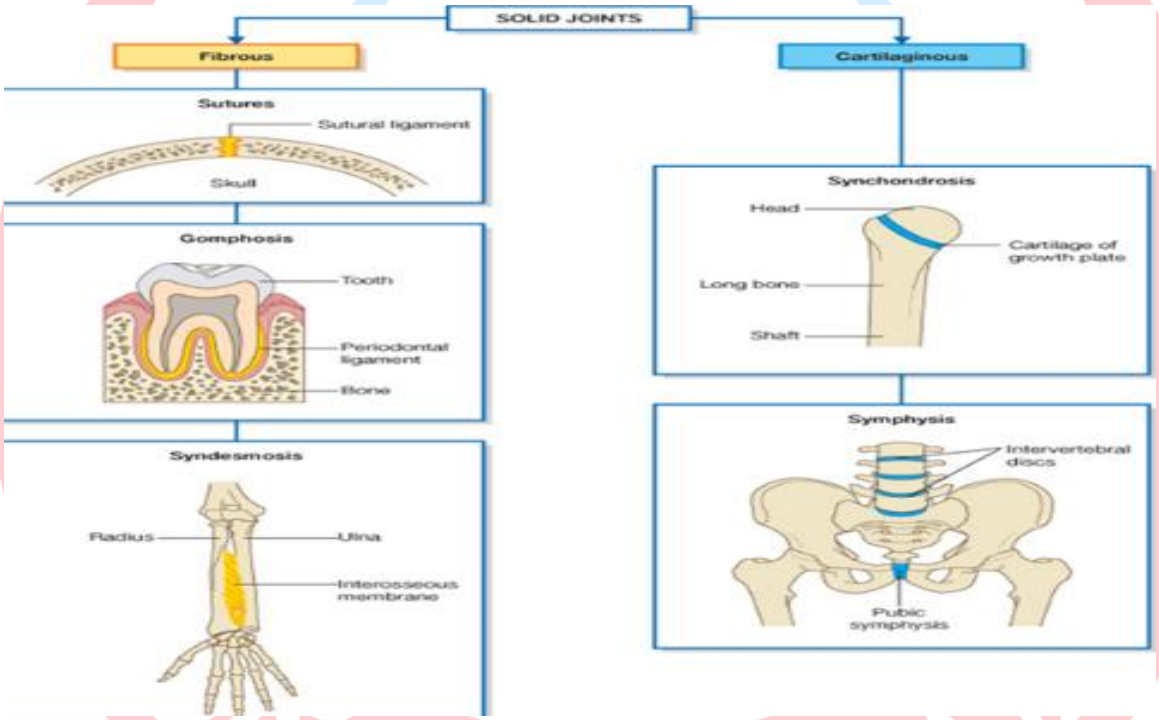


2) *Cartilaginous joints:*

The bones are connected by cartilage. They are divided into:

a- *Primary cartilaginous joints (synchondrosis): No movement occur in this joint. It is seen in: Base of skull and first costal cartilage*

b- *Secondary cartilaginous joint (symphysis): Limited movement occurs in this joint. It is seen in: The intervertebral disc and joints between the pieces of the srernum.*



***Synovial joints*:**

They are freely movable joints.

Q: Describe the Structure of synovial joint:

1- The articular surfaces are covered by a thin plate of hyaline cartilage which are separated by a joint cavity.

The joint is enveloped by a fibrous capsule. The capsule is thickened by ligaments

2-

3- The inside of the capsule is lined by a thin synovial membrane

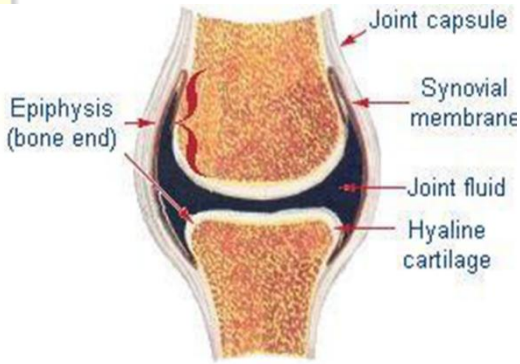
The space inside the joint is filled with synovial fluid which

act as a lubricant.

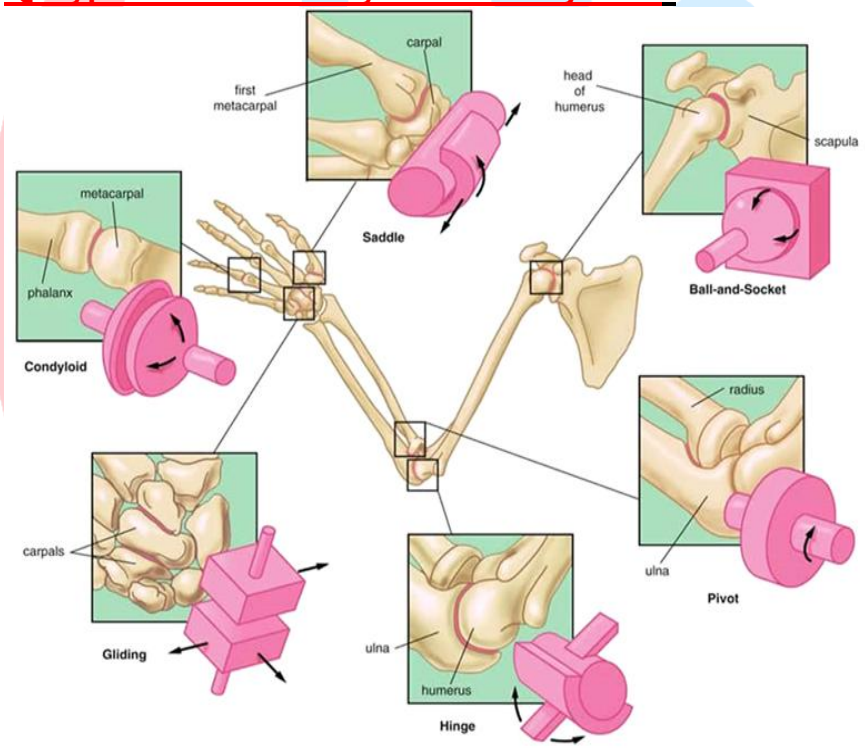
N.B:-Synovial membrane: Serous sac lines the interior of the joints for lubrication.

*Ligaments are bands of dense regularly arranged connective tissue that cross joints and reinforce the articular capsule of the joint.

Types of synovial joints



Q:Types of Synovial joints:



1- Uniaxial joint: Movements occur around one axis only:

a- Hinge joints: e.g elbow joint

b- Pivot joints: e.g. radio-ulnar joint

2- Biaxial joint: Movements occur around 2 axes:

a- Ellipsoid joints: e.g. Wrist joint

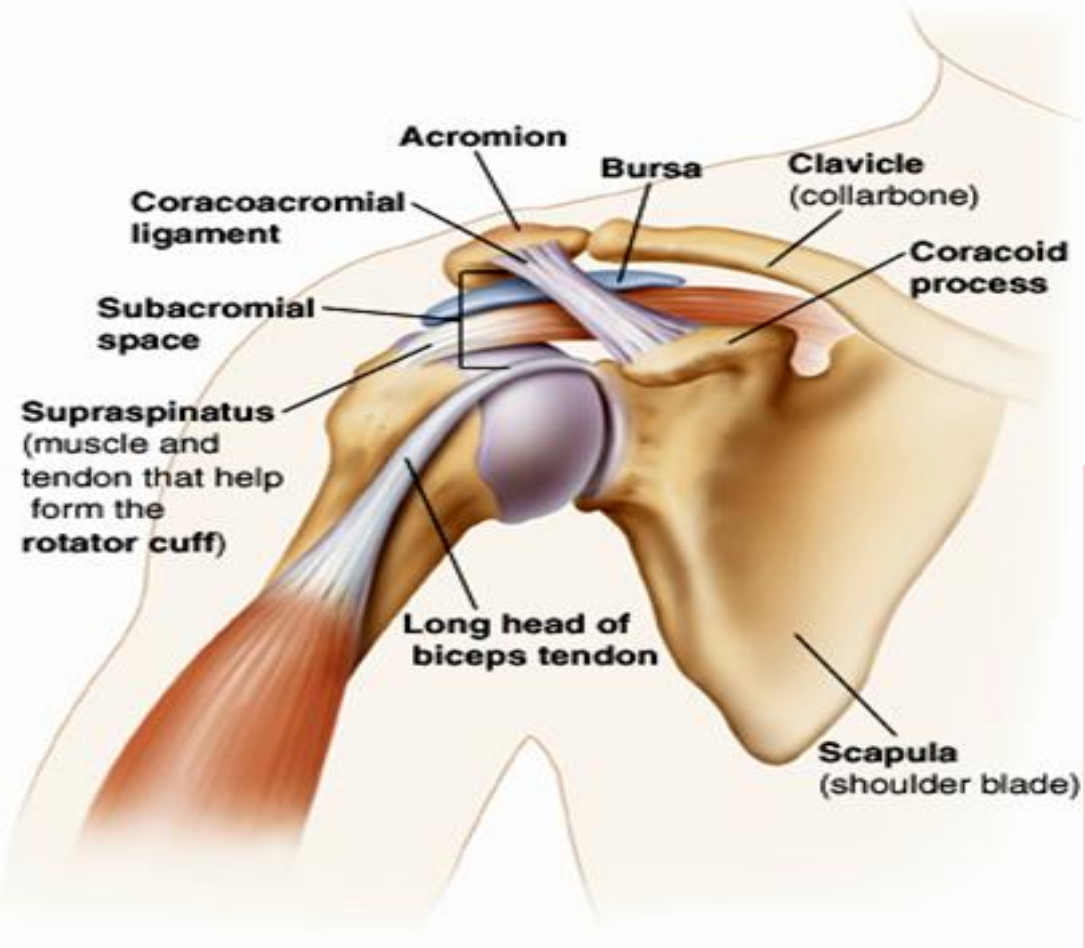
b- Saddle joints: e.g. carpo-metacarpal joint of thumb

c- Condylar joints: e.g. Knee joint

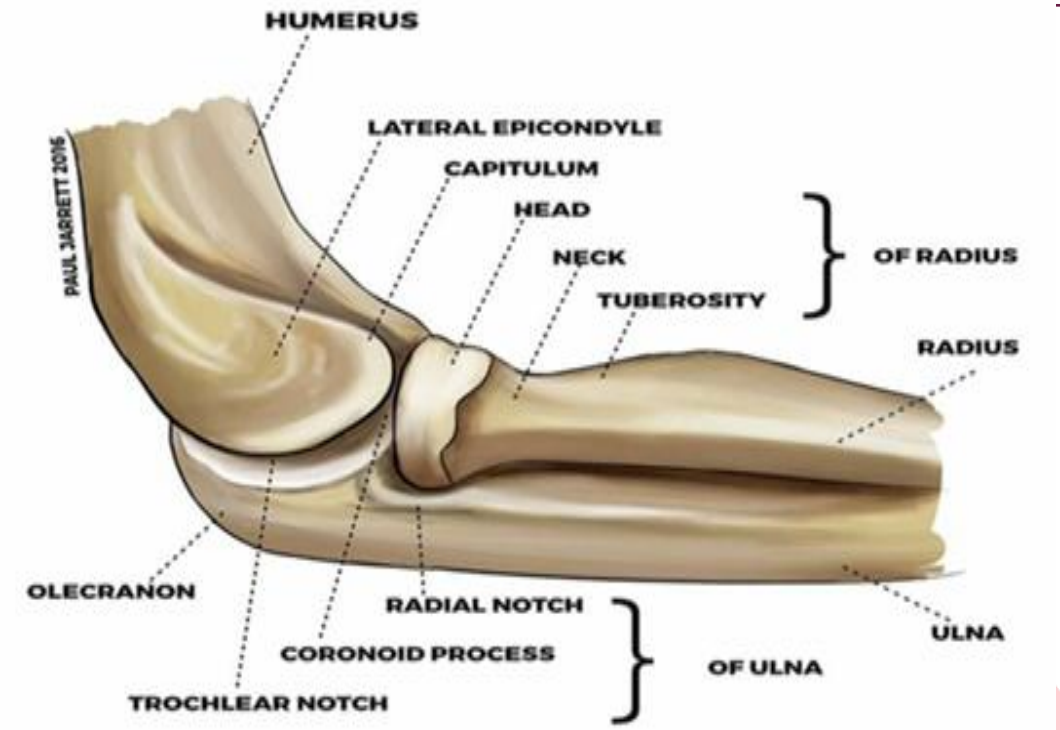
3- **Multiaxial joints: All types of movements are allowed e.g.** shoulder joint.

4- **Plane joint: e.g.** acromio-cavicular joint.

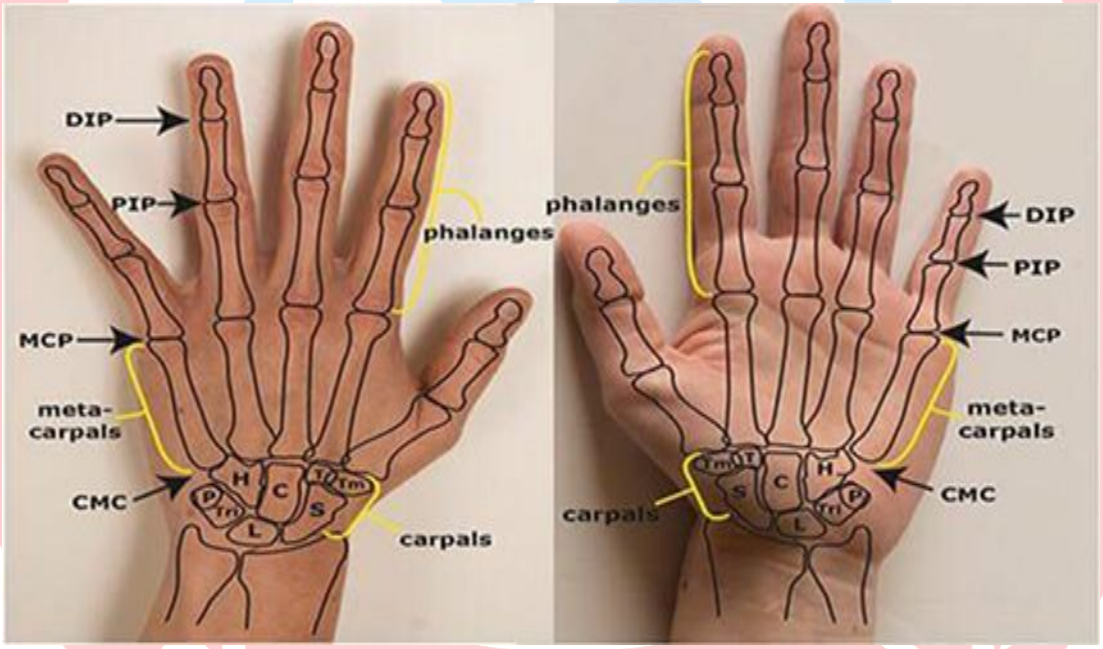
Q: 1. Name Joints of the Upper Limb:



a.Sternoclavicular Joints
b.Acromioclavicular joints
c.Radioulnar joints.

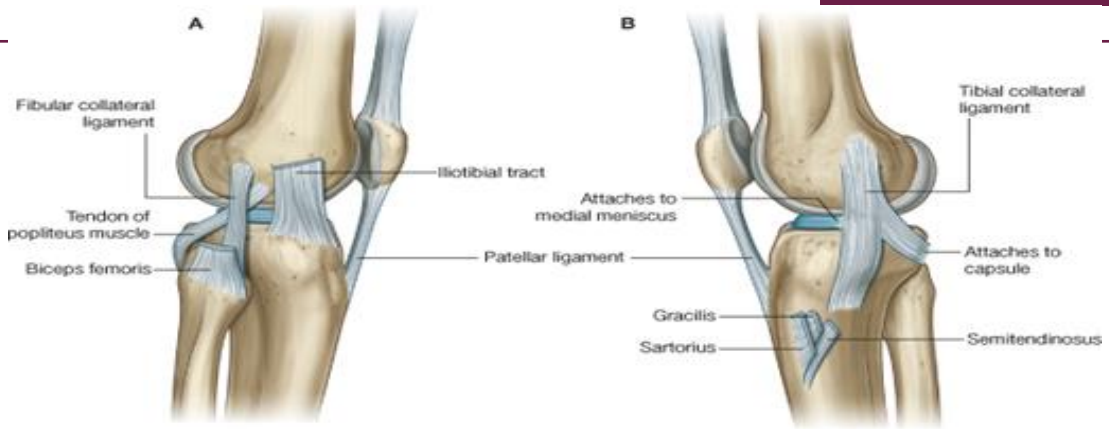


d.Small joints of the Hand

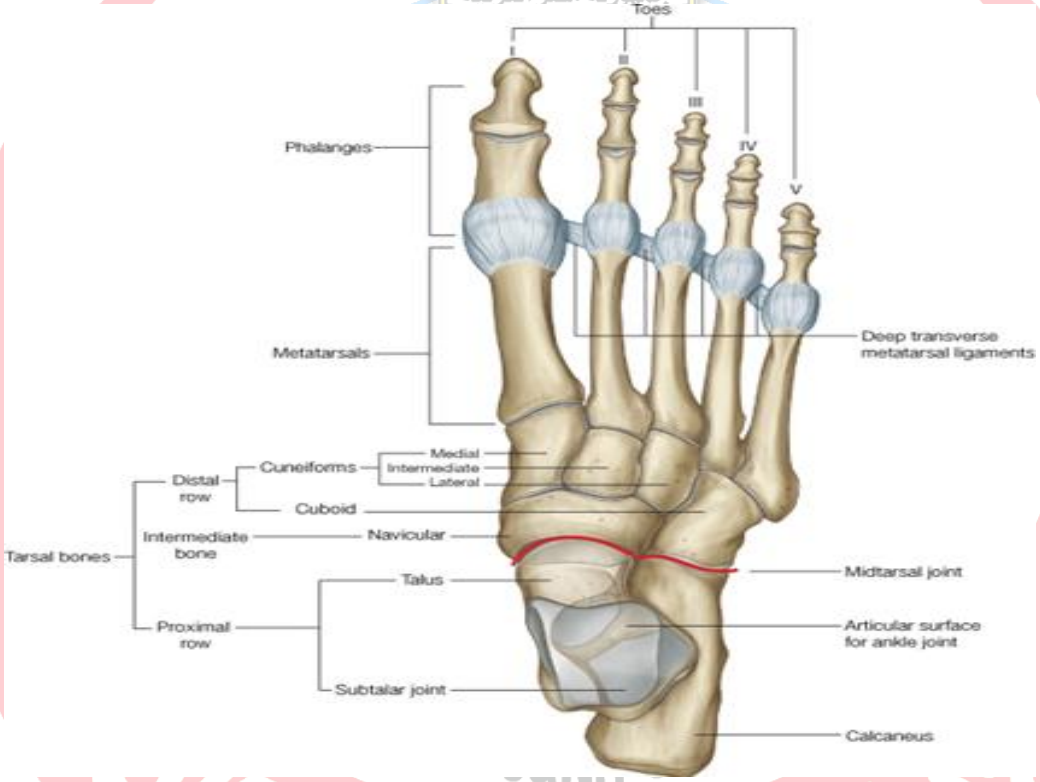


e.joints of the Digitis.

Q.2.Name Joints of the Lower limb:



a.Sacroiliac joint
b.Knee Joints
c.Tibiofibular joints
d.joints of the foot



- ***Blood supply and innervation of joints:***

All joints have a free blood supply with many anastomozing arteries. An operation on a major joint without a tourniquet provides a good demonstration of joint vascularity. There is a fi ne plexus of lymphatics within the synovial membranes.

*__*The nerve supply* of a joint__ is the same as that of the overlying muscles moving the joint and the skin over their insertions (Hilton' s Law). Most of the nerve end - organs lie in the joint capsule, but muscle and tendon end - organs are equally important for proprioception. Autonomic nerves also reach the joint, mainly with the

blood vessels, and control the blood supply and perhaps the formation of synovial fluid.

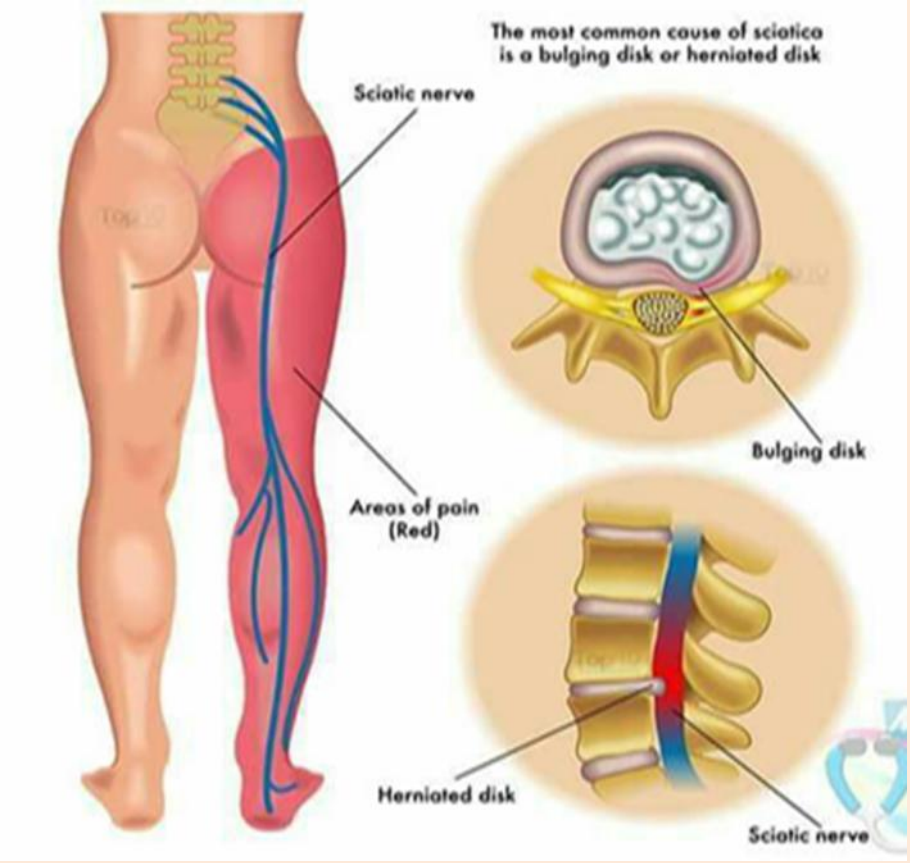
The protective and proprioceptive functions of nerves supplying joints are vital to the normal functioning of a joint, which rapidly disintegrates if this protection is lost (Charcot' s joint).

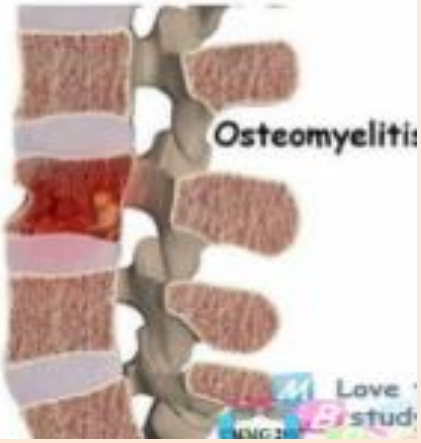
\

N.B: Q. Applied anatomy

1.Back pain is an extremely common disorder. It is often difficult to determine whether back pain relates to direct mechanical problems or to a disc protrusion impinging on a nerve. In cases involving discs, it may be necessary to operate and remove the disc that is pressing on the nerve. May be other causes e.g: Osteomyelitis…Sciatica

 # Not infrequently, patients complain of pain and no immediate cause is found; the pain is therefore attributed to mechanical discomfort, which may be caused by degenerative disease. One of the treatments is to pass a needle into the facet joint and inject it with local anesthetic and corticosteroid.

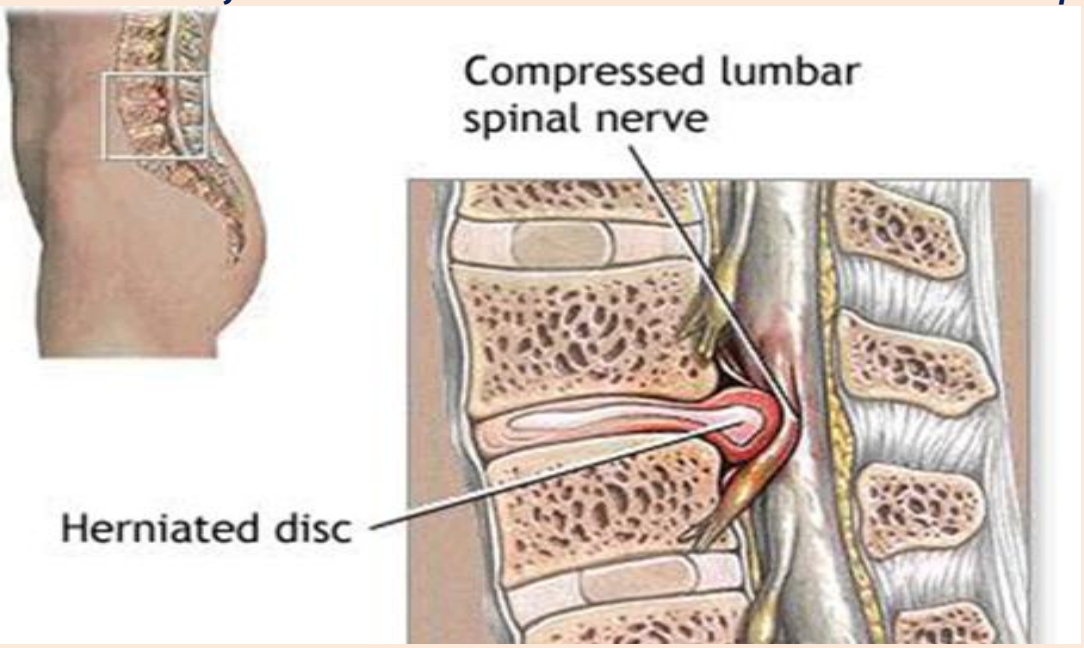




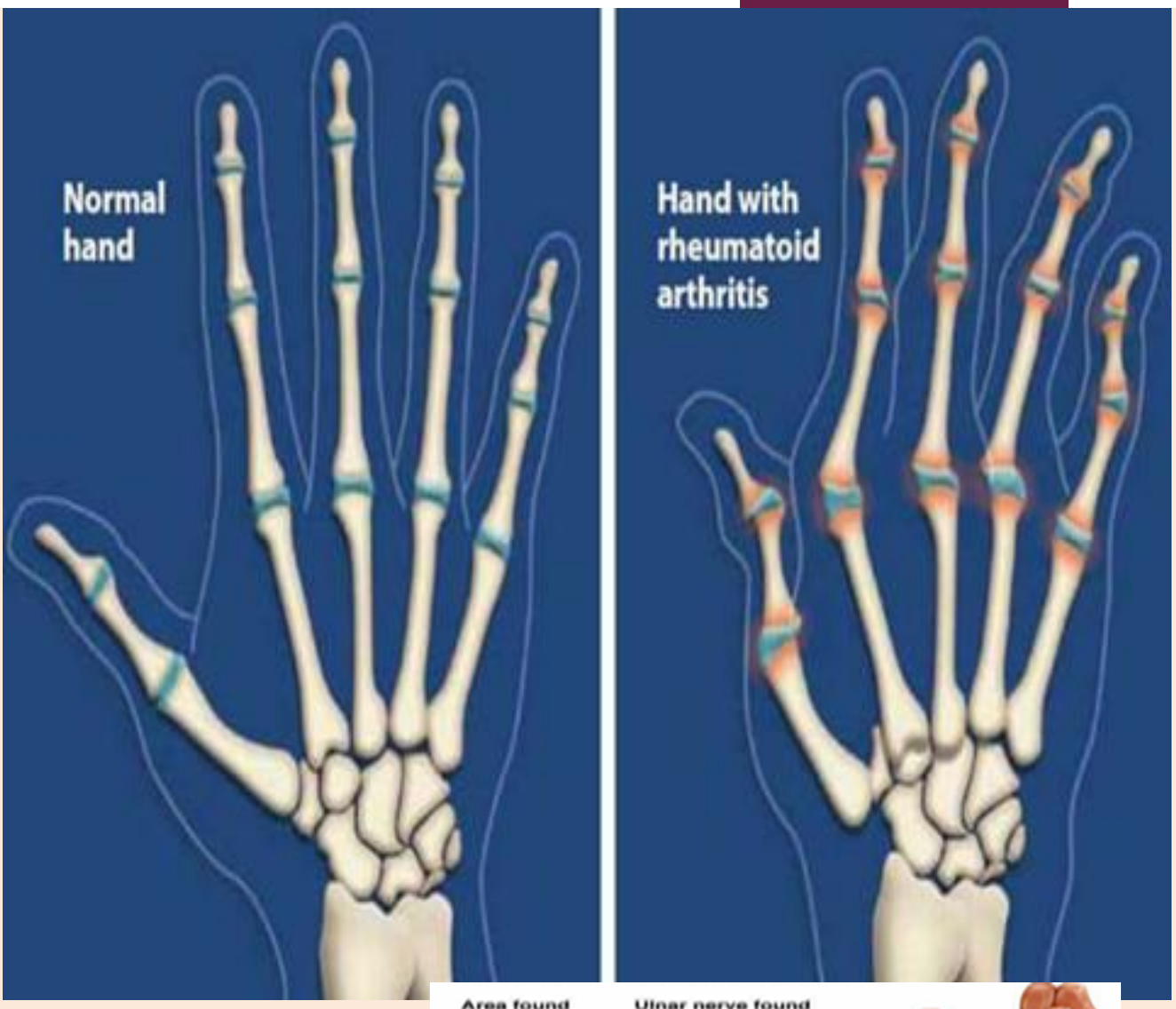
2.Herniation of intervertebral discs:

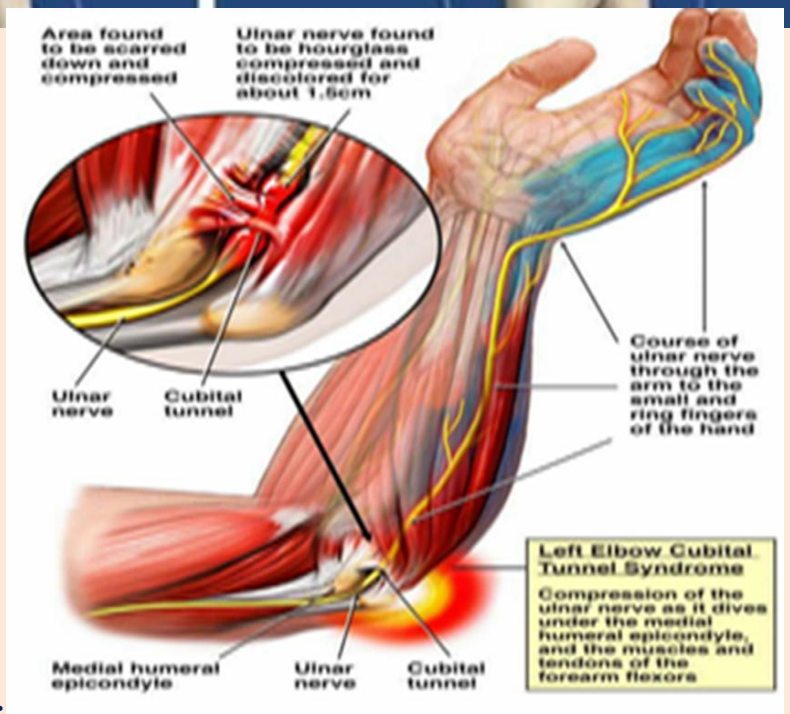
The discs between the vertebrae are made up of a central portion (the nu pulposus) and a complex series of fibrous rings (anulus fibrosus). A tea occur within the anulus fibrosis through which the material of the nu pulposus can track. After a period of time, this material may track int vertebral canal or into the intervertebral foramen to impinge on n structures. This is a common cause of back pain. A disc may pro posteriorly to directly impinge on the cord or the roots of the lumbar n depending on the level or may protrude posterolateral adjacent to the pe and impinge on the descending root.

In cervical regions of the vertebral column, cervical disc protrusions oft become ossified and are termed disc osteophyte ba



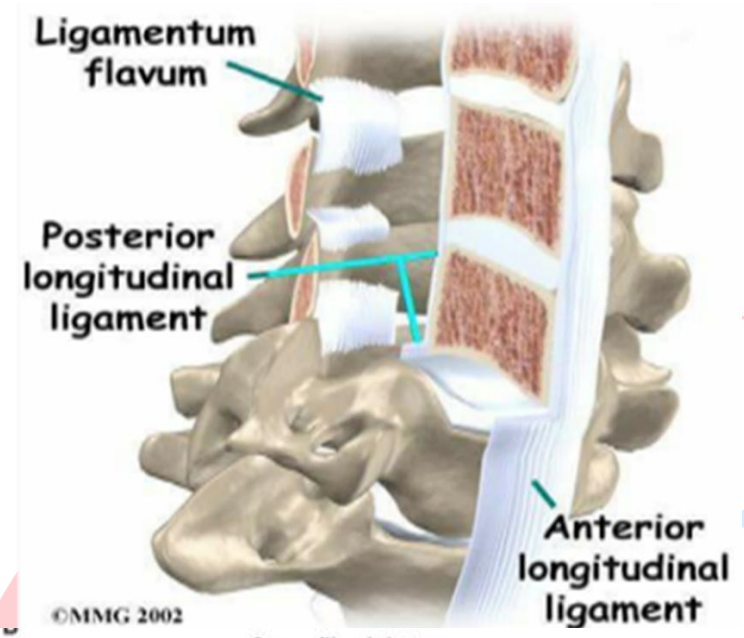
3.Some diseases have a predilection for synovial joints rather than symphyses. A typical example is Rheumatoid arthritis, which primarily affects synovial joints and synovial bursae, resulting in destruction of the joint and its lining. Symphyses are usually preserved

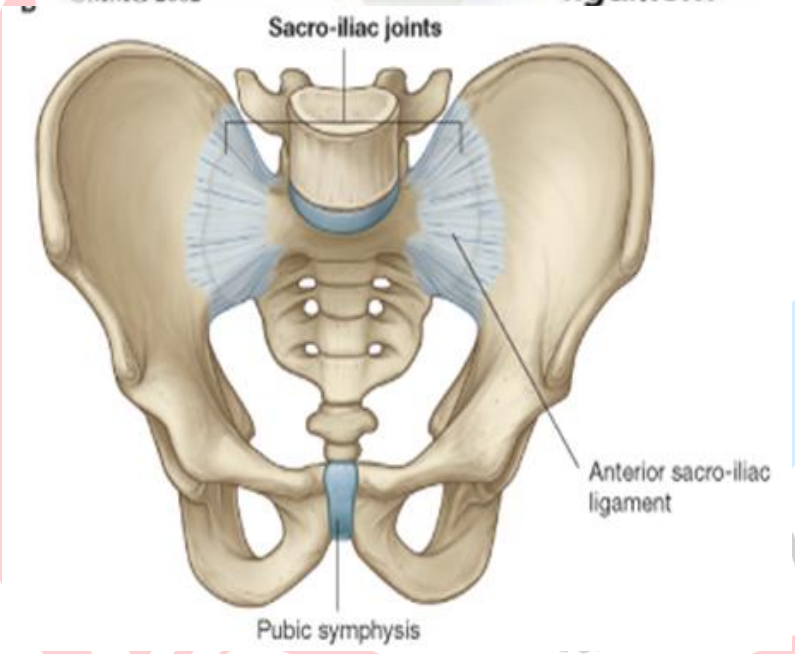




4.Cubital Tunnel Syndrome.

Ligaments These may be either discrete structures or thickenings of the joint capsule. Being necessary for joint stability, they are strong and are orientated to resist specifi c stresses.





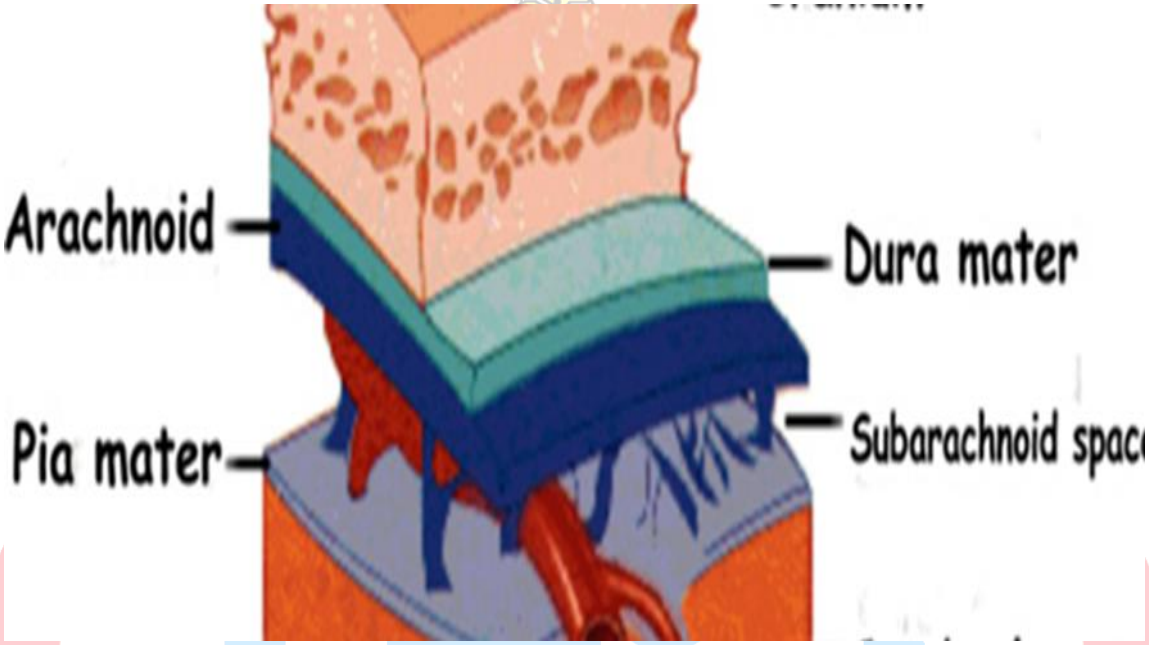
Anatomical Functions:

- *Connect the bones.*
- *Reinforce the joints.*
- *Help joint stability.*

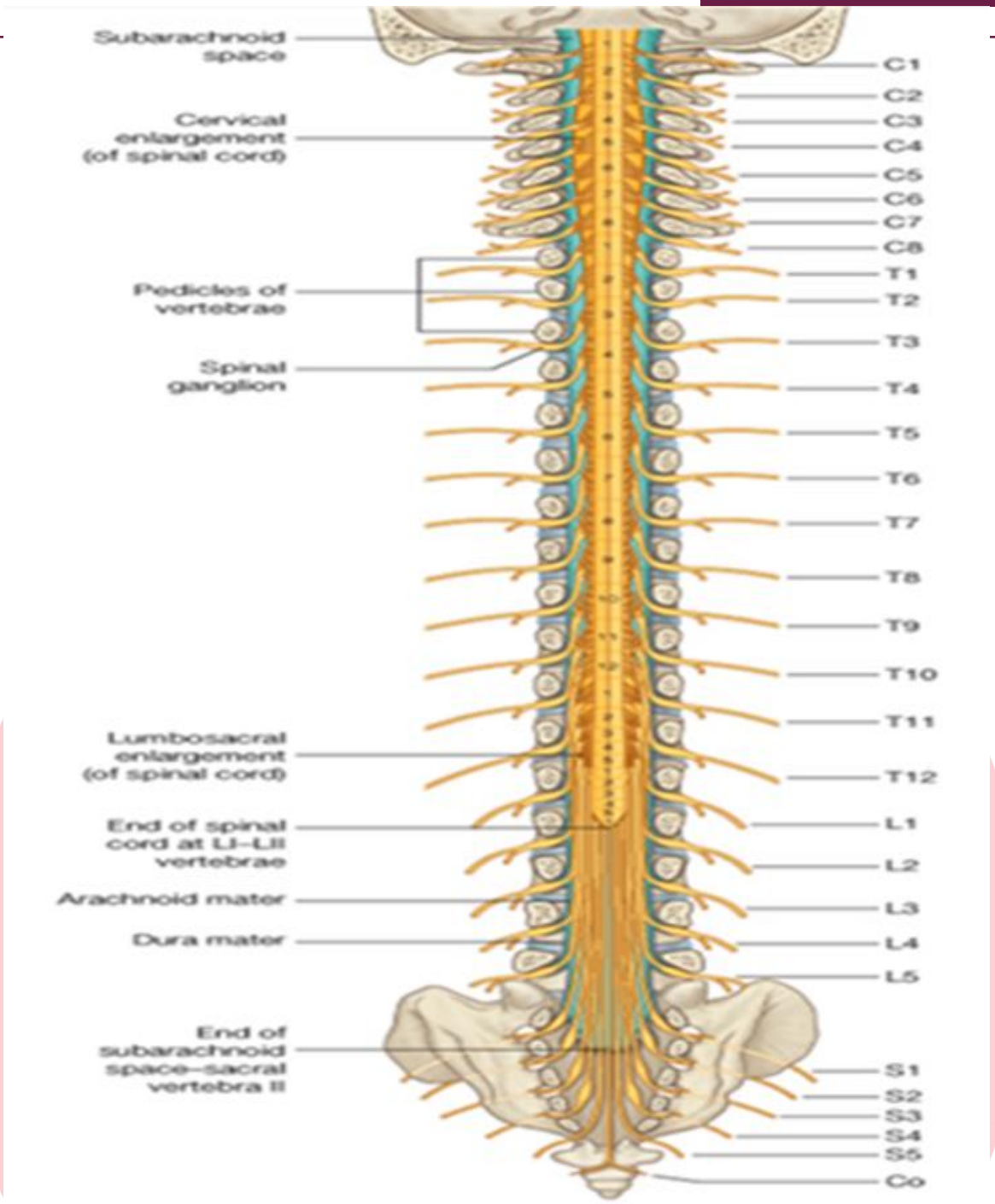
N.B: Applied anatomy They are, however, occasionally ruptured, either completely or partially, and are difficult to restore when damaged. A partial rupture is known as a sprain or strain, and usually heals completely.

N.B: Tears of ligaments heal slowly (ligaments are relatively avascular).
N.B: Torn ligaments predispose the joint to dislocation.

Q:Name Contents of the Vertebral Canal:



1.Epidural space
2.matter ldura matter
3.Subdural space.
4. Arachnoid matter
5. Subarachnoid space with cerebrospinal fluid.
6. Pia matter
7. Spinal cord &cauda equina

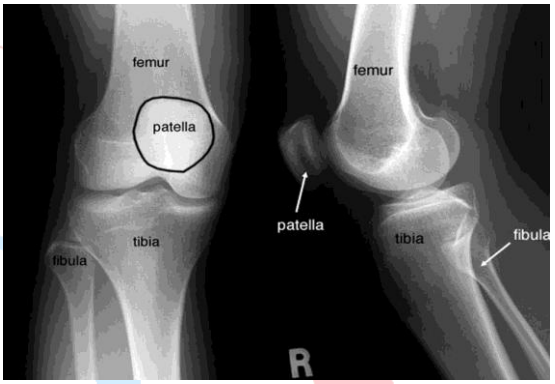


Chapter 5 : Diagnostic Imaging

N.B:.The student will be able to Define normal x ray bone after lectures.

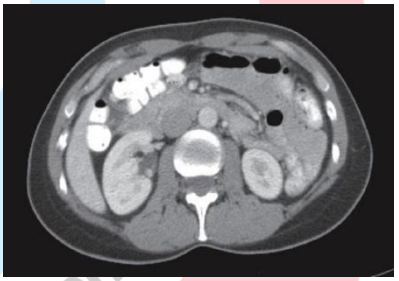
Radiographs (X- Ray):

A highly penetrating beam of x-rays shows the different tissues of the body according to their densities. A tissue that is relatively dense as the bone appears white in color. A tissue that is less dense as fat appears dark in color



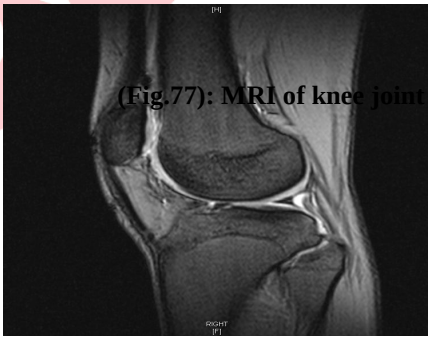
Comouterized tomography (CT) scan:

Images appear as a transverse section of the body. The amount radiation absorbed differs according to the amount of fat, water and bone in each area. Areas of the body with great absorption are relatively transparent and those with little absorption are black



Magnetic resonance imaging(MRI):

This also shows sections of the body but without use of X-rays. The person is subjected to strong magnetic field. Signals emitted from the person are reconstructed into various images of the body

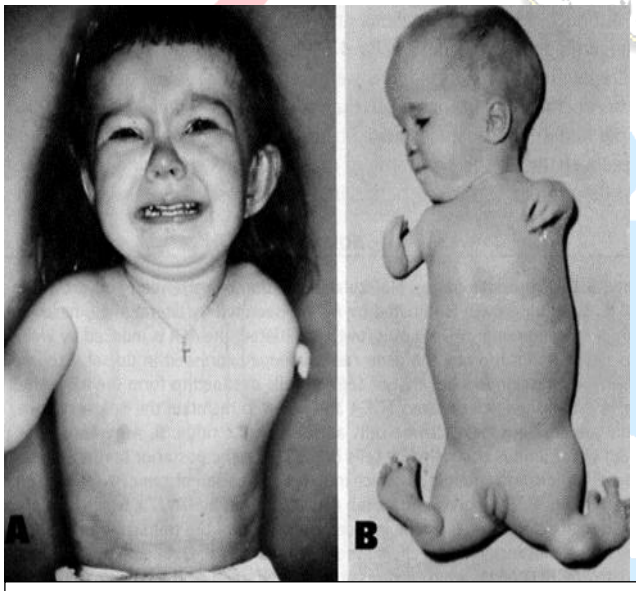


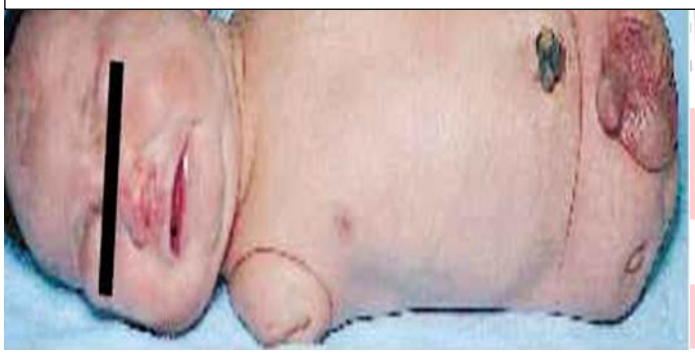
(Fig.77): MRI of knee joint

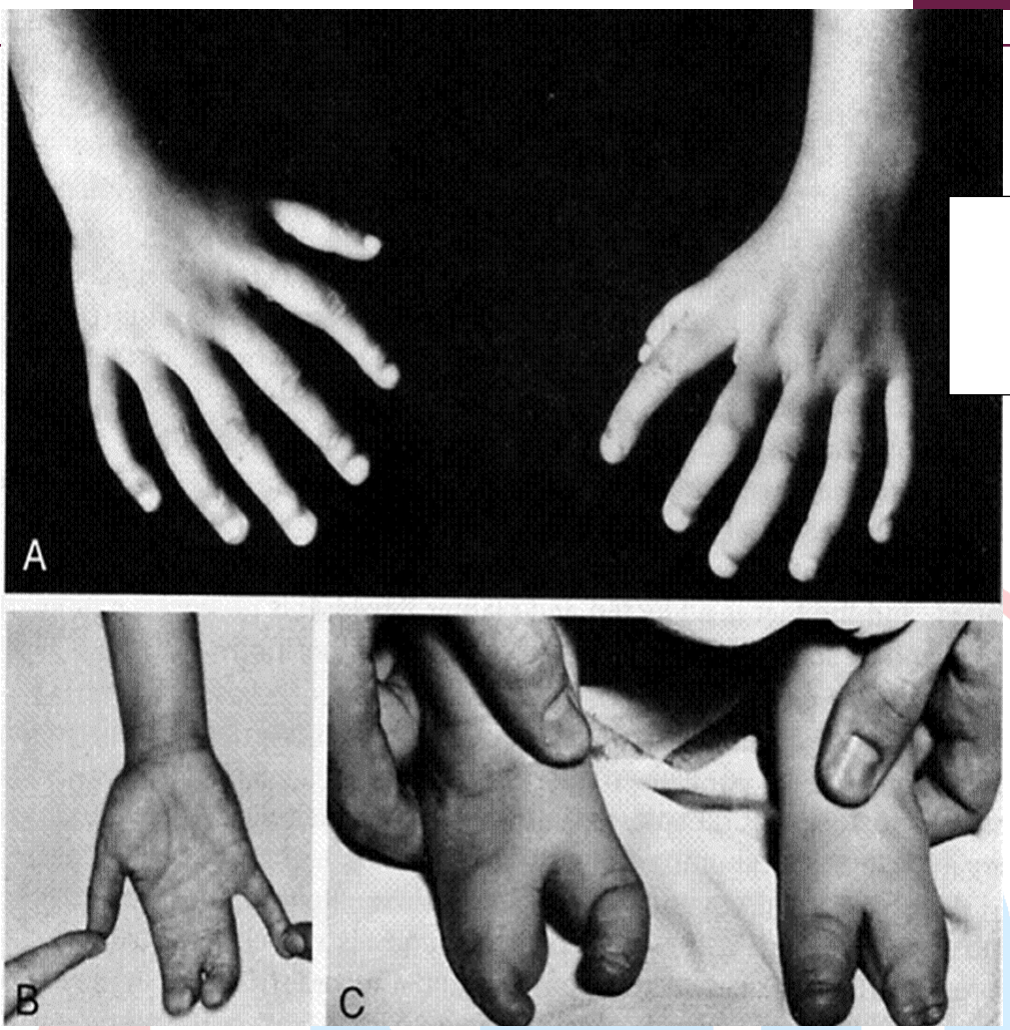
Chapter 6:
Congenital anomalies

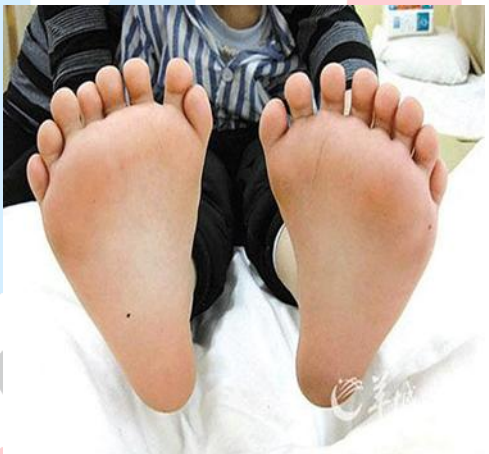
N.B:.The student will be able to Define normal human body.

MANY CONGENITAL MALFORMATIONS OCCUR FOR NO OBVIOUS REASONS, BUT CERTAIN FACTORS ARE KNOWN TO CAUSE MALDEVELOPMENT OF THE FETUS IF THEY ACT AT A TIME WHEN DEVELOPMENT IS AT A CRITICAL STAGE

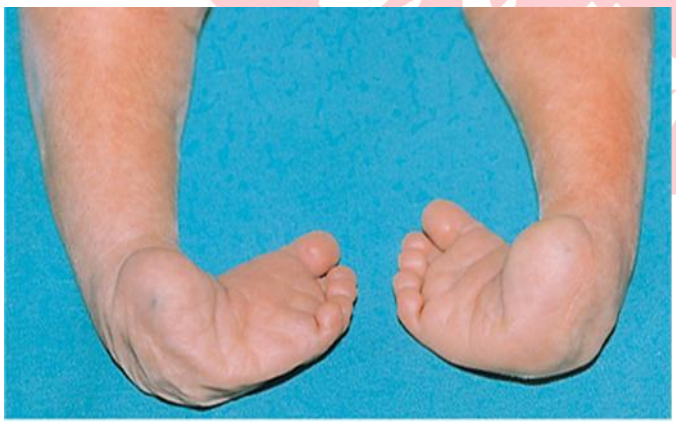








Q:Name



REFERENCES AND RECOMMENDED READINGS:

- **Gray' s anatomy for students,2nd edition,2011, Darke R . et al.**
- **ATLAS OF HUMAN anatomy (Netter)**
  Recomended books: Clinical Anatomy by Regions, 9th edition, 2011, Snell RS
- Last's Anatomy: Regional and Applied, 12th edition, 2011. Sinnatamby CS.
- Langman's Medical Embryology, 12th edition.

PART II
Physiology

Chapter 8: Skeletal muscle physiology

Objectives

- Describe the functional structure of the skeletal muscle.
- Discuss the process of excitation contraction coupling and mechanism of contraction and relaxation.
- Outline the role of calcium and ATP in both contraction and relaxation
- Compare between isometric and isotonic contraction
- Give a brief idea about the source of energy to muscle contraction at different conditions.
- Mention the causes of fatigue
- Compare between voluntary and reflex muscle contraction
- Outline some diseases affecting skeletal muscle performance

Overview

- The skeletal muscle is composed of contractile and regulatory proteins.
- Calcium binding to and release from the regulatory protein troponin is essential for muscle contraction an relaxation.
- Both contraction and relaxation processes are active processes (are in need for ATP)
- Stored Creatinine phosphate is an immediate source of energy for muscle contraction followed by glycolysis while oxidative phosphorylation is essential for longer duration of exercise.
- Isotonic contraction is the type associated with muscle shortening and ability to carry a load.
- Reflex muscle contraction may be helpful to maintain muscle state in case of neurological lesion affecting the voluntary control.
- Any factors affecting neuromuscular transmission or energy store could impair the process of contraction or relaxation

Skeletal muscles (Somatic, voluntary or striated muscles)

These muscles are usually attached to the skeleton (skeletal muscles). Their contraction moves the body (soma) or part of it (somatic muscles). Contraction of these muscles is under voluntary control (voluntary muscles). These muscles appear striated under the microscope (striated muscles).

Muscle Function:

- **Stabilizing joints**
- **Producing movement**
- **Moving substances within the body as increased venous return from lower limbs towards the heart**
- **Stabilizing body position and maintain posture by their tonic contraction and muscle tone.**
- **Producing heat– muscle contraction generates 85% of the body's heat**. Heat production from skeletal muscles represents about 50% of the metabolic rate during rest and increased very much during muscular exercise. The activity of skeletal muscles plays a very important role in the control of body temperature.
- Nearly all skeletal muscles are attached to bones by means of tendons. A tendon is composed of dense, white, fibrous connective tissue fibers, surrounded by loose connective tissue. The fibers of the tendon are fixed to sarcolemma of the muscle fibers.
- The tight connection between the cell membranes of the muscle (sarcolemma) and the surrounding connective tissue structures make the force developed by the muscle contraction to be transmitted effectively to the tendons.

The muscle fiber (myofiber):

- Skeletal muscle is made up of thousands of muscle fibers. **The muscle fiber** is the structural unit of the skeletal muscle.

- The muscle fiber is surrounded by two membranes, the outer is called the sarcolemma and the inner is the plasma membrane (true cell membrane).
- **T tubules or transverse tubules :**

  The sarcolemma make invagination and extend deep into the muscle fiber (at the junction of the A and I bands). The lumen of the T tubules is continuous with the extracellular fluid around the muscle fibers.

  The T tubules have the following functions.

  a. They increase the surface area of the sarcolemma many folds.
  b. They help in movement of ions and other substances into and out of the cell.
  c. They allow the depolarization wave to pass rapidly inside the muscle fiber to activate deep myofibrils**.**
- The muscle fiber (myofiber) consists of several hundred myofibrils (fibril = little fiber) which are surrounded by a **cytoplasm known as the sarcoplasm.**
- The sarcoplasm contains the usual cytoplasmic organelles; sarcosomes (mitochondria), sarcoplasmic (endoplasmic) reticulum which extends between the myofibrils, Golgi apparatus, ribosomes and glycogen granules
- **Sarcoplasmic reticulum :**

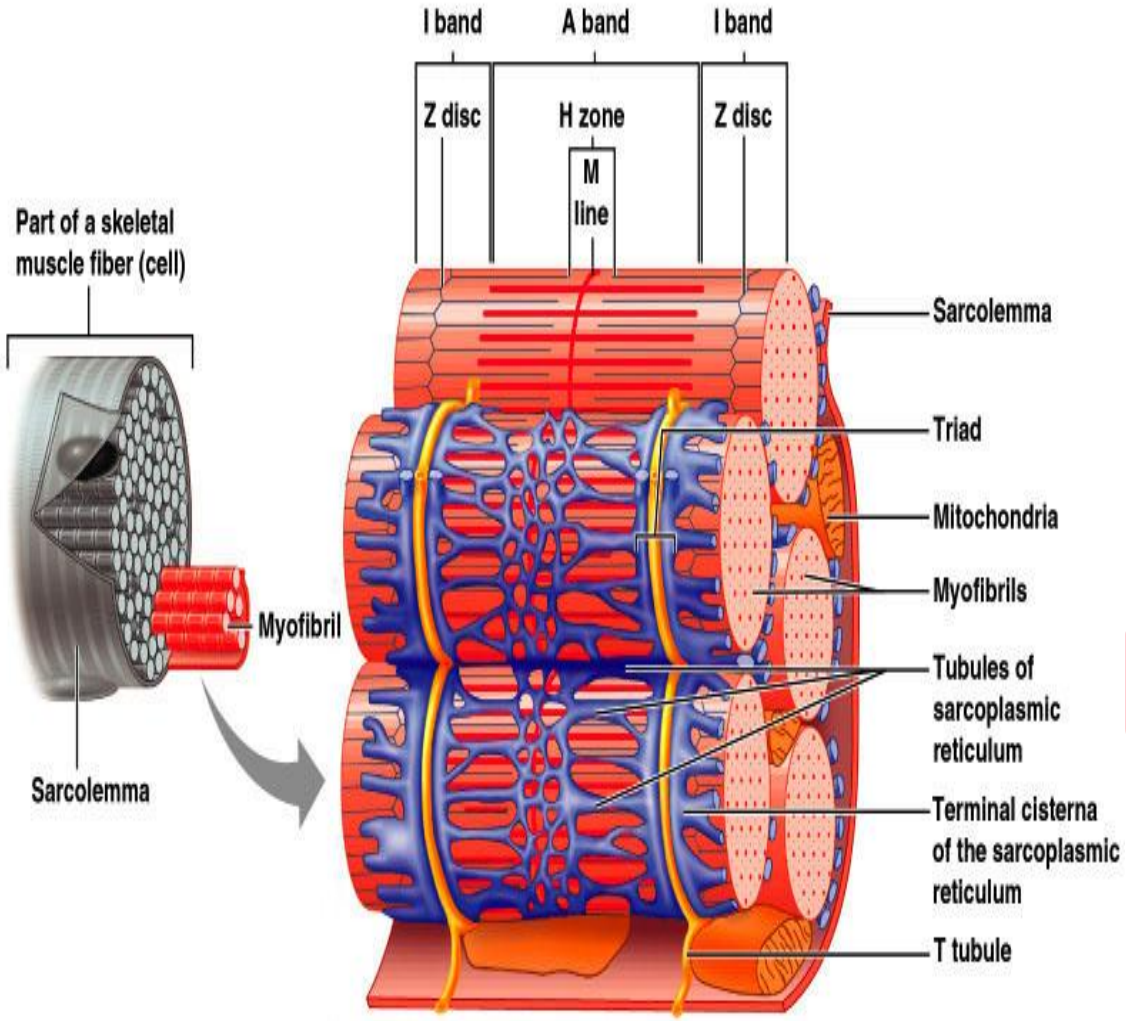
  - The sarcoplasmic reticulum is a network of anastomosing longitudinal tubules which run parallel to the myofibrils. The dilated ends of the tubules are called the terminal **cisternae.**

  --A group of the T tubule and two terminal cisternae on either side is called **a triad.**

  The sarcoplasmic reticulum has the following functions:

1. Terminal cisternae releases calcium ions during muscle contraction and store it during muscle relaxation.

It helps in longitudinal distribution of fluids, ions and substances synthesized within the sarcoplasm or mitochondria.

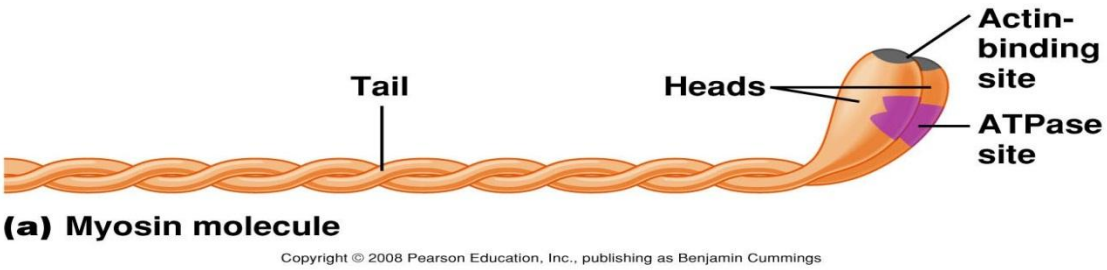


The general structure of the skeletal muscle fibers showing T tubules , sarcoplasmic reticulum and terminal cisterna.

The myofibril:

- The myofibrils extend from one end of the muscle fiber to the other giving the muscle fiber its longitudinal striation. The myofibrils are divided into **functional units called sarcomers**.
- Each myofibril is composed of filaments (myofilaments), thick filaments (**myosin**) and thin filaments(**actin**) which are **contractile proteins.**
- In addition to the contractile proteins there are also two **regulatory proteins**, **troponin and tropomyosin**

The thick filaments:



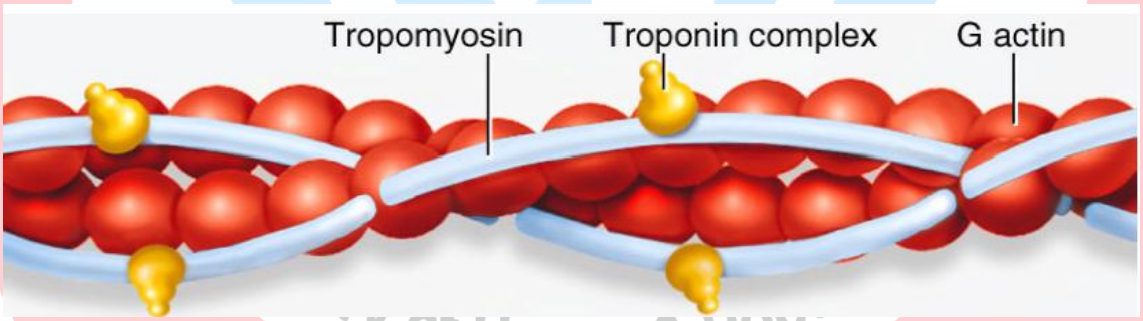
(a) Myosin molecule

- Each myosin protein has a rod like tail and two heads with a flexible hinge in between
- Myosin heads are also called cross bridges. Where :

  One head hydrolyze the molecules of ATP to use the chemical energy

  for contraction. The second head attach to and pull on actin causing the sarcomere to shorten.
- The thick filaments are located in the middle of each sarcomere, producing the dark A band.

Thin Filaments:



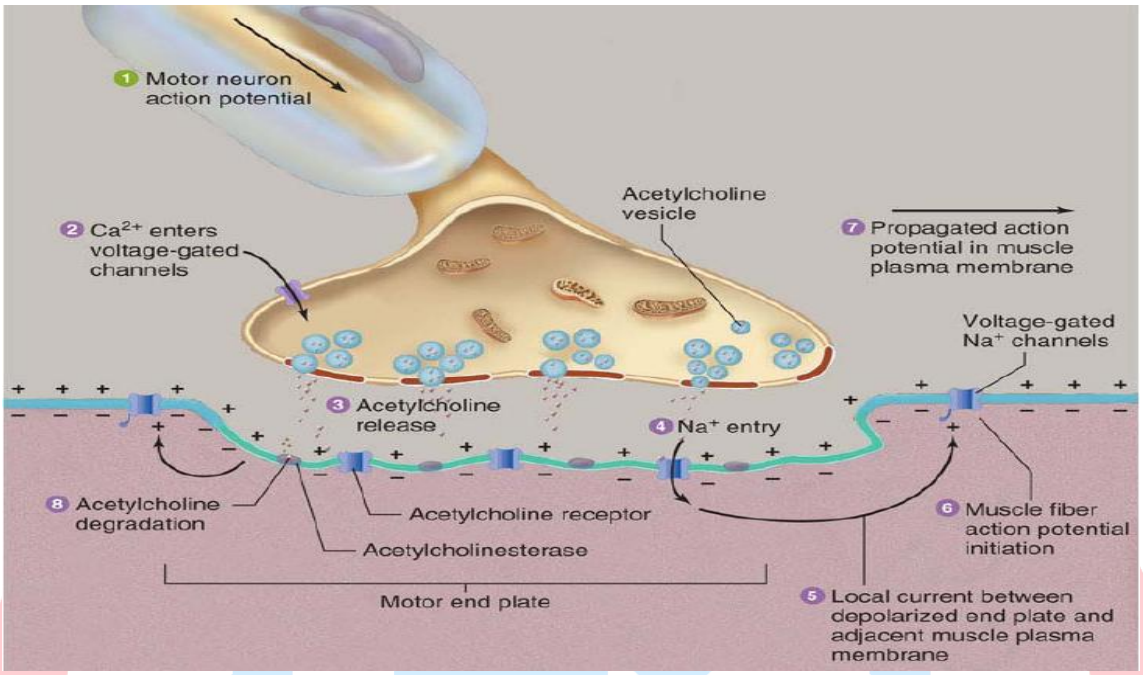
- Each sarcomere contains two sets of thin filaments, one at each end. One end of each thin filament is attached to the Z disc, where the other end overlaps a part of the thick filaments
- **Actin**
- A double helical polymer of protein subunits of G actin
- Each subunit contains a binding site for the myosin head

- **Tropomyosin**
- Thread like structure, it covers the active sites on actin and thus it blocks the interaction between actin and myosin.
- It prevents an unstimulated muscle from contraction
- **Troponin**
- Globular units attached to tropomyosin at intervals.

Each unit contains:

- **Tropinin C** : It binds to Ca2+in the sarcoplasm during contraction
- **Tropinin I** or (A) : It binds to actin to inhibit its interaction with myosin.
- **Tropinin T** : It binds to tropomyosin.

Excitation contraction coupling



Neuromuscular transmission:

- The motor orders (nerve signals) reach to the end of the nerve and it causes depolarization and opening of voltage gated calcium channels with calcium influx.
- The calcium causes release of acetylcholine which bind to its receptors on the sarcolemmal membrane of the muscle.
- At first Acetylcholine causes local potential due to increased sodium influx, then the potential will be propagated from the surface of the muscle to its deeper part through T TUBULES.

How the action potential causes muscle contraction? Mechanism of contraction:

- The action potential spreads along the T tubules which extend deep into the muscle fiber causing release of Ca^{++} ions from the terminal

cisternae (calcium-filled sacs) of the sarcoplasmic reticulum. The released Ca^{++} ions diffuse rapidly to the region of the thick and thin filaments.

- Combination of Ca^{++} ions with troponin C on the thin filament causes the tropomyosin to move away from its blocking position and thus exposing the binding sites present on actin molecules.
- Cross bridges from the thick (myosin) filaments combine with the binding sites on the actin.

Cross-bridge cycling which results in sliding of the thin filaments across the thick (myosin) filaments:

Cycling of cross-bridges occurs by the following steps

a. Binding: Cross-bridges on the thick filament bind to actin.

b. Bending: Binding of the cross bridges leads to release of energy stored in myosin (ATP by ATPase) producing angular movement of the cross bridges i.e. bending of the crossbridges and sliding of the thin filaments across the thick filaments.

c. Detachment: Detachment of the cross-bridges from the thin filaments which needs energy derived also from ATP.

d. Return to original position: The cross bridge returns to its original position and another cycle can occur by binding to another actin molecule and so on.

- sliding of the thin filaments towards the center of the sarcomere approximating the Z lines (discs) from each other (the sarcomers become shorter).

Mechanism of skeletal muscle relaxation

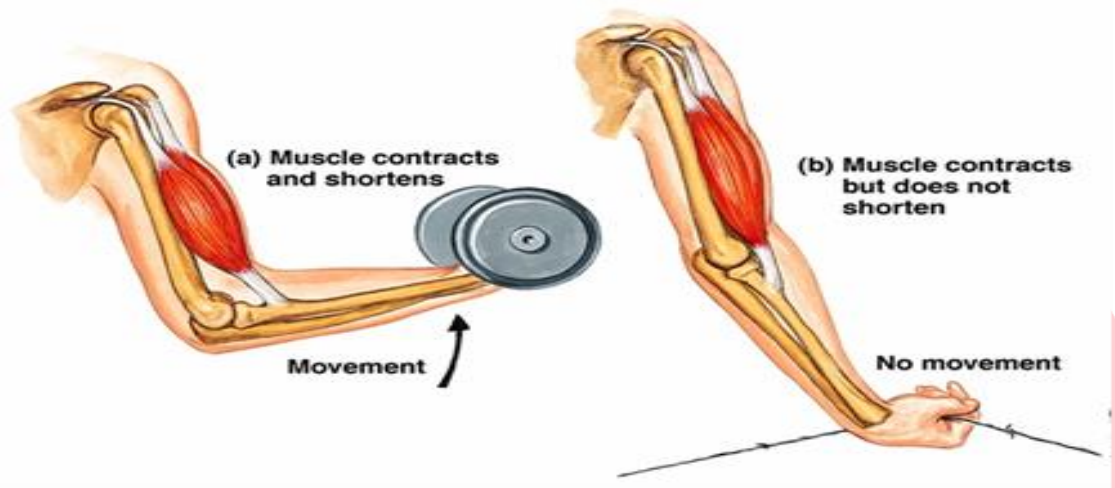
1-The signals in motor nerve stop and acetylcholine action at motor en plate id terminated by cholinesterase enzyme.

2- The action potential decreases and calcium pump in the

Sarcoplasmic reticulum collect calcium back to its store a process which in need for energy.

3- decreased calcium in sarcoplasm causes troponin C to leave its calcium and so the tropomyosin thread return back to cover binding sites on actin preventing the interaction between actin and myosin.

Types of skeletal muscle contraction:



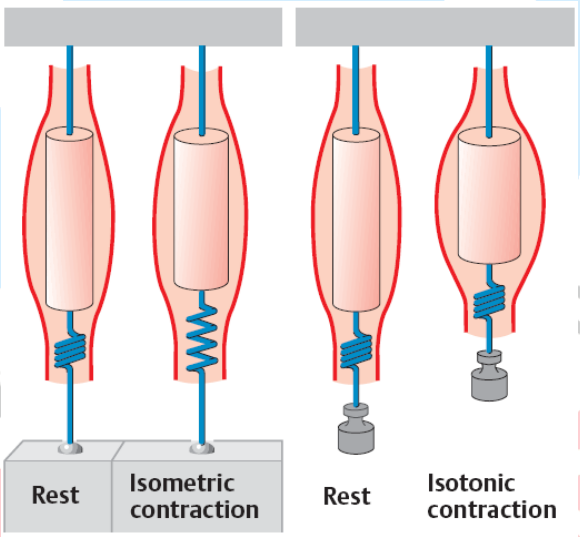
1. Isotonic (same tension) contraction:

- This type of contraction occurs when the muscle contracts against a light or moderate load.
- This contraction leads to shortening of the muscle and movement of the load.
- a work is done (work = weight of the load x distance of movement)
- the mechanical efficiency of the muscle (percentage ratio of the work done to the total energy expenditure) is maximum (40-50%).
- The tension inside the muscle increases at first, then maintained constant during the major part of contraction (isotonic)

Isometric (same length) contraction

- This type of contraction occurs when the muscle contacts against a heavy load.
- The muscle does not shorten i.e. contracts without change in length (isometric), and the load does not move.

- So, no work is done
- The mechanical efficiency is zero i.e. all the energy is converted to waste heat.
- The tension inside the muscle is markedly increased .
- The muscle is supposed to be composed of 2 components, a contractile components (sarcomers) and elastic components; one in series with the contractile components, and a second elastic element in parallel with the two components.
- When the muscle contracts against a heavy load (isometric contraction), the contractile components shorten, in the same time the elastic components are stretched to the same degree. So, the length of the muscle remains constant, but its tension is markedly increased.



Types of muscle fibers

There are two main types of muscle fibers each one is suitable for its function. **The red one** is suitable for long slow contraction to maintain body posture e.g lower limb muscle**. The pale one** is suitable for rapid short interval contraction as in eye muscle.

Red fibers type I:

- These muscles are red because they contain the respiratory pigment myoglobin which facilitates the uptake of O_2 from the blood stream.
- It contain much mitochondria (aerobic oxidation)
- It is surrounded by numerous blood capillaries (red fibers).
- It is Slow (red) muscles do not show fatigue

Fast (pale) muscle fibers (type II

- contain much more sarcoplasmic reliculum and glycogen granules.
- The myoglobin is absent
- there are few blood capillaries (pale fibers)
- few mitochondria so they are adapted to use anaerobic glycolysis
- these muscles are able to produce ATP rapidly and at high rates but quickly fatigued once their glycogen stores are depleted.

A third type of muscle fibers (intermediate type; fast oxidative)

Muscle Energetics and Fatigue

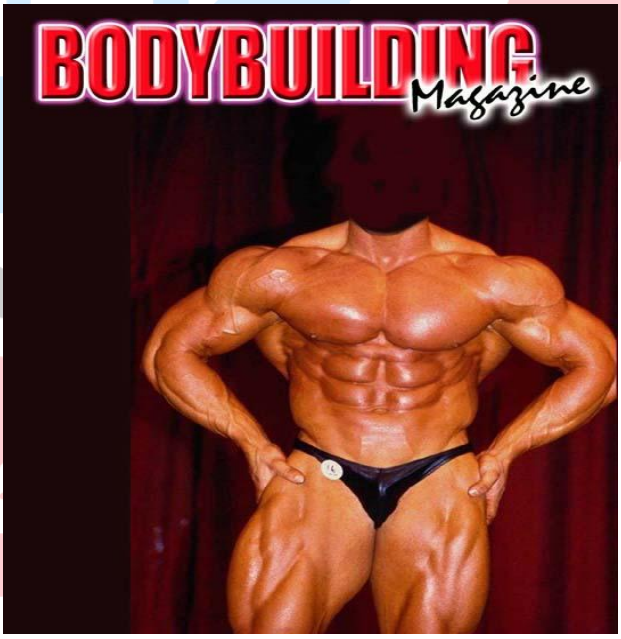
1-**Immediate source** is the creatine phosphate reaction (PCr) as it is a rapid means of cells transfering its high-energy phosphate to ADP, forming a single ATP. It is a limited supply only lasts for about 15 seconds

2- **Glycolysis** is also quick to start, providing 2 ATP per glucose molecule. It occurs with lack of oxygen in the muscles r under short, high-intensity exercise as active, contracting muscles swell and occlude arterial supply.

can provide the muscles with energy for up to 1-2 minutes of strenuous activity. It ends with lactic acid production and fatigue

3- Arobic respiration:

- is the mechanism for up to 95% of muscle ATP generation. Aerobic respiration requires oxygen and involves a series of chemical reactions that occur in the mitochondria called oxidative phosphorylation.
- Glucose is broken down into carbon dioxide and water, producing enough energy to create ~36 ATP molecules per glucose
- long sustained exercises as in marathon depends on oxidative phosphorylation
- is slow to begin, and the muscles must rely on other energy sources (such as direct (substrate) phosphorylation and lactic acid production) until aerobic respiration can produce enough ATP to take over production.



Muscle fatigue

After prolonged physical activity, muscles become fatigued and can no longer contract, even when signaled by the nervous system to do so. From the Causes of fatigue :

1- Energy stores are exhausted during exercise

2- Accumulation of lactic acids

3-Neurological : where the neurotransmitter acetylcholine is exhausted

Voluntary and reflex muscle contraction

1-Voluntary contraction: under my control

Mechanism :

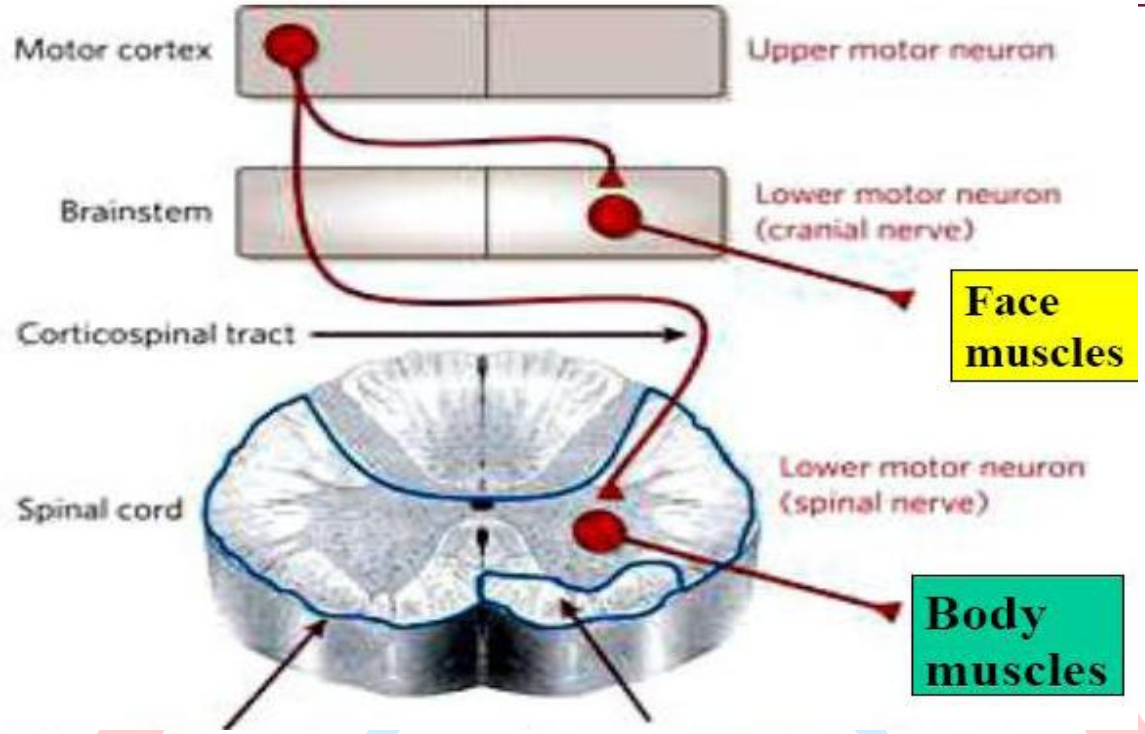
1-Motor orders to the right side muscles are generated in the left motor areas of the brain.

2-The orders descend in groups of nerve fibers which cross to right and terminate in the spinal cord.

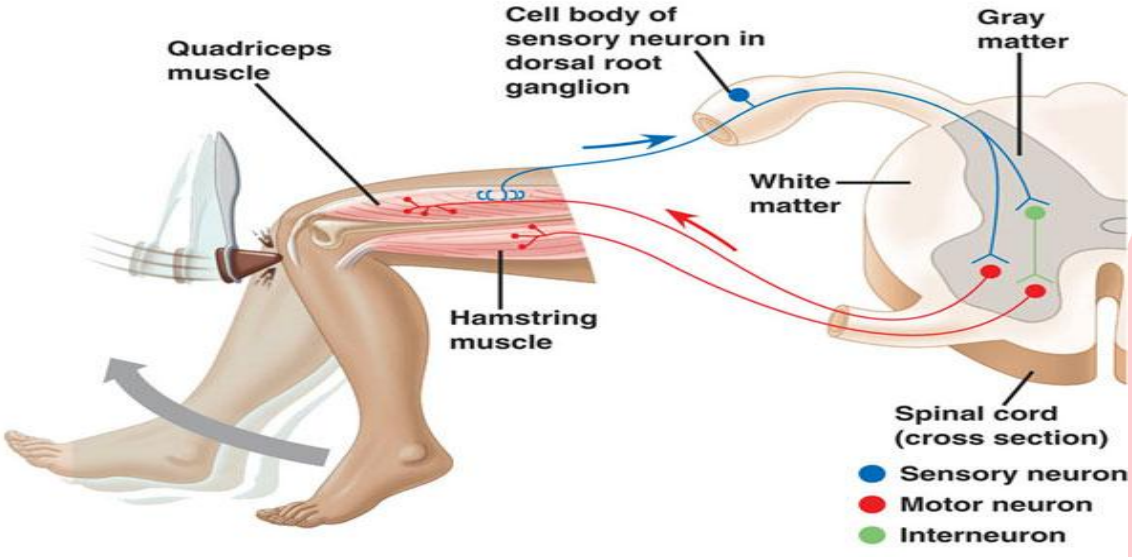
3-The neurons carrying orders to spinal cord are called upper motor neurons (UMNS).

4-From the spinal cord another neurons carry the order to the muscle and they are called lower motor neurons (LMNS) or alpha motor neurons.

Lesion in any o the UMN or LMN causes paralysis of the muscle.



2-Reflex contraction:



- In stretch of the muscle b tapping on its tendon as in knee jerk the receptors inside the muscle called muscle spindle is stretched and give signal in afferent sensory neurons which terminate in anterior horn of spinal cord . the lower motor neuron carry the signals to the muscle to contract.

- If the muscle has lesion in upper motor neuron the voluntary control disappear. But we can make electrical stimulation of the afferent of stretch reflex and the muscle could contract reflex.
- Question? What happen if there is LMN lesion?
  Both the reflex and voluntary contractions are lost

Joint

A joint

is defined as the juncture where two or more bones come together for the purpose of movement or for stability.

Normal joint function

is defined as a joint's ability to move throughout its range of motion, bear weight and perform work.

Other functions:

Some joints are immovable joints; these joints are common where protection of delicate internal structures (such as the brain and spinal cord) is important.

Muscle Diseases

- **Muscle Dystrophy:**

It is **genetic degenerative disease** that leads to progressive loss of the force generating capacity of the skeletal muscles.

- **Myotonia:**

It is **genetic disease** characterized by prolonged muscle relaxation after voluntary contraction.

- **Effects Of Muscle Denervation:**
  - **Muscle atrophy:**

This is the **decrease in the muscle size**. It occurs due to damage of the motor nerve supplies the muscle. In this disease there is paralysis and atrophy of the muscle with decrease in the actin & myosin content.

Also it may occurs with prolonged immobilization as in cast immobilization

- **Muscle fibrillation:**

It is **fine, irregular contractions** of the individual fibers (one muscle fiber activity) which are **invisible by the naked eye** but can be recorded by the electromyography. It occurs due to denervation hypersensitivity.

N.B. Muscle Fasciculation:

It **is jerky, visible contractions** of a group of muscle fiber (motor unit activity) results from pathological discharge of the spinal motor neurons as occurs in the early stages of poliomyelitis.

- **Muscle contracture:**

it is a prolonged muscle contraction without relaxation, in absence of stimulation. It is caused by **sustained elevation of cytoplasmic Ca^{++}** by an excessive release or by decrease in the reuptake by the sarcoplasmic reticulum.

- **Rigor mortis:**

it occurs **after death due to depletion of ATP**. Without ATP, Ca^{++} pumps are not function. The exposed active sites on actin attract myosin cross bridges, which attach but are not able to detach. The body becomes stiff due to these bound myosin cross bridges. Muscle will remain rigor until the cellular proteins begin to breakdown usually within 24 – 48 hours.

Electromyography

- It the process of **recording the electrical activity** of the muscle on a cathode ray oscilloscope.
- This could be done in unanesthetized humans by applying special electrodes.
- The apparatus used is called electromyograph& the record obtained is called electromyogram (EMG).

Clinical importance:

EMG is used for investigating the activity of the skeletal muscles in health & diseases e.g. detect the extent of paralysis in case of poliomyelitis or after nerve injury.

Chapter 9

bone physiology

Objectives

- Describe the functional structure of the bone.
- Understanding the interplay between different bone cells in formation and healing of fracture.
- Outline the hormonal regulation of bone mineralization
- Explain the effect of age , nutrition and mobility on bone formation
- Give a brief idea about bone marrow types, function, transplantation and diseases.

Overview

- **There is a difference between the expression bone modeling and bone remodeling**
- **Osteoblast are bone forming, osteoclasts are bone resorping while osteocytes are old mature osteoblast.**
- **osteoblast regulate the function of the osteoclast by release of certain factors**
- **PTH, active vitamin D , Calcitonin , estrogen, testosterione, corticosteroids play important role in hormonal regulation of bone formation and mineralizaion**
- **The bone , kidney and intestine are the target organs for regulation of calcium and phosphorus.**
- **Defective bone formation could be the result of deficiency of vitamin, increased PTH or defective collagen formation.**
- **Red bone marrow is important for hematopoiesis while the yellow one is a site for fat storage.**

BONE PHYSIOLOGY

The musculoskeletal system includes the bones, joints, muscles, tendons, ligaments, and bursae of the body. The problems associated with these structures are common and affect all age groups. Problems with the musculoskeletal system are generally not life-threatening, but have a significant effect on the client's normal activities and productivity.

- In the very young, the skeleton is composed of mostly cartilage and is therefore, pliable with a decreased incidence of bone fractures and breakage in childhood.
- With maturity, rigid connective tissue consisting of cells, fiber (collagen), a gelatinous material (ground substance), and large amounts of crystallized minerals (calcium, phosphate) became dominant .
- The formation and growth of bones begins early in the embryonic stage and bones continue to grow until an individual reaches maturity. Although they may seem lifeless and unchanging, bones are living parts of the body that are essential for calcium regulation, blood cell formation and structural support.

Important definition

Growth : is the process through which bones increase in size and become mineralized during childhood and adolescence.

Modelling: is the process through which bones are shaped and adapt to loading **(reshaping)** during life. Cortical modeling at the periosteal or endosteal surfaces changes bone diameter and cortical thickness. Bones normally widen with aging. It is less frequent than remodelling

Remodelling: is the continuous process of bone renewal to remove old, microdamaged bone and replace it with new, mechanically stronger bone to help preserve bone strength.

Types of bone:

1- Cortical bone: on the surface, surrounding the marrow space and it is heavily calcified. It fulfills a mainly structural and protective role. It represents 80% of the adult skeleton.

2-Trabecular bone: Under the cortical bone and it is less heavily calcified. It is a honeycomb-like network of trabecular plates and rods interspersed in the bone marrow compartment. It has a greater surface area which allows it to be metabolically active. It represent 20% of the adult skeleton .

- The proportion of trabecular and cortical bone varies by skeletal site; for example vertebrae are rich in trabecular bone but have very little cortex, but long bones have much thicker cortices and relatively less trabecular bone

Functions of the bone

1-Its mechanical nature provides support for locomotion

2-It offers protection to vulnerable internal organs as the brain

3- It forms a reservoir for storage of calcium and phosphate in the body

4-It provides an environment for bone marrow and for the development of haematopoietic cells.

5- A reservoir of growth factors and cytokines,

6- The yellow bone marrow acts as a storage reserve of fatty acids

7-Acid – base Equilibrium . Bone buffers the blood against excessive pH changes by absorbing or releasing alkaline salts.

8- Detoxification . Bone tissues are capable of storing heavy metals and other extraneous elements, thus removing them from the circulation and helping in reducing their effects on other tissues.

9- Endocrine Function. Bone controls metabolism of phosphate by **releasing fibroblast growth factor (FGF-23),** which acts on kidneys to reduce phosphate reabsorption. A hormone called **osteocalcin** is also released by bone, which contributes to the regulation of blood glucose and

fat deposition. Osteocalcin enhances both the insulin secretion and sensitivity *in addition to* boosting up the number of insulin-producing beta cells.

Functional composition of bone

Calcified bone contains about:

1- 25 % organic matrix (Osteoid) (mostly type 1 collagen and little non collagenous protein as osteocalcin , proteoglycan and alkaline phosphatase enzyme). It is secreted by osteoblasts

2- 5 % water

3- 70 % inorganic mineral (hydroxyapatite)

The bone mineral is similar to the concrete and the organic matrix is similar to the framing upon which concrete is applied.

1-Type I collagen: The collagen fibres in mature bone are orientated in alternating layers which confers maximum strength on the structure (lamellar bone). Collagen is responsible for **toughness** (the maximum amount of energy bone can absorb before fracture). Formed by osteoblast.

Bone matrix laid down acutely after fracture healing is formed without lamellar configuration (woven bone) and is weaker than lamellar bone.

2-The mineral component of bone tissue: it is calcium hydroxyapatite ($Ca_{10}(PO_4)_6(OH)_2$). The hydroxyapatite crystals make the bone **stiff**

(resists deformation in response to an applied force). The calcium and phosphorus (inorganic phosphate) components of these crystals are derived from the blood plasma and which in turn is from nutritional sources

3- osteocalcin, which is the most abundant non-collagenous protein of bone matrix**.**

4-Bone cells:

- **Osteoclasts** (remodeling cell): They are giant multinucleated cells of monocyte lineage

Function :

bone resorbing cells.. They attach to bone with integrins. They secrete hydrogen ions and enzymes. The acidification dissolves the bone mineral and the enzymes break down the matrix

It is important in remodeling (remove of old bone), but if its activity is increased it causes bone resorption.

- **Osteoblasts**: They are derived from mesenchymal stem cells of the bone marrow stroma.

Function :

1-They generate bone matrix and facilitate mineralisation.

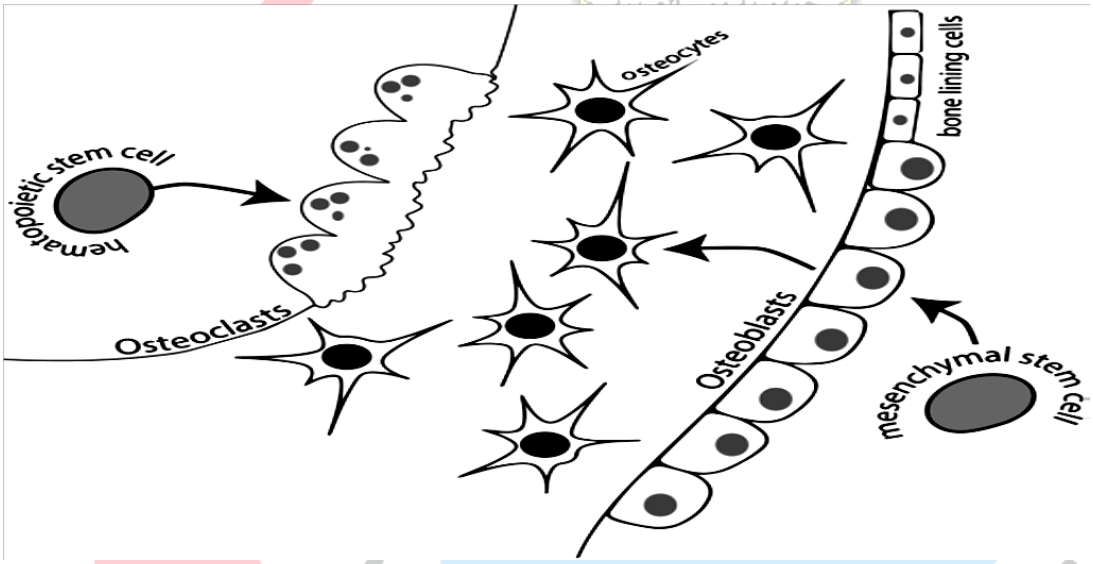
2- They regulate activity of osteoclast cells by release of certain factors (RAMK ligand increase osteoclastic activity. While **Osteoprotegerin** (OPG) inhibit osteoclastic activity.

3-Some osteoblasts become trapped in their own bone matrix, giving rise to osteocytes which, gradually, stop secreting osteoid.

- **Osteocytes** :

- Osteocytes are the most numerous cells in bone as it represent more than 90% of bone cells.

- ~~Osteocytes develop from osteoblasts that have completed their role~~ in bone formation.
- cells communicate with each other and with the surrounding medium on the surface of bone through extensions of their plasma membrane. Therefore, osteocytes are thought to act as mechanosensors, instructing osteoclasts where and when to resorb bone and osteoblasts where and when to form it (intercellular communication).
- Estrogen and physiologic loading of bone may help to prevent osteoblast and osteocyte apoptosis.



Pathophysiology of healing of Fracture

Fracture healing begins with

1- An inflammatory phase, with **hematoma** formation(2-3 days), **production of collagen from fibroblasts(1week)** and **the release of cytokines** that **attract stem cell**s to the site.

2-Hypoxia due to blood vessel damage induces stem cells to **differentiate into chondrocytes and osteoblasts and bone formation begins.**

3- Three basic steps involved in osteogenesis are:

(a) Synthesis of extracellular organic matrix (osteoid)

(b) Matrix mineralization leading to the formation of bone

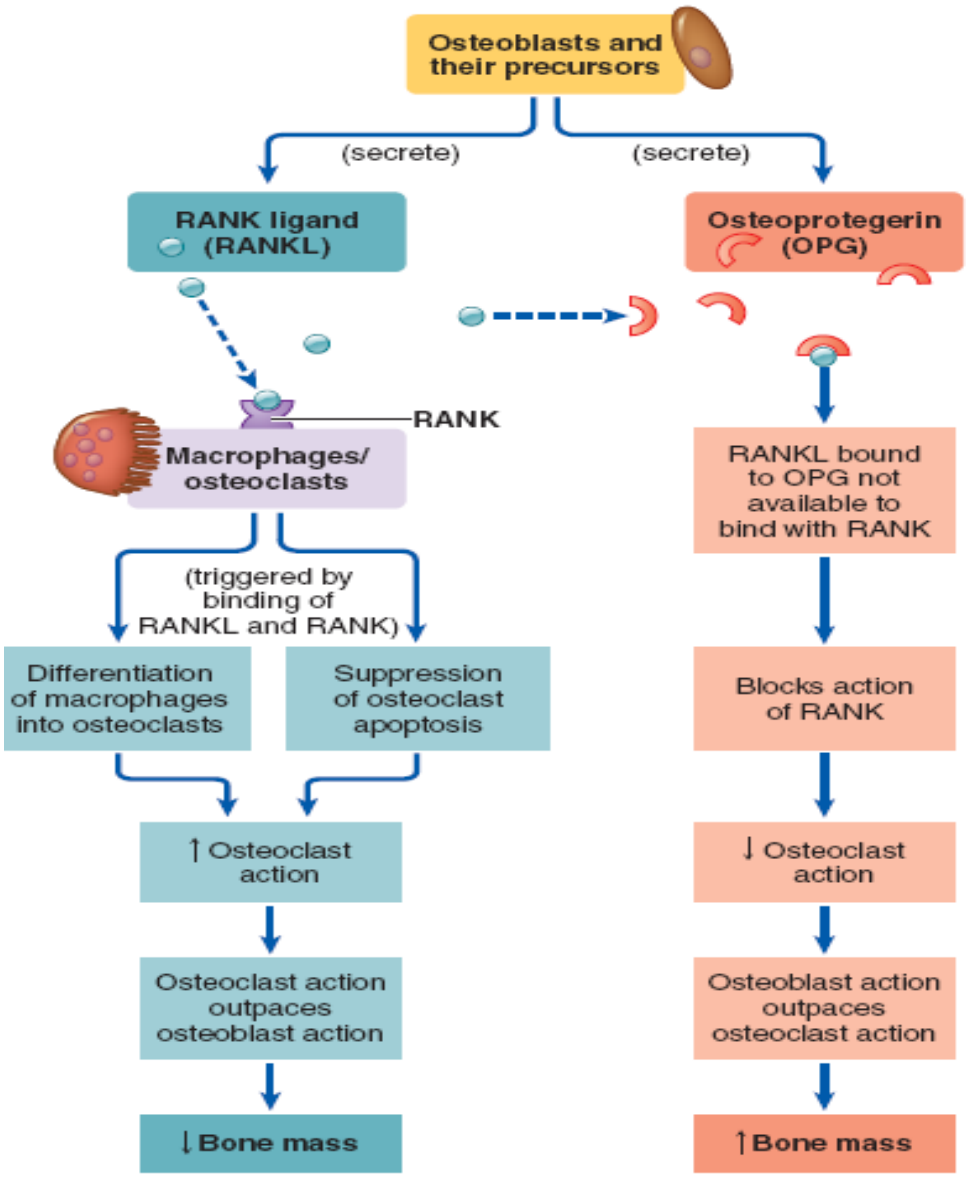
(c) Remodeling of bone by the process of resorption and reformation

4- Initial repair with woven bone (not lamella and weak and it called Callus – it takes 4 weeks) is then remodelled into lamellar bone through stimulation of osteoclast activity(8 weeks).

- **Important factors in bone remodeling**

Bone re-modeling : coupling of bone formation and bone resorption

- **Bone remodeling unite** (groups of bone forming cells osteoblast and group of bone resorping cells osteoclasts)
- Resorption and formation are coupled by **local factors**, and one of the key regulators is the RANK/RANK ligand/osteoprotegerin(OPG) system.
- **RANK** is a receptor expressed on the cell membrane of osteoclast precursors and mature osteoclasts, and its activation stimulates osteoclast differentiation and activity.
- **RANK ligand** is secreted by stromal cells or osteoblasts and is the major paracrine factor in activating the bone remodelling unit. It requires the presence of M-CSF to activate the RANK system in the osteoclast or osteoclast precursor. IT **activates the osteoclstic activity.**
- **Osteoprotegerin (OPG)** is also secreted by osteoblasts that neutralizes RANK ligand and prevent its contact with RANK so **decreases osteoclast differentiation and activity**.



Role of osteoblasts in governing osteoclast development and activity.

Importance of remodeling:

- It allows thickening of bone.
- It replaces the old organic degenerated weak matter by strong one.
- During childhood: Bone formation is more than bone remodeling puberty
- During adult life: Bone formation is parallel to bone breakdown.
- After menopause: Bone breakdown is more than bone formation

Factors affecting bone formation

1- **Physical and environmental factors:**

Decreased loading (prolonged bed rest and lack of exercise) will decrease bone density. It is explained by release of **Sclerostin** from the osteocyte which inhibits the osteoblast.

2- Nutritional factors:

A minimum amount of calcium is needed for mineralization, where diet should contains 1,200 mg/day to the age of 25, not less than 1 g/day from 25 to 45, and following menopause should be at least 1,500 mg/day. toxic habits may decrease calcium level such as smoking, caffeine, alcohol, and excess salt

3-Vascular / Nerve Factors:

Vascularization is fundamental for normal bone development, supplying blood cells, oxygen, minerals, ions, glucose, hormones,

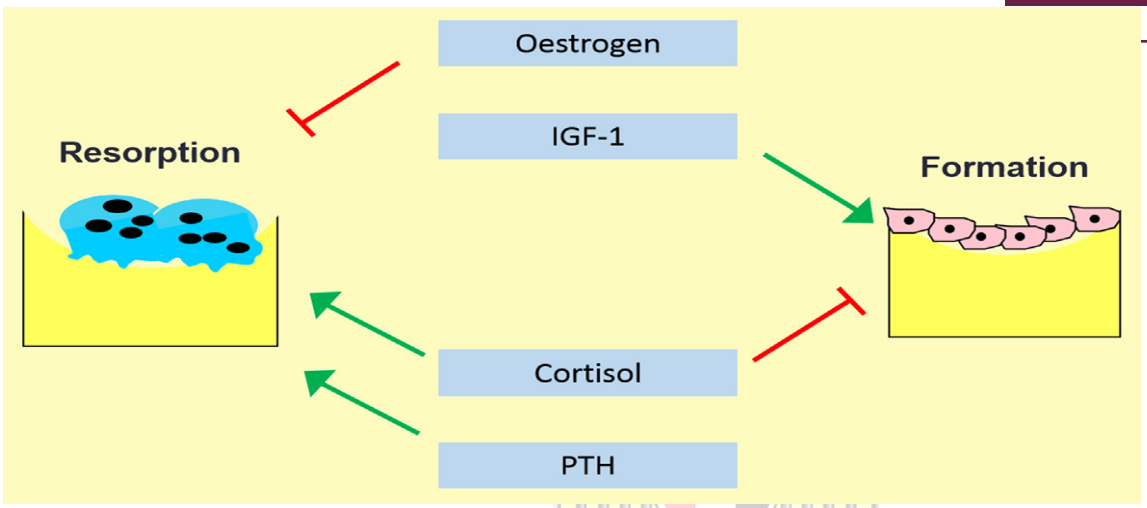
and growth factors.

Examples of the importance of innervationin bone physiology are found in osteopenia and the bone fragility present in patients with neurological disorders

4-Hormonal regulation of bone formation:

1- **Estrogen In normal puberty**, the early rise in oestrogen may drive increasing insulin growth factor 1 (IGF-1) and growth, and in the later stages oestrogen is the cause of epiphyseal fusion and the cessation of longitudinal growth.

- Oestrogen inhibits osteoclast activity
- It also increases osteoblast differentiation and bone formation, at least partly through inhibition of sclerostin secretion by osteocytes.



- Deficiency of estrogen after menopause is associated with osteoprotic changes.
- Fat tissue is an extra-sources for estrogen and this may explain osteoporosis is less common in obese female compared to thin female.

2- Testosterone: The androgen receptor is expressed in bone cells and chondrocytes.Testosterone decreases bone resorption and increases bone formation through similar mechanisms to oestrogen**.**

3-Growth hormone and IGF-1:

Growth hormone has some direct actions on target tissues, but **the majority of its growth-promoting effect is through the action of IGF-1. Most circulating IGF-1 is synthesized in the liver**, but it is also synthesized by bone cells tissues where it has paracrine or intracrine action.

4-Cortisol:

Cortisol regulates bone turnover. At high doses, they have a **catabolic effect on** bone),It increases resorption and decreases formation by

increasing osteoclast lifespan, inducing osteoblast and osteocyte apoptosis and inhibiting osteoblast differentiation

5-Adipocyte hormones: leptin is secreted by adipocytes in direct proportion to fat mass. Its first identified function was as a satiety signal, but in recent years it has been found to act directly on osteoblasts to increase bone formation,which could contribute to the positive correlation between bodyweight and bone mass.

6-*Insulin* . Insulin stimulates matrix synthesis both directly and indirectly, increasing the hepatic synthesis of IGF-I (insulin-like growth factor)

7- hormones regulating bone mineralization through regulation of calcium and inorganic phosphorus level .

A- 1 , 25 (OH) 2 Vitamin D 3 *or Calcitriol* . A steroid hormone, by favoring the intestinal absorption of calcium and phosphate, **favors bone mineralization.**

b-*Calcitonin* . Produced by the parafollicular C cells of the thyroid, **it is an inhibitor of bone resorption**, reducing the number and activity of the osteoclasts (see Sect. 2.3.2.1). However,this is a transitory action, since the osteoclasts seem to become “impermeable” to calcitonin within a few days.

c- Parathyroid hormone PTH: It is produced by the parathyroid glands in response to hypocalcemia.
Continual supply of PTH would increases osteoclast activity and **cause bone demineralization** indirectly via increased osteoblast expression of RANK ligand and decreased expression of OPG.
at intermittent doses it would stimulate the formation of bone, associated with an increase of certain growth factors and with a decrease in the apoptosis of the osteoblasts.

Thus, the hormones that regulate bone metabolism are as follows:

- **Decrease bone resorption (inhibit osteoclast)**

– Calcitonin

– Estrogens

- **Increase bone resorption (Stimulate osteoclast)**

– PTH/PTHrP

– Glucocorticoids

– Thyroid hormones

– High-dose vitamin D

- **Increase bone formation (Stimulates osteoblasts)**

– Growth hormone

- Insulin

– Vitamin D metabolites

– Androgens(estrogen – testosterone)

— Low-dose PTH/PTHrP (parathyroid related peptide)

– Progestogens

- **Decrease bone formation (inhibits osteoblasts)**

– Glucocorticoids

Markers of Bone Metabolism

Biochemical markers of bone metabolism provide dynamic information about the turnover of osseous tissue.

1-Markers of Bone Formation

Alkaline Phosphatase

In normal individuals, about half of the total alkaline phosphatase is derived from bone and the rest from liver. Alkaline Phosphatase is an ectoenzyme anchored to the cell surfaces of osteoblasts. It is non specific to bone.

Osteocalcin

It is known as bone gla protein(BGP), is a **bone specific protein**, which has proven to be a sensitive and specific marker of

osteoblast activity in a variety of metabolic bone diseases.

2-Markers of Bone Resorption

Biochemical markers used to monitor bone resorption include urinary measurements of:

(a) ***Hydroxyproline*** - *Containing Peptides* .

(b) Acid Phosphatase The type 5 isoenzyme is the one found in osteoclasts, which appear to be released during bone resorption

Factors affect strength of bone:

1- Larger bones are stronger than smaller bones. Bone mass accounts for 50–70 % of bone strength.

2- Compact bone more strong than cancellous bone

3- Collagen defects cause decreased bone strength

4-Delayed bone mineralization (as in osteomalacia/rickets, vitamin D deficiency) is associated with decreased bone mineralization.

Regulation of bone mineralization

Normal serum calcium and phosphorus concentrations are essential for healthy bone mineralization so precise control of ionic calcium levels in body fluids is absolutely critical (9-11 mg/dL). Plasma phosphorus level is 12 mg/dl

Calcium in bones:

- 99% of the total body Ca+2 is stored in skeleton (bone and teeth).

- Readily exchangeable calcium (Labile calcium –small quantity) Maintains plasma calcium level as it is removed from bones
- Stable calcium (Large amount). Helps in bone remodeling

Calcium in plasma:

- The other 1% of calcium is in soft tissues and plasma
- Calcium is present in the plasma as 2 forms:
  1-Diffusible (60%): It includes
  - The ionized Ca2+ which is the free active part (50%).
  - Non-ionized Ca2+ which is complexed with HPO4,
- HCO3 or citrate (10%).
- **2-Non-diffusible (40%):**
  -This form is bound to plasma proteins mainly albumin (physiologically inert).
- **N.B.:** Acidosis increases ionized Ca2+, as it decreases binding with albumin, while alkalosis decreases ionized Ca2+ as it increases Ca2+ binding to albumin

Role of calcium in physiologic processes:

a. Bone &teeth formation.

b. Neuromuscular excitability.
c. Muscle contraction (excitation-contraction coupling
d. Synaptic transmission (neurotransmitter release
e. Hormone secretion.
f. Intracellular communication (second messenger.
g. Blood clotting mechanism.
h. Maintenance of tight junctions between cells.

Regulation of Calcium and phosphorus

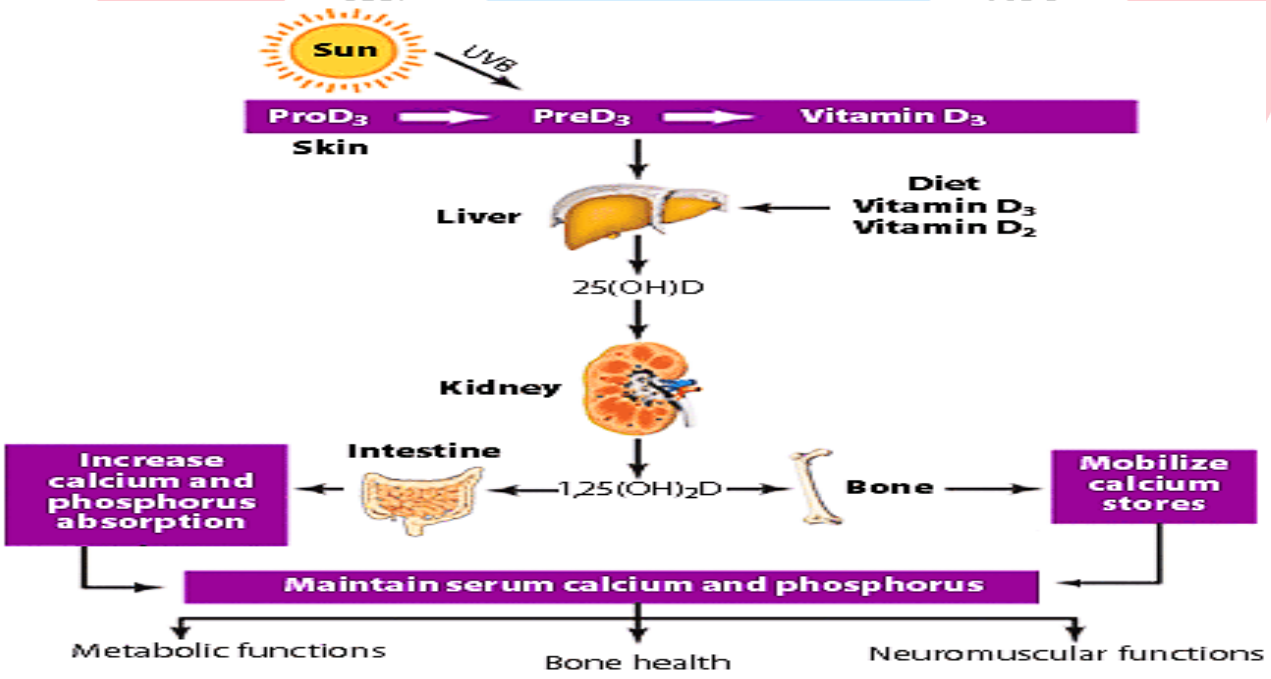
- occurs by different hormones : PTH, vitamin D, calcitonin and FGF23
- the effects they exert are through the bone, kidney, and gastrointestinal tract .

Vitamin D:

1-Vitamin D is synthesized in the skin on exposure to ultraviolet B radiation from the sun or consumed in the diet through vitamin D-enriched foods, beverages, or supplements.

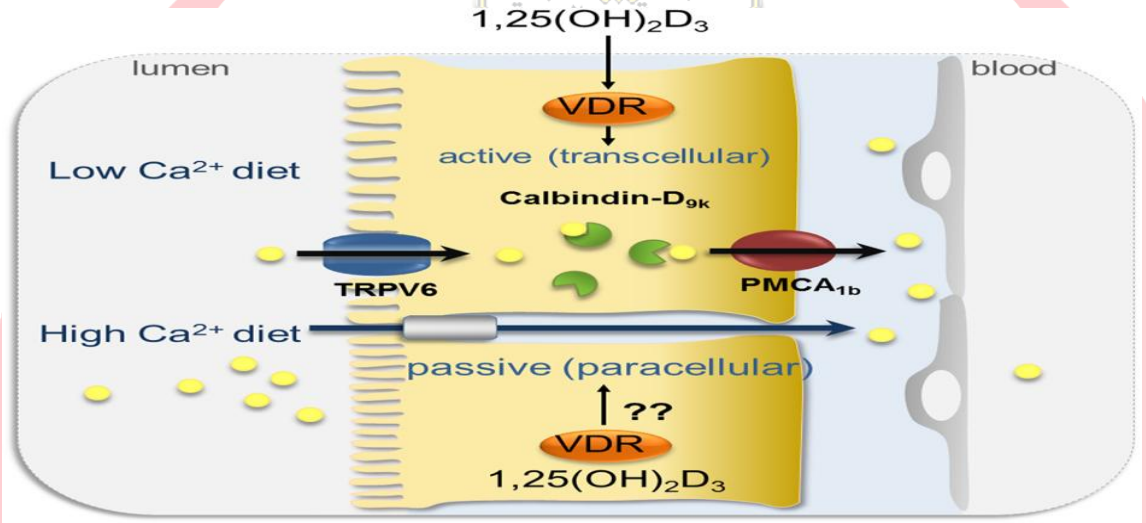
2- Vitamin D is hydroxylated in the liver to form 25-hydroxyvitamin D (the major storage form of vitamin D in the body)

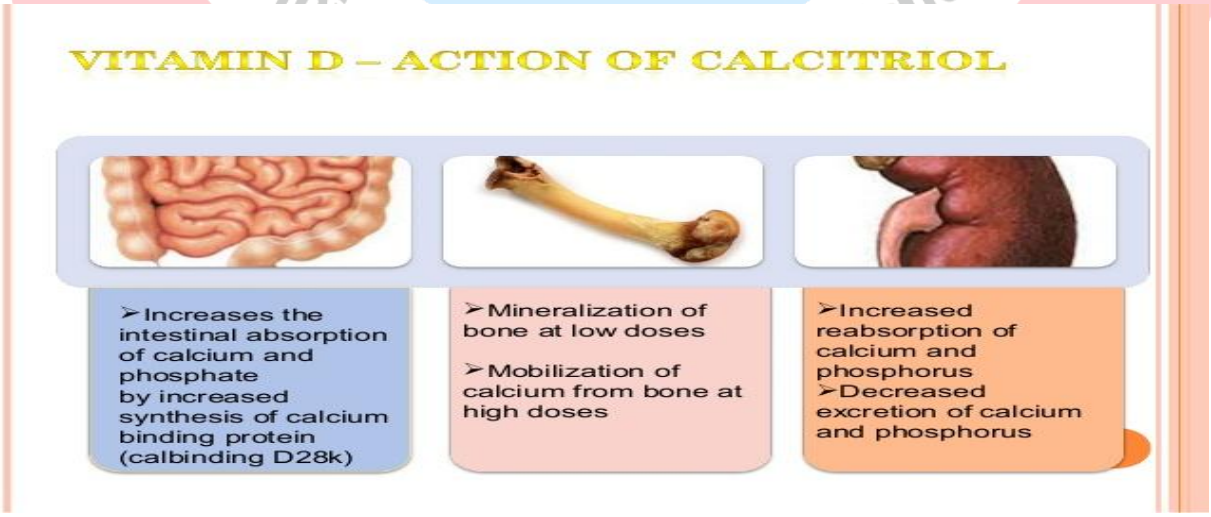
3- activated to 1,25-dihydroxyvitamin D by renal 1α-hydroxylase in the kidney



Action :

- **Mainly :** 1,25-dihydroxyvitamin D (calcitriol**) increases serum calcium and phosphorus** concentrations by stimulating **intestinal absorption** by increasing the rate of synthesis of calcium binding proteins (calbindin D) which is responsible for carriage of Ca^{++}.
- in **kidney** : It Increase both calcium and phosphorus reabsorption
- ***On bones*** :(Depend on Ca^{+2} & PO_4 – concentration)
- - High Ca^{++} & PO_4 Stimulates osteoblastic activity.
- - Low Ca^{++} & PO_4^{-} Stimulates osteoclastic activity.
- *N.b Uses of Vit. D.*: In Ricketes and osteomalacia must be preceded by elevating level of calcium in blood either by food or drugs .

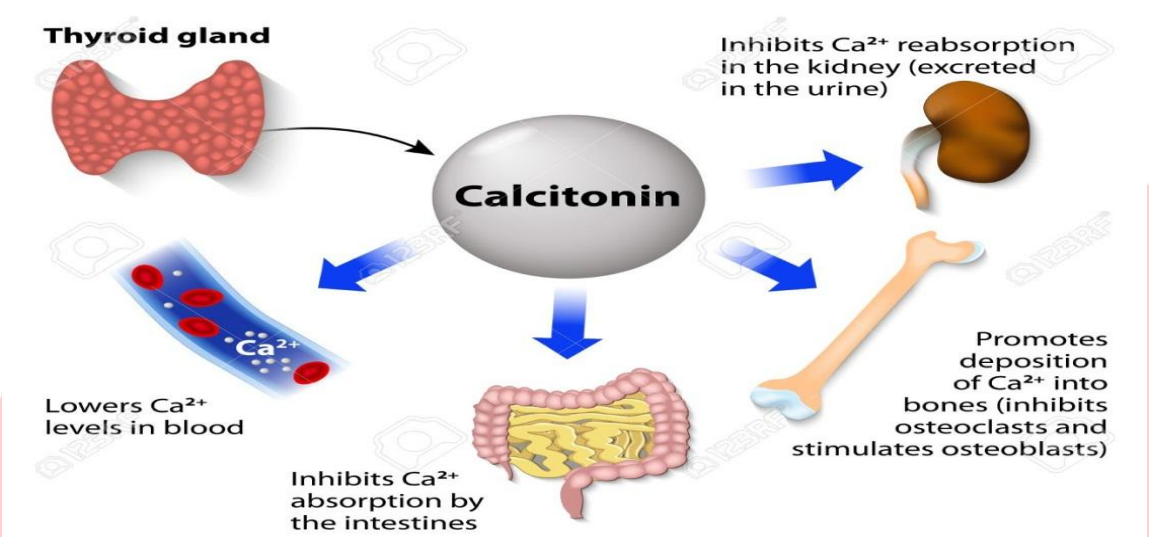




Calcitonin:

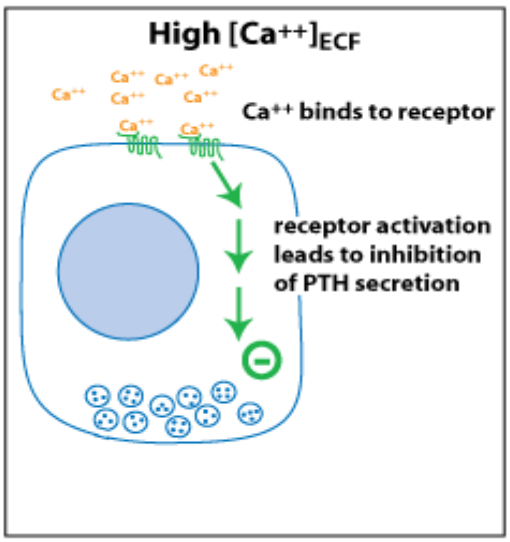
(Thyrocalcitonin)

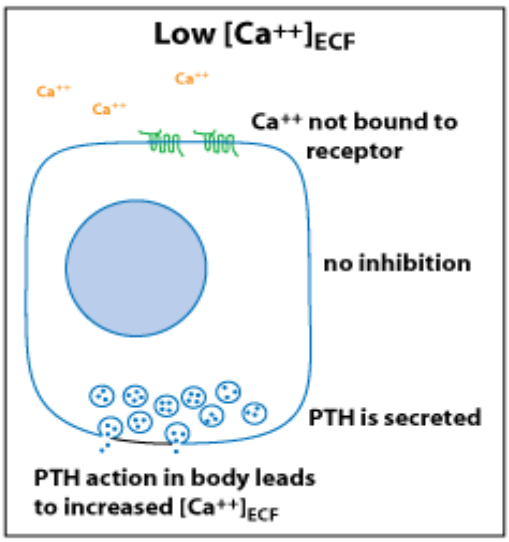
- ~~Is a hormone produced by the thyroid parafollicular cells.~~
- It is a **calcium lowering hormone by** its action on bones and kidneys.
- It is secreted in response to high calcium level
- Its Lowers serum calcium and phosphate levels by moving it into the **bone** and increase of osteoblast activity and inhibition of osteoclastic activity.
- Also it may cause loss of calcium and phosphorus in urine and it inhibits vitamin D activation(inhibit1α-hydroxylase)



3-PARATHYROID HORMONE (PTH):

- PTH secretion by the parathyroid cells is continually suppressed by the action of the calcium-sensing receptor (CaSR) which detects calcium in blood .
- In response to decreased ionized calcium binding to the CaSR, inhibition is decreased and PTH is secreted.





- **ACTION :**
- 1-**on the intestine**, indirectly, through its role in activating vitamin D increasing calcium reabsorption.

2-**In the kidney**

- PTH assists with increasing serum calcium

levels through reabsorption of calcium in the distal tubule and collecting duct.

- PTH also increases the reabsorption of phosphate in the proximal tubule.

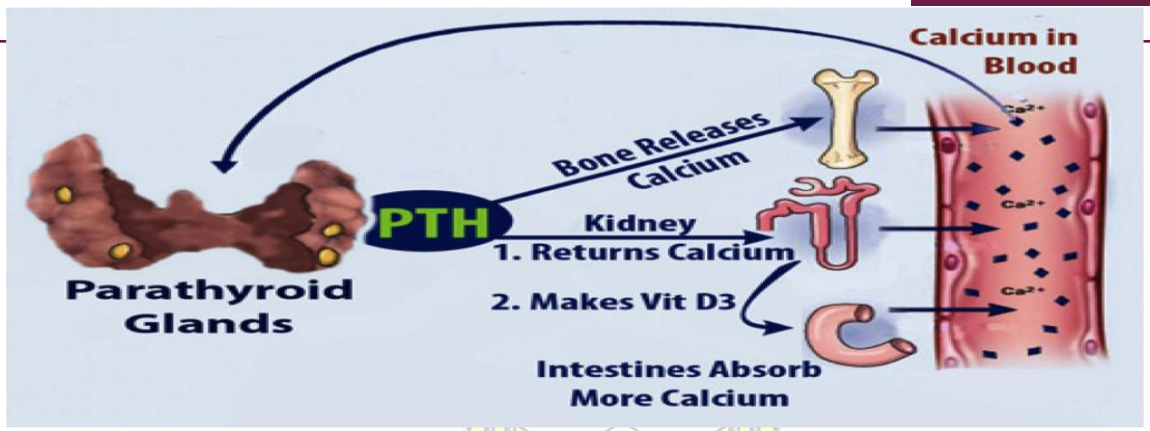
5-**In bone**,

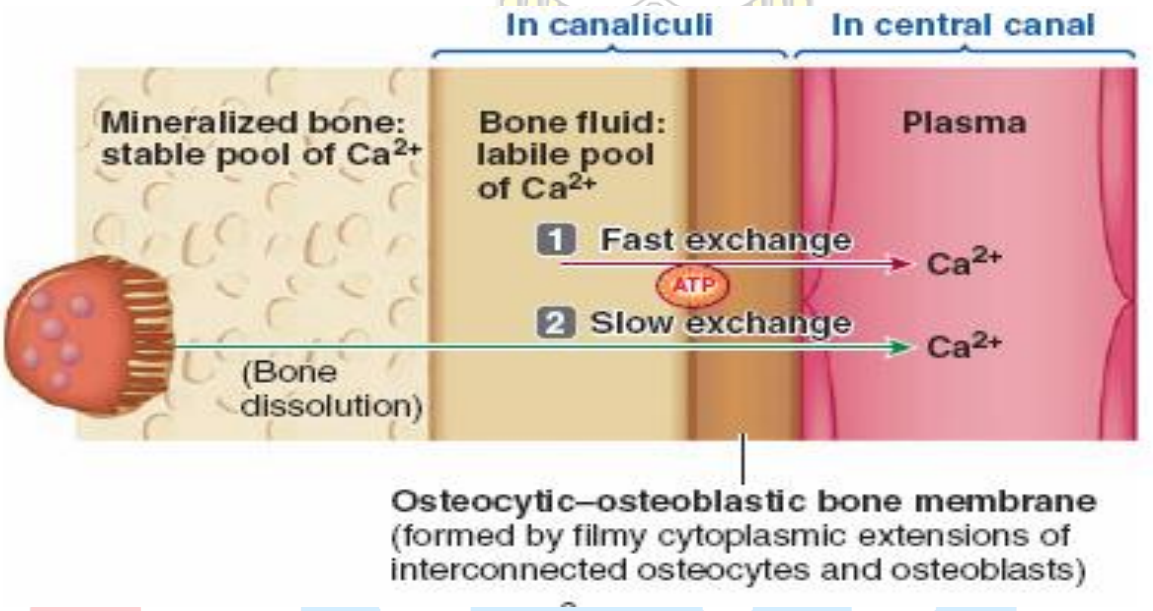
Early immediate effect :

It acts on **labile exchangeable calcium(*(<1%):*** as it increases the permeability of the osteocytic- osteoblastic bone membrane and increases activity of calcium pump in their membrane allowing release of calcium.

Late effect :

It drives the **stable calcium (*(>99%):*** release from the bone matrix by stimulating PTH receptors on osteoblasts. These cells then increase their expression of RANKL (stimulate osteoclast) and inhibit their secretion of osteoprotegerin (the inhibitor of osteoclast).





FGF 23

IT plays a central role in phosphate and vitamin D homeostasis. **SOURC**E: FGF23 is secreted by osteocytes .

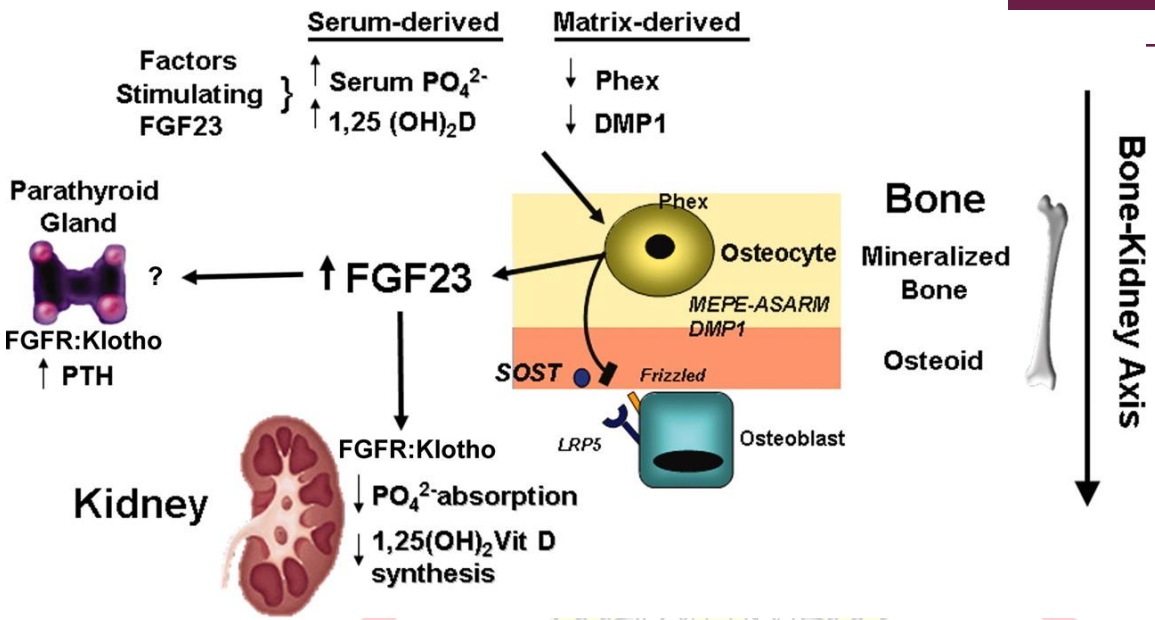
WHEN IT RELEASED:

With the increase in vitamin d or po4 in plasma

Action:

1-Elevations in FGF23 decrease 1,25-dihydroxyvitamin D concentrations through reductions in 1α-hydroxylase activity and increased expression of 24-hydroxylase,which degrades calcitriol.

2-FGF23 (similar to PTH) reduces renal phosphate reabsorption through suppression of sodium phosphate co-transporters within the proximal tubule



Diseases with defective bone mineralization

1- Increased PTH as it moves calcium from bone

- **Causes :** either due to adenoma (primary hyperparathyroidism) or in response to low calcium in blood as in renal failure and calcium loss in urine (sec hyperparathyroidism).
- There will be hypercalcemia and hypophosphatemia
- The bones soften and deform as their mineral salts are replaced by fibrous connective tissue. Multiple bone cysts are present (**Osteitis fibrosa cystica**). Thus the bone is subjected to spontaneous fractures & deformities.
- Formation of renal stones because of excess calcium salts being filtered through the kidneys leading to renal colic and hematuria and may be renal failure
- Hypercalcemia: is lethal if Ca+2 level become 17mg% affecting the heart

- **Bone diseases:**

1- ***Osteoprosis:*** Excess osteoclastic function which leads to loss of bon matrix and increased incidence of fractures. Most common cause is involutional osteoporosis which occur with advancing age and after menopause. Patient with excess glucocorticoids (Cushing syndrome) or persons who are immobilized for longtime can develop osteoporosis.

2- **Osteopetrosis**: a severe disease in which the osteoclasts are defective and are unable to resorb bone in their usual fashion so the osteoblasts operate unopposed leading to increased bone density.

3- **Paget's Disease**

In this disorder, the osteoclasts become abnormally activated, possibly by viral infection, and produce a bizarre and irregular pattern of resorption, to which there is usually an intense osteoblastic response with irregular new bone formation often in the form of woven bone. Thus, in Paget's disease there may be increased bone density, but because of the irregular architecture, bone strength is decreased and pathologic fractures may occur.

- ✓ **Osteomalacia/Rickets**
- ✓ The growth plates affecting children is seen in rickets, while in osteomalacia affecting adults
- ✓ there is incomplete mineralization of osteoid.
- ✓ There is decrease in Ca/PO 4 ratio, increase in alkaline phosphatase, and decrease in calcium excretion [Ca × PO 4 < 2.4].

Bone marrow

What is the bone marrow?

Bone marrow is the spongy tissue inside some of the bones in the body, including the hip and thigh bones. Bone marrow contains immature cells, called stem cells.

Types of bone marrow:

The two types of bone marrow are **red bone marrow**, known as myeloid tissue, and **yellow bone marrow**, or fatty tissue

- In infants, red marrow is found in the bone cavities. With age, it is largely replaced by yellow marrow for fat storage.
- In adults, red marrow is limited to the spongy bone in the skull, ribs, sternum, clavicles, vertebrae and pelvis. Red marrow functions in the formation of red blood cells, white blood cells and blood platelets.

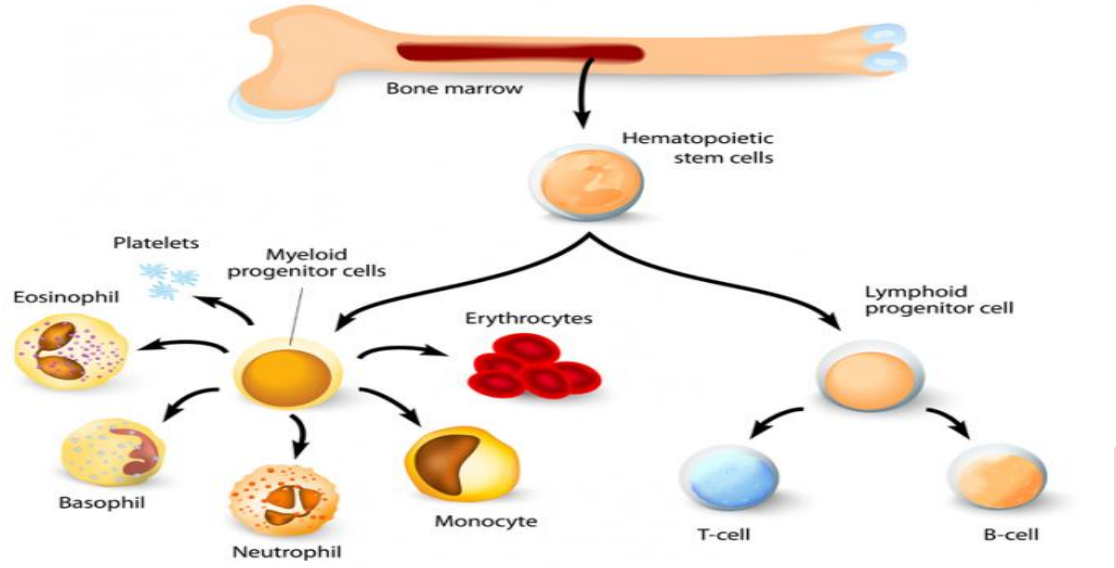
Function of bone marrow:

- The formation of blood cells, (hematopoiesis), takes place mainly in the red marrow of the bones.
- Together with the liver and spleen, red bone marrow also plays a role in getting rid of old red blood cells. (reticuloendothelial system)

Bone marrow stem cells

- The bone marrow contains **two types of stem cells,** mesenchymal and hematopoietic.
- **Red bone marrow containing** hematopoietic stem cells. These are blood-forming stem cells.
- **Yellow bone marrow contains** mesenchymal stem cells, also known as marrow stromal cells. These produce fat, cartilage, and bone.[4]
- **Hematopoietic stem cells** in the bone marrow give rise to two main type of cells: myeloid and lymphoid lineages.

- **The myeloid lineage** give rise to multiple cells so it is called **Pluripotent hematopoietic stem cells**. It differentiate into monocytes, macrophages, neutrophils, basophils, eosinophils, erythrocytes, dendritic cells, and megakaryocytes or platelets.
- **The lymphoid lineage** give rise to T cells , B cells, and natural killer cells.
- The process of development of different blood cells from these pluripotent stem cells is known as **hematopoiesis**.
- Once mature, these blood cells move from the marrow into the bloodstream, where they perform important functions required to keep the body alive and healthy.
- Blood cells have a limited life span. This is around 100-120 days for red blood cells. They are constantly being replaced. The production of healthy stem cells is vital.



Increased Bone marrow activity :

- In response to hypoxia the erythropoietin hormone is released from the kidney 90% and liver 10% causing stimulation of stem cell for more RBCS formation
- Increased white blood cells formation in response to infection (leukocytosis)
- Release of more platelets in response to bleeding
- Increased demand after blood loss may activate yellow bone marrow to help red bone marrow

Bone marrow transplantation:

- Hematopoietic stem cell transplantation involves the intravenous infusion of stem cells collected from bone marrow, peripheral blood, or **umbilical cord blood.**
- This is used in patients whose bone marrow or immune system is damaged or defective**.**
- Source of bone marrow transplantation :patients receive their own stem cells taken from their peripheral(Autologous transplant) , from their identical twin, parent or an unrelated donor, Stem cells are removed from a newborn baby's umbilical cord right after birth. The stem cells are frozen and stored until they are needed for a transplant. Umbilical cord blood cells are very immature so there is less of a need for matching

Cancer of bone marrow:

Leukemia, Hodgkin's disease, and other lymphoma cancers are known to damage the marrow's productive ability and destroy stem cells.

Bone marrow test :

- Bone marrow tests can help diagnose certain diseases, especially those related to blood and blood-forming organs. Testing provides information on iron stores and blood production.

Bone marrow donation:

- The first involves the removal of bone marrow from the back of the pelvic bone.
- The second, more common method, is called peripheral blood stem cell (PBSC) donation.

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