Physics of Skeleton

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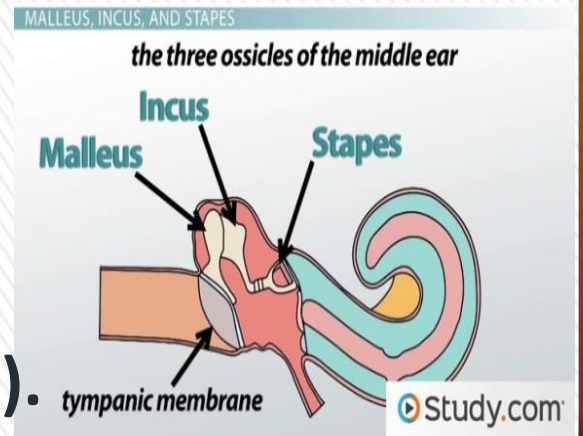
Physics of the Skeleton

- Most of the skeleton is made of bones held together by ligaments.
- The bone is a living tissue and has blood supply as well as nerves.
- The bone is mostly made of hard bone tissue, tough cover, blood vessels and marrow.
- The cells that maintain the bone in a healthy condition which called "osteocytes", make up about 2% of the volume of the bone.

Functions of the bones

» Bones has six functions in the body :

1. Support :- bones and muscles of the legs support the body.
2. Locomotion :- bone joints permit movement of one bone with respect to another.
3. Protection :- The skull protect the brain, eyes and ears. The ribs protect heart and lungs .
4. Storage of chemicals:- Ca storage in the bone which is released when it needed.
5. Nourishment:- Teeth .
6. Sound transmission :- Ossicles in the middle ear(the smallest bone in the body).



Bone Remodeling

- Bone Remodeling is: a continuous process of destroying old bone and building new bone.
- There are two types of cells in bone remodeling :
- 1. Osteoblast : cells specialized in bone building.
- 2.Osteoclast: cells specialized in bone destroying.
- Each day the osteoclast destroy bone containing about 0.5 gm. of Ca ,and Osteoblast builds a new bone using nearly the same amount of Ca.

Bone Remodeling

- While the body is young and growing the osteoblast do more than the osteoclast , But after the body is 35- 40 years old the activity of the osteoclast is greater than that of the osteoblast , resulting in a gradual decrees in bone mass that continuous until death.

- this decrees is apparently faster in women than in men and leads to a series problem of weak bone in older women .this is called Osteoporosis (Porous bones), result in spontaneous fracture, especially in the spine and hips.

What is Bone Made Of ?

- Bone consist of two different materials plus water :
- 1. Collagen :- the major organic fraction is about 40% of the weight of solid bone and 60% of its volume .
- 2. Bone Mineral :- Inorganic material , which is about 60% of the weight and 40% of volume of solid bone.
- When the bone mineral removed from the bone the reminder is collagen, the remaining collagen is quite flexible like rubber and can be bent into loops.
- When the collagen is removed from the bone , the remaining bone is very fragile and can be crushed with the fingers.

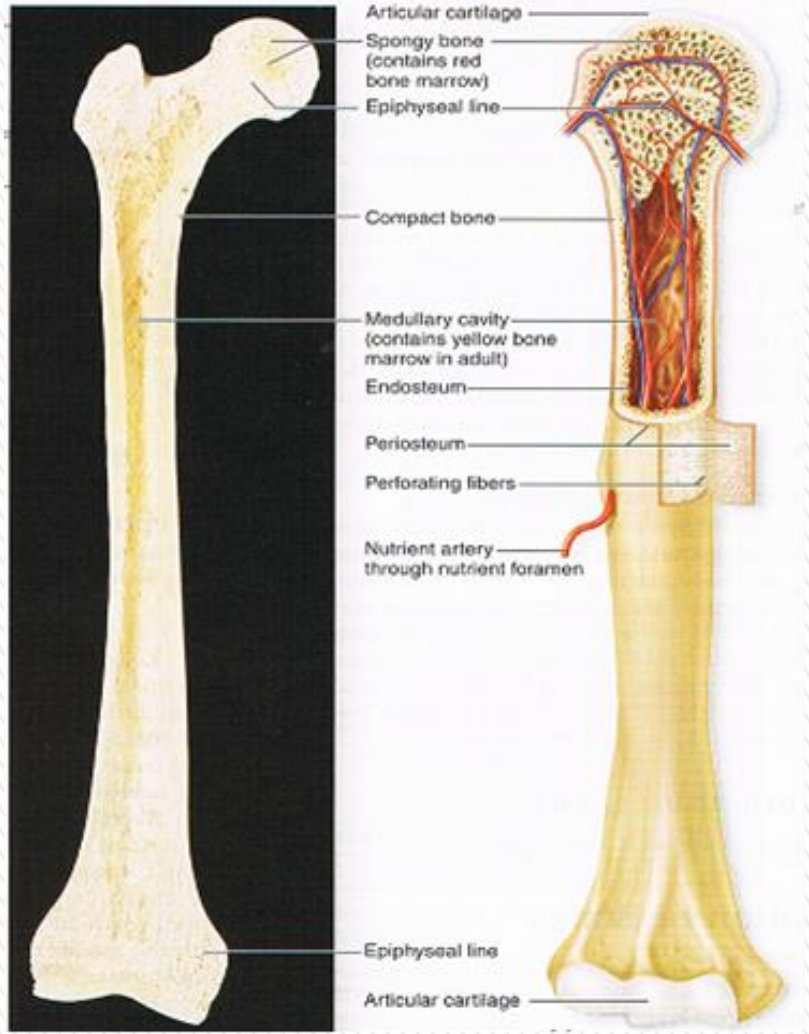
What is Bone Made Of ?

- Collagen is apparently produced by the Osteoblast cells.
- mineral is then formed on the collagen to produce bone.
- Bone collagen is not the same as the collagen found in many other parts of the body such as the skin.
- Bone mineral is believed to be made up of
  - calcium hydroxyapatite $Ca_{10}(PO_4)_6(OH)_2$.

How Strong are your body?

- If one cut some of the bones apart , he can find it composed of one or a combination of two quite different types of bone.

1. Solid or (Compact bone).
2. Spongy or cancellous bone(Trabecular bone).



What are the advantages of Trabecular bone over Compact bone?

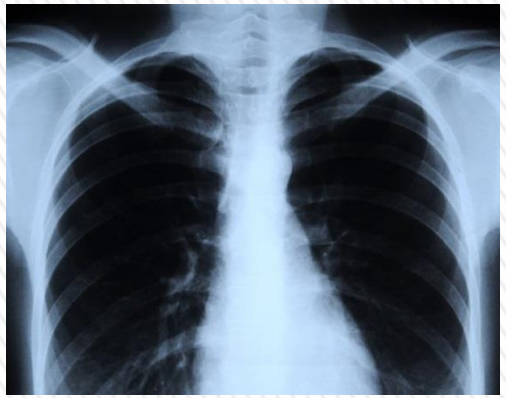
- The trabecular bone gives bone the strength necessary with less materials than compact bone.
- The trabecular are relatively flexible and bone can absorb more energy when large forces are involved such as in walking, running and jumping.

- **Note**: - The density of the bone is about 1.9 gm/cm^2 which stays constant through life.

Compositions of compact bone

Elements:	H	C	N	O	Mg	P	S	Ca	others
% Comp.:	3.4	15.5	4	44	0.2	10.2	0.3	22.2	0.2

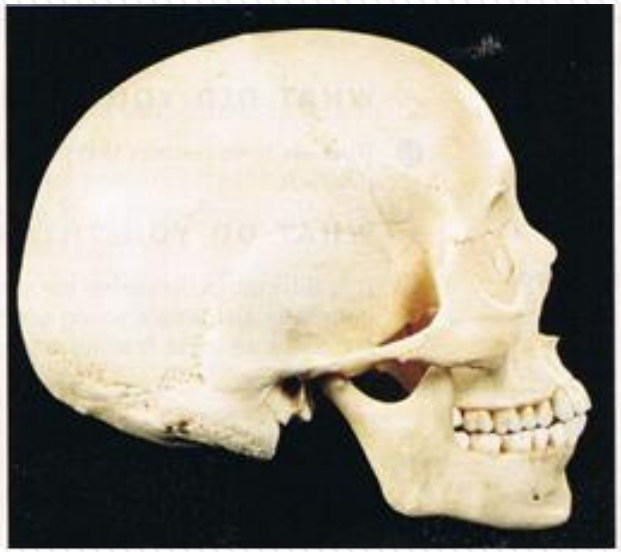
Note: **Because of the large percentage of calcium (Ca) in the bones and because calcium has a much heavier nucleus than most elements of the body, the bones absorbs X-Ray much better than the surrounding soft tissue and this the reason that X-Ray show bones so well.**



Kinds of Bones?

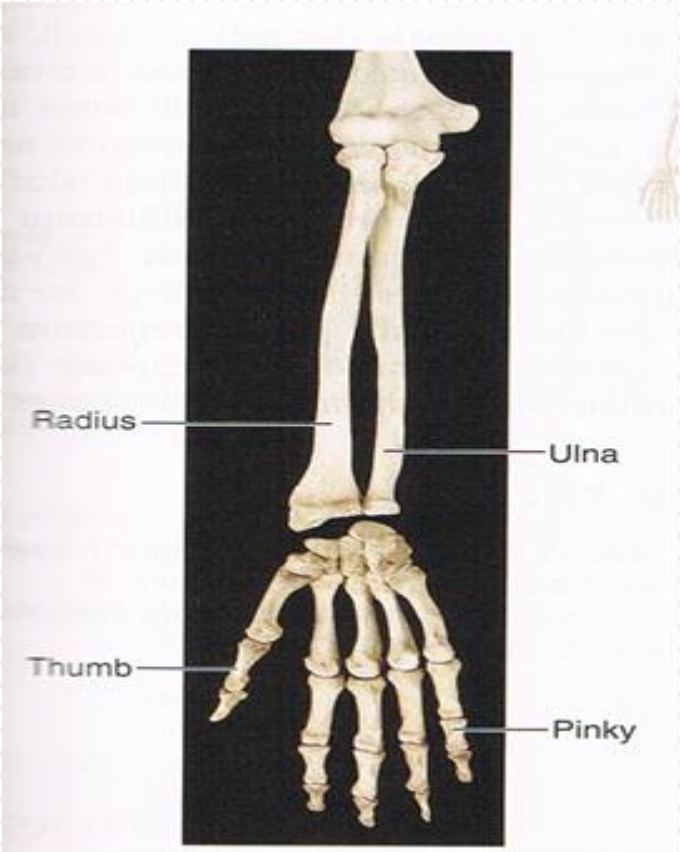
- There are about 200 bones in the body .
- The bones are shaped and constructed into five piles according to their functions to withstand forces exert on it.

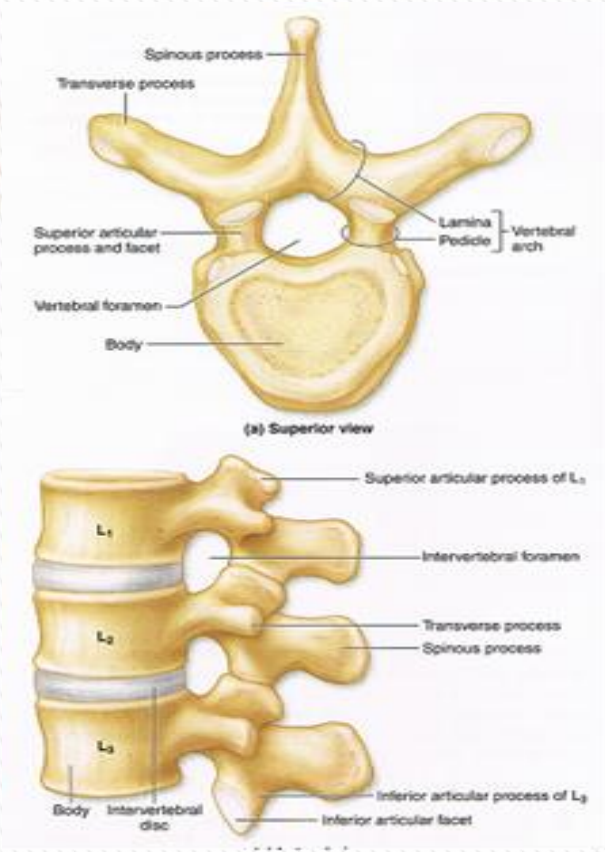
1. Plate like bones:- The shoulder blade (scapula) and some bones of the skull.



Kinds of Bones?

- 2. Long hollow bones :- Bones of the arms , Legs and fingers.
- 3.Cylindrical bones :- Bones forms the spine (vertebrae).

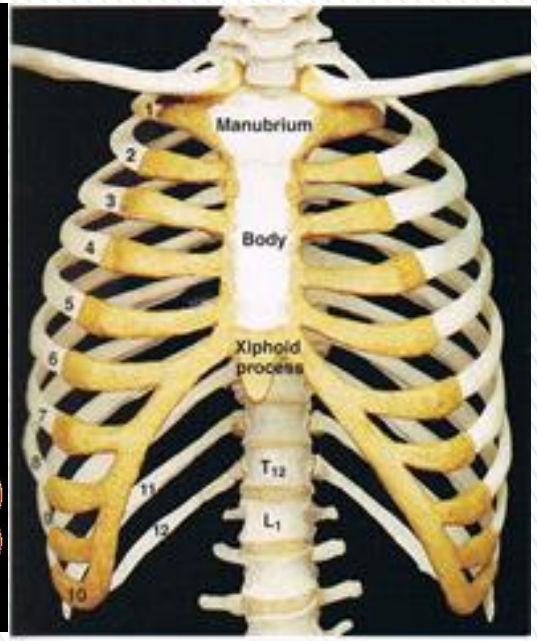




Kinds of Bones

» 4. Irregular bones :- The wrist and ankle bones.

» 5. Ribs :- Which do not belong in any of the other piles.



Strength of Bones

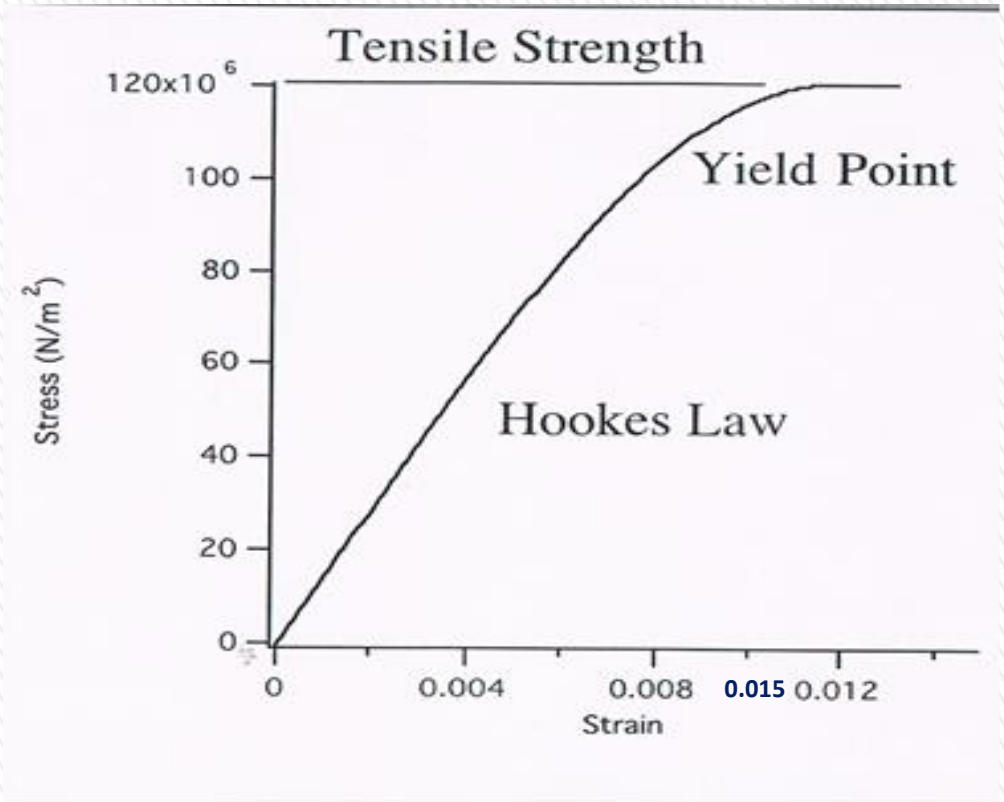
- All materials change in length when placed under tension or compression.

- If a bone is placed under tension or compression , it's length (L) is changed and the strain (ΔL / L) increases linearly at first indicating that it is proportional to the stress (F/A) ….Hook's law, where (F) is the applied forces and(A) is the cross sectional area of the bone.

Strength of Bones

» As the force increase the length increase rapidly and the compact bone breaks at the tensile stress of about 120 $\times 10^6$ N/m^2.

Strain= $\frac{\Delta L}{L} = 0.015$ at fracture



» Note:- Healthy compact bone is able to withstand a compression stress of about 170 × 10^6 N/m^2 before it fractures.

Strength of Bones

- Y= $\frac{F/A}{\Delta L/L} = \frac{Stress}{Strain}$
- → $Y = \frac{L\,F}{A\,\Delta L}$
- Y : young modulus
- Not: (Y) for bones = 1.8×10^{10} N/m^2
- To calculate the change in length (L) for a given force (F) , the above equation can be written as :
- $\Delta L = \frac{LF}{AY}$

Strength of Bones

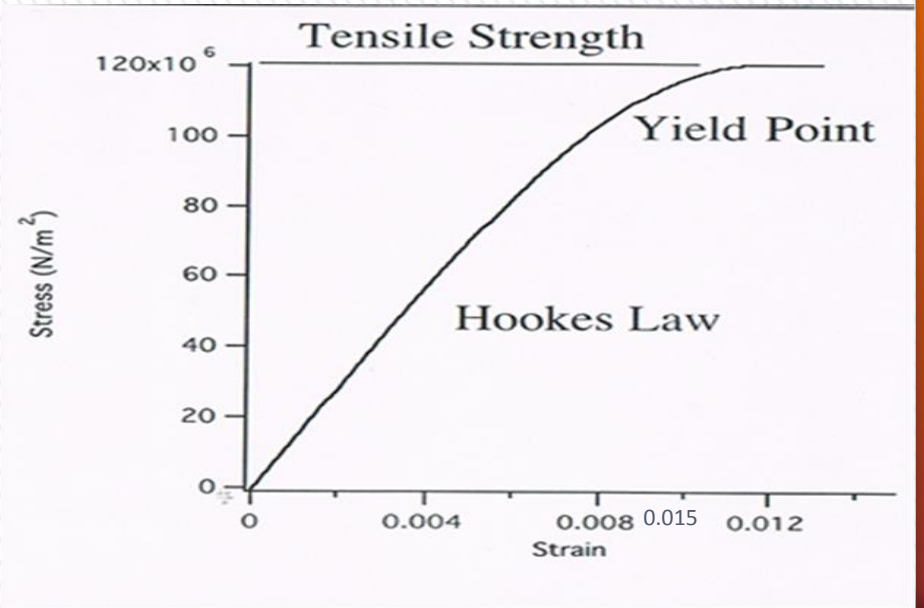
» **Example 1:-** : Using the information in the Figure.

» 1- Calculate the maximum tension (F_{max}) for a bone with a cross-sectional area of ($4cm^2$) could withstand just prior to fracture ?

Solu: $Stress = F/A \longrightarrow F = Stress \times A$

$F_{max.}$ when stress≈ 120×10^6 N/m^2

» $F_{max} = 4cm^2 \times 10^{-4} \frac{m^2}{cm^2} \times 120 \times 10^6 \frac{N}{m^2} = 48000N\ (\approx 5\ tons)$



Strength of Bones

- 2-Determine how much a bone (35cm) long would elongate under this maximum tension?

  Solu: Strain= $\Delta L/L$ =0.015 at fracture.

  ΔL = L × 0.015 = 35 × 0.015 = 0.52cm = 5.2 mm

- 3-Caculate the stress on this bone if a tension force of (10^4 N) were applied to it. How much this bone lengthen?

  Solu.:

$$\text{Stress} = \frac{F}{A} = \frac{10^4}{4\times10^{-4}} = 0.25\times 10^8\ N/m^2$$

$$= 25 \times 106\ N/m^2$$

$$\Delta L = \frac{L\times F}{A\times Y} = \frac{(35\times10^{-2})\times104}{4\times10^{-4}\times1.8\times1010} = 4.8\times10^{-4} m$$

ΔL = 0.48 mm

Strength of Bones

» **Example 2:-**

Assume a leg has a 0.6m shaft of bone with an average cross sectional area of 1.5 cm^2, What is the amount of shortening when all of the body weight of 350N is supported on the leg ?

» **Solu:**

$$\Delta L = \frac{L \times F}{A \times Y} = \frac{(0.6\,m) \times (3.5 \times 102N)}{1.5 \times 10^{4} m^2 \times 1.8 \times 1010 N/m^2} = 0.77 \times 10^{-4} m$$

ΔL= 0.077 mm

Fracture Types

Oblique: a fracture which goes at an angle to the bone's axis.
Comminuted: a fracture of bone into many relatively small fragments.
Spiral: a complete fracture which runs around the axis of the bone occurs due to twisting or rotational force.
Compound: a fracture (also called open) which pierces the skin.
Greenstick: an incomplete fracture in which the bone bends.
Transverse: a fracture that goes across the bon's axis.
Simple: a fracture which does not pierce the skin.

Compound (open) fracture

Fracture Types

Oblique fracture

Comminuted fracture

Spiral fracture

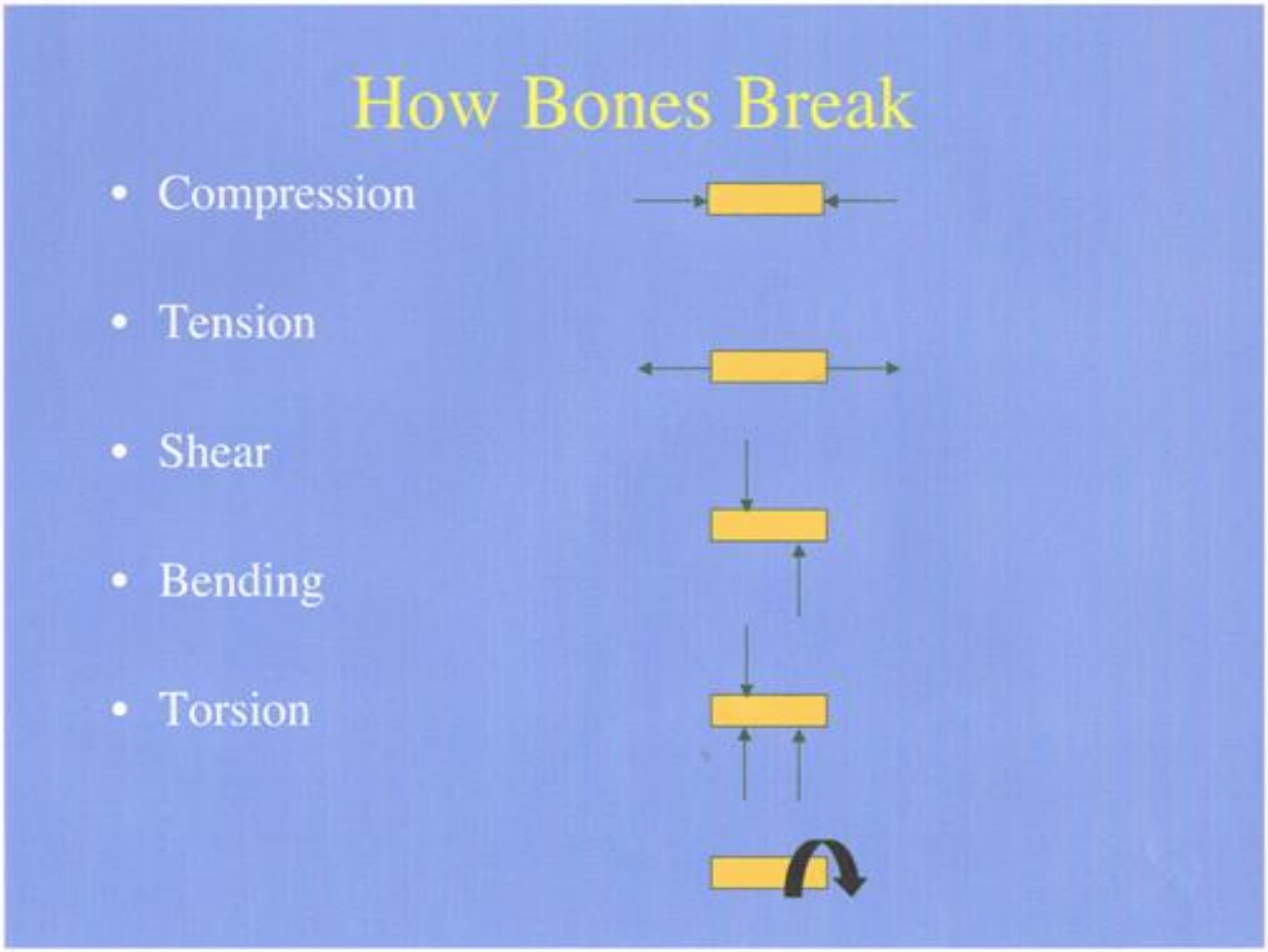
Compound fracture

Greenstick fracture

Transverse fracture

Simple fracture

How Bones Break?



How Bones Break?

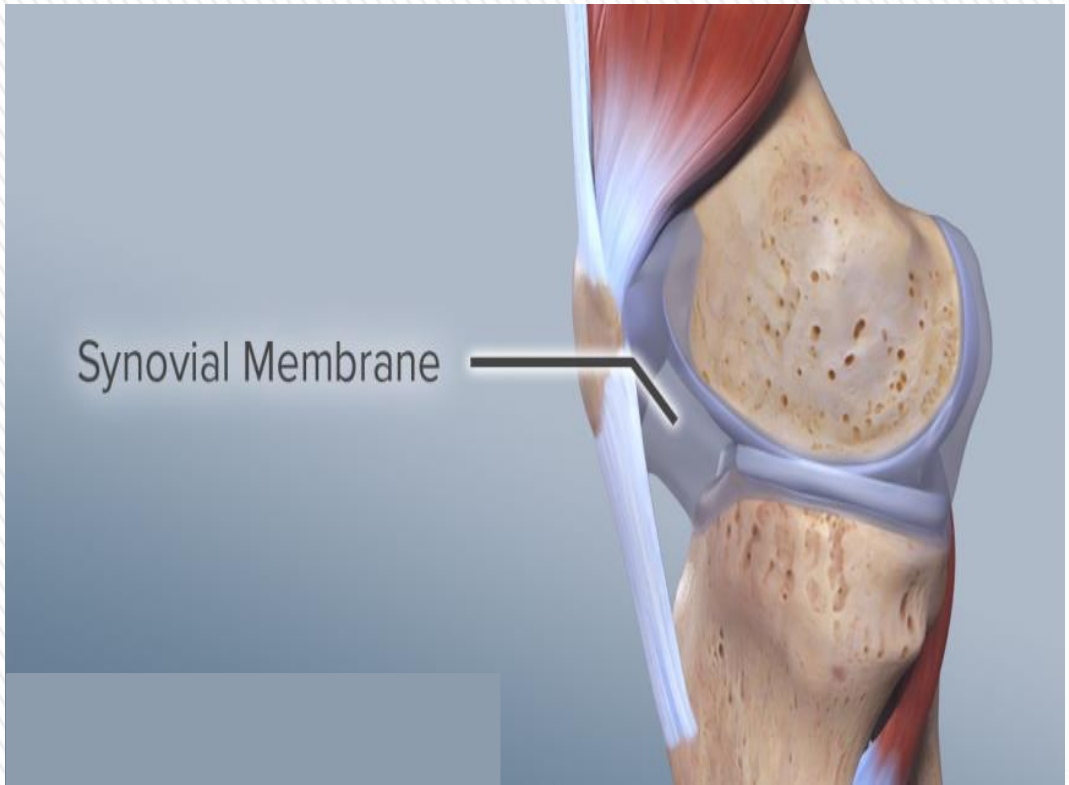
- The bones do not normally break due to compression, they usually break due to shear. A common cause of shear is catching the foot and then twisting the leg while falling.
- A shear fracture often results in a spiral break in which the bone is apt to puncture the skin.
- Compound type of fracture is more apt to become infected than a fracture in which the bone is not exposed (Simple).

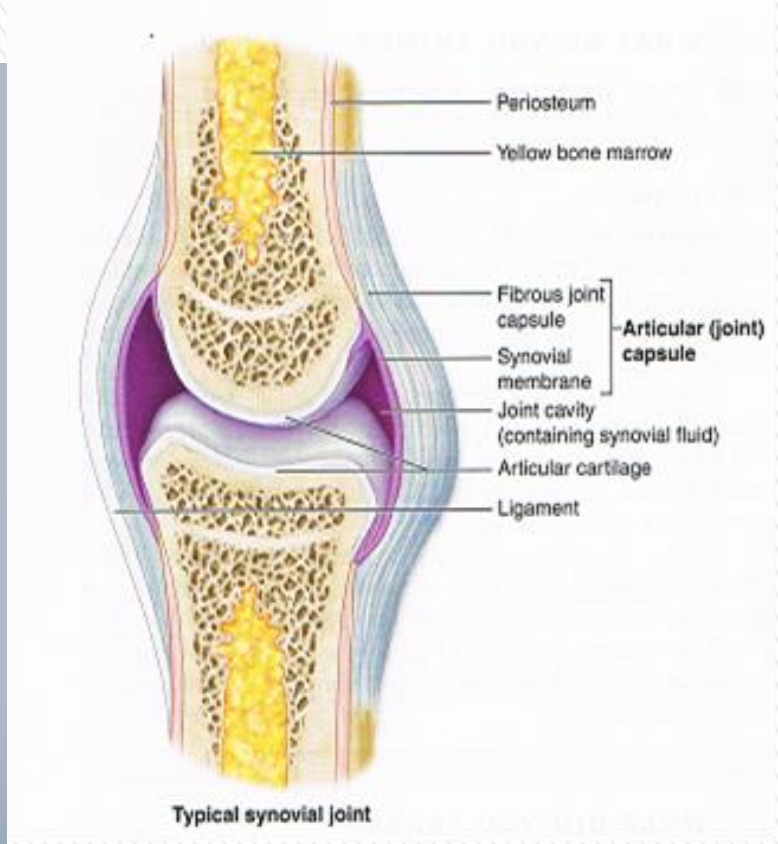
How Bones Break?

- The property of bone to withstand a large force for a short period of time without breaking, while some force over a long period may fracture it, called Viscoelasticity.
- There is a good evidence that local electrical fields may play a role.
- When bone is bent it generates an electrical charge on its surface. It has been suggested that this phenomenon (Piezoelectricity) may be the physical stimulus for bone growth and repair.

Bone Joints

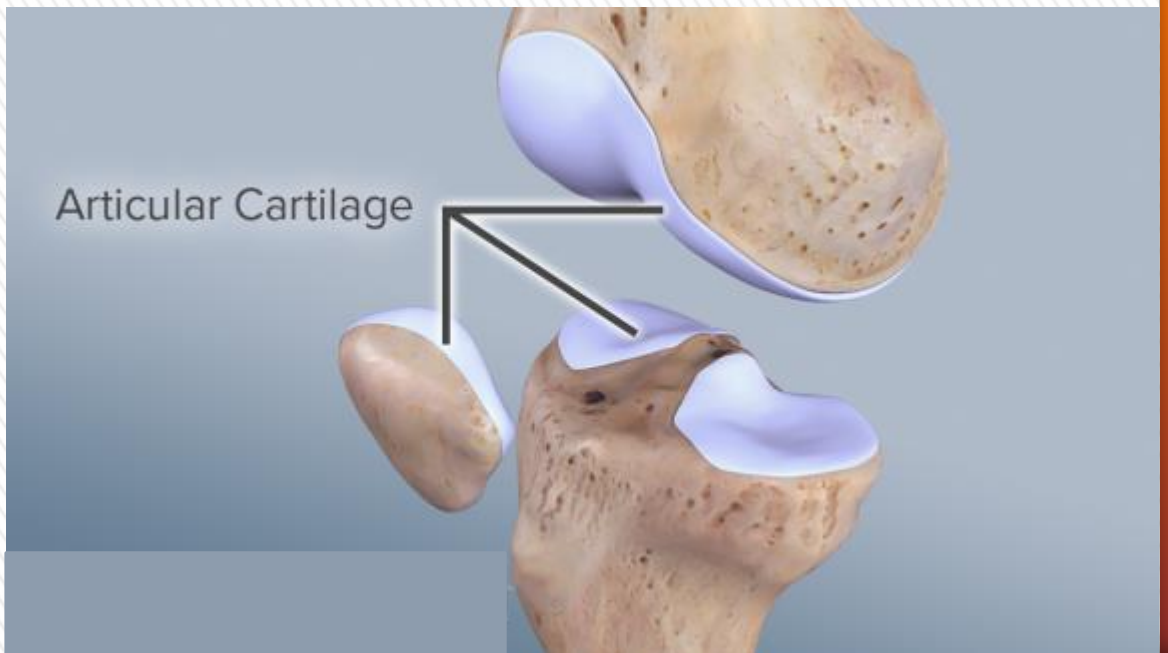
- The main components of joint are :
- 1.Synovial membranes: encases the joint and retain the lubricating synovial fluid.
- 2. Articular cartilage : a smooth rubbery material that is attached to the solid bone.





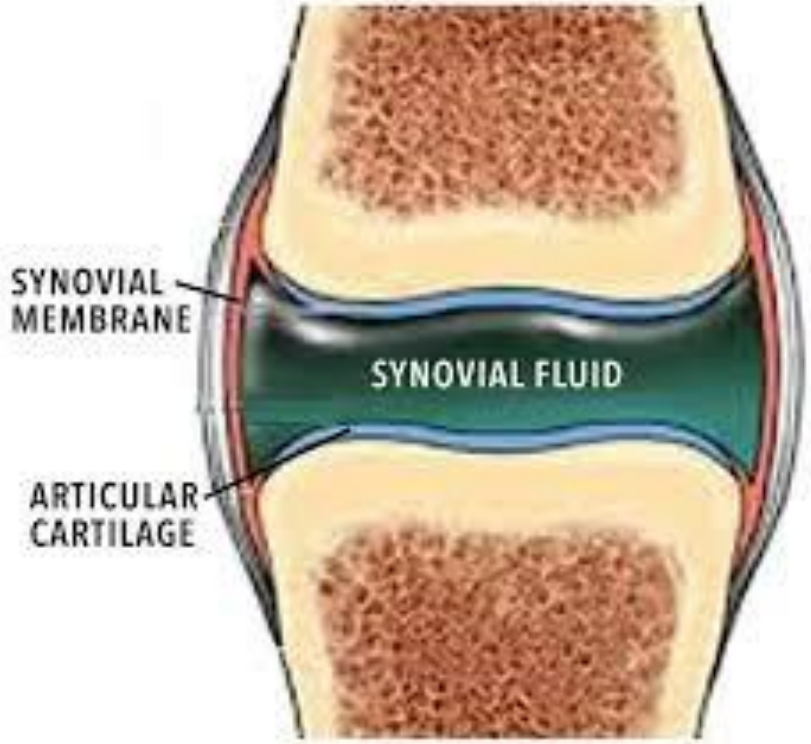
Bone Joints

- The fat in the cartilage helps to reduce the coefficient of friction (that is less than 0.01 for healthy joints).
- A coefficient of friction of 0.01 means that if there is a 100lb force on a joint, only 1lb of force is needed to move it.



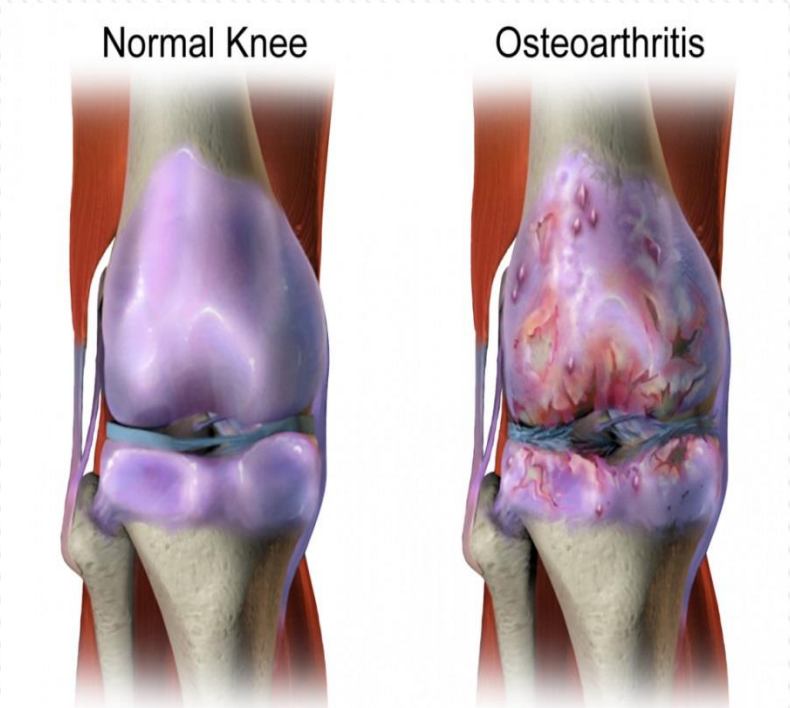
Bone Joints

- The lubrication properties of a fluid depend on its viscosity.
- Thin oil is less viscous and better lubricant than thick oil.
- The viscosity of synovial fluid decrease under the large shear stresses found in the joint.
- ….When the synovial fluid was removed ,the coefficient of friction increased considerably.



Joints Diseases

- There are two major diseases may effect the joints : -
- 1.Rheumatoid Arthritis ,Which results in over production of synovial fluid in the joint and causes swollen joint.
- 2. Osteoarthritis , a disease of the joint itself .



Thank you