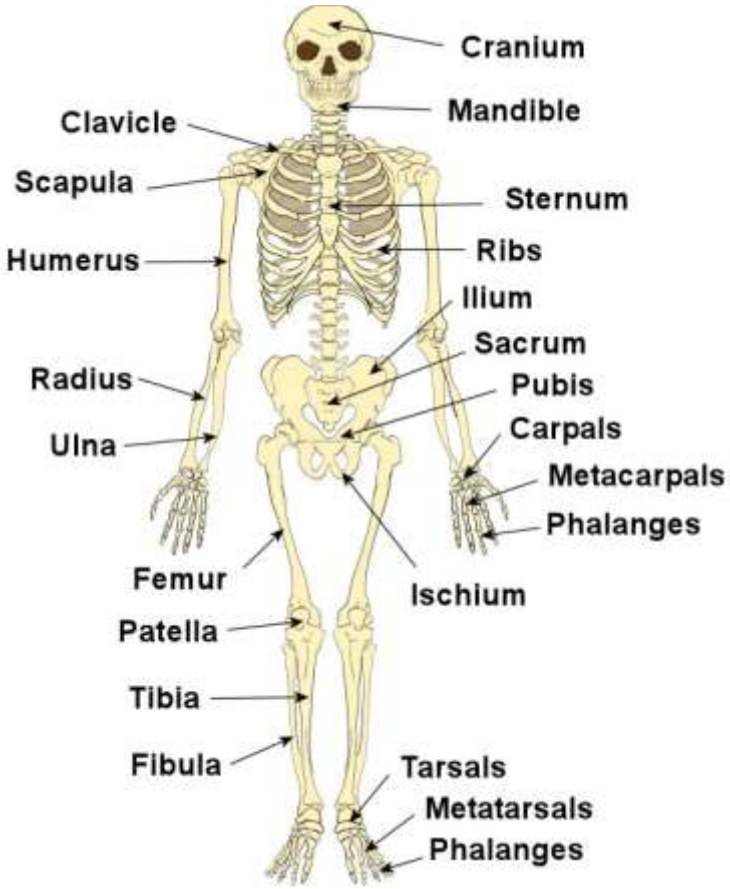
Physics of the skeleton



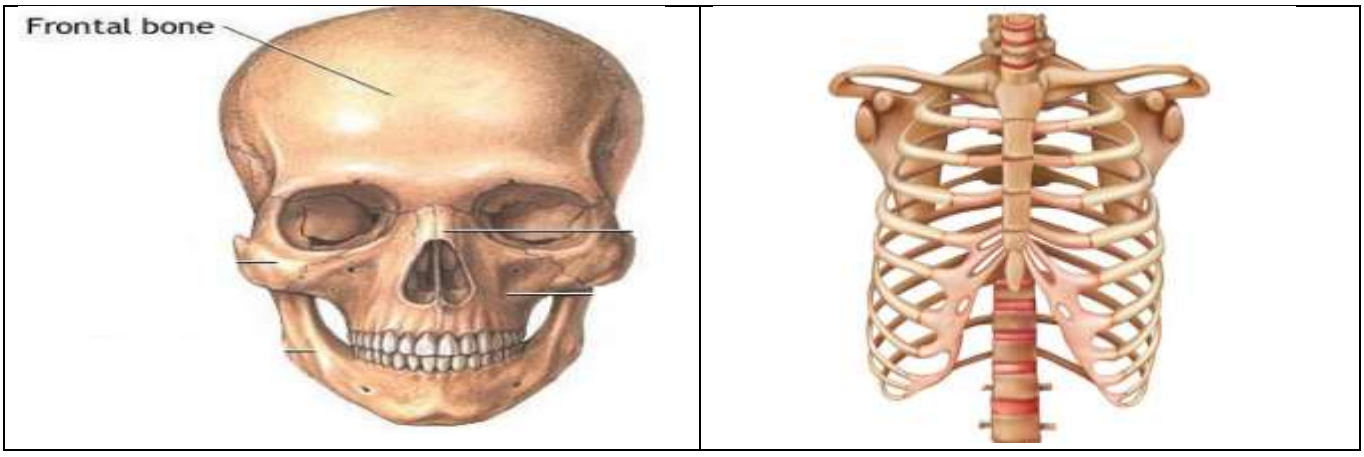
Bone: is the substance that forms the skeleton of the body. It is composed chiefly of calcium phosphate and calcium carbonate. Bones provide the structure for our bodies. These include the bones of the skull, spine (vertebrae), ribs, arms and legs. Bones are made of connective tissue reinforced with calcium and specialized bone cells.

Function of bones:

1. *Supporting*: The system of bones and muscles support the body weight. The muscles are attached to the bones through tendons and ligaments.

2. Locomotion: Bone joints which permit the movement of one bone with respect to another.

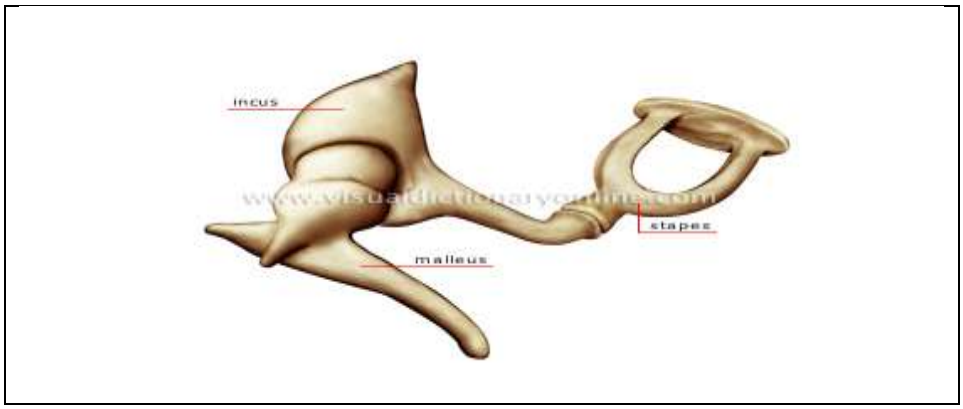
3. Protection of various organs: protection of delicate body parts is an important function of some of the bones. The skull, which protects the brain and several of the most important sensory organs (ears and eye) is extremely strong container while the ribs form a protective cage for the heart and lungs.



4. storage: bones store chemicals like Ca is stored in bones which are released when it is needed.

5. Nourishment deciduous: The teeth are specialized bones serve in providing nourishment for the body. eg. Incisors, canines.

6. Hearing: The three smallest bones in the body are the Ossicles**.** They act as **levers** which provide an **impedance matching.** -They form a system form converting sound vibration in the air into sound vibration in the fluid of the cochlea.



7- Red blood cells generation: The stem cells in the bone marrow generate the RBCs.

Composition of bone

The bone is a living tissue and has a blood supply has as well as nerves, the cells that maintain the bone in a healthy condition; The make up about 2% of the volume of bone which called **"Osteocytes".**
It is sometimes thought that the bone are dead or inert part of the body and that once it has reached adult size it remains the same until death. Most of the bone tissue is inert, but distributed through it is the osteocytes.

Poor blood supply ⇒ osteocytes die ⇒ bone dies ⇒ loss of its Strength

Bone consists of two different materials plus water these materials are:

Bone = collagen + bone mineral + water

a- Collagen: about 40% of the weight of the solid bone & 60% of the volume.

b- Bone minerals (inorganic component): 60% of the weight of the solid bone & 40% of the volume. The bone minerals (mainly calcium hydroxyapatite [Ca10(PO4)6(OH)2]) can be removed by chemical reactions.

c- Water ⇒ stores nutrients

As described above bone is composed of small hard bone mineral crystals attached to a soft flexible collagen matrix. These components have vastly different mechanical properties. This combination provides a material that is strong as granite in compression and 25 times stronger than granite under tension.

- **The normal range for blood calcium level is 8.6 to 10.3 mg/dL.**

Bone remodeling:

A continuous process of destroying old bone and building new bone by specialized bone cells during human life period.

or

Since bone is a living tissue it under goes change throughout life. A continuous process of destroying old bone & building a new bone is called. **"bone remodeling"**

There are two types of cells in bone remodeling:

1. Osteoblast: **which build up bone using about 0.5 g of calcium each day.**

2. Osteoclast: **which destroy the bone containing about 0.5 g of calcium each day.**

Bone remodeling depends on:

1. Age
2. Gender

- When the body is young & growing, the osteoblasts do more than the osteoclasts. After the body is (35) to (40) year old, the activity of the osteoclasts resulting in a gradual decrease in bone mass that continues until death.
- This decrease is apparently faster in women than in men lead to a serious problem of
weak bone in older women.
- This condition called osteoporosis.

It is one of the bone diseases which is produced by the reduction of the amount of Ca as a result:

- The volume decreases
- The mass of the bone decrease
- The density of the bone = mass /volume= 1.9 kg/cm3 it remains constant.

Types of Bones

If we cut the bones apart, we can find it's composed of one or a combination of different types of bones:

1. Spongy or cancellous bone made up of thin thread like trabecular bone

2. Solid or compact bone

Examples: in long bones, the long shaft (central shift), is a compact bone, while the ends are spongy (trabecular bone). (trabecular bone is considerably weaker than compact bone due to the reduced amount of bone in a given volume).

1. Spongy or cancellous bone made up of thin thread like trabecular bone

a. It made up of thin thread.

b. It predominately found in the ends of the long bones.

c. It is considerably weak due to the reduced amount of bone in a given volume.

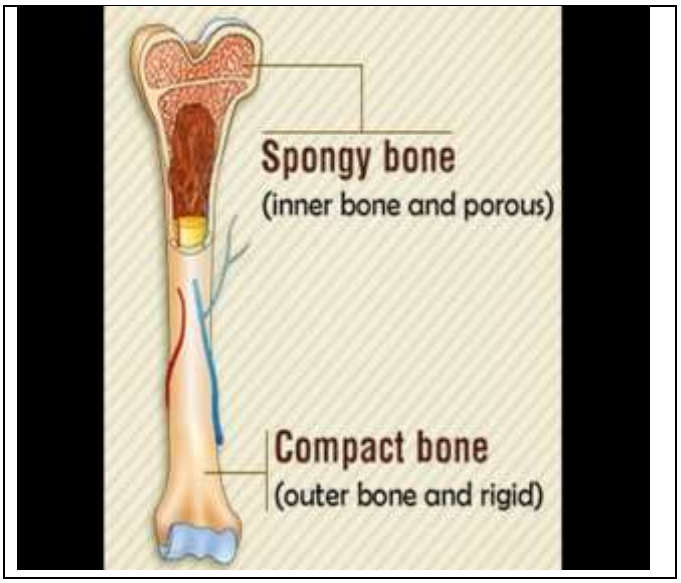
2. Solid or compact bone

a. It made up of thick plates.

b. It predominately found in the central shaft of the bone.

c. It is considerably strong due to the large amount of bone in a given volume.

Note: Bone tissue is the same in the Trabecular and compact bone



Picture show the compact and spongy Bones.

Stress-strain curve

All materials change in length when placed under tension or compression. When a sample of fresh bone is placed in a special instrument for measuring the elongation under tension a curve similar to that in below Fig. is obtained.

Hooke's law

The strain ΔL/L increases linearly at first, indicating that it is proportional to the stress (F/A), As the force increases the length increases more rapidly, and the bone breaks at stress of about 120 N/mm2.

The ratio of stress to strain in the initial linear portion is Young's modulus Y

$$Y = \frac{L\ F}{A\ \Delta L} \quad \ldots\ldots\ldots 1$$

$$\Delta L = \frac{L\ F}{A\ Y} \quad \ldots\ldots\ldots 2$$

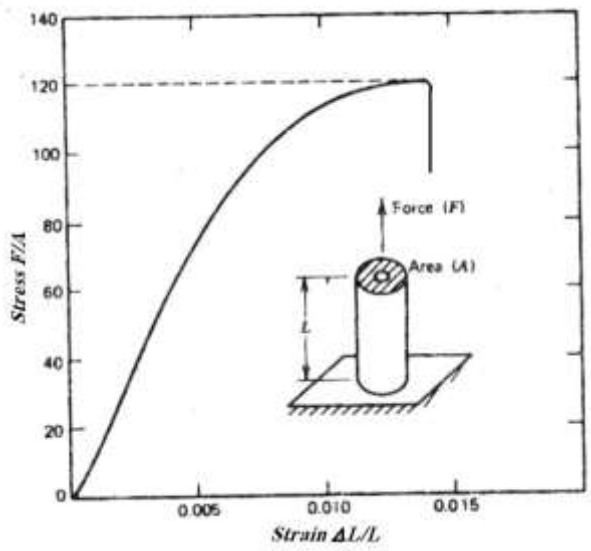
Where

L= the length of the bone (mm)

F= the force exerting on the bone (N)

A= the cross-section area of the bone (mm2)

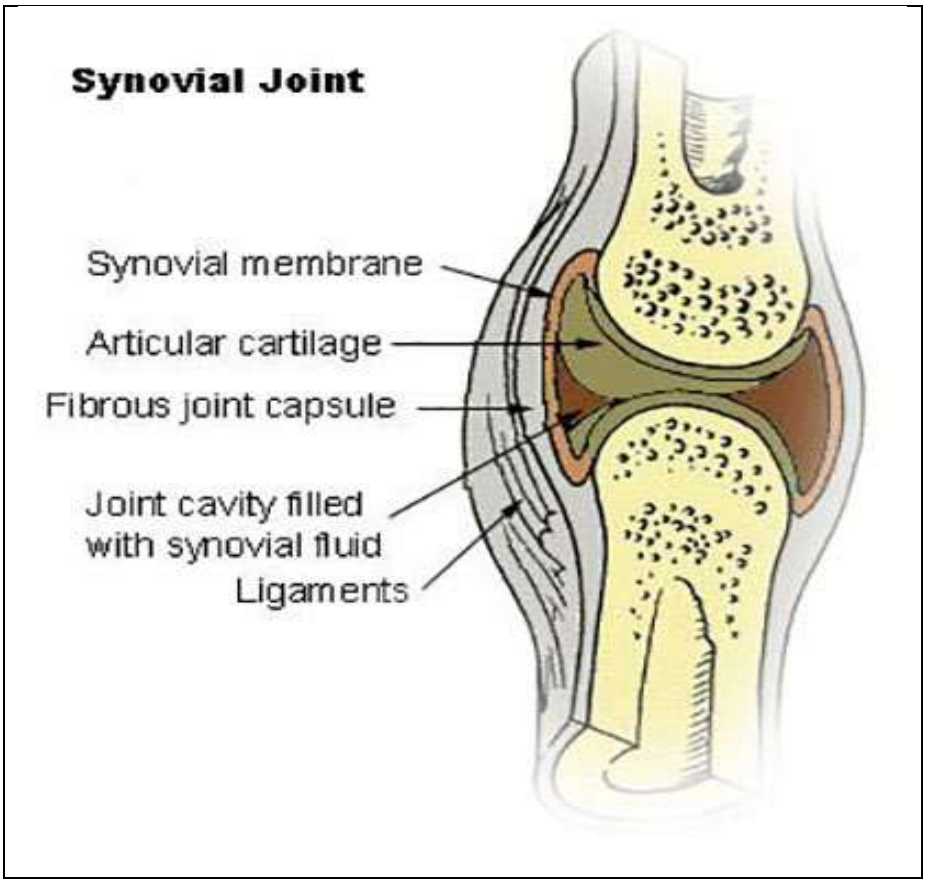
The compressive breaking stress of the compact bone is 170 (N/mm2), while **the tensile** breaking stress is 120 (N/mm2), Young's modulus of the compact is about 179 x 102 (N/mm2).



Bone joints

Joints: are places in the body where two bones or more come together. Each bone ended with synovial fluid. The joint made most of the body movement possible.

In this type of joint, the ends of the opposing bones are covered with hyaline cartilage, the articular cartilage, and they are separated by a space called the joint cavity. The components of the joints are enclosed in a dense fibrous joint capsule, also called an articular capsule. The outer layer of the capsule consists of the ligaments that hold the bones together. The inner layer is the synovial membrane that secretes synovial fluid into the joint cavity for lubrication. Because all these joints have a synovial membrane, they are sometimes called synovial joints.



Joints Diseases:

There are two major diseases affect the joints:

a. joints-rheumatoid arthritis: which results in overproduction of synovial fluid in the joint and commonly causes swollen joints

b. osteoarthrosis: a disease of the joint itself.

Bone Joints Lubrication Mechanism:

• Each bone ended with porous and not very smooth cartilage lubricated with the Synovial fluid.
• The roughness of the cartilage plays useful role in joint lubrication trapping some of the synovial fluid and because of its porous nature, other lubricating material is squeezed into the joints.
• Pressure causes lubricating threads to squeeze out of the cartilage into the joints, one end of each lubricating thread remains in the cartilage, and as the pressure is reduced the threads pull back into their holes
• Under a large sheer stress, the viscosity of the synovial fluid reduces.
• The coefficient of friction of the healthy joints was found to be 0.01 i.e: when 100 N of force exert on a joint, only 1N of force is needed to move it, it is the least friction in the nature.