Anesthesia Techniques Department
First stage /medical physics
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physics Of Skeleton

The skeletal system is one of the important systems in the human body. At birth, the human body consists of about 300 bones. Babies have more cartilage than bone tissue. As they grow up, some of the bones fuse together to form a single bone. As a result, the adult human skeleton consists of 206 bones.

The size and shape of a bone varies according to its location in the body. Bones sort into various piles according to their shapes, so there are five piles as shown in figure below:

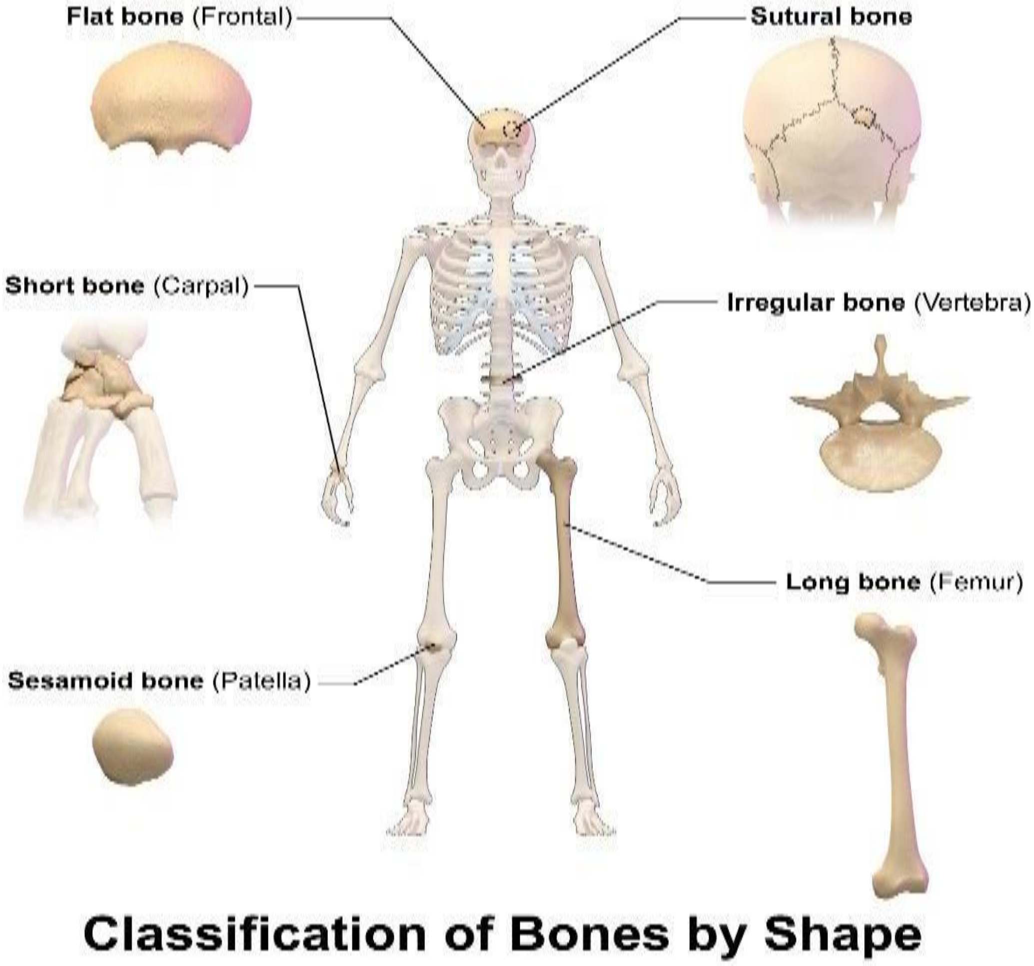
1-*Flat bones*: flat bones are thin, flattened, and usually curved, as in shoulder blade, some bones of the skull

2- *Long Bones:* bones in the arms, legs.

3- *Short Bones*: Short bones include the bones of the wrist and ankle.

4-*Irregular bones:* bones from the wrist, ankle and skull.

5- *Other bones*: ribs, etc.



Functions of the bone

Bone has at least six functions in the body:

1- Support
2- Locomotion
3- Protection of various organs
4- Storage of chemicals
5- Nourishment
6- -Sound transmission (in the middle ear)

1- Support:

The support function of bone is most obvious in the legs. The body's muscles are attached to the bones through tendons and ligaments and the system of bones plus muscles supports the body.

2- Locomotion:

Bone joints permit movement of one bone with respect to another. But the destruction of joints by arthritis can limit locomotion.

3- protection of various organs:

For protection, the skull, which protects the brain and several of the most important sensory organs like eyes and ears. Also, ribs form a protective cage for the heart and lungs.

4-storage of chemicals:

The bones act a chemical " bank " for storing elements for future use by the body. The body can withdraw these chemical as needed. For example, a minimum level of calcium sensor causes the parathyroid glands to release more parathormone into the blood, and this in turn causes the bones to release the needed calcium (Ca).

5- nourishment:

For nourishment the teeth are specialized bones that can cut food, tear it and grind it and thus serve in providing nourishment for the body.

6- sound transmission (in the middle ear):

For sound transmission the smallest bones of the body are the ossicles in the middle ear. These three small bones use for converting sound vibrations in air to sound vibrations in the fluid in the cochlea.

Composition of Bone:

Note the large percentage of calcium (Ca) in bone, since calcium has a much heavier nucleus than most elements of the body, it absorbs x- rays much better than the surrounding soft tissue. This is the reason x- ray show bones so well. Bone consists of two quite different materials plus water : collagen , the major organic fraction , which is about 40 % of the weight of solid bone and 60 % of its volume , and bone mineral , the so-called " inorganic " component of bone, which is about 60 % of the weight of the bone and 40 % of its volume. Collagen is apparently produced by the osteoblastic cells. Because of the small size of the crystals, bone mineral has avery large surface area. Bone mineral is believed to be made up of calcium hydroxyapatite $Ca_{10}(po_4)_6(OH)_2$.

Bone = collagen + bone mineral + water

Either of these components may be removed from bone, and in each case the remainder, composed of only collagen or bone mineral, The collagen remainder is quite flexible, some what a chunk of rubber, it bends easily if it is compressed. When the collagen is removed from the bone, the bone mineral remainder is very fragile and can be crushed with fingers.

So the composition of Bone:

Collagen, Mineral $Ca_{10}(PO_4)_6(OH)_2$, Water

• Collagen makes bones flexible (elastic)

• Mineral makes bones rigid

How strong are your bones?

Two quite different types of bone. solid or compact and spongy, Bone made up of thin thread –like trabecular, trabecular bone is found in the ends of the long bones, while most of compact Bone Is in The Central Shaft. Trabecular Is Weaker Than Compact bone due to the reduced amount of bone in a given volume. so, what are the advantages of trabecular bone over compact bone? There are at least two, where a bone is subjected primarily to compressive forces, such as at the ends of the bones, trabecular bone gives the strength necessary with less material than compact bone, also because the trabecular are relatively flexible, trabecular bone can absorb more energy when large forces are involved such as in walking, running and jumping, on other hand, trabecular bone cannot withstand very well the bending stresses that occur mostly in the central portions of long bones.

All materials change in length when placed under tension or compression. When a sample of fresh bone placed in a special instrument for measuring the elongation under tension, a curve similar to that in scheme [1] is obtained.

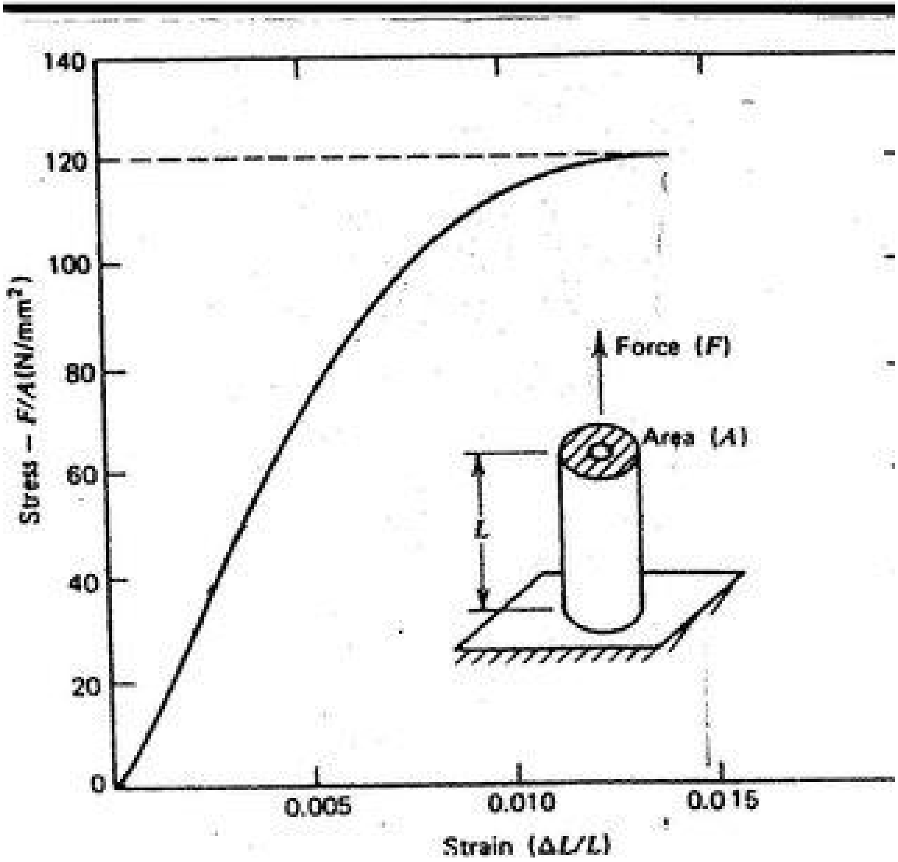
The strain $\Delta L/L$ increases linearly at first, indicating that is proportional to the stress (F/A) Hooks law. As the force increases the length increases more rapidly, and the bone breaks at stress of about 120 N/mm2. The ratio of stress to strain in the initial linear portion is Young's modulus Y.

That is: $Y = (L F) / (A \Delta L)$

Stress: force per unit area, $\sigma = F / A$

Strain: fractional change in length due to stress, $\mathcal{E} = \Delta L / L$

Hooke's law: $\sigma = Y \varepsilon$, stress-strain diagram



Scheme [1] When A Piece of Bone Placed under Increasing Tension, Its Strain ΔL/L Increases Linearly at First (Hooks Law) And Then More Rapidly Just before It Breaks in two at 120 N/mm^2

Young's modulus of elasticity:

How much forces are needed to break the bone by compression, tension and twisting. When the bone placed under tension or compression there is change in its length from the stress – strain curve in fig [1].

Stress = F/A N/mm^2 , (Stress = 120 N/mm2)

Strain = $\Delta L/L$

The strain $\Delta L/L$ increase linearly at first with the stress F/A (hook's law)

If F increases the L increase more rapidly and the bone breaks at stress of 120 N/mm^2.

∴ The ratio of stress to strain in the initial linear portion is called young's modulus Y $\quad\quad Y = LF/A\,\Delta L$

Example: Assume a leg has 1.2 m shaft of bone with an average cross-sectional area of $3 \times 10^2\ cm^2$. what is amount of shortening when all of the body weight of 700 N is supported on this leg? Where young's modulus Y of the bone is ($Y_{bone} = 1.8 \times 10^{10}\ N/m^2$)

Sol:

$\Delta L = LF/AY$

$= (1.2m)\ (7 \times 10^2\ N)\ /\ (3 \times 10^{-4}\ m^2)\ (1.8 \times 10^{10}\ N/m^2)$

$= 1.5 \times 10^{-4}\ m$

$= 0.15\ mm$

H.W

Q// Why x-ray shows bone so well?