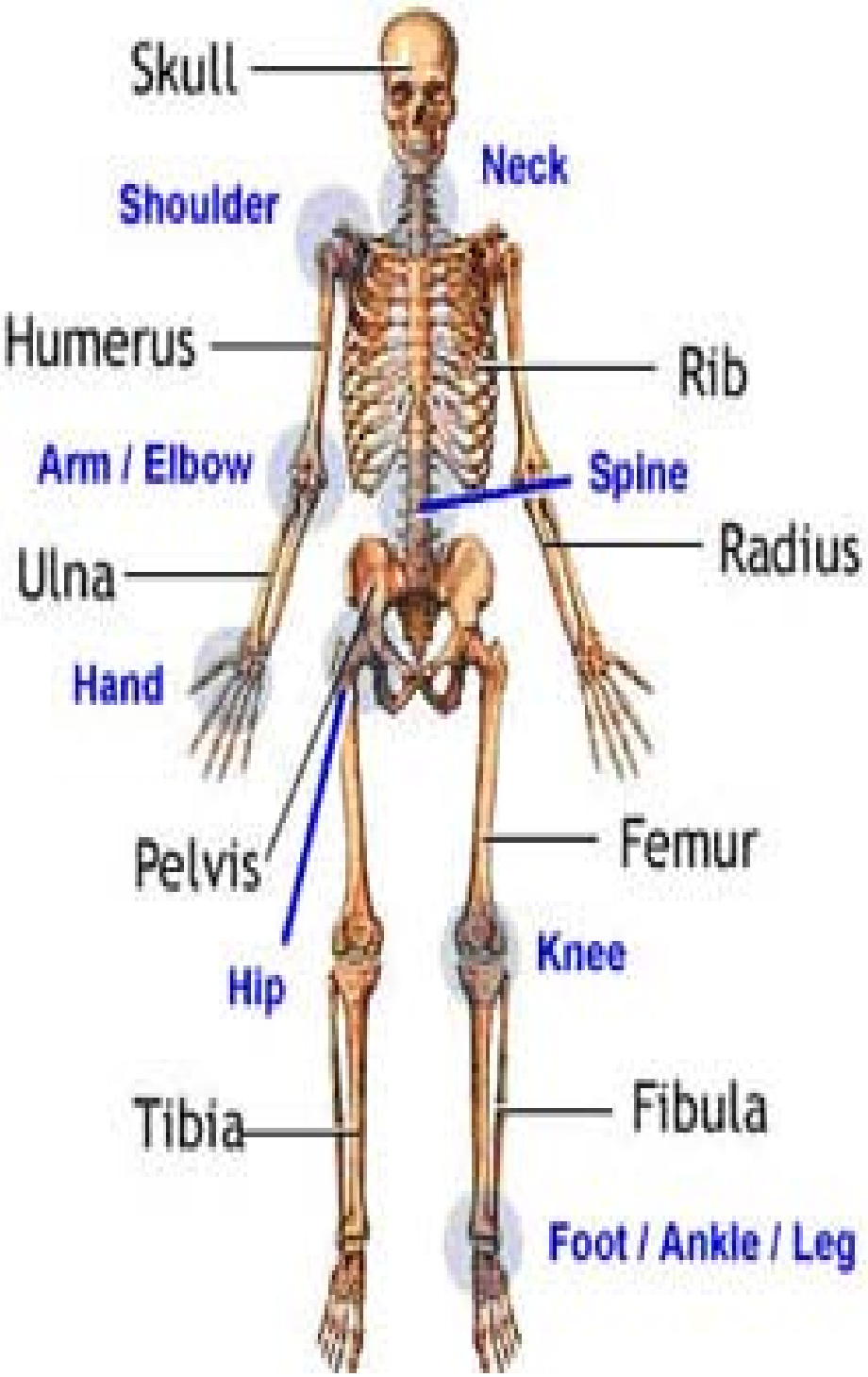
The Skeleton



Lecture#4, Medical Physics, phy.136.

Functions of the Skeleton

1. Supporting الاسناد:-

The body's muscles are attached to the bones through ***tendons*** and ***ligaments*** الاوتار والاربطه and the system of the bones plus muscle support the body.

2. Locomotion الحركه:-

Bone joints permit يسمح movement of one bone with respect to another.

3. Protection الحمايه:-

The skull which protects the brain and several of the most important sensory organs (***eyes or ears***), is an extremely strong container. The ribs form a protective cage قفص of the heart and lungs.

4. Storage of Chemicals:-

The bones act as a chemical "bank" for storage elements for future use by the body. For example, ***Calcium,*** a minimum level of Ca is needed in the blood; if the level falls too " ***Calcium sensor*** " causes the bones to release the needed Calcium.

5. Production of Red Blood in the bone marrow نخاع**.**

6. Sound Transmission:- ex. ***Ossicles*** عظيمات in the middle ear.

7. Nourishment الغذاء:- ex. ***Teeth***.

Bone Remodeling اعادة تشكيل العظام:-

A continuous process of destroying old bone and building a new bone, is called ***bone remodeling*** is preformed by specialized bone cells.

We have two type of cell?

*** Osteoclasts** destroy خلايا تحطيم the bone, and **Osteoblasts** build خلايا بناء it, compared to many body process, **bone remodeling is slow work**. We have the equivalent of new skeleton about **every seven years.**

* Each day the Osteoclasts destroy bone containing about **0.5** gm of calcium (the bones have about **1000** gm of Ca), and the **Osteoblasts** build new bone using about the same amount of Ca.

*** While the body is young and growing the Osteoblasts do more than osteoclasts.**

*** But after the body is 35 - 40 years old the activity of the osteoclasts is greater than that of the osteoblasts, resulting in a gradual** تدريجي **decrease in bone mass that continues until death.**

This condition, called **osteoporosis** هشاشة العظام which is **faster in women than men** and leads to a serious problem of weak bones in older women, such as fractures كسور in the spine العمود الفقري and hips والافخاذ.

Bone Composition:-

Bone consists of two quite different materials as well as water :
1. **Collagen**الكولاجين**:-**
The major organic fraction, which is about **40%** of the weight of solid bone and **60%** of its volume.

2. **Bone Minerals** معادن العظام**:-** In organic component of a bone which is about **60%** of the weight of the bone and **40%** of its volume.

• It is composed of calcium hydroxyapatite $\mathbf{Ca_{10}(PO_4)_6(OH)_2}$
• The bone mineral constructed from very **small rod shape** crystals with diameters about **20 to 70 A^o**, and length of from **50 to 100 A^o**.

***** Because of the small size of the crystals, bone mineral has **very large surface area** nearly **$4x10^5 m^2$** , which permits the bones to interact rapidly with chemicals in the blood and other body fluids.

Elements of Composition of Compact Bone:-

The Element	% Composition
H	3.4
C	15.5
N	4.0
O	44.0
Mg	0.2
P	10.2
S	0.3
Ca	22.2
others	0.2

*** Because bone consist of large percentage of Ca^{+2} it appears clearly in X-ray.**

Classification of The Bone:-

The bones are shaped and constricted into five parts (piles) according to their functions to with stand forces exert on it.

Plate - like Bones(الألواح العظمية(مسطحه**:-** Such as shoulder blade (Scapula)الكتف_ and some of the bone of the skull and Bone pelvisالحوض.

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Long Hollowمجوفه**Bones:-** Such as bones found in the arms, Legs and fingers.

Cylindrical Bones:- e.g. the spine (Vertebraeالفقرات).

Irregular غير منتظمه**Bones:-** e.g. Wrist رشغand ankleكاحل.

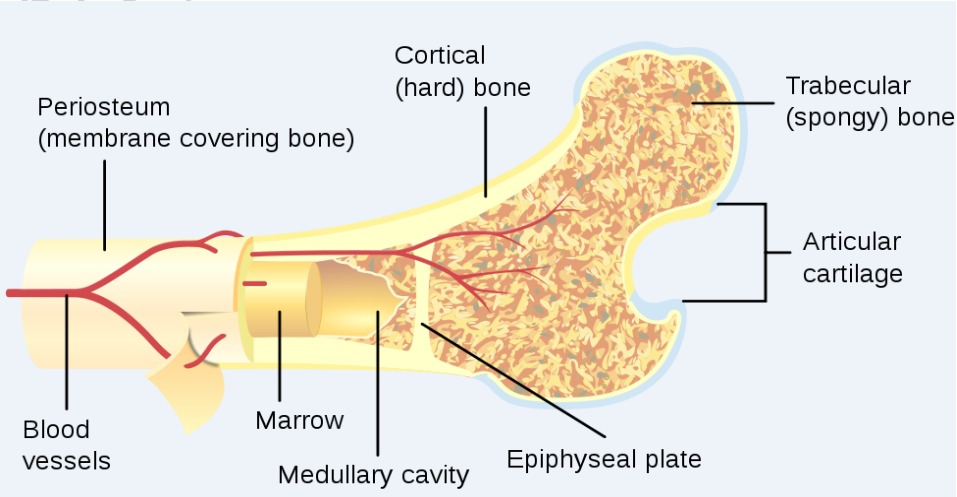
The ribs:- That do not belong in any of the other types .

If we were to cut some of the bone a part, you would find that they are composedيتكون **of one** من واحد **or a combination** او خليط **of two different types of bone:**

1. Compact boneعظم مضغوط**:-** The bone is solid and strong, and this bone is found in central shaft.

2. Trabecular boneعظم تربيقي**:-** This one is spongy, bone is made up of the thread-like Trabecular, and this bone is found in the ends of the long bones.

***** Trabecular bone is considerably weaker than compact bone due to the reduced amount of bone in a given volume, but the bone tissue in a trabecular is the same as the compact bone.



What are the advantage ما فائدة **of the Trabecular bone over compact bone?**

<u>There are at least two advantages</u> :-

1. Where a bone is subjected primarily to compressive force, such as at the ends of the bones in the spine, trabecular bone gives the strength necessary with less material than compact bone.

2. Also because the trabecular is relatively flexible عظم مرن نسبيا trabecular bone can absorb more energy when large forces are involved such as in walking, running, and jumping.

On, the other hand, trabecular bone cannot with stand very well the bending stress that occur mostly in the central portions أجزاء **of long bones.**

*** The density of bone = 1.9 gm/cm^3 which stays constant through life time (or 1.9 time as dense as water) even the mass of the bone is changed.**

<u>Stress</u>

Stress is the ratio of applied force F to a cross section area - defined as "force per unit area"

* If a length bone L (or *l*) is placed under tension or compression its length is changed by ΔL (or *dl*).

- *<u>Tensile Stress</u>* - stress that tends يمثل to stretch or lengthen the material - acts normal to the stressed area

- *<u>Compressive Stress</u>* - stress that tends to compress or shorten the material - acts normal to the stressed area

- *<u>Shearing Stress</u>* - stress that tends to shear the material - acts in plane to the stressed area at right-angles to compressive or tensile stress

Tensile or compressive stress normal to the plane is usually denoted "**normal stress**" or "**direct stress**" and can be expressed as

$$\sigma = F_n / A$$

where

σ = *normal stress (Pa (N/m^2)*

F_n = *normal force acting perpendicular to the area (N)*

A = *area (m^2)*

Example - Tensile Force acting on a bone

A force of *10 N* is acting on a circular bone with diameter *10 mm*. The stress in the bone can be calculated as

$\sigma = (10\ N) / (\pi\ ((10 * 10^{-3}\ m) / 2)^2)$

=

= (N/m^2)

Strain (Deformation)

Strain is defined as "deformation of a solid due to stress".

- Normal strain - elongation استطالة or contraction انكماش of a line segment
- Shear strain - change in angle between two line segments originally perpendicular

Normal strain and can be expressed as

$\varepsilon = dl / l_o$

$= \sigma / Y$ *(3)*

where

dl = change of length (m)

l_o = *initial length (m)*

ε = *strain*

Y = Young's modulus (Modulus of Elasticity) (Pa , (N/m^2)

Young's Modulus (or Tensile Modulus) - Hooke's Law

Most metals deforms proportional to imposed load over a range of loads. Stress is proportional to load and strain is proportional to deformation as expressed with **Hooke's Law.**

$Y = stress / strain$

$= \sigma / \varepsilon$

$= (F_n / A) / (dl / l_o)$ (4)

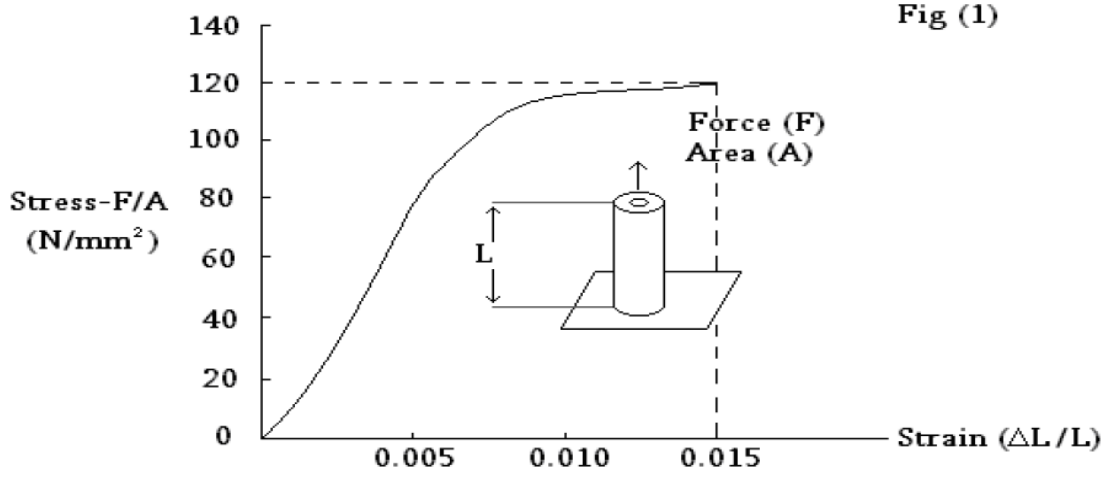
where

$Y =$ *Young's Modulus* (N/m^2)

Modulus of Elasticity, or Young's Modulus, is commonly used for metals and metal alloys and expressed in terms N/m^2 *or Pa*. Tensile modulus is often used for plastics and is expressed in terms $10^5\ lb_f/in^2$.

Hook's law indication that the strain الانفعال (*dl/l*) increasing linearly at first, and it is proportional to the stress الإجهاد (*F/A*), where (F) is the applied force, and (A) is the cross section area of the bone as in the (Fig.1)

Fig (1)



Young's Modulus of Elasticity of compact bone = 1.8×10^{10} N/m^2

***** As the force increases, the length increase rapidly, and the bone **breaks** يكسر**at a stress of about 120 (N/mm^2) and strain 0.015.**
***** Healthy compact bone is able to with stand **a compressive** الانضغاطيه **stress of about 170 (N/mm^2).**

• The ability of the bones to support the body's weight without breaking not only weight but also other forces such as bending انحناء, running, and jumping.

• **In old age the bone become more porous** مثقب**, the density of the remaining compact bone still about 1.9 gm/cm^3, It is reduced in strength because it is thinner** انحف**, not because it is less dense but the mass of the bone changes.**

The viscosity of the synovial زلالي **fluid decreases under the large shear stresses found in the joint.**

***Viscosity α 1 / Lubrication**

The coefficient of friction of healthy joint was found to be **0.01** (***much less than that of the steel blade on ice 0.03)***. (i.e. when 100 N force excretion a joint only 1 N of force needed to move it, which is the least friction in nature).

Question: Using the information in fig. (1)
a. Calculate the maximum tension of the bone with a cross sectional area of **4 cm^2** could with stand just prior to fracture قبل ان يكسر.
b. Determine how much a bone **35 cm** long would elongate under this maximum tension.
c. Calculate the stress on this bone if a tension force of **104 N** were applied to it. How much would this bone lengthen??