الكلية	طب الاسنان
القسم	---
المادة باللغة الانجليزية	**Medical Physics**
المادة باللغة العربية	الفيزياء الطبية
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اسم التدريسي	سيف باسم محمد حسن
عنوان المحاضرة باللغة الانجليزية	**Physics of Skeleton**
عنوان المحاضرة باللغة العربية	فيزياء الهيكل العظمي
رقم المحاضرة	الرابعة
المصادر والمراجع	Herman, I. P. (2007). *Physics of the human body*. Berlin, Heidelberg: Springer Berlin Heidelberg.
	Manual, C. (2002). The Physics of the Human Body. *Imaging*, 1-72.

Medical Physics

Lecture (4)

Physics of Skeleton

BY

Dr. SAIF B. Moh

Physics of Skeleton

Bone is of interest to medical physics and engineers. Perhaps this organ system of the body appeals most to physical scientists because engineering type problems dealing with static and dynamic leading forces that occur during standing, walking, running and lifting

Bone has at least six functions in the body:

1. Support: bone and muscles of the legs support the body.

2. Locomotion: bone joint permit movement of one bone with respect to another.

3. Protection: The skull protects the brain, eyes and ears. The ribs protect the heart and lungs.

4. Storage of chemical: Ca storage in the bone which is released when it needed.

5. Nourishment: The teeth are specialized bones that can cut food.

6. 6-Sound transmission. The smallest bones of the body are the ossiclesin middle ear.

Bone is a living tissue and has a blood supply as well as nerves, the cells that maintain the bone in a healthy condition. They make up about 2% of the volume of bone which called osteocytes.

Bone remolding:

A continuous process of destroying old bone and building new bone, there are two

types of cells in bone remolding:

1. Osteoclasts: cells specialized in bone destroying.

2. .Osteoblasts: cells specialized in bone building.

Young body is growing and the osteoblasts do more than the osteoclasts, but after the body is 35 to 40 years old the activity of the osteoclasts is greater than that of the osteoblasts. This faster in the women than in the men and leads to a serious problem of weak bones in older women, this condition called osteoporosis.

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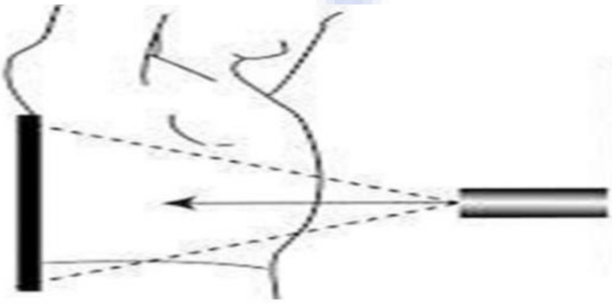
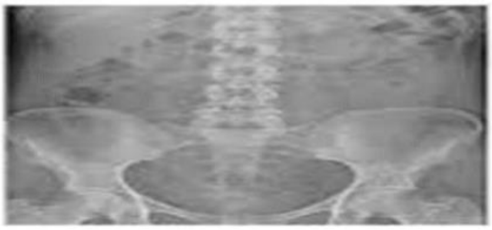
What is bone made of?

1. Collagen: the major organic fraction, which is about 40% of the weight of solid bone and 60% of its volume.
2. Bone mineral: inorganic component of bone, which is about 60% of the weight of the bone and 40% of its volume.

The large percentage of calcium 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-rays show bones so well.

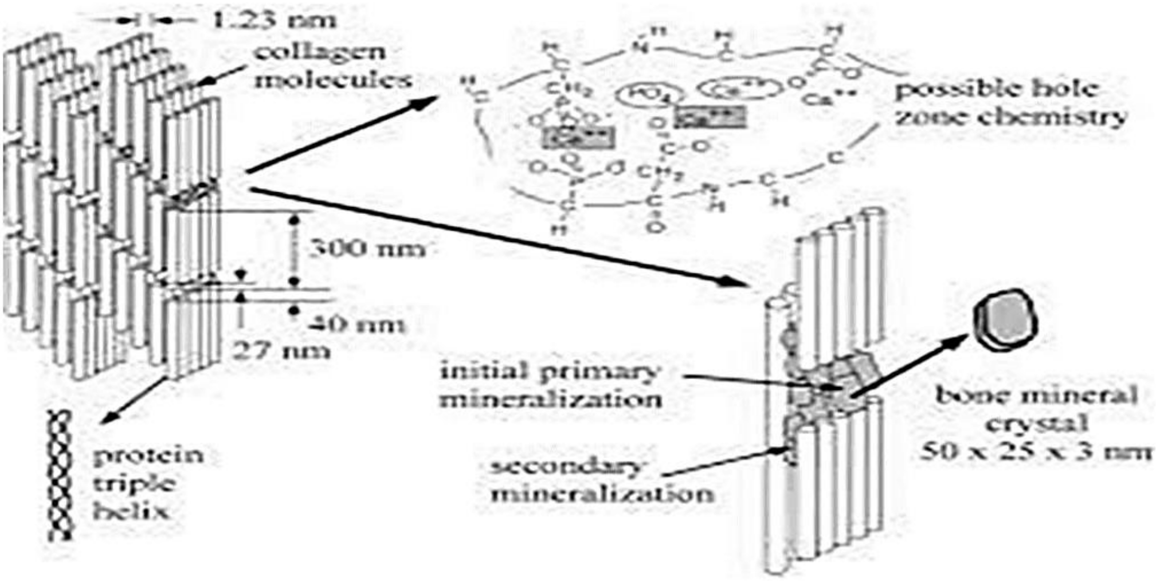




Either of these components my be removed from bone, and in each case the remainder, composed of only collagen or bone mineral, will look like the original bone. The collagen remainder is quit flexible, some what a chunk of rubber, it bends easily if it is compressed. When the collagen is removed from the bone,

the bone mineral remainder is very fragile and can be crushed with fingers. Bone mineral is believed to be made up of calcium hydroxyapaite $Ca_{10}(PO_4)_6(OH)_2$.

Studies using x-ray scattering have indicated that bone mineral crystals are rod . Because of smallo , and lengths of from 50 t0 100o shape with diameters of 20 to 70 size of the crystals, bone mineral has a very large surface area. The large area of exposed bone mineral crystal permits the bones to interact rapidly with chemicals in the blood and other body fluids



Within a few minutes after small quantity of radioactive fluorine(14F) is injected into a patient, it will be distributed throughout bones of his body.

How strong are your bones?

Two quite different types of bone: solid or compact, 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.

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.

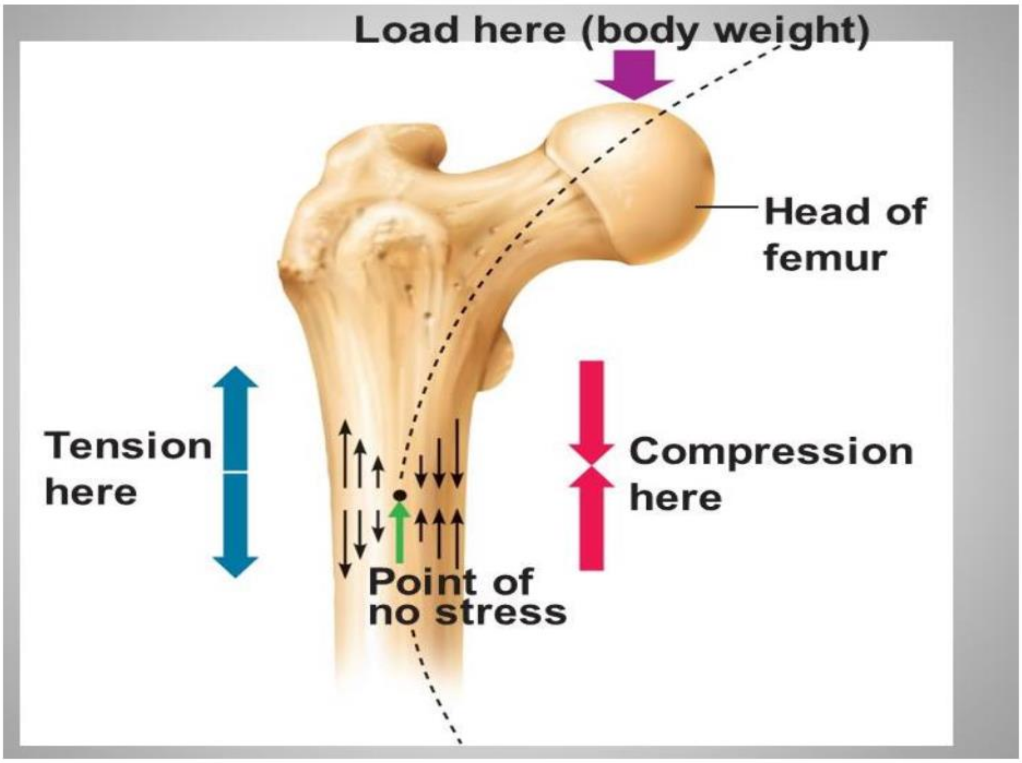


Figure 1. The head and neck of the femur.
(The lines of compression and tension due to weight W of The body)

All materials change in length (ΔL) 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 (figure.2) is obtained. The strain ΔL/L increases linearly at first, indicating that is proportional to the stress (F/A)

Hooks law.

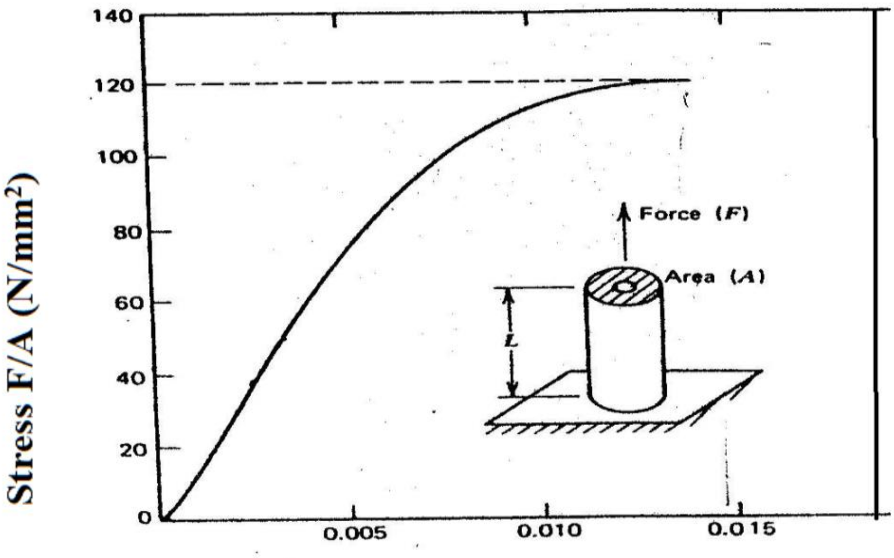
As the force increases the length increases more rapidly, and the bone breaks at stress of about 120N/mm2.The ratio of stress to strain in the initial linear portion is Young's modulus (Y).

That is:

$Y = (L \times F)/(A \times \Delta L)$

Where: Y= Young's modulus L= Original length F=Force A= area

and ΔL= change in length.



Strain (ΔL/L)

Figure. 2: 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 at120 N/mm^2.

Example: Assume a leg has 1.2 m shaft of bone with an average cross-sectional area OF $3x10^{-4}$ m^2. What is amount of shortening when all of the body weight of 700 N supported on this leg, Assume the Young's modulus (Y)= $1.8x10^{10}$ (N/m^2).

Sol:

$$\Delta L = \frac{L\,F}{A\,Y} = \frac{(1.2m)(7x10^{2}N)}{(3x10^{-4})(1.8x10^{10}N/m^{2})} = 1.5x10^{-4}m = 0.15mm$$

Homework:

Assume a leg has a bone shaft of 0.6 meters with an average cross-sectional area of 1.5×10^{-4} m21.5×10^{-4}m^2. What is the amount of shortening when the entire body weight of 350 N is supported on this leg? Assume Young's modulus (Y) is 1.8×1010 N/m21.8×1010N/m^2.

To determine the amount of shortening of the bone when a force is applied, we can use the formula for axial deformation:

ΔL=F·LY·AΔL=Y·AF·L

Where:

- ΔLΔL is the change in length (shortening in this case).
- FF is the force applied (350 N).
- LL is the original length of the bone (0.6 m).
- YY is the Young's modulus (1.8×10^{10} N/m 21.8×10^{10}N/m2).
- AA is the cross-sectional area of the bone (1.5×10^{-4} m21.5×10^{-4}m^2).

Plugging in the values:

ΔL=350 N×0.6 m1.8×10^{10} N/m$^2\times1.5\times10^{-4}$ m^2

ΔL=1.8×1010N/m2×1.5×10^{-4} m^2 350 N×0.6 m

First, calculate the denominator:

$1.8\times10^{10}\times1.5\times10^{-4} = 2.7\times10^{6}$ N/m

Now, calculate the numerator:

350×0.6=210 N·

Finally, divide the numerator by the denominator:

ΔL=2102.7×106≈7.78×10^{-5} m

So, the amount of shortening is approximately 7.78×10^{-57}.78×10−5 meters, or 0.0778 millimeters.

Lubrication of Bone Joints

There are two major diseases that affect the joint-rheumatoid, arthritis, which results in over production of the synovial fluid in the joint and commonly causes swollen joints, and osteoarthritis, a disease of the joint itself. The synovial membrane encases the joint and retains the lubricating synovial fluid.

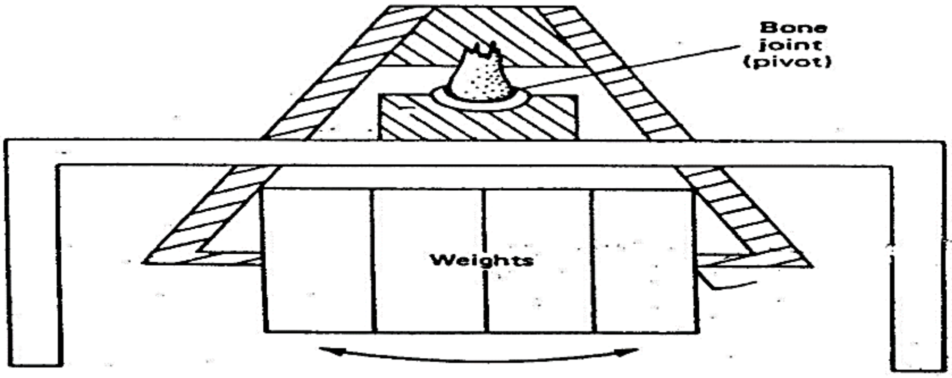
The surface of articular cartilage is not as smooth as that of a good man-made bearing.

Because of the porous nature of the articular cartilage, other lubricating material is squeezed into joint when it is under its greatest stress-when it needs lubrication the most. The lubricating properties a fluid depend on its viscosity, thin oil is less viscous and better lubricant than thick oil.

The viscosity of synovial fluid decreases under the large shear stress found in the joint. The good lubricating properties of synovial fluid are thought to be due to the presence of hyaluoric acid and mucopolysacharides that deform under load.

The coefficient of friction is measured by a normal hip joint from a fresh cadaver was mounted upside down with heavy weights pressing the head of the femur into the socket. The weight on the joint could be varied to study the effects of different loads the whole unit acted

Like a pendulum with the joint serving as the pivot. From the rate of decrease of the amplitude with time the coefficient of friction was calculated.



Arrangement for determining the coefficient of friction c
d as the pivot in a pendulum and the decrease in amp
with time is measured.

The strength of bone depends to a large extent on the mass of bone mineral present , and the most striking feature in osteoporosis is the lower than normal bone mineral mass. Thus a sample technique to measure bone mineral mass in vivo with good accuracy and precision was sought. It was hoped that such a technique could be used to diagnose osteoporosis before a fracture occurred and also to evaluate various types of therapy for osteoporosis. Since bone mineral mass decreases very slowly, 1 to 2% per year, a very precise technique were needed to show changes.