Biomechanics

Third Stage/ Biomaterials Engineering and prosthesis Branch

Presented By

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Lecture Six

Bone Biomechanics (Hard tissue)

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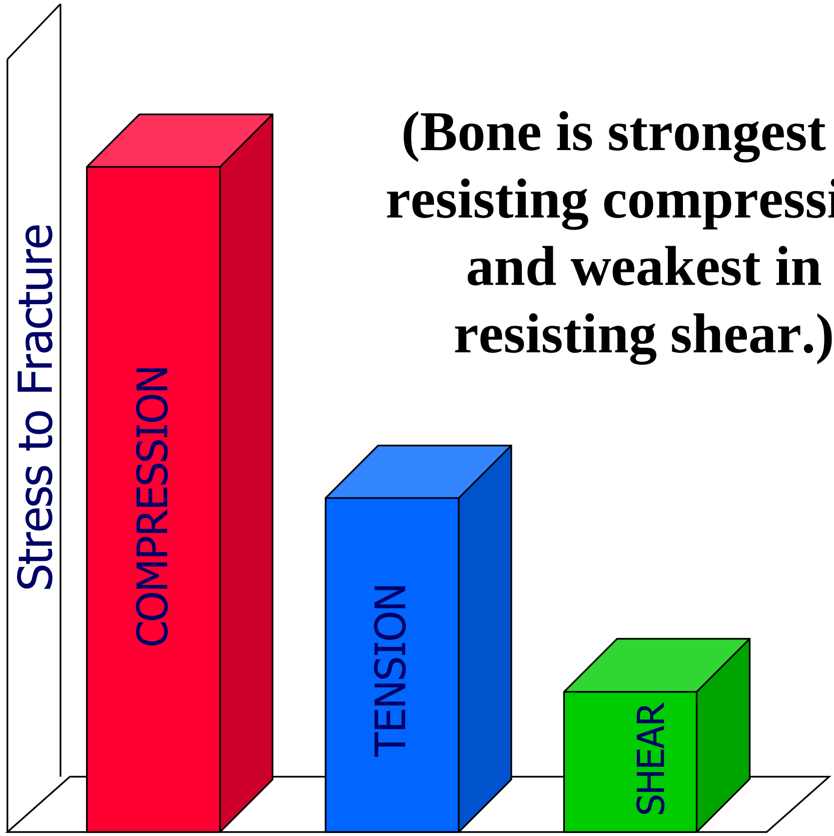
- **Bone**: is anisotropic material (modulus is dependent upon the direction of loading).
- **anisotropic**: exhibiting properties with different values When measured in different directions.

Effect The Structure of Bones on strength:

- Bones has different strength and stiffness depending on the direction of the load, as shown in the this figure



(Bone is strongest in resisting compression and weakest in resisting shear.)

- **For Example**: Ultimate Stress at Failure Cortical Bone:

Compression < 212 N/m^2

Tension < 146 N/m^2

Shear < 82 N/m^2

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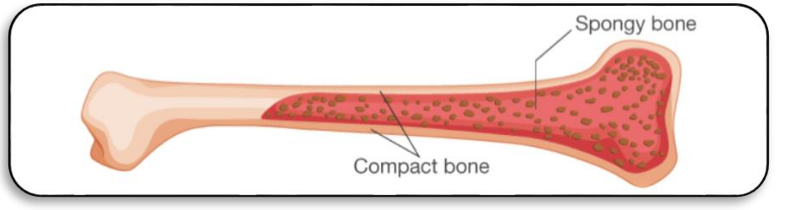
Classification of Bones

1. **Compact bone:** also called cortical bone surrounds spongy bone. They are heavy, tough, and compact in nature. It is found in the shafts of long bones.

2. **Spongy bone:** also called cancellous, or trabecular bone. It is surrounded by compact bone. It is found in the ends of long bones and the vertebrae.



❖ **this categories of bones is based on porosity, where cortical bone has low porosity while cancellous bone has high porosity.**

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Effects bone porosity:

- The behavior of bones when loaded depended the amount of porosity in bone:

- cortical bone is **stiffer** than cancellous bone, it can withstand greater stress but less strain.

- cancellous bone is **spongier** than cortical bone, it can undergo more strain before fracturing.

Composition of Bone

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- The major building materials of bone (calcium carbonate, calcium phosphate , collagen and water).

The effect of each component on bone property

- **Mg ,Na and F** important for growth and health.
- **calcium carbonate** and **calcium phosphate** contributed to stiffness and compressive strength in bone which represent 60-70% of bone weight.
- **collagen (Protein)** contributes to flexibility and tensile strength in bone.

* collagen is progressively lost and bone brittleness increases with aging

Composition of Bone

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➢bone strength is affected by:

1. **Water content** of bone, which comprises 25%-30% of bone weight.
2. bone **porosity**, or the amount of bone volume filled with pores or cavities.

Types of bones

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- irregular bones: have different shapes to serve different functions; include vertebrae, sacrum, coccyx, maxilla.
- long bones: form the framework of the appendicular skeleton; include humerus, radius, ulna, femur, tibia, fibula.
- short bones: approximately cubical; include the carpals and tarsals.
- flat bones: protect organs & provide surfaces for muscle attachments; include the scapulae, sternum, ribs, patellae, some bones of the skull

Types of bones
Examples

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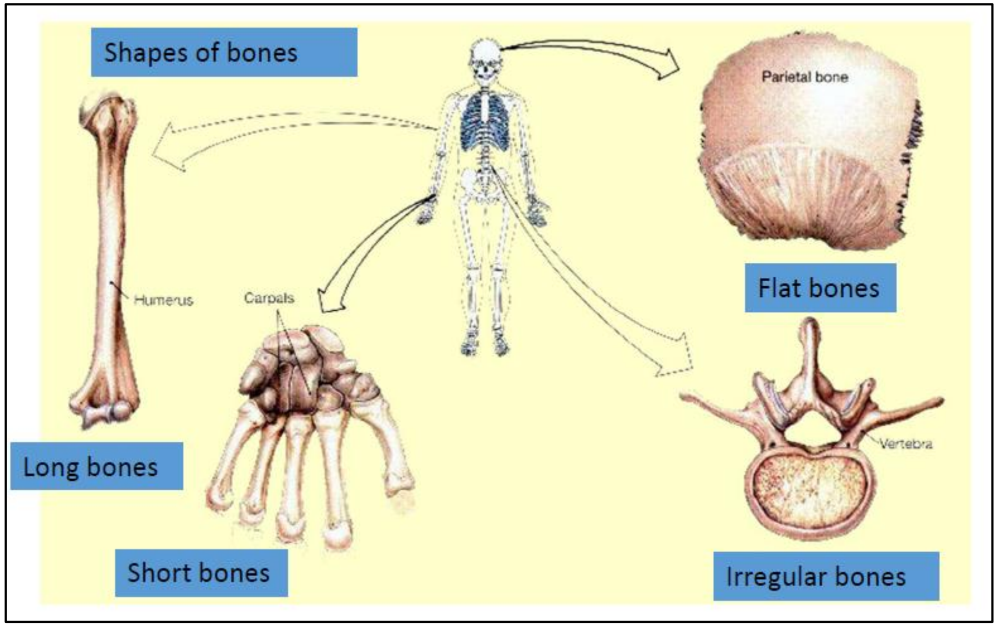
A. The carpals are categorized as short bones.
B. The scapula is categorized as a flat bone.
C. The vertebrae are examples of irregular bones.
D. The femur represents the long bones.



Basic Biomechanics of Fracture

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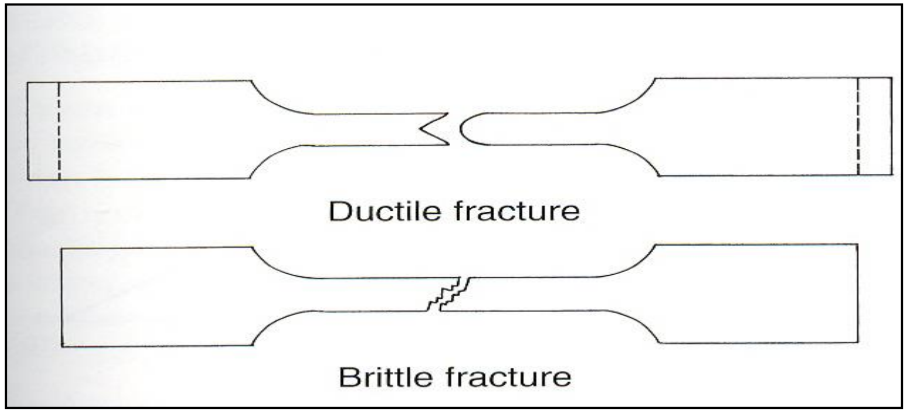
- The fracture types of bones may be **Ductile** **or** **Brittle** **(as shown in the following figure) Depends on age and rate at which it is loaded.**

-for example:

- Younger bone is more ductile

- Bone is more brittle at high speeds



return to original shape after fracture

Basic Biomechanics of Fracture

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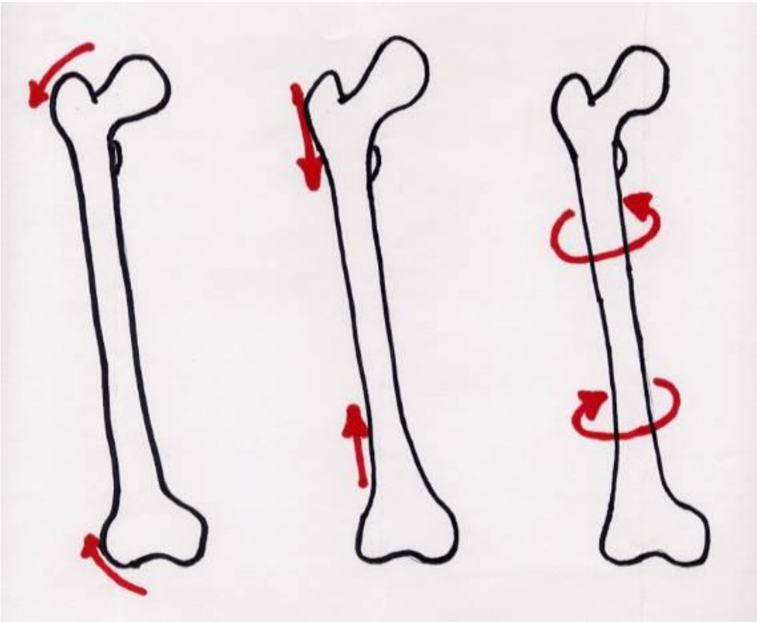
Factor independent of shape
* Material Properties
– Elastic-Plastic
– Yield point
– Brittle-Ductile
– Toughness

Factor dependent of shape and material properties
* Structural Properties
– Bending Stiffness
– Torsional Stiffness
– Axial Stiffness

Load to Failure
- Continuous application of force until the material breaks (failure point at the ultimate load).
– Common mode of failure of bone .

Fatigue Failure
– Cyclical sub-threshold loading may result in failure due to fatigue.
– Common mode of failure of orthopaedic implants and fracture fixation constructs.

Type of Loading



Bending

Torsion

Axial Loading
Compression
Tension

Fracture Mechanics

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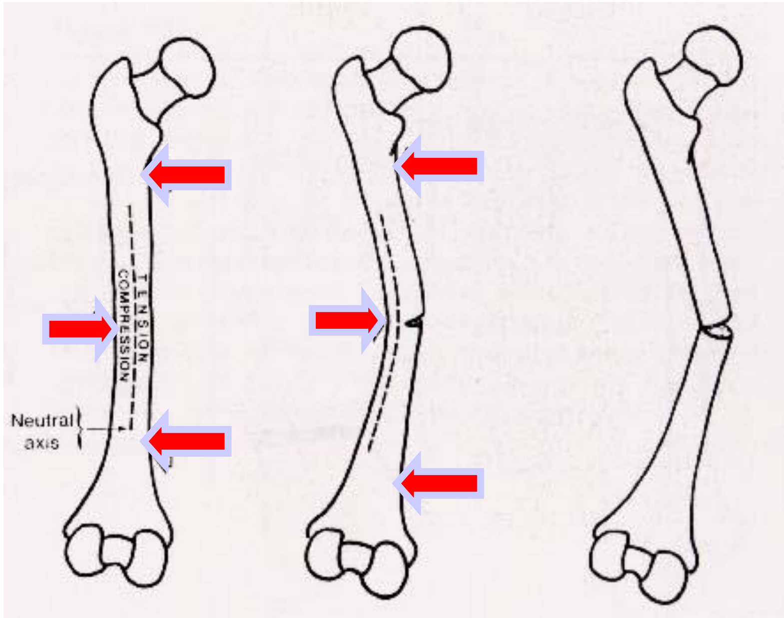

- **Bending load:**
  - Compression strength greater than tensile strength
  - Fails in tension

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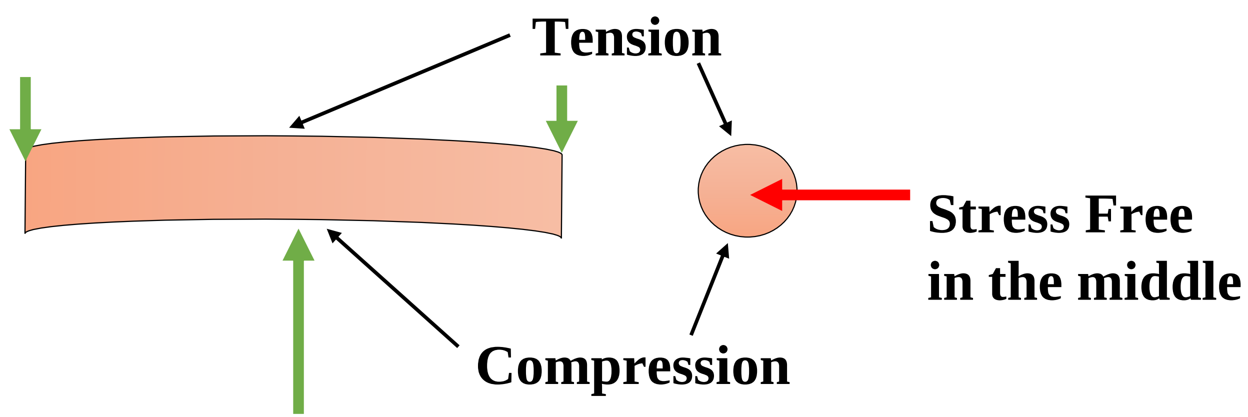
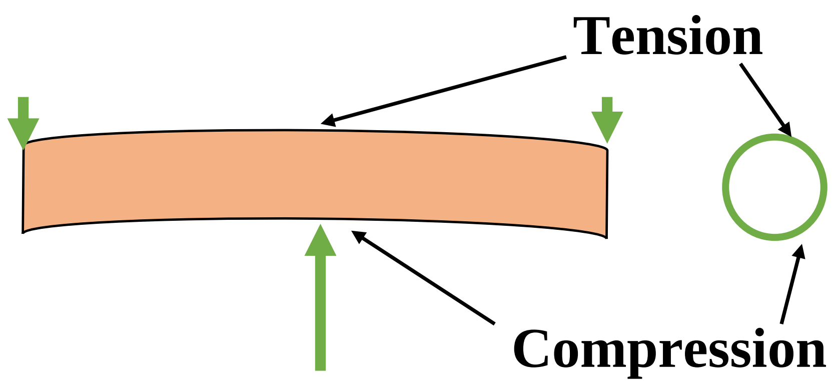
Bending of a Long, *Solid* Bone:



Bending of a Long, *Hollow* Bone:



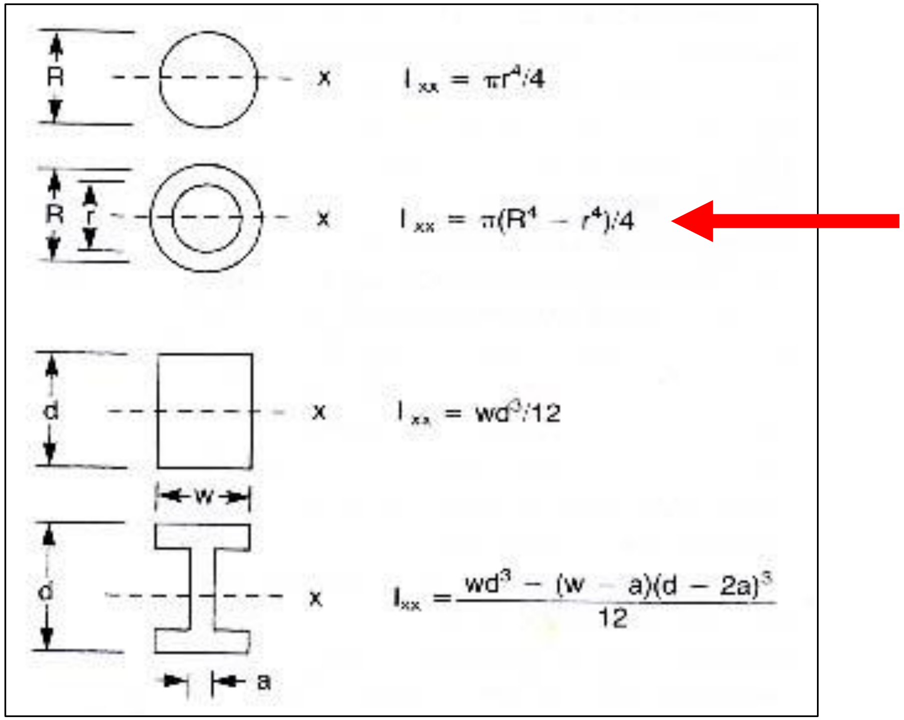
$\sigma = M \cdot y / I$
Where:
σ = stress of bending
y = bending moment
I: moment of inertia

$I = \pi.(R^4 - r^4)/4$

*** long bone with hollow structure this make them stronger than solid bone. So, this led to hollow bone <u>Save weight & keep strength</u>**

Moments of Inertia

- Resistance to bending, twisting, compression or tension of an object is a function of its shape
- Relationship of applied force to distribution of mass (shape) with respect to an axis.



The End of Lecture