
ORTHOPAEDIC CENTER
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Biomechanics Review

Part 1

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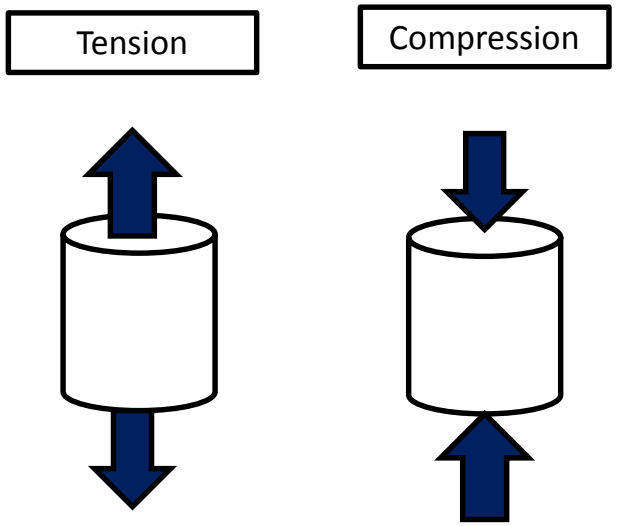
Quick Mechanical Physics Review

- **Force**: The action of one object onto another that results in a change of motion or shape
- Forces that act on a body can also be called loads
  - Newtons are the Units
- Types
  - Linear: A force that goes along the axis of movement
  - Rotational: a force that revolves around the axis or results in rotational motion

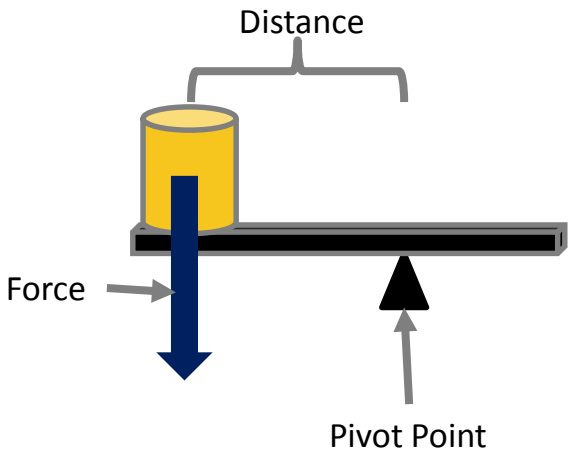
Linear Forces

- Perpendicular forces to an axis are known as **normal** forces.
- **Tangential** forces are parallel to the axis
- Compression is a negative change in length or shorter
- Tensile forces are a positive change in length or longer



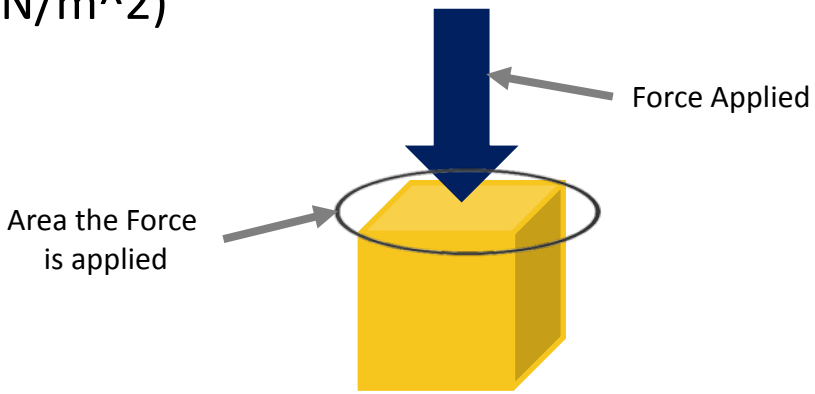
Rotational Forces

- **Moment/Torque**: The rotational effect of a force a distance away from a point
  - Newton * Meters
  - M=F X D
- Moment: force parallel to long axis
- All forces occur about an axis



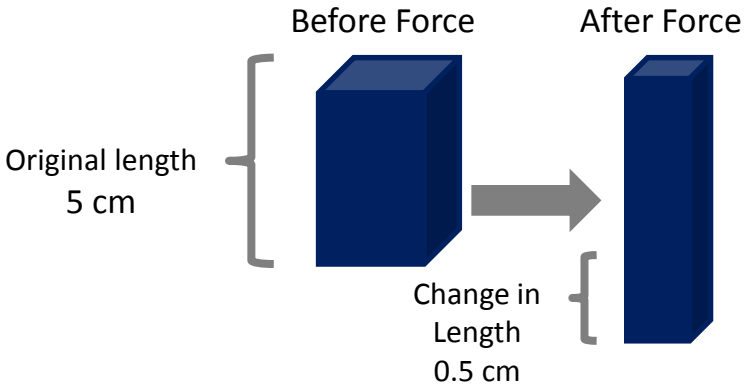
Elasticity

- Elasticity is the ability of an object to return to its original shape after a force has been removed and is measured from the stress and strain observed on an object.
- Stress
  - The pressure of the force applied on an area
  - Units: Pascal (Pa = N/m^2)



Elasticity Continued

- Strain
  - Changes in length of an object due to stress
  - Strain is the $\frac{\text{Change in Length}}{\text{Original Length}}$
  - Strain is normally given as a percent



$$Strain = \frac{0.5\ cm}{5\ cm} = 0.1 = 10\%$$

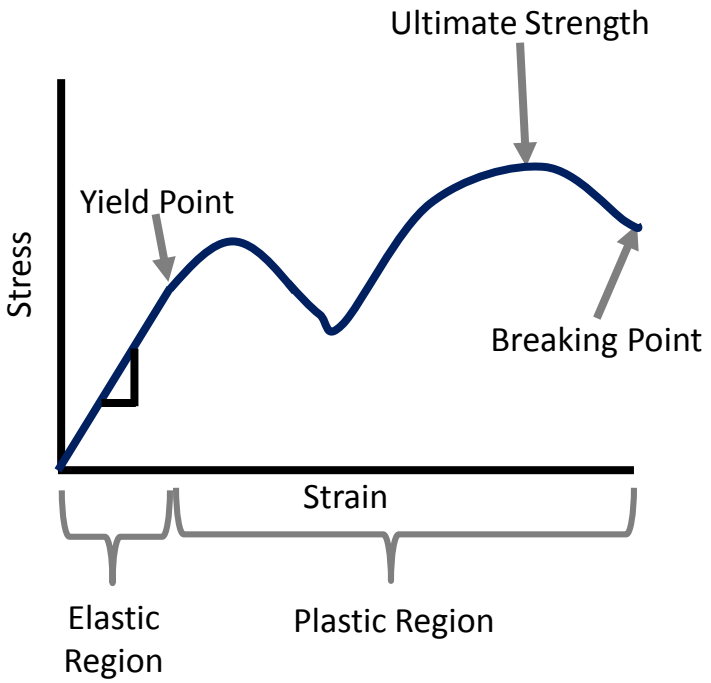
Stress-Strain Curve

- Young's modulus (Elastic Modulus or E) is the slope of the linear portion of the curve or elastic region
  - E=Stress/Strain
- The larger the E the stiffer the material and the more force is required to cause a deformation in the object
- **The stress-strain curve will be the same for each elastic material independent of its shape**

Stress-Strain Curve Continued

Important Places on the Curve

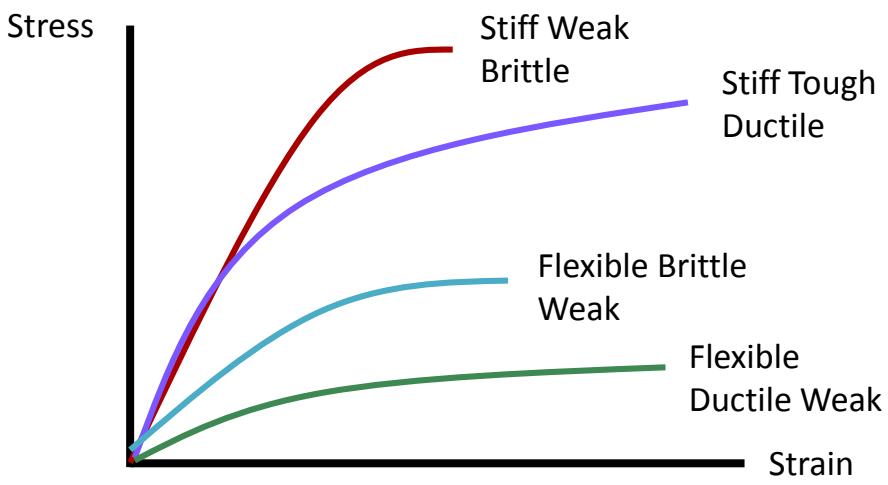
- **Yield Point/Elastic Limit**: the level of strain that is the point where the deformation changes from elastic to plastic
- **Ultimate Strength:** the highest stress observed on the material
- **Breaking Point/Failure Point:** the point where the strain will cause a break in the material
- **Elastic vs. Plastic Deformations:** non-permeant vs. permeant deformations



Elasticity Continued

- Elastic Properties:
  - Endurance Limit: Stress level at which a material can be cyclically loaded an infinite number of times without failing
  - Fatigue Failure: Number of cycles to material failure at a specific stress level
- Material Properties
  - **Brittle**: A material that experiences little plastic deformation before it fails
  - **Ductile**: A material that experiences large plastic deformations before it fails
  - **Toughness**: A material that can absorb more energy (area under the curve) prior to failure (resistance to failure)
  - **Weakness**: A material that can absorb little energy (area under the curve) prior to failure (prone to failure)
- Materials can have different combinations of properties:
  - Ex. Flexible, Brittle, Strong vs. Stiff, Ductile Strong

Curves of Materials of Mixed of Properties



Elastic materials are not confined to one material property. Often a material will have a mix and this makes some materials better for certain implants than others.

Common Orthopedic Materials Young's Modulus

Material	Xs Stiffer than Cortical Bone	Xs Stiffer than Cancellous Bone
Ceramic (Al2O3)	18-22x	21-41x
Alloy (Co-Cr-Mo)	10-13x	11-24x
Stainless Steel	10-11x	11-20x
Titanium	5-5.5x	5.7-10.3x
Matrix Polymers (Collagen)	0.24-0.59x	0.28-1.1x
PMMA (Bone cement)	0.087-0.167x	0.1-0.31x
Polyethylene (UHMWPE)	0.0432-0.0518x	0.0497-0.0963x

Source

- Özkaya, Nihat, et al. *Fundamentals of biomechanics: equilibrium, motion, and deformation*. Springer, 2016.