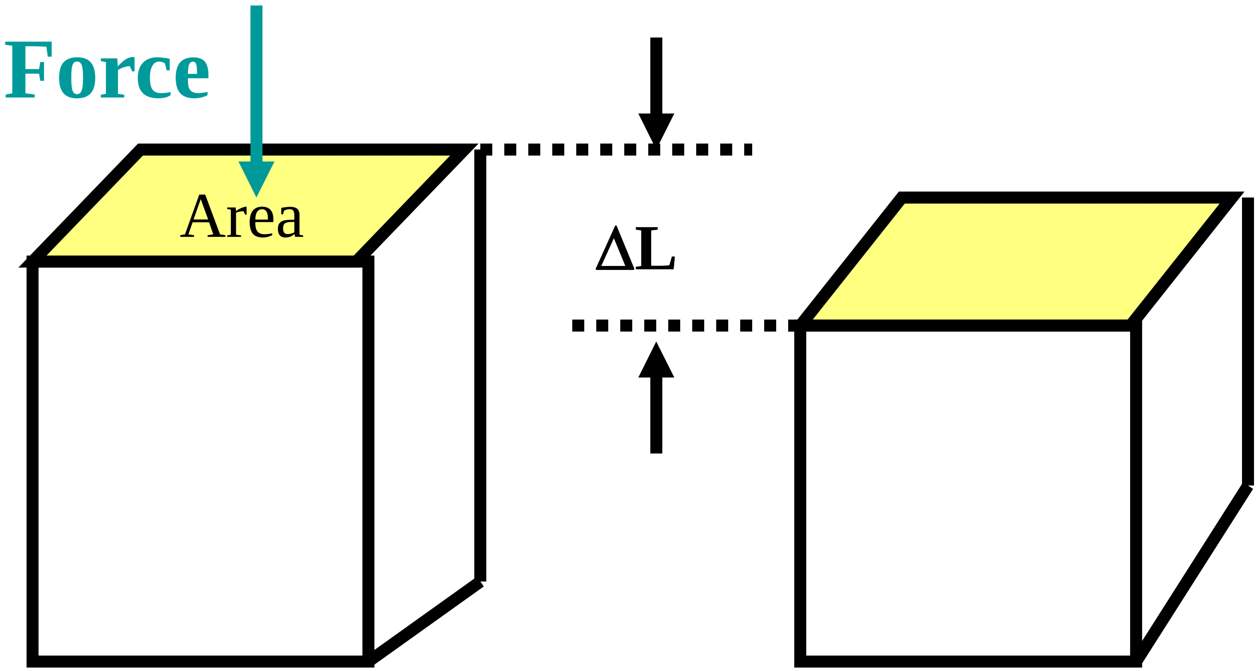
Section 12: Mechanics of Materials – Stress / Strain

Basic Biomechanics



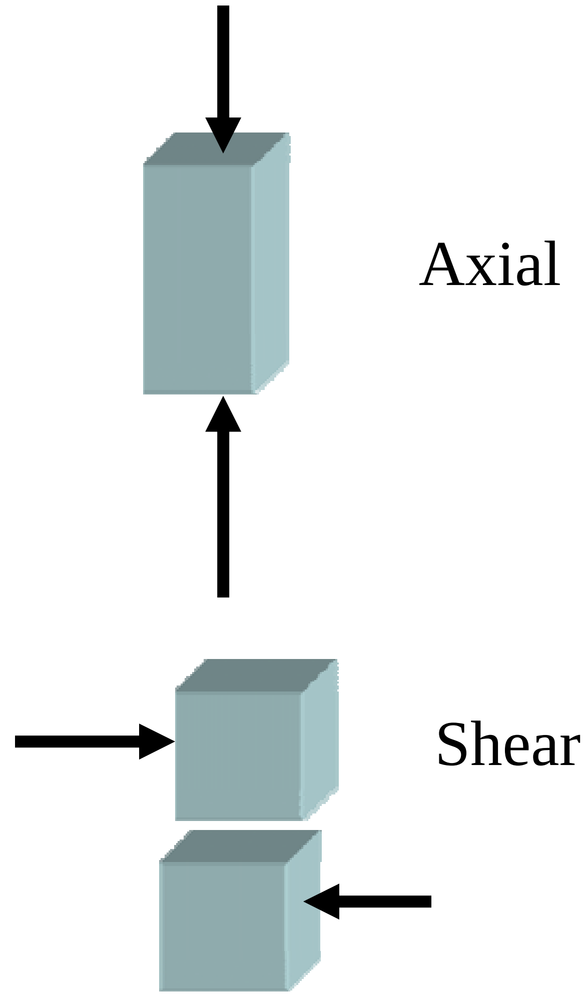
Stress =
Force/Area

Strain =
Change Height (ΔL) /
Original Height(L_0)

From: Le

Stress

- Stress (σ): internal resistance to an external load
  - Axial (compressive or tensile) $\sigma = F/A$
  - Shear $\tau = F/A$ (parallel or tangential forces)
- Units Pascal (Pa) = $1 Nm^2$



From: Noffal

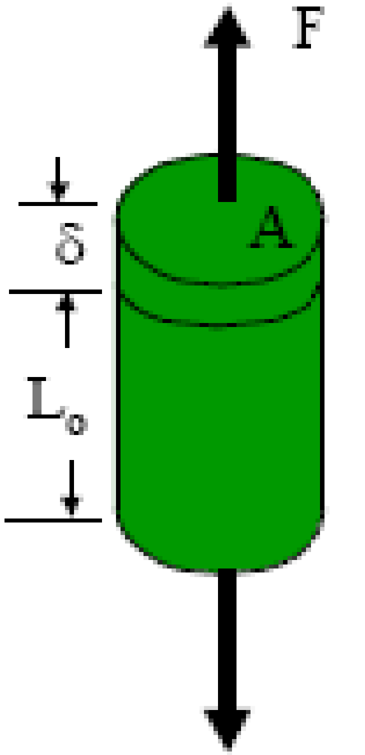
Basic Mechanics

- Material properties
  - relate stress σ and strain ε (constitutive equation)

σ = force/area (N/m²)

$\varepsilon = \delta / L_o$

$\gamma = \theta$ in radians



From: Grimm and Atkinson

Stress/Strain

Stress (σ):

load (N) divided by cross sectional area (m^2); units are N/m^2, or Pascals

Strain(ε): $(\ell - \ell_o)/\ell_o$ ℓ = stretched length; ℓ_o = original length; strain is dimensionless

Elastic Modulus (E):

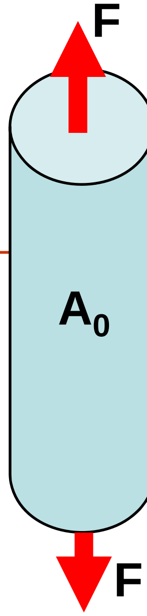
describes the intrinsic stiffness of a tissue, or perhaps more simply, this is the slope of the stress-strain curve

$$E = \frac{\Delta \sigma}{\Delta \varepsilon}$$

From: Seeley

Definition of Stress

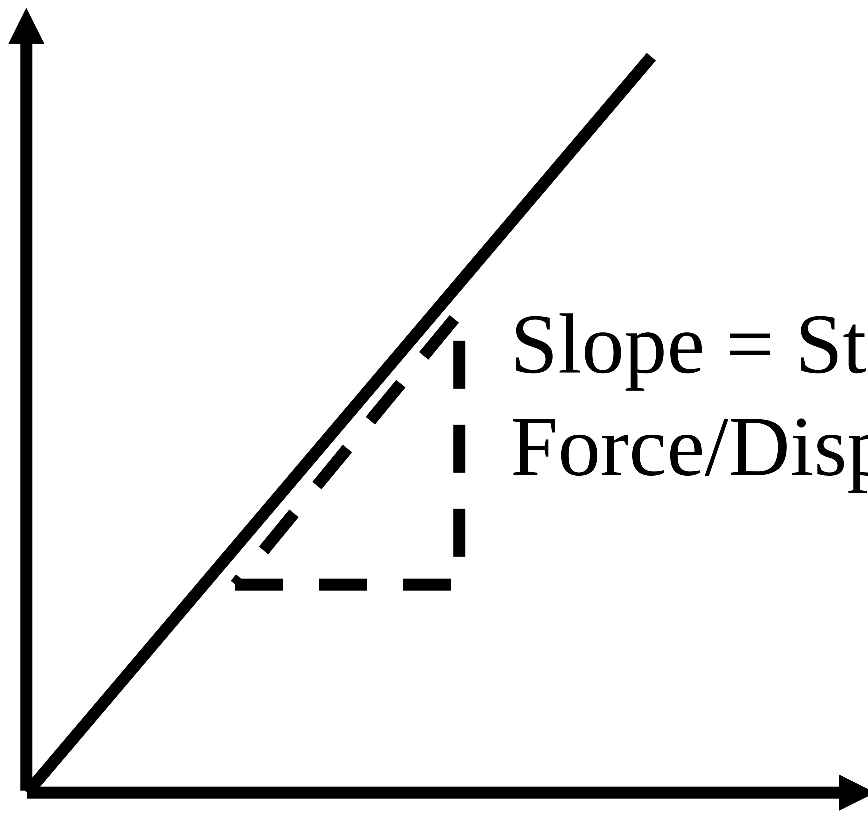
$$\sigma = \frac{F}{A_o}$$



- This is the definition of **engineering** stress.
- F is the force in Newton (N)
- A_0 is the **initial** area of the specimen in m^2.
- The unit of stress is therefore N/m^2.
- 1 N/m^2=1 Pascal or 1 Pa.
- 1 KPa=10^3 Pa; 1 MPa=10^6 Pa; 1 GPa=10^9 Pa.
- Strengths of metals are usually in MPa; elastic modulus of metals usually in GPa.

From: Wei

Basic Biomechanics
Force, Displacement & Stiffness

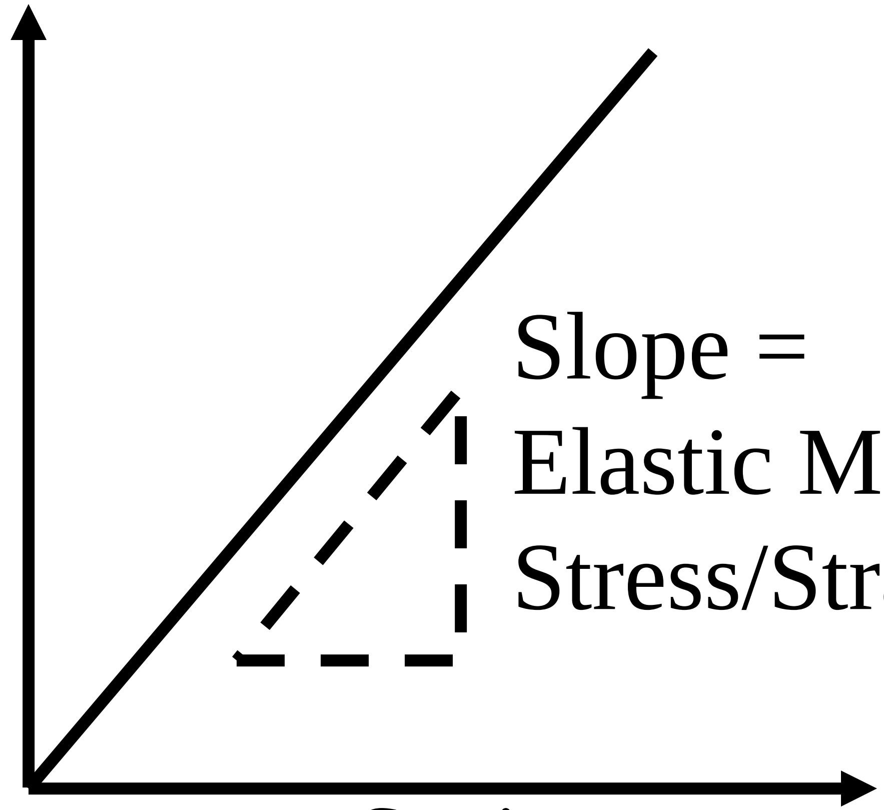


From: Le

Basic Biomechanics

Stress-Strain & Elastic Modulus

Stress = Force/Area



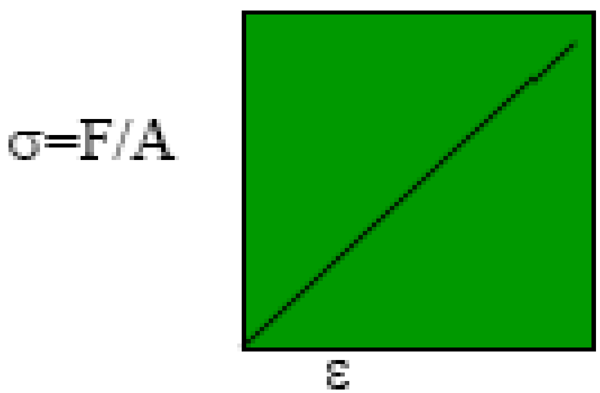
Slope = Elastic Modulus = Stress/Strain

Strain = Change in Length/Original Length ($\Delta L / L_0$)

From: Le

Linear Elastic

- Linear: stress varies linearly with strain
- Elastic: material follows the same stress/strain curve during loading and unloading therefore no energy is lost, material returns to its original shape



$E_{cartilage} = 0.3 - 1.0$ MPa (N/mm^2)

$E_{meniscus} = 0.1 - 0.6$ MPa

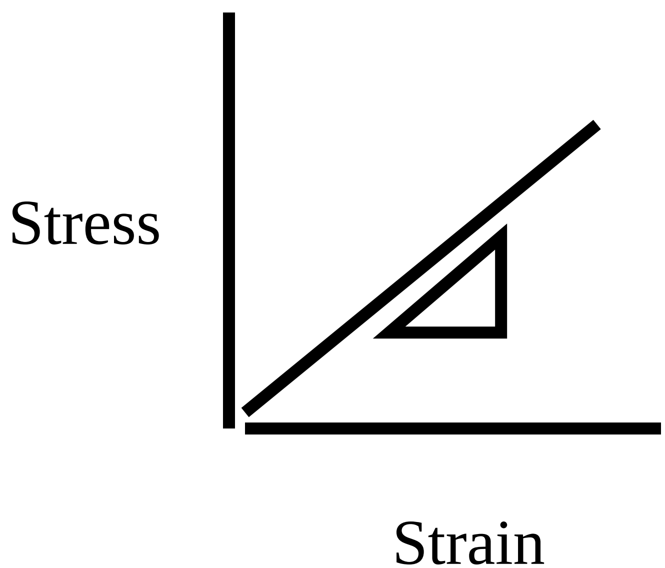
$E_{bone} = 2{,}400 - 3{,}50$ MPa

$E_{steel} = 193{,}000$ MPa

From: Grimm and Atkinson

Basic Biomechanics
Common Materials in Orthopaedics

- Elastic Modulus (GPa)

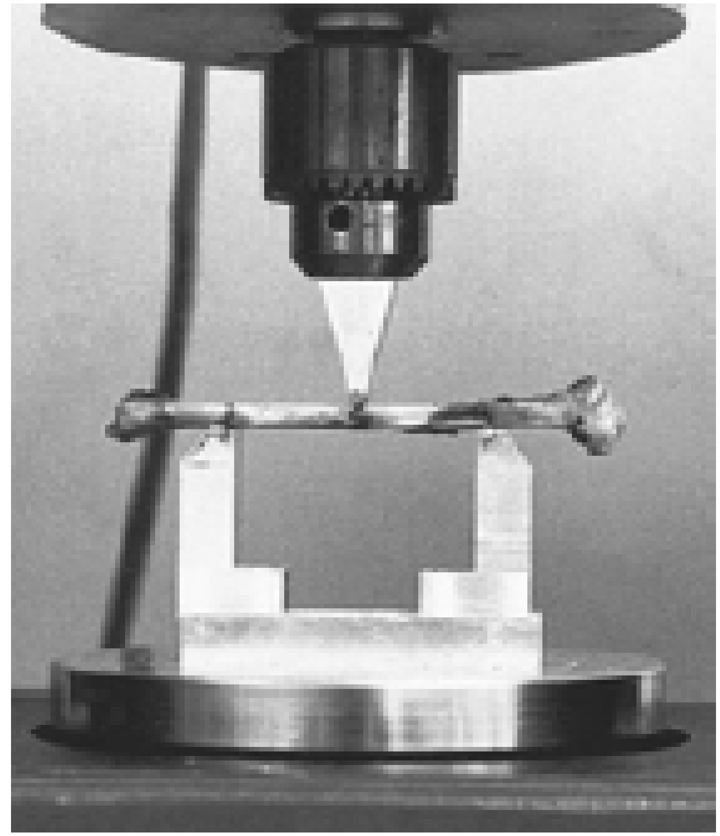


- Stainless Steel 200
- Titanium 100
- Cortical Bone 7-21
- Bone Cement 2.5-3.5
- Cancellous Bone 0.7-4.9
- UHMW-PE 1.4-4.2

From: Le

Sample Problem

A bone sample is subjected to a shear load of 80,000 N. Its cross sectional area is 1 cm^2. The elastic modulus for this material is 70 GPa. Using the equation below, what strain results from this tensile load?



$$E = \frac{\Delta\sigma}{\Delta\varepsilon}$$

From: Seeley

$$F = 80{,}000\ \text{N}$$

$$A = 1\text{cm}^2 = 0.0001\text{m}^2$$

$$E = 70\text{GPa}$$

$$E = \frac{\sigma}{\varepsilon}$$

$$70\text{GPa} = \frac{\dfrac{80{,}000\text{N}}{0.0001\text{m}^2}}{\varepsilon} = \frac{800\text{MPa}}{\varepsilon}$$

$$\varepsilon = \frac{800\text{MPa}}{70\text{GPa}} = 0.0114 = 1.14\%$$

From: Seeley