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Materials and Mechanics in Medicine
Exercise Lesson 1: Biomaterials 1

Jack Kendall

Admin

- Tuesday 15:15- 16:00
  - 15 min theory recap
  - 30min interaction
- 4 papers to be read in advance
  - Required to solve the moodle quiz (+0.25 Bonus!)
    - 5 questions per Paper → Total: 20 points
    - You need 16/20 to get the bonus
    - Not mandatory
    - Papers are also relevant for the exam
- Questions: kendallj@ethz.ch
- Slides on: Moodle and at end of Semester

Papers (on Moodle)

- 08.10.19 - Paper 1: Particle hydrogels based on hyaluronic acid building blocks.
- 29.10.19 – Paper 2: 3D Bioprinting of collagen to rebuild components of the human heart.
- 05.11.19 – Touch, Tension and Transduction – The Function and Regulation of Piezo Ion Channels.
- 03.12.19 – A Joint Coordinate System for the Clinical Description of Three-Dimensional Motions: Application to the knee.

Lecture recap

- Ceramics
- Metals/Metal alloys
- Polymers

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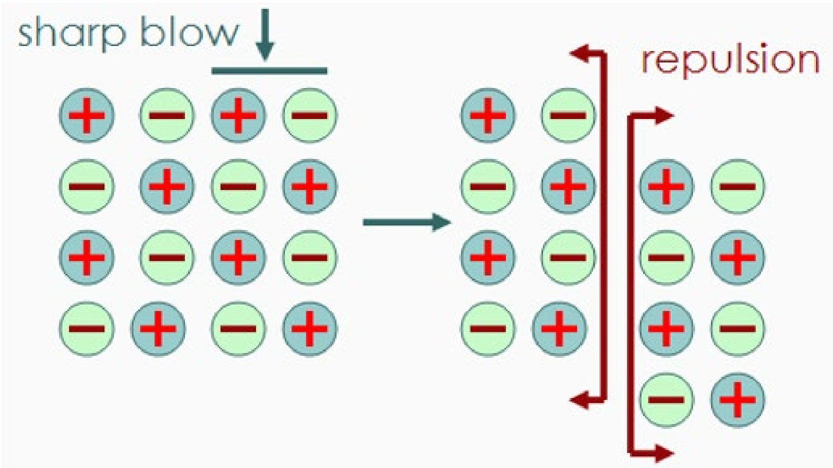
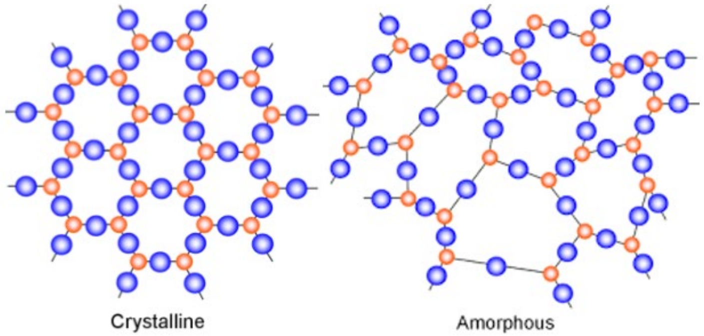
Biomaterials - Ceramics

- Pro
  - Biocompatible
  - No corrosion
  - Strong in compression
- Cons
  - Expensive
  - Brittle → catastrophic failure
  - Difficult to machine and shape

Biomaterials - Ceramics

- Ionic bonding
- No slip dislocation → brittle

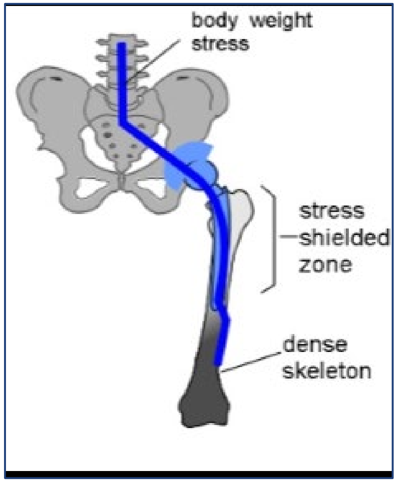




- Crystalline: ordered
- Amorphous: random

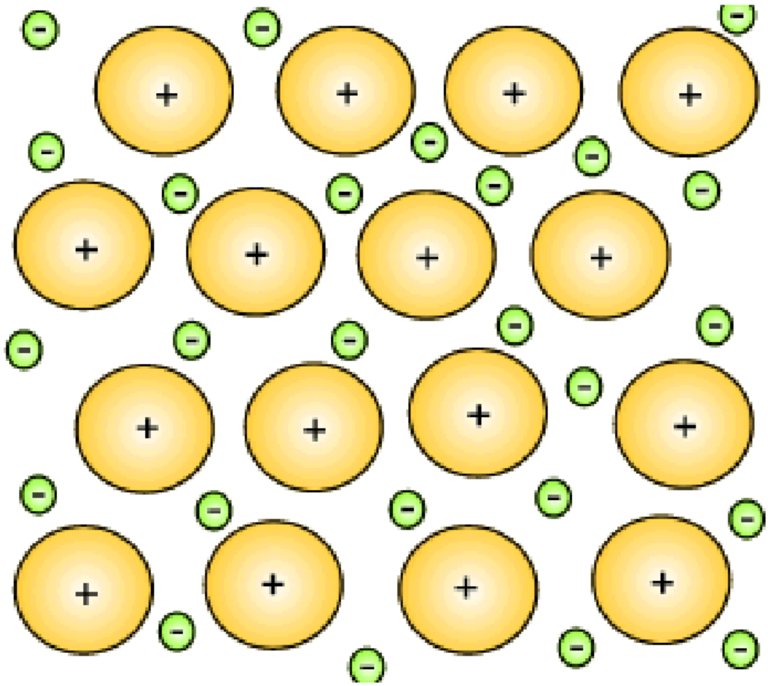
Biomaterials - Metals

- Pros
  - Ductile (=deformable)
  - Strong
  - Resistance to fracture
  - Tough
  - Ease of manufacturing
- Cons
  - Form oxides upon electron loss→Corrosion
  - **Stress shielding**
  - Debris
  - Metal ions
  - Thermally and electrically conductive



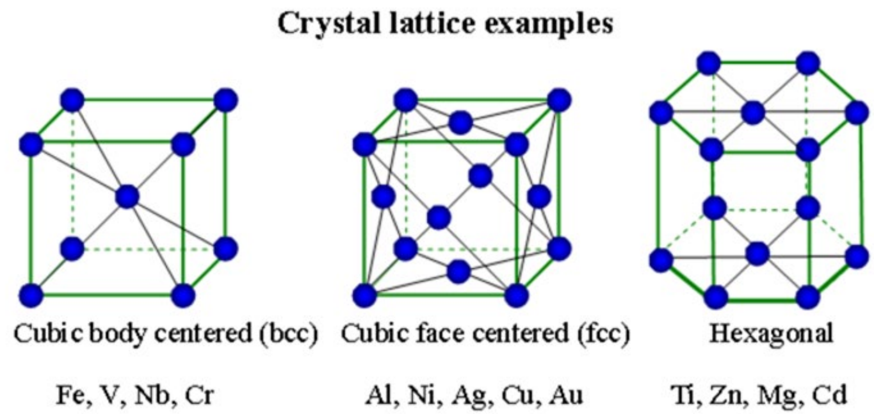
Biomaterials - Metals

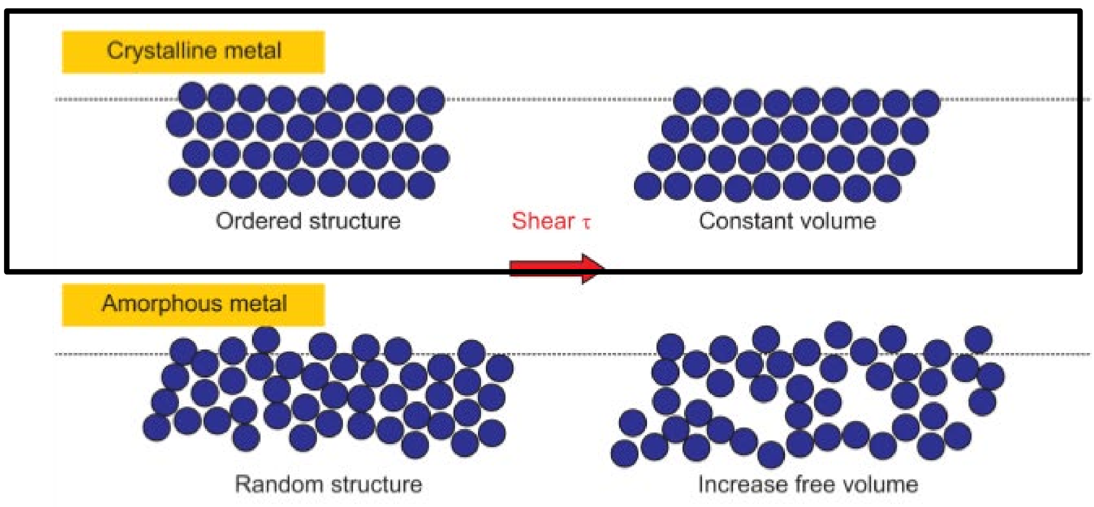
- Delocalized electrons

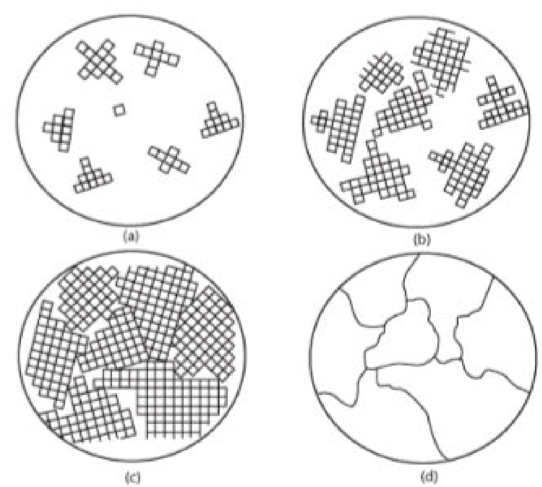


Biomaterials - Metals

- Delocalized electrons
- Metal Lattices
- Cristallinity

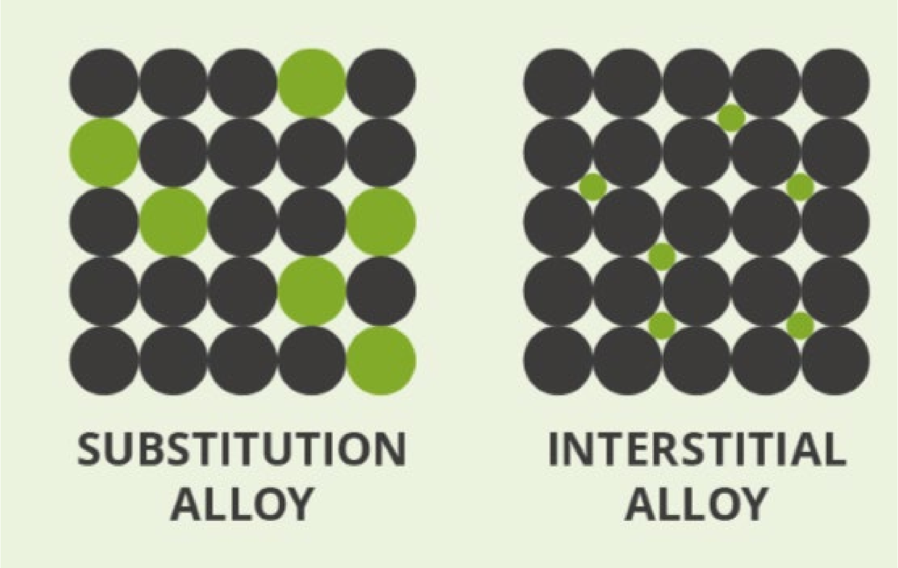






Biomaterials – Metal Alloys

- Combine properties of different metals
- Examples: Carbon + Iron
- 3 Main types used: Stainless steels(=iron-base alloys), cobalt-base alloy, titanium-base alloys

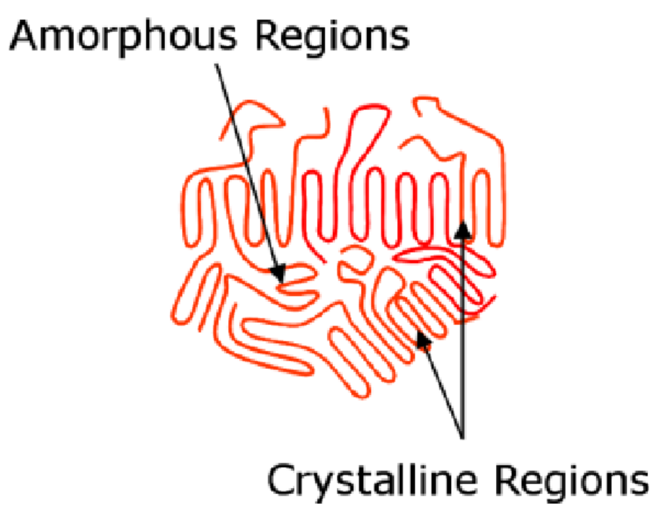


Biomaterials - Polymers

- Pros
  - Ease of manufacturing
  - Biocompatible and biodegradable
  - Flexible
  - Tunable
  - Low friction
  - Inert
- Cons
  - Toxic degradation byproducts
  - Sterilization
  - Weak

Biomaterials - Polymers

- Crystalline
- Amorphous
- Semicrystalline: Consists of both

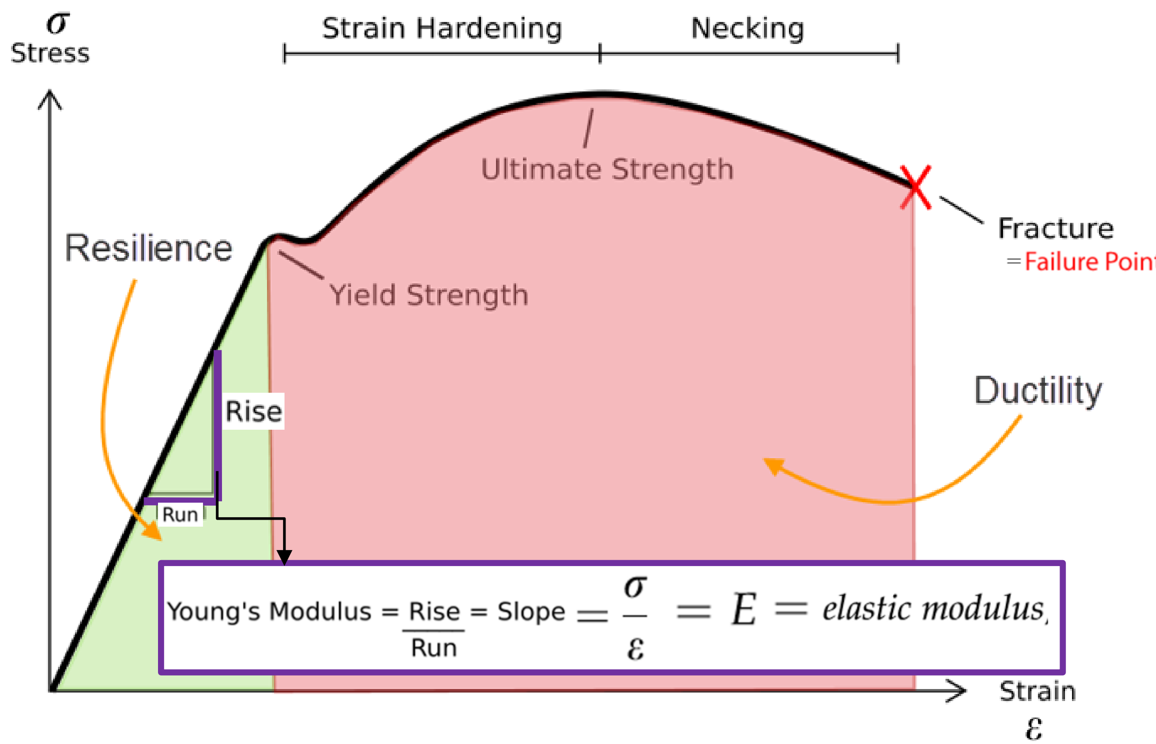


Review

	Ceramics	Metals	Polymers
Pros	Biocompatible, No corrosion, Strong in compression	Ductile, Strong, Tough, ease to manufacturing, high resistance to fracture	Ease of manufacturing, biocompatible, biodegradable, flexible, tunable, low friction, inert
Contras	Expensive, Brittle, Difficult to machine and shape	Form oxides upon electron loss, stress shielding, Debris, Metal ions, thermally and electrically conductive	Toxic degradation byproducts, sterilization, weak

Stress – Strain Curve

- **Strength:** Measures how much stress the material can handle before permanent deformation or fracture
- **Yield Strength:** The Stress at which material begins to deform plastically (=non-linear)
- **Ultimate strength:** Maximum stress before failure occurs.
- **Stiffness(E):** Resistance of the material to elastic deformation.
- **Toughness:** How well the material can resist fracturing when force is applied. Requires strength and ductility.



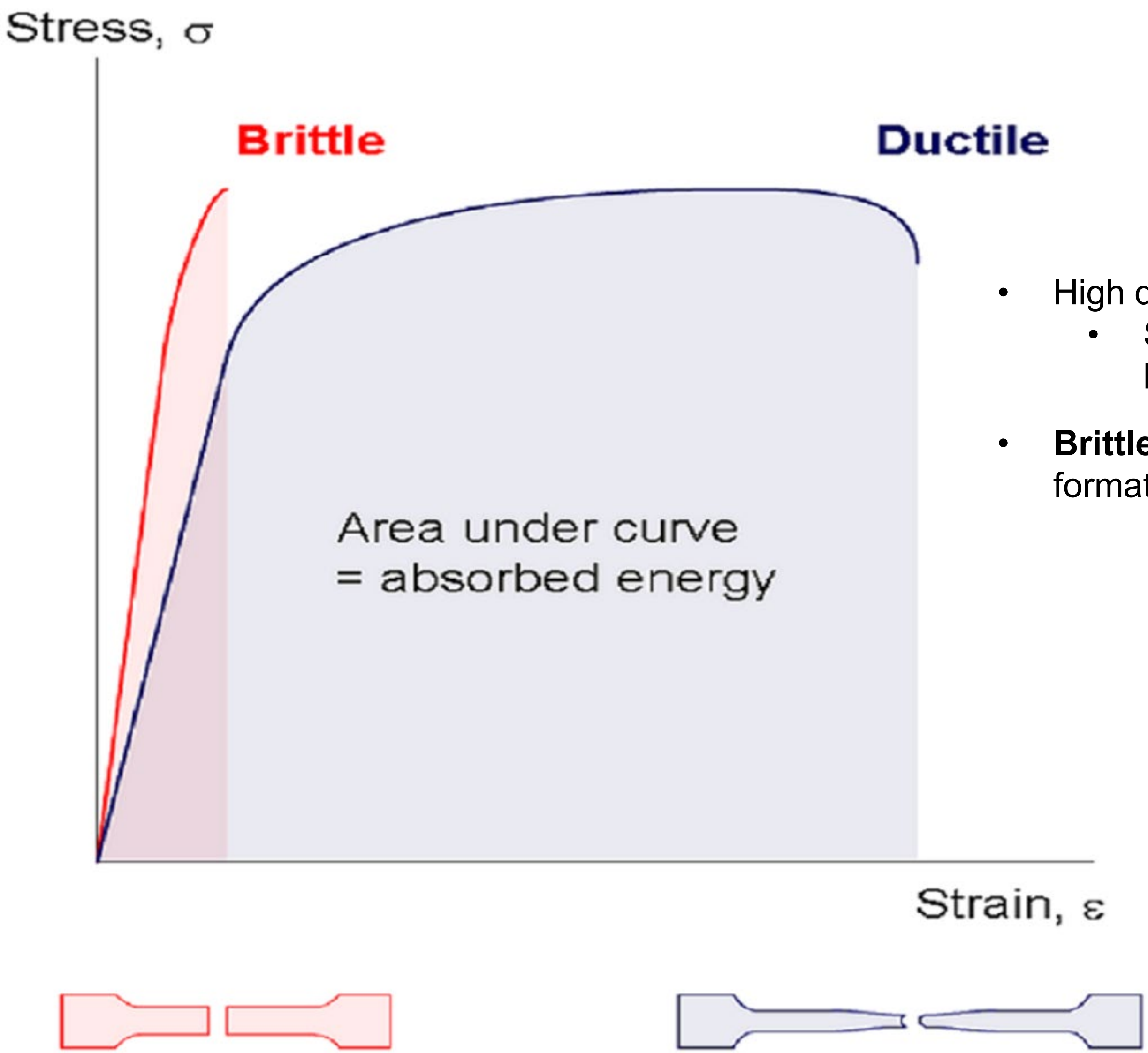
$$\text{Young's Modulus} = \frac{\text{Rise}}{\text{Run}} = \text{Slope} = \frac{\sigma}{\varepsilon} = E = \textit{elastic modulus}$$

- **Resilience:** Ability of the material to spring back into shape; elasticity
- **Ductility:** Ability of a material to undergo permanent deformation through elongation

Stress $\sigma = \frac{F}{A}$ [Pa]

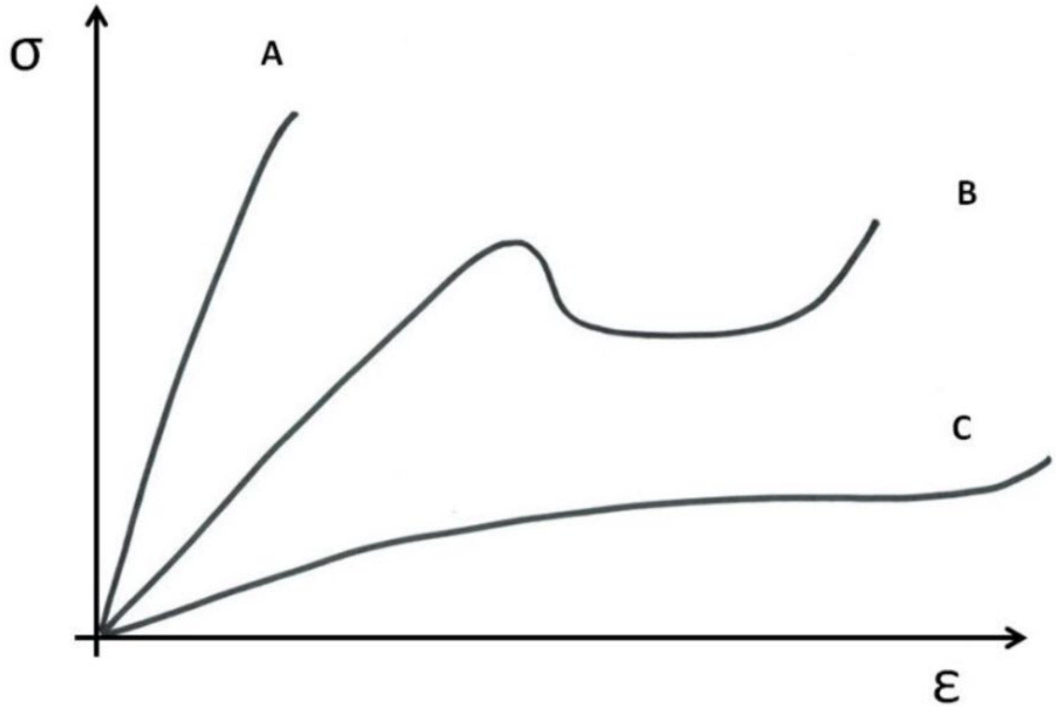
Strain $\varepsilon = \frac{\Delta \ell}{\ell}$

Stress - Strain Curves



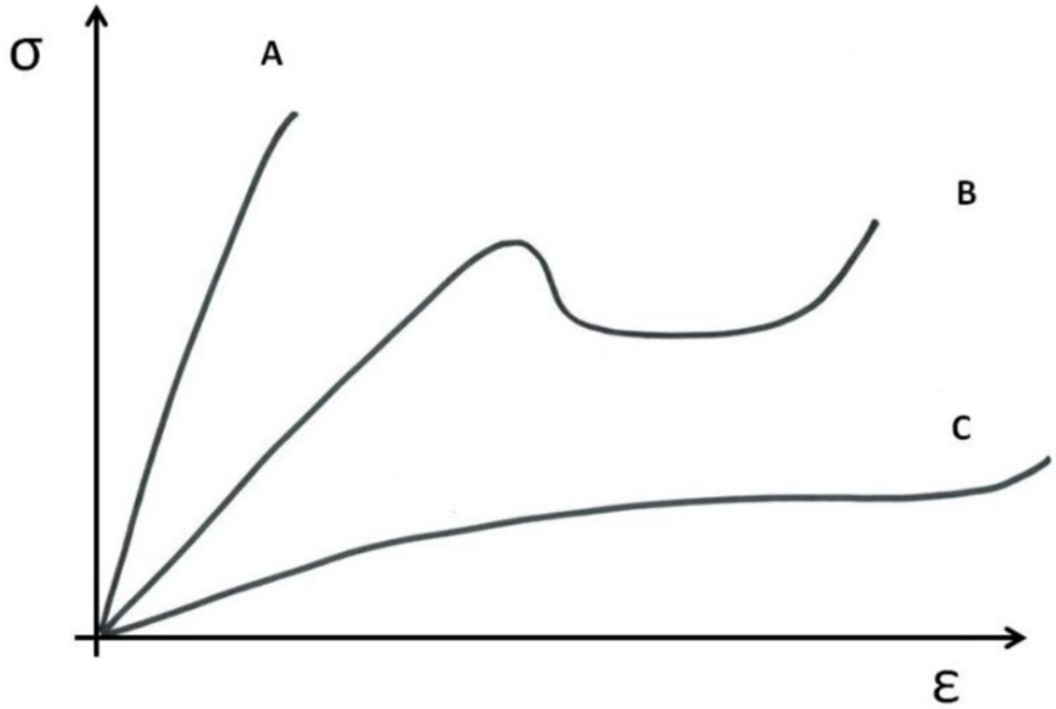
- High ductility → «tough»
  - Shows plastic deformation before fracture
- **Brittle:** There's hardly any formation before fracture

Stress – Strain Curve



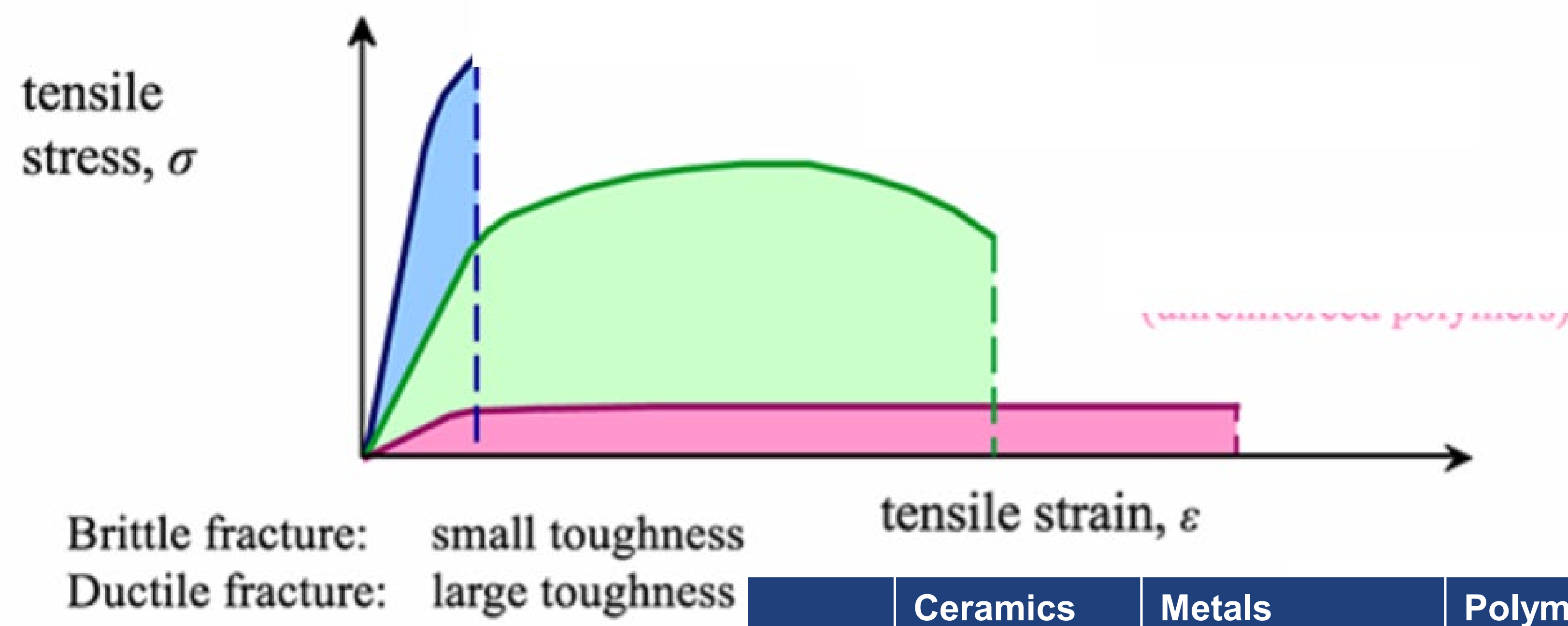
a) Which curves correspond to stiffer materials?
b) Which curve represent a non-stiff material?

Stress – Strain Curve



a) Which curves correspond to stiffer materials?
→A,B
b) Which curve represent a non-stiff material?
→C

Stress – Strain of Biomaterials



Which curve represents:
a)Ceramics
b)Metals
c)Polymers

	Ceramics	Metals	Polymers
Pros	Strong in compression	Ductile, Strong, Tough	Flexible, tunable, low friction,
Contras	Brittle, Difficult to machine and shape	Stress shielding	weak

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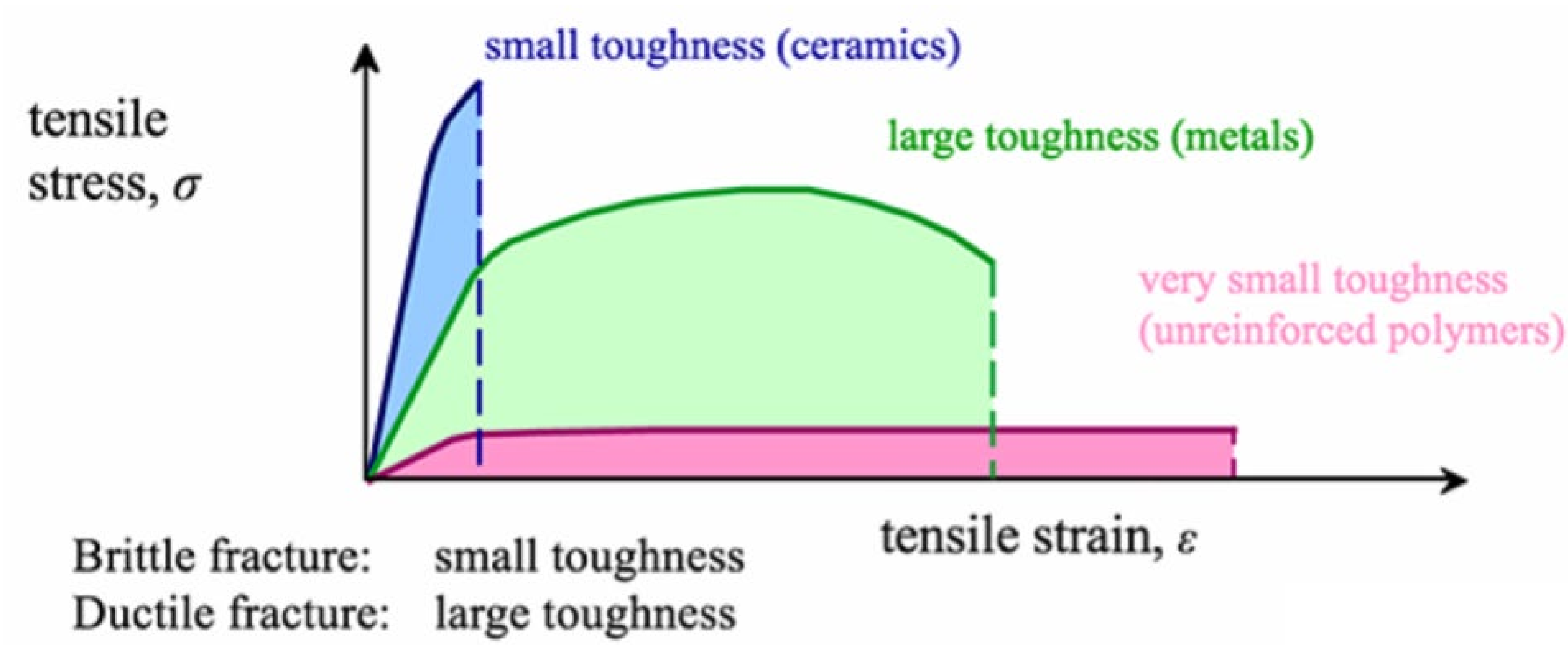
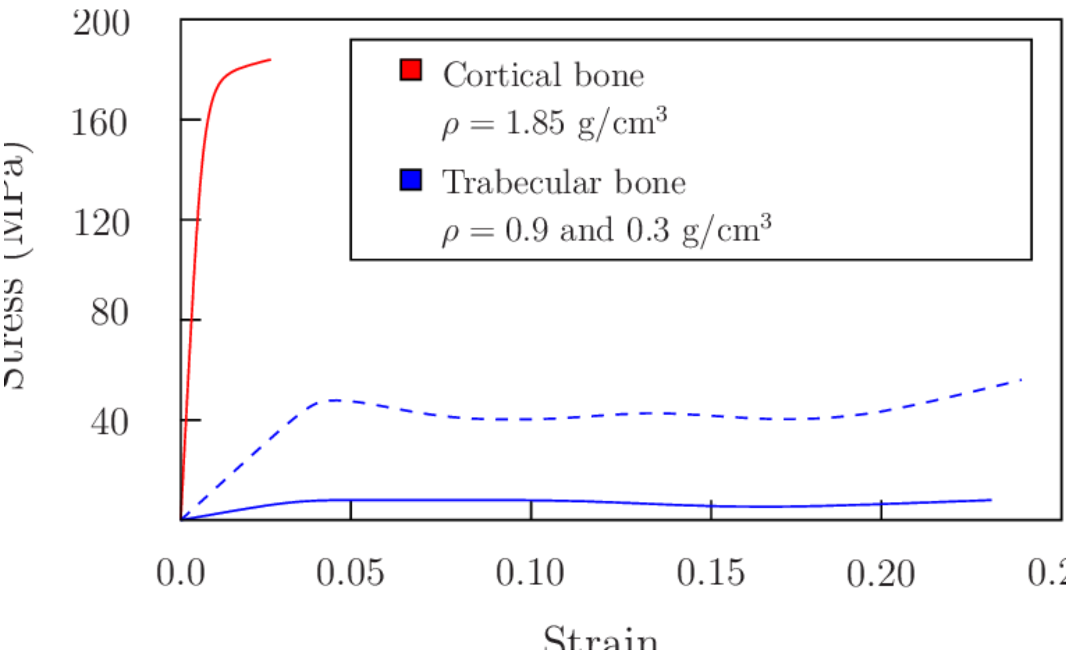
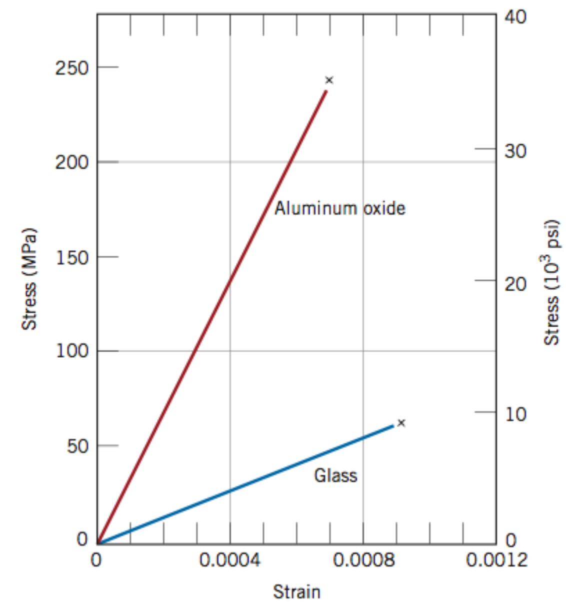
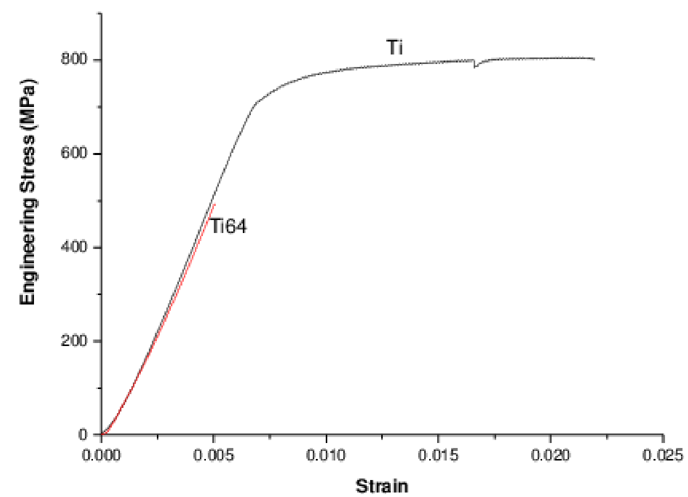
Strain of Biomaterials



Strain of Biomaterials







Any Questions?