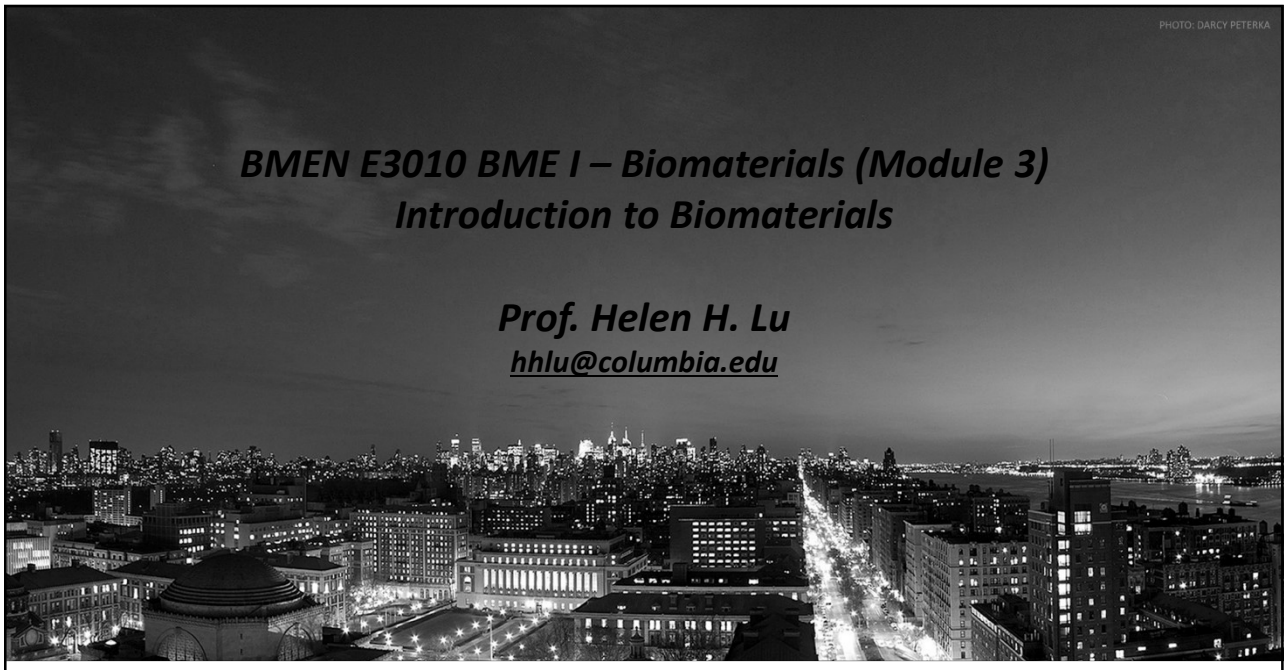
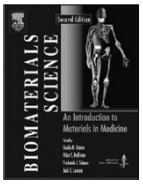


BMEN E3010 BME I – Biomaterials (Module 3)
Introduction to Biomaterials

Prof. Helen H. Lu
hhlu@columbia.edu

Useful Information



Office hours: Tues 12-1pm (in-person), Wed 1-2pm (zoom)
or by appt. hhlu@columbia.edu

TA: Hannah Childs, h.childs@columbia.edu
Office hours – Mon 11:30am-12:30pm, Thurs 1-2pm

Reference Texts (PDF available on courseworks)

1. **B.D. Ratner et al. (Eds.), *Biomaterials Science: An Introduction to Materials in Medicine*, Academic Press, San Diego, 2014.**

2. **W. D. Callister, Material Science and Engineering, an Introduction, John Wiley & Sons, 7th Edition, 2008.**

3. **J. Black, Biological Performance of Materials, 4th Edition, Marcel Dekker, New York.**

Biomaterials Module

Objective

- **Introduction to Biomaterials**
- **Understanding of factors important in the *design* and *selection* of biomaterials for medical applications**

Focus Areas (4)

- **Structure-Property Relationships of Biomaterials**
- **Biocompatibility - Host Response to Biomaterial**
- **Types of Biomaterials**
- **Biomaterial Selection and Example Applications**

WELCOME!

Module Outline (8 Sessions)

- **S0 (11/12): *Hwk-1 assigned, due 11/14***
- **S1 (11/15): Biomaterials-Structure/Function**
- **S2 (11/17): Structure-Function/Biocompatibility**
  Hwk-2 (S1-S4) assigned, due 12/01
- **S3 (11/22): Biomaterials – Metals**
- **S4 (11/29): Biomaterials – Polymers**
- **S5 (12/01): Biomaterials – Ceramics**
- **S6 (12/06): Current Trends in Biomaterials**
- **S7 (12/08): Review**
- **S8 (12/13): Module Exam**

BIOMATERIALS

- What is it?
- Why is it needed?
- Where is it used?
- What happens to it in the body?
- How and how well does it work?

OUTLINE

BIOMATERIALS

- Definition
- Clinical Significance
- Biocompatibility
- Biofunctionality
- Types of Biomaterials
- Tissue Engineering

Biomaterials: Old and New

3000 BC - 1900 AD
- **Surgical Sutures/Dressings: Plant, Mineral, Animal, Human Sources (e.g. "Catgut")**

Prior to 700 BC
- **Acupuncture: Stone, Metal**

16th Century
- **Contact Lens (Da Vinci): Glass**

19th Century
- **Artificial Cornea: Glass, Crystal, Celluloid**

19th Century
- **Dental Restoratives: Silver Alloys**

Science, 2002

BIOMATERIALS: A little bit of history

Definitions (version 1)

A biomaterial is a non-viable material used in a medical device, not intended to interact with biological systems

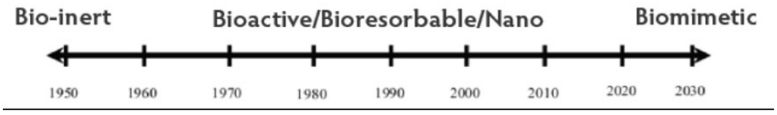
Williams DF, 1987

A biomaterial is a synthetic material used to replace part of a living system or to function in intimate contact with living tissue

Park JB et al, 1992

BIOMATERIALS

fr. KWL

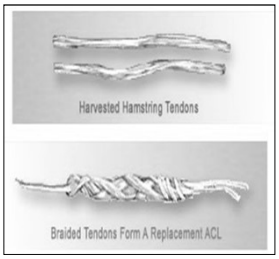


A biomaterial is a viable or non viable material that interacts with the biological environment, and its function is to diagnose, treat, support, augment or replace part or all of a living system

- **Functional**
- **Biocompatible**
- **Non-carcinogenic**
- **Non-toxic**
- **Long term functionality**

CLINICAL NEED FOR BIOMATERIALS

- **Biological Grafts**
  - **Autografts**
  - **Allografts**
  - **Xenografts**
- **Autograft is the clinically preferred grafting material**
- **Disadvantages**
  - **Limited in supply**
  - **Donor site morbidity**
  - **Additional surgery**
  - **Structural constraints**



Unmet Clinical Need Drives interest in biomaterials and tissue engineering

Biomaterials – Impact on Society

- **Increased Life Expectancy**
  - In U.S., population ≥ 65 increased 11-fold from 1900 to 1994, to 33.2 million in 2019, 54.1M ≥ 65 in US, 727M worldwide (9.3%)
  - Worldwide – 2017, 137M ≥80 years old, expect to reach 425M by 2050 (UN)
  - Baby Boomers: 65 at 2011, 70.6 million (2019 data)
- **Aging yet still physically active population**
  - AAOS – increase in sports injuries (400%, 1991-98)
  - High school athletes – 2M injuries per year (2010)
- **Diseases and Age-related Biological Changes**
  (Cardiac diseases, arthritis, osteoporosis, cancer)
- **U.S. Market for Biomaterials**
  - $1 billion annually - orthopedic (2004)
  - $10 billion annually – cardiovascular (2003)
  - $74.5 billion market revenue for devices (2005)
  - >$231 billion by 2024

CLINICAL APPLICATIONS

Where are Biomaterials used?

- **Medical and surgical devices**
- **Tissue engineering**
- **Commodity medical products**
- **Apparatus for pharmaceuticals**
- **Products for cell and molecular biology**
- **Biosensors and Diagnostics**

Science, vol. 295, 2002

BIOMATERIALS

What happens to it in the body?

Biocompatibility
Biofunctionality

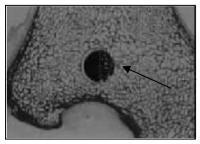
- **Interaction between materials and living systems**

- **Host Response**
  - **Systemic and local biological response**

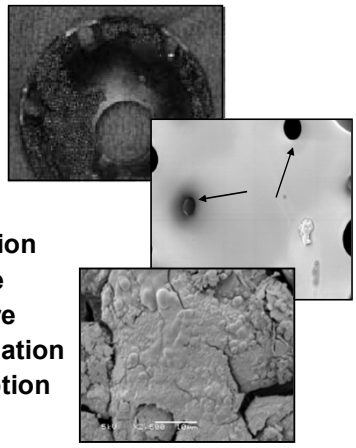
- **Material Response**
  - **Response of material to living systems**

BIOCOMPATIBILITY

- **Biocompatibility is the ability of a material to perform with an appropriate host response in a specific application** *(Williams, 1987)*
  - **Inflammation**
  - **Wound Healing Response**
  - **Allergic Response**
  - **Infection**



BIOFUNCTIONALITY



Host Response

- Initial Events
- Inflammation
- Immunological
- Enzymatic/biochemical
- Bacterial Infection
- Neoplasia (cancer)

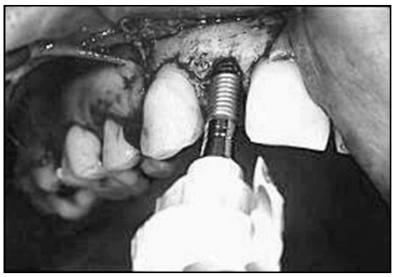
- Corrosion
- Fatigue
- Fracture
- Degradation
- Adsorption

BIOCOMPATIBILITY

Material Response

TYPES OF BIOMATERIALS

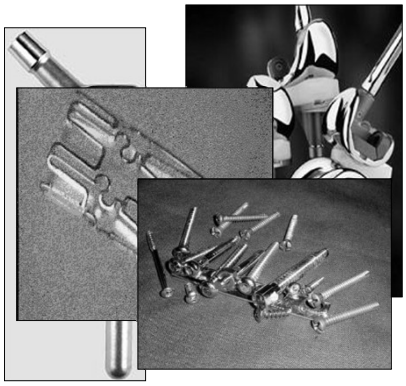
- Metals
- Polymers
- Ceramics
- Glasses
- Natural Materials
- Composites



BIOMATERIALS: Metals

Applications

- Load bearing conditions
- Joint replacement
- Fixation device, cardiovascular



Advantages

- Controllable design
- Biocompatible
- Blood-compatible

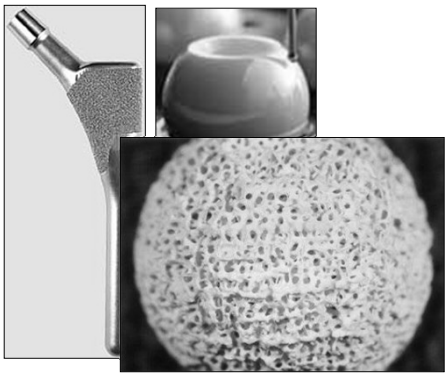
Limitations

- Stress Shielding
- Corrosion
- Fatigue and wear
- Lifetime

BIOMATERIALS: Ceramics

Applications

- Load bearing conditions
- Joint replacement
- Orthopedic



Advantages

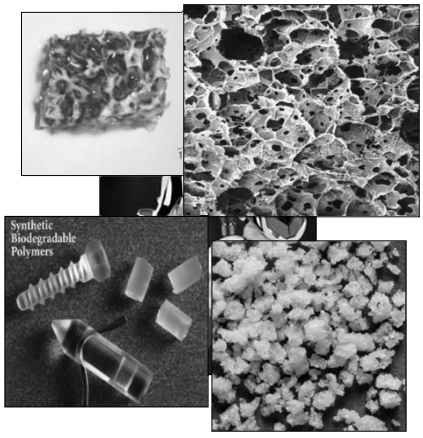
- Controllable design
- Biocompatible/Inert
- Lubrication
- Biomimetic

Limitations

- Stress Shielding
- Low fracture toughness

BIOMATERIALS: Polymers

Polyesters - sutures
Polyanhydrides-drug delivery
Polycaprolactone – drug delivery



Advantages

- Controllable design
- Biocompatible
- Biodegradable

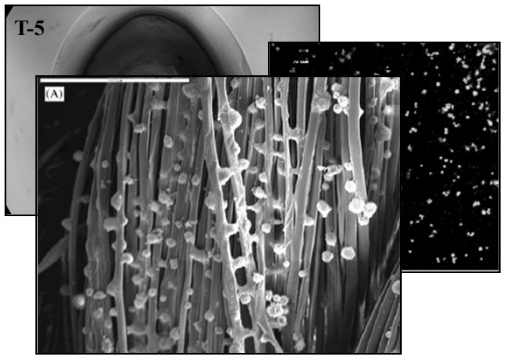
Limitations

- Mismatch in properties
- Degradation products

BIOMATERIALS: Biological Materials

Applications

- Wound dressing
- Drug Delivery
- Tissue Engineering Research



Advantages

- Biomimetic
- Biocompatible

Limitations

- Non-economical
- Inferior mechanical properties
- Limited supply

BIOMATERIALS - Applications

Ratner, p.3

TABLE 1 Some Applications of Synthetic Materials and Modified Natural Materials in Medicine

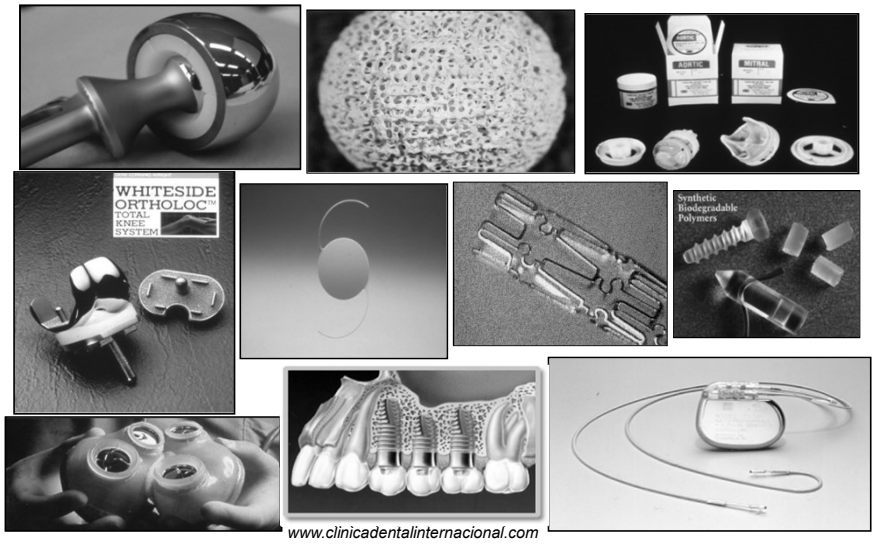
Application	Types of materials
Skeletal system	
Joint replacements (hip, knee)	Titanium, Ti–Al–V alloy, stainless steel, polyethylene
Bone plate for fracture fixation	Stainless steel, cobalt–chromium alloy
Bone cement	Poly(methyl methacrylate)
Bony defect repair	Hydroxylapatite
Artificial tendon and ligament	Teflon, Dacron
Dental implant for tooth fixation	Titanium, alumina, calcium phosphate
Cardiovascular system	
Blood vessel prosthesis	Dacron, Teflon, polyurethane
Heart valve	Reprocessed tissue, stainless steel, carbon
Catheter	Silicone rubber, Teflon, polyurethane
Organs	
Artificial heart	Polyurethane
Skin repair template	Silicone–collagen composite
Artificial kidney (hemodialyzer)	Cellulose, polyacrylonitrile
Heart–Lung machine	Silicone rubber
Senses	
Cochlear replacement	Platinum electrodes
Intraocular lens	Poly(methyl methacrylate), silicone rubber, hydrogel
Contact lens	Silicone–acrylate, hydrogel
Corneal bandage	Collagen, hydrogel

Module 3: Biomaterials – Everyday Materials and Beyond

- **Metals**
- **Ceramic**
- **Polymer**

- Structure-Function

- Design across length scales: nano to macro



www.clinicadentalinternacional.com

SUMMARY I

Biomaterial

- viable or non-viable material
- interacts with the biological environment
- functional

Focus Areas (4)

- Structure-Property Relationships of Materials
- Biocompatibility - Host Response to Biomaterial
- Types of Biomaterial
- Current Trends in Biomaterials

Lec 2 - Materials Science: Structure-Function

- Structure and Properties
- Bonding Energy in Solids
  - Definitions
  - Relevance in material properties
  - Biomaterials used in Medicine
- Interatomic Bonds (Primary vs. Secondary)
  - Primary: Ionic, Covalent and Metallic bonding
  - Secondary bonding (van der Waals and hydrogen bonding)
- Bonding Energy in Solids
  - Definitions
  - Relevance in to Biomaterials