Lec.2 Classification of Biomaterials

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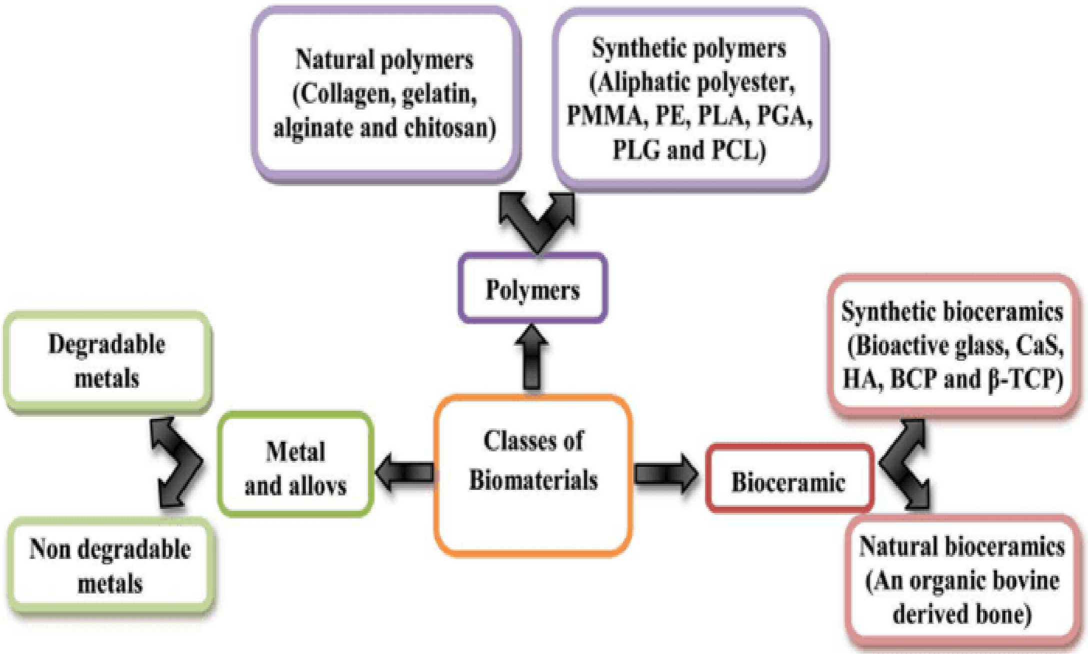
Classification of Biomaterials

- Biomaterials are materials that are designed to interact with biological systems. They can be classified based on their origin, properties, and applications. Here's a breakdown of common classification methods:

- **Natural Biomaterials:** These are derived from living organisms.
  - **Animal-derived:** Collagen, bone, silk, chitin, etc.
  - **Plant-derived:** Cellulose, starch, alginate, etc.

- **Synthetic Biomaterials:** These are man-made materials.
  - **Polymers:** Polyethylene, polypropylene, polyesters, etc.
  - **Ceramics:** Alumina, zirconia, hydroxyapatite, etc.
  - **Metals:** Titanium, stainless steel, cobalt-chromium alloys, etc.

- **Hybrid Biomaterials:** These combine natural and synthetic materials to leverage their respective advantages.



Polymers

- There are a large number of polymeric materials that have been used as implants or part of implant systems. The polymeric systems include acrylics, polyamides, polyesters, polyethylene, silicon rubber, polyurethane, and a number of reprocessed biological materials.

- Some of the applications include the use of membranes of ethylene-vinyl-acetate (EVA) copolymer for controlled release and the use of poly-glycolic acid for use as a resorbable suture material. Some other typical biomedical polymeric materials applications include: artificial heart, kidney, liver, pancreas, bladder, bone cement, catheters, contact lenses, cornea and eye-lens replacements, external and internal ear repairs, heart valves, cardiac assist devices, implantable pumps, joint replacements, pacemaker, encapsulations, soft-tissue replacement, artificial blood vessels, artificial skin, and sutures.

2- Metals

- The metallic systems most frequently used in the body are:
- (a) Iron-base alloys of the 316L stainless steel
- (b) Titanium and titanium-base alloys, such as
- (i)Ti-6% Al-4%V, and commercially pure ≥ 98.9%
- (ii) Ti-Ni (55% Ni and 45% Ti)
- (c) Cobalt base alloys of four types
- (i) Cr (27-30%), Mo (5-7%), Ni (2-5%)
- (ii) Cr (19-21%), Ni (9-11%), W (14-16%)
- (iii) Cr (18-22%), Fe (4-6%), Ni (15-25%), W (3-4%)
- (iv)Cr (19-20%), Mo (9-10%), Ni (33-37%)
- The most commonly used implant metals are the 316L stainless steels, Ti-6%-4%V, and Cobalt base alloys of type "i" and "ii". Other metal systems being investigated include Cobalt-base alloys of type "iii" and "iv", and Niobium and shape memory alloys, of which (Ti 45% - 55%Ni) is receiving most attention. Further details of metallic biomedical materials will be given later.

Ceramics

The most frequently used ceramic implant materials include aluminum oxides, calcium phosphates, and apatites and graphite. Glasses have also been developed for medical applications. The use of ceramics was motivated by:

(i) their inertness in the body,
(ii) their formability into a variety of shapes and porosities,
(iii) their high compressive strength, and
(iv) some cases their excellent wear characteristics.

Selected applications of ceramics include:

- (a) hip prostheses,
- (b) artificial knees,
- (c) bone grafts,
- (d) a variety of tissues in growth related applications in
- (d.1) orthopedics
- (d.2) dentistry,
- (d.3) heart valves.
- Applications of ceramics are in some cases limited by their generally poor mechanical properties: (a) in tension; (b) load bearing, implant devices that are to be subjected to significant tensile stresses must be designed and manufactured with great care if ceramics are to be safely used

4- Composite Materials

- Composite materials have been extensively used in dentistry and prosthesis designers are now incorporating these materials into other applications. Typically, a matrix of ultrahigh-molecular-weight polyethylene (UHMWPE) is reinforced with carbon fibers. These carbon fibers are made by pyrolizing acrylic fibers to obtain oriented graphitic structure of high tensile strength and high modulus of elasticity. The carbon fibers are 6- 15□m in diameter, and they are randomly oriented in the matrix. In order for the high modulus property of the reinforcing fibers to strengthen the matrix, a sufficient interfacial bond between the fiber and matrix must be achieved during the manufacturing process. This fiber reinforced composite can then be used to make a variety of implants such as intra-medullary rods and artificial joints. Since the mechanical properties of these composites with the proportion of carbon fibers in the composites, it is possible to modify the material design flexibility to suit the ultimate design of prostheses. Composites have unique properties and are usually stronger than any of the single materials from which they are made. Workers in this field have taken advantages of this fact and applied it to some difficult problems where tissue in-growth is necessary.
- Examples:
- Deposited Al2O3 onto carbon;
- Carbon / PTFE;
- Al2O3 / PTFE;
- PLA-coated Carbon fibers.

5-Biodegradable Materials

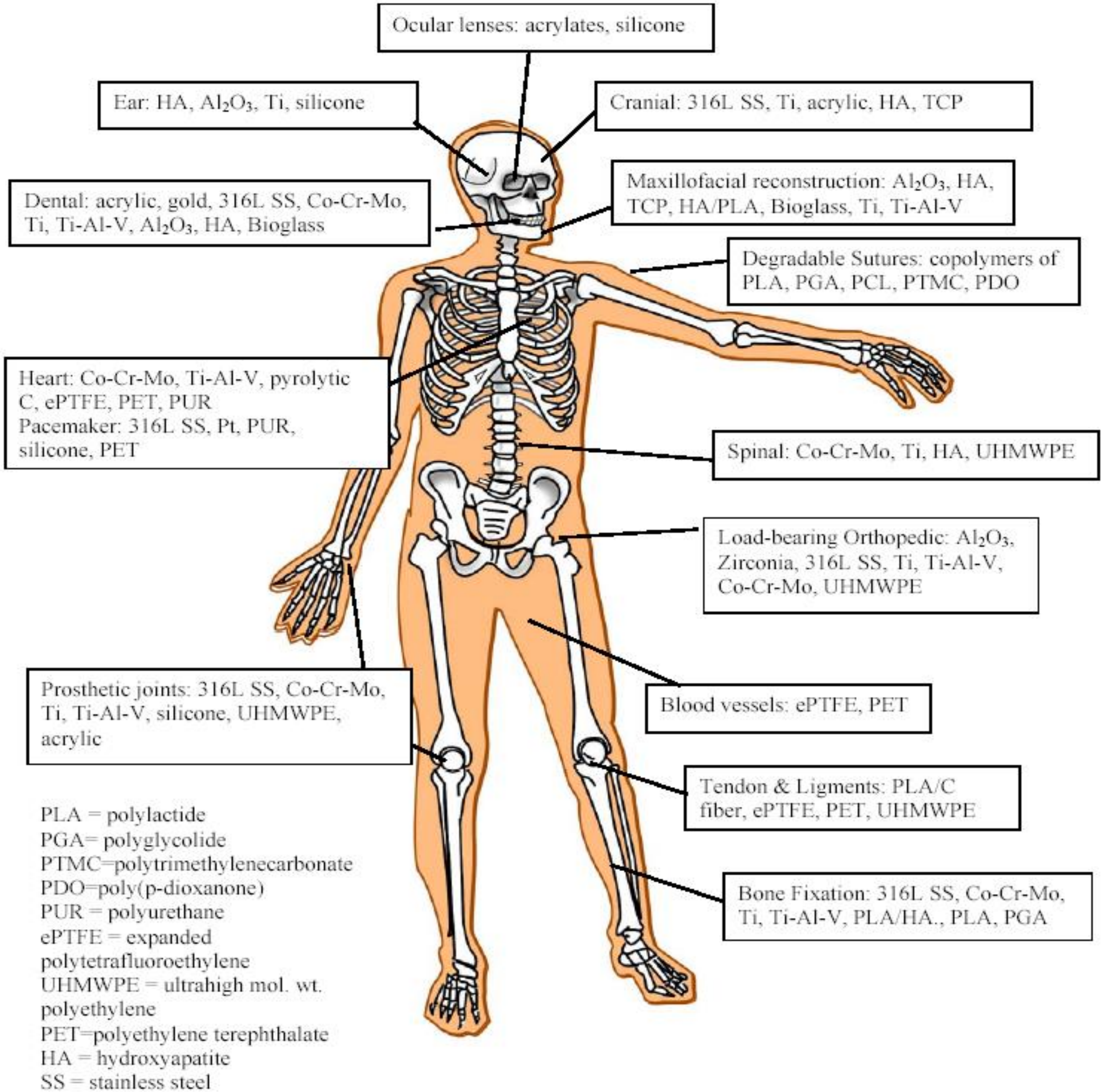
- Another class of materials that is receiving increased attention is biodegradable materials. Generally, when a material degrades in the body its properties change from their original values leading to altered and less desirable performance. It is possible, however, to design into an implant's performance the controlled degradation of a material, such that natural tissue replaces the prosthesis and its function.

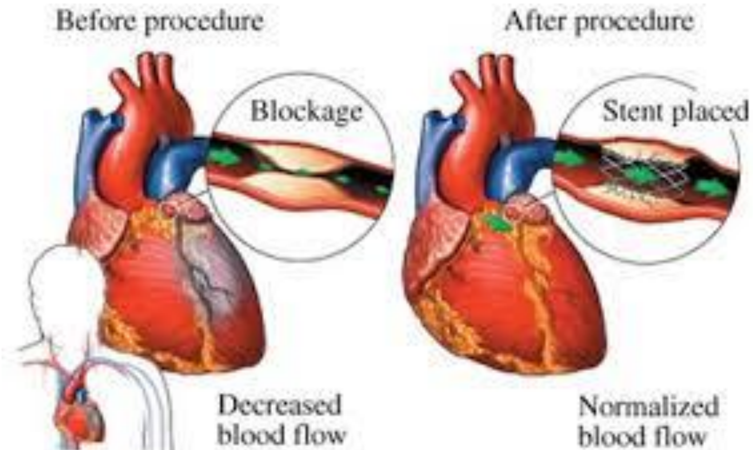
- Examples include: Suture material that hold a wound together but resorb in the body as the wound heals and gains strength. Another application of these materials occurs when they are used to encourage natural tissue to grow. Certain wound dressings and ceramic bone augmentation materials encourage tissue to grow into them by providing a "scaffold". The scaffold material may or may not resorb over a period of time but in each case, natural tissue has grown into the space, then by restoring natural function. One final application of biodegradable materials is in drug therapy, where it is possible to chemically bond certain drugs to the biodegradable material, when these materials are placed within the body the drug is released as the material degrades, thereby providing a localized, sustained release of drugs over a predictable period of time.

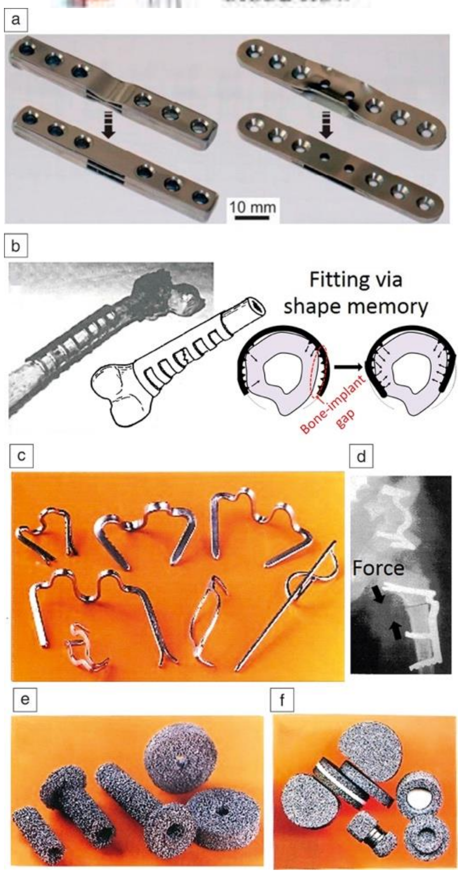
Materials for Use in the Body

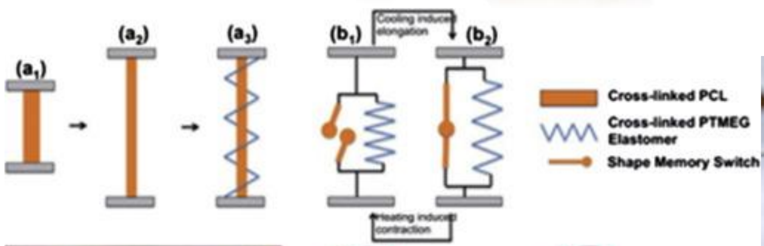
Materials	Advantages	Disadvantages	Examples
Polymers (nylon, silicon Rubber, polyester, PTFE, etc)	Resilient Easy to Fabricate	Not strong Deforms with time May degrade	Blood vessels, Sutures, ear, nose, Soft tissues
Metals (Ti and its alloys Co-Cr alloys, stainless Steels)	Strong Tough ductile	May corrode, dense, Difficult to make	Joint replacement, Bone plates and Screws, dental root Implant, pacer, and suture
Ceramics (Aluminum Oxide, calcium phosphates, including hydroxyapatite carbon)	Very biocompatible Inert strong in compression	Difficult to make Brittle Not resilient	Dental coating Orthopedic implants Femoral head of hip
Composites (Carbon-carbon, wire Or fiber reinforced Bone cement)	Compression strong	Difficult to make	Joint implants Heart valves

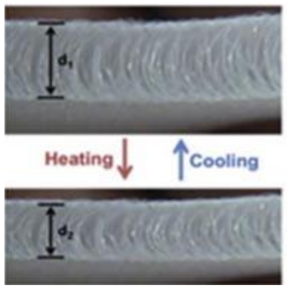
BIOMATERIALS TYPES AND IMPLEMENTATIONS

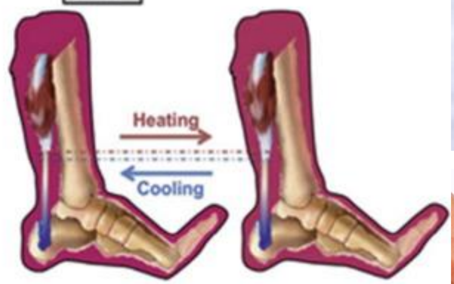



Before procedure
After procedure
Blockage
Stent placed
Decreased blood flow
Normalized blood flow


a
10 mm
b
Fitting via shape memory
Bone-implant gap
c
d
Force
e
f


(a1)
(a2)
(a3)
(b1)
(b2)
Cross-linked PCL
Cross-linked PTMEG Elastomer
Shape Memory Switch


Heating
Cooling


Heating
Cooling

Success and Failure are seen with Biomaterials and Medical Devices

Most biomaterials and medical devices perform satisfactorily, improving the quality of life for the recipient or saving lives. Still, man-made constructs are never perfect. Manufactured devices have a failure rate. Also, all humans differ in genetics, gender, body chemistries, living environment, and physical activity. Furthermore, physicians also differ in their "talent" for implanting devices.

The other side to the medical device success story is that there are problems, compromises and complications that occur with medical devices.

- Central issues for the biomaterials scientist, manufacturer, patient, physician, and attorney are:

1. what represents good design;
2. Who should be responsible when devices perform with an inappropriate host response;
3. What is the cost/risk or cost/benefit ratio for the implant or therapy?

- These characteristics of biomaterial science-multidisciplinary, multi-material, need driven, substantial market, and risk-benefit, color the field of biomaterials.

APPLICATION OF BIOMATERIALS

Skeletal System

Knee implant

Hip implant

Shoulder implant

Ankle implant

Joint replacement

- **Purpose** : To replace dysfunctional/damaged joint organs
- **Materials** : Titanium (Ti) & its alloys, stainless steel (SS) & its alloys, polyethylene (PE), UHMWPE, alumina , etc
- **Required property** : Able to withstand high load bearing, bioactive, light-weight

APPLICATION OF BIOMATERIALS

Skeletal System

Bone plate

- **Purpose** : To hold and to assist remodeling of two broken/fractured bones
- **Materials** : Ti & its alloys, SS & its alloys, cobalt-chromium (Co-Cr) & its alloys, etc
- **Required property** : Able to withstand load bearing

APPLICATION OF BIOMATERIALS

Oral System

Dental implant

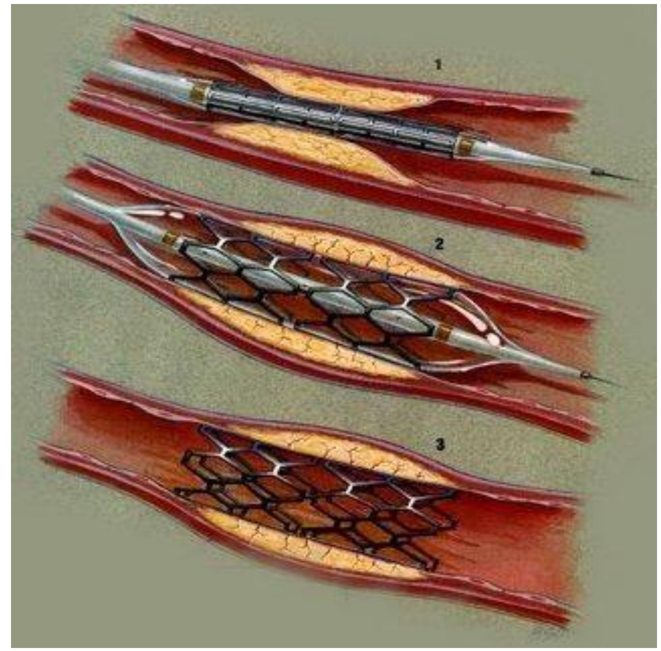
Dental implant

- **Purpose** : To hold artificial tooth in replacing dysfunctional/damaged tooth
- **Materials** : Ti & its alloys, SS & its alloys, alumina, etc
- **Required property** : Able to withstand high occlusion load, bioactive, antibacterial

Application of Biomaterials

Cardiovascular System

Balloon stent system

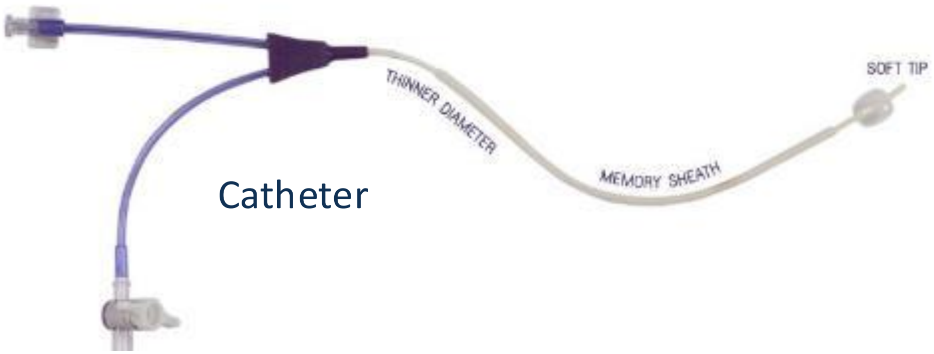


Stent

- **Purpose** : To remove blood clot inside the blood vessel and to support weak blood vessel
- **Materials** : SS & its alloys, Teflon, Co-Cr & its alloys, etc
- **Required property** : Able to deploy, hydrophobic, adequate mechanical strength

Application of Biomaterials

Cardiovascular System



Catheter

Catheter

- **Materials** : Silicon rubber, Teflon, nylon, polyurethane (PU), latex, etc
- **Required property** : Flexible, hydrophobic

Pacemaker

Pacemaker casing

- **Materials** : Ti & its alloys, SS & its alloys, etc
- **Required property** : Light-weight, anti-corrode

Application of Biomaterials

Organ

Artificial heart

- **Purpose** : To replace dysfunctional/damaged heart
- **Materials** : Polyurethane

Artificial kidney

- **Purpose** : To replace dysfunctional/damaged kidney
- **Materials** : Cellulose, polyacrylonitrile

Artificial skin

- **Purpose** : For skin grafting and to induce regeneration of skin
- **Materials** : Silicone-collagen composite
- **Required property** : Flexible, low stiffness, biodegradable

Thank you for your Kind Attention