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Lecture 1
"Introduction to Biomaterials"

Introduction:

Materials Science is the investigation of the relationship between processing, structure, properties, and performance of material. These elements: properties, structure and composition, synthesis and processing, and performance and the strong interrelationship among them-that define the field of materials science and engineering.

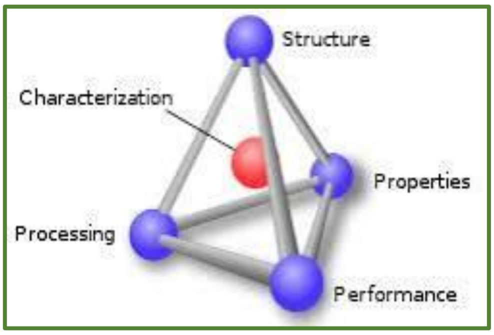


Figure (1): Materials optimization loop.

Biomaterials are those materials that come in contact with the human body closely or directly to support or substitute defective tissues. More specifically, any material with high biocompatibility whether it naturally occurs or man-made is considered biomaterial and can be used to substitute or support a part of the living tissue, organs, or other function of the body in a safe, reliably economical, and physiologically acceptable manner.

A variety of devices and materials are used in the treatment of disease or injury. Commonplace examples include suture needles, plates, teeth fillings, etc.

Term Definitions:

Biomaterial: A synthetic material used to make devices or implants to replace part of a living system or to function in intimate contact with living tissue.

Biological Material: A material that is produced by a biological system, including tissues, organs, blood, plasma, skin, serum, DNA, RNA, proteins, cells, hair, nail clippings, urine, saliva, and other body fluids.

Biocompatibility: Acceptance of an artificial implant by the surrounding tissues and by the body as a whole.

Requirements of Biomaterials

Biomaterials must have special properties that can be tailored to meet the needs of a particular application - this is an important concept to bear in mind. For example, a biomaterial must be biocompatible, non-carcinogenic, corrosion-resistant, and has low toxicity and wear.

However, depending on the application, differing requirements may arise. Sometimes these requirements can be completely opposite. In tissue engineering of the bone, for instance, the polymeric scaffold needs to be biodegradable so that as the cells generate their own extracellular matrices, the polymeric biomaterial will be completely replaced over time with the patient's own tissue. In the case of mechanical heart valves, on the other hand, we need materials that are biostable, wear-resistant, and which do not degrade with time.

Generally, the requirements of biomaterials can be grouped into **four broad categories**:

1. **Biocompatibility:** is the most important property of any biomaterial that will be implanted in the body, and it is affected by the mentioned features below in Figure 1. The material must not disturb or induce unwelcoming response from the host, but rather promote harmony and good tissue-implant integration. An initial burst of inflammatory response is expected and is sometimes considered essential in the healing process. However, prolonged inflammation is not desirable as it may indicate tissue necrosis or incompatibility.

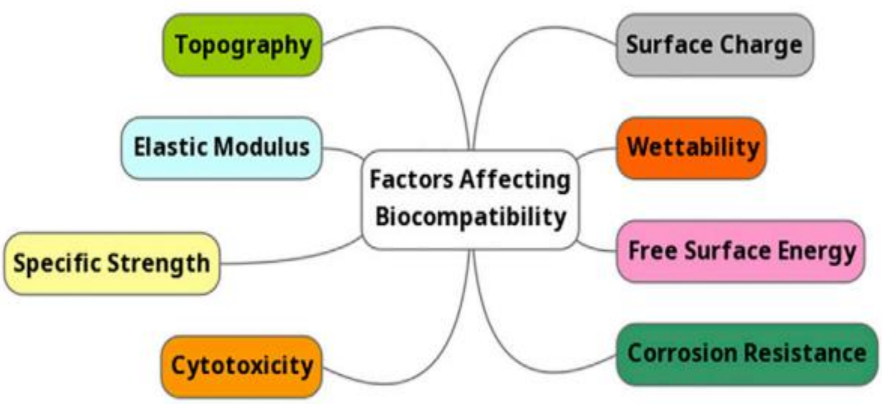
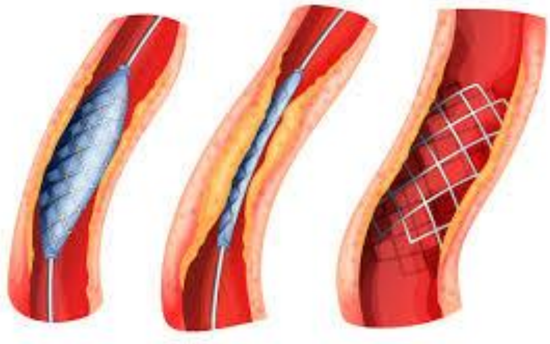


Figure (2): Factors Affecting the Biocompatibility of Implant.

2. **Sterilizability**: The material must be able to undergo sterilization. Sterilization techniques include ***gamma*, *gas (ethylene oxide (ETO))*** and ***steam autoclaving.*** Some polymers such as polyacetal will depolymerize and give off the toxic gas formaldehyde when subjected under high energy radiation by gamma. These polymers are thus best sterilized by ETO.

3. **Functionability:** The functionability of a medical device depends on the ability of the material to be shaped to suit a particular function. The material must therefore be able to be shaped economically using engineering fabrication processes. For example, the success of the coronary artery stent - which has been considered the most widely used medical device - can be attributed to the efficient fabrication process of stainless steel from heat treatment to cold working to improve its durability.



4. **Manufacturability:** It is often said that there are many candidate materials that are biocompatible. However, it is often the last step, the manufacturability of the material, that hinders the actual production of the medical device. It significantly.

Classification of Biomaterials

Biomaterials can broadly be classified as:

i) Biological biomaterials: can be classified into soft and hard tissue types.
ii) Synthetic biomaterials: it is further classified into: a) Metallic; b) Polymeric; c) Ceramic; and d) Composite biomaterials.

Table (1): Classification of Biomaterials

I. Biological Materials	II. Synthetic Biomedical Materials
1. Soft Tissue *Skin, Tendon, Pericardium, Cornea*	1. Polymeric *Ultra High Molecular Weight Polyethylene (UHMWPE), Polymethylmethacarylate (PMMA), Polyethyletherketone (PEEK), Silicone, Polyurethane (PU), Polytetrafluoroethylene (PTFE)*
2. Hard Tissue *Bone, Dentine, Cuticle*	2. Metallic *Stainless Steel, Cobalt-based Alloy (Co–Cr–Mo), Titanium Alloy (Ti–Al–V), Gold, Platinum*
	3. Ceramic *Alumina ($A1_2O_3$), Zirconia (ZrO_2), Carbon, Hydroxylapatite [$Ca_{10}(PO_4)_6(OH)_2$], Tricalcium Phosphate [$Ca_3(PO_4)_2$], Bioglass [$Na_2O(CaO)(P_2O_3)(SiO_2)$], Calcium Aluminate [$Ca(A1_2O_4)$]*
	4. Composite *Carbon Fiber (CF)/PEEK, CF/UHMWPE, CF/PMMA, Zirconia/Silica/BIS–GMA*

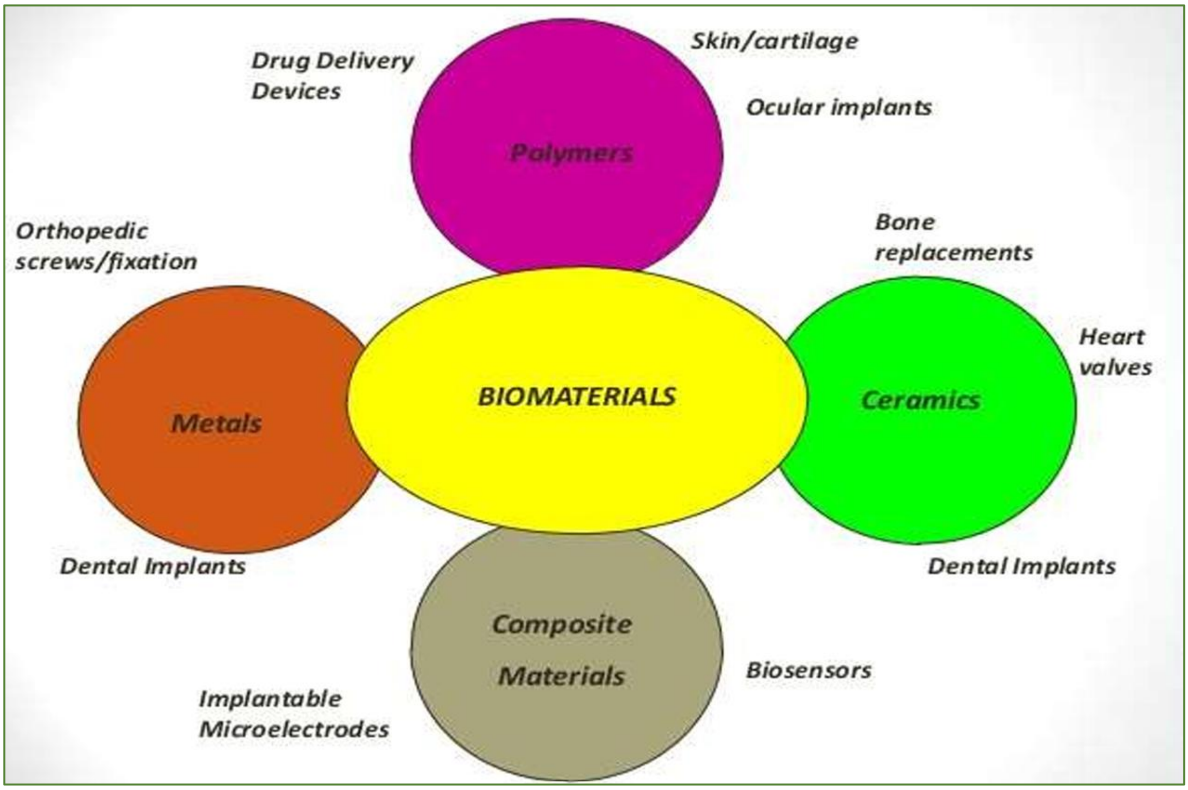


Figure (3): Some applications of biomaterials.

Table (2): 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