BIOMATERIALS

Biomaterials are used to make devices to replace a part or a function of the body in safe, reliably economically, 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

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

A **biomaterial** is any substance that has been engineered to interact with biological systems for a medical purpose - either a therapeutic (treat, augment, repair or replace a tissue function of the body) or a diagnostic one. As a science, **biomaterials** is about fifty years old. The study of biomaterials is called **biomaterials science or biomaterials engineering**. It has experienced steady and strong growth over its history, with many companies investing large amounts of money into the development of new products. Biomaterials science encompasses elements of medicine, biology, chemistry, tissue engineering and materials science.

Types of Biomaterials

- Biomaterials are classified as:
  - Organic if contain carbon
  - Inorganic if they do not.

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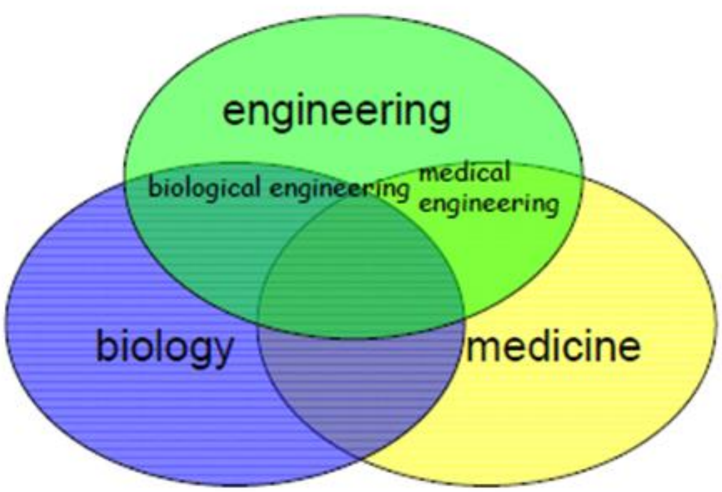
- More specifically biomaterials fall into one of three of materials:
  - Metals (inorganic material)
  - Polymers (organic material)
  - Composite
  - Ceramics (inorganic material)

Different disciplines have to work together, starting from the identification of a need for a biomaterial through development, manufacture, implantation and removal for the patient



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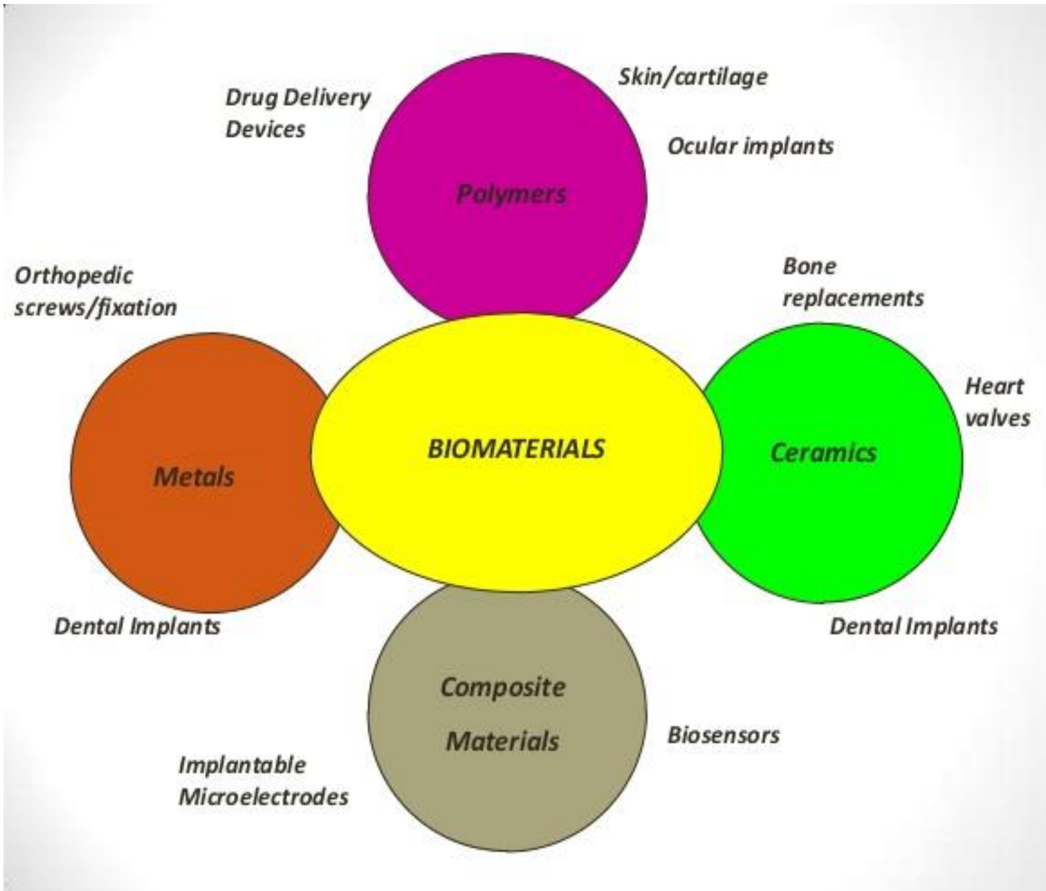

Metals

In modern history, metals have been used as implants since more than 100 years ago when "*Lane*" first introduced metal plate for bone fracture fixation in 1895. The first metal alloy developed specifically for human use was the "vanadium steel" which was used to manufacture bone fracture plates (Sherman plates) and screws. But it was no longer used in implants because its corrosion resistance is inadequate **in vivo** environment.

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Advantages and disadvantages of metallic Biomaterials:

Advantages

- High strength.
- High hardness.
- Fatigue and impact resistance.
- Wear resistance.
- Easy fabrication.
- Easy to sterilize.
- Shape memory.
- inert

Disadvantages

- High modulus.
- High corrosion.
- Metal ion sensitivity and toxicity.
- High density.

In general metallic biomaterials can be grouped in the following categories:

- Stainless steels.
- Co-based alloys.
- Titanium-based alloys.

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Metals and their alloys are widely used as biomedical materials. On one hand, **ceramics or polymers cannot replace metallic biomaterials** at present because the mechanical strength and toughness are the most important safety requirements for a biomaterial under load-bearing conditions. On the other hand, metallic materials sometimes show toxicity and are fractured because of their corrosion and mechanical damages. Therefore, development of new alloys is continuously trialed.

Stainless steels

is stronger and more resistant to corrosion than the vanadium steel.

TABLE (1): Compositions of 316L Stainless Steel

Element	Composition (%)
Carbon	0.03 max.
Manganese	2.00 max.
Phosphorus	0.03 max.
Sulfur	0.03 max.
Silicon	0.75 max.
Chromium	17.00 – 20.00
Nickel	12.00 – 14.00
Molybdenum	2.00 -4.00

The Ni stabilizes the austenitic phase (γ) face centered cubic crystal (FCC) structure at room temperature and enhances corrosion resistance.

The advantages of stainless steels, especially type **316** and **316L** over other grades of steel:

1- Biocompatible.

2- This group of stainless steels is **nonmagnetic** and possesses better corrosion resistance than any others.

TABLE (2): Mechanical Properties of 316L Stainless Steel for Implants (American Society for Testing and Materials. F139—86, p.61, 1992).

Condition	Ultimate tensile strength, min. (MPa)	Yield strength (0.2% offset), min. (MPa)	Elongation 2 in. (50.8 mm) min. %	Rockwell hardness
Annealed	485	172	40	95 HRB
Cold-worked	860	690	12	—

A wide range of properties exists depending on the heat treatment (annealing to obtain softer materials) or cold working (for greater strength and hardness).

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(Co Cr) Alloys

The castable CoCrMo alloy has been used for many decades in dentistry and, relatively recently, in making artificial joints.

TABLE (3): Mechanical Property Requirements of Co-Cr Alloys

Property	Cast CoCrMo (F75)	Wrought CoCrWNi (F90)	Wrought CoNiCrMo (F562) Solution annealed	Wrought CoNiCrMo (F562) Cold-worked and aged
Tensile strength (MPa)	655	860	793–1000	1793 min.
Yield strength (0.2% offset) (MPa)	450	310	240–655	1585
Elongation (%)	8	10	50.0	8.0
Reduction of area (%)	8	—	65.0	35.0
Fatigue strength (MPa)[a]	310	—	—	—

[a] From Semlitch, M. (1980). *Eng. Med.* 9, 201–207.

The corrosion products of CoCrMo are more toxic than those of stainless steel 316L.

The advantages and disadvantage of CoCrMo:

- wrought or forged forms has the highest strength/wear resistance,
- hardest to fabricate,
- may produce cobalt or chromium ion sensitivity/toxicity.

Ti Alloys

Ti-based alloys are finding ever-increasing applications in biomaterials due to their excellent mechanical, physical and biological performance.

1-Pure Ti and Ti6Al4V

Commercially pure titanium (Ti CP) and Ti-6Al-4V are the two most common titanium base implant biomaterials. These materials are classified as biologically inert biomaterials.

Comparison betweenTitanium alloy (Ti-6Al-4V) versus Titanium (Ti) metal

- titanium alloy is stronger than titanium metal,
-both have the best corrosion resistance,
-both have excellent bone bonding.

The modulus of elasticity of these materials is about (110 GPa.) This is much lower than stainless steels and Co-base alloys modulus (210 and 240 GPa.) respectively.

2- TiNi Alloys

The titanium—nickel alloys show unusual properties, that is, after it is deformed the material can snap back to its previous shape by following heating of the material. This phenomenon is called **shape memory effect (SME)**.

(Nitinol) exhibits an exceptional SME near room temperature, if it is plastically deform below the transformation temperature, it revert back to its original shape as the temperature is raised.

In order to develop such devices, it is necessary to understand fully the mechanical and thermal behavior associated with the martensite phase transformation. A widely known NiTi alloy is (55-Nitinol) (55 wt% atomic Ni)

Some possible applications of shape memory effects alloys are orthodontic dental archwires, intracranial aneurysm, skull clip, contractible muscles for artificial heart, vascular stent, and catheter wire guide.

In general, The advantage and disadvantage of Ti alloys are :

Advantages

•Easily formed.

•Highly biocompatible.

•Outstanding corrosion resistance.

•Better than stainless steel and cobalt-chromium alloys.

•Forms protective oxide (TiO_2) layer.

•Low elastic modulus.

Disadvantages

•Poor wear resistance.

•Should not be used in articulated surfaces such as hip or knee joints unless surface-treated through ion implantation which improves wear resistance.

In General Titanium alloys used in implants present three main problems:

- High cost because the amount of processing energy and melting and casting difficulties.

- Higher elastic modulus compared to bone.

- Although the inert behavior of Ti is a good property, its bone attachment is difficult because it do not react with the human tissues**.**

The following table represents the comparison of mechanical properties of metallic biomaterials with bone.

Table (4): Comparison of mechanical properties of metallic biomaterial with bone.

Material	E (GPa)	σ_y (MPa)	σ_{UTS} (MPa)	Fatigue Limit, (MPa)
Stainless steel	190	221–1213	586–1351	241–820
Co-Cr alloys	210–253	448–1606	655–1896	207–950
Titanium (Ti)	110	485	760	300
Ti-6Al-4V	116	896–1034	965–1103	620
Cortical bone	15–30	30–70	70–150	

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