Composite

The term 'Biocomposites' refers to the composites that can be employed in bioengineering which are contain two or more distinct constituent materials or phases, on a scale larger than the atomic (macroscopic scale).

The bones, cartilage, tendons, skin, ligaments, teeth, etc. are natural composite structures in the human body.

Bone and teeth → **Matrix** (collagen)

Bone and teeth → **Reinforcement** (calcium and phosphate ion and hydroxyapatite)

These natural composite have anisotropic properties. The anisotropy of the elastic properties of the biological tissues has to be considered in the design criterion for implants made from composite biomaterials.

Natural composites have hierarchical structures particulate, porous and fibrous structural features which are seen on different micro-scales.

The amount, distribution, morphology and properties of structure components determine the final behaviour of resultant tissues or organs.

Some synthetic composites can be used to produce prosthesis able to simulate the tissues, to compromise with their mechanical behavior and to restore the functions of the damaged tissues.

The factors that are largely affected to the properties of biomedical composites represent by: shape, size, distribution, volume fraction, bioactivity properties of the reinforcement or matrix phases; in addition to molecular weight of matrix and interfacial situation between the reinforcement and matrix.

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Applications of composite biomaterials:

1- Dental filling composites (like polymer matrix filled with barium glass or silica).
2- Joint prostheses fixation (like bone particles or carbon fibers reinforced methylmethacrylate bone cement and ultra-high molecular weight polyethylene.
3- Orthopedic implants with porous surface.
4- Rubber used in catheters, rubber gloves are usually filled with very fine particles of silica to improve the properties of rubber.

Advantages of bio-composite:

1- Good durability in small to moderate restorations.
2- High biocompatibility.
3- Moderate resistance to wear and corrosion.
4- Inert.
5- Provides high fracture toughness.
6- Resistance against fatigue failure.
7- These biocomposites are highly compatible with modern diagnostic methods, magnetic resonance imaging (MRI).
8- Their combinations of low density/weight that make them ideal materials for such applications.
9- Polymer composites offer low modulus but high strength, suitable for some orthopedic application.
10- For dentistry, composites offer better aesthetic characteristic & more economical than metal.

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Disadvantages of bio- composite:

1- Each constituent of the composite be biocompatible.

2- Water absorption in case of polymer composite causes a reduction in stiffness and others mechanical properties.

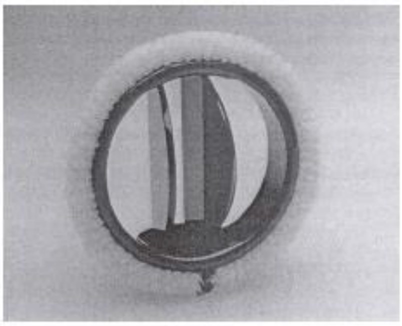
3- The degradation of interface between components is also problem which must be avoided.

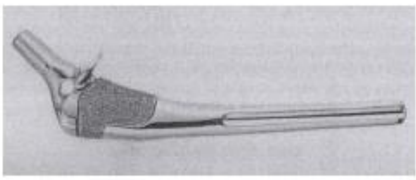
Materials	Advantages	Disadvantages	Examples
Polymers Nylon، Polyethylene، Silicone ، Teflon، Dacron، Acrylates، PGA, PLA	Resilient، Easy to fabricate	Not Strong, Deforms with time ، may degrade	Sutures ، vascular graft ، hip socket, intraocular lenses
Metals Titanium and its alloys ، Co-Cr alloys, stainless steel، Gold	Strong ، Tough، Ductile	May corrode، Dense، Difficult to make	Joint replacement، Bone plates and screws ، Dental root implant
Ceramics Aluminum oxide, Calcium phosphates، Carbon	Very biocompatible، Inert، Strong in compression	Brittle، Not resilient ، Difficult to make	Dental implant, Femoral head of hip replacement، Coating of dental and orthopedic implants
Composites Carbon-carbon Ceramic-polymer	Strong ، less stiff than metals، Strong in compression	Difficult to make، Weak in tension	Joint implants Dental fillings

- **The success of biomaterials in the body depends on factors such as:**
  - Material properties
  - Design of the implants
  - Biocompatibility of the materials
  - Technique used by the surgeon
  - Health and condition of the patient
  - Patient activities

Examples of biomaterial applications (USA)

- Substitute heart valves (45,000/year)
- Artifical hips (90,000/year)
- Dental implants (275,000/year)
- Intraocular lenses (1.4 millions/year)





Definition of biocompatibility:

“Biocompatibility is the ability of a material to perform with an appropriate host response in a specific application

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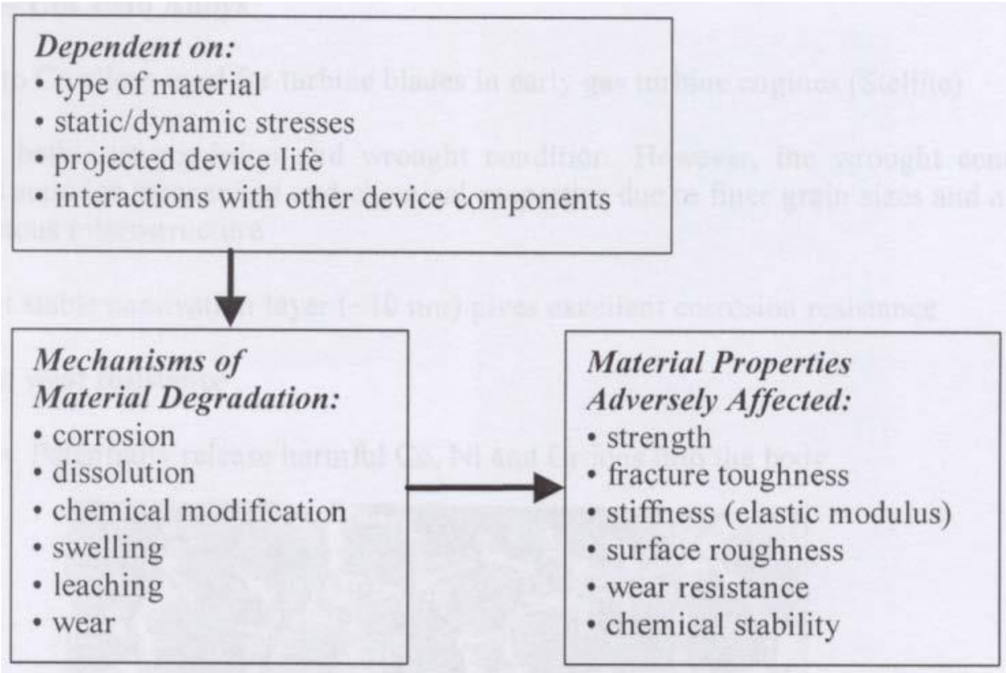
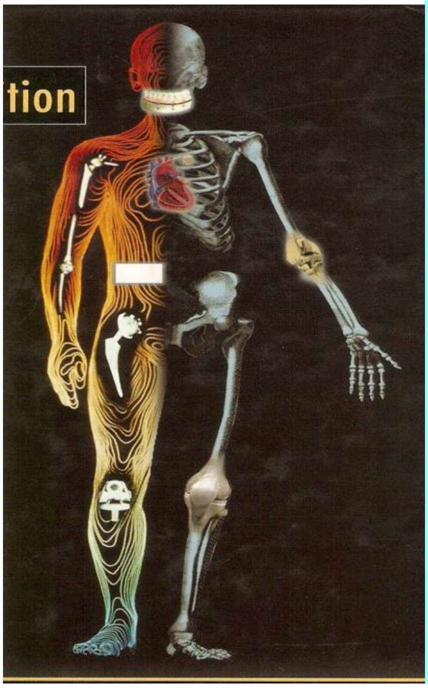


Biomaterial Application in Human Body

Biomaterials must be compatible with the body, and there are often issues of biocompatibility which must be resolved before a product can be placed on the market and used in a clinical setting. Because of this, biomaterials are usually subjected to the same requirements as those undergone by new drug therapies.

All manufacturing companies are also required to ensure traceability of all of their products so that if a defective product is discovered, others in the same batch may be traced.

Today, biomaterials represent a significant portion of the healthcare industry, with an estimated market size of over $9 billion per year in the United States.



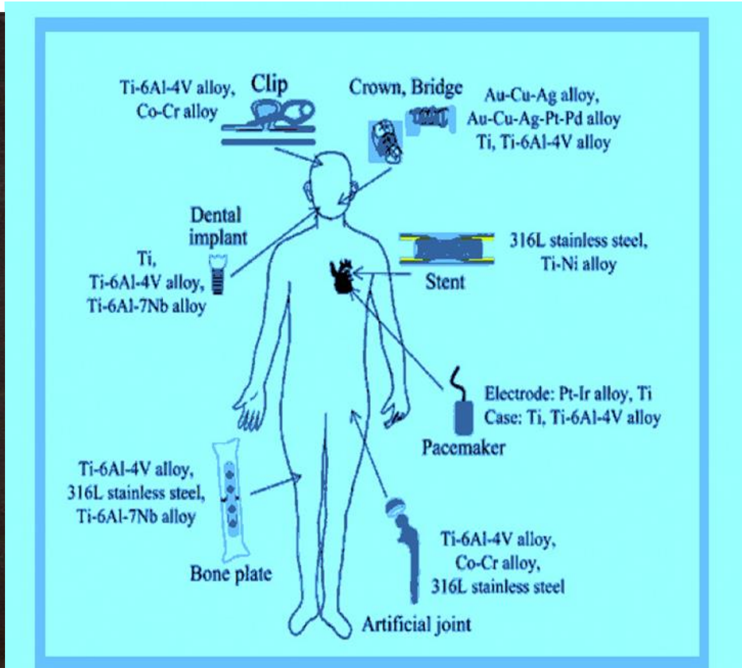


FIG. 1. *Metallic devices and metallic biomaterials used for them.*

- Starting 1960s-1970s
  - The first generation of biomaterials was designed to be inert, or not reactive with the body
  - Decreasing the potential for negative immune response to the implant.
- In 1990's until now
  - Materials designed to be bioactive, interacting in positive manner with the body to promote localized healing.
- Development of "smart" material which can help guide the biological response in the implant area.
- Design of injectable materials that can applied locally and with minimal pain to the patient.

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Biomaterials are used in:

- Joint replacements
- Bone plates
- Bone cement
- Artificial ligaments and tendons
- Dental implants for tooth fixation
- Blood vessel prostheses
- Heart valves
- Skin repair devices (artificial tissue)
- Cochlear replacements
- Contact lenses
- Breast implants
- Drug delivery mechanisms
- Sustainable materials
- Vascular grafts
- Nerve conduits
- Surgical sutures, clips, and staples for wound closure
- Pins and screws for fracture stabilization

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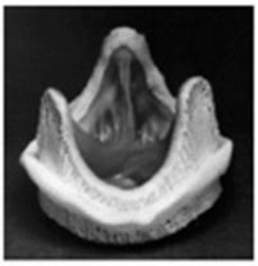
Heart valves

In the United States, 45% of the 250,000 valve replacement procedures performed annually involve a mechanical valve implant. The most widely used valve is a bileaflet disc heart valve. The mechanics involve two semicircular discs moving back and forth, with both allowing the flow of blood as well as the ability to form a seal against backflow. The valve is coated with pyrolytic carbon, and secured to the surrounding tissue with a mesh of woven fabric called DacronTM

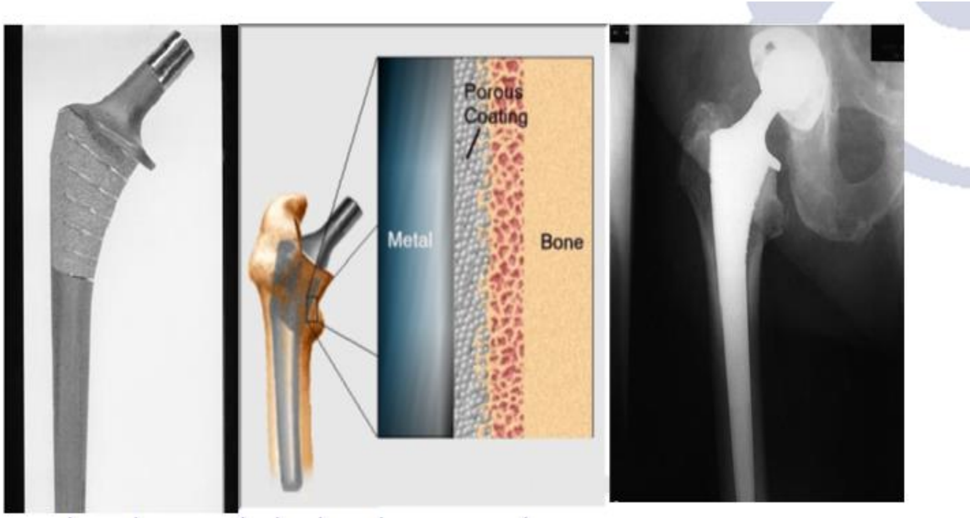
The mesh allows for the body's tissue to grow while incorporating the valve.



Artificial hip joint

Replacement hip joint are implanted in more than 90 000 humans each year in US. Fabricated from titanium, ceramics, composite and UHMWPE. After 10-15 years, the implant may lose, require another operation.



Dental Implants

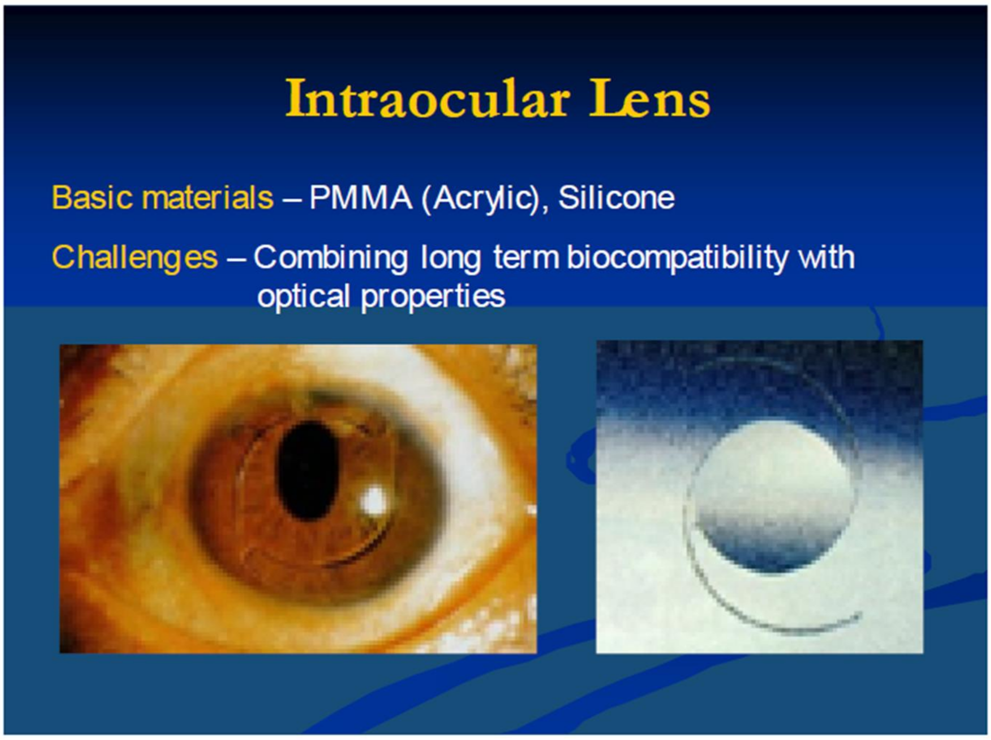
Capable of bonding to bone, a phenomenon known as "osseointegration”. Bio-inert, there is no reaction in tissue and no rejection or allergic reactions.

Intraocular lenses (IOL)

Used to replace natural lenses when it become cloudy due to cataract formation.

Fabricated of poly (methyl methacrylate), silicone elastomer, soft acrylic polymers or hydrogels .

Complication: IOL stimulate outgrowth cells from the posterior lens capsule → cloud the vision .



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- New set of nano-structured biomaterials for nano-scale objects as reinforcing agents.

- Biomaterials that will be used may be considered from the point of view of the problem area that is to be solved:

Problem Area	Examples
Replacement of diseased or damaged part	Artificial hip joint, kidney dialysis machine
Assist in healing	Sutures, bone plates, and screws
Improve function	Cardiac pacemaker, intraocular lens, cochlear implant
Correct functional abnormality	Cardiac pacemaker
Correct cosmetic problem	Breast implant, soft tissue augmentation, chin augmentation
Aids to diagnosis	Probes, catheter
Aid to treatment	Catheters, drains

- Biomaterials that will be used may be considered from the point of view of the organ that will need to be replaced or improve:

Organ	Heart
Heart	Cardiac pacemaker, artificial heart valve, total artificial heart
Lung	Oxygenator machine
Eye	Contact lens, intraocular lens
Ear	Cochlear implant
Bone	Bone plate, screw
Kidney	Kidney dialysis machine
Bladder	Catheter and stent