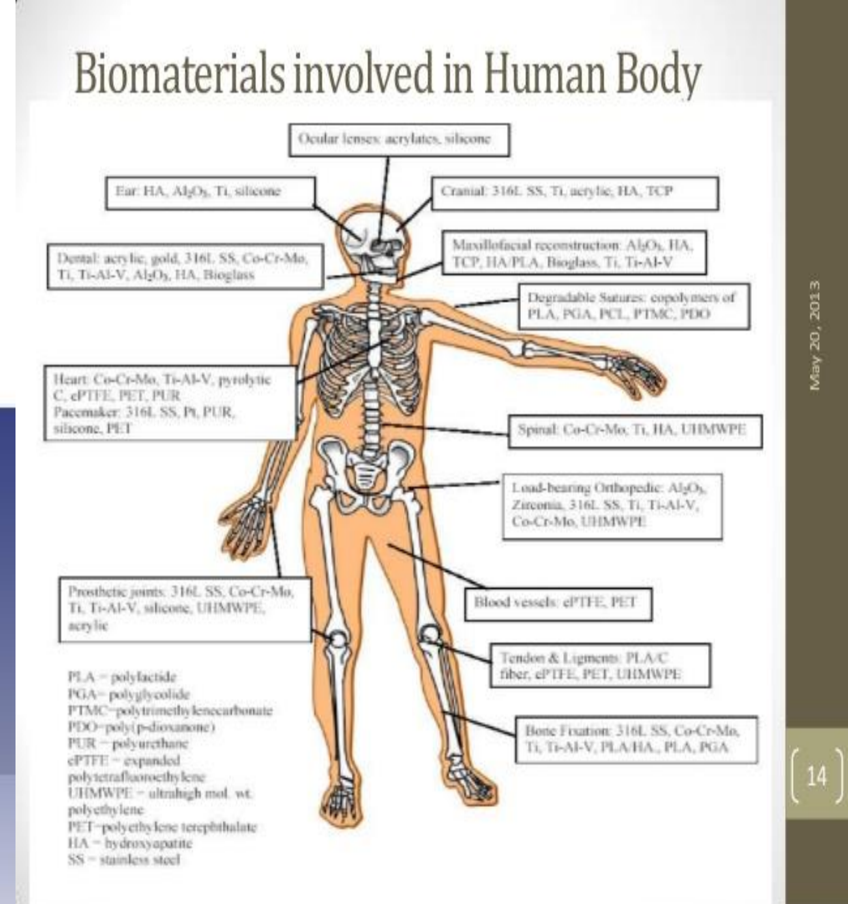
Biomaterials

Course overview

BIOMATERIALS



Lecture 1: Introduction to Biomaterials

Objective

- Define biomaterials
- Describe biomaterial applications
- Define and describe biocompatibility principle
- Explain factors contribute to the performance of biomaterials in the body.

What is it biomaterial?

- A material intended to interface with biological systems to evaluate, treat, augment, or replace any tissue, organ or function of the body (Williams, 1999).

- Any substance (other than drugs) or combination of substance , synthetic or natural origin, which can be used for any period of time, as a whole or as a part of a system which treats, augments, or replace any tissue, organ or function of the body.

What is it biomaterial?

- A biomaterial is any material, natural or man-made, that comprises whole or part of a living structure or biomedical device which performs, augments, or replaces a natural function "
- “A systemically and pharmacologically inert substance designed for implantation within or incorporation with living system nosmelC ehT) ”).slairetamoiB rof draoB yrosivda ytisrevinU

Biomaterial Application in Human Body

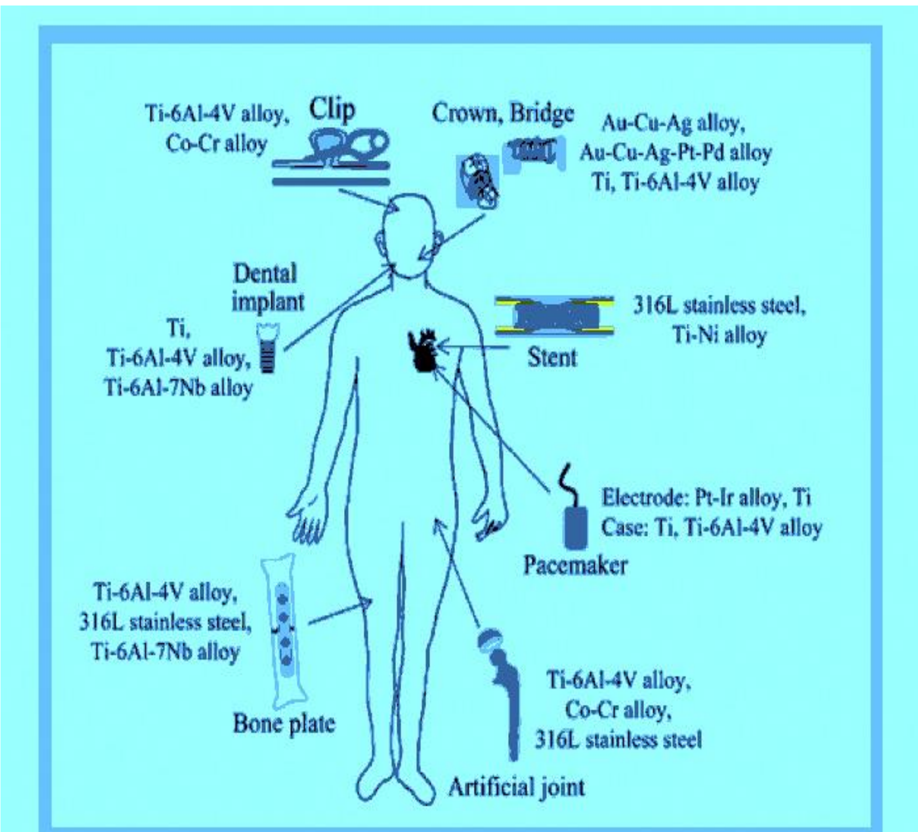
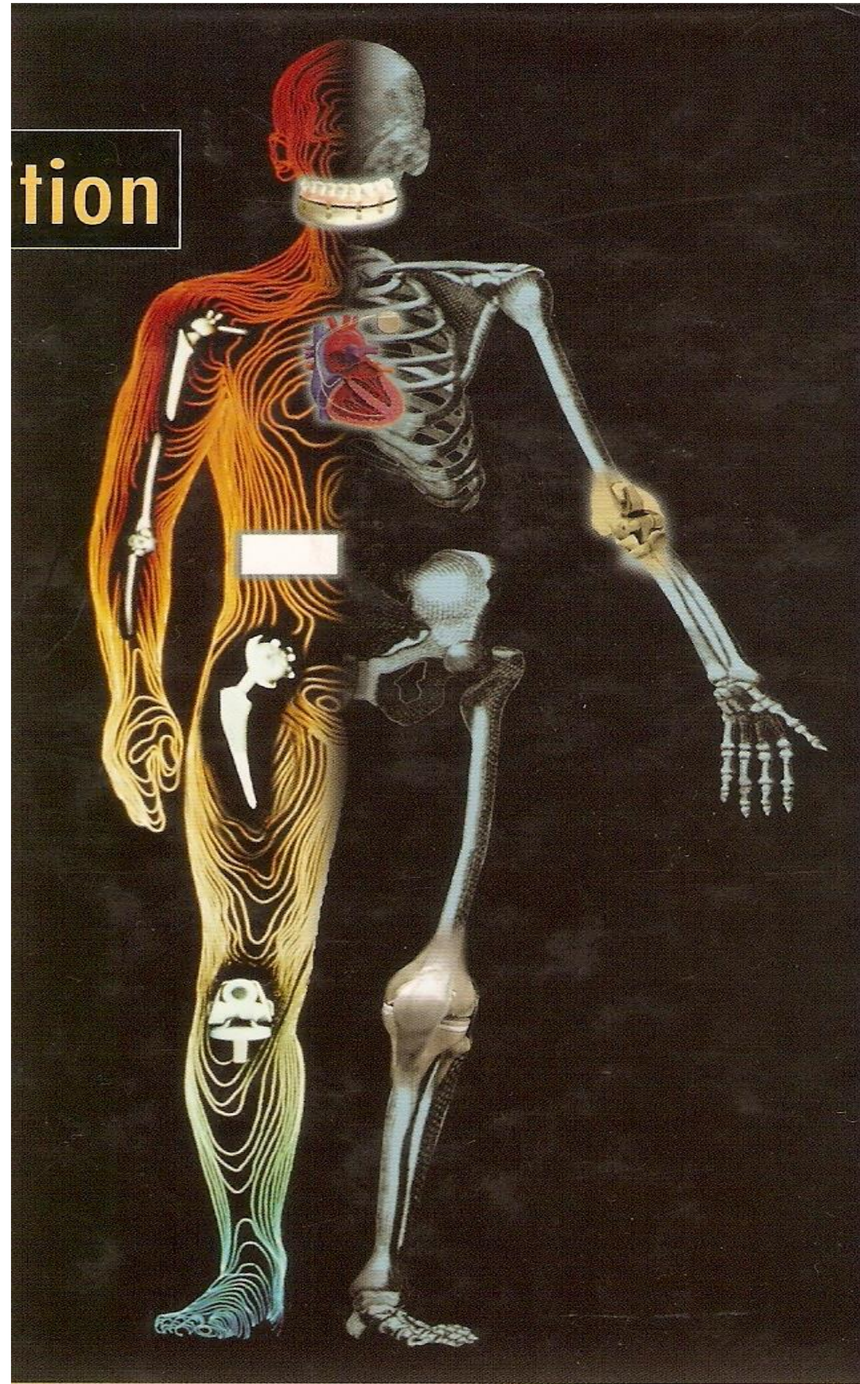


Fig. 1. *Metallic devices and metallic biomaterials used for them.*



History

- More than 2000 years ago, Romans, Chinese, and Aztec’s used gold in dentistry.
- Turn of century, synthetic implants become available.
- 1937 Poly(methyl methacrylate) (PMMA) introduced in dentistry.
- 1958, Rob suggests Dacron Fabrics can be used to fabricate an arterial prosthetic.

History (Continued)

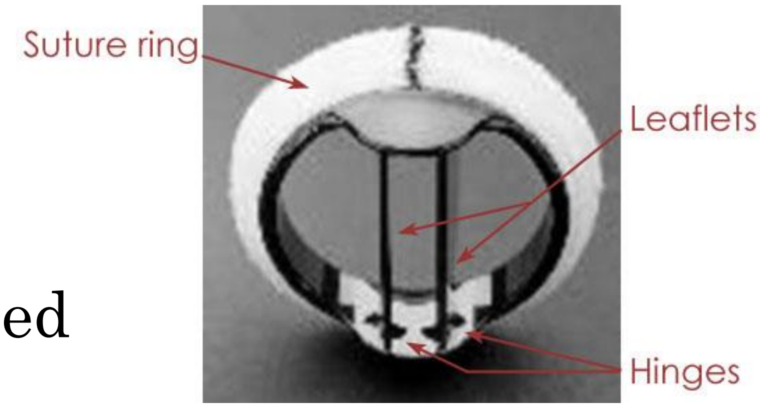
- 1960 Charnley uses PMMA, ultrahigh-molecular-weight polyethylend, and stainless steal for total hip replacement.
- Late 1960 – early 1970's biomaterial field solidified.
- 1975 Society for Biomaterials formed.

Current status of the field

- 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.

Current status of the field

- Cardiovascular area:
  - approximately 100,00 replacement heart valves and 300,000 vascular graft implanted per year in US.



- Artificial joints replacements:
  - Over 500,000 artificial joint replacements, such as knee or hip, are implanted yearly in United States.

Future Directions

- 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.

Future Directions

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

Application of Biomaterials

- 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

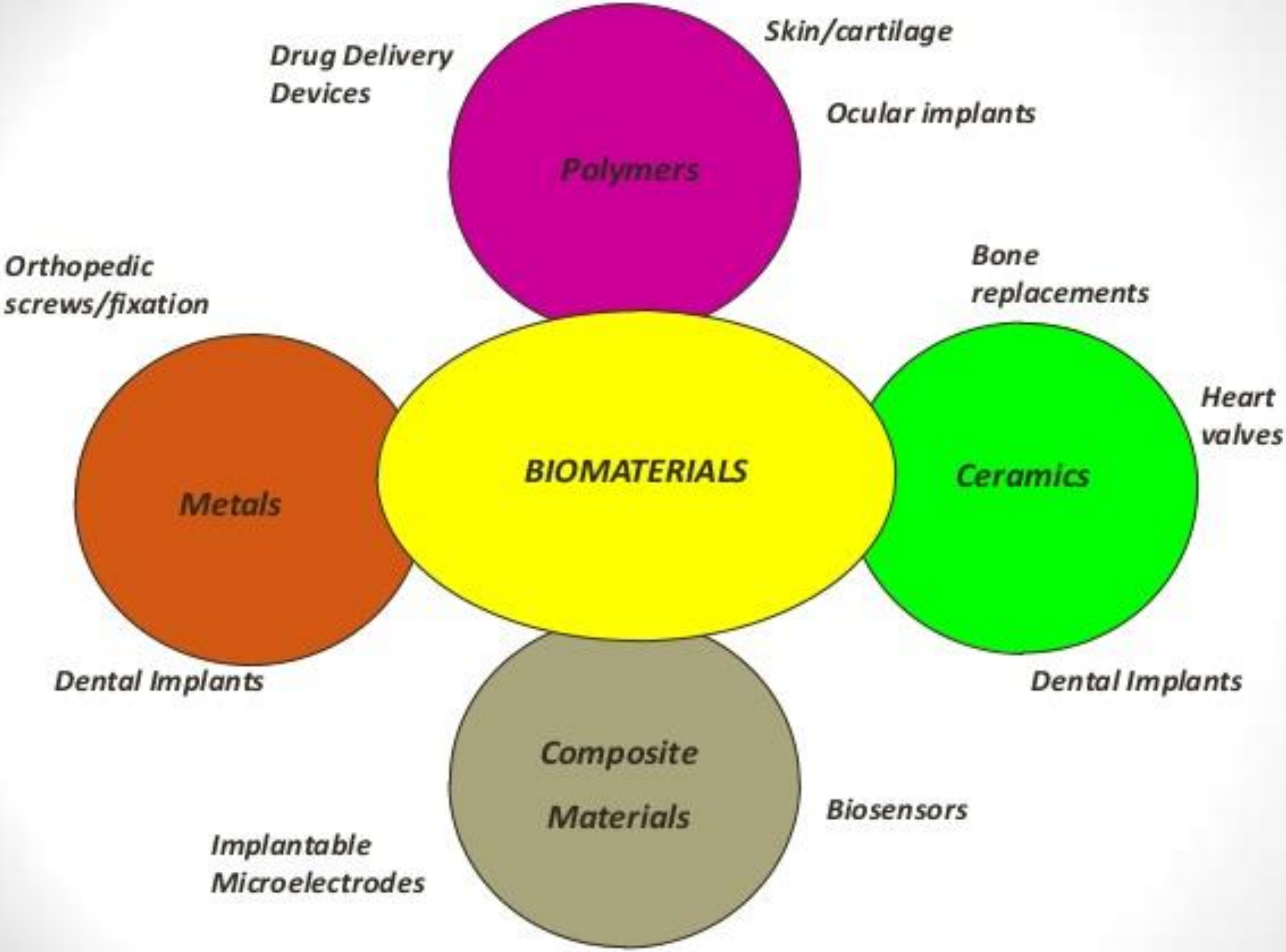
Application of Biomaterials

- 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

Type of Biomaterials

- Biomaterials are classified as:
  - Organic if contain carbon
  - Inorganic if they do not.
- More specifically biomaterials fall into one of three of materials:
  - Metals (inorganic material)
  - Ceramics(inorganic material)
  - Polymers (organic material)


Drug Delivery Devices
Skin/cartilage
Ocular implants
Polymers
Orthopedic screws/fixation
Bone replacements
Heart valves
Metals
BIOMATERIALS
Ceramics
Dental Implants
Dental Implants
Composite Materials
Biosensors
Implantable Microelectrodes

Type of Biomaterials

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

Type of Biomaterials

Materials	Advantages	Disadvantages	Examples
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

Performance of biomaterials

- 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

The Concept of Biocompatibility

- Definition of biocompatibility:

“Biocompatibility is the ability of a material to perform with an appropriate host response in a specific application mailliW) ”1987).

The Concept of Biocompatibility

- Biocompatibility characteristic:
  - Biocompatibility involves the acceptance of an artificial implant by the surrounding tissues and by the body as a whole.
  - Biocompatible materials
    - Do not irritate the surrounding structures
    - Do not provoke an abnormal inflammatory response
    - Do not incite allergic or immunologic reactions
    - Do not cause cancer

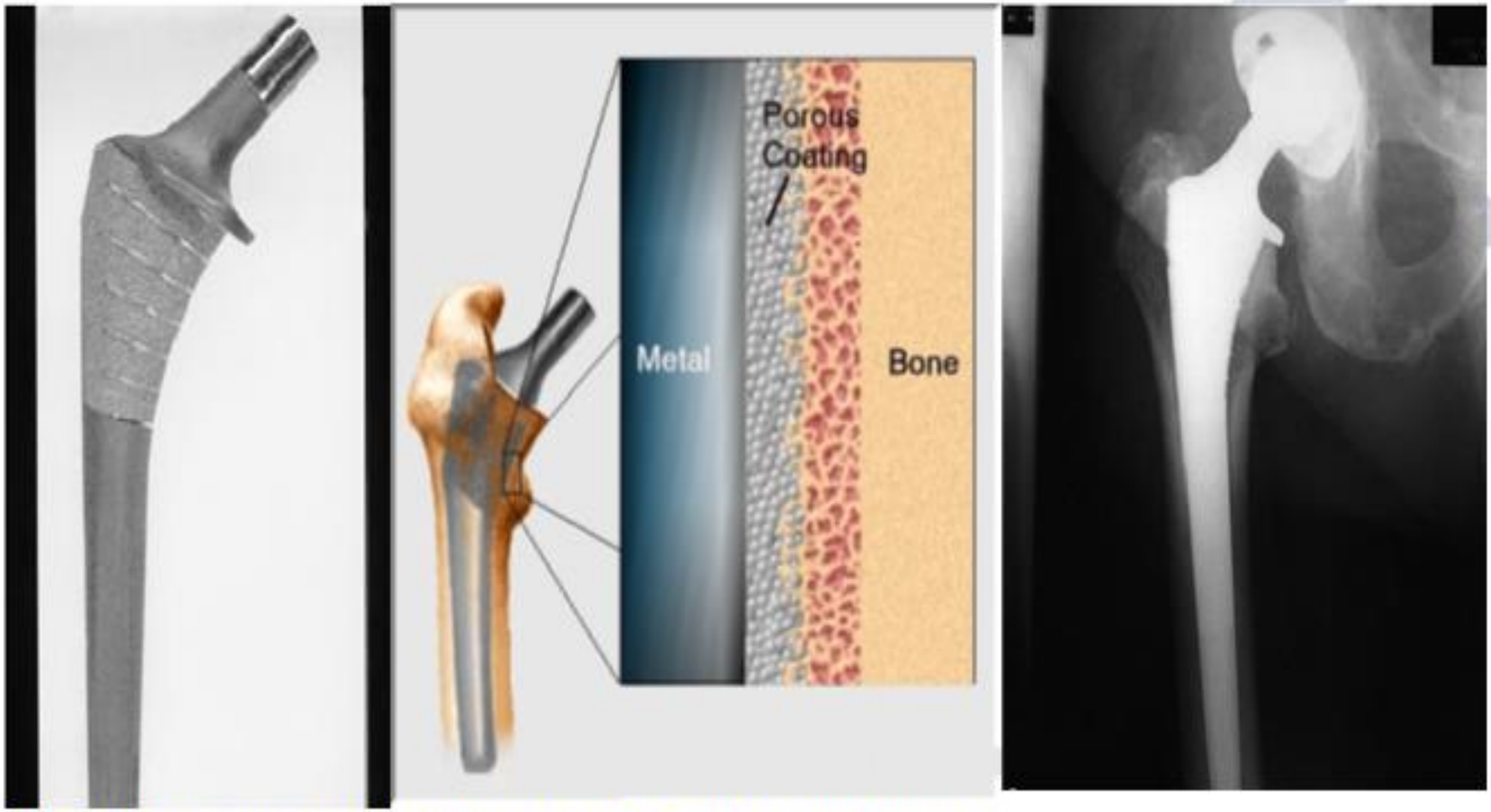
The Concept of Biocompatibility

- Biocompatible materials have adequate mechanical properties.
- Biocompatible materials have appropriate optical properties (eye).
- Biocompatible materials have appropriate density.

Examples of Biomaterials application

- Artificial hip joint
  - Needed because natural joint wear out.
  - Replacement hip joint are implanted in more than 90 000 humans each year in US.
  - Fabricated from titanium, ceramics, composite, UHMWPE.
  - After 10-15 years, the implant may loose, require another operation.

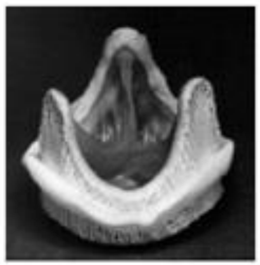
Total Hip Joint Replacement

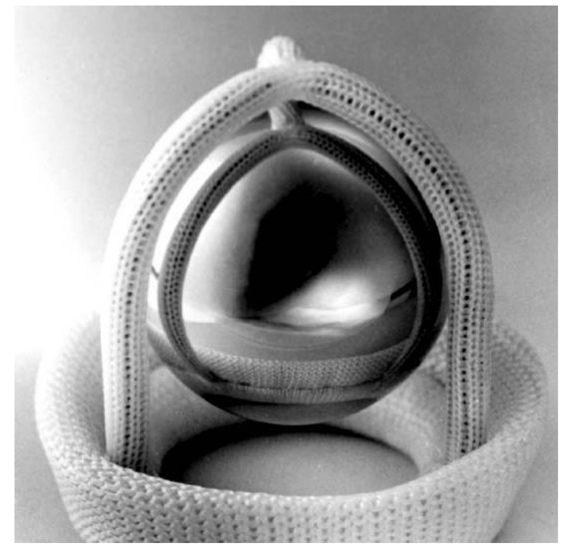


- 50,000 hip replacements (arthroplasties) in Britain each year.
- Hydroxyapatite porous coatings in orthopaedic prostheses: Bioactivity, Osteoconductivity.
- Problem: Infections in orthopedic surgery (10% of cases)

Examples of Biomaterials application

- Prosthetic Heart valve

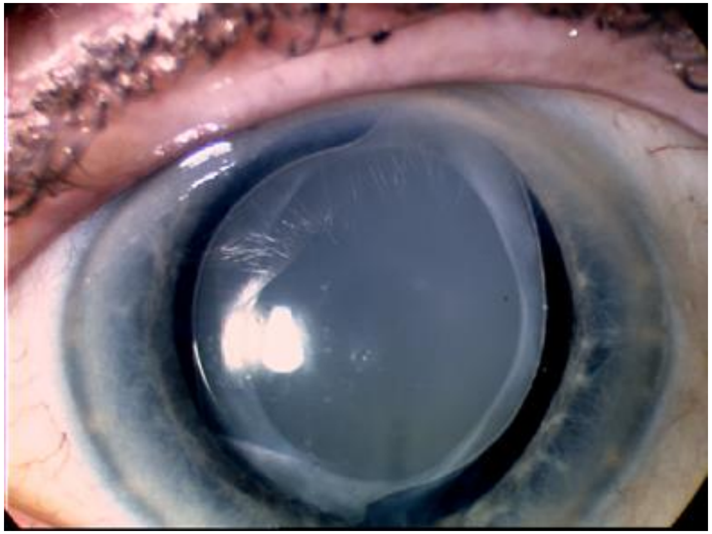



  - Fabricated from carbon, metal, elastomers, fabrics, natural valves and tissue chemically pre-treated.

- Show good performance as soon as the valve is implanted but have some problems:
  - Degeneration of tissue
  - Mechanical failure
  - Postoperative infection
  - Induction of blood cloth

Examples of Biomaterials application

- Intraocular lenses (IOL)
  - Used to replace a natural lense 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.



Intraocular Lenses

- Made of PMM, silicone elastomer, and other materials.
- By age 75 more than 50% of population suffers from cataracts.
- 1.4 million implantations in the United States yearly.
- Good vision is generally restored almost immediately after lens is inserted.

Intraocular Lens

Basic materials – PMMA (Acrylic), Silicone

Challenges – Combining long term biocompatibility with optical properties

Vascular Grafts

- Must Be Flexible.
- Designed With Open Porous Structure.
- Often Recognized By Body As Foreign.

Vascular Grafts

Basic Material:
Polyurethane, Teflon & Dacron

Challenges:
Maintenance of mechanical integrity

Long term blood compatibility (avoidance of blood clotting).

Thank you !