Outline

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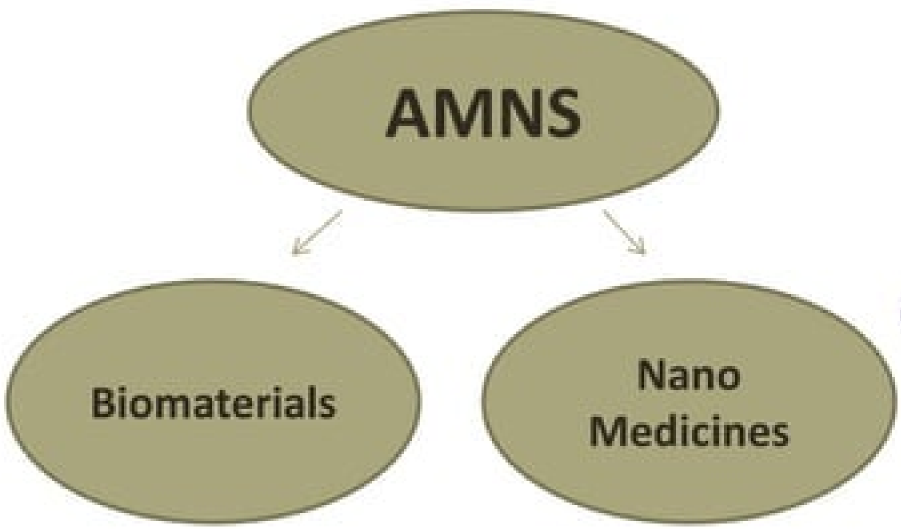
Introduction

- How AMNS (Advanced Material and Nano Science) is been applied to the Medical World ?



Healthcare Market (U.S. Data) [*1]

Total U.S. health care expenditures (2000)	$1,400,000,000,000
Total U.S. health research and development (2001)	$82,000,000,000
Number of employees in the medical device industry (2003)	300,000
Registered U.S. medical device manufacturers (2003)	13,000
Total U.S. medical device market (2002)	$77,000,000,000
U.S. market for disposable medical supplies (2003)	$48,600,000,000
U.S. market for biomaterials (2000)	$9,000,000,000
Individual medical device sales:	
Diabetes management products (1999)	$4,000,000,000
Cardiovascular Devices (2002)	$6,000,000,000
Orthopedic-Musculoskeletal Surgery U.S. market (1998)	$4,700,000,000
Wound care U.S. market (1998)	$3,700,000,000
In Vitro diagnostics (1998)	$10,000,000,000

Continued..

Numbers of devices (U.S.):

Intraocular lenses (2003)	2,500,000
Contact lenses (2000)	30,000,000
Vascular grafts	300,000
Heart valves	100,000
Pacemakers	400,000
Blood bags	40,000,000
Breast prostheses	250,000
Catheters	200,000,000
Heart-Lung (Oxygenators)	300,000
Coronary stents	1,500,000
Renal dialysis (number of patients, 2001)	320,000
Hip prostheses (2002)	250,000
Knee prostheses (2002)	250,000
Dental implants (2000)	910,000

Definition

- Biomaterial is used to make devices to replace a part or a function of the body in a safe, reliable, economic and physiologically acceptable manner [Hench and Erthridge, 1982,·₂].

- Materials of synthetic as well as of natural origin in contact with tissue, blood, and biological fluids, and intended for use for prosthetic, diagnostic, therapeutic, and storage applications without adversely affecting the living organism and its components" [Bruck, 1980].

History

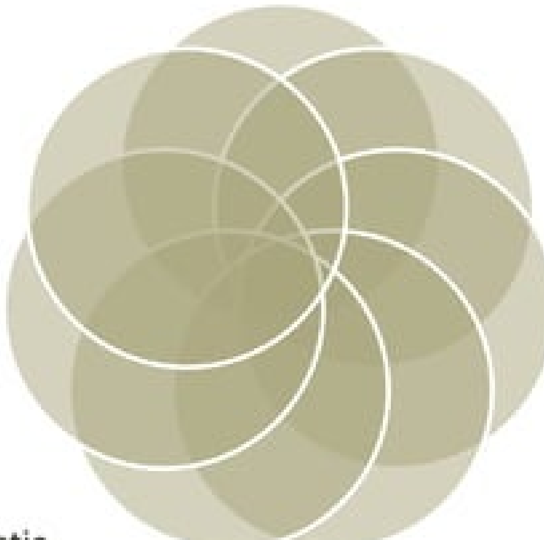
- More than 2000 years ago, Romans and Chinese used gold in dentistry.
- 1937 Poly(methyl methacrylate) (PMMA) introduced in dentistry.
- 1958, Rob suggests Dacron Fabrics can be used to fabricate an arterial prosthetic.
- 1960 Charnley uses PMMA, ultrahigh-molecular-weight polyethylend, and stainless steal for total hip replacement.
- Late 1960 – early 1970's biomaterial field solidified.
- 1975 Society for Biomaterials formed.

Uses of Biomaterials

Replacement of diseased or damaged part: Artificial hip joint, kidney dialysis machine

Aid to treatment: Catheters, drains

Assist in healing: Sutures, bone plates, and screws



Aid to diagnosis: Probes and catheters

Improve function: Cardiac pacemaker, intraocular lens

Correct cosmetic problem: Augmentation mammoplasty, chin augmentation

Correct functional abnormality: Cardiac pacemaker

Characteristics of Biomaterials

Physical Requirements

- Hard Materials.
- Flexible Material.

Chemical Requirements

- Must not react with any tissue in the body.
- Must be non-toxic to the body.
- Long-term replacement must not be biodegradable.

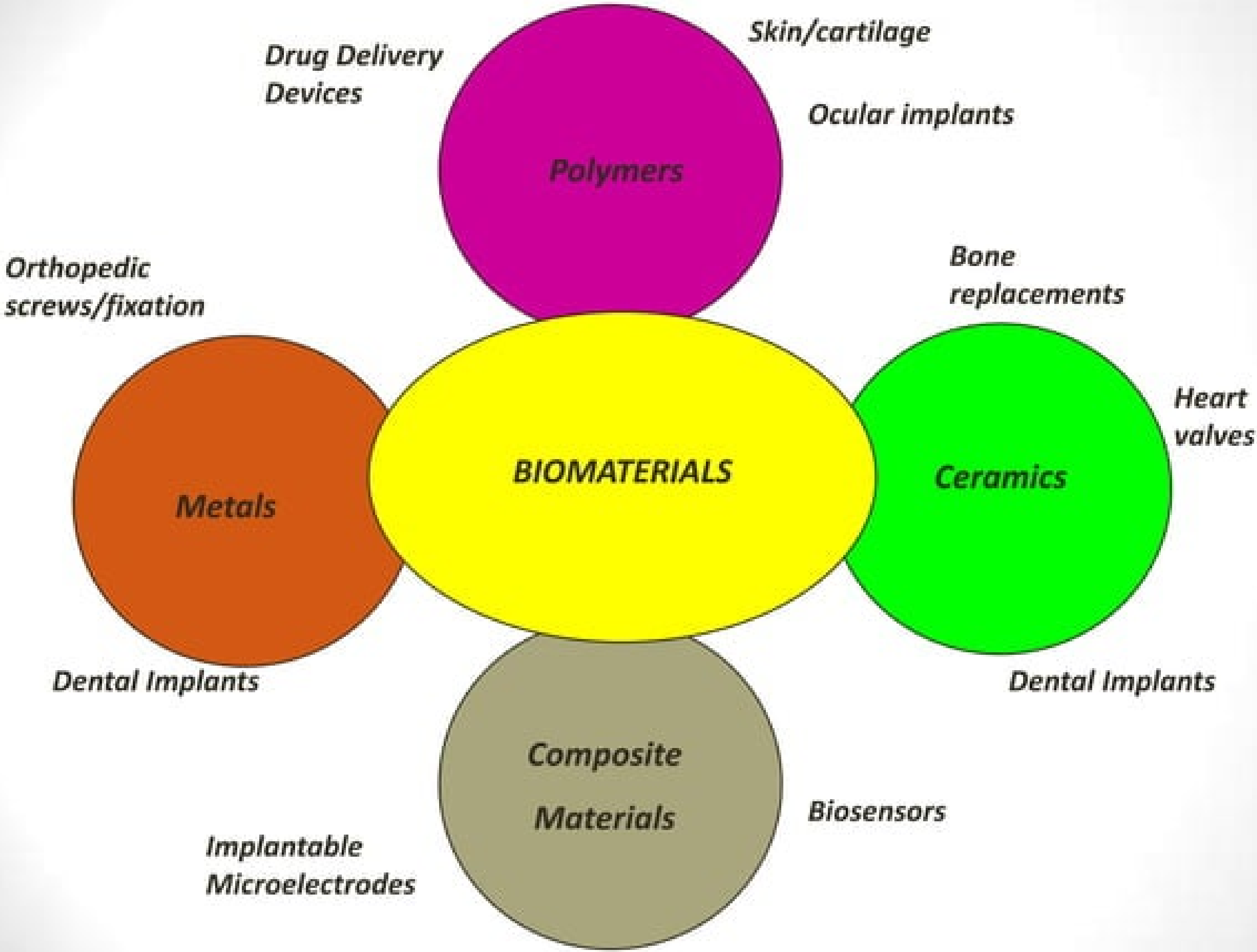
Main features for medical applications

- **Biofunctionality**
- Playing a specific function in physical and mechanical terms

- **Biocompatibility**
- Concept that refers to a set of properties that a material must have to be used
- safely in a biological organism

Biocompatible material features

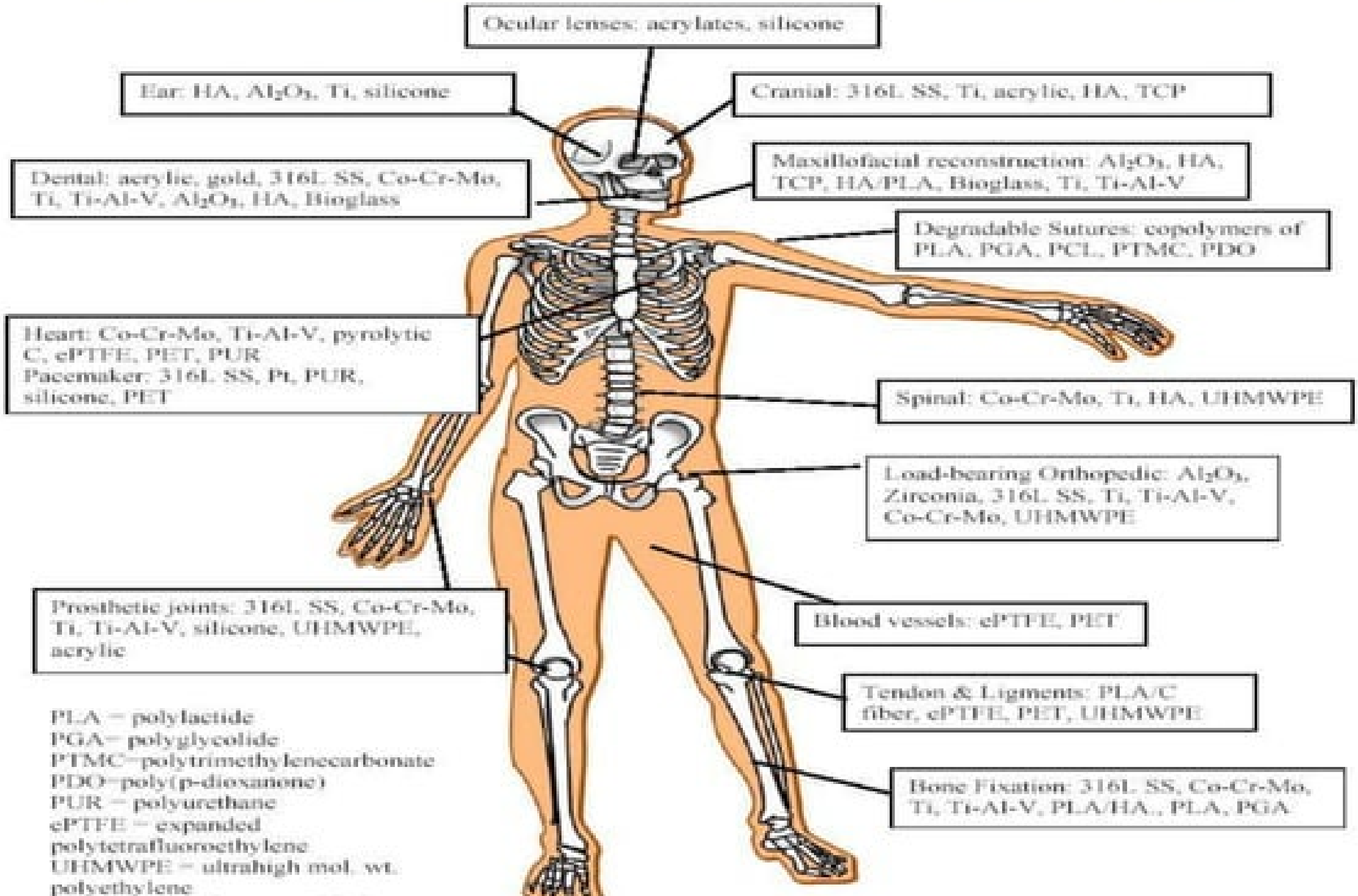
- Absence of carcinogenicity (the ability or tendency to produce cancer)
- Absence of immunogenicity (absence of a recognition of an external factor which could create rejection)
- Absence of teratogenicity (ability to cause birth defects)
- Absence of toxicity


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

Materials for Use in the Body

Materials	Advantages	Disadvantages	Examples
Polymers (nylon, silicone rubber, polyester, polytetrafuoroethylene, etc.)	Resilient Easy to fabricate	Not strong Deforms with time May degrade	Sutures, blood vessels, hip socket, ear, nose, other soft tissues, sutures
Metals (Ti and its alloys, Co–Cr alloys, stainless steels, Au, Ag, Pt, etc.)	Strong, tough, ductile	May corrode Dense Difficult to make	Joint replacements, bone plates and screws, dental root implants, pacer and suture wires
Ceramics (aluminum oxide, calcium phosphates including hydroxyapatite, carbon)	Very biocompatible, Inert Strong in compression	Brittle Not resilient Difficult to make	Dental; femoral head of hip replacement, coating of dental and orthopedic implants
Composites (carbon–carbon, wire or fiber reinforced bone cement)	Strong, tailor-made	Difficult to make	Joint implants, heart valves

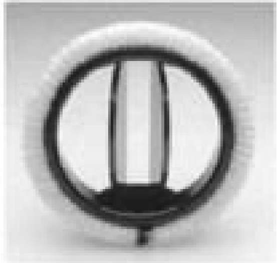
Biomaterials involved in Human Body

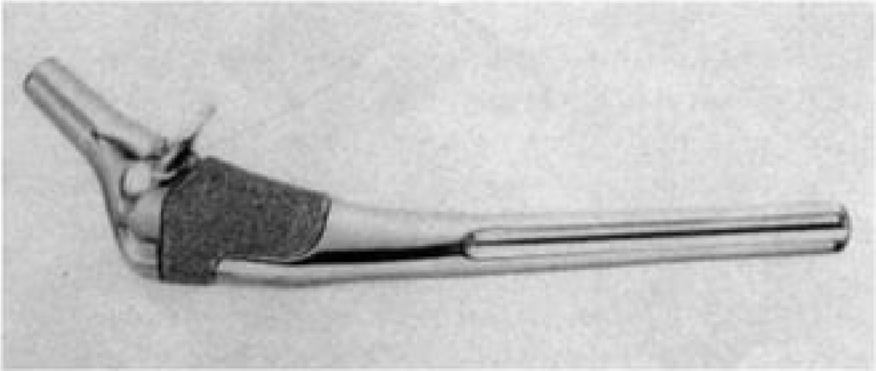


PLA = polylactide
PGA= polyglycolide
PTMC=polytrimethylenecarbonate
PDO=poly(p-dioxanone)
PUR = polyurethane
ePTFE = expanded polytetrafluoroethylene
UHMWPE = ultrahigh mol. wt. polyethylene
PET=polyethylene terephthalate
HA = hydroxyapatite
SS = stainless steel

Examples of Biomaterial Applications

- Heart Valve
- Dental Implants
- Intraocular Lenses
- Vascular Grafts
- Hip Replacements





Intraocular Lenses

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

Heart Valve

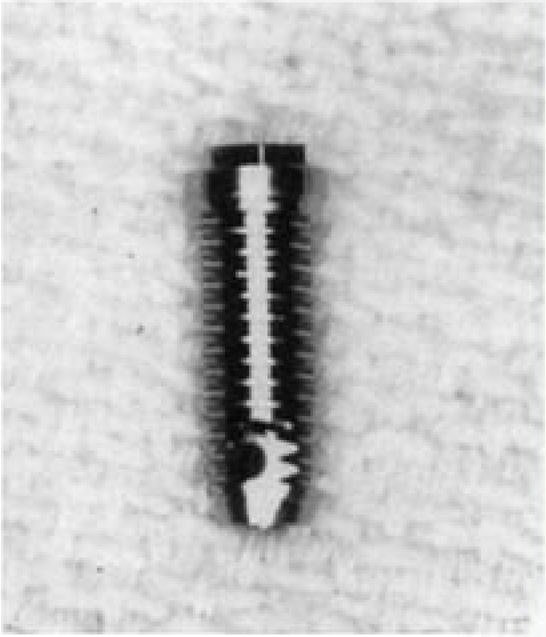
- Fabricated from carbons, metals, elastomers, fabrics, and natural valves.
- Must not React With Chemicals in Body.
- Attached By Polyester Mesh.
- Tissue Growth Facilitated By Polar Oxygen-Containing Groups.

Heart Valve

- Almost as soon as valve implanted cardiac function is restored to near normal.
- Bileaflet tilting disk heart valve used most widely.
- More than 45,000 replacement valves implanted every year in the United States.

Dental Implants

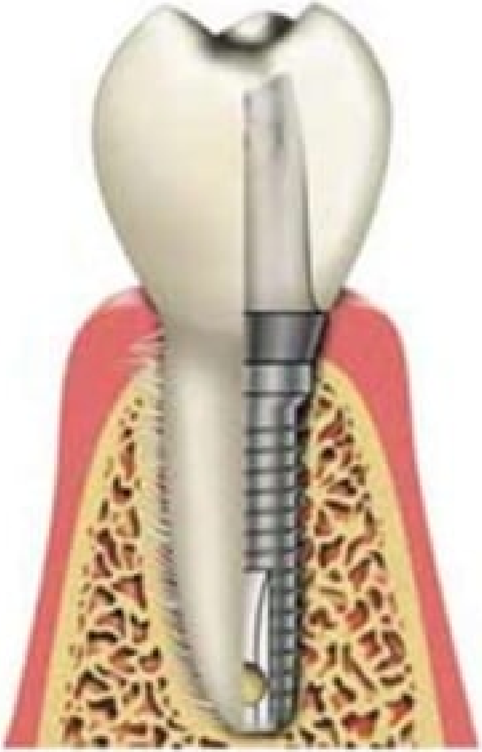
- Small titanium fixture that serves as the replacement for the root portion of a missing natural tooth.
- Implant is placed in the bone of the upper or lower jaw and allowed to bond with the bone.
- Most dental implants are: pure titanium screw-shaped cylinders that act as roots for crowns and bridges, or as supports for dentures.



A titanium dental implant. (Photograph courtesy of Dr. A. Norman Cranin, Brookdale Hospital Medical Center, Brooklyn, NY.)

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.



Vascular Grafts

- Must Be Flexible.
- Designed With Open Porous Structure.
- Often Recognized By Body As Foreign.
- Achieve and maintain homeostasis.
- Good structure retention.
- Adequate burst strength.
- High fatigue resistance.
- Poly(ethylene terephthalate)—PET or Dacron
- Good handling properties.
- Biostable.

Hip-Replacements

- Most Common Medical Practice Using Biomaterials.
- Corrosion Resistant high-strength Metal Alloys.
- Very High Molecular Weight Polymers.
- Thermoset Plastics.

Host Reactions to Biomaterials

- Thrombosis
- Hemolysis
- Inflammation
- Infection and Sterilization
- Carcinogenesis
- Hypersensitivity
- Systemic Effects

What are some of the Challenges?

- To more closely replicate complex tissue architecture and arrangement *in vitro*.
- To better understand extracellular and intracellular modulators of cell function.
- To develop novel materials and processing techniques that are compatible with biological interfaces.
- To find better strategies for immune acceptance.

Biomaterials - An Emerging Industry

- Next generation of medical implants and therapeutic modalities.
- Interface of biotechnology and traditional engineering.
- Significant industrial growth in the next 15 years -- potential of a multi-billion dollar industry.

Future Scope (Surgical Robotics)

- Instead of manipulating surgical instruments, surgeons use their thumbs and fingers to move joystick handles on a control console to maneuver two robot arms containing miniature instruments that are inserted into ports in the patient. The surgeon's movements transform large motions on the remote controls into micro-movements on the robot arms to greatly improve mechanical precision and safety.
- A third robot arm holds a miniature camera, which is inserted through a small opening into the patient. The camera projects highly magnified 3-D images on a console to give a broad view of the interior surgical site.

Surgical Robotics

- UCI Medical Center's da Vinci Surgical System is currently approved for gall bladder, prostate, colorectal, gynecological, esophageal and gastric bypass procedures.

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Thank You!