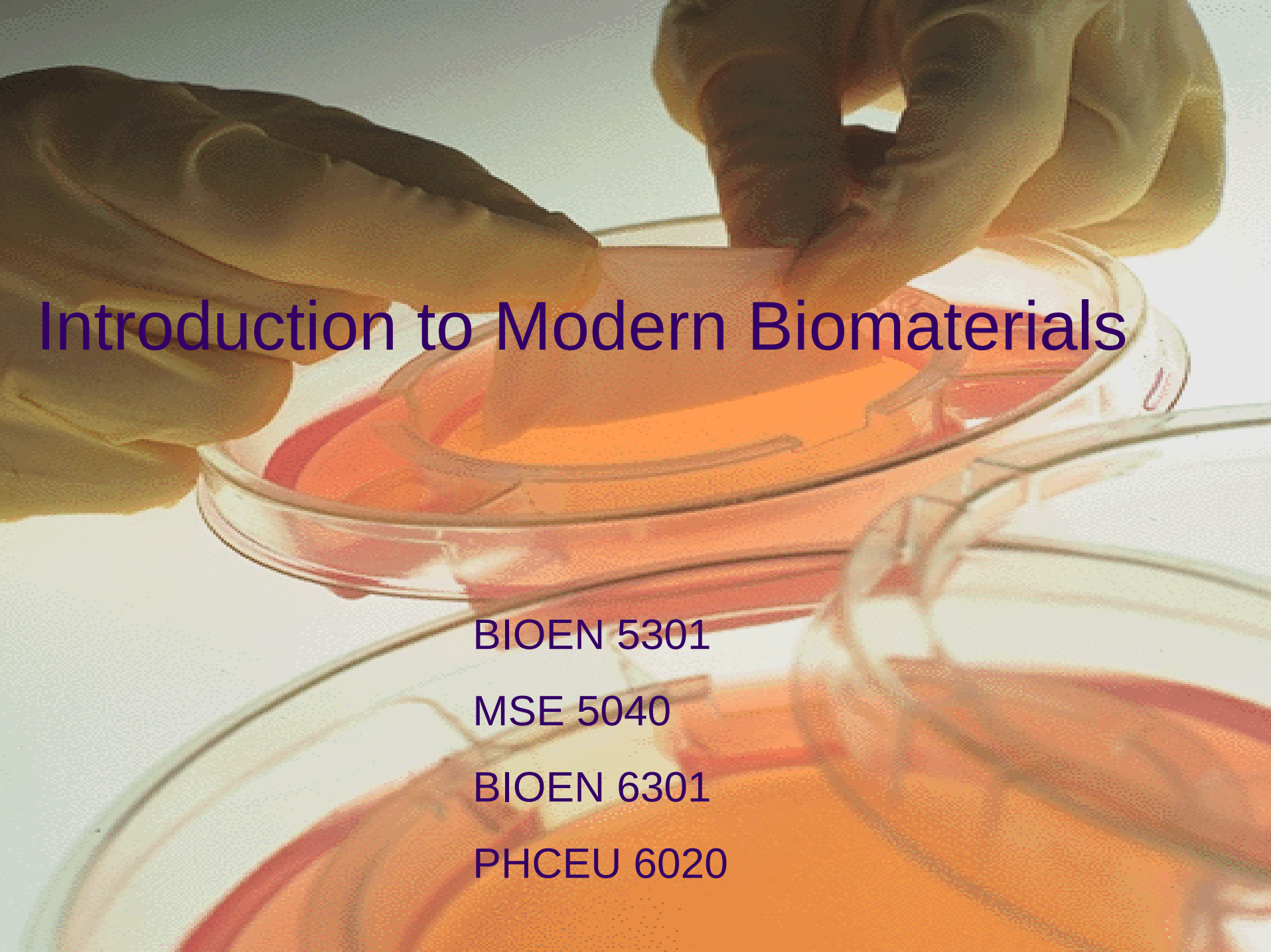


Introduction to Modern Biomaterials

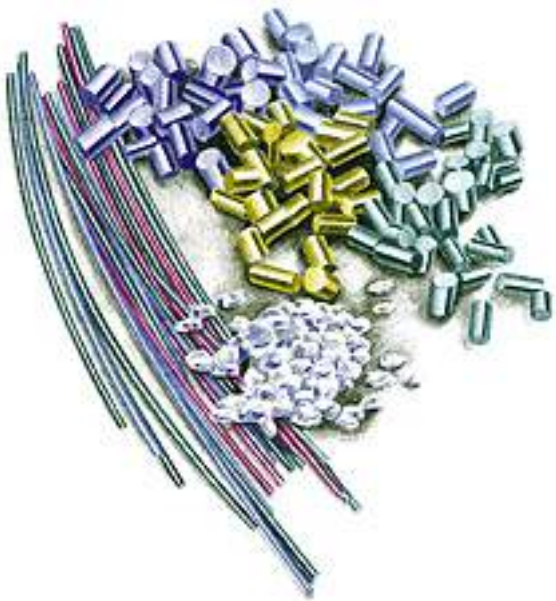
BIOEN 5301

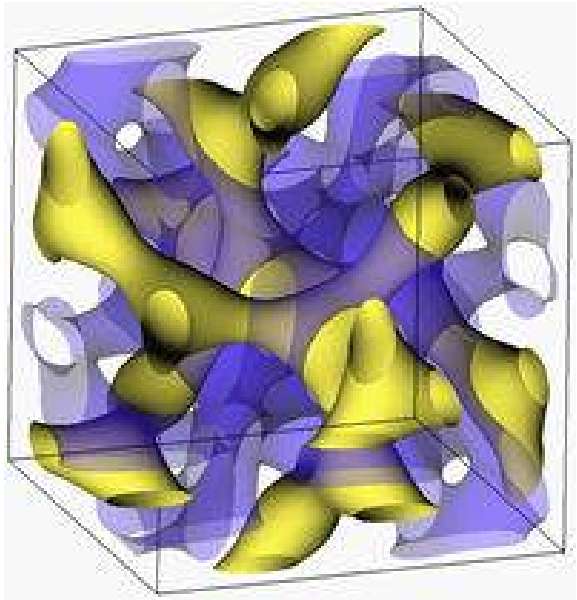
MSE 5040

BIOEN 6301

PHCEU 6020

What is a biomaterial?

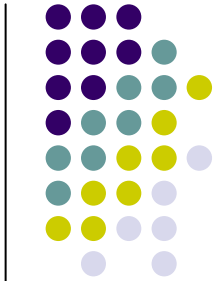




Definition: Biomaterial

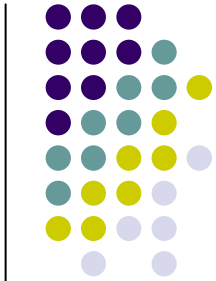
Any material of natural or of synthetic origin that comes in contact with tissue, blood or biological fluids, and intended for use in prosthetic, diagnostic, therapeutic or storage application.

Course Goals:



- Differentiate the various class of biomaterials;
- Differentiate the various analytical methods used to characterize biomaterials;
- Differentiate the molecular and cellular events that follow exposure of materials to tissues and fluids;
- Differentiate the various biomedical devices; &
- Describe various aspects of biomedical device design, fabrication and testing.

Introduction to Modern Biomaterials



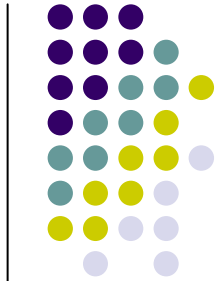
- **Textbook-required**

Biomaterials Science: An Introduction to Materials in Medicine, 2nd Edition, Ratner et al., Elsevier Academic Press, 2004 -

Additional References (Weblinks)
& Other Reading Material

Required reading material other than that in the required textbook will be announced in class and will be posted on the course web site.

Introduction to Modern Biomaterials



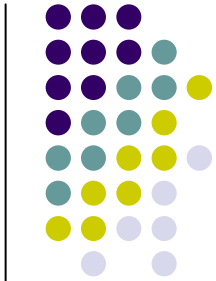
TA

Jeff Wolchok (585-5890) j.wolchok@utah.edu

Xiaoyu Chen (585-5890) xiaoyu.chen@pharm.utah.edu

- Please use WebCT to contact them - use the above email only if you do not have access to WebCT

Grading



- 5000-level

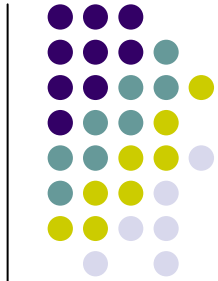
  75% 3 exams

  25% laboratory exercises
- 6000-level

  75%-3 exams

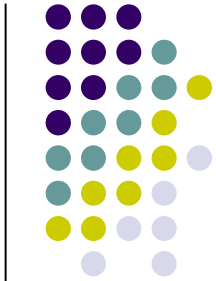
  25% project (20%-proposal/report; 5% oral presentation)

Learning Objectives



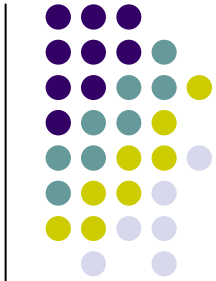
- I will provide you with the exam questions
- You have to provide the answers

Course Methodology



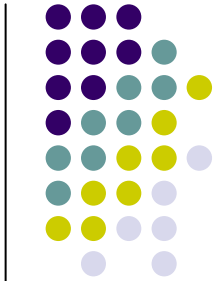
- Interactive lecture style format.
- Laboratories
- Exams will be given in class consisting of short answer and essay questions and will be closed book.

Announcements



- Information about labs
- Safety
- Other important information

The Lab Experience



- Lab protocols -WebCT
- On the first days of lab (11, 12 Jan), half of the students will stay and perform the lab (Wednesday A and Thursday A) and half will be asked to leave and return the following week (Wednesday B and Thursday B).
- You will then attend lab every other week. Check your schedule and determine whether the A weeks or the B weeks are better for you.
- All laboratory assignments will be submitted to the TA via WebCT. If Biomaterials 5301 is not listed on your WebCT homepage, please contact the TA.
- If you are registered for BIOEN 6900 – No Lab

Lab Topics

Lab 1 - Introduction to Biomedical Devices
Classify Your Medical Device

Grading Sheet for Lab 1
Group Divisions

Lab 2 - Surface Characterization of Biomaterials

Lab 3 –Biomaterial Fabrication and Testing I

Lab 4 –Introduction to Adhesives and Composite Structure

Lab 5 – Biomaterial Fabrication and Testing II- 2 part lab

Syllabus

Date	Instructor	Topic
09 Jan	Tresco	Introduction
11 Jan	Tresco	Overview
13 Jan	Tresco	Classes of Materials Used in Medicine
16 Jan	Tresco	Martin Luther King Jr. Day Holiday
18 Jan	Tresco	Polymeric Materials - Part I
20 Jan	Tresco	Polymeric Materials - Part II
23 Jan	TBA	Surface Properties of Biomaterials
25 Jan	TBA	Surface Characterization
27 Jan	TBA	Surface & Protein Interactions

Syllabus

Date	Instructor	Topic
30 Jan	Tresco	Acute Wound Healing
01 Feb	Tresco	Blood Clotting
03 Feb	Tresco	Chronic Wound Healing and Foreign Body Response
06 Feb	Tresco	Inflammation: Part I
08 Feb	Tresco	Inflammation: Part II- Degradation of Implanted Materials
10 Feb	Tresco	Exam I

Syllabus

13 Feb	TBA	Device Development
15 Feb	TBA	The Regulatory Environment
17 Feb	Tresco	Sterilization & Implant Associated Infections
20 Feb	President's Day -Holiday	
22 Feb	Tresco	Biomaterials Testing
24 Feb	Tresco	Surface Coatings
27 Feb	Tresco	Wound Dressings and Sutures
01 Mar	Tresco	Elastomers
03 Mar	Tresco	Intravenous Catheters
06 Mar	Tresco	Applications in Cardiology
08 Mar	Tresco	Biomaterial Fabrication
10 Mar		Exam II

Syllabus

13 Mar	Spring Break	
15 Mar	Spring Break	
17 Mar	Spring Break	
20 Mar	Tresco	Applications in Nephrology
22 Mar	Tresco	Hydrogels
24 Mar	Tresco	Applications in Ophthalmology
27 Mar	Tresco	Metals-Part I
29 Mar	Tresco	Metals- Part II
31 Mar	Tresco	Applications in Orthopedics
03 Apr	Tresco	Ceramics and Bioglasses
05 Apr	Tresco	Adhesives and Sealents
07 Apr		Applications in Dentistry

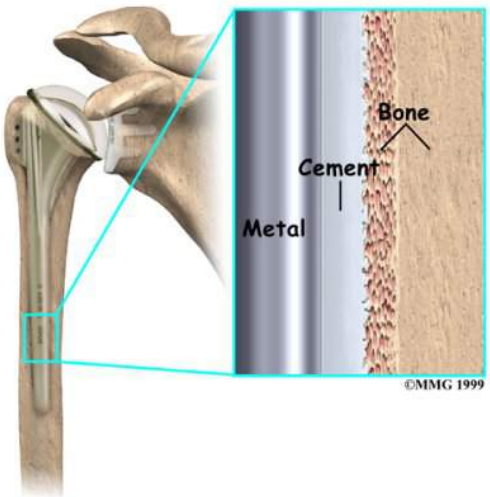
Syllabus

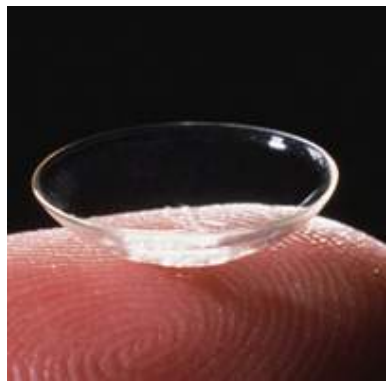
10 Apr	Tresco	Degradable Materials-Part I
12 Apr	Tresco	Degradable Materials-Part II
14 Apr	Tresco	Applications in Drug Delivery
17 Apr	Tresco	Applications in Tissue Engineering
19 Apr	Tresco	Project Presentations
21 Apr	Tresco	Project Presentations
24 Apr	Tresco	Project Presentations
26 Apr	Tresco	Exam III
28 Apr	Project Report due	

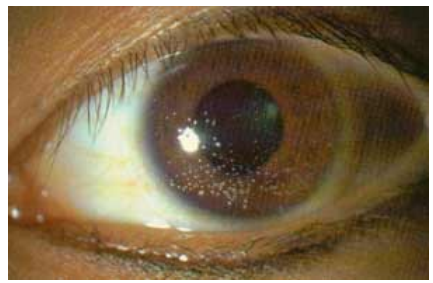
Biomaterials Graduate Project:

Purpose

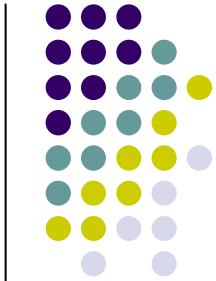
- To apply knowledge of biomaterial properties to a material selection/ biomedical device design problem.





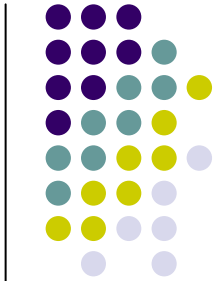


Suggested Process:



- Select a Class III biomedical device that has or is being developed for commercial use;
- Identify the various major parts of the device or implant, provide a drawing or illustration and list the biomaterials used. This may involve contacting the manufacturer and/or locating the appropriate information within the patent literature;
- Using the peer-reviewed literature describe what is known of the biocompatibility of the device;
- Justify the selection of the materials used with regards to similar successful applications, physical characteristics, suitability for processing/ manufacture, cost, and favorable federal regulations; &
- Provide an alternative biomaterial solution to improve biocompatibility and justify your selection based upon relevant peer-reviewed literature.
- List benefits and drawbacks of the existing components and those of the proposed alternative.

Timeline



- Project proposal due Feb 17th, 2 page maximum and bibliographic sources (use endnote if available). It should describe the selected device and propose ideas for completing the project. This will enable the instructor to provide feedback on the project topic.
- Final report due April 28th , 25 pages maximum Times New Roman 11 point.
- Oral project presentations of 12 minutes during final three lecture periods.

Headlines

Biocoral, Inc. Announces Approval of its French Patent
Monday January 9, 9:01 am ET

NEW YORK, January 9 /PRNewswire-FirstCall/ -- Biocoral, Inc. (OTCBB: BCRA - News) announced today that recently the French Patent Office (Institut National de la Propriete Industrielle "INPI") approved and granted a company patent called "Device for delivering of Biomaterial into a determined portion of bone"

Headlines

CryoLife Receives FDA Approval of New, Larger Delivery System for BioGlue(R) Surgical Adhesive

Disposable Syringe Provides Surgeons with Improved Site Access and Ease of Use ATLANTA, Jan. 12 /PRNewswire-FirstCall/ -- CryoLife, Inc., (NYSE: CRY) a biomaterials and biosurgical device company, today announced that it has received approval from the Food and Drug Administration (FDA) for a new 10ml disposable syringe for BioGlue Surgical Adhesive.

Headlines

TyRx Pharma's Anesthetic Coated Surgical Mesh Combination Product Assigned to 'Device' Center at FDA

TyRx plans to initiate clinical trials in the first half of 2006
MONMOUTH JUNCTION, N.J., Jan. 9 /PRNewswire/ -- TyRx Pharma, Inc., announced today that its Anesthetic Coated Surgical Mesh has received a designation of "Combination Product with Device Primary Mode of Action (PMOA)" from the Office of Combination Products at the U.S. Food and Drug Administration (FDA). This designation and assignment to the Center for Devices and Radiologic Health (CDRH) has historically indicated a faster regulatory and commercial timeline for a product as compared to when the FDA considers a combination product to be a "drug".

Headlines

Angiotech Initiates Anti-Infective CVC U.S. Pivotal Study

ADVANCING NOVEL APPROACH TO PREVENT MEDICAL DEVICE INFECTIONS VANCOUVER, Jan. 5 /PRNewswire-FirstCall/ - Angiotech Pharmaceuticals, Inc. (NASDAQ: ANPI, TSX: ANP) today announced the initiation of its United States pivotal study examining an anti-microbial central venous catheter (CVC). This U.S. multi-center study is designed to evaluate the efficacy of a CVC coated with the drug 5-Flourouracil (5-FU), a non-traditional anti-infective agent. The study enrolled its first patient last week in Rapid City, South Dakota, and will involve approximately 600 patients at 20 centers in the United States.

Headlines

CeTaQ announces MCA testing for lasers in medical, biomedical device manufacturing

Jan 09, 2006

CeTaQ Americas announces the availability of Machine Capability Analysis (MCA) testing applicable to laser systems.

CeTaQ's test methodology measures the width of the laser cut as well as beam size and consistency, comparing the actual result with the programmed pattern and process settings. The test method is applicable to lasers used in such processes as cutting, welding, and scribing, stencil cutting, laser marking (such as matrix labeling), and other applications such as drilling. All types of lasers, including UV (excimer and DPSS) can be evaluated.

Headlines

Antibacterial coatings on hip and knee implants cut infection rates

Putting antibacterial coatings on hip and knee implants and biomedical devices such as catheters could cut infection rates following surgery and significantly reduce health care costs and improve quality of life for patients, researchers at the University of South Australia have found.

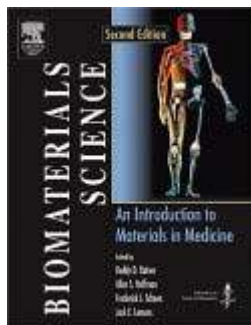
A significant number of hip and knee implants are prone to infection after surgery and in many cases are not amenable to treatment with antibiotics, according to Hans Griesser, Professor of Surface Science and Deputy Director of UniSA's Ian Wark Research Institute.

Introduction

Biomaterials Science: A Multidisciplinary Endeavor

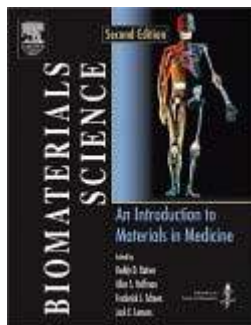
Definitions

- Biomaterial-a nonviable material used in a medical device to interact with biological systems
- Biocompatibility-the ability of a material to perform with an appropriate host response in a specific application



Biological Response to Contact with Materials

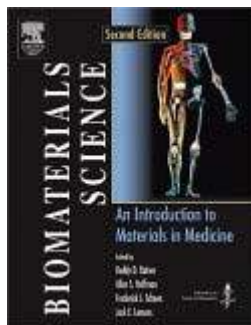
A study of the molecular and cellular events that follow contact with biological fluids or tissues whether *in vitro* or *in vivo* from initial contact to the eventual culmination of the response.



Biocompatible

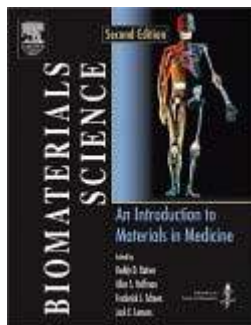
A general term meaning that a biomaterial, device or construct can be brought into direct contact with living tissue without:

- causing a harmful tissue reaction (pain, swelling or necrosis) that could compromise function;
- causing a systemic toxic reaction; or
- having tumorigenic potential.

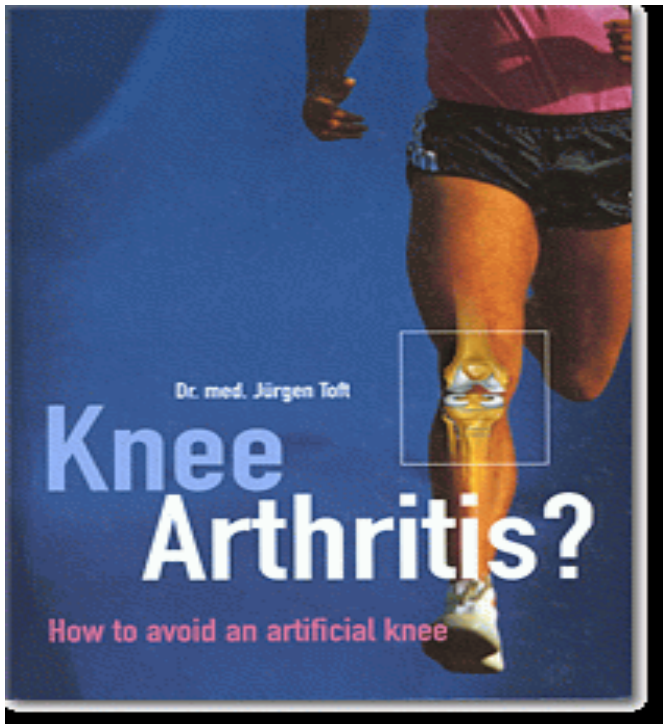


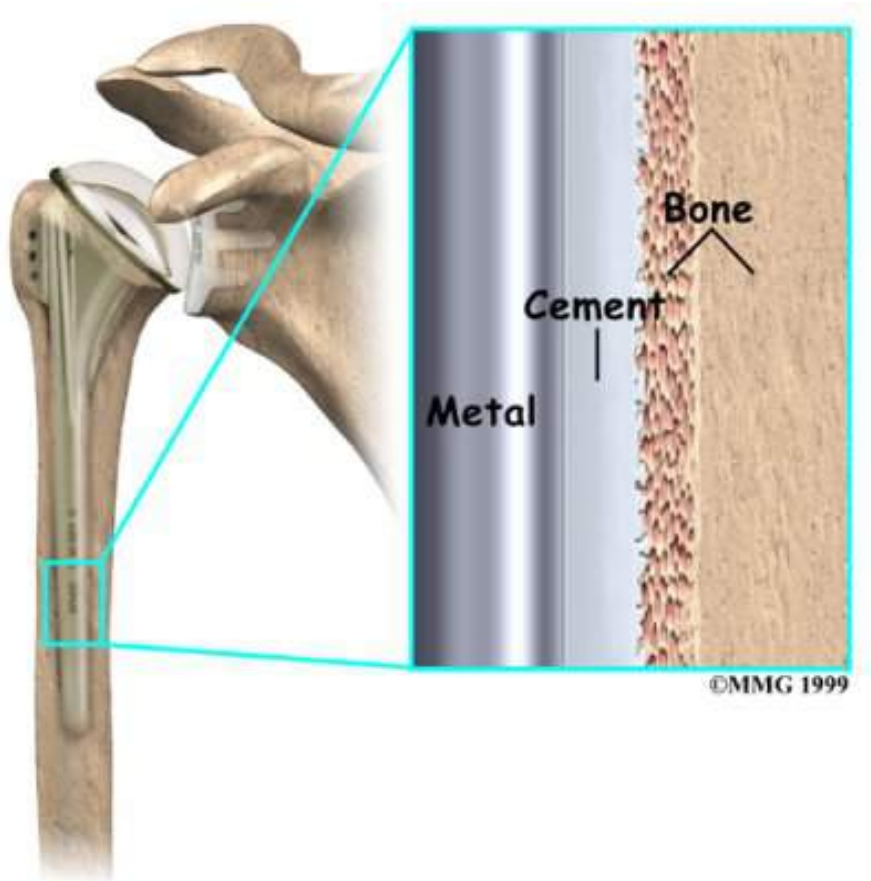
Biocompatibility testing include procedures designed to evaluate:

- cytotoxicity;
- acute, subchronic, and chronic toxicity;
- irritation to skin, eyes, and mucosal surfaces;
- sensitization;
- hemocompatibility;
- short-term implantation effects;
- genotoxicity;
- carcinogenicity; and effects on reproduction, including developmental effects.

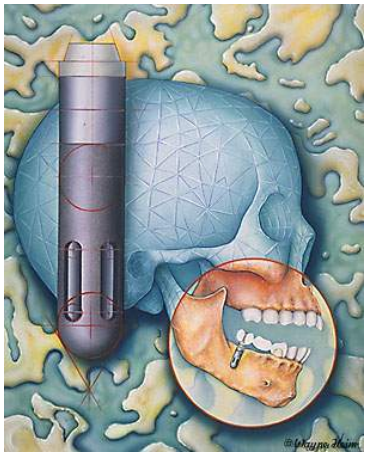


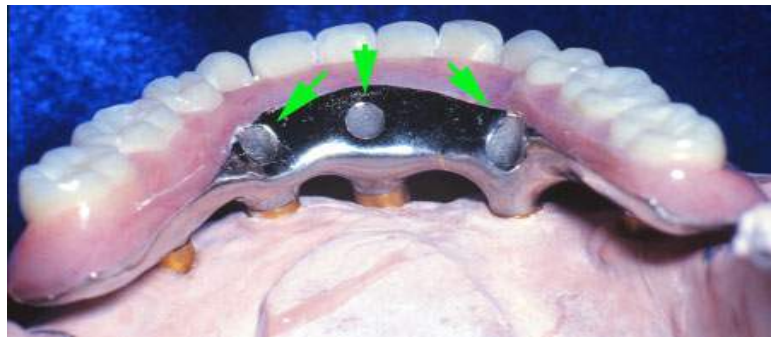
Applications in Orthopedics



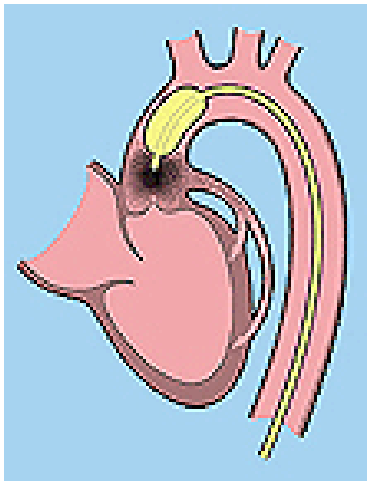


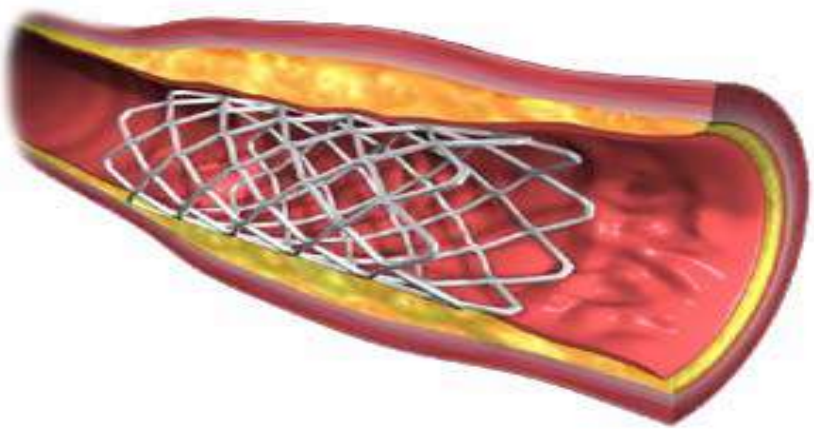
Applications in Dentistry



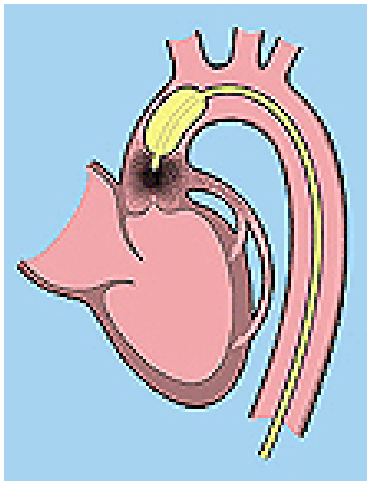


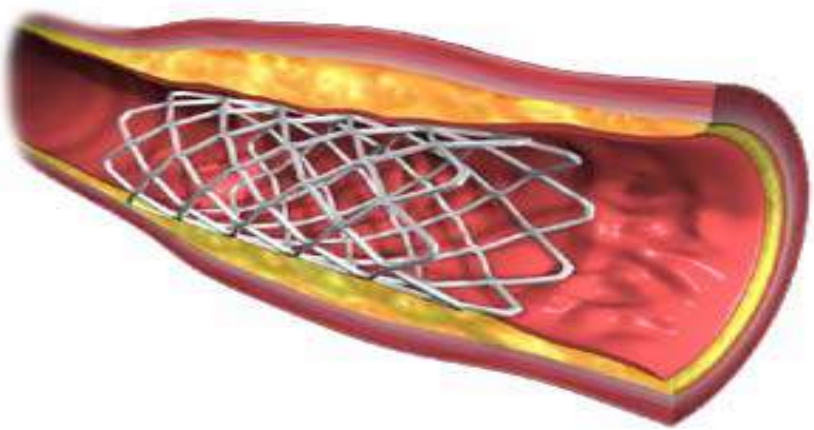
Cardiovascular Applications

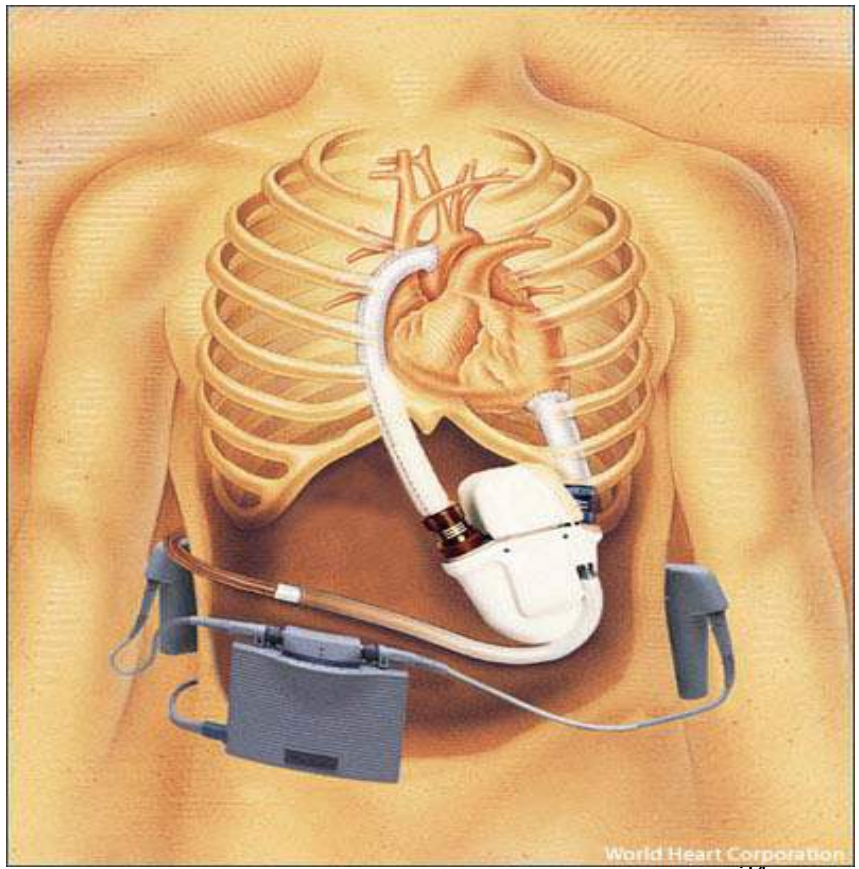




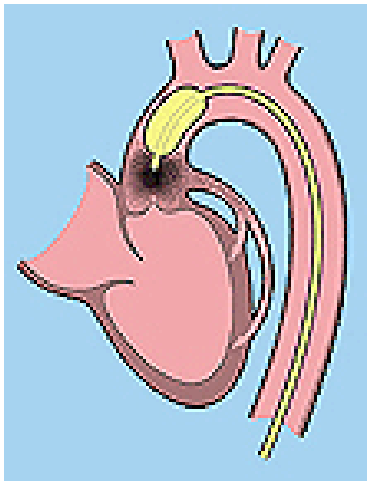
Cardiovascular Applications

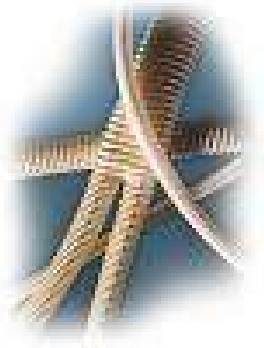


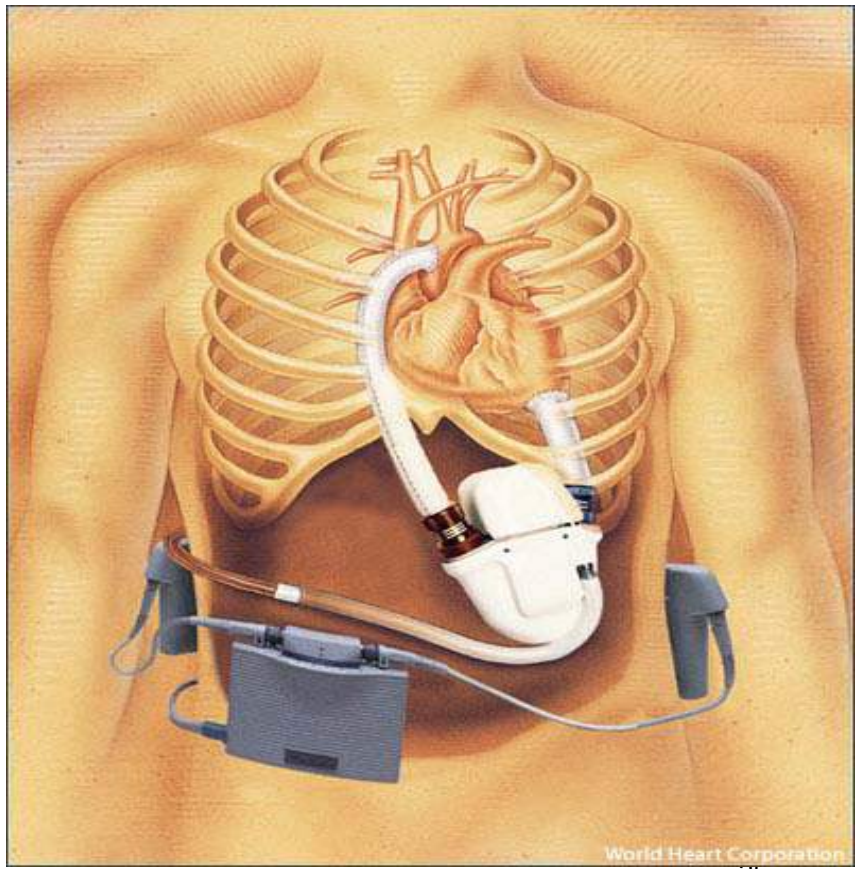




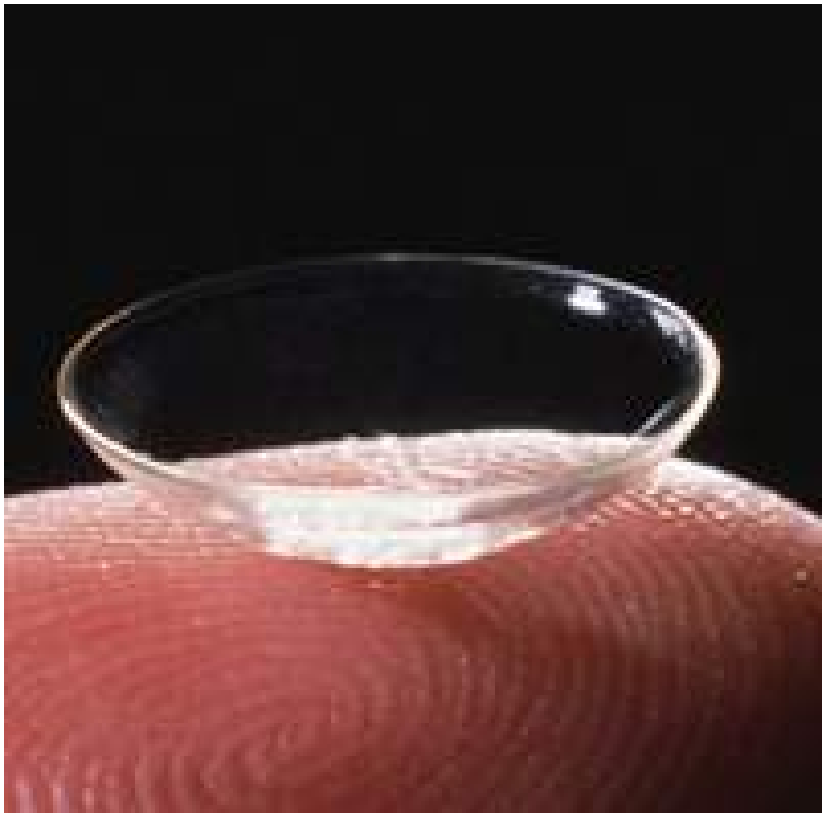
Cardiovascular Applications



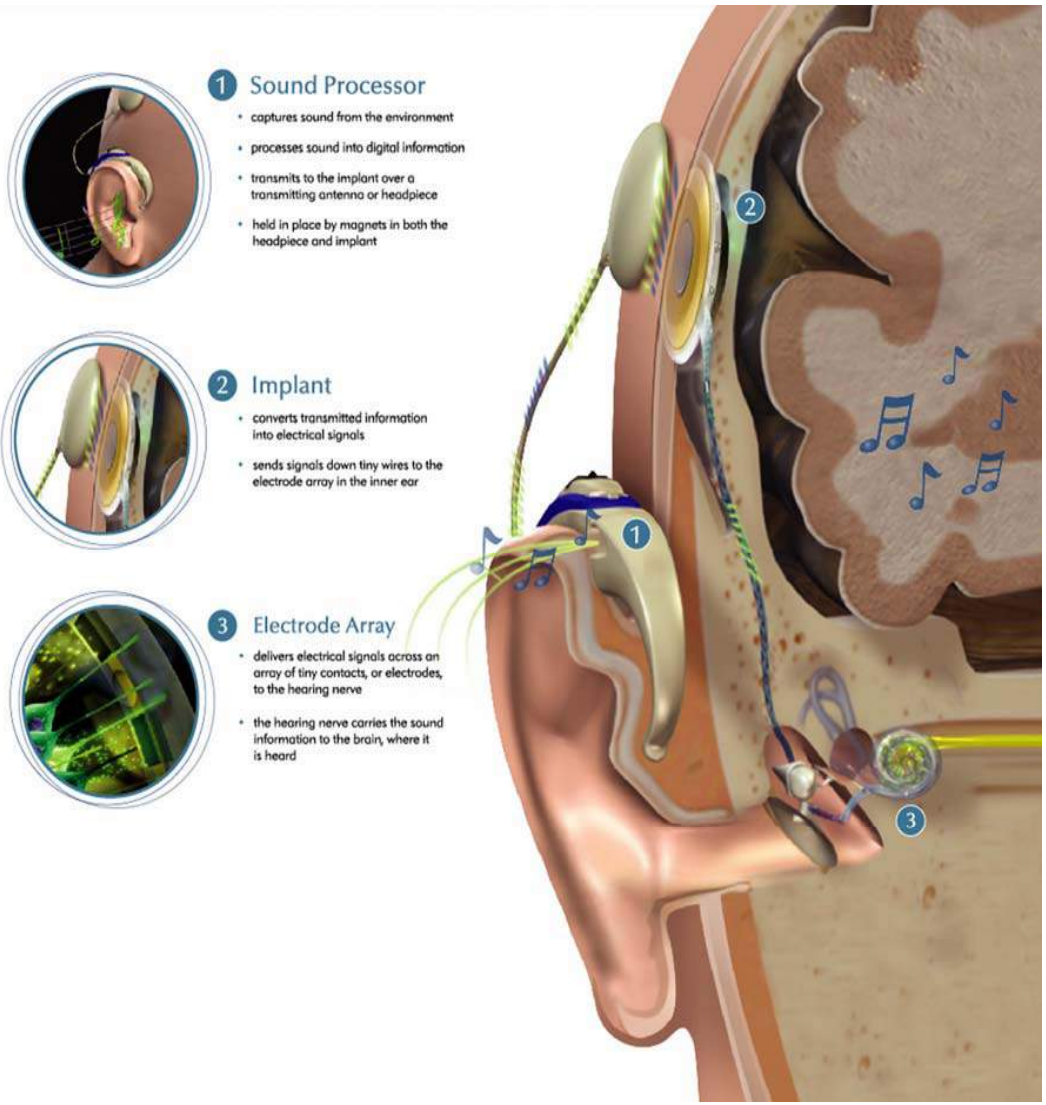




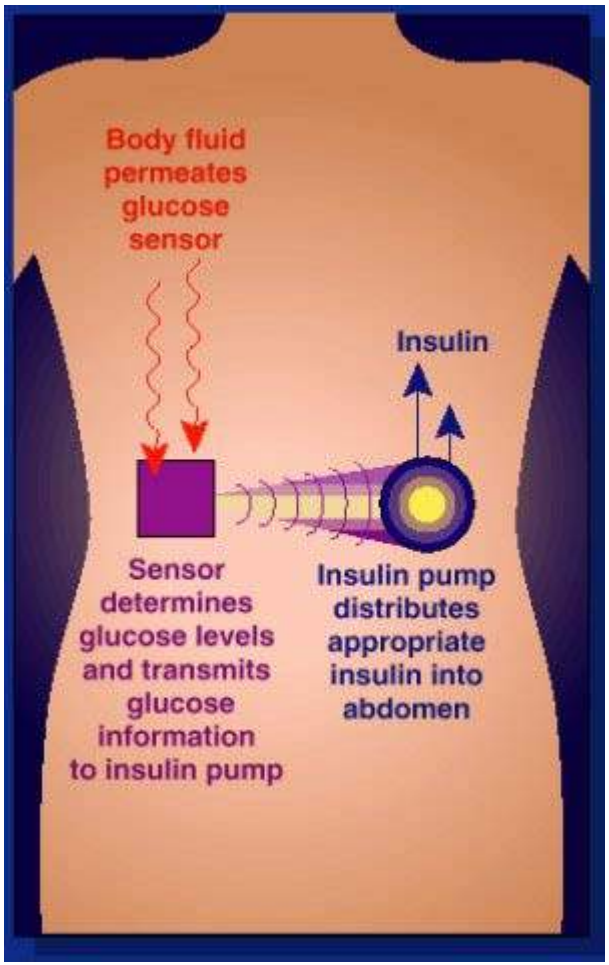
In Ophthalomolgy



In Neurology

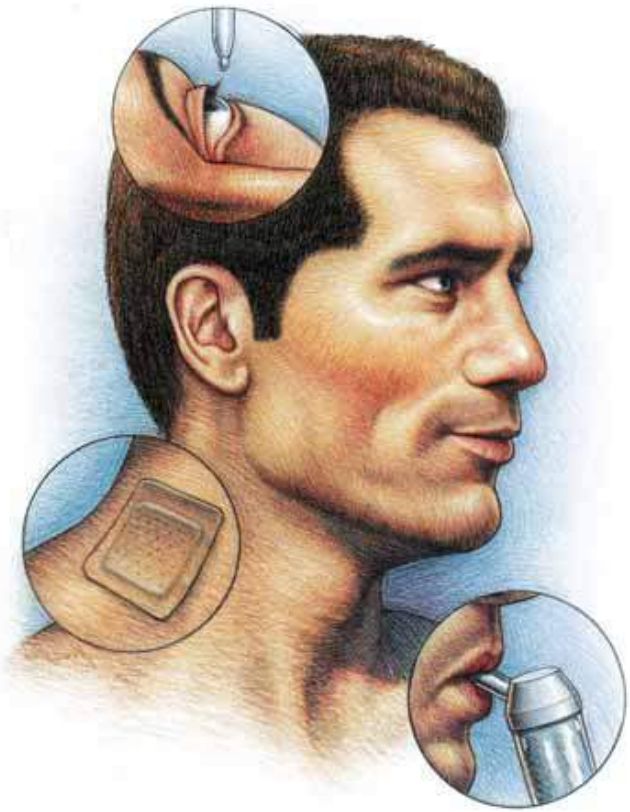


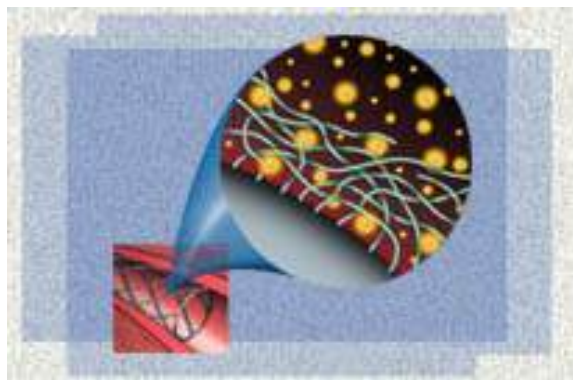
Internal Medicine



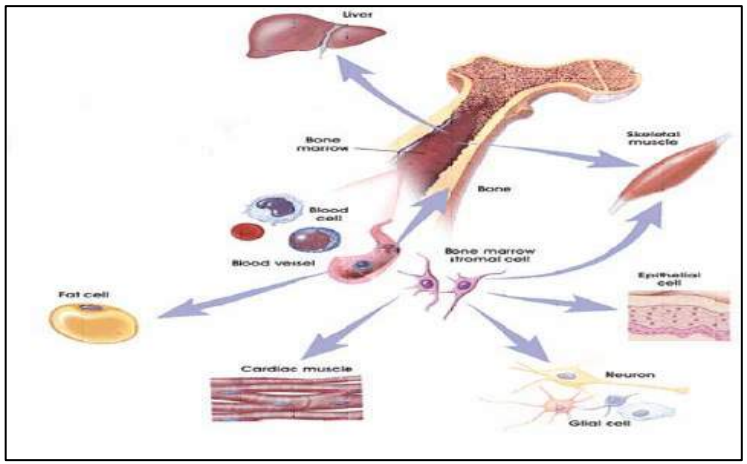
In Nephrology

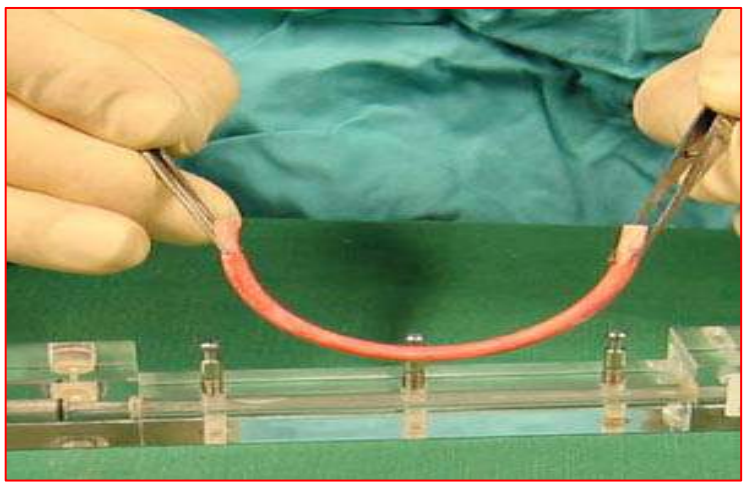
In Drug Delivery

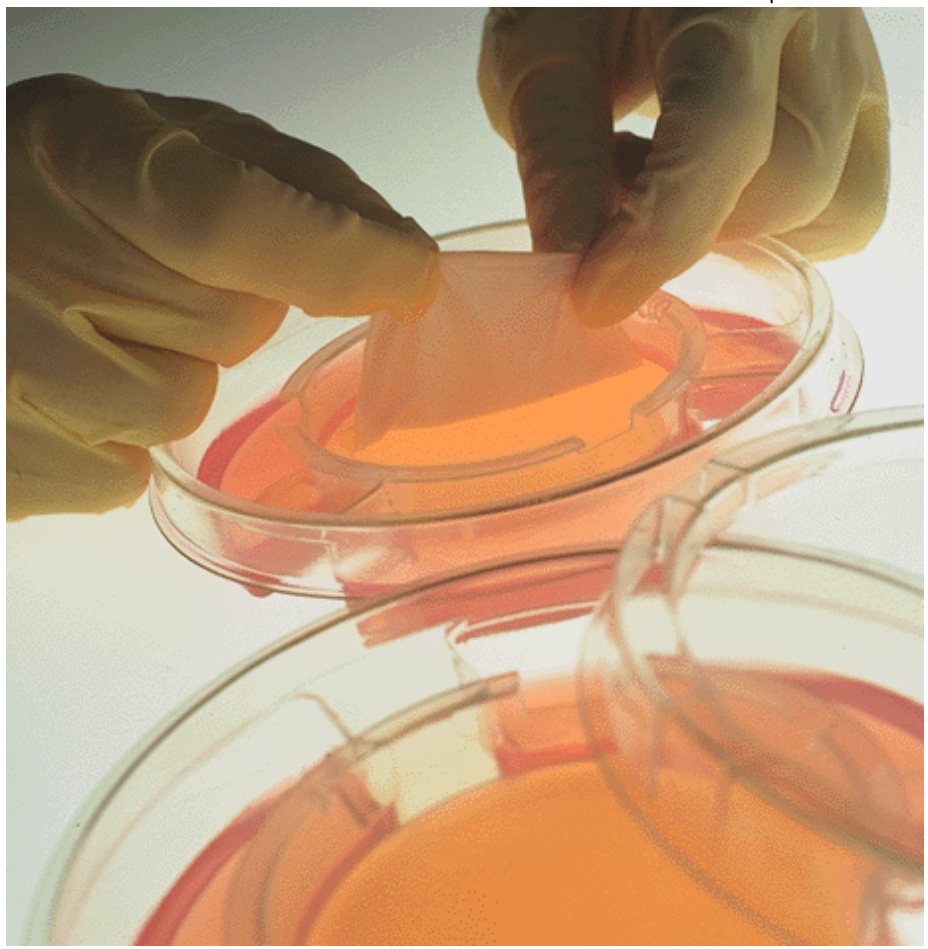


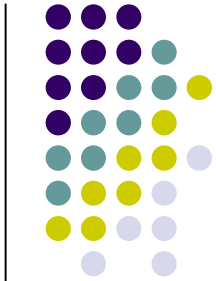


Future Applications- Tissue Replacement





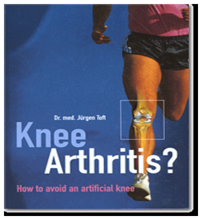


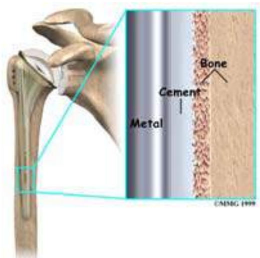


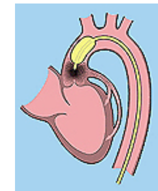
"Ask courageous questions. Do not be satisfied with superficial answers."

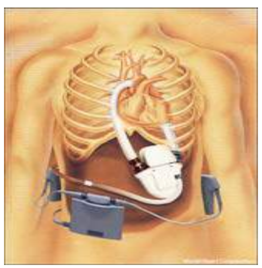
-- Carl Sagan

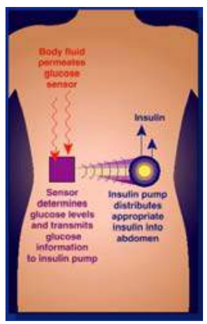
Examples of Biomaterials Applications

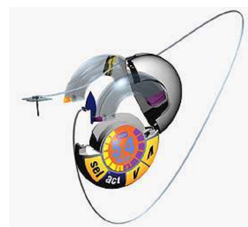


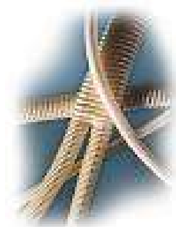


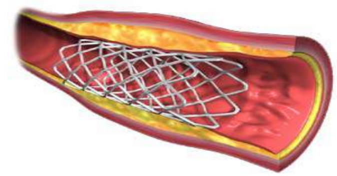


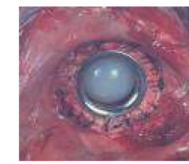


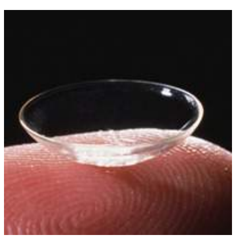


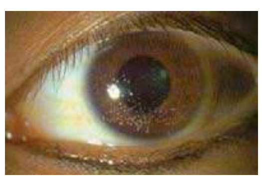


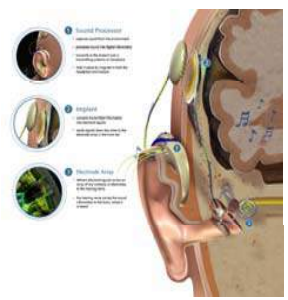


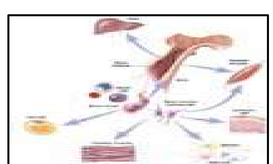


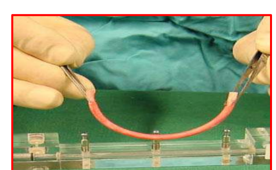


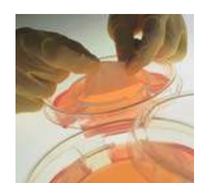


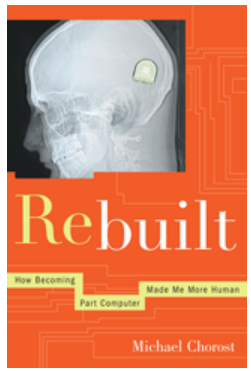






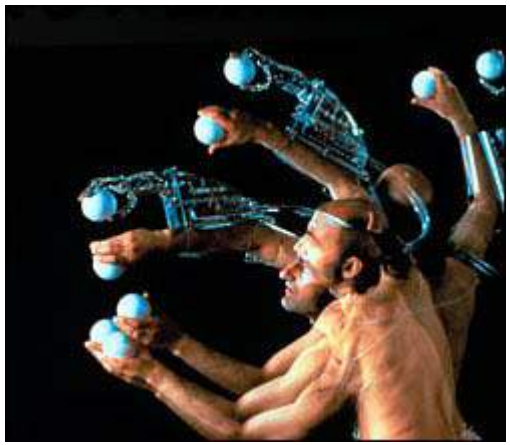


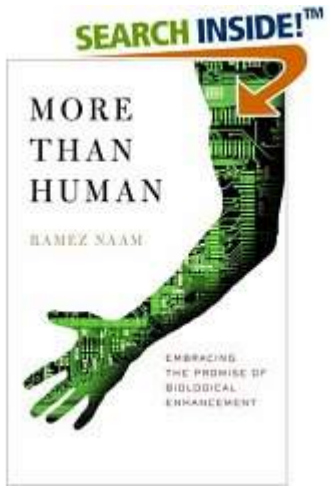


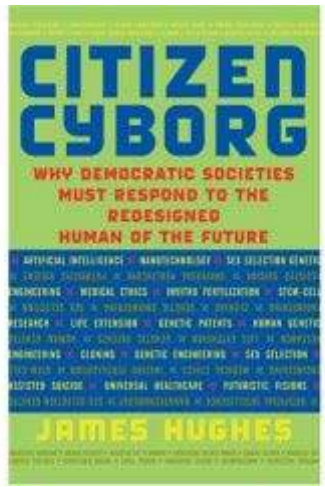

Rebuilt
How Becoming
Part Computer
Made Me More Human
Michael Chorost

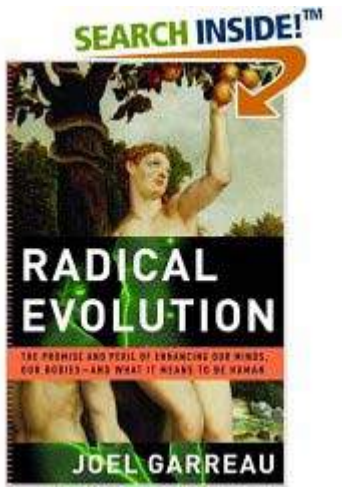

KSL
TV

The upgrade

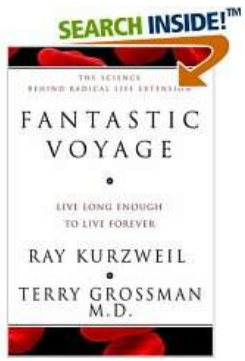



SEARCH INSIDE!™
MORE THAN HUMAN
RAMEZ NAAM
EMBRACING THE PROMISE OF BIOLOGICAL ENHANCEMENT


CITIZEN CYBORG
WHY DEMOCRATIC SOCIETIES MUST RESPOND TO THE REDESIGNED HUMAN OF THE FUTURE
JAMES HUGHES

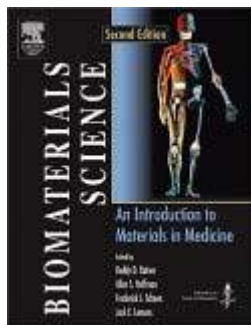

SEARCH INSIDE!™
RADICAL EVOLUTION
JOEL GARREAU


SEARCH INSIDE!™
The Scientific Conquest of Death
Essays on Infinite Lifespans


SEARCH INSIDE!™
FANTASTIC VOYAGE
LIVE LONG ENOUGH TO LIVE FOREVER
RAY KURZWEIL
TERRY GROSSMAN M.D.

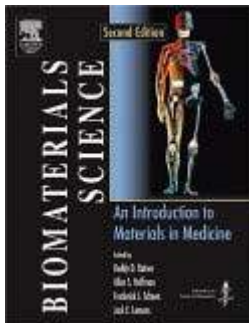
Are medical devices monolithic?

- No
- Composites
- Many diverse materials
- Dependent on applications



Biomaterials Research in Industry

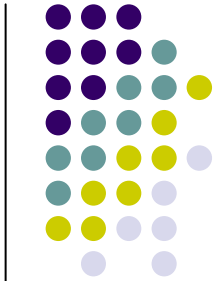
- is dominated as much by the regulatory approval process and submission requirements as by the physical, mechanical, and chemical properties of the medical device.



Definition: Biomaterial -FDA

"an instrument, apparatus, implement, machine, contrivance, implant, in vitro reagent, or other similar or related article, including a component part, or accessory which is recognized in the official National Formulary, or the United States Pharmacopoeia, or any supplement to them, intended for use in the diagnosis of disease or other conditions, or in the cure, mitigation, treatment, or prevention of disease, in man or other animals, or intended to affect the structure or any function of the body of man or other animals, and which does not achieve any of it's primary intended purposes through chemical action within or on the body of man or other animals and which is not dependent upon being metabolized for the achievement of any of its primary intended purposes."

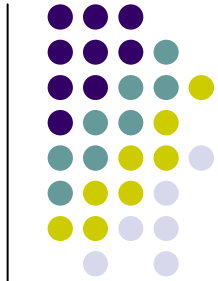
The Food and Drug Administration (www.fda.gov)



Regulates:

- Food
- Drugs-*Prescription, Over-the-Counter, Generic*….
- Medical Devices
- Animal Feed and Drugs-*Livestock, Pets* …
- Cosmetics-*Safety, Labeling…..*
- Radiation Emitting Products-*Cell Phones, Lasers, Microwaves…..*

Center for Devices and Radiologic Health- (CDRH)

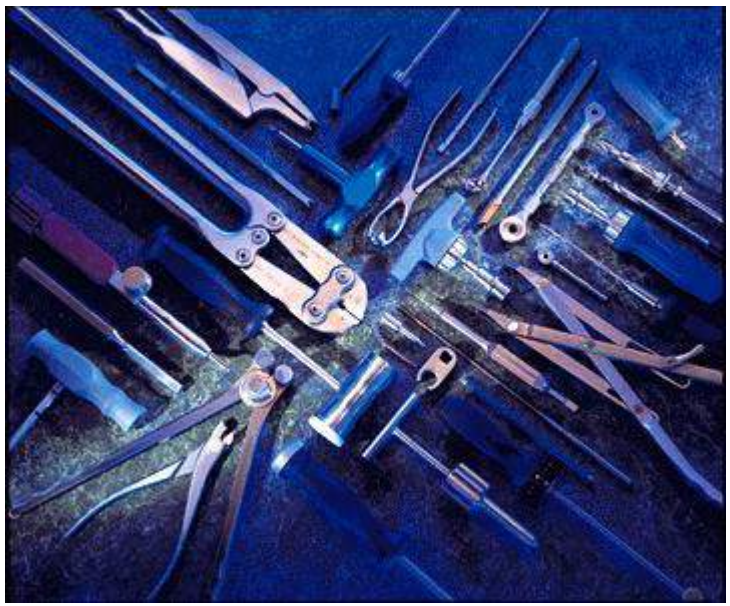


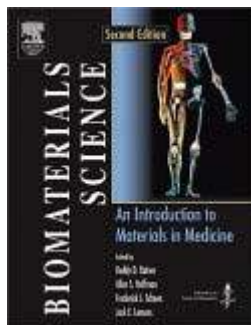
(www.fda.gov/cdrh/)

- Responsible for regulating firms who manufacture, repackage, relabel, and/or import medical devices sold in the United States.

BIOMATERIAL OR MEDICAL DEVICE?

- FDA neither approves materials nor maintains a list of approved materials
- the properties and safety of materials must be carefully assessed with respect to the specific application in question and its degree of patient contact.
- the final assessment must be performed on the finished product, under actual use conditions.



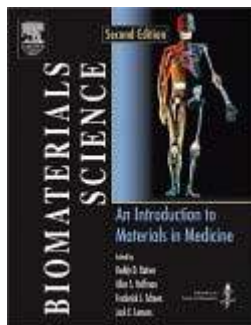


Manufacture of a Medical Device

1. materials selection;
2. types of tests required for evaluation depend on the physical and chemical nature of its materials and the nature of the device's exposure to the body;
3. its physical properties, cost, and availability may be acceptable, but might contain toxic chemical components;
4. screen the candidate materials at an early stage to eliminate those that are toxic, and select those that are sufficiently biocompatible or nontoxic for their intended use.
5. Chemical constituents and potential extractables should be identified and quantitated for overall safety assessment of the device.

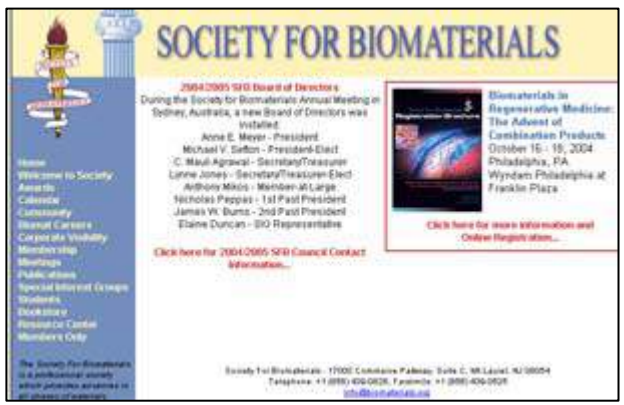
Biomaterials Science is an Interdisciplinary Affair

Biomaterialists include physical scientists, engineers, dentists, biological scientists, surgeons, and veterinary practitioners in industry, government, clinical specialties, and academic settings.



The Society For Biomaterials

A professional society which promotes advances in all phases of materials research and development by encouragement of cooperative educational programs, clinical applications, and professional standards in the biomaterials field. Internationally recognized leaders in the biomaterials field participate in the Society and sponsored events. (www.biomaterials.org)



Relevant Biomaterials Journals

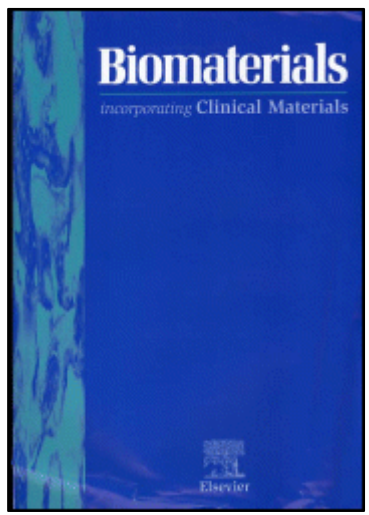
Journal of Biomedical Materials Research

Biomaterials

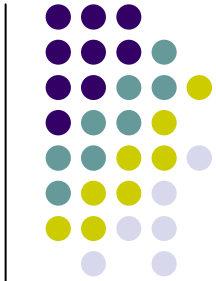
Journal of Biomaterials Science. Polymer Edition

Journal of Biomaterials Applications

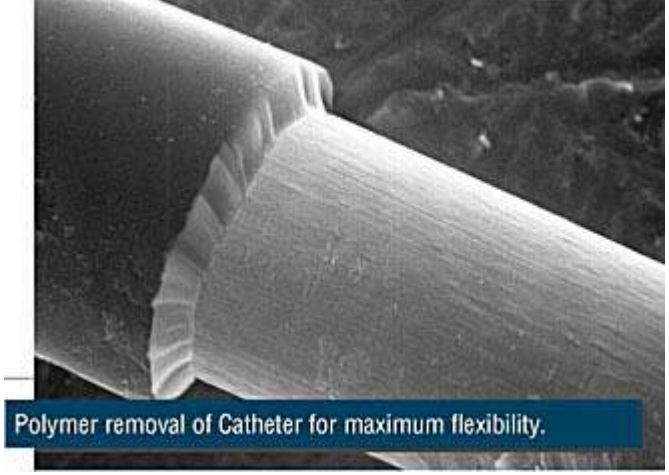
Journal of Materials Science: Materials in Medicine

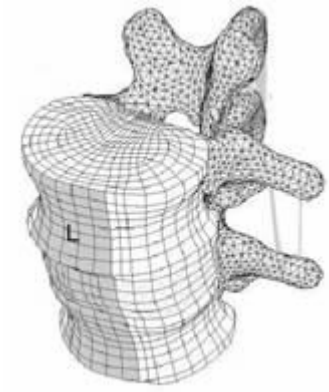


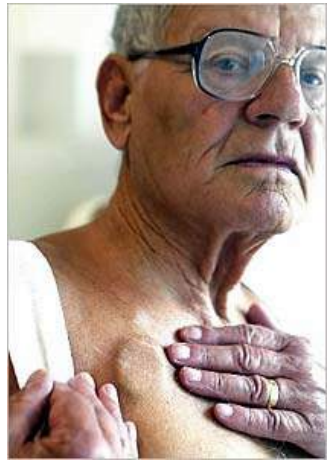
Relevant Websites



- Biomaterials Network (www.biomat.net)
- Medical Device Information (www.devicelink.com)
- Medical Materials Engineering reference (www.engineeringreference.com)
- United States Patents and Trademarks Office (www.uspto.gov)
- General search-Google (www.google.com)
- MEDLINE-(www.ncbi.nih.gov/entrez/query.fcgi)

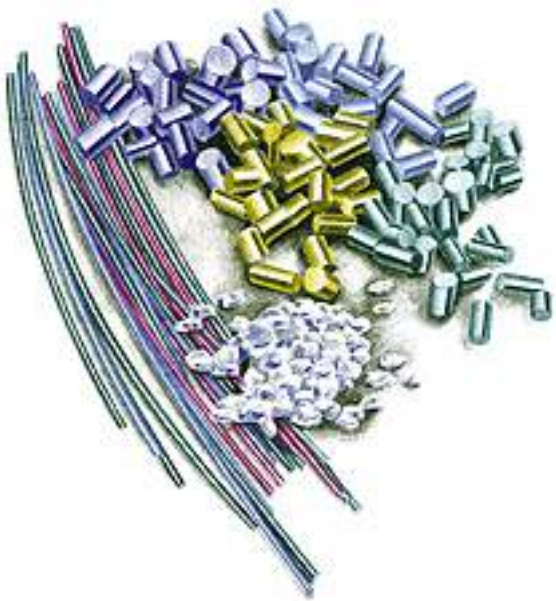






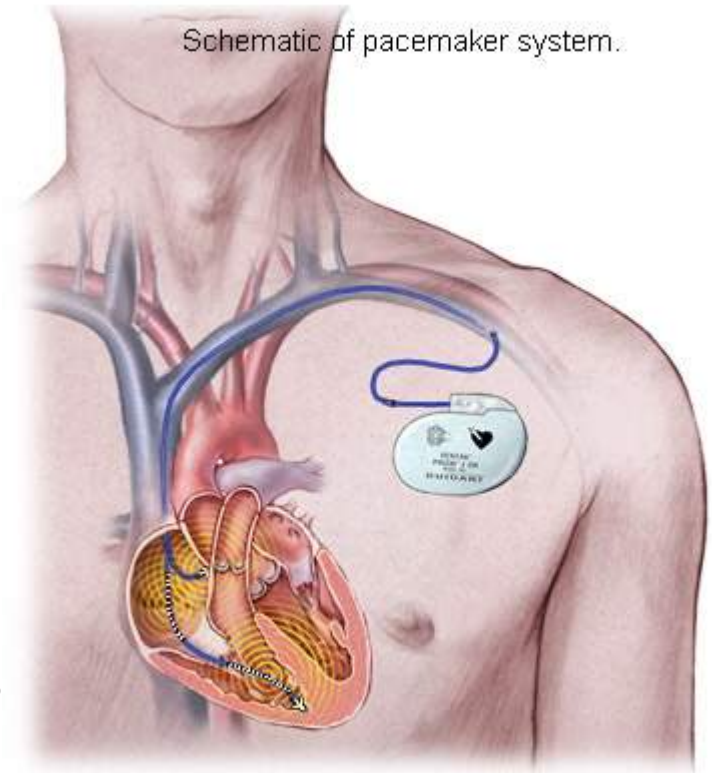
Classes of Materials Used in Medicine

How many different types of biomaterials are in use today?

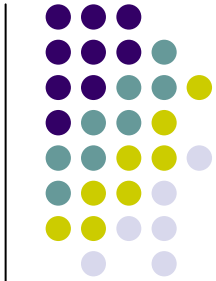


Fact-

The FDA regulates 100,000 different products that represent at least 1,700 Different Types of Biomedical Devices

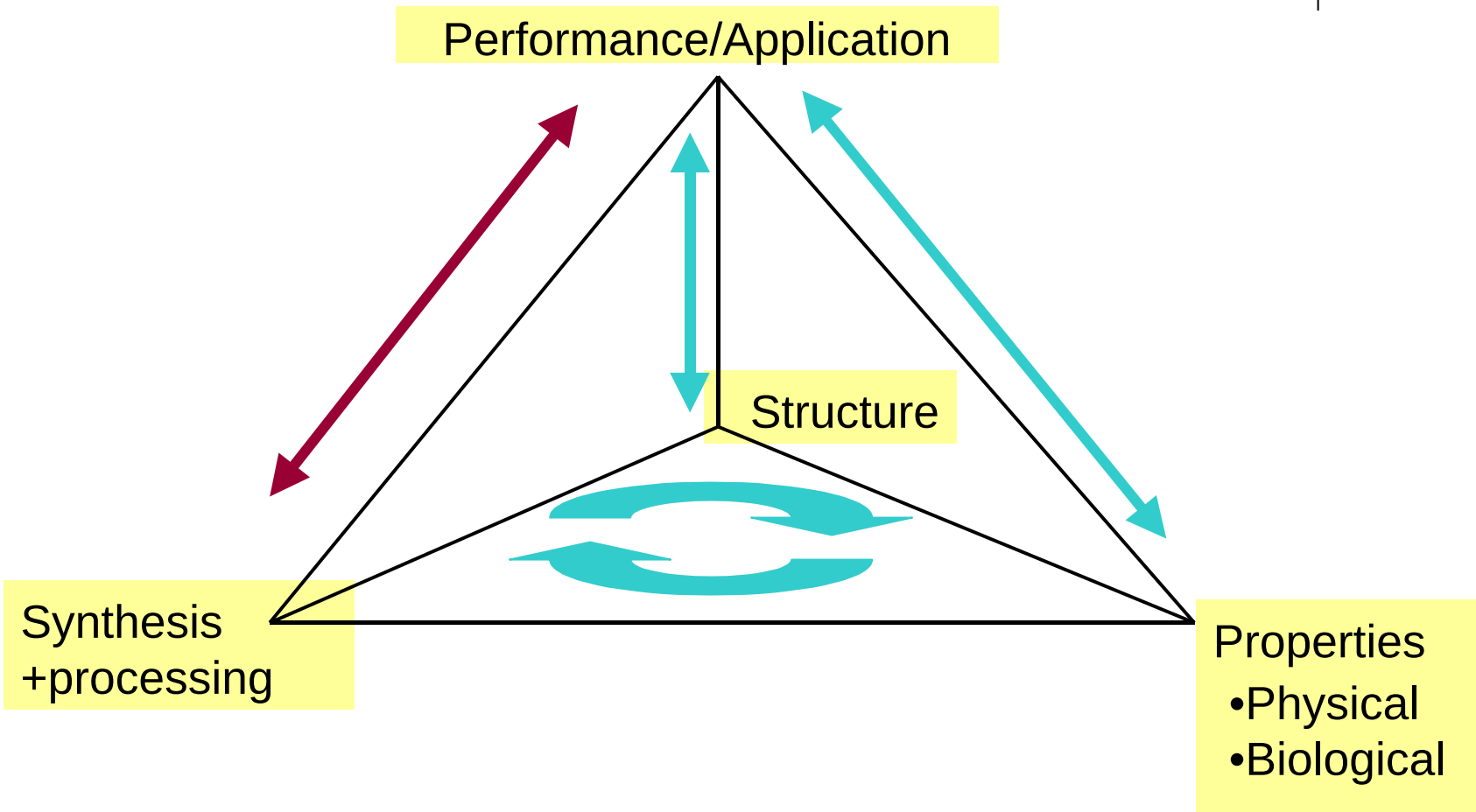


Broad Classification- Types of Biomaterials



- ceramics
- metals
- polymers, synthetic and natural

Material Science Logic



Bio-inertness vs. Bioactivity

Bioactive materials play a more aggressive role in the body. While a biocompatible material should affect the equilibrium of the body as little as possible, a bioactive material recruits specific interactions between the material and surrounding tissue.

Requirements of Biomaterials

A biomaterial must be:

- inert or specifically interactive
- biocompatible
- mechanically and chemically stable or
- biodegradable
- processable (for manufacturability)
- nonthrombogenic (if blood-contacting)
- sterilizable

Ceramics

- Inorganic compounds that contain metallic and non-metallic elements, for which inter-atomic bonding is ionic or covalent, and which are generally formed at high temperatures.
- Derivation: From the Greek word *"keramos"* meaning the art and science of making and using solid articles formed by the action of heat on earthy raw materials.
- Most ceramics occur as minerals:
- (1) The abundance of elements and geochemical characteristics of the earth's crust govern mineral types.
- (2) Composition of *Earth's Crust*: [84% = O + Si + Al]

  O = 50% Fe = 5% K = 2.5%

  Si = 26% Ca = 3% Mg = 2%

  Al = 8% Na = 2.5% H = 1%

Ceramics

Advantages:

- inert in body
- high wear resistance
- high modulus (stiffness) & compressive strength
- fine esthetic properties for dental applications

Disadvantages:

- brittle
- low tensile strength
- poor fatigue resistance

Ceramic Applications

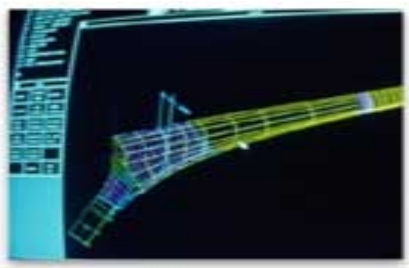
- artificial hip;
- knee prostheses;
- spinal fusion devices;
- dental-crowns, bridges, implants and caps;
- inner ear and cochlear implants (cochlear implants);
- drug delivery devices; and,

Ceramics

- Alumina, Zirconium, Calcium phosphate, Silica, pyrrolytic carbon, hydroxyapatite are common;
- Porous ceramic materials exhibit much lower strengths but have been found extremely useful as coatings for metallic implants;
- The coating aids in tissue fixation of the implant by providing a porous surface for the surrounding tissue to grow into and mechanically interlock; and,
- Certain ceramics are considered bioactive ceramics if they establish bonds with bone tissue.

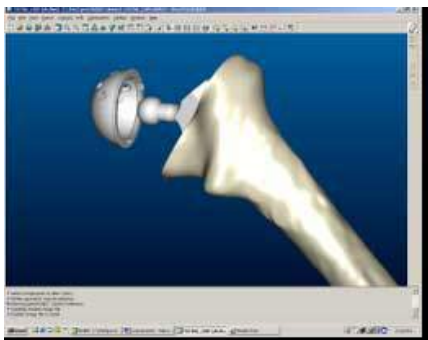
Metals

- closely packed crystal structure; the type of bonding in metals and metal alloys render them valuable as load bearing implants as well as internal fixation devices used for orthopedic applications as well as dental implants;
- when processed suitably they contribute high tensile, fatigue and yield strengths; low reactivity and good ductility to the stems of hip implant devices; and,
- Their properties depend on the processing method and purity of the metal, however, and the selection of the material must be made appropriate to its intended use.

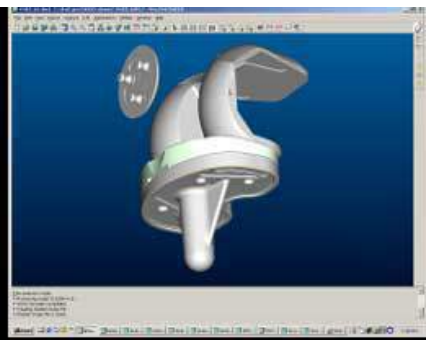


Metals Manufacturing

High Temperature Vacuum Furnaces



Solid Model of Total Hip System

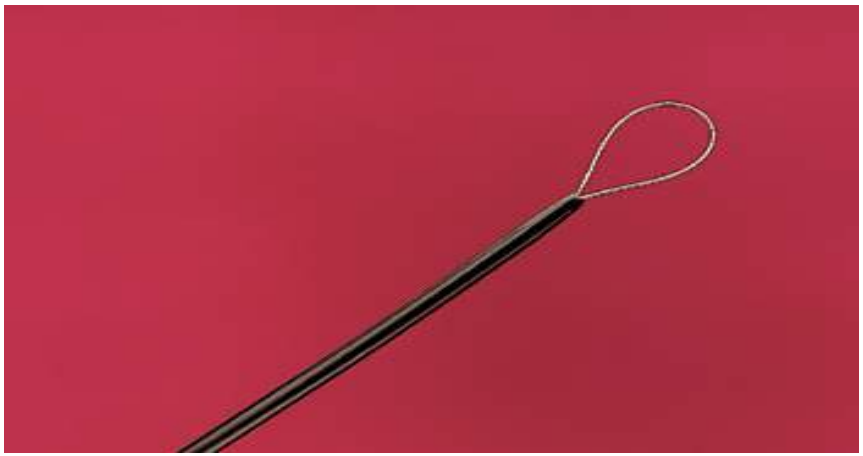


Solid Model of Total Knee System

Other Uses of Metals

Medical Tubing

Stents



Catheters